Mineral Resources Section
Cfy.

RB. ~~74/98~~ 72/30
DM 374/69
Env 1084

1/1/110

October 1972

SOUTH AUSTRALIAN GOVERNMENT DEPARTMENT OF MINES

Amdel Report

No.877

LABORATORY EVALUATION OF SOUTH AUSTRALIAN TALCS FOR INDUSTRIAL PURPOSES

by

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CONTENTS

CONTENTS

SUMMARY

Background

The systematic laboratory investigation by Amdel of the industrial potential of South Australian talcs began in 1968 under the sponsorship of the South Australian Government Department of Mines. Six progress reports have been issued but it was felt that the work of the past four years should be considered to be the first stage in the programme and summarised and reviewed even though the investigation is coutinuing.

Objectives

The report is intended to provide an overall compilation and review of the work to date to form a basis for the continuing investigation, now in its second stage, and to complement the South Australian Department of Mines report by Hiern (1969) on field aspects.

Summary of Work Done

Detailed laboratory testing on samples of talc from Mount Fitton (first and third grade), Gumeracha (first and third grade), Tumby Bay (first grade, orebody A and orebody E), Truro and Yongala were carried out. Mineralogy, chemical analysis, determination of acid and water soluble salts, pH, PCE, particle size distribution, bulk density, oil absorption, fired properties, refractive index, colour and reflectivity were recorded.

The specifications for various commercial useages are summarised and each South Australian talc is evaluated for possible industrial application. The general problem of use-classification of talcs is considered and a preliminary evaluation based on Al_2O_3 and $FeO + Fe_2O_3$ content is advanced.

As particle-size distribution is very important, measurements of sizing were made after dry and wet grinding for 6, 12, 24 and 48 hours, cycloning and micronizing. Further attention must be given to this aspect.

Preliminary attempts were made at beneficiating talc by flotation. This is successful with some talcs (Truro and Yongala) but not with Gumeracha third grade where it has now been proved that in excess of 1.5% FeO is located within the talc structure.

Attention has been given to ceramic uses for South Australian talcs and experiments on various talc-clay blends show that successful floor

and wall tiles, glazed and unglazed can be produced.

Conclusions

1. Cosmetic Grade. Mt Fitton talc is used for cosmetic purposes and is the only material to satisfy requirements. The best Tumby Bay if gritty, alkaline, has high acid solubles and is insufficiently bright. Truro talc might reach requirements after beneficiation although treatment tends to spoil the properties. Hiern (1969) stated that first grade Gumeracha is used for low-quality cosmetics but the material tested falls far short of the stated specifications. It may be that the Amdel sample was not representative, but a certain proportion of first grade was hand-picked for this use, or that the purchaser had a more-liberal specification. The best Tumby Bay is better than the Gumeracha so that it might have a similar use.

2. Paint Grade. Pigment specifications are rather imperfectly defined but Mt Fitton (first and third grade) and Gumeracha (first grade) appear suitable from the Amdel tests. Hiern (1969) stated that these two were used as paint pigments. Tumby Bay (first grade) appears to be generally suitable but is high in both acid and water solubles; it is lower in iron and whiter in colour than Gumeracha.

3. Ceramic Use. Mt Fitton (first and second grade) would be satisfactory for the brightest quality and all Tumby Bay for high grade ceramics. Truro, Mt Fitton (third grade) and Yongala look promising for medium quality ceramics. The talc from Gumeracha and Lyndoch is too high in iron for good quality ceramics and it would appear to be suitable only for the lowest grade unless sorting or treatment could separate out a low-iron fraction.

4. Miscellaneous: Fillers, Absorbents, Dusting Powder, Roofing Compounds. Most talc from Gumeracha, Lyndoch and Cowell and much from Tumby Bay is suitable only for lowest grade uses. Even here there are difficulties as shown by the failure of preliminary attempts to produce a sample of Gumeracha talc for filling in vinyl tiles; the deficiencies were in colour and bulk density.

Recommendations

1. The field investigations of Hiern (1969) together with the material in this report form a useful summary of the characteristics of South

Australian talcs and it is recommended that additional information be obtained to allow publication of a comprehensive coverage of the subject.

2. Discrepancies between Amdel results and those of other workers suggest that the Amdel samples were not representative of the various deposits and the first requirement is for testing of a sufficiently large number of samples from all deposits to allow meaningful evaluation.

3. The most promising field of use for many of the mediocre talcs is in ceramics (and possibly paint pigments). A detailed investigation should be carried out on the ceramic uses for a range of talcs, including natural talc-kaolin and talc-tremolite mixtures.

4. The work to date suggests strongly that talcs from Gumeracha, Lyndoch, Truro and Yongala will require treatment before they can be sold; this will involve pulverising, micronising and flotation. The economic and technical feasibility of beneficiation should be studied in detail.

1. INTRODUCTION

1.1 Review of the Project

South Australia contains a large number of talc deposits but most are of indifferent quality and limited size and the others tend to be in remote locations. However, as talc is a mineral of considerable economic potential a project was initiated in 1968 to carry out a systematic laboratory evaluation of the various South Australian talc deposits (particularly those not being exploited) and to assess their potential for a variety of industrial processes.

Six progress reports issued between 1969 and 1970 covered investigations of material from Gumeracha, Tumby Bay, Mount Fitton and Yongala.

The scope of the present project has been limited by the lack of samples and it is regarded as essential that a comprehensive and representative set of samples from all known occurrences be examined.

The present report is an overall compilation and review of the work to date and covers laboratory testing, test methods and industrial specifications, preliminary experiments on beneficiation and an evaluation of their possible use.

As was expected, great difficulty has been encountered, both in obtaining details of the requirements of industry and also of standardised test procedures. A continuing review of test procedures, repeated cross-checking of results and calibration of equipment by exchange of samples with other organisations, have resulted in the modification of some results reported in earlier progress reports.

An attempt has been made to relate this report to the recent work by Hiern (1969) so as to make the field and laboratory reports complementary.

2. TALC

2.1 Talc Mineralogy

The term 'talc' is applied loosely to all forms of the mineral although the massive impure variety may be called soapstone. Talc has the ideal formula of $Mg_3(Si_2O_5)_2(OH)_2$ but few commercial talcs approach this and contain impurities such as quartz, carbonates, tremolite, chlorite, serpentine, pyroxene, amphibole etc.

Pure talc is intrinsically white to pale greenish (but grinds white) with a pearly lustre; it has a hardness of 1 to 1½ on the Moh's scale, a specific gravity of approximately 2.75, perfect basal cleavage, and indices of refraction of X = 1.539, Y = 1.589, Z = 1.589. It is recognised by its extreme softness, soapy feel, flaky habit and inertness. The properties which determine its usefulness are whiteness when ground, and/or fired, softness and smoothness, lubrication power, chemical inertness, high fusion point, low electrical conductivity and high absorption.

The mineral pyrophyllite closely resembles talc, is easily confused with it and has rather similar properties and uses but is an hydrated aluminium silicate.

The chemical compositions of commercial talcs show a wide variation and examples of typical commercial types, originating from outside of South Australia, are given in Table 1.

2.2 Terminology

The commercial terminology is somewhat vague but is generally as follows:

1. 'Talc' is material that is rich in that mineral although considerable impurities may be present.
2. 'Soapstone' was originally the term used for massive talc but now is used also for impure grades of non-massive talc.
3. 'Steatite' was originally the name given to massive and blocky talc and this was synonymous with soapstone but now the term also is used as a trade specification for a high grade powdered variety used for the best insulators.
4. 'Block talc' or 'lava talc' is massive and able to be turned, carved or shaped into bodies.
5. 'Asbestine' (fibrous talc, tremolitic talc, calcareous talc, California hard talc, tremoline, loomite) was originally the term given to natural mixtures of talc and tremolite favoured in the USA for paint and ceramics. There is a tendency now, however, to extend the term to natural talc-clay mixtures.
6. 'French chalk' is finely powdered talc.
7. Commercial talcs may be referred to by trade names ('Agolite' is one filler) or by their use, for example, paint-talc, cosmetic-talc etc.

2.3 Origin of Talc

Most deposits of commercial talc are formed by the alteration of magnesia-rich rocks such as ultrabasic or basic igneous rocks or magnesium limestones and dolomites (Engels and Wright 1960, Wright 1957). Most of the talc deposits in South Australia were formed by the metamorphism of dolomitic sediments (Dickinson *et al.* 1951, Hiern 1969) e.g. Mt Fitton and Tumby Bay, but those in the Gumeracha-Lobethal-Lyndoch belt are unusual in that they appear to be due to an unusual process of complex metamorphism and metasomatism of mica schists. No deposits formed from ultrabasic igneous rocks are known in South Australia.

2.4 Talc in South Australia

Various aspects of the occurrence, geology and utilisation of South Australian talcs have been reviewed by Dickinson *et al.* (1951), Hiern and Adam (1969) and Hiern (1969).

Two major kinds of talc occur here:

a. The pure type (Mt Fitton first grade) which is of good quality and has an assured market, at a high price;

b. Lower grade types such as occur at a number of localities. Markets for this material are hard to find but it is more abundant and consequently has received most attention in the present project.

There are two possible approaches to the utilisation of impure talcs:

i. Beneficiation to enable it to meet buyer specifications and thus achieve a market. This is technically feasible but the economics may be in question.

ii. Finding established or new uses and markets for low grade materials.

Gourlay (1969) gave the following information concerning the production of talc in South Australia and other parts of Australia for the year 1969 which was the last full year for which information is available:

State	Tonnage	Value
South Australia	12,262	$188,963
Western Australia	36,293	$290,340
New South Wales	363	$ 3,289

Production in South Australia was almost entirely from Mt Fitton with a small quantity from Gumeracha. The quality was mainly of high grade; the average ex-mine value of South Australian product was $15.4 per ton (NSW $9.1; WA $8) but retail prices quoted by Rodda, ex-works Port Melbourne are:

Grade	$/ton
Cosmetic	58- 77
Industrial	30- 45
Micronised	75-120*

* Price dependent on particle size.

Production from Western Australia was from the Western Mining Corporation (WMC) Three Springs mine; the material was mainly for export (33,595 tons valued at $863,292) as ceramic grade to Belgium.

Australian imports in 1969 were mainly from:

	Tons	Average $/ton
China	984	27.5
India	310	43.3
USA	435	68.9

Imports totalled 1,794 tons valued at $77,000; much of this is probably black steatite which is deficient in Australia.

It was reported in 1969 that current domestic consumption averaged 20,000 tons per year, that there was a growing use in ceramics, cosmetics, paint, rubber and industrial chemicals with a fall-off in paper manufacture, textile and foundry use.

Partial figures for talc production for July 1970-June 1971* are as follows:

	Tons
South Australia	11,682
Western Australia	101,534
New South Wales	8,303
Total	121,519

As from 1969 these figures imply a slight decrease in production in South Australia coupled with a slight increase in New South Wales and a marked increase in Western Australia; at the same time there has been a marked increase in

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* Aust. Min. Ind. Q. Rev. 24(2), Pt.2, p16, 1971.

imports, particularly from China.

Gourlay (1971) reviewed the latest developments and stated that the main Australian uses (total use 17-18,000 tons per annum) are in cosmetics and as a filler in paint and rubber (two-thirds of the total); the proportion used in ceramics is much less than in other countries. Main imports are of high grade material, mainly block steatite and main exports are for ceramic purposes. Gourlay (1971, p 18) stated that there had been a steady increase in exports from Mt Fitton.

2.5 Classification of Talcs

Talc may be classified on the following basis; blockiness, purity, use, and locality.

Blockiness. Steatite and soapstone may be cut into blocks whereas most talc is pulverised and used in the powdered form.

Purity. The major distinction between the various grades of talc is made on the basis of purity. The very pure, white pharmaceutical or cosmetic grade is much more valuable than the off-white ceramic and filler grades.

Use. The industrial use (and hence value) depends mainly on purity. The main types are as follows:

a. Cosmetic
b. Paper filler and coater
c. Paint extender and pigment
d. Rubber filler
e. Ceramics
f. Roofing material
g. Miscellaneous
(absorbents for chemicals, dusting powder, rock-wool).

Examples of South Australian talcs filling the requirement for these grades are given in detail in Table 2.

Locality. South Australian talcs vary according to their occurrence, hence a classification based on locality also tends to be based on grade, useage and value. The major localities are as follows:

a. Mt Fitton
b. Gumeracha-Lyndoch-Truro
c. Tumby Bay.

3. LABORATORY TESTING OF TALC

Complete testing of talc can be a long procedure because of the wide range of uses, hence there is a large number of tests. Interpretation of the significance of the tests and evaluation of the potential value of a raw material is not easy.

The following procedures are those used at Amdel:

a. Mineralogy

i. Confirmation of the identity of the talc by X-ray diffraction, followed by identification of mineral contaminants and determination of the approximate talc content.

Comment: Talc may be confused in hand specimen with pyrophyllite, sericite or even kaolinite. The presence of comparatively small amounts of talc in clay may impart a misleading slippery feel. A semi-quantitative assessment of the total mineralogy to identify impurities is important.

ii. Petrography of the talc-rock, the host and associated rocks by optical microscopy.

Comment: Determination of whether the talc has resulted from the alteration of an ultrabasic igneous rock or from a magnesian or other sediment is important in understanding the nature of the material and the probable size and shape of the deposit.

iii. Refractive index of the talc.

Comment: This is probably not of great significance but is included in some specifications for paint or other pigments.

iv. Particle shape by electron microscope.

Comment: Problems of absorption, abrasiveness, viscosity etc. may require detailed investigation of particle size and shape.

b. Chemical Composition

Chemical analysis for SiO_2, Al_2O_3, MgO, Fe_2O_3, H_2O^+ and H_2O^-; additional analysis for FeO, Fe_2O_3, CaO, Na_2O, K_2O, TiO_2, MnO, CO_2; trace element analyses for Pb, As, Sb, Sn etc.

Comment: A chemical analysis is an essential part of the specification and is the parameter which most clearly indicates the quality. Details are as follows:

SiO_2	theoretical talc contains 63.5%. An excess above this value indicates free quartz, a deficiency is caused by diluting impurities.
MgO	theoretical talc contains 31.7% A deficiency indicates the presence of diluting impurities but high MgO should be coupled with appropriate SiO_2, not with CO_2 which would indicate dolomite or magnesite.
Al_2O_3	indicates clay content generally; also in feldspar, mica, amphibole etc.
FeO	in magnetite, ilmenite or chromite but also may be present in the talc molecule where it imparts a green colour and lower reflectivity.
Fe_2O_3	in hematite and goethite staining.
$FeO+Fe_2O_3$	total iron is very important and must be as low as possible.
CaO	in carbonate or tremolite. Should be low but may be around 13% in tremolitic talcs used for ceramics.
Na_2O+K_2O	present mainly in feldspars and micas. Should be as low as possible as feldspars act as fluxes and impart grittiness.
CO_2	deleterious: indicates carbonates.
SO_3	deleterious: indicates sulphates such as gypsum and anhydrite.
Cl	deleterious: usually indicates the presence of soluble salts; such as - i. Acid and water soluble salts. Acid solubles are mainly carbonates and are therefore undesirable. Water soluble salts (particularly $NaCl$ and soluble iron salts) are

undesirable as they may affect the chemistry of paint, may irritate the skin, affect the colour, alter absorbance of perfume etc. Talc for cosmetic use must be neutral to acid but not alkaline as it may upset the natural acidity of skin perspiration.

c. Physical Properties

i. Specific gravity and bulk density. Talc has a true specific gravity of 2.75 and departure from this depends on impurities. The bulk density of ground material is nominated in certain specifications and its achievement may require a special grinding schedule.

ii. Particle size analysis. A particle size distribution is stated in specifications for all products as it has a marked control on use.

iii. Oil absorption. Two methods are available (spatula rub-out and Gardner-Coleman). The absorptive value is important in cosmetic grades (absorption of perfume and also of perspiration) and in paint or paper filling materials.

iv. Brightness. TAPPI specification. A high reflectivity (bright white colour) indicates a high purity and this is desirable. It is particularly essential for the best cosmetic grades, for paint pigment and paper filler and coater.

d. Thermal Behaviour

i. Colour, raw and fired. Talc ceramics should show an even white to cream colour.

ii. Fusibility (pyrometric cone equivalent, PCE to ASTM (24-56) indicates the refractoriness.

iii. Dilatometry.
Indicates changes of volume on firing.

iv. Fired properties. Water absorption, linear contraction, colour of a 1:1 talc-kaolin dry pressed body. Indicates general ceramic behaviour.

4. USES OF TALC: STANDARD SPECIFICATIONS

Throughout the world, the main uses of talc are in ceramics and as extenders in paint and rubber. Talc is a low-cost commodity and for some uses its selection is based more on price than on its physical properties. A high price caused by remote location or the necessity for treatment introduces substitution and talc is subject to competition from kaolin and whiting as filler, from feldspar in ceramics, from ground mica in roofing and from kyanite, quartz, gypsum and wollastonite in other uses.

Specifications for individual uses are not clearly defined but this report attempts to list those specifications which are available from Australian consumers and the general requirements stated by various sections of industry.

In order to emphasise the concept of quality or grade, this section deals with talcs in order of decreasing quality. Uses fall in the following categories:

- Cosmetics
- Ceramics
- Paints
- Insecticide
- Roofing
- Rubber
- Asphalt filler
- Paper
- Textiles
- Foundry
- Adhesives
- Putty
- Pipe enamel
- Auto filler

4.1 Cosmetic Use (Pharmaceutical, Purified Talc)

The cosmetics industry is one of the largest consumers of talc in Australia although elsewhere in the world the proportion used in this manner is much smaller. The highest grade, whitest, grit-free varieties (such as that from Mt Fitton) is used in the manufacture of talcum powder, soaps, lipsticks and lotions. Some coloured talc grinds to a white colour, thus allowing its use, and some off-colour talc is used in cheaper cosmetic preparations.

Specifications from manufacturers are stringent. In general, the colour must be pure white (that is reflectivity above about 85%), it must be free from grit, from abrasive substances (calcite, dolomite, tremolite), from germs, and from any substances likely to cause irritation to the skin. Contaminants prevent the use of many white talcs. The talc must have a high absorptive power (to absorb perfume during manufacture and perspiration during use), must have a good unctuosity (slippery feel) and must adhere to the skin. In contact with water it must have a neutral and never alkaline reaction or it may upset the normal acidity of the skin. Water soluble salts must be absent.

The grain-size is important but extreme grinding is not permissible to produce a small particle size. Dry grinding is recommended to retain the plate-like character and "slip". Micronising is common practice as over-grinding may produce very fine particles which are objectionable because of the danger of inhalation during use. The majority of cosmetic grades are 99% minus 200 mesh (75 μm) and 97-98% minus 325 mesh (44 μm). For demo-paediatric use, micronised talcs between 10 and 40 μm are used.

It is most important that the talc be free from bacteria, hence products from open-cut mines may need to be sterilised, by heat (150°C) or treatment (ethylene oxide gas). Sterilisation is expensive, hence it may be more economic to mine uncontaminated talc underground than sterilise that from open-cuts.

TGA (USA Toilet Goods Association Board of Standard No.10. Specification limits are compared with some commercial cosmetic grades in Table 3.

Johnson and Johnson (Australia) Pty Ltd. Johnson and Johnson require:

Smooth, non-gritty, must adhere to skin

Acid solubles	1.25% max.
Bulk density	20-25 lb/cu ft
Fe_2O_3	0.3 % max.
-200 mesh	98.5 % min.
-200 mesh	100 % min.

Reckitt and Coleman Pty Ltd, Victoria. Reckitt and Coleman use Mt Fitton talc which is described as follows:

SiO_2	59.4 %
Al_2O_3	2-3 %
Fe_2O_3	0.6 %
CaO	0.5 %
MgO	31.5 %
Loss on ignition	5.6 %
Acid soluble BPC	0.64%
Water soluble BPC	0.04%

Residue on 200 mesh	0.2 %	max.
Bulk density	0.87	g/cc
Oil absorption	43	ml/100 g
Colour	white	

British Pharmacoepia and USA Dispersatory. The specifications for these two are not rigid and require:

		BP	USD
Iron		low	free from soluble iron
Acid solubles,	max.	1 %	1 %
Water solubles,	max.	0.5%	0.5%
Loss on drying (105°C)	max.	1 %	-
Loss on ignition (1000°C)	max.	6 %	5 %

4.2 Paint Grade

The paint industry is the largest single industrial user of ground talc. High grade white talc is used as a pigment and an extender whereas the fibrous variety ('tremoline', 'asbestine', 'loomite' etc.) prevents settling out and supports pigment. The chief advantage of talc is that it disperses easily in both oil and water systems. Talc is second in importance to calcium carbonate as a paint extender.

Talc has a flattening effect on paint, reduces the cracking effect when hard pigments are used, has good covering or extending properties and provides a slow-weathering surface which repaints easily (Weitz, 1970; Kollonitsch *et al.* 1970).

Whiteness (brightness) is important; Kollonitsch et al. (1970) give a range of 65-90% for talc pigments and Weitz states a range of 70 to 98% for all pigments.

The great variety of paints leads to a range of specifications usually based on agreement between consumer and supplier. The particle size is generally between 10 and 44 μm and it is generally required that it should be 100% passing 200 mesh and 99% passing 325 mesh. Micronising is a common process for producing material in the size range 1-20 μm.

Oil absorption is important. Ordinary ground talc has an absorption of about 27-34 (reaching around 70 for finer sizes) and asbestine has 20-35. Soluble salts must be low.

The standard specification detailed by the following sources are as follows:

Magnesium Silicate Pigment: ASTM D605-69

In the USA the term refers to a low micron-sized talc that has been ground to a Hegman fineness value of 4-5 or better:

MgO	24-32%
SiO_2	50-65%
CaO	9%
MgO + SiO_2 + CaO	88%
Loss on ignition	7%
Moisture, volatiles	1%
Water solubles	1%

Normally Fe_2O_3 should be less than 0.5% for reasons of colour.

Asbestine, British Standard 1795

Passing 240 mesh	0.5% max.
Water soluble matter	0.5% max.
Loss on ignition (98-102°C)	0.75% max.

Acidity or alkalinity of the water soluble extract must not exceed 0.1% calculated as H_2SO_4 or Na_2CO_3.

Jarvis Industries

Private contact has been made with Jarvis Industries who produce four grades for paint:

	Fineness
-240 mesh	95 % min.
-200 mesh	99 % min.
-300 mesh	99 % min.
-300 mesh	99.5% min.

4.3 Ceramics

4.3.1 General Features

The ceramic industry is one of the main consumers of talc elsewhere in the world but this is largely restricted to highly developed countries (USA,Europe etc.) because of the need for close control of processing and kiln treatment. Large tonnages are used in floor and wall tiles, electrical porcelain, high frequency insulators, whiteware, saggar bodies and kiln furniture (Gaskins 1952). Many electrical and refractory articles are made by dry pressing or extruding followed by firing but some are made by machining block steatite.

The use of talc in ceramics makes them resistant to crazing, (increases thermal expansion and decreases moisture expansion) reduces shrinkage and speeds up production by permitting faster firing. It is a cheap source of MgO which acts as a flux, it imparts a high thermal shock resistance, a high electrical resistance at elevated temperatures but a low dielectric loss and low power factor. Consistency of properties is most essential to users, and this will affect marketing of South Australian materials.

Talc fired to about 1000°C inverts to clinoenstatite plus cristobalite (Engel and Wright 1960), an addition of MgO (or Mg CO_3, $Mg(OH)_2$) gives a fosterite body (Alderman 1952) and an addition of alumina (generally as kaolin or chlorite) gives a cordierite body. Natural lime-bearing (tremolitic) talcs fire to enstatite diopside bodies. It is common to add minor barium carbonate or clay to steatite bodies; organic resins are used as bonders.

Low-iron (less than 0.5% total iron oxides) or white firing talc is essential for whiteware and is preferred for wall tiles.

Talc for steatite electrical insulators has low iron, low alumina and low calcium,but high alumina (talc-clay) material is used for the more-refractory, low-expansion bodies.

Earthenware bodies are generally composed of lean china clays, plastic ball clay, flint and some form of feldspar. Feldspar may be partly or entirely replaced by talc. In practice, talc may constitute nearly 40% of the body composition; clay (about 80% kaolin and 20% ball clay) constitutes about 30% and flint the remaining 30%, but there is no single recipe for earthenware bodies.

In wall tiles, it has been stated (Industrial Minerals, Jan. 1971, p 14) that bodies containing up to 80% talc give beautiful colours; medium-high talc (40%) and low (15%) pyrophyllite compositions have a resistance to crazing;

high pyrophyllite and low talc gives resistance to delayed moisture expansion and crazing. In tableware the particle shape is important. Fifteen percent of talc gives bright colours. Art pottery bodies may contain about 20% of talc.

Steatite ceramics were developed for insulators because orthodox porcelain has a high power factor (that is, a comparatively large proportion of the electrical energy is transformed into heat). A high proportion of steatite (70-90% range with 85% the average) is mixed with about 10% of clay and flux (normally barium carbonate). Feldspar is excluded because the alkaline oxides result in high dielectric loss.

Steatites low in alumina, calcium and iron are preferred for low-loss ceramics but green steatites containing iron have been successfully used when blended with white steatites.

4.3.2 United States Practice

The following is a specification adopted by one American manufacturer and is of general interest (Anon 1971). A uniform quality is important:

1. The talc shall be massive and soft, substantially free from foliated, flaky and fibrous crystals. It shall be free from gangue which makes a dark colour in kilning and produces dark spots or specks in the ware.
2. It shall be ground to such particle size that at least 95% passes a 325-mesh screen (43 μm) and 99% passes 200 mesh (74 μm).
3. Colour in the unfired state is of no importance but it is important that after being heated to approximately 1350°C in an oxidising or neutral atmosphere, the material should be uniformly cream to white.
4. The following analysis gives the limits of impurities acceptable:

	%
SiO_2	60 min.
MgO	30 min.
Al_2O_3	2.5 max.
CaO	1.0 max.
Fe_2O_3	1.5 max.
Alkalies	0.4 max.
Loss on ignition	6.0 max.
Acid soluble lime	1.0 max.

The USA Bureau of Mines. The USA Bureau of Mines, specification for steatite for electrical insulators states that it consists of talc (at least 90%, preferably 98%):

Fe_2O_3	1.5% max.
CaO	1.5% max.
Al_2O_3	4.0% max.

High Alumina Talc. Requirements for electrical porcelain have been stated as:

MgO	30 % min.
Loss on ignition	5 % max.
CaO, Fe_2O_3, Al_2O_3,	alkalies total "not much more than 5%" (Norton 1970)
CaO	2 % max.
Fe_2O_3	0.3% max.
(Na_2O,K_2O)	0.3% max.

Tremolitic Talc (Lime-talc, Asbestoline, Tremoline). The most common type of talc used for wall tiles in the USA normally consists of 60-70% talc with fibrous tremolite; it fires from Cone 03 to 2.

Analyses of typical commercial tremolitic talc are given in the following tabulation:

		Vanderbilt		International Talc Company
		Nytal 100	Nytal 99	tremoline
CaO	%	7.6	8.0	5.61
SiO_2	%	56.6	57.3	58.18
MgO	%	29.4	28.3	-
Fe_2O_3	%	0.3	0.4	-
Al_2O_3	%	0.5	0.2	-
MnO	%	0.3	0.3	-
Loss on ignition		5.1	4.7	-
Residue on 200 mesh		2.6	3.1	-
Bulk density, cc/150 g		140	110	-

4.3.3 Specifications for Wall and Floor Tiles

The ceramic potential of natural talcs is tested by combining them with a proportion of clay etc. firing the body, and testing for colour, water absorption and linear shrinkage.

British Standard 1286:1945 states limits for water absorption as follows for "clay tiles for flooring":

Type A (floor quarries and quarry sills)		Type B (floor tiles and tile sills)	
Class 1	6% max.	Class 1, fully vitrified	0.3% max.
Class 2	10% max.	Class 2, vitrified	5.0% max.

British Standard 1281:1966 states a maximum of 18% water absorption for "glazed ceramic tiles and tile fittings for internal walls".

4.4 Roofing Material

The roofing industry ranks about third in the USA as regards use of talc. Coarse-grained, inferior, low-grade, off-colour material is acceptable. It acts as a filler and as a non-sticking, inert, fireproof and weather-resistant surfacing on tar paper, asphalt shingles and roll roofing.

The only user known in Australia is Osmonoid Roofing and Asphalt who state that they specify:

Retained on 20 mesh	0.3% max.
Retained on 25 mesh	3.0% max.

The proportions of fines must be as small as possible.

4.5 Rubber Industry

Fine-grained talc finds a rather large outlet in the rubber industry as a blocking agent, for dusting moulds and as a filler. Poor quality grey talc is acceptable and the main specification relates to grainsize (usually 100% passing 100 mesh and most passing 200 mesh).

Jarvis Industries. Jarvis Industries Pty Ltd state that they supply three grades for the rubber industry:

	Fineness
-240 mesh	95%
-200 mesh	80%
-300 mesh	98%

4.6 Paper Industry

The paper industry is a large consumer of certain grades of talc, where it is used in conjunction with kaolin to increase the retention of fillers and pigments, gives better sizing and prevents strainers from becoming choked with resin. Talc has recently been used also for coating paper; it imparts an unusual semi-gloss surface which is attractive.

This use is a comparatively new one and hence specifications are not clearly defined. The Australian Paper Manufacturers Limited use the following clays not talcs and it is assumed that properties would need to be similar:

a. Paper filler (Victorian source).
   Brightness: 80% (minimum 78.5%)
   Plus 200 mesh, prefer zero, 0.1% maximum.

b. Paper coater (English source)
   Brightness: 87% (violet), 4 (yellowness)
   Plus 300 mesh, 0.02% (BSS)
   Minus 2 μm ESD 75% minimum
   Plus 10 μm ESD 0.5% maximum.
   pH 5 - 5.5
   Solids content at 25 poises 71%
   (a later specification was 5 poises at 72%).

Filler grade talcs are marketed by the Finnish producer Suomen Talkki Oy. 'A' grade has a reflectivity of 82-84%, 'B' grade of 76-78%. A micronized talc for resin control in paper is stated to have a whiteness of 85% and particle size of 99% below 7 μm; a coating talc with 86-88% whiteness and 99% below 7 μm.

4.7 Plastic Filler

Considerable benefits are obtained by the use of talc. It acts as a filler, thus reducing material costs, and also reduces mould shrinkage and increases flexural modulus (Weitz 1970).

The CSR Building Materials specification for talc filler in vinyl floor tiles is as follows:

Test	Test Method	Limits
Colour	FT 312	Match standard
Wet screen analysis	FT 316	C200 mesh (BSS) 5% max.
Blaine index	FT 315	To be determined
Consistency	FT 314	-
Moisture	FT 313	0.5% max.
Bulk density	FT 317	57 lb/cu ft

4.8 Absorbents (Insecticide, Fertilisers, Agricultural Chemicals)

The flow properties, non-abrasive nature and absorption make talc useful as a dusting agent for insecticides such as DDT. Talc is the next most important after attapulgite. Impure talcs may be used for this purpose.

4.9 Miscellaneous Uses

Talc is widely used as a filler in adhesives, putty, wall plasters, compositional flooring, linoleum, oilcloth, rope, string, cordage and textiles and as a dusting agent in the manufacture of rubber, wire nails, linoleum, oilcloth, felt paper, leather, corks, glass and chewing gum (Engel and Wright, 1960, p 848).

The lubricating properties of talc are utilised in polishing wire nails, glass and some cereals such as rice and barley. Its slip properties make it useful as foundry facing.

The UK Ministry of Supply, Aircraft Material Specification for 'French Chalk' is as follows:

MgO	25-35%
SiO_2	40-75%
Loss on ignition (900°C)	20% max.
Plus 200 mesh	1% max.

5. MARKET SURVEY

The main problem in the exploitation of industrial mineral deposits lies in establishing a market; talc is no exception. Published information has been compiled in Section 4 but this is scanty and of doubtful validity. The accepted procedure in assessing the value of a talc deposit is to measure its chemical composition and physical properties, then decide the general field of potential use, prepare a large sample and finally submit the material to potential users.

During this investigation, considerable emphasis has been placed on the general evaluation of the potential of raw material as deduced from the chemical composition and physical properties. In order to increase the meagre amount of published information, a direct approach was made to Australian consumers asking for their specification for the talc which they used. The following were approached:

1. Australian Paper Manufacturers Limited, South Gate, Melbourne, Vic.
2. Colonial Sugar Refineries, Building Materials Division, Concorde New South Wales.
3. Dunlop Rubber Australia, Melbourne.
4. Pabco Products Pty Ltd, Glebe, NSW.
5. Australian Clays and Industrial Minerals, Melbourne, Vic.

6. Foseco Industries, Padstow, New South Wales.
7. Vinylpore Products, Silverwater, New South Wales.
8. Austral Rock Milling Pty Ltd, Newtown, New South Wales.
9. Michael Nairn & Co. Auburn, New South Wales.
10. Taubmans, Villawood, New South Wales.
11. BALM Paints, Cabarita, New South Wales.
12. Parke Davis & Co.,Rosebery, New South Wales.
13. International Majora Paints Pty Ltd, West Melbourne.
14. Johnson and Johnson Limited, Sydney.
15. Reckitt and Coleman Pty Ltd, Clayton, Victoria.
16. William Cumming & Co.,Botany, New South Wales.
17. Cematile Industries Pty Ltd, Clayton, Victoria.
18. Nylex Corporation Ltd, Richmond, Victoria.
19. Walker Ceramics, Wantirna, Victoria.
20. Glazebrooks Paints and Chemicals Pty Ltd, Port Melbourne.
21. Colgate Palmolive Pty Ltd.,Balmain, New South Wales.
22. Alex Minter and Co. Pty Ltd, Northmead,NSW.
23. ICIANZ Limited, Melbourne, Vic.
24. Bells Asbestos and Engineering Pty Ltd, Sydney.
25. Gibson Kelite Chemicals Ltd, Cheltenham, Victoria.
26. Drug Houses of Australia Ltd, Melbourne.
27. James Hardie Trading Co., Melbourne.
28. Blundell Spence & Co. (Aust) Pty Ltd, Mascot, New South Wales.
29. Minerals Pty Ltd, Alexandria, New South Wales.
30. Lewis Berger & Sons Ltd, Rhodes, New South Wales.
31. British Paints Ltd, Bankstown, New South Wales.
32. Ormonoid Roofing & Asphalt Ltd, Waterloo, New South Wales.
33. Gordon Abbot Industries, Somerton Park, South Australia.

Less than one-third of our letters were answered and useful information was obtained from the following:

BALM Paints
Johnson and Johnson Limited
Reckitt and Coleman
James Hardie
Ormonoid Roofing

CSR Building Materials Research Laboratories.
Australian Paper Manufacturers.

Samples of Gumeracha talc were processed to meet the specifications of CSR, and Ormonoid (as detailed in Section 6) and samples were forwarded to these manufacturers for evaluation.

6. LABORATORY INVESTIGATIONS OF SOME SOUTH AUSTRALIAN TALCS

A study in depth was made of a limited number of samples from the three main localities (Mt Fitton, Gumeracha and Tumby Bay) as specified by the South Australian Department of Mines; limited consideration was also given to talcs from Yongala, Truro and Lobethal.

6.1 Mt Fitton

The occurrence of talc at Mt Fitton has been recently summarised by Coats and Blissett (1971) and earlier mainly by Dickinson *et al.* (1951) and Nixon (1961). According to Nixon (1961, p 5) the talc is classified at the mine into:

No.1	grade brushed talc
No.1	QS grade (similar to No.1 but not brushed)
No.2	slightly coloured
No.3	chloritic talc

Two samples were studied in detail; one of first grade (Sample CE3529) and one of third grade (CE3532). Details are as follows:

		CE3529	CE3532	Dickinson *et al.**
1.	Colour:	White	Grey-white	-
2.	Chemical composition,%:			
	SiO_2	60.3	49.6	62.16
	Al_2O_3	1.50	8.05	0.61
	Fe_2O_3	<0.01	0.14	0.58
	FeO	0.47	0.69	-
	MgO	30.9	31.9	32.06
	CaO	0.14	0.34	Nil
	Na_2O	0.03	0.04	Nil
	K_2O	<0.01	<0.01	Nil
	TiO_2	0.12	0.50	-
	MnO	<0.01	<0.01	-

		CE3529	CE3532	Dickinson *et al.**
	CO_2	0.50	0.60	-
	SO_3	0.03	0.12	-
	Cl	0.01	0.01	-
	H_2O^+	5.60	8.00	4.51
3.	Trace elements, ppm, detection limits in brackets:			
	Cu (0.5)	100	100	-
	As (50)	nd(a)	nd	-
	Sn (1)	nd	nd	-
	Sb (30)	nd	nd	-
4.	Mineralogical composition:			
	Talc	D(b)	D	-
	Chlorite, %	5	5-10	-
	Albite	nd	nd	-
	Clay	Tr(c)	Tr	-
	Quartz	nd	nd	-
	Kaolin	nd	nd	-
5.	Refractoriness:			
	PCE Cone number	15	14-15	-
	Temp. equiv., °C	1430	1398-1430	-
	Firing shrinkage, %	2.3	2.25	-
	Linear expansion (0-500°C)	$9x10^{-6}$	$9x10^{-6}$	-
6.	Reflectivity and grinding:			
	Ground to -300#	92.5	85.3	-
7.	Reflectivity and beneficiation:			
	Grinding in rod mill	-	75%	-
	Grinding in ball mill	-	85	-
	Grinding in pebble mill	-	91	-
	Grinding in micronizer	-	87	-
	Feed	-	91	-
	Flotation concentrate	-	92	-
	Tailing	-	85	-
8.	Acid bleaching (HCl):			
	Feed (after flotation)	-	91	-
	Product	-	94	-
	Feed (after ball milling)	-	85	-
	Product	-	90	-

* Dickinson *et al.* (1951), p 7.
(a) nd = Not determined.
(b) D = Dominant
(c) Tr = Trace.

Mt Fitton first grade talc is of excellent quality and is suitable for all purposes. It is used in Australia mainly for the more-highly priced cosmetic grades but Alderman has shown that it would be suitable for fosterite ceramics and the present work has shown that it fires to a light fawn tile.

Hiern (1969) reported that three grades were produced at the mine:

First grade	for cosmetics
Second grade	for paint and cheaper cosmetics
Third grade	for ceramics

Third grade has a lower whiteness than first, contains more iron (total FeO + Fe_2O_3 of 0.83% as against 0.47%) and more chlorite (5-10% as against 5%). Third grade is of much better quality than Gumeracha or Lyndoch but is generally inferior to first grade Tumby Bay.

The Mt Fitton deposits are reported to be varied in mineralogy, with various amounts of kaolin, tremolite, chlorite etc., and some of these natural varieties may have a commercial value. The deposits have great potential, the main obstacle lying in their isolation.

6.2 Gumeracha Talc

Details of the Gumeracha talc deposit have been given in Dickinson *et al.* (1951) and the mineralogy and petrology have been discussed by Stillwell and Edwards (1951). Stillwell in Gartrell and Blaskett (1945) described Grades 1, 2 and 3 as ranging from white talc with minor albite and biotite, through talc with biotite and possibly chlorite to third grade which is spotted with biotite and contains albite.

Details of analyses of Gumeracha talcs and testing of first and third grade material are given in Table 4.

6.2.1 Discussion

Hiern (1969, p 15) reported that production at Gumeracha has been fairly steady at 2500-3000 tons per year since 1964, and that four grades are produced by hand selection. Gumeracha talc suffers from discolouration, the presence of albite and pyrite and of iron staining. All grades are reported to be difficult to grind.

Grade 1 is stated by Hiern to be about equivalent to Grade 2 from Mt Fitton and to be used for lower quality cosmetics and for paint. It is free from iron staining and albite grains.

Grade 2 is stated by Hiern to be used for paints but Grades 2 to 4 are of lower quality stained talc suitable mainly for insecticides dusting powders, waterproof paints etc.

The Amdel investigation involved a detailed examination of two samples which were stated to be of first and third grades but the results indicate an inferior material to that discussed by Hiern above. It is assumed that the Amdel samples are not representative of the deposit as described by Hiern because the first grade Gumeracha sample was far inferior to even third grade Mt Fitton.

Stillwell and Edwards (1951) suggested that the iron was mainly combined in the structure of the talc and hence was not removable by physical beneficiation. The refractive index is not unduly high, nor does X-ray diffraction show the spacing of the basal plane to be perturbed (as would be minnesotaite).

This point is so critical in considerations of possible use and possible beneficiation that electron probe analyses were made to locate iron in Sample CE3528 (Gumeracha 3rd grade — detailed in Table 4), separate splits of which showed values of FeO = 1.57% and 2.20% and Fe_2O_3 = 0.19% and <0.01% by normal chemical analysis. This work showed that the abundant form of talc in the sample contained an average of 1.96% FeO (see Table 7) and that iron-stained areas contained additional iron which averages 1.23% expressed as Fe_2O_3.

The probe results are compatible with the bulk analyses; the whole chemical evidence implies that third grade Gumeracha talc at best will contain a little in excess of 1.5% Fe (2% expressed as FeO) the majority of which is in the crystal structure and hence not mechanically separable. The worst, iron stained and weathered third grade talc, would be expected to contain goethitic iron totalling an additional 1.7% Fe_2O_3. The worst material might be avoidable by selective mining. The minimum figure for third grade Gumeracha talc has iron in excess of that generally accepted for ceramics (1.5%) and hence even though first grade would be acceptable it is doubtful if third grade would be useful for any but the lowest value products.

Tile Blends. An experimental investigation was made of blends of Gumeracha talc and various local clays to evaluate the behaviour in wall tiles.

The tiles were fired at a range of temperatures (1050 to 1220°C); firing shrinkage and 24-hour cold-water absorption were measured. The tiles fired in shades of fawn. Details are shown in Tables 5 and 6.

Samples were glazed and fired; the glazes covered well and showed no adverse properties.

Experiments on the ceramic use of Gumeracha talc have had some success. The talc itself is refractory (Seger cone 15-16) and talc blends have satisfactory firing shrinkages and water absorptions.

The fired colour is light-fawn to fawn in blends incorporating first grade Gumeracha and dark dark-fawn will be the third grade Gumeracha talc. There seems no reason why light coloured tiles should not be acceptable for coloured and glazed floor and wall tiles even though the composition may fall outside of the normal range.

The Gumeracha talc must be considered very seriously as a raw material for a ceramic tile industry, although the samples submitted to Amdel would not be acceptable for cosmetic or paint use. If talc were to be used, then the Gumeracha deposit is the closest to a city centre and to transport to markets in the Eastern States. Three Springs talc is of much better quality but is much more remote, both from Perth and from Eastern States markets although it must be appreciated that Three Springs material is sufficiently attractive to be at present exported to Europe for ceramic purposes.

Grainsize of Gumeracha Talc. Particle size determinations were carried out on seven samples of Gumeracha first grade which had been subjected to between 6 and 48 hours wet or dry grinding. Attempts were made to determine the Blaine surface area but the results are not considered reliable for materials above 5000 Sw cm^2/g.

The results are given in Table 11.

It can be seen that the particle size decreases with increased grinding (being highest in the 48-hour dry grind at 58.4% passing 3 μm). Particle size also is smaller for wet than for dry grinding over 12 and 24 hours but is smaller at 48 hours for dry grinding.

Filler in Vinyl Tiles. The Colonial Sugar Refinery Research Laboratories submitted a sample of talc which is used as a filler in vinyl tiles. Its properties are compared below with Gumeracha first grade after a 6-hour dry grind:

Particle Size, less than	CSR Sample %	Gumeracha 1st Grade, %
50 μm	100.0	100.0
25 μm	86.0	81.0
20 μm	75.7	76.0
15 μm	66.1	70.0
10 μm	54.4	55.0
8 μm	44.8	46.2
7 μm	38.8	40.3
6 μm	31.6	33.0
5 μm	25.1	26.4
4 μm	17.3	20.2
3 μm	9.3	14.1
2 μm	3.7	-
1 μm	0.9	-
Scott volumeter (lb/cu ft)	27.8	29.4
Brightness, %	90	90

A sample of this material was despatched to CSR for testing. They reported that their comparison showed the following:

	Gumeracha Talc	CSR Talc
Colour	Darker & yellower than CSR talc	Good
Bulk density, lb/cu ft:		
loose	29	38
packed	46.5	59.5

CSR stated that the talc did not meet their requirements in colour and bulk density. There is clearly a discrepancy between the results obtained by CSR and Amdel, apparently on the same samples; we are in communication with the company on the matter of standardised test procedures in order to resolve the anomalies.

Gumeracha Talc in Asbestos Sheet. An evaluation was made of the possibility of incorporating talc as an inert filler in fibrous asbestos cement sheet after contact with James Hardie and Company Pty Ltd.

The formulation is confidential but the product is composed of asbestos, Portland cement, inert filler and a proportion of a density-reducing material (calcium silicate hydrate). Test specimens were made using Hardie's materials and also incorporating Gumeracha first and third grade talc. Specimens were manufactured at Amdel, cured at Hardie's and tested at Amdel for density, cold water absorption, modulus of rupture, compressive strength, Brinell hardness, tensile strength and modulus of elasticity.

The talc was intended to replace either the density reducing material or the inert filler. Comparative figures are given in Table 8 but in general it may be stated that the incorporation of talc has the following advantages and disadvantages:

1. It improves the 24-hour cold water absorption, markedly increases the hardness, increases the compressive and tensile strengths marginally, and increases the modulus of elasticity;
2. It does not reduce the density of the product (because talc is denser than the compounds it replaces), and reduces the modulus of rupture.

6.3 Truro

Little information is available on the talc deposits at Truro (Johns, 1962; Olliver 1967a, Hiern 1969) where off-white gritty talc has been reported, but preliminary investigations indicate that the material is of considerable interest.

Hiern (1969, p 18) reported a sample containing 68% talc, 28% quartz and 4% kaolin and another containing up to 50% talc. Preliminary tests showed the talc to be suitable for medium grade ceramics.

Amdel investigations dealing with a variety of samples indicate that the quality is variable from excellent to very poor. Some samples consist of 99% talc with very minor impurities (quartz, feldspar, opaques) and are white to pale cream in colour. Talc-kaolin (equal proportions) rocks also occur as do discoloured impure iron-bearing talc-clay rocks.

A report (McColl, Consultant's report in prospectus for Panamin NL) states that talcose metasediments occur over a wide range. The material is variable in quality and one sample is stated to consist of 67% talc, 27% quartz, 5% clay and mica and 1% accessories. Two analyses were given by McColl, the third is from Hiern (1969, p 32):

	McColl		Hiern	Average
	%	%	%	%
SiO_2	71.5	60.6	71.7	67.9
Al_2O_3	2.98	7.59	1.68	4.08
Fe_2O_3	0.74	1.07	0.50	0.77
MgO	18.3	21.7	21.7	20.2
CaO	0.63	0.03	0.15	0.27
K_2O (+Na_2O)	0.05	0.22	0.10	0.12
TiO_2	0.24	0.69	0.08	0.34
Loss on ignition	5.4	6.9	3.60	5.3

The value of the talc is decreased by the high quartz content but this could be reduced by preferential comminution. The talc could probably be used directly in ceramics but certainly could be upgraded to excellent ceramic material, by simple beneficiation, and possibly to cosmetic or paint grade by flotation.

6.4 Lyndoch

Hiern (1969) reported that talc bodies at Lyndoch occurred in a similar environment to those at Gumeracha which is about 14 miles to the south.

No samples from this area were included in the present Amdel investigation but a previous Amdel report (referred to by Olliver 1967b) and the chemical analyses tabulated below (Olliver 1967b) allow some comparisons to be made with the Gumeracha material:

	Lyndoch Talc, %	
	Best Green	Good White
SiO_2	61.0	63.7
Al_2O_3	0.43	6.25
Fe_2O_3	0.43	0.43
FeO	1.78	1.36
MgO	29.4	20.4
CaO	0.21	0.04
Na_2O	0.05	3.0
K_2O	0.21	0.09
TiO_2	0.39	0.28
MnO	0.02	0.01
CO_2	0.10	0.10
H_2O^+	5.10	3.75
H_2O^-	0.66	0.52
P_2O_5	0.99	0.02

The analyses indicate that the talc is similar to that at Gumeracha with a range of composition, a significant albite content, high iron and small clay and/or chlorite contents. The compositional fields overlap as indicated in Appendix A. Olliver (1967b, p 108) reported Amdel results stating that contaminants such as albite, quartz, chlorite, apatite, rutile, tourmaline and sphene are present.

6.5 Tumby Bay

The talc deposits at Tumby Bay have been discussed in detail by Dickinson (1943), Broadhurst (1951) and their petrology given by Stillwell and Edmonds (1951). Further details have been given by Hiern (1967, p 81; 1969, p 19). Three samples have been studied in this project: high grade (sample CE3558), orebody A (Sample CE3559) and orebody E (Sample CE3560). Results are given in Table 9.

6.5.1 Discussion

The highest grade material is good quality with a high proportion of talc, low total iron, alkalies, alumina and lime and a high reflectivity. It would make excellent ceramic material and looks promising as paint pigment but is deficient for cosmetic grade, particularly in the few percent of quartz, a high pH and excessive acid and water solubles. These would require correction before use in the more valuable categories.

The material from orebodies A and E are much lower in grade but would be acceptable for ceramic purposes in their raw state although test tiles fired pale pink and pale fawn. Hiern (1967, p 81) stated that the talc used for tile blends was second grade but had been cut out by the leaseholder and this might not be representative.

Tumby Bay Tile Blends. The following fired and glazed blends were prepared as detailed below:

	Blend 1	Blend 2	Blend 3
Tumby Bay talc	35	35	35
Tumby Bay talc	0	50	0
Axedale ball clay	50	50	50
Cromer kaolin	10	10	10
Silica	5	5	5

The tiles fired in colours of off-white, pale pink and pale fawn. The glazes covered well and showed no deleterious features.

6.6 Yongala

Hiern (1969, p 20) reported that impure gritty talc was associated with dolomitic limestone 2 miles south-west of Yongala which is itself south-west of Peterborough.

A single sample of impure talc from the vicinity of Yongala submitted for routine identification was incorporated in the general study. Its properties are as follows:

1. Colour: white

2. Chemical Composition, %:

SiO_2	70.3	K_2O	2.4
Al_2O_3	10.8	TiO_2	0.58
Fe_2O_3	0.2	MnO	nd*
FeO	0.57	CO_2	0.15
MgO	9.95	SO_3	nd
CaO	0.25	Cl	0.04
Na_2O	0.1	H_2O^+	6.1

3. Mineralogical Composition - X-ray Diffraction:

Talc	major
Chlorite	nil
Albite	moderate
Illite, mica	nil
Quartz	approx. 25%

Kaolin	major
Montmorillonite	appreciable proportions of -2 μm fraction
Tourmaline	<1%

A calculation based on the chemical analysis suggests the following mineralogical composition:

Talc	30%
Feldspar	25%
Quartz	25%
Kaolin	20%

Another sample from the same area was reported to be richer in kaolin, poorer in quartz (less than 1%) and to contain appreciable rutile and tourmaline.

4. Firing Tests:

Firing of a semidry pressed tile to 1250°C resulted in a porous body with 8.7% water absorption and a linear contraction of 1.2%. The material may be suitable as a natural tile body. This opinion differs from that given in Service Report MT1165/71.

6.6.1 Discussion

The Yongala talc is of interest because of its white colour and comparatively low iron (Fe_2O_3 = 0.2%, FeO = 0.57%). It contains free quartz and feldspar (which cause grittiness) and also clay.

The preliminary firing test of a talc sample was not successful but the mineralogical composition is such that it might serve as a ceramic raw material with a little treatment or might yield a valuable talc with more-complex treatment.

The deposit is accessible by rail and the few details available suggest that it might be extensive. It should be regarded as of considerable interest and be investigated further.

Preliminary investigation of the possibility of beneficiation suggests that flotation techniques are most successful in removing kaolin, quartz and feldspar; however, recovery of the refined talc is low, approximately 16% of the total sample.

6.7 Yatina

Hiern (1969, p 21) reported an occurrence of talcose kaolinitic clay in a shear zone through Adelaide System rocks near Yatina which is just north of Peterborough. Preliminary firing tests showed the material to be suitable for ceramic whiteware. No details are known.

6.8 Hallett

Hiern (1968, p 181) reported white clay and talcose clay near Hallett.

Amdel has investigated the firing behaviour of three samples of talc-clay mixtures ranging from white (Sample 2027/67), to cream (Sample 2028/67) to yellowish brown (Sample 2029/67). The samples showed a high salt content and fired in colours through off-white, cream, pink, grey, yellow and red. The purer Samples 2027/67 and 2028/67 although not satisfactory showed some potential and warranted further investigation.

7. SOUTH AUSTRALIAN TALCS CLASSIFICATION AND USE

7.1 Classification by Chemical Composition

Apart from the talc at Mt Fitton, which suffers from a location problem, South Australian talcs are of mediocre to poor quality only. One pressing problem is to select one or two simple parameters from the whole range of properties quoted in order to evaluate the potential of the talc quickly.

Emphasis is placed on chemical composition in this section but it is emphasised that the use of talc depends mainly on its physical properties and the chemical composition is only of importance in that it readily demonstrates the presence of impurities which affect the physical properties.

Talcs range in grade, use and price as follows, from highest grades (top) to lowest grades (bottom):

a. Cosmetic

b. Paint fillers, high-grade ceramics (insulators, steatite bodies);

c. Medium-grade ceramics (table ware, electrical and sanitary porcelain, wall and floor tiles, corderite bodies);

d. Low-grade ceramics (stone tiles, kiln furniture);

e. Rock wool, roofing materials.

In general, the higher grades are whitest, have highest reflectivity, richest in pure talc, free from grit and lowest in impurities. The main impurities which affect the use of talc are Al_2O_3 (in clay and chlorite), SiO_2 (in quartz) and $FeO + Fe_2O_3$ (as hematite, magnetite, limonite, chlorite and other ferromagnesian minerals and in the talc lattice). Of all the impurities, Al_2O_3 and total $FeO + Fe_2O_3$ are most important, hence a means of diagrammatically distinguishing between different types is here based on these two components. The compositions of a wide range of South Australian and foreign talcs are plotted in Figure 5 and it is seen that there is a considerable spread. Figure 6 is a preliminary attempt to outline compositional boundaries between talcs of different use (grade and price) and in general it is clearly seen that the best talcs fall near the origin (low iron and alumina), that there is a considerable field of medium-grade ceramic talcs (under a limit of 1.5% iron but with considerable and variable amounts of alumina) but that the higher iron talcs (which are coloured green to grey) have limited use and value.

The best quality talc from Mt Fitton plots in the cosmetic field and low grade Mt Fitton, Tumby Bay, Truro and Yongala all plot within the ceramic field. The limitations of this diagram must be borne in mind; it does not take into account the presence of quartz, chlorite and rutile; it is rather insensitive to the presence of feldspar and does not distinguish between iron in oxides or silicates.

Tumby Bay talc is low in both iron and alumina and hence would be predicted to be of high quality. However, mineralogical analysis indicates the presence of up to 6% of quartz and also the presence of traces of kaolinite and chlorite. The reflectivity is remarkably low at 65 to 81% for a talc of this composition, however, it is probable that much of the difficulty is due to insufficient sampling; for example, Stillwell and Edwards (1951, p 29) describes some samples as being "snow-white" and this colour matches the low iron values (total FeO + Fe_2O_3) of 0.37 to 0.55%.

The Gumeracha deposits pose a substantial problem. The iron content is high, thus the compositions plot out of the field for even low-grade ceramics (Fig.6). Earlier attempts at beneficiation (Blaskett, in Dickinson *et al.* 1951) were not successful in obtaining a talc concentrate low in iron (FeO = 2.8%), and it has been shown here that much of the FeO is present in the talc molecule. Hence, no method of physical beneficiation will be able to upgrade bulk Gumeracha talc to make it saleable, and only restricted, higher grade portions will be useful.

8. ECONOMIC POSSIBILITIES FOR IMPURE TALCS

The use of talc and hence its value is dependent almost entirely on the presence or absence of impurities. The effect of particle size is also important but this aspect, and the means of overcoming it, will be discussed later. Impurities consist of definite minerals such as clay, quartz, feldspar, chlorite, mica, carbonates, amphibiles, iron oxides, rutile, tourmaline etc or occur in less definite forms such as solid solution of FeO in the talc structure or as iron and manganese-oxide staining of minerals.

There are two possible approaches to the use of impure talcs:

a. Determination of an industrial use for the material in its raw form;

b. Beneficiation to remove impurities and upgrade the talc.

8.1 Talcs in Ceramic Tile Blends

A variety of blends of clays and talcs were evaluated as described in Section 6.

One-kilogram batches were prepared by grinding the talc to minus 60 mesh (BSS) and then milling for 2 hours with 1 litre of distilled water in a ball mill. Various proportions of Axedale ball clay, Cromer kaolin and silica were added together with a further 500 ml of water and the whole milled for 5 hours. The slurry was filter pressed and the filter cases dried in an oven at 105°C until the moisture content was 9.2% at which time the material was broken up to pass an 18-mesh screen. A manually operated press was used to form 2 by 2 by ¼-inch tiles which were dried in an oven at 105°C and fired at various temperatures as shown in Table 10. Temperatures to 1220°C were used in order to achieve a low water-absorption value to meet specifications and for floor tiles (See Section 4.3.3).

Selected tiles were spray-coated with commercial glazes and fired at 1030 to 1080°C. In all cases the glazes covered well and revealed no adverse properties such as crazing, crawling, or pinholing; no delayed crazing was apparent after 1 month in room atmosphere.

8.2 Use of Some Impure Raw Materials

The relationship of composition and purity to possible use has been discussed at length in Section 4 but attention is here drawn to one particular point which is relevant to South Australian material.

Some impurities, such as iron oxides, are strongly deleterious and cause talc to be of little or no value but it does not appear to be appreciated that other impurities need not be deleterious for certain purposes. The highest quality talc must be extremely pure and free from all but traces of impurities, but ceramic-grade talcs need not be pure. Talc is used in conjunction with a number of natural materials which may be acceptable in a talcose raw material; these include kaolin, feldspar, tremolite, dolomite, magnesite, chlorite and quartz.

Tremolitic talc (asbestine) is highly favoured in the United Sates of America for the manufacture of wall tiles and pigments. Talc is combined with kaolin in the production of wall and floor tiles. A combination of talc and magnesia (as $MgCO_3$,$Mg(OH)_2$ or MgO) gives a forsterite body; combined with kaolin or chlorite gives a cordierite body; and combined with tremolite gives an enstatite body.

The following natural mineral assemblages are found in various South Australian localities:

talc + kaolin	Mt Fitton, Yongala
talc + kaolin ± tremolite	Mt Fitton
talc + chlorite	Mt Fitton, Gumeracha
talc + dolomite	Mt Fitton
talc + albite	Gumeracha
talc + clay + chlorite	Tumby Bay

It would appear desirable to carry out an investigation of the possibility of using these natural talcose mixtures as ceramic raw materials as an alternative to seeking methods of upgrading them by removing impurities.

8.3 Beneficiation of Talc

Talc is a comparatively low-cost commodity and its price allows little in the way of physical or chemical treatment for upgrading. Apart from block steatite, all commercial talc is used in the pulverised, powdered form. The crushing process is of vital importance because a particle size-range is part of the specification for all grades. It is emphasised that micronising is becoming increasingly important.

8.3.1 Grinding

The particle-size distributions resulting from various periods of wet and dry ball milling of Gumeracha first grade are recorded in Table 11.

The raw material was jaw crushed and then 500-g batches were placed in a ball mill and ground under uniform conditions, both wet and dry, for periods of 6, 12, 24 and 48 hours. The samples were dried, re-powdered and size analyses carried out.

Comparative properties of various dry-ground South Australian talcs are given in Table 12.

The particle size requirements of various Australian manufacturers are as follows:

Ormonoid Roofing	0.3% retained on 20 mesh, 3 % retained on 25 mesh, not too many fines.
Reckitt & Coleman	0.2% max. residue on 200 mesh
CSR	5 % max. residue on 200 mesh
Jarvis (paint) (four grades)	95 % -240 mesh 99 % -200 mesh 99 % -300 mesh 99.5% -300 mesh
Jarvis (rubber) (three grades)	95 % -240 mesh 80 % -200 mesh 98 % -300 mesh

It can be seen that Gumeracha first grade meets Jarvis' size requirements for paint and rubber but are too fine for Ormonoid's roofing material.

A comparison between the various grinding methods are as follows (figures approx):

Size	6 hr	12 hr		24 hr		48 hr	
µm	Dry, %	Dry, %	Wet, %	Dry, %	Wet, %	Dry, %	Wet, %
+23	22	8	2	5	2	4	7
8-23	33	36	24	25	11	15	19
-8	46	58	75	71	87	81	74

The particle size has a considerable effect on colour and reflectivity. Samples are darker in the massive than in the ground state, and in addition, increased grinding tends to increase reflectivity as shown below:

Material		Reflectivity,%	
		Ground to -300 mesh	Dry ground 6 hr
Gumeracha:	1st grade	87.5	90.0
	3rd grade	77.0	83.5
Tumby Bay:	1st grade	81.5	88.3
	Orebody E	65.0	76.2

Considerable differences in reflectivity were obtained by different grinding methods, as shown by the following results for Mt Fitton (3rd grade):

Grinding Method	Reflectivity, %
Rod mill	75
Ball mill	85
Pebble mill	91
Microniser	87

8.3.2 Flotation

This project has not included consideration of beneficiation by flotation but the topic is raised here because it would appear that the economic exploitation of most of the South Australian deposits will require flotation and it is recommended that any extension of this project include a study of the technicalities and economics of the process.

Flotation is not used in Australia to beneficiate talc but is in use overseas. The published work on South Australian talcs has not shown impressive results but studies at Amdel, not related to this project, have shown that modern techniques and reagents can achieve considerable success so that the obstacles will be economic not technical.

To summarise: Blaskett (1946) showed that flotation of Gumeracha talc was possible but this and later attempts (Stillwell and Edwards 1951) did not obtain a concentrate of satisfactory grade.

Jackson (1951) discussed the beneficiation of Mt Fitton talc and a preliminary attempt by Moskovits (1964) showed that third grade could be markedly improved by flotation. The colour was further improved by acid leaching.

Investigations by Amdel suggest that the impure Yongala talc plus kaolin mixture could be improved in quality by both cyclosizing and flotation. The quality of the material was much improved but the recoveries were rather low.

9. SUMMARY OF THE POTENTIAL OF SOME SOUTH AUSTRALIAN TALCS

The general characteristics of each of the talcs have been described in Section 6, and the chemical classification given in Section 7 allows some evaluation and comparison to be made.

An attempt is made in Table 13 to integrate all the details available and relate each of the talcs to possible usage.

This table must be regarded as only a preliminary attempt designed to promote discussion. Many of the decisions made are subjective and based on inadequate information but it is hoped that the comparison will clarify some general relationships and stimulate further investigation.

9.1 Cosmetic Grade

Mt Fitton talc is used for cosmetic purposes and is the only material to satisfy requirements. The best Tumby Bay is gritty, alkaline, has high acid solubles and is insufficiently bright. Truro talc might reach requirements after beneficiation although treatment tends to spoil the properties. Hiern (1969) stated that first grade Gumeracha is used for low-quality cosmetics but the material tested falls far short of the stated specifications. It may be that the Amdel sample was not representative, that a certain proportion of first grade was hand-picked for this use, or that the purchaser has a more-liberal specification. The best Tumby Bay is better than the Gumeracha so that it might have a similar use.

9.2 Paint Grade

Pigment specifications are rather imperfectly defined but Mt Fitton (first and third grade) and Gumeracha (first grade) appear suitable from the Amdel tests. Hiern (1969) stated that these two were used as paint pigments. Tumby Bay (first grade) appears to be generally suitable but is high in both acid and water solubles; it is lower in iron and whiter in colour than Gumeracha.

9.3 Ceramic Use

Mt Fitton (first and second grade) would be satisfactory for the brightest quality, all Tumby Bay for high grade, Truro, Mt Fitton (third grade) and Yongala look promising for medium quality ceramics. The talc from Gumeracha and Lyndoch is too high in iron for good quality ceramics and it would appear to be suitable only for the lowest grade unless sorting or treatment could separate out a low-iron fraction.

9.4 Miscellaneous: Fillers, Absorbents, Dusting Powder, Roofing Compounds, etc.

Most talc from Gumeracha, Lyndoch and Cowell and much from Tumby Bay is suitable only for lowest grade uses. Even here there are difficulties as shown by the failure of preliminary attempts to produce a sample of Gumeracha talc for filling in vinyl tiles; the deficiencies were in colour and bulk density.

10. RECOMMENDATIONS

The field investigations of Hiern (1969) together with the material in this report form a useful summary of the characteristics of South Australian talcs and it is recommended that additional information be obtained to allow publication of a comprehensive coverage of the subject.

Discrepancies between Amdel results and those of other workers suggest that the Amdel samples were not representative of the various deposits and the first requirement is for testing of a sufficiently large number of samples from all deposits to allow meaningful evaluation.

The most promising field of use for many of the mediocre talcs is in ceramics (and possibly paint pigments). A detailed investigation should be carried out on the ceramic uses for a range of talcs, including natural talc-kaolin and talc-tremolite mixtures.

The work to date suggests strongly that talcs from Gumeracha, Lyndoch, Truro and Yongala will require treatment before they can be sold; this will involve pulverising, micronising and flotation. The economic and technical feasibility of beneficiation should be studied in detail.

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APPENDIX A

COMPOSITION OF VARIOUS TALCS
Plot of FeO + Fe_2O_3 against Analyses*

1.	Average mined, Talcville, NY	Analyses, Table 1**
2.	Average mined, Fowler, NY	
3.	Hewitt Mine, North Carolina.	
4.	Steatite grade, Talc City Mine, California.	
5.	Tremolitic talc, Silver Lake Mine, California.	
6.	Steatite grade, Yellowstone Mine, Montana.	
7.	Refined talc, steatite bodies, Pfizer.	
8.	Refined talc, tile bodies, Pfizer, California.	
9.	Best white, Luzenac, France.	
10.	Second white, Luzenac, France.	
11.	Best white, Mantern, Austria.	
12.	Superfine cosmetic, Italy.	
13.	Grey talc, mill produced, Bergen, Norway.	
14.	Grey talc, soapstone, USSR.	
15.	Finnish, A & B grades.	
16.	Norweigian, AT.	
17.	Norweigian, IT.	
18.	A to H: Talcumwerke Naintsch, ceramic grades.	A and G analyses not given.
19.	White, Three Springs, Western Australia.	
20.	White, Three Springs, Western Australia.	
21.	First grade, Mt Fitton.	Analyses, p. 20-21**
22.	First grade, Mt Fitton.	
23.	Third grade, Mt Fitton.	
24.	Tumby Bay, first grade.	Analyses, Table 9**
25.	Tumby Bay, orebody 'A'.	
26.	Tumby Bay, orebody 'E'.	
27.	Tumby Bay, run-of-mine 4.	
28.	Tumby Bay, run-of-mine 5.	
29.	Tumby Bay, run-of-mine 6.	
30.	Tumby Bay, run-of-mine 7.	
31.	Tumby Bay, run-of-mine 8.	

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* Figures 5 & 6 in Main Report.

** In Main Report.

32.	Gumeracha, 1st grade.	Analyses, Table 4**
33.	Gumeracha, 3rd grade.	
34.	Gumeracha, hand picked — Analysis No.3 (Dunstan's talc mine)	
35.	Gumeracha, hand picked — Analysis No.4 (Symonds' No.2 shaft)	
36.	Gumeracha, white soapstone — Analysis No.5.	
37.	Gumeracha, fibrous talc Porters', Analysis No.6	
38.	Gumeracha, bulk sample, Dunstan's mine, — Analysis No.7.	
39.	Gumeracha, flotation concentrate from No.38, — Analysis No.8	
40.	Yongala, impure talc-kaolin	Page 28**
41.	Truro talc	Analyses, page 26**
42.	Truro talc	
43.	Truro talc	
44.	Lyndoch, best green	Analyses, page 27**
45.	Lyndoch, good white	

** In Main Report.

TABLES 1 to 13

FIGURES 1 to 6

TABLE 1: CHEMICAL ANALYSES OF COMMERCIAL TALCS, NON-SOUTH AUSTRALIAN

	Analyses, %																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SiO_2	59.80	66.23	61.35	59.61	57.40	62.65	61.5	50.2	61.00	57.00	61.54	60.34	38.4	58.93	55.8	38.9	62.4	46.3	62.08	62.47
Al_2O_3	0.57	1.05	4.92	1.65	1.29	0.31	0.8	0.5	2.36	6.38	1.74	1.77	1.74	3.59	-	0.9	0.2	12.6	0.46	0.58
Fe_2O_3	0.05	0.13)	1.68	-)	0.86	1.51	1.0	0.6	0.84	0.99	0.76	0.23	0.91	0.29	0.4	0.6	0.1	-	0.08	0.20
FeO	0.15	0.22)		0.92)					0.03	0.03	-	0.85	5.21	3.29	-	5.9	0.2	1.5	0.77	0.76
MgO	27.45	25.71	26.03	30.01	23.91	30.23	30.2	23.0	33.75	32.70	30.09	31.14	31.98	29.27	31.5	32.8	31.3	30.6	31.33	30.55
CaO	6.80	2.26	0.82	0.84	13.55	Tr*	0.2	11.5	0.56	0.56	1.81	0.64	1.22	0.72	0.4	1.0	0.3	0.1	0.04	0.07
Na_2O+K_2O	-	-	-	0.26	0.44	0.20	0.07	1.3	-	-	-	-	-	-	0.1	-	-	-	0.42	0.08
SO_3	0.07	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H_2O or LOI**	4.75	3.86	5.10	5.94	2.20	4.95	5.3	12.03	1.03	1.83	3.65	5.20	3.58	3.08	5.0	3.0	4.9	4.6	4.68	4.80
H_2O^-	0.45	0.25	-	-	2.12	4.87	-	-	-	-	-	-	-	-	1.5	0.1	0.1	-	0.33	0.44
CO_2	1.18	0.56	-	-	-	0.27	-	-	nil	nil	-	0.78	16.26	0.50	3.6	16.8	0.5	4.0	0.06	0.06
MnO	0.39	0.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01

* Tr = Trace.

** LOI = Loss on ignition.

Key:

1. Average mined, Talcville, NY.
2. Average mined, Fowler, NY
3. Hewitt mine, N. Carolina.
4. Steatite grade, Talc City Mine, California.
5. Tremolitic talc, Silver Lake Mine, California.
6. Steatite grade, Yellowstone Mine, Mont.
7. Refined talc, electrical bodies, Pfizer MP98-24, Mont.
8. Refined talc, tile bodies, Pfizer CP 96-46, Calif.
9. Best White, Luzenac, France.
10. Second white, Luzenac, France.
11. Best white, Mantern, Austria.
12. Superfine cosmetic, Italy.
13. Grey talc, mill product, Bergen, Norway.
14. Grey talc, soapstone, Miass. USSR.
15. Finnish, A. & B. grades, 'papertalc', 95% talc, reflectivity 76-84%.
16. Norwegian, AT.
17. Norwegian, IT.
18. Talcumwerke Naintsch, grade H (low grade ceramics), whiteness 60%.
19. Three Springs, Western Australia, white.
20. Three Springs, Western Australia, off-white.

Analyses: 1-6, Engel & Wright 1960; 7, 8, Norton (1970, p 74); 9-18, Industrial Minerals; 19-20, Unknown source.

TABLE 2: TALC USE

Locality	Potential Use of SA Talcs								
	1	2	3	4	5	6	7	8	9
Mt Fitton, first grade	x	x	.	x	x	.	.	.	.
Mt Fitton, third grade	?	?	x	x	x	x	.	.	.
Gumeracha, first grade	?	.	x	.	x	x	x	x	x
Gumeracha, third grade	.	.	.	.	.	?	.	x	x
Tumby Bay, first grade	.	.	?	x	x	x	.	.	.
Tumby Bay, 'A' body	.	.	.	.	.	x	x	x	x
Tumby Bay, 'E' body	.	.	.	.	.	x	.	x	x
Yongala, raw	.	.	.	.	x	x	x	.	.
Yongala, beneficiated	.	?	?	x	x	x	x	.	.
Truro, raw (average)	.	.	.	x	x	x	.	.	.
Truro, beneficiated	?	?	?	x	x	x	.	.	.

Key: 1. Cosmetic
2. Pigments, paper
3. Pigments, paints
4. Ceramics, high grade (insulators)
5. Ceramics, medium grade (table-ware, wall tiles)
6. Ceramics, low grade (floor tiles, kiln furniture, earthenware)
7. Plastic and rubber fillers
8. Rock-wool, roofing materials
9. Dusting agent, absorbents for fertiliser etc.

TABLE 3: COMPARISON BETWEEN TGA LIMITS AND SOME COMMERCIAL COSMETIC TALCS

	TGA Limits	Canadian	Indian	French	Italian	NY State	California	North Carolina	Mt Fitton
Loss on ignition: max. %	7	9,92	1.98	4.18	2.28	3.94	6.79	2.26	4.51
R_2O_3 (Fe_2O_3, Al_2O_3, SiO_2) max. %	6	1.40	0.43	0.85	0.40	1.08	0.63	0.07	1.19
Acid soluble Fe_2O_3, max. %	0.75	1.30	0.43	0.48	0.40	0.57	0.63	0.07	0.58
CaO max. %	1.5	4.09	0.11	0.24	0.53	2.73	3.72	0.94	nd*
Carbonates	nil	Tr**	nil	nil	nil	Tr	nil	Tr	nil
Pb, max. ppm	20	0	1	2	0	0	0	1	-
As max. ppm	2	1	1	1	0	0	0	1	-

* nd = Not determined.
** Tr = Trace.

TABLE 4: GUMERACHA TALC

		1	2	2.1	3	4	5	6	7	8
a.	Colour	Grey-white	White	Yellowish-tinge	-	-	-	-	-	-
b.	Chemical composition, %:									
	SiO_2	63.1	62.8	62.2	61.90	61.42	61.98	60.66	61.98	61.86
	Al_2O_3	3.8	4.80	1.48	1.88	0.72	5.74	0.78	2.71	0.59
	Fe_2O_3	0.22	0.19	<0.01	0.65	0.70	nil	0.37	0.76	0.28
	FeO	1.84	1.57	2.20	1.66	1.75	1.93	2.94	1.70	2.57
	MgO	23.8	22.9	28.4	28.23	29.82	25.60	29.31	26.82	30.20
	CaO	0.14	0.03	0.52	nil	nil	0.18	nil	0.22	0.08
	Na_2O	2.25	2.40	0.45	0.68	0.10	-	0.04	1.42	0.02
	K_2O	0.03	0.02	0.01	nil	nil	-	nil	nil	nil
	TiO_2	0.35	0.57	0.44	0.07	0.10	-	nil	0.13	0.04
	MnO	<0.01	<0.01	<0.01	-	-	-	-	-	-
	CO_2	0.25	0.20	0.10	nil	nil	nil	nil	-	-
	SO_3	0.03	<0.01	0.30	nil	nil	-	nil	-	-
	Cl	<0.01	<0.01	<0.01	nil	nil	-	nil	-	-
	H_2O^+	3.9	4.10	4.00	4.66	4.96	4.10	5.41	4.20	4.90
c.	Trace elements, ppm, detection limits in brackets:									
	Cu (0.5	120	250	-	-	-	-	-	-	-
	As (50)	nd*	nd	-	-	-	-	-	-	-
	Sn (1)	3	10	-	-	-	-	-	-	-
	Sb (30)	nd	nd	-	-	-	-	-	-	-
d.	Soluble salts:									
	Acid soluble, %	2.52	3.09	-	-	-	-	-	-	-
	Water soluble, %	0.03	0.04	-	-	-	-	-	-	-
e.	Mineralogical composition:									
	Talc	Dominant	Dominant	-	-	-	-	-	-	-
	Chlorite	?	?	-	-	-	-	-	-	-
	Albite, %	10	2-10	-	-	-	-	-	-	-
	Illite	Trace	Trace	-	-	-	-	-	-	-
	Quartz	nd	nd	-	-	-	-	-	-	-
	Kaolin	nd	nd	-	-	-	-	-	-	-
f.	Refractoriness:									
	PCE cone number	15-16	15	-	-	-	-	-	-	-
	Temp equiv., °C	1430-1491	1430	-	-	-	-	-	-	-
	Firing shrinkage, %	1.7	2.3	-	-	-	-	-	-	-
	Coefficient of linear expansion (0-500°C)	9×10^{-6}	7×10^{-6}	-	-	-	-	-	-	-
g.	Particle size distribution:									
	% retained on 200#	-	34.4	-	-	-	-	-	-	-
	% retained on 300#	9.5	3.09	-	-	-	-	-	-	-
h.	Bulk density, lb/cu ft	29.2	22.7	-	-	-	-	-	-	-
i.	pH of 25% slurry	9.15	9.05	-	-	-	-	-	-	-

(Continued)

TABLE 4: CONTINUED

	1	2	2.1	3	4	5	6	7	8
j. Fired properties:									
Pressing moisture content, %	9.2	4.0	-	-	-	-	-	-	-
Firing temperature, °C	1120	1220	-	-	-	-	-	-	-
Fired shrinkage, %	5.0	5.0	-	-	-	-	-	-	-
Water absorption, %	1.9	1.7	-	-	-	-	-	-	-
Fired colour	light fawn	dark fawn	-	-	-	-	-	-	-
k. Grinding and reflectivity:									
Reflectivity, % ground to -300#	87.5	87.0	-	-	-	-	-	-	-
Dry ground 6 hours, %	90.0	83.5	-	-	-	-	-	-	-

* nd = Not determined. **Fired properties of talc tile blends incorporating 35% Gumeracha talc (refer Table 5, Blends 1 & 2, and Table 6).

Key:		
	Analysis 1	Sample CE3527 - Gumeracha 1st grade.
	Analysis 2	Sample CE3528 - Gumeracha 3rd grade.
	Analyses 3-8	Stillwell & Edwards, 1951, p 37.
	Analysis 2.1	Sample CE3528 - Gumeracha 3rd grade (analysis 1972).

TABLE 5: TALC BLENDS*

	Blend 1	Blend 2	Blend 3	Blend 4
Gumeracha first grade	35	-	40	45
Axedale ball clay	50	50	40	50
Stokes kaolin	-	-	15	-
Cromer kaolin	10	10	-	-
Silica	5	5	5	3
Whiting	-	-	-	2
Gumeracha third grade	-	35	-	-

* % Proportions.

TABLE 6: FIRED PROPERTIES OF GUMERACHA TALC CERAMICS

Sample	Grade	Pressing Moisture Content	Firing Temp °C	Firing Shrinkage %	Water Absorption %	Colour
35% Gumeracha	1st	9.2	1120	5.0	1.9	Light fawn
40% Gumeracha	1st	7.6	1120	3.6	3.4	Fawn
45% Gumeracha	1st	5.8	1120	3.0	3.8	Fawn
35% Gumeracha	3rd	4.0	1220	5.0	1.7	Dark fawn

TABLE 7: PROBE ANALYSES OF TALC CRYSTALS, SAMPLE CE3528

Normal Talc		Iron Stained Talc	
Iron Measured as Fe %	Iron Expressed as FeO %	Iron as Fe %	Calculated Fe Stain* %
1.53	1.97	2.58	1.69
1.55	1.99	2.35	1.32
1.54	1.98	2.16	1.13
1.71	2.20	2.15	1.0
1.62	2.08	2.15	1.0
1.37	1.76	-	-
1.47	1.89	-	-
1.54	1.98	-	-
1.45	1.86	-	-
1.47	1.89	-	-
1.53**	1.96**	-	-

* The amount of iron not in the lattice is estimated by subtracting the average lattice iron (1.53% in column 1) from total Fe then expressing the difference as Fe_2O_3.

** Average.

TABLE 8: ASBESTOS CEMENT SHEET BLENDS

Blend Property		Manufacturers Blend	Gumeracha Talc	
			First Grade	Third Grade
Density (dry)	lb/cu in.	0.031	0.053	0.050
24 hr cold water absorption:	%	64.5	27.6	34.5
Modulus of rupture (saturated)	lb/sq in.	2750	2465	1890
Compressive strength (saturated)	lb/sq in.	2634	3139	2651
Brinnell Hardness (10 mm ball - 100 kg load)		4.55	10.40	5.65
Tensile strength, lbf/sq in.		1090	1440	1170
Modulus of elasticity,	lbf/sq in.	0.78×10^6	0.96×10^6	0.91×10^6

TABLE 9: TUMBY BAY TALC

	1	2	3	4	5	6	7	8
a. Colour	White	White	Yellow white	-	-	-	-	-
b. Chemical Composition, %:								
SiO_2	64.2	68.7	63.4	61.26	62.02	63.32	61.94	61.08
Al_2O_3	0.87	2.05	0.66	1.76	1.34	0.92	2.16	3.11
Fe_2O_3	0.12	0.62	1.08)	0.37	0.15	0.15	0.29	0.55
FeO	0.22	0.25	0.12)					
MgO	29.9	2.37	30.1	30.53	33.99	33.14	33.95	28.42
CaO	0.20	0.17	0.18	nil	0.48	0.97	nil	0.12
Na_2O	0.26	0.12	0.12	0.17	-	-	-	0.02
K_2O	0.1	<0.1	0.1	0.10	-	-	-	0.10
TiO_2	<0.07	0.13	<0.05	-	-	-	-	-
MnO	0.04	<0.04	0.04	-	-	-	-	-
CO_2	0.04	0.01	0.01	-	-	-	-	-
SO_3	0.04	<0.01	<0.01	-	-	-	-	-
Cl	0.34	0.08	0.01	0.30	-	-	-	0.01
H_2O^+	4.77	4.35	4.83	4.90	1.30	1.06	1.22	5.55
c. Trace elements, ppm, detection limits in brackets:								
Cu (0.5)	250	200	150	-	-	-	-	-
As (50)	nd*	nd	nd	-	-	-	-	-
Sn (1)	10	10	4	-	-	-	-	-
Sb (30)	nd	nd	nd	-	-	-	-	-
d. Soluble salts:								
Acid soluble	3.78	-	7.38	-	-	-	-	-
Water soluble	0.75	-	0.11	-	-	-	-	-
e. Mineralogical Composition:								
Talc	D	D	D					
Chlorite	?Tr	nd	?Tr	-	-	-	-	-
Albite	nd	nd	nd	-	-	-	-	-
Illite, %	2-5	5-10	2-5	-	-	-	-	-
Quartz	nd	Tr	nd	-	-	-	-	-
Kaolin	-	-	Tr	-	-	-	-	-
Dolomite	-	-	-	-	-	-	-	-
f. Refractoriness:								
PCE cone number	16	19	19	-	-	-	-	-
Temperature equivalent	1491	1541	1541	-	-	-	-	-
g. Particle size distribution: (dry ground)								
% retained on 200 mesh	9.7	-	5.7	-	-	-	-	-
% retained on 300 mesh	14.1	-	8.9	-	-	-	-	-
h. Bulk density (Scott volumeter)	20.7	-	20.7	-	-	-	-	-
i. Oil absorption								

(Continued)

TABLE 9: CONTINUED

		1	2	3	4	5	6	7	8
j. pH of 25% aqueous extract:		8.80	-	8.92	-	-	-	-	-
k. Fired properties:									
Pressing moisture content,	%	7.4	11.4	3.0	-	-	-	-	-
Firing temperature,	°C	1200	1200	1200	-	-	-	-	-
Fired shrinkage,	%	8.2	7.0	7.7	-	-	-	-	-
Water absorption		2.7	2.6	2.5	-	-	-	-	-
Fired colour		yellow	light grey	light grey	-	-	-	-	-
l. Reflectivity and grinding:									
Reflectivity ground to -300 mesh		81.5	72.5	65.0	-	-	-	-	-
Dry ground 6 hours		88.5	-	76.2	-	-	-	-	-
m. Refractive index (±0.003)	X =	1.545	-	1.540	-	-	-	-	-
	Y =	1.580	-	1.575	-	-	-	-	-
	Z =	1.583	-	1.582	-	-	-	-	-

* nd = Not determined.

Key: Analysis 1 Sample CE3558 - high grade.
Analysis 2 Sample CE3559 - orebody 'A'.
Analysis 3 Sample CE3560 - orebody 'E'.
Analysis 4 *Mining Review* (1943), 78, 87.
Analyses 5-7 Various authors.
Analyses 8 *Mining Review* (1943), 78, 87.

TABLE 10: FIRED PROPERTIES OF TALC TILE BLENDS

Talc Used	Pressing Moisture %	Firing Temp. °C	Firing Shrinkage %	24 hr Water Absorption %	Fired Colour
Gumeracha (first grade)	9.2	1120	5.0	1.9	Light fawn
Tumby Bay (high grade)	7.4	1200	8.2	2.7	Off-white
Tumby Bay (orebody 'A')	11.4	1200	7.0	2.6	Light grey
Tumby Bay (orebody 'E')	3.0	1200	7.7	2.5	Light grey
Gumeracha (third)	4.0	1220	5.0	1.7	Dark fawn

TABLE 11: PARTICLE SIZE AND BULK DENSITY
Gumeracha first grade - % passing

Size Fraction	Dry Ground	12 hr		24 hr		48 hr	
µm	6 hr	Dry	Wet	Dry	Wet	Dry	Wet
53	-	99.80	99.60	-	-	-	-
38	89.16	99.44	99.52	99.96	-	99.73	98.87
28	83.28	95.84	98.72	97.84	99.04	98.53	95.27
20	74.40	87.64	96.72	92.44	96.64	94.11	89.82
13	63.20	76.32	93.08	85.20	94.48	88.93	85.98
10	54.92	67.96	87.12	80.20	92.32	85.90	83.68
8	46.21	57.66	74.97	70.92	86.72	81.01	74.29
7	40.31	53.45	65.07	65.92	78.76	79.04	69.21
6	32.96	47.13	56.48	58.61	70.72	75.72	62.86
5	26.36	39.42	46.59	51.19	58.32	70.51	53.67
4	20.19	29.82	37.35	42.85	49.14	65.84	45.21
3	14.10	21.63	27.98	34.74	37.40	58.44	35.36
Bulk density, lb/cu ft	29.2	19.7	19.5	21.6	13.2	21.8	20.6

TABLE 12: PROPERTIES OF DRY-GROUND SA TALCS**

Property		Gumeracha Talc		Tumby Bay Talc	
		1st Grade	3rd Grade	High Grade	Orebody 'E'
Retained on 200#	%	-	20.0	9.7	5.7
Retained on 300#	%	9.5	34.4	14.1	8.9
Acid soluble	%	1.16	3.09	3.78	7.38
Water soluble	%	0.03	0.04	0.75	0.11
Reflectivity	%	90	83.5	88.5	76.2
Bulk density,	lb ft^3*	29.2	22.7	20.7	20.7
pH (25% aqueous extract)		9.15	9.05	8.80	8.92

* Scott volumeter.
** Six hours dry grinding by ball mill (Amdel investigation).

TABLE 13: SUMMARY OF SOME SOUTH AUSTRALIAN TALCS AND THEIR POTENTIAL USEAGE

	Sample Number																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Composition:																		
SiO_2 %	-	60.3	55.8	50.65	-	64.2	49.6	60*	68.7	61.0	63.4	67.9	70.3	63.1	55.8	62.8	46.3	40.75
Al_2O_3 %	6.0**	1.50	-	-	-	0.87	8.05	2.5**	2.05	1.4	0.66	4.08	10.7	3.8	5.4	4.80	12.6	-
$FeO + Fe_2O_3$ %	0.3**	0.47	0.4		-	0.34	0.83	1.5**	0.87	1.1	1.20	0.77	0.77	2.06	1.2	1.76	1.5	-
MgO %	-	30.9	31.5	24-32	-	29.5	31.9	30*	23.7	31.3	30.1	20.2	9.95	22.9	30.8	22.9	30.6	25.35
CaO %	1.5**	0.14	0.4	9**	-	0.20	0.34	1.0**	0.17	0.3	0.18	0.27	0.25	0.03	0.3	0.03	0.4	-
$Na_2O + K_2O$ %	-	0.03	0.1	-	-	0.26	0.04	0.04**	0.12	-	0.12	0.12	2.5	2.46	-	2.46	-	-
Loss on ignition,%	5.7**	5.60	5.0	7	-	4.77	8.00	6.0**	4.35	4.8	4.83	5.3	6.1	4.10	4.9	4.10	4.6	20**
CO_2 %	nil	0.50	3.6	-	-	0.04	0.60	-	0.01	0.1	-	-	-	0.20	1.6	0.20	4.0	-
Physical Properties:																		
Reflectivity	?85*	88	82-84	70*	-	-	82	-	68	97.5	-	-	-	-	84.5	-	60.0	-
pH	7	-	-	-	4- 9	8.8	-	-	-	-	8.92	-	-	9.15	8.8	9.05	8.7	-
Bulk density p.c.f.	20-25	-	-	-	-	21	-	-	-	-	-	-	-	21	-	23	-	-
Oil absorption	-	-	-	27-34	47-53	-	-	-	-	51	21	-	-	-	50	-	49	-
?	-	-	-	-	-	-	-	-	-	61	-	-	-	-	59	-	59	-
Acid solubles	1.1**	-	-	-	-	3.78	-	-	-	-	7.38	-	-	1.16	-	3.09	-	-
Water solubles	0.5**	-	-	1**	0.3**	0.75	-	-	-	-	0.11	-	-	0.03	-	0.04	-	-
Minus 25 mesh																		
Minus 100 mesh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	99*
Minus 200 mesh	100*	-	-	100*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Minus 200 mesh	98.5*	-	-	100*	-	90	-	99*	-	-	94.3	-	-	-	-	-	-	-
Minus 325 mesh	-	-	99*	99	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Minimum.

** Maximum.

Continued

TABLE 13: CONTINUED

Use:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Sample Number																	
Cosmetics	x	x												?				
Paper coater		x	x															
Paper filler		x	x															
Paint pigment		x	x	x	x	?	x							?				
Steatite bodies		x				?	x		?	x	?				x		x	
Table ware		x	x			x	x	x	x	x	x				x			
Insulating porcelain			x			x	x	x							x			
Sanitary porcelain			x			x	x	x	x		?	x	x				x	
Earthenware			x						x		x	x	x	x	x		x	
Wall and floor tiles			x			x	x	x	x		?	x	x				x	
Kiln furniture			x				x	x				x					x	
Stoneware			x				x	x	x		x	x	x	x			x	
Heavy clay products			x					x			x	x	x	x			x	
Rock wool			x								x	x		x		x	x	
Plastic filler			x				x					x	x	?				
Adsorbent			x				x		x		x	x		x		x		
Roofing material			x				x		x		x	x		x		x		

Key:
1. Cosmetic grade (specification TGA BP etc.)
2. Mt Fitton (first grade.
3. Guomen Talki Oy, paper quality, A grade.
4. Paint pigment specification (ASTM 605; reflectivity Weitz 1970).
5. Paint filler (BALM).
6. Tumby Bay (high grade).
7. Mt Fitton (third grade).
8. Ceramic grade (USA practice).
9. Tumby Bay ('A' body)
10. Ceramic grade (Talcumwerke Naintsch A grade).
11. Tumby Bay ('E' body).
12. Truro (average).
13. Yongala talc-kaolin.
14. Gumeracha (first grade).
15. Ceramic grade (Talcumwerke Naintsch D Grade).
16. Gumeracha (third grade).
17. Ceramic grade (Talcumwerke Naintsch H Grade).
18. French chalk (UK specification).

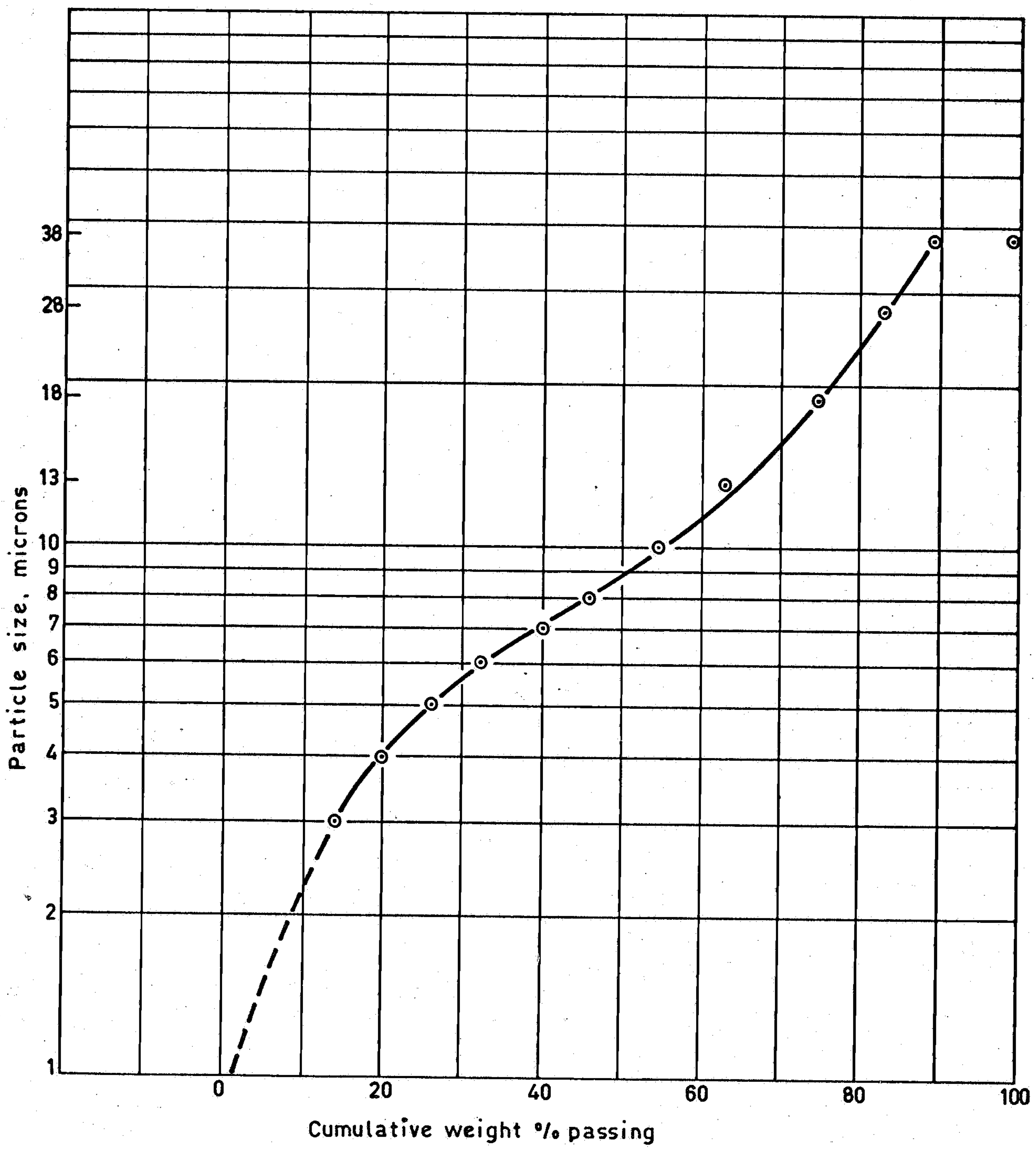

FIGURE 1: 6 HOURS DRY GROUND – GUMERACHA 1st. GRADE

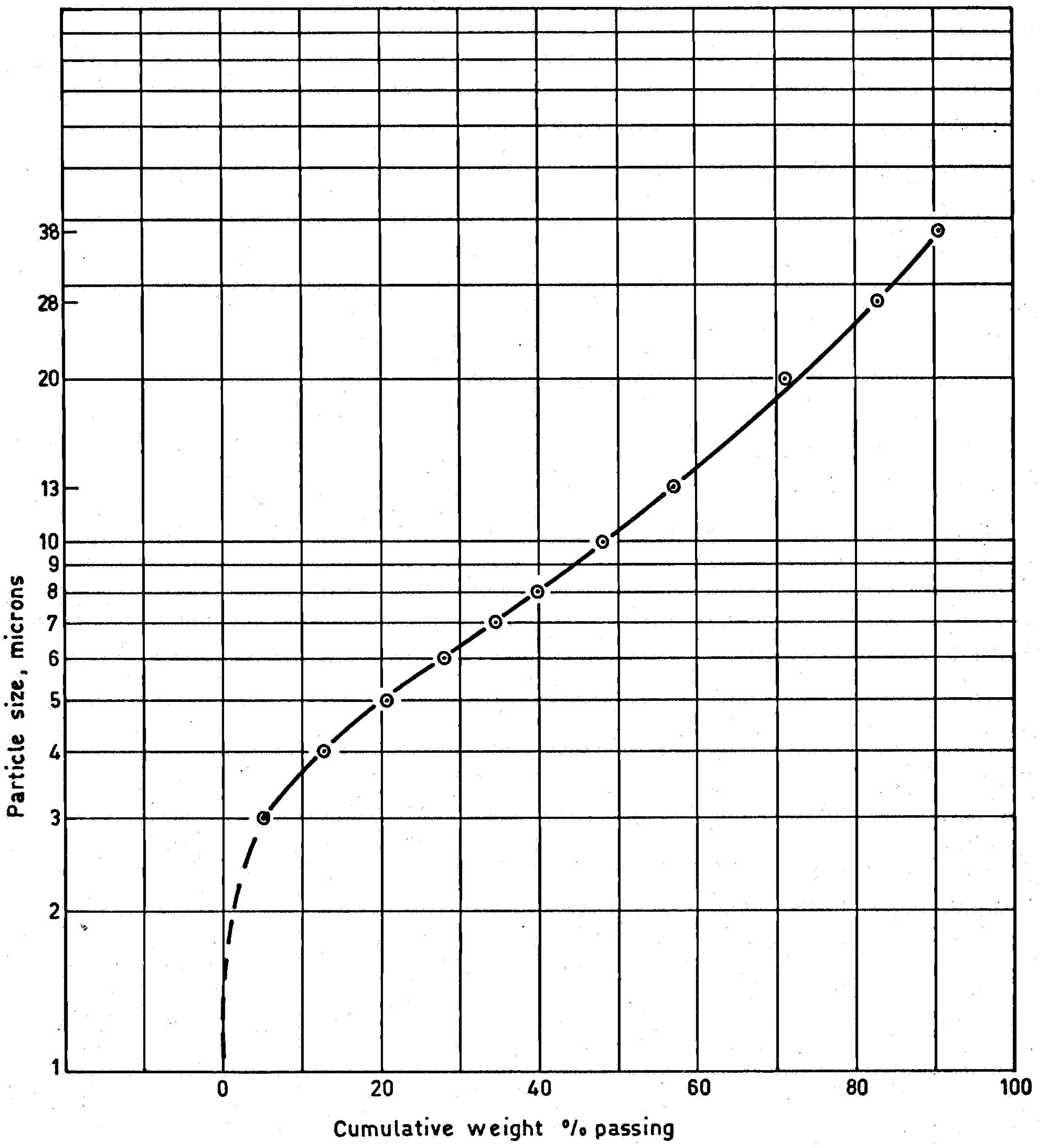

FIGURE 2: 6 HOURS DRY GRIND — GUMERACHA 3rd. GRADE

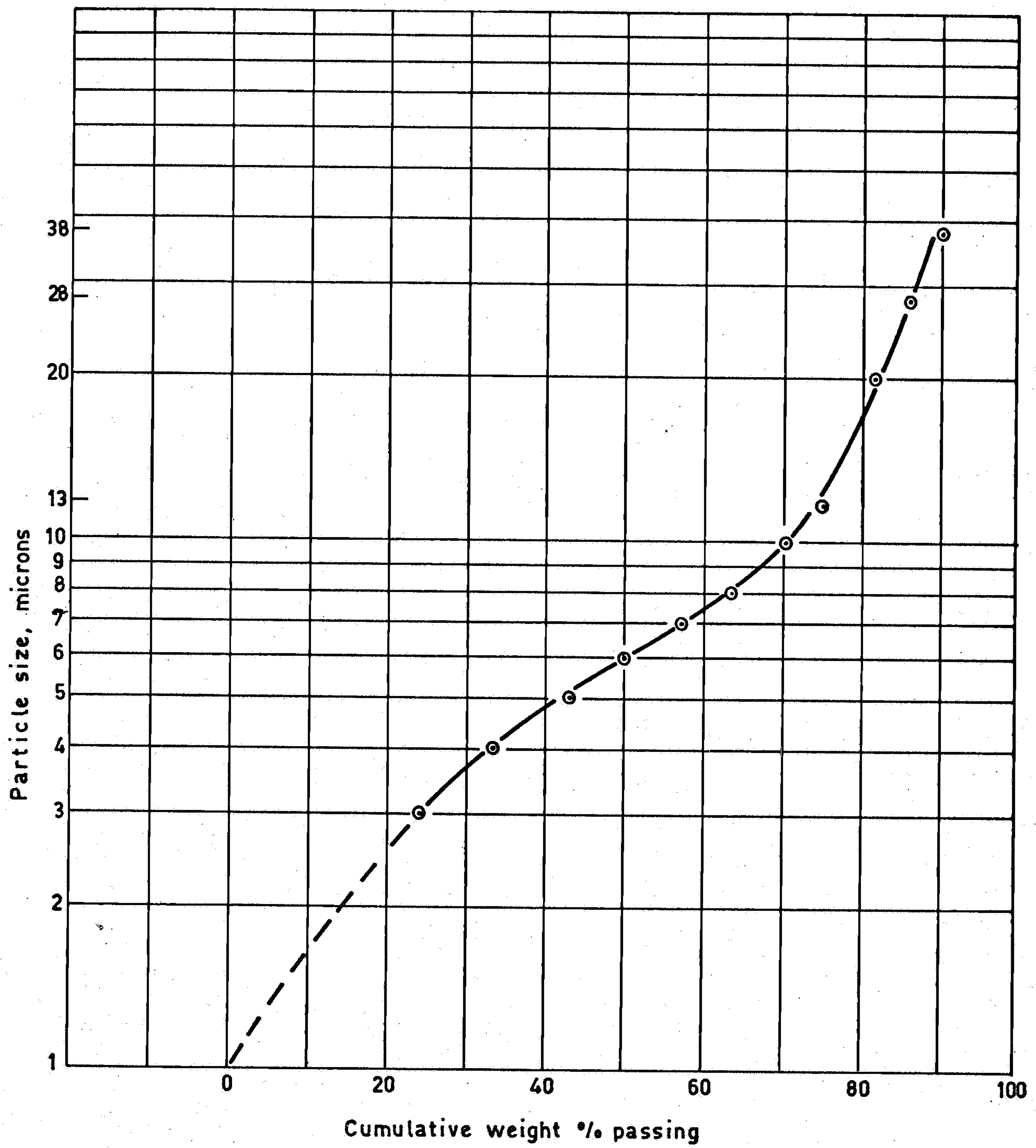

FIGURE 3: 6 HOURS DRY GRIND – TUMBY BAY HIGH GRADE

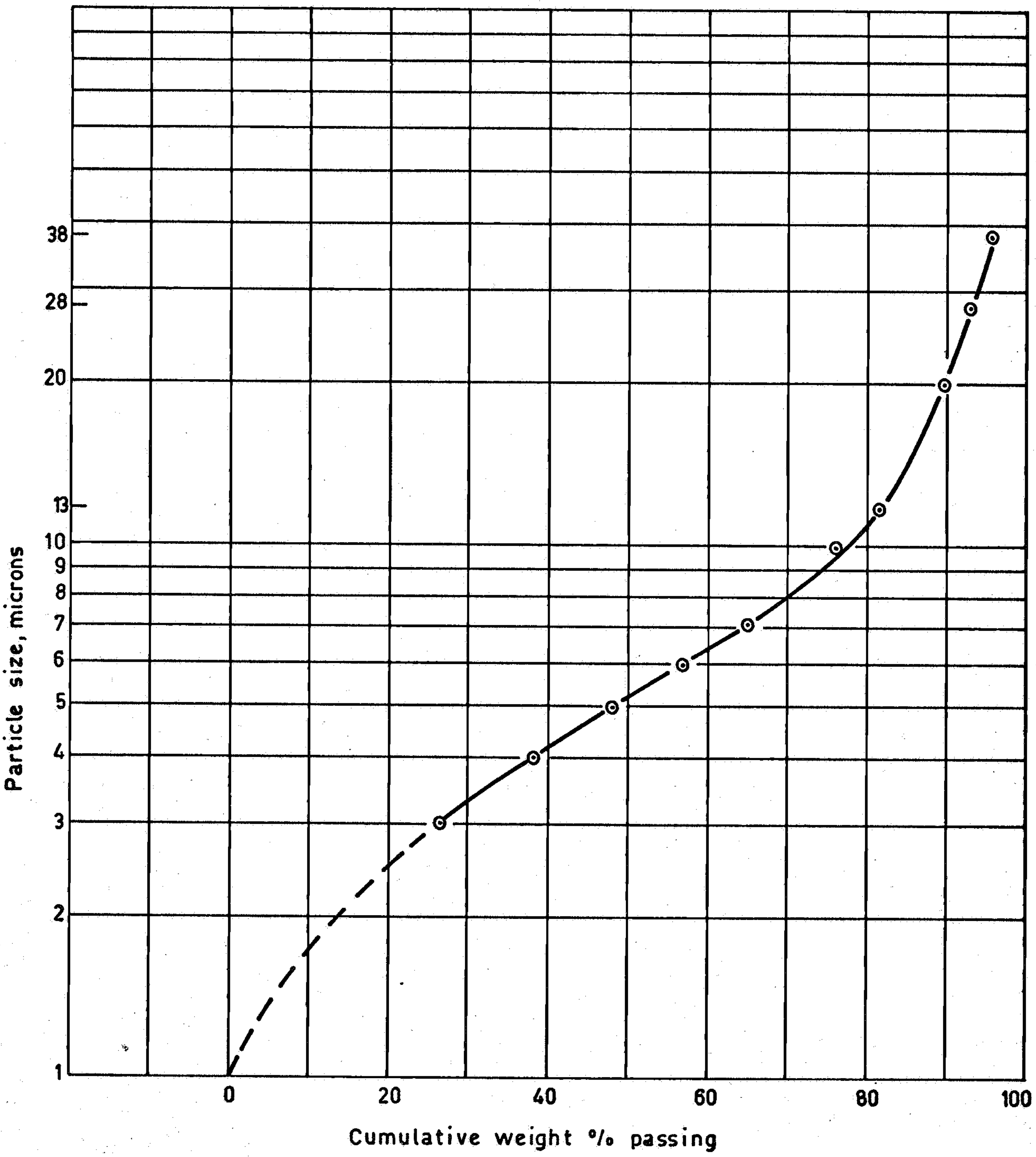

FIGURE 4 : 6 HOURS DRY GRIND – TUMBY BAY ORE BODY E

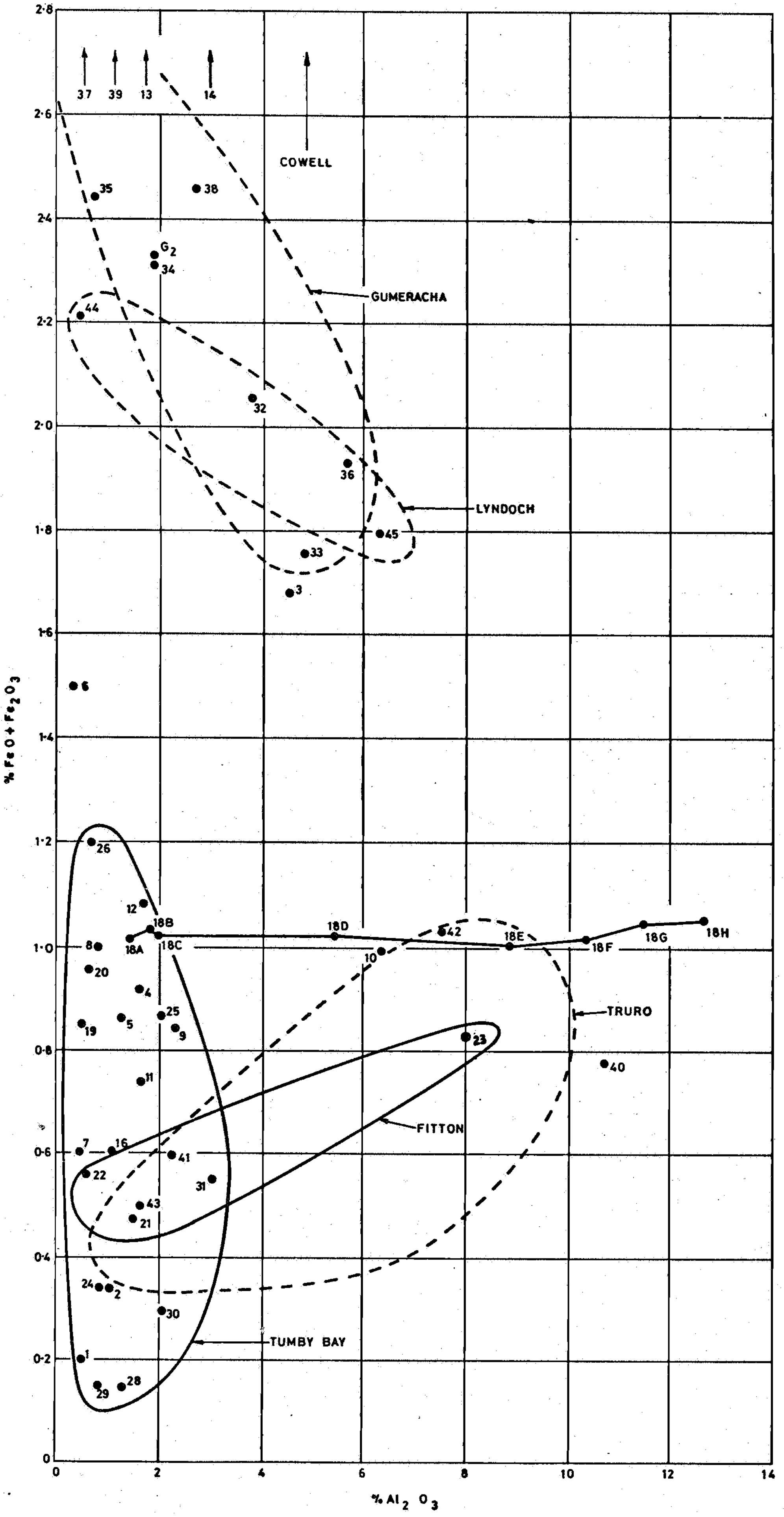

FIGURE 5: COMPOSITION OF TALCS FeO + Fe_2O_3/Al_2O_3

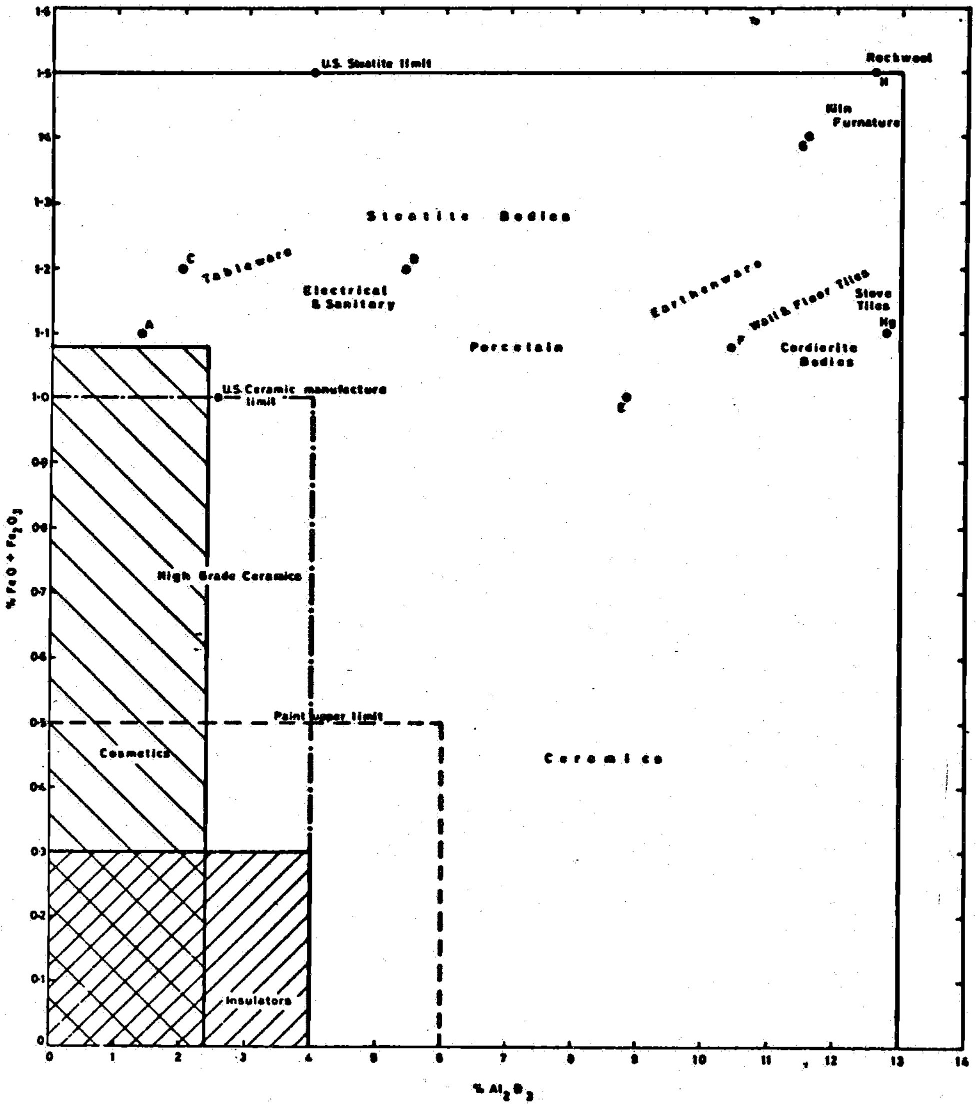

FIGURE 6: COMPOSITION CLASSIFICATION OF TALCS