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MANUFACTURE OF TALC-BASED TILES

by

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SUMMARY

Background and Objectives

Large deposits of talc/albite rock are known at Gumeracha, about 30 kilometres from Adelaide. The deposits have been worked for low grade talc. Albite feldspar impurity precludes use of the material for many purposes. Since feldspar is a commonly-used ceramic raw material, the talc/albite material was investigated as a ceramic raw material for the manufacture of once-fired, vitrified glazed floor tiles. This product was selected in order to assist and re-establish the tile-making plant at Elizabeth, currently in receivership, and also to promote the use of the local raw material.

Summary of Work Done

Compositions of bodies suitable for the production of once-fired, pressed floor tiles using the fast-firing kiln at CTM Ltd, Elizabeth, were investigated on a laboratory scale. The effect of firing cycles was studied. Glazes for use in such a tile were developed and tested.

It was found that high quality glazed tiles could be made using fast firing methods. The body composition 70% talc/albite, 30% clay (Dreckows) was found to give good results when fired at a rate equivalent to 1000 square metres per day at the CTM Ltd plant.

Staining of the body to produce coloured unglazed tiles was investigated but results indicated that only a small variation in colour could be produced. Glazing results were satisfactory and a range of suitable matt and gloss glazes were developed.

Conclusions

The laboratory investigations indicate that the talc/albite material is suitable for the production of fast fired, vitrified, glazed floor tiles. The thermal shock resistance properties of this material are very good and indicate that considerably higher production rates are possible compared to a traditional clay body. The low firing shrinkage should lead to better shape and size control. These and other factors indicate that talc/albite is an attractive raw material for tile making.

Although stains were not found successful for unglazed tile production, glazes were developed to produce a satisfactory range of tile finishes.

1. INTRODUCTION

Over the past ten years the South Australian Department of Mines and Energy has sponsored a number of laboratory projects designed to evaluate, assess and characterize the large number of talc deposits within South Australia.

Results of this work, in conjunction with previous published data and concurrent with geological investigation, have established that large tonnages of low grade talc occur in deposits close to Adelaide. Unfortunately, due to the variations of grade resulting from mineralogical and chemical alterations within these deposits and the overall inconsistency and impure nature of the talc, the material being exploited commanded, overall, a relatively low price and restricted market.

One such extensive deposit at Gumeracha has been worked by a number of companies for many years providing, at best, low quality cosmetic grade material, obtained by selective hand sorting, and in general filler grade material.

A large percentage of the talc obtained from this deposit and from similar deposits in the Lyndoch-Truro area is relatively unique in that the talc is associated with the feldspar, albite. This association affects the general potential industrial filler grade market of even unstained material unless it is feasible to separate the talc and albite by simple beneficiation techniques.

Alternatively, a new market could be considered which would benefit from the natural combination of the minerals. This, the ceramic market, has been investigated in some depth over the past few years and it has been shown that the talc-albite assemblage (hereinafter referred to as TALBITE) is a promising raw material for ceramic purposes. Furthermore, new bodies utilizing a high percentage of talbite have been recently developed that are suitable for fast firing applications.

Over recent months one such body has been investigated with particular emphasis toward its use for the production of once fired, vitrified glazed ceramic floor tiles. This specific product has been selected primarily as a means of assisting and re-establishing the Ceramic Tile Makers Ltd. plant at Elizabeth as a producing plant while concurrently assisting local industry by providing a new potential market for a presently produced product which does not have full potential market penetration.

2. GENERAL INVESTIGATION OF THE CERAMIC BEHAVIOUR OF TALBITE

Initially a number of sources of talbite were considered together with two plastic clays - one a red burning and the other a cream burning material from the Meadows[1] and Golden Grove[2] areas respectively.

The talbite samples were analysed by X-ray diffraction and chemical techniques and two sources were selected for a preliminary investigation into the ceramic behaviour of various blends incorporating clay and talbite.

[1] County: Adelaide. Hundred: Kuitpo. Section: 340E.
[2] County: Adelaide. Hundred: Yatala. Section: 5470.

The samples were selected on the basis of (a) they contained the highest proportion of albite and (b) they were from currently worked deposits. The clays chosen for the investigation were readily available, being from currently worked deposits, and were known to have good plasticity and provide good green and dry strengths to bodies incorporating them.

Twelve bodies were compounded using talbite and clay in the proportions 60:40, 70:30 and 80:20 and pressed samples were fired (a) in an electric kiln at a rate of 5°C/minute over a range of temperatures from 1050 to 1150°C and (b) in a gas fueled Walking Beam kiln to 1180°C over a 2 hour heating and 1 hour cooling cycle.

Shrinkages, water absorptions and other general observations were made on the fired products.

This work, described in detail in a series of Progress Reports Nos. 1-7 Project 1/1/179, suggested that blends of talbite and local clays could be used to produce a series of porous and vitrified products under normal and relatively fast firing conditions at temperatures between 1100 and 1150°C. The results obtained were sufficiently encouraging to warrant a detailed investigation of the possibility of producing a definite product from talbite and the development of a glazed and vitrified floor tile which could be manufactured under fast firing conditions was selected.

3. RAW MATERIALS

With due consideration to locality and availability of a talc in a pre-ground form, material from Gumeracha rather than the Lyndoch-Truro area was selected for further investigation. The material selected would generally be classified as 3rd or 4th grade talc on a basis of its yellowish-pink colour due to the presence of iron oxides in the form of hematite and goethite. The clay was the white plastic clay used previously for the initial testing since this generally produced bodies of lower water absorption than the alternative red plastic clay when fired at the same temperature.

Results from a drilling programme conducted over the Gumeracha talc deposit, of interest herein, indicated that the albite content varied significantly from approximately 5% to 30% although zones within the deposit could feasibly be delineated and worked to provide a product with a reasonable variation of albite content.

Therefore the effect of a variation of the talc:albite ratio in the talbite on a high talbite product required initial investigation. As the talbite sample chosen for the work contained only 5% albite, a 200 mesh B.S.S. soda feldspar, as marketed by Steetley Industries Ltd., was obtained for addition to the standard talbite to vary the talc:albite ratio.

Analyses of the talbite, feldspar and clay were as follows:

TABLE 1

Chemical, Mineralogical and Size Analysis of Talbite, Feldspar and Clay

	Talbite	Feldspar	Clay
SiO_2	61.2	67.28	59.4
TiO_2	0.16	0.09	1.7
Al_2O_3	1.51	19.76	25.8
Fe_2O_3	0.83	0.08	1.32
FeO	2.07	0.02	0.38
MnO	0.01	0.01	<0.01
MgO	28.44	0.08	0.32
CaO	0.13	0.88	0.04
Na_2O	0.56	10.95	0.3
K_2O	0.06	0.26	2.45
P_2O_5	0.10	0.25	N/D
H_2O^+	4.46	0.21	7.85
H_2O^-	0.24	0.01	N/D
Talc	Dominant		
Feldspar (albite)	app. 5%	Dominant	
Dolomite	Trace		
Quartz	Faint trace	Trace (app. 3%)	Accessory -Sub.Dominant
Muscovite		app. 5%	
Kaolin			Dominant
Illite			Trace
Smectite			Slight trace
Mixed layer			Slight trace
Cum.% coarser than µm			
150	0.02	-	-
105	0.02	-	-
75	0.26	2.0	-
53	2.28	7.3	

4. COMPOSITION OF TALC TILE BODIES AND FIRING TRIALS

Bodies were prepared by holding the clay to talbite ratio constant at 30:70 and by varying the talc to albite ratio between 95:5 and 70:30 in 5 unit increments.

It follows that the compositions of the bodies were:-

TABLE 2

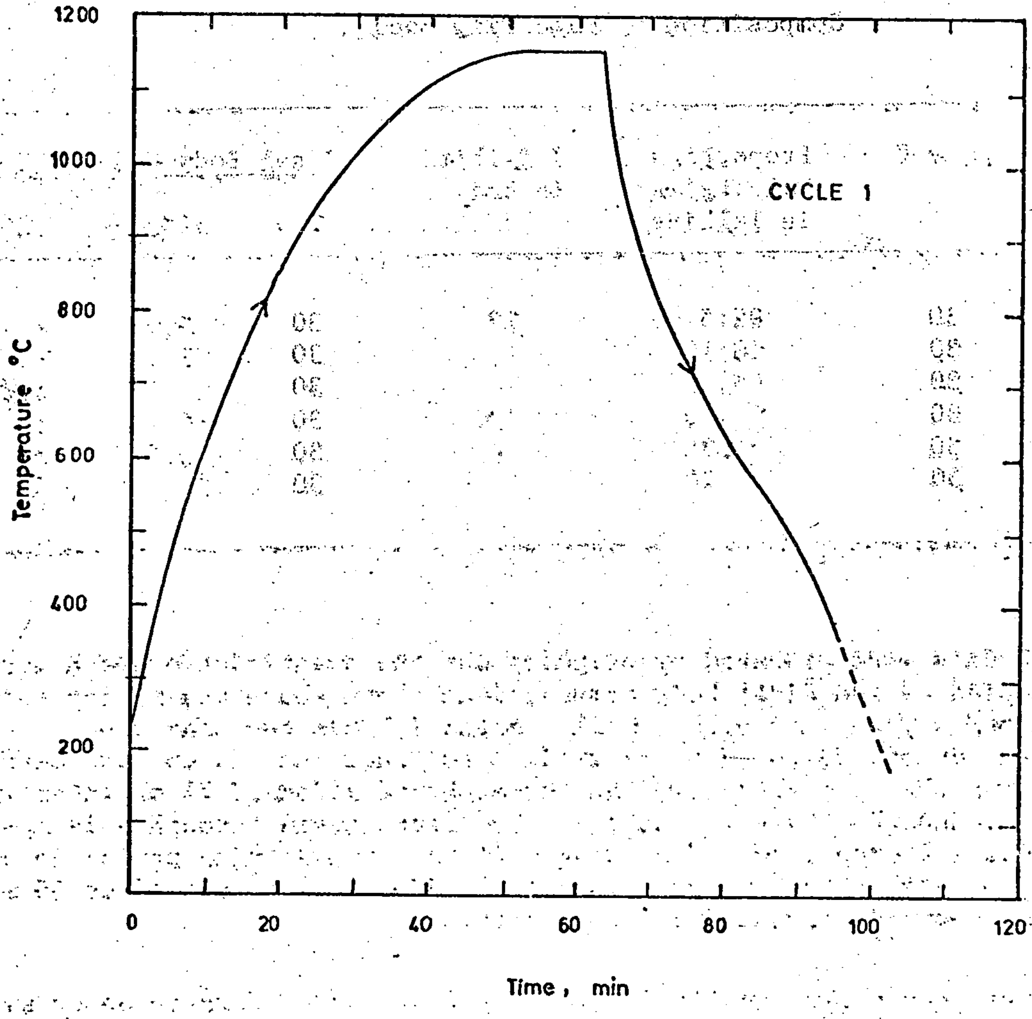
Composition of Talc Tile Bodies

Body No.	Clay %	Proportion Talc:Feldspar in Talbite	% Talbite in body	Final Body Composition Clay	Feldspar	Talc
TB2	30	95:5	70	30	3.5	66.5
TB4	30	90:10	70	30	7	63
TB5	30	85.15	70	30	10.5	59.5
TB6	30	80:20	70	30	14	56
TB7	30	75:25	70	30	17.5	52.5
TB8	30	70:30	70	30	21	49

The bodies were prepared by weighing out the quantities of each material required to produce the final body compositions shown above and mixing these in a slurry at 50% solids in a pebble mill. After 2 hours the slurry was discharged and dried, followed by regrinding to finer than 75 µm (200 mesh B.S.S.). A granulate was then produced from the powder by addition of 7% of water which was rubbed through the powder. The moist body was passed through a 14 mesh B.S. sieve to produce a granulate. Following a 24 hour humidifying period in a sealed bag the bodies were pressed under a load of 55,000 Newtons to produce 50 mm square, 10 mm deep, specimens for firing trials.

Samples were dried and fired in an electric tunnel furnace on ceramic boats which were pushed through the kiln at predetermined rates. The maximum temperature of firing was 1150°C and the firing cycle 64 minutes including a 10 minute soak on peak temperature. Tiles were controlled cooled over a 32 minute period to 350°C at which temperature they were removed from the kiln and allowed to cool naturally in the atmosphere. This firing cycle, shown in Graph 1, would produce 1,000 square metres of tile per 24 hour day at the C.T.M. Ltd. plant.

GRAPH 1 - FIRING CYCLE OF TILES



5. BEHAVIOUR OF THE BODIES

The tiles were readily fired and showed no obvious defects resulting from the fast firing cycle. Water absorptions of the blends decreased with increasing albite content, corresponding to increases in the bulk specific gravities and firing shrinkages.

Reference to Table 3 suggests that the fired properties of the bodies are not critically dependent upon composition, with particular reference to the albite content. It may be possible, therefore, to manufacture a tile to a satisfactory production standard without imposing an unnecessarily hard specification upon the supplier of the talbite with respect to the talc:albite ratio.

The firing shrinkages of the tiles are considerably lower than would be experienced from a traditional clay body and the talc bodies would not be as susceptible to firing distortion.

TABLE 3

Water Absorption, Bulk Specific Gravity and
Dry-Fired Shrinkages of Blends

Body	Water Absorption 2 Hr Boil %	Bulk Specific Gravity	Dry-Fired Shrinkage %
TB2	7.5	2.18	2.9
TB4	4.4	2.23	3.1
TB5	3.1	2.25	3.3
TB6	1.5	2.29	3.4
TB7	0.6	2.30	4.1
TB8	0.17	2.35	4.3

The fired tiles were generally a yellowish-grey to grey-brown colour. An X-ray diffraction trace of body TB7 detected the presence of 5-10% quartz and, although not readily identifiable, possibly enstatite.

6. EFFECT OF INCREASED FIRING RATES AND VARIATION OF FIRING CYCLE

Although the significance of shape and size of a body could not be evaluated during fast firing cycles, it was considered worthwhile to examine the effects of a faster firing cycle and a lower temperature cycle on the individual bodies.

One cycle investigated (Cycle 2) followed the initial heating cycle to 1100°C followed by a slower rate of increase to 1130°C over a 14 minute period. The tiles were then allowed to soak for 10 minutes at temperature followed by cooling as per the initial cycle. Thus, the time period of firing and cooling was the same as the original cycle although the soaking temperature was 20°C lower.

Results shown in Table 4 are remarkably similar to those obtained from the initial higher temperature cycle (Table 3) giving some indication that a reasonable firing tolerance may be expected from the bodies.

Two of the tile bodies, TB4 and TB7, were fired considerably faster to assess their resistance to thermal shock. These were put into the kiln at 500°C and fired to 1050°C in 10 minutes followed by a slower rate of increase to 1150°C during the next 10 minutes where they were allowed to soak for 15 minutes. The tiles were cooled to 350°C in 20 minutes and removed from the kiln. Thus the complete firing cycle (Cycle 3) was 35 minutes followed by a 20 minute controlled cooling period compared with the initial cycle of 64 minutes and 32 minutes respectively.

Results of this cycle shown in Table 4 indicate a marginal difference in shrinkage and absorption of the body with low albite content, and of shrinkage in the high albite body, may be expected. However, a significant variation in absorption may be expected for bodies with higher albite contents when fired at considerably faster rates to the same temperature. No firing defects were observed in the samples.

TABLE 4

Water Absorption & Firing Shrinkages of bodies

Body	% Water Abs. 2 Hr boil	Dry-Fired Shrinkage %
Cycle 2		
TB2	8.8	2.9
4	5.1	3.1
5	3.6	3.1
6	2.3	3.5
7	0.83	4.0
8	0.23	4.1
Cycle 3		
TB4	6.5	2.6
7	4.1	3.2

7. COLOURED UNGLAZED TILES

The possibility of producing vitrified coloured unglazed tiles from the talc-clay bodies was investigated with only limited success. Body TB7 was used for testing with additions of red iron oxide, managnese dioxide and by substituting a red burning plastic clay from the Meadows area[1] in lieu of the cream-burning clay which had been found to be the most acceptable clay for producing a low absorption product.

The normal preparation procedure for preparing the 50 mm square tiles for firing was adopted. Additives used were 5%, by addition, of either iron oxide or manganese dioxide and 5% iron oxide and 3% manganese dioxide addition to the bodies incorporating either the cream or red burning clays.

A Bickley gas kiln was used for firing the samples over a 110 minute firing cycle to 1150°C, including a 10 minute soaking period, followed by an initial rapid cooling to 800°C in 20 minutes. The gas kiln was used for firing in lieu of the electric kiln since, as the major aspect of the test was to determine the potential fired colours, it was considered more appropriate to use

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[1] County: Adelaide. Hundred: Kuitpo. Section 340E.

a gas fueled kiln even though the fast firing cycle of earlier tests could not be maintained.

Results showed that as previously determined bodies incorporating the cream burning clay had lower absorptions than those bodies incorporating the red burning clays and that the extended firing cycle produced a body of lower water absorption than the initial 64 minute cycle for the basic 70:30 talbite: cream clay body.

When iron oxide, manganese dioxide or a combination of these was added to a mix the water absorption of the resultant fired bodies increased.

Reference to Table 5 shows the general trend. Fired colours were greyish-brown for the cream burning clay/talc series and reddish-brown for the red burning clay/talc series. The colours produced were not, in general, sufficiently distinctive to suggest that a successfully marketable range of unglazed tiles could be produced using iron and manganese oxides as colourants. Higher additions would certainly provide better results but normally the costs of the oxides would prove prohibitive and would be more expensive than alternative glazing costs. Furthermore, the aspect of increased absorption of the tiles with oxide additions must be considered and the bodies may have to be "dosed" with additional fluxing agents to promote a greater degree of vitrification or, alternatively, clear glazing could be considered to eliminate surface absorption of the tiles where required.

TABLE 5

Composition & Water Absorptions of Coloured Tile Bodies

Body No.	Talbite**	Cream Clay	Red Clay	Iron Oxide %***	Manganese Dioxide %***	Water Absorption %
TB7*	70	30		–	–	0.6
TB7	70	30		–	–	0.33
TB7/1	70	30		5	–	2.2
TB7/2	70	30		–	5	0.64
TB7/3	70	30		5	3	1.04
TB7/4			30	–	–	1.65
TB7/5			30	5	–	3.65
TB7/6			30	–	5	2.15
TB7/7			30	5	3	2.8

* Original 64 minute electric kiln firing. All other samples fired in 110 minute gas kiln cycle.

** Talbite = Talc 75:Albite 25.

*** % by addition.

8. GLAZE DEVELOPMENT

A brief investigation into the glazing of a once fired, "fast" fired, high talc component body was undertaken to assess the possibility of using readily available frits and glazes with minor modification if required.

Initially a number of glazes were considered which had previously been developed or had been found suitable for "fast" firing applications. Although these glazes had been used with a different body at a temperature of approximately 1180°C and fired over a longer time cycle (approx. 2 hours), they were regarded as a useful starting point.

The standard tile body used for the most part for the glaze trials was TB7, having previously been established as a suitable body for the production of vitrified floor tiles. Firing trials were undertaken in the electric kiln according to the cycle shown in Graph 1.

A few glazes were found to be compatible with the talc body and these proved readily modifiable with titanium dioxide, zinc oxide and glaze stain to produce a range of glazes with matt to gloss finishes.

The effect of titanium dioxide and zinc oxide additions to a matt glaze composed of two low temperature frits with china clay, zinc oxide and feldspar as modifying agents, proved interesting.

A small addition of titanium to the matt glaze, 5 parts, resulted in a high gloss finish and additions of zinc oxide further tended to matt the glaze. Further, additions of titanium dioxide and zinc oxide produced intermediatory gloss finishes. The titanium dioxide was found to be an effective "softening" agent for the glaze allowing a reduction in firing temperature by producing softer and less viscous glaze at temperature.

Some of the glazes developed were examined to determine their tolerances to temperature, firing cycle and composition. In all cases wide variations in the results, particularly of colour and gloss, were observed with only minor alterations to the conditions or the composition. The results suggest that precise kiln control and detailed monitoring of all production conditions would be necessary in order to maintain acceptable quality control standards.

Overall the glaze development was successful in delineating a number of important areas for consideration when firing under extremely fast conditions. It considered the problems of volatile evolution during firing and in this instance overcame them by using less viscous "softer" glazes. Commercially available glazes were found to be satisfactory for the talc tiles, and the fast firing cycle, with only slight modification.

9. DISCUSSION

The investigation into the ceramic behaviour of talbite has led to the development of a body composition which is well suited to "fast" firing technologies.

The body composed of 70 parts talbite and 30 parts clay has been used to produce 50 mm square vitrified tiles (0.6% water absorption), in firing periods of 64 minutes. Cycles of 35 minutes, firing, and 20 minutes cooling, successfully produced 50 mm square tiles with 4% water absorptions.

Standard commercial glazes with only minor modification were found to fit the body satisfactorily indicating that a range of vitrified glazed tiles could be readily produced. The body developed shows considerable tolerance to compositional variation, with respect to the albite percentage, low firing shrinkages and a high resistance to thermal shock. The quartz content of both the raw and fired bodies is low reducing the normal firing problems associated with this mineral and thus allowing for a linear cooling contraction and regular thermal dilatometric changes. As a result of these properties the body developed has considerable advantage over a traditional clay-feldspar body in both fast and conventional firing situations. With respect to "fast" firing technology the properties of the body will assist the manufacture of uniform products, both regular size and shape, and will reduce losses resulting from thermal shock.

Drilling results have shown that large deposits of talbite are available in close proximity to Adelaide and that material could be mined to comply with a specification allowing for a ±5% variation in feldspar content. Results obtained suggest that a material containing 25% albite, with limits of 20% to 30%, would be suitable for the manufacture of a 'fast' fired vitrified floor tile which would comply with presently accepted standards. The main contaminant known to occur within the deposit which could affect the 'fast' firing process is pyrite (iron sulphide). This mineral can cause 'black cores' or localized 'bloats' in the fired product if not completely oxidised and decomposed during the early stages of firing. The ease and rate of oxidation and thus the permissible limit of sulphides is dependent upon the rate of firing, the amount of oxygen available for reaction, the kiln draught, the porosity and shape of the article and the fineness of the body.