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The Clay Deposit at Dover

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With 4 Text Figures

Abstract

A field and laboratory examination of the clay deposit at Dover showed that it consists of three types of clay, two of which are residual clays on Permian rocks while the third, a transported deposit, is probably of Tertiary age. Although the main constituents of all types are kaolinite, quartz and illite, they are easily distinguished by appearance and grain size analysis. It is considered that they are the products of ordinary weathering processes.

Introduction

The clay deposit of the Granton Brick Pty. Ltd. at Dover (see Hale (1953), this volume) is situated at the southern end of Hopetoun Beach on the western shore of Port Esperance at a distance of approximately 1¼ miles from the Dover Post Office. It occupies the small peninsula that forms the north bank of the Esperance River at its outlet into Port Esperance and is about 53½ miles from Hobart. The area held by the company is approximately 30 acres.

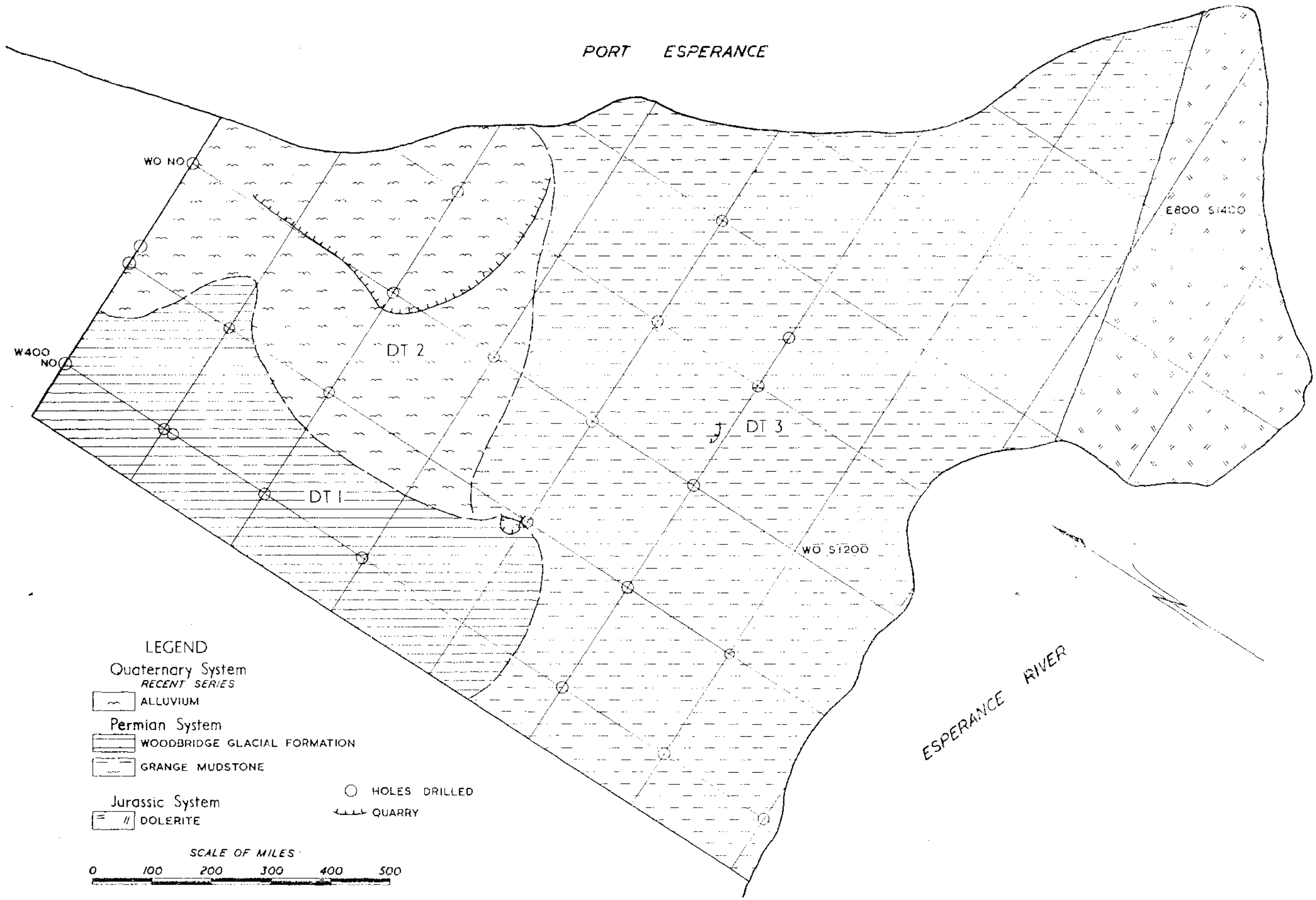
In the immediate vicinity of the deposit the country consists of bush and bracken covered slopes leading up to a low escarpment beyond which extends a plain covered with a similar vegetation but interspersed with button-grass swamps. The whole is lightly sprinkled with eucalypts, generally of small size, and some patches of other scrub. The banks of the Esperance River are usually densely vegetated. The area provides a poor pasturage but is used in no other way at present.

The field investigation was carried out by drilling with a 4″ post-hole borer (hand operated) on a grid of 200 feet intervals. The clay was sampled at every detectable change of physical properties, such as colour, grain-size, and grittiness or, if no change occurred, every two feet. Later after some washing of the dumps had occurred, each waste pile was examined for fossils and rock fragments. By these means it was determined that there were three types of clay present and these types are referred to hereafter as DT^1, DT^2, DT^3. (See fig. 1.)

The investigation was made at the request of the Granton Brick Pty. Ltd. to ascertain the reserves of clay, if the clay could be differentiated into types, its firing characteristics, and to ascertain if the clay would be useful for purposes other than brick making.

Discussion of Results

An examination of the clay at Dover showed that the deposit there consisted of three main types which were called DT_1, DT_2 and DT_3 which can be differentiated visually and by grain size determination. It is



PORT ESPERANCE
WO NO
W400 NO
DT 2
DT 1
DT 3
E800 S1400
WO S1200
ESPERANCE RIVER
LEGEND
Quaternary System
RECENT SERIES
ALLUVIUM
Permian System
WOODBRIDGE GLACIAL FORMATION
GRANGE MUDSTONE
Jurassic System
DOLERITE
HOLES DRILLED
QUARRY
SCALE OF MILES
0 100 200 300 400 500

FIG. 1

considered that DT_2 is a transported clay of Tertiary age while the others have been formed by the weathering *in situ* of Permian sediments.

These clays were examined by petrographic methods, by Differential Thermal Analysis, by X-ray Diffraction photos, and dye tests. All tests showed that the clay minerals present are kaolinites with some illite. The only other abundant mineral is quartz.

The firing characteristics of the clays were tested, see tables I and II, and it was determined that better bricks could result from extrusion methods than from dry pressing the raw materials. All the clays tested showed that they could, at least, be used as the components of a low heat duty fire brick. Most of them showed a rather high absorption value indicating that little vitrification had taken place during firing. The colourless clay of the DT_3 type burns a white colour and shows a refractory nature. Both this and the DT_2 type could be used as ball clays in the manufacture of earthenware or pottery.

With careful preparation, these clays could be used to produce bodies of the terra-cotta, earthenware, stoneware, and china types; the iron content would be rather too high for producing porcelain. The clays have been used, especially the DT_2 and DT_3 white clay types, for slip-casting and art pottery with satisfactory results. The DT_2 clay yields a pink or cream porous body at about 900°C. At the same temperature, the DT_3 white clay produces a pure white rather denser body.

The grain size determination (see Table III) and firing tests showed that the clay of this deposit is a valuable source of raw material capable of producing a much higher grade of ware than at present. Other components, mainly silica in some form and felspar, would be necessary for such a product but these may be found locally. For instance, the felspar particles in the clay at Surges Bay or the syenite dykes of the Cygnet area may prove to be suitable for ceramic uses. The amorphous silica from the boulders of "grey-billy" in the clay deposit itself would serve as a raw material at the testing stage.

The estimated clay reserves are as follows:—

DT_1		4,038,000 cubic feet.
DT_2		4,995,000 cubic feet.
DT_3	total	6,450,000 cubic feet.
	white clay	70,000 cubic feet.

General Geology*

The clay deposit lies in a district composed of fault blocks of Permian and more abundant Triassic sediments intruded by transgressive bodies of Jurassic dolerite which has intruded along contemporaneous faults (see Hale (1953) this volume). Since this intrusion, further faulting, erosion, and eustatic change of sea level have produced the present topography.

The rocks recognised on the clay property are:—

Tertiary:	DT_2 clay
Jurassic:	Dolerite
Permian:	Woodbridge Glacial Formation
	Grange Mudstone Formation

* For greater detail see Hale, "Geology of the Dover District", this journal.

The dolerite outcrops on the southern tip of the peninsula and has a very straight contact with the fossiliferous Grange beds. The dolerite is fine-grained at the boundary and shows extremely close jointing. In places, it is cut by narrow veins of basaltic material which, in one place, is seen to intrude the sediments. The effect of the intrusion is variable but it usually has resulted in a hardening and fracturing of the intruded beds. The hardening seldom extends for more than a foot or two from the contact and in some cases is seen for less than an inch.

The tillitic Woodbridge Glacial Formation occurs under the Risdon Sandstone and above the Grange Mudstones. It is a massive conglomerate about fifty feet thick and shows great variation in grain size and composition. It is usually composed of a mixture of pebbles and boulders of granite, basic rocks, slates, schists, and quartzites with a matrix of angular quartz. It is cemented with some iron compounds and argillaceous material and is unfossiliferous. It is thought that, in the clay deposit, it has weathered to form the DT_1 type of clay.

The Grange Mudstone underlying this can be traced along the shores of Esperance River from Ghost Corner to its mouth and from the dolerite boundary there along Port Esperance to the first point south of the brick making plant. In this area, the grain size and composition and therefore the appearance of these beds are extremely variable but everywhere it is characterised by the presence of abundant fossils of Permian age. The weathering of those beds gives rise to the DT_3 type of clay which also yields fragments of fossils in nearly every hole. These mudstones also carry pebbles of granite, slate, schist, and, more often, quartzite but these erratics are small and their occurrence sporadic.

Although close jointing is very common in all the sediments, no large faults can be detected in the clay deposit. It is possible that some faults with a throw of less than 50 feet are present but the lack of beds which can be correlated over the area make it impossible to find these structures. The whole of this block extending from Dover to beyond Raminea, despite its low topographical aspect, lies in an upthrown block for this is the only place in the area that the Grange Mudstone, the oldest stratigraphic unit at the surface, outcrops.

The Origin of the Clays

There are three mechanisms by which this clay deposit could have been formed; hydrothermal action along faults, igneous activity, and weathering.

The first is eliminated by the absence of any appreciable faulting in the area under consideration. The deposit is traversed by many joints and perhaps by some small faults with throws of less than 50 feet but nowhere are these emphasised by the clay profile to a noticeable extent.

In the second case, no igneous rocks except the dolerite can be suspected to have had any influence in the area. No signs of a surface flow of basalt appear in the district and the possibility of a deeper intrusion unrevealed at the surface is discounted by the fact that the clay deposit is shallow and lies over a solid rock floor. The effect of the dolerite is very limited elsewhere and usually results in a hardening of the intruded rocks not kaolinization; therefore it would be unwise to consider this the cause of the clay formation.

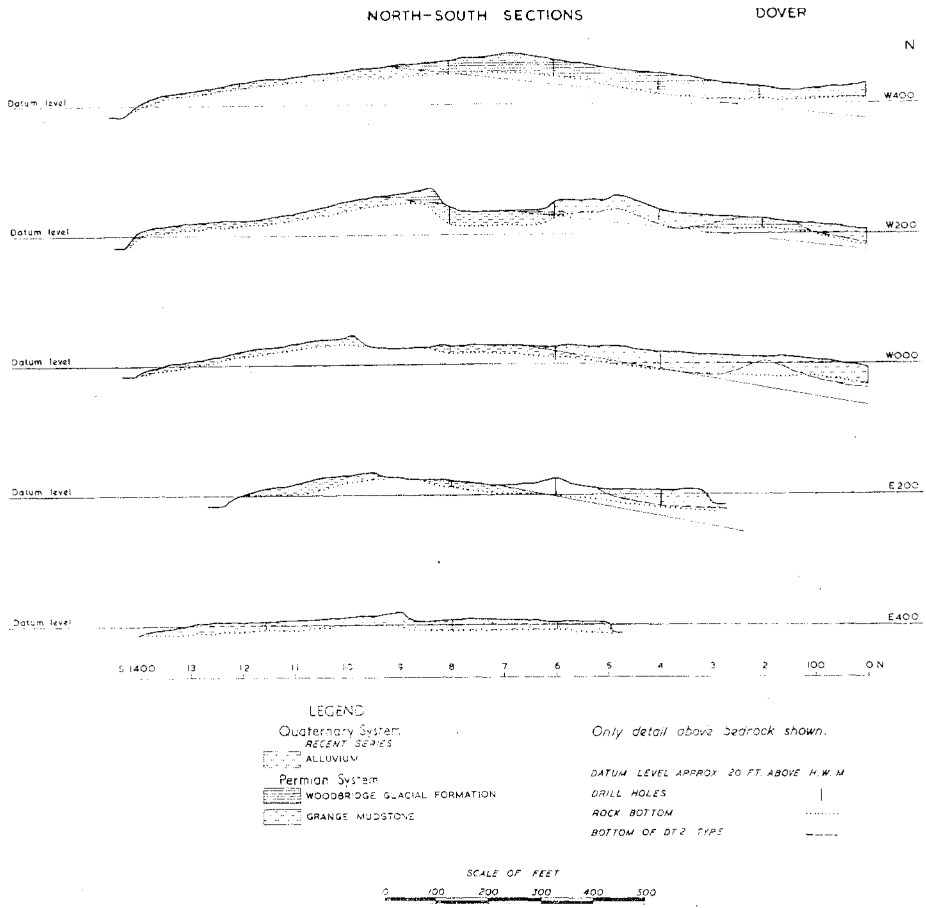


FIG. 2

A feature of the whole of the Dover area is the deep weathered zone. Away from the streams and shores, rocks outcrop rarely and the soil cover is usually between 5 to 10 feet deep. Also the bottom of this deposit everywhere shows a relationship to the water table depth often paralleling the ground surface. (See sections Figs. 2 and 3). The important exception to this is in the area occupied by the DT_2 type of clay.

The type of pebbles and boulders, arranged in the same sort of pattern, is common to the adjacent sediments and the DT_1 and DT_3 type of clay. There is a similar banding in the rocks and the higher parts, i.e., the DT_1 clay, shows a high iron content and the lack of stratification typical of the adjoining Woodbridge beds. Below this, the DT_3 type of clay carries the same fossils as the lower Grange beds. As the Risdon Sandstone outcrops along the low escarpment above the deposit, the stratigraphical position of these beds supports the idea that the DT_1 and DT_3 type of clay have been produced by the weathering *in situ* of the Grange and Woodbridge beds, i.e., they are residual clays.

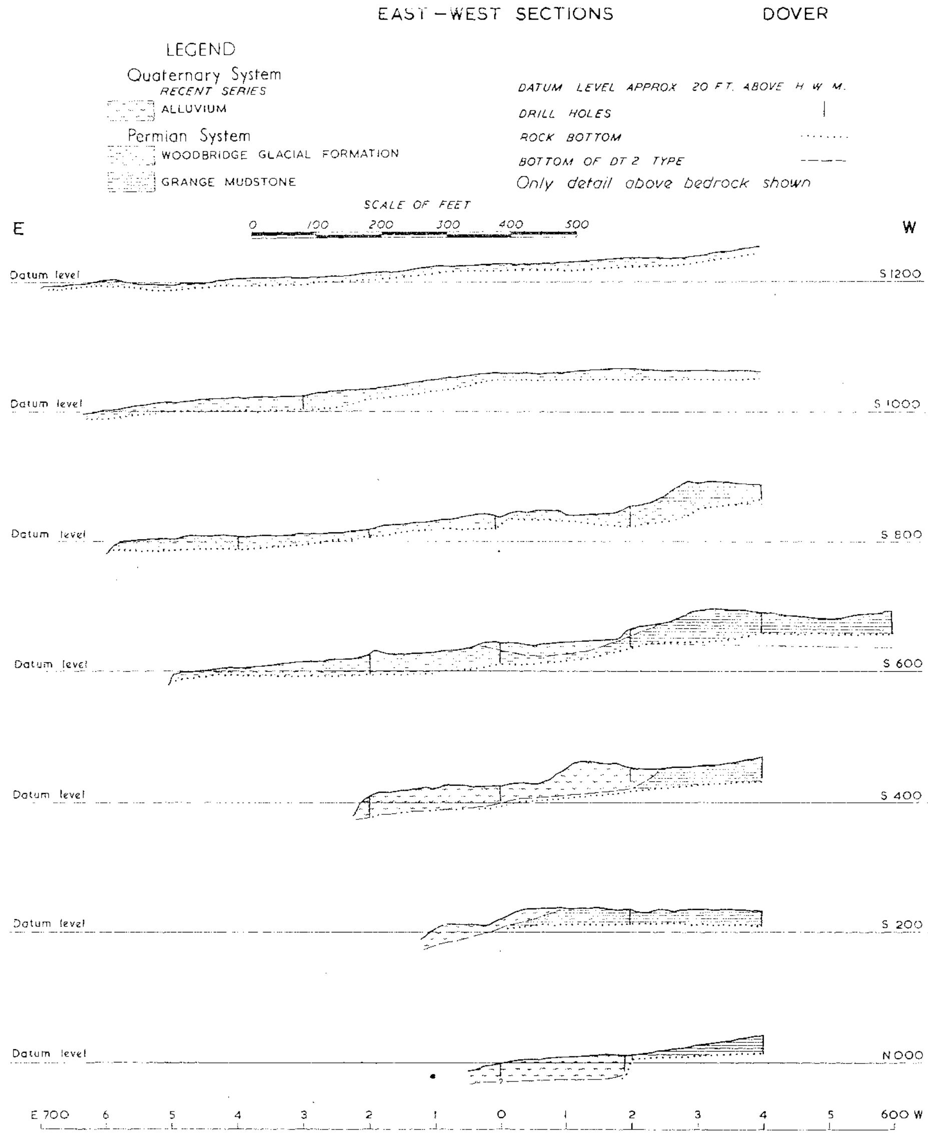


Fig. 3

However, the DT_2 type is of a different nature. An examination of the grain size distribution by means of the cumulative curves, clearly shows that it is a much better sorted deposit than the other two. All the coarse material has gone or, perhaps, was never available in the depositional environment. The cleanly segregated fine sandy patches as well as the fossil tree trunks with their outline of coarse sediments—the result of turbulence around the logs—suggest a subaqueous deposition.

Beyond the lignitic trees or odd pieces of plant fragments, no fossils were found in this clay. At this stratigraphical level, there is no known bed that would yield such a clay by weathering *in situ.*

The grain size analysis suggests that this is a secondary clay, i.e., it has been formed by deposition of clay in a lake. In particle size, it resembles the clay that is being shed from the dolerite at the present time.

No age for the formation of this clay is known but it may have been deposited in the Pleistocene in a period of high sea-level and revealed by the lowering of the sea-level in the last ice age or it may have been deposited in a Tertiary fault lake.

The boulders of silicified material often encountered in the deposit could be " grey-billy " or, as seems more likely, it could have been formed as a siliceous deposit in the B horizon of a soil profile. This is supported by the existence in many places of a siliceous hardpan overlying the clay material.

Description of Clays

(1) DT_1

This type of clay material which by its grain size analysis (see Fig. 4) must be classified as a clayey silt rather than a clay is found in the north-west section of the property.

The colour of this material is variable. Extensive patches are distinctly pink due to disseminated haematite but it is more usual to find it mottled, white, pink and yellow, or yellow in colour. In some places the material consists of alternating bands a few millimetres thick of yellow and white colour and occasionally red bands either with the white or yellow.

The main beds are often cut by narrow ramifying veins of white plastic clay (kaolinitic)* which has leached into cracks and openings in the massive material. At the bottom of all holes completed in this area the material recovered was extremely rich in angular quartz and the texture of the material resembled that of the Risdon Sandstone.

Drilling in this material is easy but, unless the hole is damp, its sandy nature makes recovery difficult. At intervals, beds a few inches thick of pebbles and cobbles up to 2″ in diameter are encountered. These are usually quartz or quartzite but pebbles of black slate and schist have been found. The distribution of the bands is apparently haphazard.

From the list of holes it will be seen that this deposit is fairly thick. One hole (W 400 S 400) exceeded the length of the drill rods and showed no bottom at 32′. It is estimated that this deposit contains 4,038,500 cubic feet of material or roughly 72,616,000 bricks.

No fossils were seen in any of this material but at W200 S800 it is seen to overlie the fossiliferous Grange Mudstone. Thus its stratigraphic position supported by the haphazard distribution of pebble bands, and the species of pebbles found suggest strongly that this is a weathered portion of the Woodbridge Glacial Formation which is poorer than usual in erratics.

This material disaggregated easily in water and rapidly settled out into a silt and a clay fraction. Grain size determinations were carried out by both the pipette method and the hydrometer method. Both showed that as much as 69% of the material was above the clay grade size.

* See Cole and Carthew, 1953, this volume.

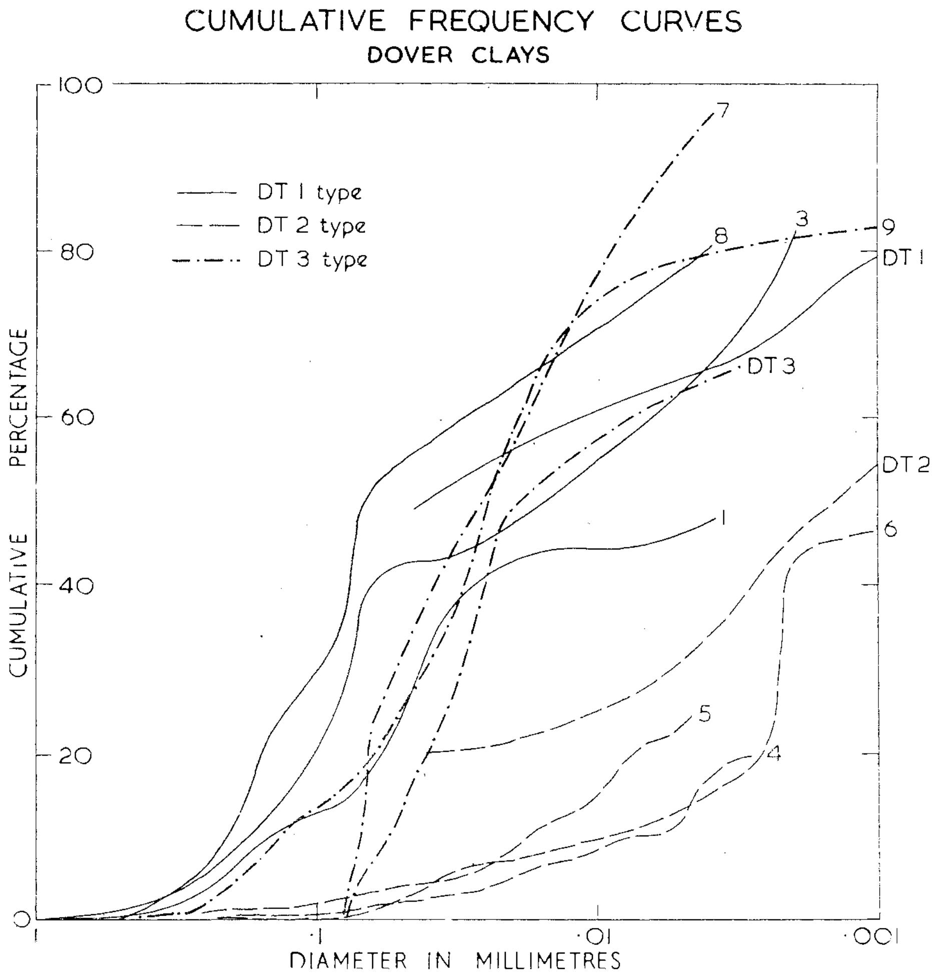


FIG. 4

The samples determined were:—

DT$_1$ A channel sample from the top quarry
W200 S600
W400 S400
W400 S800

As well as the kaolinite, quartz, and illite identified by Cole and Carthew (this journal), the following heavy minerals have been identified in this clay from the hole at W400 S800:—tourmaline (brown), rose garnet, black spinel, pyrite, limonite, rutile, brookite, haematite, and apatite.

The light fraction, composed mainly of clear vitreous and iron-stained angular quartz, contained felspar (usually heavily kaolinized) talc, quartz, mica schist, and carbonaceous material.

(2) DT_2

The area occupied by this bluish-white extremely plastic clay is shown on the map. The hole at E200 S600 was at first thought to be in this material but the whiteness of the fired material from this hole indicates that it is part of the DT_3 material.

This type of clay has been found in the bore holes to overlie the DT_3 type and, along the shore at E400 S500, it again overlies this clay with an undulatory contact which dips northward at about 10°.

Its relation to the DT_1 type is not entirely clear as the surface of both is covered with fine quartz sand. However the hole at the W200 S600 shows what appears to be this type of clay over the DT_1 type.

When fresh and wet this clay shows considerable variation in colour. Some dark brown beds owe their colour to carbonaceous matter which everywhere may be traced by blue, orange, and yellow stringers in the clay. Nodules of red haematite occur in many places. The occasional sandy patches are usually of a mauve colour. The top few feet are stained by the transportation of iron oxide to various shades of red and yellow.

On the foreshore at E300 S380, the outline in sand and the brown colouration of fossil trees can be seen. Some lignitic material can be collected from parts of these trees. Similar lignitic wood stopped drilling in the hole at W0 S400. An age determination of these trees is being investigated by Dr. Mary Calder of Manchester University but, as yet, there is no indication of the age of these beds.

Large limonitic concretions up to 10 feet across occur in this clay and especially near the base of it. Sandy lenses and occasional pebbles occur at infrequent intervals. The reserves of this clay are estimated to be 4,995,000 cubic feet, i.e., 79,920,000 bricks.

The clay is extremely hard to bore and is practically impervious to water when compacted. A green colour later turning to orange and brown often appears on slickensided surfaces.

The grain size analyses, carried out by the pipette and hydrometer methods, show that 55% of the material is in the clay grade, and of the total, 34% is smaller than ·65 mm. in diameter.

This clay is a very plastic one and the smaller particles would not deposit completely even after lengthy centrifuging. For the fine aggregate used in the X-ray determination, this suspension was flocculated with $CaCl_2$. The clay broke down after soaking for 24 hours in water containing sodium oxalate.

Samples were selected as follows:—

DT_2 — Channel sample from the hole at E200 S400.
IV — W200 S600 No. 5.
V — W200 S400 No. 18.

The chief minerals present are kaolinite, quartz (especially in the submicroscopic grades) some illite, felspar, garnet, rutile, tourmaline, spinel, pyrite, limonite, and some white mica. Marcasite was also found replacing rootlets.

A specimen from hole W200 S400 gave the following trace elements*:

Ni	Cu	Zn	Mo	Mn	Va
32&38 ppm†	12&11 ppm	20&24 ppm	4 ppm	70&68 ppm	440&435 ppm

(3) DT_3

The remaining area, except that occupied by the dolerite, is covered with a mantle of clay of the DT_3 type. This mantle is never as thick as in the other areas, the deepest hole in it, at E300 S1000, reaching a depth of 23′ 2″.

The clay is composed of two types. One is a clayey silt of yellow or reddish yellow colour and bearing abundant fragments of bryozoans and brachiopods. This is similar in colour to the DT_1 type but does not contain as high a proportion of quartz sand. The other component is white, cream or sometimes brownish in colour and is essentially a non-gritty plastic clay. This white clay outcrops at the small clay pit and in the bank at E200 S600. In both types, fragments of angular quartz, quartzite, slate, and schists (micaceous and garnetiferous) up to 2″ across have been found.

Along the shore, this clay overlies the Grange Mudstone and as the fossil content, the erratics and the bed of tillitic conglomerate which outcrops on the shore at E437 S600 are seen elsewhere in the district to be typical of this formation in its unweathered state, it is considered that DT_3 is a product of the weathering of the Grange Mudstone.

If this is so and the patches of white clay are not formed *in situ,* it is almost certain that this clay will be found distributed as lenses or pockets in the coarser yellow material and not confined to any one horizon.

The behaviour of this clay in drilling is variable. The fine plastic patches such as at W400 S1200 are fairly tough but not as tough as the DT_2 clay while the sandy portions such as found at E300 S1000 are fairly friable.

The total reserves of this clay are estimated to be 6,450,000 cubic feet or 103,200,000 bricks. Of this about 70,000 cubic feet or 1,120,000 bricks is contained in the known deposits of white clay.

As with the other types, the most abundant mineral present was kaolinite. Quartz was less abundant than in the DT_2 type and there was the usual small amount of illite present. No heavy mineral separation was carried out on this type.

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I desire to thank the Directors and Officers of the Granton Brick Pty. Ltd. for the opportunity to do this investigation, for the ready help given in transport and accommodation and for their permission to publish the results of the examination.

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I am deeply indebted to the Masonry Investigation Branch of the C.S.I.R.O., Highett, Victoria, which is administered by Mr. I. Langlands who, at the time of my study there, was deputised by Dr. J. J. Hosking.

* Determination by R. J. Ford, Geology Department, University of Tasmania.
(† ppm—parts per million.)

The course of the investigation at Highett was directed by Dr. Lex Ferguson. Dr. H. Heuber gave help with chemical and burning problems; Mr. Holland with the preparing of specimens for firing. Dr. W. F. Cole took X-ray Diffraction photographs, calculated the spacings, and interpreted them; Mr. A. Carthew* produced D.T.A. curves and gave instruction in the grain-size analysis by the hydrometer method. To all these officers I wish to express my thanks for their assistance.

LIST 2

Holes Drilled

Hole		Depth	Reason for Stopping
W 600	S 600	28′ 6″	
W 400	N 0	25′ 9″	Rock
W 400	S 200	25′ 3″	Rock
W 400	S 400	32′	End of drill rods
W 400	S 600	32′	Rock
W 400	S 800	22′	Rock
W 400	S 1000	10′ 2″	Rock
W 400	S 1200	8′ 10″	Rock
W 400	S 1400	6′ 5″	Rock
W 200	N 0	24′	Rock
	S 200	15′	Rock
	S 400	21′	Hole caved in
	S 600	24′	Rock
	S 800	30′ 2″	Soft Rock
W 0	N 0	21′ 6″	Hole caved in
	S 200		Under the plant
	S 400	23′ 5″	Stopped in lignitic wood
	S 600	30′ 9″	Rock
	S 800	15′ 6″	Rock
	S 1000	3′	Hardpan under sand
E 200	S 4400	32′ 8″	Rock
	S 600	30′ 9″	End of drill
	S 800	10′ 4″	Rock
	S 1000	1′	Hardpan
E 300	S 1000	23′ 2″	Rock
E 400	S 525	8′	Rock
	S 600	13′	Rock
	S 800	20′ 4″	Rock

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* For greater detail see Cole and Carthew, 1953, this journal.

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TABLE 1

Firing Characteristics of Hand Moulded Samples.*

	$DT_{1\&2}$	DT_A	DT_B	DT_C
Firing Temp. (in °C.)	1100	1150	1100	1100
Tempering H_2O	32%	31%	34%	36%
Water Absorption	22·2%	23·2%	21%	20·3%
Total Shrinkage	10·7%	10·4%	11·7%	12·2%
Warpage	nil	some cracking and deformation in one sample.	nil	nil
Cohesion	good	good	good	good
Vitrification	beginning	beginning	beginning	beginning
Remarks	Samples burnt in muffle kiln are pinkish orange at low temp. but pale pink by 1100°C.	As for $DT_{1\&2}$	As for $DT_{1\&2}$	As for $DT_{1\&2}$

* This firing was carried out in a gas-fired kiln and the details supplied by Dr. J. A. Ferguson of the Masonry Investigation Branch, C.S.I.R.O., Highett, Victoria.

TABLE 2

Firing Characteristics of Dry Press Samples*

	DT_1	DT_2	DT_3	DT_{1+2}	DT_A	DT_B	DT_C	DT_E
Firing Temp. (max.)	1100°C	1100	1100	1100	1100	1100	1100	1100
Tempering H_2O	nil	nil	nil	nil	nil	nil	nil	6% + ·6% Na_2CO_3
Water Absorption	16%	24%	25%	21%	21·5%	21·5%	21%	....
Warpage	nil	nil	nil	nil	nil	nil	nil	nil
Shrinkage	nil	nil	nil	nil	nil	nil	nil	nil
Cohesion	fair	poor	poor	poor	poor	poor	poor	good
Colour (at max. temp.)	light greyish orange pink; flecks of red.	grey pink thickly flecked with red. Cream colour increases with temp.	white	flecked orange pink to yellow grey.	flecked orange pink to yellow grey.	flecked orange pink to yellow grey.	flecked orange pink to yellow grey.	orange pink
Vitrification	nil	nil	nil	nil	nil	nil	nil	some bonding developed.
Remarks	At 1450°C: vitrified; grey to white colour; not deformed		At 1580°C: vitrified; not deformed white with black spots.	1580°C:— brown; white vitreous with hard edges.	1580°C:— light grey and brown mottled; vitreous with hard edges.	1580°C:— darker than A and some melting on the edges.	1580°C:— similar to other but some melting at edges.	A much harder brick than the others.

* Fired in an electric muffle kiln.

TABLE 3

List 1—Mechanical Analyses

Diameter mm.	Cumulative % greater than given Diameter								
	DT_1 TYPE				DT_2 TYPE			DT_3 TYPE	
	DT_1	1	3	8	DT_2	4	5	DT_3	7
1·000	....	·036	....	·26	....	....	....	....	....
0·5	....	·443	·1	1·21	....	....	....	....	·04
·2945	...	2·19	·34	3·16	....	·02	·078	....	·12
·1522	...	10·18	11·9	21·56	....	·36	1·166	....	·55
·0761	...	14·11	30·5	38·59	....	·75	2·35	1·66	1·04
·0625	....		41·5	52·06	....	1·88	3·34	..	23·44
0·44	49·6	....	42·8	....	20·00	2·04	4·63	....	....
·0312	....	38·37	....	60·16	....	....	5·50	26·58	44·76
·023	55·6	..	46·2	...	21·8	....	7·23	46·72	....
·0156	....	44·34	50·5	65·08	....	6·17	11·20	....	64·37
·011	59·4	...	53·5	....	24·7	7·83	13·62	....	....
·0078	...	44·76	53·5	73·34	....	9·99	19·10	....	81·69
·006	63·7	...	61·5	....	30·6	....	....	....	....
·0039	....	...	67·1	82·30	..	17·12	26·60	....	95·48
·00276	...	...	71·1	....	....	19·57	....	61·91	...
·0024	69·4	....	...	....	44·4	....	...	....	..
·00195	....	52·67	82·5	....	....	....	..	..	..
·0013	77·9	..	....	....	54·4	..	...	....	..
·00068	84·4	....	....	....	65·7	....	....	..	....