15. SITE INVESTIGATION OF THE PROPOSED CEMENT SILOS, DEVONPORT

by W. R. Moore

INTRODUCTION

The Devonport Marine Board requested the Mines Department to undertake a drilling programme at the site of the proposed cement silos on the W bank of the Mersey River immediately adjacent to No. 1 berth.

Marine Board records show that the bedrock at the site is overlain by filling and by a hand-packed "dike" or embankment wall composed of dolerite boulders. This superficial material overlies Tertiary basalt between 20 and 60 feet in thickness, which in turn overlies a fairly thin sequence of Tertiary sediments over Jurassic dolerite. The upper portions of both the basalt and dolerite are decomposed to form clay layers of variable thickness and the top of the basalt surface slopes towards the Mersey River. The general geological sequence and position of the proposed silos in relation to the river is shown in fig. 24.

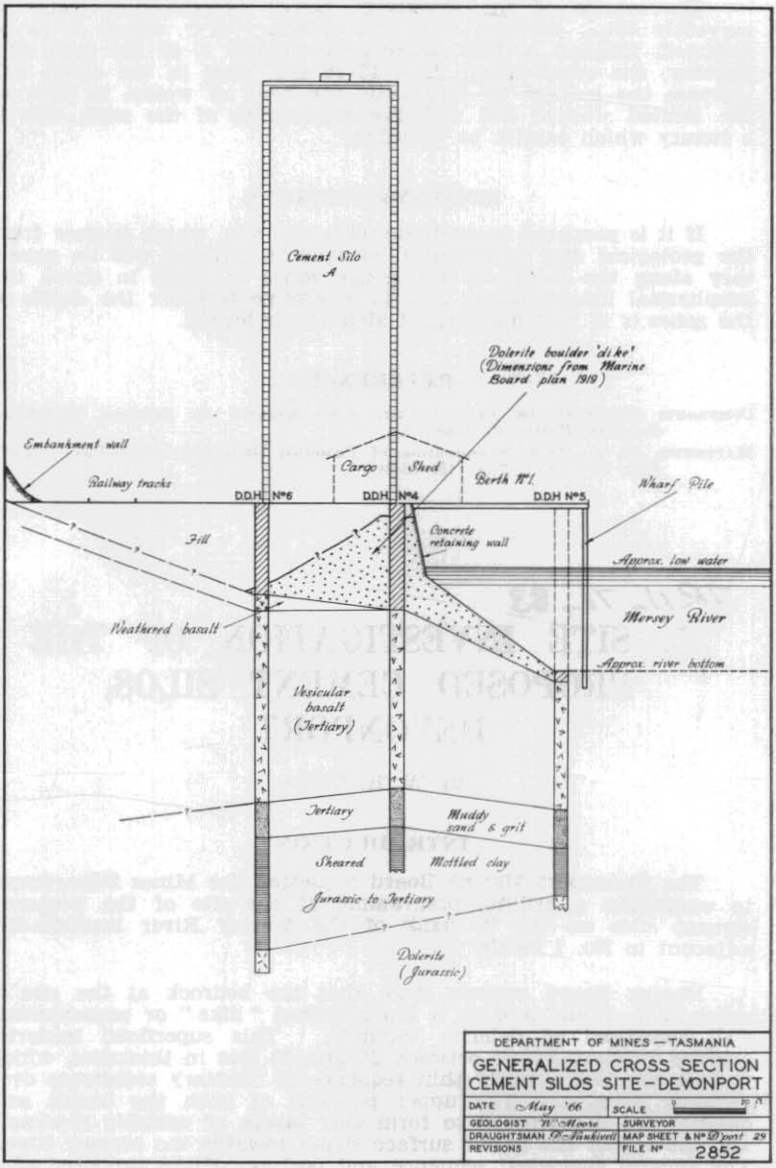


FIGURE 24

5 cm

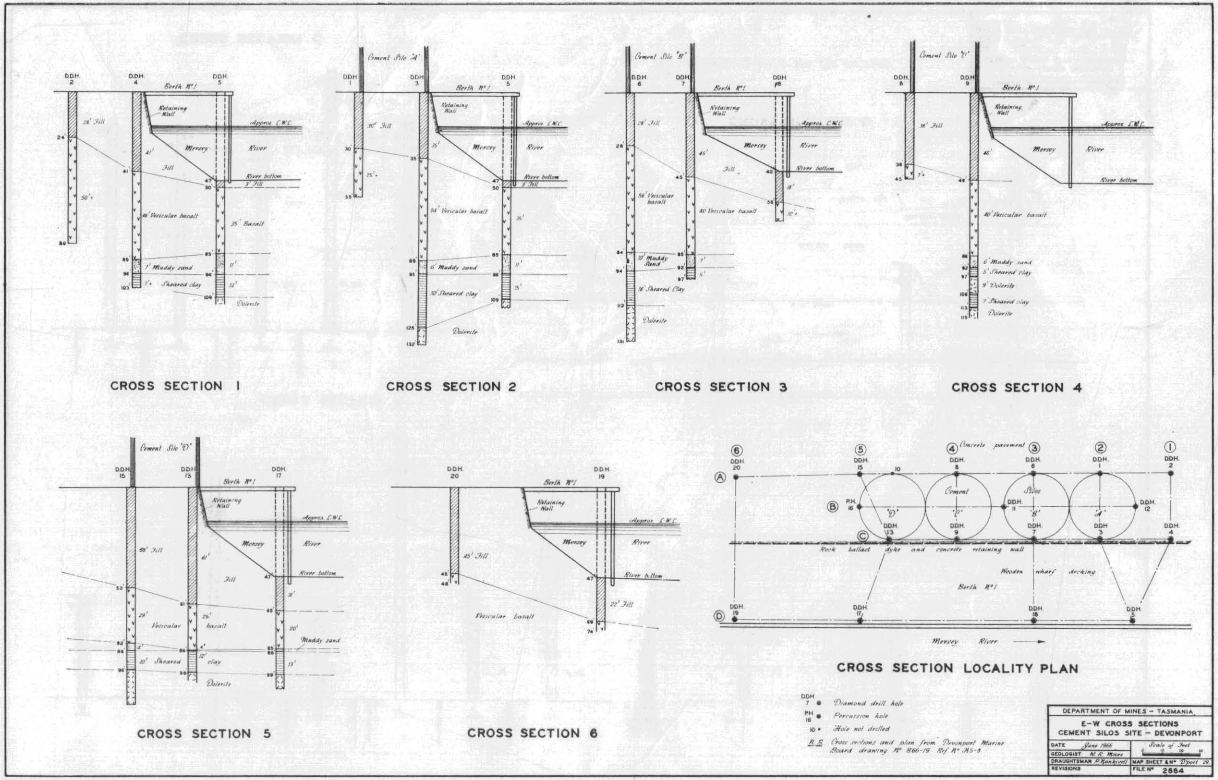


FIGURE 25

5 cm

5 cm

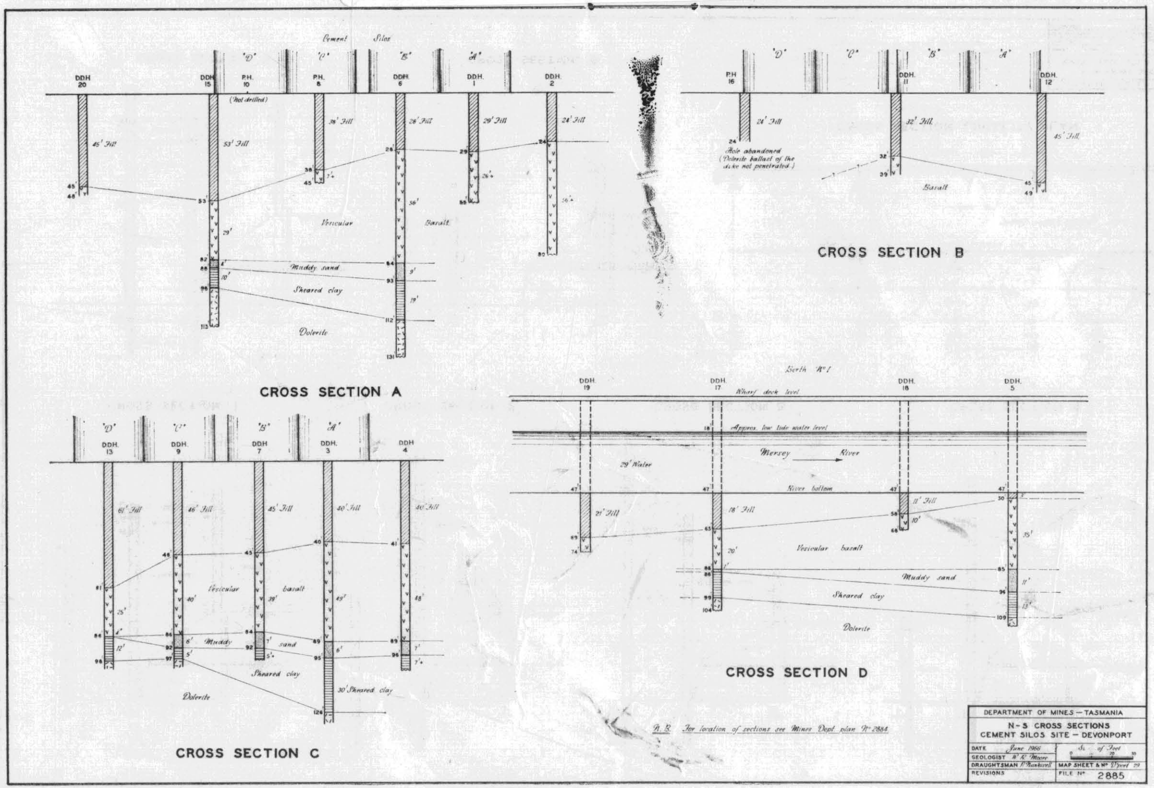


FIGURE 26

More information was desired on the following geological factors which appeared to influence the proposal:—

1. The depth of superficial material overlying the basalt.
2. The depth of weathering on top of the basalt.
3. The slope of the top of the basalt surface.
4. The thickness and uniformity of the basalt and its capacity to carry the proposed loads with regard to jointing and other structural and textural considerations.
5. The nature of the sub-basaltic Tertiary sediments, their thickness, load-bearing capacity, direction of dip and shear strength.
6. The nature and orientation of the surface or interface below the Tertiary sediments and the influence this surface may have on the proposed structure.

A series of drill holes was carried to the top of the basalt by means of a cable tool and completed with the diamond drill. At the time of writing, 18 holes totalling 1320 feet have been completed. Of these, 7 holes were carried to the top of the basalt to provide information on piling lengths and to establish the orientation of the top of the basalt surface and the remainder were aimed to reach fresh dolerite to establish the geological conditions at depth.

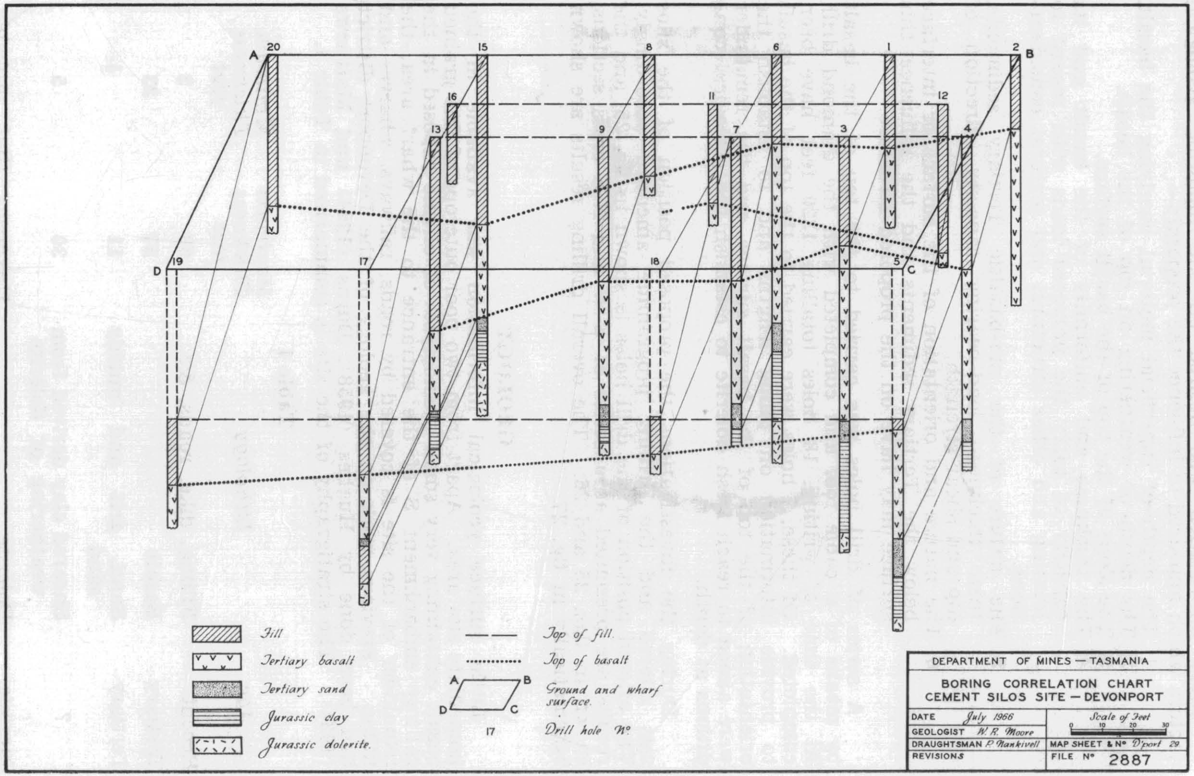
During the investigations the proposed position of the silos was altered and the drilling programme amended accordingly. The altered position of the drill holes is shown in fig. 25, and the results are presented as a series of E-W and N-S cross sections, shown in figs. 25 and 26. The overall drilling results are shown schematically in fig. 27.

GEOLOGY

Little surface geological information was available in the immediate site area. Apart from two poor outcrops of fine grained basalt containing very small phenocrysts of olivine exposed in the railway embankment S of the entrance to the wharf area, the remainder of the site is covered by roads, railways, wharves and filling. Previous work on the geology of the Devonport district had been done by Hughes (1958), Burns (1964) and Matthews (1964). The stratigraphy of the site is summarized in Table 1.

Table 1

Age	*Lithology*	*Maximum Thickness feet*	*Minimum Thickness feet*
Recent	Filling, dike, roads, &c.	69	3
Tertiary	Basalt	57	23
Tertiary	Sand, grit and muddy sand	11	$\frac{1}{3}$
?	Sheared clay derived from weathering of dolerite	30	5
Jurassic	Dolerite	Unknown (but probably several hundred feet)	



A
B
C
D
20
15
8
6
1
2
16
11
12
13
9
7
3
4
19
17
18
5
Fill
Tertiary basalt
Tertiary sand
Jurassic clay
Jurassic dolerite.
Top of fill.
Top of basalt
Ground and wharf surface.
Drill hole No.
DEPARTMENT OF MINES — TASMANIA
BORING CORRELATION CHART
CEMENT SILOS SITE — DEVONPORT
DATE July 1966
GEOLOGIST W. R. Moore
DRAUGHTSMAN P. Nankivell
REVISIONS
Scale of Feet
0 10 20 30
MAP SHEET & No. D'port 29
FILE No. 2887

FIGURE 27

Jurassic Dolerite

In hand specimen some of the dolerite in the cores is coarsely crystalline and some fine grained. Apart from the upper mantle of clay and weathered dolerite it is a hard, dense, competent rock capable of successfully carrying any loads which may be imposed on it. The thickness of the dolerite mass has not been determined in this locality, but it is expected to be in the order of several hundred feet.

Sheared Clay Derived from Weathering of Dolerite

Overlying the dolerite and underlying the Tertiary sediments is a layer of sheared dark green and grey mottled clay characterized by the ghost igneous texture found in clay derived by weathering from dolerite. The feldspars of the parent rock have been altered to grey clay minerals, and the ferro-magnesium minerals to green chlorite.

The age of the formation of this clay is unknown. It has been logged as Jurassic clay in the drill holes to indicate its relationship to the dolerite, but it was probably formed during early Tertiary times.

The clay generally passes downwards abruptly into unweathered dolerite, but sometimes a transition zone of concentrically weathered dolerite is present. The unweathered dolerite kernels resulting from concentric weathering may be 3 to 6 inches across as in cores 6 and 17, or up to 8 feet across as in core 9. The partly decomposed dolerite transition layer between clay and unweathered dolerite is harder than the clay, but softer than the dolerite. It is darker than the dolerite, joints in it contain clay and it has been referred to in the literature as " rotten " dolerite.

This concentric weathering is so deep that it is difficult to be positive where the drill intersects the main mass of unweathered dolerite or how thick the zone of sheared clay may be. It is therefore impossible to locate accurately the boundary between the clay and the dolerite or estimate the slope of the top of the unweathered dolerite (see Table 2).

Table 2

Lithology	*Thickness*	*Depth from*	*Depth to*
Hole No. 3—			
Clay	19′ 10″	94′ 10″	124′ 8″
Rotten dolerite	0′ 5″	124′ 8″	125′ 1″
Dolerite	1′ 11″	125′ 1″	127′ 0″
Rotten dolerite	1′ 0″	127′ 0″	128′ 0″
Dolerite	4′ 0″	128′ 0″	132′ 0″
Hole No. 9—			
Clay	5′ 0″	92′ 0″	97′ 0″
Core lost	0′ 10″	97′ 0″	97′ 10″
Dolerite	8′ 5″	97′ 10″	106′ 3″
Rotten dolerite	0′ 3″	106′ 3″	106′ 6″
Clay	5′ 3″	106′ 6″	111′ 9″
Rotten dolerite	1′ 3″	111′ 9″	113′ 0″
Dolerite	2′ 0″	113′ 0″	115′ 0″

The degree of shearing in the clay varied considerably from hole to hole and within individual holes but all cores showed some shearing. Some clay could be described as sheared pug, and some as mudstone. Shears are generally very abundant with polished surfaces and conspicuous slickensides. The dip of the shear planes varies considerably but is generally steep (50°-70° relative to the core). Most slickensides indicate movement parallel to the dip of the shear surface, but some show slight transverse movement as well as the dominantly vertical one.

Similar shears with slickensides are present but less abundant in the rotten dolerite where they appear to occupy pre-existing joints. In the underlying fresh dolerite a polished joint face with slickensides was found in Hole No. 3 at a depth of 125 feet. Joints showing shears and shear polish in the dolerite and rotten dolerite have similar steep dips to those in the clay.

Tertiary Sediments

The change from the underlying sheared clay to the Tertiary sediments is quite sharp. In a few places the contact is sheared but in Holes Nos. 3 and 5 grit is present. The grit band is 1 inch thick in No. 3 and 5 inches thick in No. 5 where it is pyritized. The grit contains coal fragments and quartz pebbles.

Near the base of the Tertiary sediments the rock is a muddy sandstone with wood fragments and carbonaceous material. Further up the section the sediments become coarser and contain less mud and no carbonaceous material. At the top of the sequence is a brown sandstone horizon of variable thickness. The sandstone is white flecked, soft, poorly sorted, often with grit bands, and varies in grain size from medium to coarse. Immediately below the overlying basalt is a baked zone only 2-3 inches thick with its lithology varying in each hole from which a core of the contact has been recovered, i.e., Holes Nos. 3, 9 and 17 have gritty mudstone, sandy mudstone and muddy sandstone respectively at the contact.

The water loss experienced at the contact, the poor core recovery and the broken nature of the core indicate that in some of the holes broken ground exists at this horizon.

In most of the cores the Tertiary sediments average 4 to 6 feet in thickness, but the exceptional thickness of 11 feet was encountered in Hole No. 5. The Tertiary sediments thin towards the S, being 6 feet thick in Hole No. 9 and only 4 inches in Hole No. 13 (fig. 26).

These sediments show evidence of shearing. The shear planes have steep dips similar to the shear planes found in the underlying clay developed on top of the dolerite. The shears were seldom found in the brown sandstone at the top of the section but occur frequently in the muddy sandstone towards the base. In the core of Hole No. 17 a sheared clay with slickensides was found along the contact between the basalt and the baked Tertiary mudstone.

Possible Cause of Shearing

The shearing in the clay is thought to have originated in Tertiary times by the development of a gravity slide or slump. This slump was probably triggered by the momentum of the basalt as the lava flowed from higher ground in the S.

Most of the shearing appears to have occurred on the clay horizon between Tertiary sediments and the unweathered dolerite. The Tertiary sand in front of the basalt flow was rafted along the top of the clay horizon as it slid. On this hypothesis little evidence of shearing would be expected in the sand, especially towards the top of the sequence, and none in the basalt.

Tertiary Basalt

Where fresh the basalt is a fine grained grey rock containing small phenocrysts of olivine. It is strongly jointed and contains vesicles to a varying degree in all the drill cores. In some cores the basalt is amygdaloidal with large vesicles filled with crystalline calcite or clay but in others the vesicles are close and evenly spaced forming a sponge-like texture characteristic of tachylyte (basaltic glass). In other cores the vesicles are closely spaced near the surface, becoming less frequent at depth, or the size and frequency of the vesicles may be constant throughout the entire core.

Jointing in the basalt is also variable but in general the rock is best described as strongly jointed. Three sets of joints can be recognized in the cores and of these the vertical joints appear to be contraction joints relating to the cooling of the basalt flows. Some movement is evident along one of the sets and this could be related to post-cooling movement or to disorientation of fragments of core during drilling.

Vertical Joints are mostly well-developed and open with chilled glassy margins and calcite veins up to 6 mm thick filling the joints.

Inclined Joints intersect the core at angles of 30° and 60°. Some have glassy margins which in a few places appear to be polished with incipient slickensides. They are sometimes calcite filled, sometimes open and in other cases totally closed.

Horizontal Joints tend to be irregular and at the base of the basalt are characteristically filled with calcite veins.

Veins of calcite and/or zeolite are common along many of the joints, especially near the chilled margins and are sometimes associated with disseminated pyrite. Where weathering or circulating ground waters have penetrated along the joints the vein filling has been dissolved out leaving weak open joints coated with a thin facing of clay.

In all the cores it is uncommon to find pieces of basalt larger than 6 inches. Many of the fractures in the core are probably due to the opening up of tightly closed joints and the vesicular zones by drilling.

In spite of the fractured appearance of the core, the high core recovery in the unweathered basalt and the fact that little or no water return was lost during the drilling suggests that the basalt is a fairly competent rock.

Number of Basalt Flows at Silo Site

Chilled margins of glassy basalt, weathered to clay, zeolites, residual carbonates, limonite and vesicles are present in the following holes:—

Hole No. 2	from 58 to 64 feet
Hole No. 3	from 58 to 61 feet
Hole No. 4	from 59 to 61 feet
Hole No. 7	from 55 to 60 feet

Below the chilled margin encountered in Hole No. 3, inclusions up to 3 inches across of material which in hand specimen appears to be either baked sediments or baked weathered basalt were encountered. In Hole No. 5 at 66 feet a clay band, originating from decomposition of glassy basalt, overlain by 3 feet of highly vesicular basalt was intersected. In Hole No. 6 a similar highly vesicular layer of basalt was found between 56 and 61 feet and the basalt in this zone was found to be extensively decomposed to clay and contained clay-filled voids 1 to 2 inches in diameter.

The above evidence suggests that two basalt flows are present in the northern section of the site. The contact between the flows appears to be horizontal, but the alteration and the presence of the clay between them suggests that it may be potentially a zone of weakness.

Weathering of the Surface of the Basalt

The upper surface of the basalt sequence is irregularly weathered. Generally two zones can be recognized, the uppermost consisting of decomposed limonitic basalt in which the original joints are no longer recognizable. This horizon was interpreted from the drilling results by the poor core recovery and by the highly broken core. The thickness of this zone is variable (2-12 feet) and cannot be obtained accurately from the available records.

In the holes farthest away from the river the thickness of the weathered zone is 5-12 feet, but the holes under the river near the wharf edge show only 2 feet of weathering on top of the basalt.

Below this layer is a transition zone of unweathered basalt characterized by extensive decomposition and deposition of limonite along the joints and in the vesicles. The thickness of this zone varies according to the degree of jointing and is as much as 10 feet in some of the cores.

In general the depth of weathering on top of the basalt is greater to the W away from the Mersey River.

Orientation of the Top of the Basalt

The top of the basalt slopes down towards the river 10°-30° beneath the proposed silos and flattens from there to the river's edge, 7°-19° (fig. 25).

In a N-S direction the top of the basalt slopes irregularly down towards the S with a pronounced change of slope indicated beneath silos C and D. Along the wharf edge the top of the basalt slopes uniformly to the S at 10° (fig. 26).

The thicker basalt under the N part of the silo site and the steeper slope to the S beneath silos C and D could be explained by two flows of basalt as suggested earlier northwards from Holes Nos. 6 and 7.

The depth to the top of the basalt in Holes Nos. 13 and 15 is 53 feet and 61 feet respectively which approximates to the level suggested for the contact between the two flows. However, no chilled margin was found in Hole No. 9 where the top of the basalt is at the same level as that found in Hole No. 7 where the well-chilled margin is recorded in the core at 55 to 60 feet (cross section C, fig. 26). In addition, the slope on the top of the basalt is constant and low (15°) beneath silos C and D beside the railway whereas beneath these silos beside the river the top of the basalt slopes abruptly down between Holes Nos. 9 and 14 (cross-sections A and C, fig. 26). It is, therefore, considered likely that this irregularity in the slope and other irregularities that occur on the top of the basalt are due to erosion. It is to be expected that the top of the basalt would be irregular and not as uniform as indicated on figs. 24, 25 and 26. However, the drilling results indicate only relative minor irregularities at this site compared with those encountered during the investigation for the wheat silos further S (Hughes, 1958, p. 117).

Orientation of the Bottom of the Basalt

The drilling results indicate that the bottom of the basalt is remarkably flat and uniform. The greatest difference in level so far encountered is 5 feet.

Extension of the Basalt Eastward Beneath the Mersey River

By extrapolation of the erosional surface on top of the basalt and the depositional surface at the base of the basalt some indication of the extent of basalt to the E of the site may be obtained. Taking the steepest and gentlest slopes on top of the basalt, extensions of basalt are postulated under the river to distances of 60 feet and 140 feet respectively from the wharf. These figures are from theoretical models, but serve to illustrate the possibility that the basalt may terminate in the bed of the river a comparatively short distance from the wharf.

Recent Deposits

These consist of filling and artificial structures, the chief of which is a stoutly constructed " dike " made of hand-packed dolerite boulders indicated on old Marine Board plans. Evidence from the drilling shows that it is neither as extensive nor as thick as the old records indicate. The depth at which dolerite boulders were encountered in the drilling varied from 13 feet to 40 feet and the thickness of the dike varied from 7 feet to 20 feet.

No difficulty was experienced in driving 5 inch casing through the dike with a light cable tool drill and the structures should not present any major difficulties to pile driving operations.

CONCLUSIONS

1. The top of the basalt has a steep slope of up to 30° towards the river at the silo site.

2. The thickness of basalt beneath the site varies from 25 to 56 feet.

3. The basalt is a strong, fairly competent rock, but it is strongly jointed and appears sensitive to fracturing. Pile driving into the top of the basalt could re-open the old joints and tend to wedge off a slice of basalt.

4. The original thickness of the basalt and the number of flows present before the Mersey River eroded it to its present level is unknown.

5. Both the Tertiary sand and the dolerite clay moved in Tertiary time, probably due to slumping rather than faulting.

6. The age of the movement cannot be precisely established from the available information, but it seems most likely to be penecontemporanous with the out-pouring of the basalt. The movement may have been substantial and affected a large area with the silo site behaving as a unit, or the movement may have been quite small affecting only a limited area.

7. Soil tests undertaken on the clay are reported to indicate that this material has considerable shear strength and that failure through overloading is unlikely. However, it must be recognized that these tests were carried out on unsheared samples and that the behaviour of the clay layer as a whole may be quite different.

8. The loading tests are confined tests and do not apply to the conditions which would occur in the case of a gravity slide along a decollement horizon.

9. The thickness and extent of the basalt to the E under the Mersey River is unknown, but this is a critical factor.

10. The thickness of the sheared clay and the slope between this clay and the unweathered dolerite surface to the E under the river is unknown.

RECOMMENDATIONS

1. The silos should be situated as far away from the river as possible in order to obtain the maximum thickness of basalt beneath them.

2. The load on the top of the basalt should be kept to a minimum and it should be as widely distributed as it is economical to do so.

3. Fracturing of the basalt by pile driving and other means should be kept to a minimum.

4. A series of holes should be drilled eastward from the silo site across the Mersey River to determine the distribution and thickness of the basalt for 300 and 400 feet from the edge of the wharf.

5. A sonar reflection line should be run to determine if the top of the basalt is continuous between the proposed drill holes and to determine if possible the slope on the top of the dolerite.

6. Some of the holes suggested above should be drilled into unweathered dolerite to provide information on the slope of the dolerite and the thickness of the sub-basaltic sediments.

7. Further tests should be undertaken by a suitably qualified authority to determine the physical properties of the sheared clay.

8. If it is shown that the basalt is not continuous or is very thin across the Mersey River an analytical study should be made of the loading which can be tolerated by a wedge-shaped block of basalt together with silos. Such a study should consider the worst possible condition of the sheared clay, but should assume little or no strength in tension for the eastern edge of the basalt wedge.

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