



Slope stability and engineering geology of the Blackstone Heights area

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Abstract

During 1987–88 a large subdivisional project of approximately 11.5 km², immediately west of Launceston, was mapped for slope stability and engineering geology. The area is underlain by dolerite, dolerite boulders, and clay from the *in situ* weathering of dolerite. The total area is enclosed by a 9 km long loop of the South Esk River, which is now dammed to form Lake Trevallyn. Two NW-trending ridges form the western and eastern sections of the area, and are separated by a low relief down-faulted central area.

Three zones are shown on the slope stability map. They are:

- Zone 1: Building recommended;
- Zone 2: Building may be recommended. Subject to investigation;
- Zone 3: Building not recommended.

No active landslides were found, and only a few old landslides were present at Blackstone Heights.

Units used on the engineering geology maps were:

- (a) alluvium;
- (b) clay;
- (c) clay with small outcrops of dolerite and boulders;
- (d) talus;
- (e) dolerite outcrops and near outcrops.

Detailed lithological descriptions, the engineering geology properties, the potential engineering geology problems, and the investigation methods required for each unit are listed. The three major engineering problems of the Blackstone Heights area are expansive clay, differential movements of the foundations, and the potential risk of landslides.

In the eastern half of the area the investigation was undertaken at subdivisional levels. As well as mapping, the investigations included a considerable amount of geophysics (magnetometer traverses and shallow refraction seismic surveys) followed by confirmatory trenching and drilling. These subsurface findings were extrapolated into the western

section of Blackstone Heights, where only surface mapping was undertaken.

The clays occurring at Blackstone Heights are highly plastic and expansive, with montmorillonite a major component in their composition. Shear box testing gave low values for internal angles of friction and effective cohesion; consequently the potential for slope failure on slopes above 12° is high, given an adequate thickness of clay. The properties of the Blackstone Heights clay show them to be equally as reactive to seasonal movements, and they would appear to have as high a potential for slope failure as the depositional clay of the Launceston Beds of the Tamar Valley Trough.

Blackstone Heights is part of the western margin of the Tamar Trough, and deposits of *in situ* clay are exposed. The thickness of the clay which has been proved in the subdivisional project area is such that the three engineering geology problems cannot be ignored when subdivisions are planned and building follows.

At Blackstone Heights the clay is thickest in valleys associated with faulting and associated metasomatic alteration. The clay does occur upslope, in and under the talus boulders above the weathered dolerite rock. There is a general decline in thickness up the slopes but this is irregular and unpredictable in its distribution. Because the clay occurs on slopes, a potential risk for landslides does exist at Blackstone Heights but this risk is considered lower than for the Tamar Valley areas to the east.

Because of the areas location on the western margin of the Tamar Trough, the clay at Blackstone Heights is thinner, and the potential landslide risk lower, than in areas in the centre of the trough, such as at Windermere, where thick deposits of clay occur on the slopes. The potential risk of landslide at Blackstone Heights is also lower than at Lilydale, east of the Tamar Trough, where *in situ* clay occurs above the mudstone of Permian age. The clay in the Lilydale area forms a thin continuous layer under the entire length of the slopes, in contrast to Blackstone Heights where the clay is very variable in distribution and thickness on the slopes.

INTRODUCTION

The Blackstone Heights project covers an area of land of approximately 11.5 km² [EQ070100] on the south-western outskirts of Launceston City. The land is being developed, for residential purposes, by Sanieth Ltd. The project covers the land enclosed by the loop the South Esk River makes from Hadspen to the Cataract Gorge. At the upper end of the gorge

the Trevallyn Dam impounds water which backs up to the south-west corner of the Blackstone Heights area (fig. 1).

The Blackstone Heights project comprises a series of subdivisions which vary from closely-spaced residential to semi-rural blocks varying in size from 600 m² to greater than

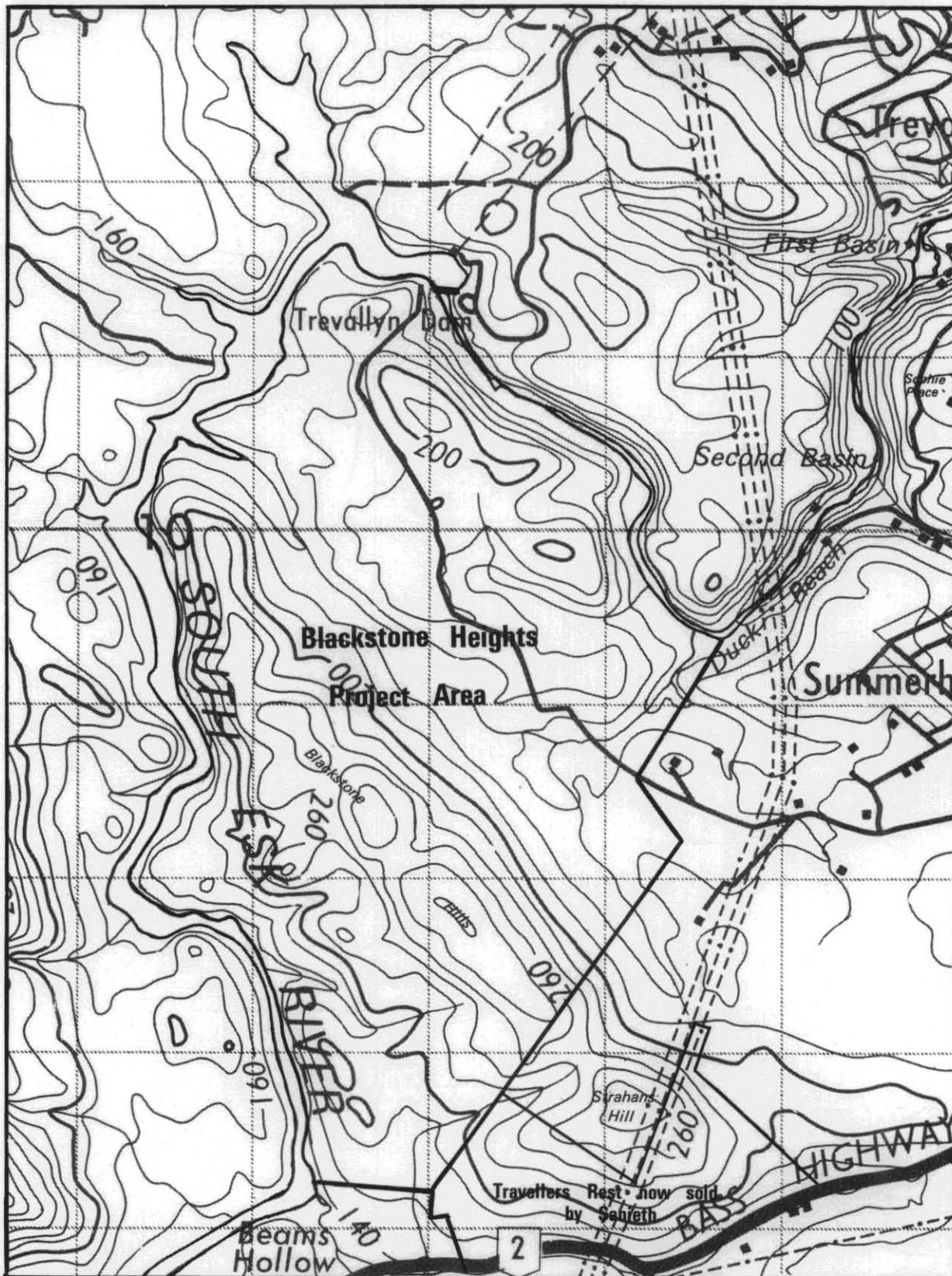


Figure 1. Location of Blackstone Heights area.

Table 1. Investigated and reported subdivisions, eastern section, Blackstone Heights.

Section C Report No.	Name of Subdivision	Area hectares (approx.)	Number of blocks planned	Stage of development
1	Mount Leslie	43	46	Building
2	South Lake View Court	3.8	2	Approved
3	South Panorama Road	8.2	11	Building
4	Kelsey Road	3.5	2	Building
5	Lake View Court	5.9	2	Approved
6	West Blackstone Road	11	40	Serviced
7	Blackstone Hills	40.8	14	Surveyed
8	Trulls Saddle	25.5	30	Investigated
9	Plateau	70	306	Planned
10	Reservoir	11.3	33	Approved
11	Panorama Road	2.0	10	Building
12	North Panorama Road	4.2	34	Serviced
13	Bay View 4	2.4	11	Approved
14	Bay View 5	125	127	Approved
15	Deadmans Hollow	27	13	Building
16	Dalrymple Rise	100	213	Approved
17	West Travellers Rest*	26.2	12	Building
18	East Travellers Rest*	89.3	14	Planned
	Travellers Retreat (western section)	78.3	34	Approved and now being developed

*These two subdivisions have since been sold by Sanieth Ltd to another developer, Mr R. Harrison

five hectares. The subdivisions are at various stages of development. The whole of the project is located in the Municipality of Westbury, and to date approximately 1200 blocks have been approved, or are awaiting approval, by the Westbury Municipal Council (Table 1). These subdivisions cover only the eastern section of the project area (fig. 2). The western section, as yet with no development, was mapped for slope stability and engineering geology using seven large blocks as units for the mapping (fig. 3).

HISTORY OF THE INVESTIGATION

The Westbury Council carried out a planning concept study prior to any development occurring. The Council's consultant reported that the Department of Mines had stated that the area was underlain by dolerite rock, and that no landslide problems were foreseen. The source of this information is unknown.

The area of the Blackstone Heights project is immediately to the west of the area of the Tamar Valley mapped for landslide zoning by the Department of Mines in 1972. If the Blackstone Heights area had been mapped in 1972, the landslide potential of the area would probably have been investigated. When development started—with building of roads, service drains and house sites—it became apparent that, even though dolerite rock was present, there were surprisingly large amounts of clay exposed. It was also suspected that some of the ground irregularities on the western side of Mt Leslie may have been caused by downslope movement.

DEPARTMENT OF MINES 1987 INVESTIGATIONS

In 1987 the Department of Mines was requested to inspect the Mt Leslie subdivision. After a brief reconnaissance visit it was realised that this area may be one of the difficult western margin areas of the Tamar Trough (Moore, 1987). In these areas thick deposits of yellow-white clay occur; in many exposures this clay retains its original igneous texture, and is clearly derived from the *in situ* alteration and weathering of

dolerite. In some areas of Blackstone Heights this clay appeared to be overlain by a dark brown and brown-orange clay, lithologically similar to the clays of the Launceston Beds (Longman, 1966).

The potential instability of the brown-orange clay of the Launceston Beds is well documented, and this potential is appreciated by Councils and their professional staff throughout the Tamar Valley. In contrast, the yellow-white *in situ* clay, derived from the weathering and alteration of dolerite, is seldom exposed, and consequently is only encountered infrequently. Its potential instability is not well known, and the potential risk was not appreciated by the Council staff.

Through two previous investigations in Launceston (at Sophie Place and Ambrose's subdivisions, Ernest Street; Moore, 1985a), the potential engineering problems of these yellow-white clays became apparent. The construction of new roads on the southern and western outlets of Launceston resulted in the excavation of a number of high cuttings. These cuttings showed the great depth of weathering producing this clay, and indicated that the clay had a wider distribution than was formerly realised (Plate 1). Prior to the development of the subdivisions at Sophie Place and Ernest Street, and the excavations along the outlet roads, these doleritic clays had only been found in isolated drill holes in Hobart and Devonport (Moore, 1965; 1968a, b).

The three engineering geology problems likely to be associated with these clays at Blackstone Heights are (as stated in the 1987 reconnaissance report):

- Expansiveness causing the houses to crack.
- Differential movements because of the rapid change from clay to rock below building foundations, causing structural problems in the building.
- If an adequate thickness of clay is present there is a potential for landslide.

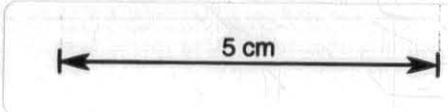


Figure 2. Location of subdivisions investigated, eastern section, Blackstone Heights

5 cm



Figure 3. Mapping units, western section, Blackstone Heights



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INVESTIGATION PROGRAMME AND RESPONSIBILITY

The 1987 report alerted both the Westbury Council and the subdivider, Mr K. Pybus of Sanieth Ltd, to the potential problems. At a conference in 1987, initiated by the Director of the Department of Mines and the subdivider's consultant engineer (Mr P. Spratt), the following programme was planned and the responsibilities delineated between Mr Peter Stevenson (Supervising Geologist, Engineering Geology and Groundwater Section, Department of Mines) and Mr Pybus of Sanieth Ltd.

- (1) The Department's engineering geology section would map and zone the Blackstone Heights area for slope stability at subdivisional levels, and provide a compilation map at the end of programme. This work would cover the problem of clay thickness (Map 1).
- (2) The area would also be mapped for engineering geology, which would cover the expansiveness and differential movement problems. This work would include some regional geophysics, soil laboratory testing, and auger drilling. The subdivider undertook to provide the necessary equipment for subsurface trenching without cost (Map 2).

For each subdivision application a slope stability map and a report would be submitted to the Westbury Council. Mapping started after the initial report in 1987, and continued through to 1988. With many of the subdivisions already planned and some approved, the initial mapping was undertaken to cover each subdivision application, with the order of priority being decided by the subdivider.

This piecemeal approach of individual subdivisions is not considered an effective utilisation of time, as is obvious by comparing the time spent on the eastern section of the Blackstone Heights area compared with the western section. Because subdivisions in the eastern section had frequently been planned and surveyed, roads cut etc., the investigation was not for an individual subdivision but at times covered individual blocks, as for example the Deadmans Hollow seismic investigation. In contrast only regional surface mapping was undertaken in the western section, and the area was covered in less than one-third of the time.

The list of the subdivisions, with their area and number of proposed blocks, is given in Table 1. The initial reports for the developer were done on a subdivisional basis and remain as issued. The second stage, or additional investigations, were undertaken at Deadmans Hollow, Dalrymple, and Trulls Saddle subdivisions. These investigations were required to obtain approval of planned subdivisions. These were detailed site investigations within the Zone 2 investigation zone, and included seismic surveys followed by trenching.

DEPARTMENT OF MINES AIMS

In 1987 the Department of Mines was hoping to obtain support from the Councils of the Tamar Valley for an upgrading of the existing 1972 Landslip Zone maps of this area. Not only would the landslide maps be of a larger scale and plotted on orthophoto maps, but they would be broader in scope. This increase in content would include the other two

major engineering geology problems of the Tamar Valley—namely expansive soils and differential movements; these were the three problems being mapped at Blackstone Heights. With the two compilation maps of the Blackstone Heights area as examples of the type of upgrading planned for the Tamar Valley, the Department hoped to gain the Councils' approval, as well as financial support.

The Blackstone Heights work could be used as a guide for the time required to revise the Tamar maps, and produce engineering geology maps of Greater Launceston, Devonport and Burnie—all of which have broadly similar geology.

As a subsidiary aim, the Blackstone Heights area was to be used as training for staff engaged in the Geodata Mapping Project in Hobart, an area with less complex engineering geology problems than either Blackstone Heights, Launceston, or the Tamar Valley.

SUBDIVIDER'S AIMS

The subdivider wished to be able to state publicly that the Blackstone Heights area had been thoroughly investigated for landslides by the Department of Mines, and requested that this investigation be as thorough, and preferably of a higher standard, than any other subdivision in Launceston. To achieve this aim a slope stability zone map for the entire project area, equivalent to the Tamar Valley landslip map of 1972, was required.

Although the engineering geology map was not the responsibility of the subdivider, he readily appreciated that any subsurface investigation would add to an understanding of slope stability investigation as well as the engineering geology. He made available any machinery required for any subsurface investigation.

As a subsidiary aim, the subdivider and his planners desired to achieve the optimum utilisation of the land, with the *Building Recommended* zone land maximised for housing development. This aim has been achieved. Cohen and Associates Ltd, Surveyors and Planners, estimate that the field mapping of the western section of the Blackstone Heights area has increased by up to one-third the land available for subdivision compared with the original Council conceptual report with its slope profile study.

WESTBURY COUNCIL'S REQUIREMENTS

Council has the ultimate responsibility for building approval on all subdivisions within its Municipality. For Blackstone Heights the Council's Engineer requires, for each subdivision, a slope stability map and report from the Department of Mines. The slope stability zones are required to be located, surveyed and pegged for each subdivision, with the survey plan of the slope stability zones certified as being correct by the geologist concerned with the mapping (Map 3).

Council has additionally required that each block has an adequate amount of land, recommended as Zone 1 land, for a house site in all the subdivisions.

SLOPE STABILITY AND ENGINEERING GEOLOGY INVESTIGATIONS

TOPOGRAPHY

The topography at Blackstone Heights is controlled by the faulting, thought to be of Tertiary age, on the western margin of the Tamar Trough (Longman, 1966). There are two high NW-trending ridges—the Blackstone Hills to Strahans Hill ridge along the western margin; and the Mt Leslie ridge on the eastern side. Separating these two ridges is a down-faulted central area which has little relief, and with low rounded topography (fig. 4).

Two NW-trending faults border this low central block. The western fault is exposed as a crush zone at the Blackstone Road quarry, while the eastern fault is exposed in the old access track and drainage ditch of the Bakers Court quarry. Here dolerite is faulted against siltstone sediments of Permian age.

Steep, often cliffed slopes fall from the high dolerite-capped ridges of Blackstone Hills and Mt Leslie to the South Esk River and Lake Trevallyn. The course of the South Esk River is possibly controlled by two similar NW-trending faults bordering the central block.

Cross faulting occurs at Trulls Saddle, and may continue to Dalrymple Creek and down Duck Reach into the Second Basin in the gorge of the South Esk River.

As well as the crush zones which occur along these faults, wide areas of metasomatic alteration of the dolerite also occur, as shown by the red bauxitic soil and clay exposed south of Panorama Road and on the Dalrymple subdivision. In addition to differential vertical movement, the dolerite was also tilted by the faulting. Steep scarp slopes face Blackstone Creek to the west, with long back slopes to the east to the central creek.

Along the Mt Leslie ridge and in the Blackstone Hills—Strahans Hill ridge, closer faulting is thought to have resulted in narrow hog-back ridges, with dolerite outcrops along the ridge tops. Thick talus boulder deposits overlie the dolerite and its mantle of clay on these steeper slopes.

During down cutting of the Cataract Gorge by the South Esk River extensive rock ledges were cut as far upstream as Dalrymple Creek, and on the low rock promontories at Lake Trevallyn and on the low slopes of Badger Plains.

GEOLOGY

The overall geology at Blackstone Heights is simple. The area comprises a block-faulted area of Jurassic dolerite, with residual and possibly some depositional deposits of clay presumed to be Tertiary in age. In one area only has the fault uplift been large enough to expose sediments of Permian age.

The faulting is inferred to be Tertiary in age as it is associated with wide areas of metasomatic alteration, where hot migratory fluids normally associated with basaltic intrusions formed ferric and bauxitic staining in the clay. No basalt was found at Blackstone Heights but extensive outcrops occur at Bradys Lookout and Grindelwald, 15 km to the north.

Good exposures of this chemically-altered dolerite occur at the junction of the Trulls Saddle and Blackstone roads (Plate 2), and this clay was drilled at 7 m depth in a nearby bore hole (Excavation 1 and Bore 1 logs; Appendix 1).

The faulting, and its associated metasomatism, was followed by deep weathering of the dolerite to orange-yellow and yellow-white clay, often retaining its original igneous texture.

This weathering is different from the mechanical iron-staining of dolerite of the cold Pleistocene age, and is thought to be dominantly chemical and of the warmer Tertiary age. The weathering is frequently concentric, and develops along vertical jointing within the dolerite, forming deep as well as wide zones of clay (Plate 3).

In some areas this yellow-white clay is overlain, with a sharp lithological break, by brown clay while in other areas there is a transitional zone between the clays. The brown clay appears to be lithologically similar to the brown and orange-brown clay of the Tamar Valley Launceston Beds (Longman, 1966). It is possible that small pockets of the Launceston Beds clay were deposited above the residual yellow and white clays in some areas at Blackstone Heights.

During the Pleistocene, talus and scree deposits comprised of large dolerite boulders were deposited on the steeper slopes below the ridges, particularly on the colder SW-facing slopes. Cliffed outcrops of dolerite were formed as the South Esk River gorge was eroded. At Blackstone Heights the dolerite varies from the unweathered cliffed outcrops of the gorge, to completely weathered dolerite, to clay to a known depth of seven metres. This change occurs within very short distances, as can be seen in the quarry and reservoir (Plate 4) at Blackstone Heights, and in exposures along the southern and western outlets of Launceston (Plate 5).

GEOPHYSICS

From the lithological variety seen in the road, quarry and reservoir exposures of the early subdivisions, it was apparent that surface mapping alone would not be adequate for slope stability assessment, and would be unreliable for any engineering geology mapping. At surface exposure level it was frequently impossible to distinguish isolated dolerite outcrops from large dolerite boulders produced by concentric weathering, or large boulders within talus deposits (Plate 6).

The clay produces no natural outcrop, and its location could only be generalised from where no dolerite boulders were present on the ground surface. Surface mapping thus required a further back-up of geophysics, with confirmatory trenching and drilling. At Sophie Place (West Launceston), a small steep subdivision east of the First Basin of the South Esk River, 2.5 km from Blackstone Heights (fig. 1), was investigated for slope stability. This subdivision had similar dolerite and dolerite-derived clays, and required a seismic refraction survey, auger drilling, and trenching (Moore, 1985a).

PROTON MAGNETOMETER TRAVERSES (Map 2)

As the area to be covered at Blackstone Heights was far greater than at Sophie Place, a more rapid geophysical method than seismic refraction was required to distinguish between dolerite and clay. Two trial traverses using the proton-electron magnetometer, with readings taken every 10 m, were undertaken from Long Bottom inlet to the top of Blackstone Hills, and another from Panorama Road to the top of Mt Leslie.

The traverses detected dolerite contacts near the top of Mt Leslie and Blackstone Hills, where extensive areas of dolerite crop out. They also showed that only clay was present in the valleys of Panorama and Blackstone Roads, associated with the two NW-trending faults. Also important for slope stability was the fact that clay extended upslope, and was likely to occur below and in some of the mapped talus deposits.

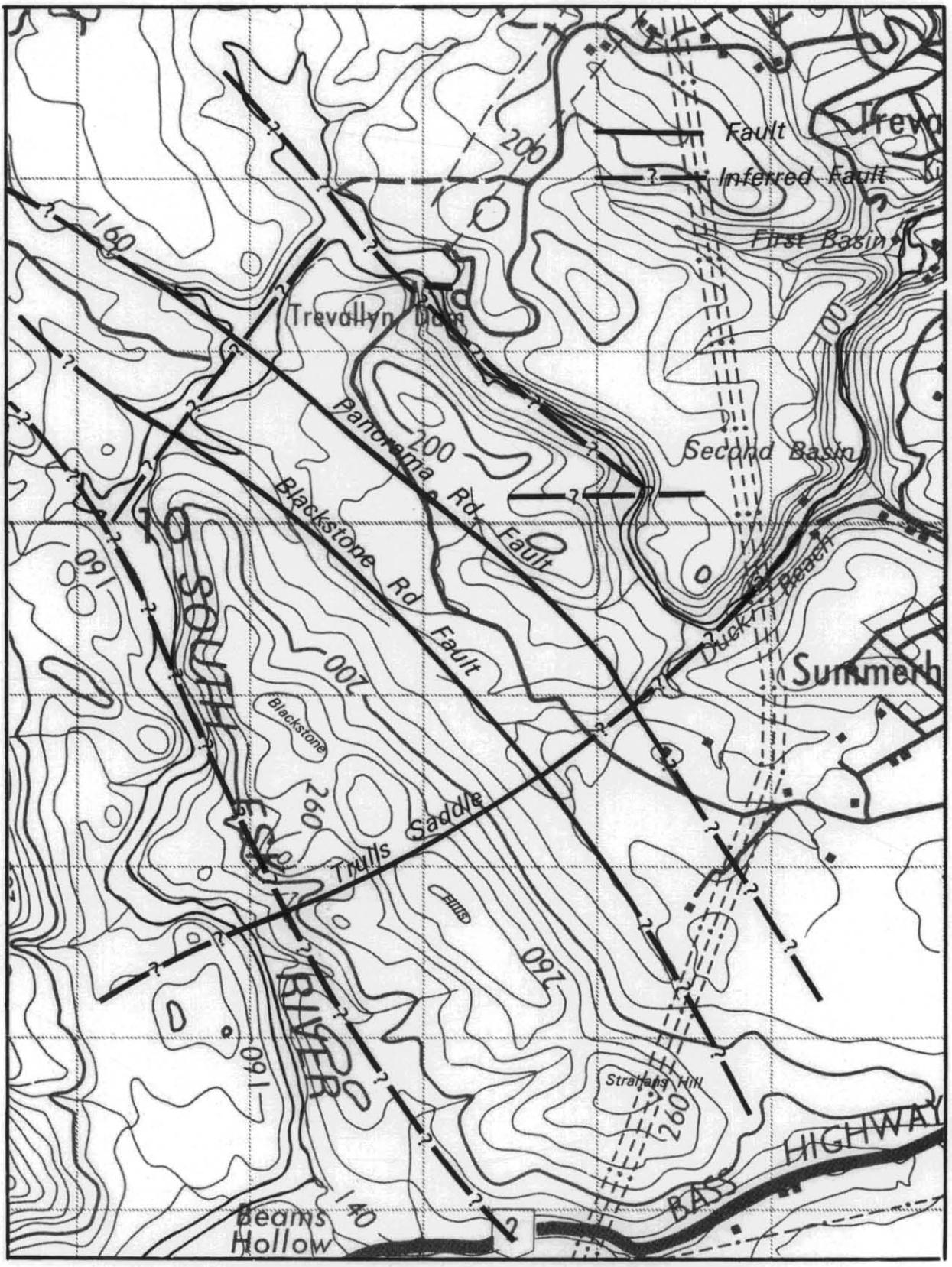
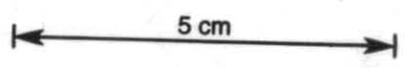


Figure 4. Faulting and topography, Blackstone Heights area.



These traverses added considerably to the surface mapping interpretation, as shown in Traverse 1 (fig. 5), and justified the surface mapping placement of the steeper western slope of the Mt Leslie subdivision in the Zone 2 slope stability zone, where some old translational downslope movement may have occurred. Trenching at the north-west end of this zone in Bay View 5 (Lot 64) exposed faceted clay with shear polish, confirming the downslope movement in this zone.

Because of the above results, the two short magnetometer traverses were joined by traversing across the central block. Outcrops in this area, except for the quarries at Long Vista and Bakers Court, were few on the Plateau subdivision (Traverse 1, fig. 5).

Two further traverses were undertaken; one from the col on Blackstone Hills across the southern area of the Plateau subdivision to the Reservoir subdivision (Traverse 2, fig. 6); and one from Blackstone Road up to Trulls Saddle (Traverse 3, fig. 7).

The results of these two traverses up the ridge to Blackstone Hills are similar to Traverse 1, except that the anomalies are larger (making the swings or roughness greater), indicating that dolerite is closer to the surface on the higher slopes, and on the ridge is more continuous towards the south. The profile across the central block indicates a decrease in the thickness of the overlying clay, with dolerite closer to the surface towards the south. All of these profiles show a rapid change from outcrop to clay. All three magnetometer profiles correlate with surface mapping, with additional information refining the engineering geology boundaries.

SEISMIC REFRACTION TRAVERSES (Map 2)

The magnetometer traverses indicated the areas where dolerite cropped out or was close to the surface, and where thicker clay deposits could be anticipated. Refraction seismic was used to:

- confirm the regional magnetometer results;
- to indicate the degree of weathering of dolerite;
- to calculate the thickness of the surface clay;
- to indicate the depth to unweathered rock.

Thirteen long spreads, using 7.5 m geophone spacings, were used regionally (Appendix 2, Table 2), and supplemented by five short weathering spreads with geophone spacings of 1.0 m, increasing to 2.0 m half-way along the spread (Appendix 2, Table 3). A further eight spreads were fired in the investigation zone (Zone 2) of the Dalrymple Subdivision, where 2.5 m geophone spacings were used (Appendix 2, Table 4). Five spreads, with geophone spacings of 3 m, were fired in Zone 2 at Trulls Saddle Subdivision, and one spread was fired on Bay View 5 Lot 64 (Appendix 2, Table 5). These last two seismic investigations were followed by trenching.

Seismic Velocity Layers

Three seismic velocity layers have been established in the Blackstone Heights area. These are:

- (a) The slow surface velocity layer (V_0), of 500–600 m/sec, which is a soil layer of organic clay and silt, with or without boulders, and the underlying subsurface clay. The clay may be brown clay and/or yellow-white clay of extremely weathered dolerite. With slopes on the underlying interfaces, or thickening of the surface layer, the velocity of the V_0 layer may range from 400–900 m/sec.

- (b) The second or intermediate velocity layer (V_1) has a normal velocity range of 1200–1500 m/sec but may range from 1000–1800 m/sec, depending on the lithologies and slope on the velocity interfaces. This intermediate velocity layer frequently does not coincide with lithological boundaries or thicknesses. This is not unexpected, as this layer covers the transition zone between clay and rock. It also includes gritty, and friable weathered dolerite, to concentric weathered dolerite.

- (c) The third velocity layer (V_2) has high velocities of 2000–3000 m/sec, although they may be as high as 4000–5000 m/sec. The lithologies of this layer range from iron-stained dolerite to grey, unweathered dolerite.

Seismic Results—Summary

- (1) Clay changes rapidly to dolerite within short distances. This change will frequently occur within the length of one seismic spread.
- (2) The seismic surveys indicated that thick clay occurs in the valleys of Blackstone Heights.
- (3) Individual spreads showed the slope direction of the rock interface and a very good guide to the depth to the rock below ground surface—something which frequently was not possible from surface mapping or trenching.

Seismic Limitations

- (1) The seismic surveys do not indicate the detailed lithologies of the surface layer. They cannot distinguish between clay, clay and unweathered boulders, or concentric weathered boulders within clay.
- (2) It gives no indication as to the moisture content of the surface layer or the depth of the moist clay layer overlying a dry clay layer, or weathered rock.
- (3) The intermediate velocity layer (V_1) frequently did not coincide with the intermediate lithological layer when trenching followed a seismic spread.
- (4) The depth to rock interface was frequently shallower than that calculated from the seismic results, even with small geophone intervals of 2.5 m.

Usefulness of the Seismic Method

Given the above limitations, short seismic spreads of 2–3 geophone spacing followed by confirmatory trenching was found to be a reliable investigation tool to establish the depth to rock on the difficult talus slopes. Neither surface exposures, trenching nor seismic surveys alone are reliable in these sediments. Even by using a large traxcavator to dig a trench it is most difficult to be sure that the bucket's refusal is caused by *in situ* rock, or by large boulders in these sediments.

The combination of refraction seismic followed by trenching was successfully used to investigate the feasibility of building in the investigation Zone 2.

SUBSURFACE INVESTIGATIONS

EXCAVATIONS

It was the excavations of the first stages of development, and particularly those in the banks of the reservoir, which showed that the Blackstone Heights area had large and thick deposits of clay (Plate 4). Other early exposures showed that clay

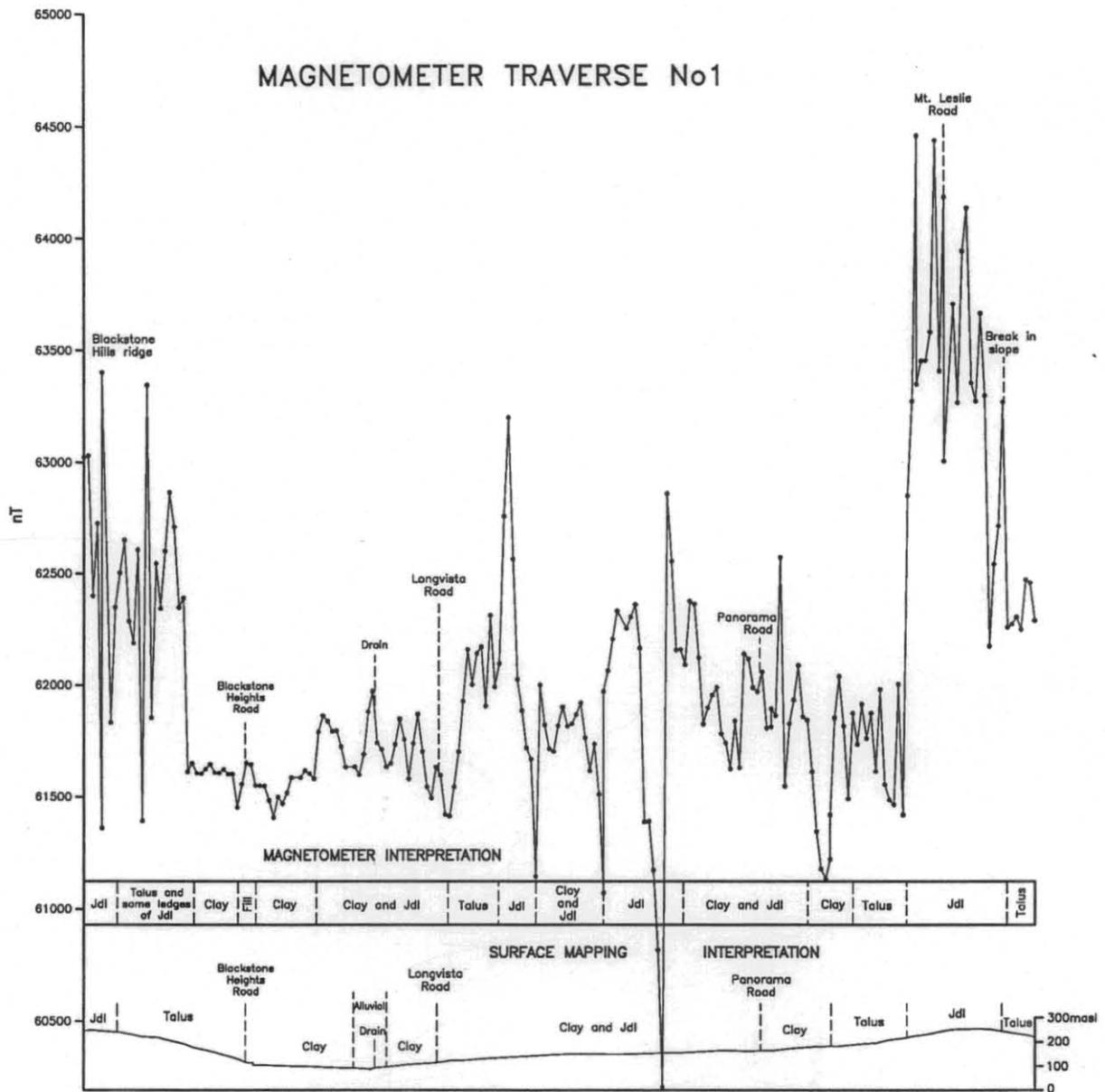


Figure 5.

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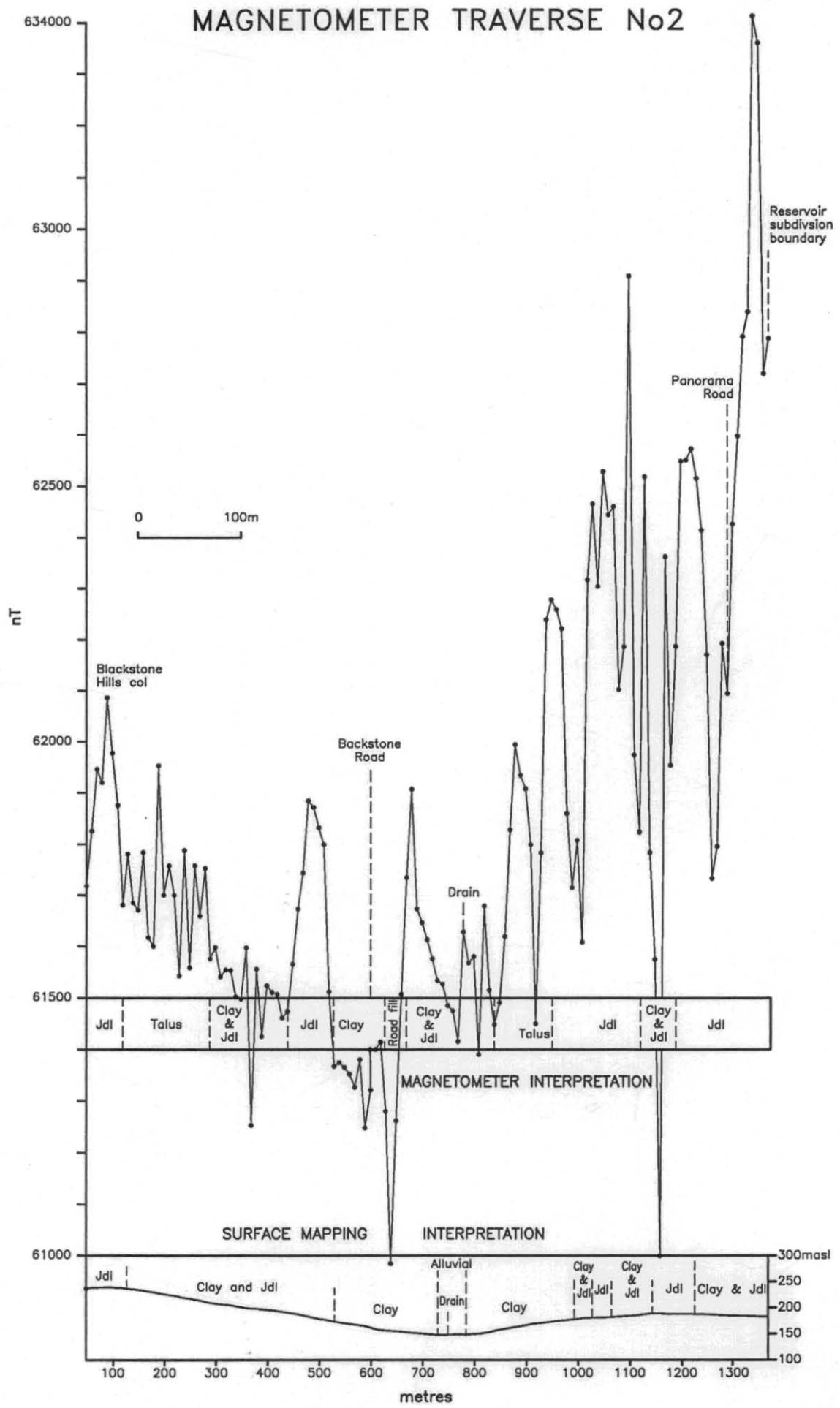
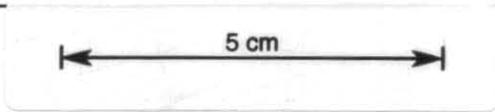
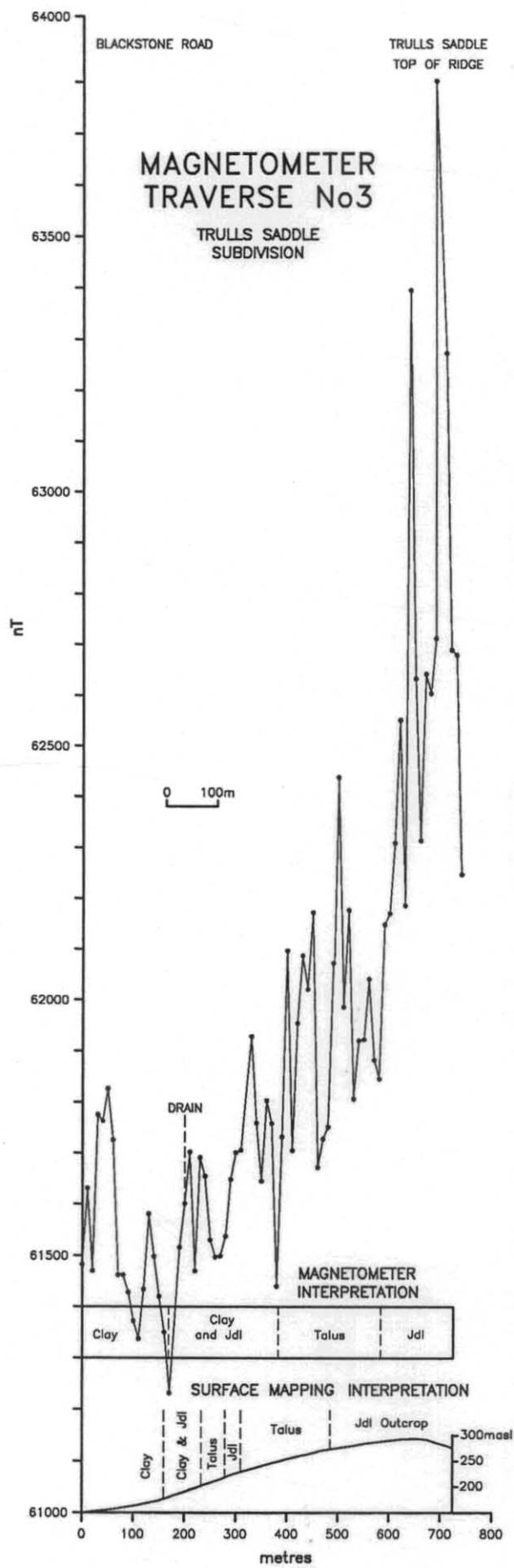


Figure 6.





could occur very close to dolerite, and that the profile of the clay and rock could be very irregular (Plates 4 and 7).

To confirm the engineering geology mapping and slope stability investigations, four auger holes were drilled using the Triefus trailer-mounted drill rig, and thirteen excavations were examined, of which eleven were trenches dug by Sanieth Limited's traxcavator.

The locations of these auger holes and trenches are shown on Map 2, and the lithological logs are attached as Appendix 1.

AUGER DRILLING

The auger drilling showed that clay extended to depths of seven metres in the valley floors in the areas mapped. It also showed that auger drilling could not penetrate surface boulders of dolerite (BH2).

BH1: Sited in the upper Blackstone Creek valley floor, this hole encountered seven metres of bauxitic clay. The clay was moist beneath the surface soil to 1.8 m depth, where the water table was struck. This had a small pressure head and continued to rise. In the nearby Panorama Road service trench a spring continued to flow from this clay. The clay in BH1 showed a decline in plasticity with depth, as did the linear shrinkage and montmorillonite content (Table 6). The sample at 5.1 m depth was one of the low-plasticity clays (fig. 8).

BH2: In this hole, sited near the Blackstone Road fault, the Triefus rig could not penetrate beyond the surface dolerite boulders.

BH3: This hole was located in a shallow valley of Bay View 4 subdivision. The area had been mapped as clay, based on poor outcrops in the service drain. The clay in the drill hole was dry to 1.3 m, and continued to be moist to a depth of seven metres. In this hole there was evidence of concentric weathering from some small dolerite rock nodules drilled. The clays of this hole were not tested in the Soil Laboratory, as they appeared lithologically similar to those of BH4.

BH4: This hole was sited on seismic lines 7 and 8 (Table 2), where no high velocity rock was reached seismically. The hole was on the Panorama Road Fault. The clay was moist except for a dry hard-pan layer of ironstone at 2.0-2.4 metres. Water was struck at 3.0 metres. These clays showed a decline in plasticity and linear shrinkage with depth (Table 6), and two low plasticity clays were sampled at 4.2 m and 6.0 m depth (fig. 8).

TRENCHING

Trenching was required at specific locations, particularly to confirm the geological interpretation of the seismic velocity layers and their depths. This confirmed, in many of the investigation zone areas of Dalrymple and Trulls Saddle Subdivisions, that building was possible within economic limits. A house could be founded on rock below the surface clay, and clay and boulder layers. Alternatively these fragile layers could be removed on cut and fill house sites.

Trenching confirmed that clay was present within the boulders in areas which had been mapped as talus slope deposits. The variability of the thickness of surface clay layers, with or without boulders, was often exposed in one trench.

Below the moist brown clay and the underlying yellow clay, a dry, low to medium plastic clay was sometimes present, while in some trenches weathered dolerite rock was exposed.

Figure 7.

Table 6. Soil laboratory testing results.

Sample Location & Subdivision	Depth m	Moisture Content %	Atterberg Limits		Plastic Index	Linear % Shrinkage	Clay Composition % (XRD)			
			Plastic Limit	Liquid Limit			Montmorillonite	Kaolinite	Goethite	Halloysite
Bore No. 1	0.5	-	28	103	75	24	15	70	15	-
Panorama Road	1.0	-	29	98	69	23	10	75	15	-
	2.0	-	27	65	38	16	10	75	15	-
	5.1	-	29	44	15	10	5	80	15	-
Bore No. 4	0.9	-	32	154	122	30	25	65	10	-
Mt Leslie	1.5	-	31	102	71	23	35	60	5	-
	4.2	-	27	48	21	11	55	30	5	10
	6.0	-	26	43	17	3	-	-	-	-
Mt Leslie	0.5	3.6	26	149	123	28	15	75	10	-
Kara Lot 2 (Private)										
Kelsey and Longvista Rds (Trench)	1.0	49	22	103	81	24	90	10	-	-
	1.5	53	20	89	69	22	90	10	-	-
Blackstone Rd Excavation No. 2	0.5	-	25	90	65	23	85	15	-	-
	1.0	-	32	136	104	28	-	-	-	-
Blackstone Rd Bore 2	0.5	-	30	127	97	26	60	35	5	-
Trulls Saddle Excavation No. 1	0.5	-	32	140	118	29	25	60	15	-
	1.0	-	31	125	94	26	20	60	20	-
	1.5	-	33	49	16	10	5	80	15	-
Bay View I Lot 13 (Private)	0.5	-	37	120	83	25	25	-	30	45
	1.0	-	Non Plastic							
Dalrymple Trench 5	0.8	H-W	29	131	102	26	45	-	5	50
	1.2	D	26	67	41	15	-	-	-	-
Dalrymple Trench 6	0.9	-	27	125	98	26	35	-	5	60
	1.2	-	28	67	39	16	80	20	-	-
	1.6	-	29	128	99	25	30	-	5	65
Dalrymple Trench 8	0.7	-	30	132	102	27	10	-	5	85
Trulls Trench 10	0.8	48	32	129	97	27	80	20	-	-
	1.0	34	34	135	101	28	90	10	-	-
Trulls Trench 11	1.2	51	28	106	78	23	75	25	-	-
	2.2	55	29	118	89	26	85	15	-	-
Trulls Trench 12	1.4	39	31	115	84	22	45	-	5	50
	1.8	56	34	123	89	26	95	5	-	-
Trulls Trench 13	1.0	37	26	110	84	25	40	-	10	50
Bay View 5 Lot 64 Trench 9	1.0	35	27	79	52	19	55	-	-	45

Soil testing by R. N. Woolley, Department of Mines, Hobart

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Table 7. Results of shear box testing, Blackstone Heights clay samples.

Sample location and subdivision	Depth (m)	Angle of friction (ϕ) (degrees)	Effective cohesion (C') (kPa)	Lithology
Kelsey Road (S1)	1.0	20	1.9	Brown clay with igneous texture
Dalrymple (S1) (Trench 5)	0.8	9	5	Brown clay
Dalrymple (Trench 6) (S4)	1.6	13	5	Orange-brown (moist zone)
Dalrymple (Trench 8) (S1)	0.7	12	6	Brown clay
Bay View 5 (Trench 9)	1.0	14	5	Brown clay, faceted and polished

Soil testing by R. N. Woolley, Department of Mines

A generalised transition of weathering was seen in the trenches. This transition was from brown clay to extremely weathered dolerite—a yellow clay with no igneous texture present—to highly weathered dolerite—a clay with igneous texture. Below the clay was a rubbly gravel of highly weathered rock and/or low plastic clay. The transition was then to highly weathered dolerite rock—a friable rubbly soft rock—then to moderately weathered dolerite—a brown, completely iron-stained rock. Below was slightly weathered dolerite rock with iron staining only along joints.

The above generalisation was never seen in one trench, and never occurred in layers. The weathering process was aided by previous metasomatic alterations in some exposures. In others the weathering was concentric, with kernels of hard dolerite, or in wide zones along vertical jointing in the dolerite.

The clay was frequently moist below the surface soil and boulder layers.

The greatest thickness of clay exposed above dolerite rock occurred in Trench 6 (Dalrymple Subdivision), with 2.9 m of clay exposed. In this trench a moist, highly plastic zone, occurred at a depth of 1.4–1.7 m below dry, low to medium-plasticity clay. Such a moist zone is a potential failure plane (Plate 9).

SOIL LABORATORY RESULTS

Thirty-two clay samples have been tested for Atterberg limits and linear shrinkage. Twenty-nine of these samples were also X-rayed for composition (Table 6). In addition, five samples have been shear box tested (Table 7).

ATTERBERG LIMITS

Of the 32 samples, 28 were classified on soil laboratory results as highly plastic and four as low to high plasticity (fig. 8).

Of the four low to high plasticity samples, three were collected from Auger Holes 1 and 4 at depths of 4.0–6.0 metres. The fourth sample is from 1.5 m depth in Excavation 1 (Trulls Saddle and Blackstone Roads), in concentric weathered and altered dolerite (Appendix 1).

As noted in drilling, a general decline in plasticity occurs with depth in the auger holes, with the plastic index in BH1 declining from 75 to 17 at 5.1 m depth and in BH2 declining from 122 to 17 at 6.0 m depth. A similar decline is noted in many of the trenches.

When the clays are moist the plastic index is generally high, and the three samples with plasticity indexes of 38–41 were of dry clay. The remainder of the samples have a PI range from 69–123, and liquid limits as high as 154.

LINEAR SHRINKAGE

The linear shrinkages reflect the high plasticity of the clays, with fourteen samples being very expansive (25–30% range), with a further eight samples considered expansive (20–24%). Only four samples tested were non-expansive, with linear shrinkages of less than 15%. The two bore samples showed a decline in linear shrinkage with depth, with values in BH1 declining from 24–10%, and values in BH4 declining from 30–3%, the highest and lowest values for linear shrinkages of the samples tested.

CLAY MINERAL COMPOSITION

All the 29 samples X-rayed for mineral composition contained the low strength and expansive montmorillonite clay. The montmorillonite compositions ranged from 95% of the total clay composition down to only 5%. Four samples were composed almost entirely of montmorillonite (90% and above), with the montmorillonite content of a further four samples ranging from 80–89% of the total clay composition. Of the samples tested, 12 samples contained more than 50% montmorillonite, with only ten samples testing 10% or less (fig. 9).

Kaolinites, of medium strength and expansiveness, form the second most common mineral. These are present in 21 of the 29 samples tested, with ten samples comprising 50% or more kaolinite. The non-expansive halloysite family of clay is present in nine of the samples tested, with seven of these containing 5% halloysite. Goethite forms the minor clay mineral in 19 samples tested, ranging from 3–5% in these samples. In eight samples goethite comprised 15–30% of the clay composition, while it comprised 5% in nine samples.

The high montmorillonite composition of the clays at Blackstone Heights is a major cause of their low shear strength and expansive properties.

SHEAR BOX TESTS

Of the five samples tested in the shear box, the internal angle of friction was low, ranging from 20° to the exceptionally low value of 9°.

The three other samples had angles of friction of 12°, 13° and 14°, and effective cohesion values of 1.9 kPa to 6 kPa. With

BLACKSTONE HEIGHTS

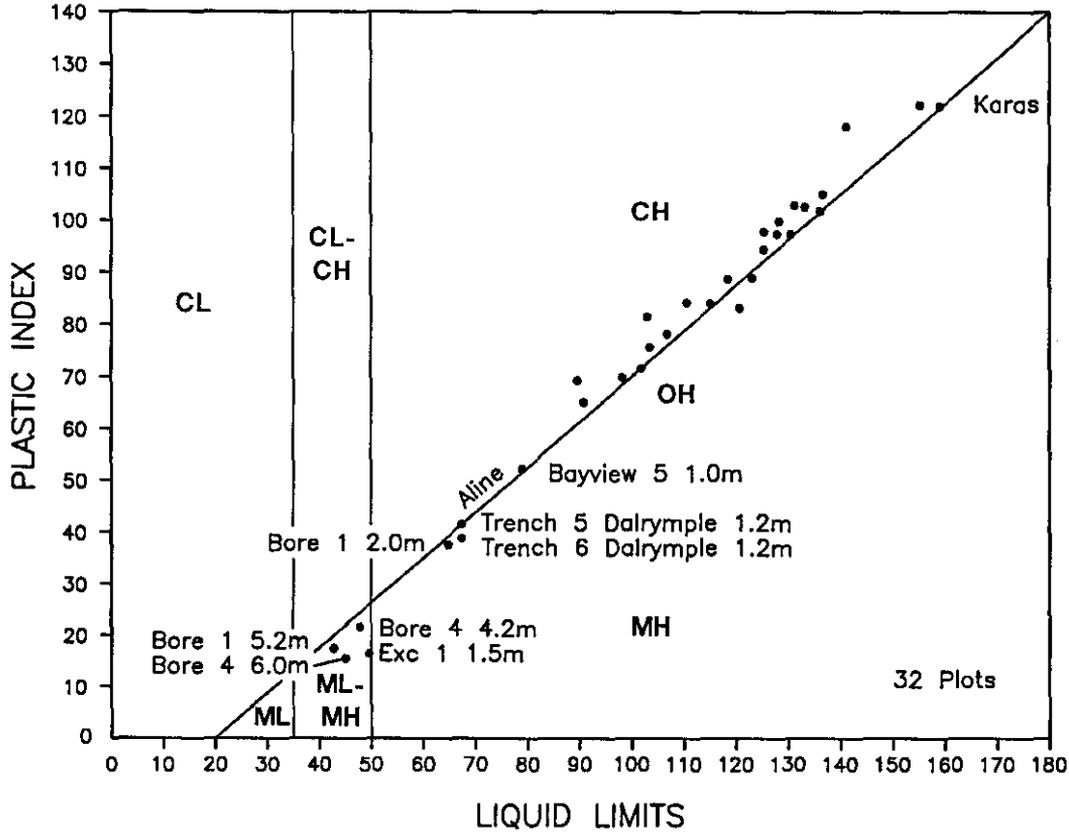


Figure 8. Plasticity chart, Blackstone Heights clays

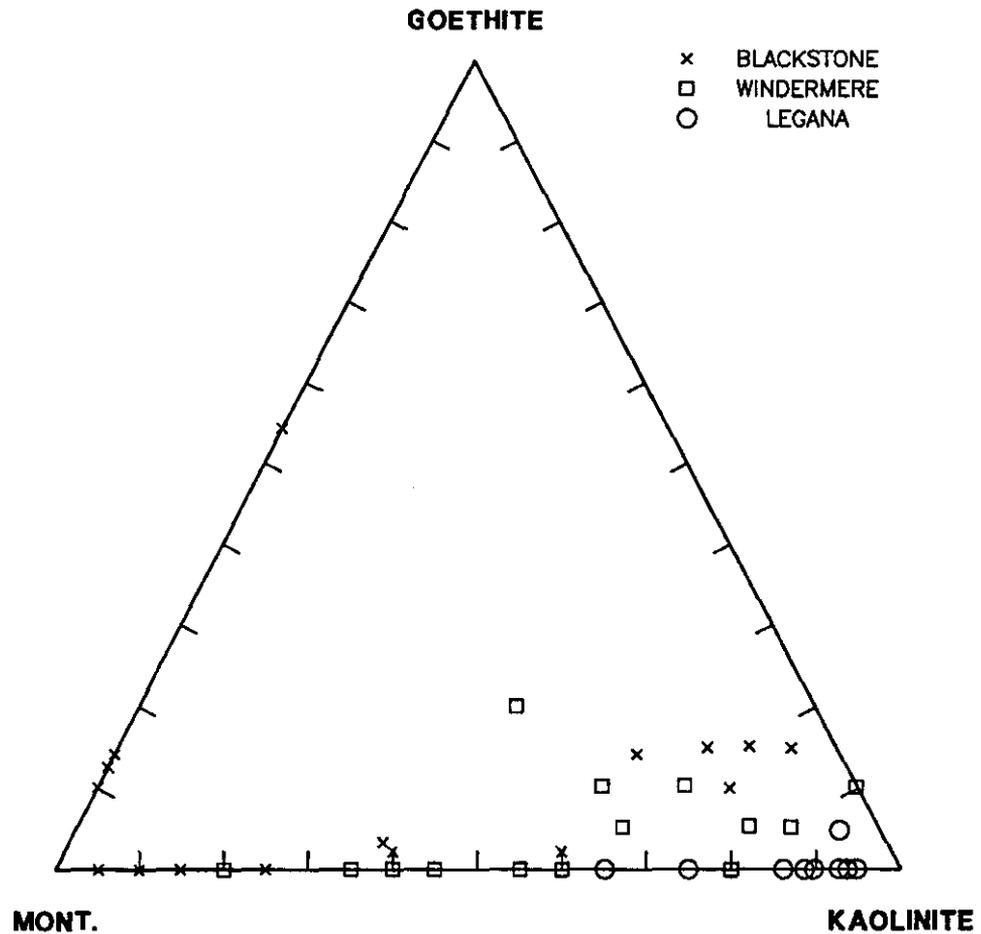


Figure 9. Comparative composition of clays, northern Tasmania

such shear test values these clays must be considered to have a very high potential for slope failure.

SLOPE STABILITY

LANDSLIDES

Field mapping has shown that no active landslides are present in the area covered by the Blackstone Heights project. Several old landslides have been identified and these are shown on Map 2.

These old landslides vary in age, size and type. The types identified are boulder toppling, shallow translational boulder and debris slides, to rotational slumps (both boulder and debris), one with a mudflow toe and valley head collapse. The most recent slide appears to be a small boulder slide at the foot of the steep western slope of blocks near water level on Lake Trevallyn. The largest slide is a rotational slide with a mudflow at its toe above the Central Creek-Dalrymple subdivision (Plate 7). Some of these old landslides are in the *Not recommended building-Zone 3* areas, whereas others, generally the older, appear to have attained enough stability since the initial failure to warrant further detailed investigation with the aim of building close to, and possibly on them. These latter types were mapped and placed in the Zone 2 investigation zone area on the slope stability map.

Such an area has already been investigated in the Dalrymple subdivision and an old landslide has been reclassified from Zone 2 to Zone 3, *Building Not Recommended Zone*.

Surface discontinuities and irregularities were observed in certain areas during mapping. It has been impossible to distinguish if these irregularities are very old landslides, in which failure features are no longer recognisable, or if they are caused by some other geological features, such as small discontinuous rock benches. These areas required further geophysical and subsurface investigation before slope stability could be assessed. These difficult areas have been placed in the investigation Zone 2.

SLOPE STABILITY ZONES

A three zonal system was used in the slope stability assessment mapping of the Blackstone Heights subdivision. The three zones are:

Zone 1: Building recommended

Zone 2: Building may be recommended. Subject to an investigation

Zone 3: Building not recommended

Mapping for slope stability is trying to assess a slope's potential for failure, or its risk from landslide when the area is developed. The factors considered in this assessment were the slope angle, the length of slope, the location of the slope, the slope's drainage potential, and its underlying geology.

The three slope stability zones used were considered more suitable to the geology of Blackstone Heights rather than the five zones used in the Tamar Valley Landslip Zone Maps of 1972. Although a considerable correlation exists between the two zonal systems, there are also important differences. Zone 1 at Blackstone Heights is a combination of Zones 1 and 2 of the Tamar Valley maps. Zone 2 approximates broadly to the Tamar Valley Zone 3, the potential landslide zone. Zone 3 at Blackstone Heights is not the same as Zone 4 of the Tamar Valley maps, which is defined as old landslides and adjacent areas. As there are no active landslides at Blackstone Heights there is no equivalent to the Zone 5 of the Tamar Valley maps.

It should be noted that the recommendations for Zone 4 and 5 of the Tamar Valley maps are essentially the same as for the Blackstone Heights Zone 3—no building recommended.

SLOPE ANGLES AND RELATION TO THE ZONES OF BLACKSTONE HEIGHTS

In mapping at Blackstone Heights the major slopes were measured and approximate correlation exists between the slope angles and the three zones. The upper slope limit for Zone 1 is an 11°-12° slope, with the intermediate Zone 2 ranging from 11°-12° to 14°-15° slopes, depending on the slope's length, drainage etc. Slopes generally above 15° are in Zone 3. These figures are the result of regional field mapping, with no detailed individual block subsurface investigation or slope stability analyses.

DEFINITION OF THE BLACKSTONE HEIGHTS SLOPE STABILITY ZONES AND THEIR RECOMMENDATIONS

Zone 1—Building recommended

In this zone the slopes are considered stable, with no slope stability problems foreseen. No slope stability investigation is required before building in this zone.

Zone 2—Building may be recommended. Subject to investigation

In this zone slopes have a potential to fail. A landslide risk is present which needs to be assessed by an investigation before building in the zone is permitted. This investigation may be for a single block or a group of blocks, and should include some subsurface investigation. It should be carried out by a competent engineering geologist or soils engineer familiar with slope stability problems. A written report on the investigation and its findings should be received by the Council before building is permitted in this zone. After initial Council approval, further subdivision in this zone is not recommended.

Zone 3—Building is not recommended

This is a zone of steep slopes, often with considerable water run-off. There is a high potential for slope stability problems with landslides, which could include rock and boulder slides as well as boulder toppling. Building is not recommended at a subdivisional level.

If the Council is to permit building in this zone it should be for a chosen house site on a particular block within this zone. Before building is permitted the house site and the surrounding slope should be thoroughly investigated, with foundations specially designed to be tied into hard rock. The engineering geologist or soils engineer should be prepared, in his written report, to state to the Council that the house is tied to *in situ* rock, and the safety of the site and the house foundations guaranteed. After initial Council approval, further subdivision in this zone is not recommended.

ENGINEERING GEOLOGY (MAP 2)

Compared with the slope stability map the engineering geology map is a multi-purpose map and a subsurface map. It is aimed at all the potential engineering problems that are recognised, or known to exist, in the area mapped. At Blackstone Heights this included not only the potential slope stability problems but also the expansive soil, and differential soil and foundation movements.

This mapping relies heavily on information obtained from geophysical surveys, trenching and drilling, as well as service

and construction outcrops. It is aimed at a wider clientele than the slope stability map, which is primarily the concern of the subdivider, his planners, the Council engineer, and the Town and Country Planning Commission. The engineering geology map is for the service engineer, the contractor, Council building inspector, builder, Council engineer and house owner. It covers the planning to the construction stage of a subdivision.

MAPPING UNITS

The engineering geology mapping units used are:

- Alluvium
- Clay
- Clay and dolerite with small outcrops and boulders
- Talus
- Dolerite outcrop and near outcrop

WEATHERING SUCCESSION

With the exception of the alluvium, these mapping units were first attempted in the early subdivisions from outcrops along the sewerage drains and roads along Kelsey, Longvista, Bayview, Panorama and Blackstone Roads.

From these outcrops, plus the exposures in the quarries at Blackstone Road, Longvista Road and Bakers Court, and the reservoir, a succession was built from clay to unweathered dolerite.

In a trench dug at the corner of Kelsey and Longvista Roads in 1987, a dark brown clay, thought to be lithologically similar to the clay of the Launceston Beds, appeared to overlie a bed of orange-yellow to yellow-white clay. This clay, with no remnant igneous texture visible, graded down to similar yellow-white clay with an igneous texture. These two clays were sampled and tested—the Kelsey-Longvista Road samples (Moore, 1987). One clay was considered to be depositional, probably lacustrine deposited, the other *in situ*.

In some outcrops, and later trenches and drill holes, the above moist, high plasticity clays were underlain by a dry yellow clay or sandy clay with low to high plasticity. This clay generally retains an igneous texture and shows evidence of concentric weathering or wide vertical joint weathering, with nodules of weathered dolerite or blocks of dolerite rock.

The brown surface clay frequently grades into the yellow-white clay, although in other exposures there appears to be a sharp lithological boundary. Whether the upper brown clay at Blackstone Heights is of the Launceston Beds has not been established, but the whole clay sequence is possibly one produced by deep weathering *in situ*.

Below the clay is a transition layer between clay and weathered rock. This transition layer is frequently a mixture of low plasticity clay and/or silt and fine rubbly gravel derived from highly weathered dolerite rock. This weathered rock crumbles easily in the hand, or flakes readily from exposures, and can be easily removed by the traxcavator bucket. The highly weathered rock changes irregularly to medium or moderately weathered rock, where it retains a rock hardness such that it can only be dug with difficulty by a pick and the teeth of the traxcavator bucket.

When the rock is completely or partially iron-stained, and so hard that it can only be broken with a geological pick with difficulty and causes the traxcavator bucket to bounce and not remove the material, the dolerite is defined as slightly weathered. When staining is not present, or only present along the joints, the dolerite is considered to be unweathered.

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This weathering and clay-to-rock sedimentary succession covers all the engineering geology mapping units from dominantly clay, to dolerite outcrops and near outcrops, except the talus unit.

Exposures of talus occur on the eastern slopes of Blackstone Hills, where a bulldozed track had been cut from the middle of the Blackstone Hills subdivision north to the Lakeview subdivision blocks. South of this a deep drainage ditch has been cut from this track to Trulls Saddle Road. These exposures showed that a high percentage of clay was mixed with the dolerite boulders, and in some areas clay pockets and lenses underlie the upper surface clay-boulder layer. These exposures confirmed the interpretation of the magnetometer profile of these slopes (fig. 5-7).

LITHOLOGIES AND PROPERTIES OF THE ENGINEERING GEOLOGY MAPPING UNITS

Alluvium

This is the normal geological mapping unit of stream bed and flood-plain sediments. These sediments only cover a limited area of the valley floors of the small creeks within the area. The sediments are dominantly organic, black-dark grey clays and silts with minor deposits of sandy clay and clayey sands, with fine gravel beds of ironstone and small angular dolerite pebbles.

The likely engineering problems for the alluvial areas are expansive soils, poor drainage, and minor flooding. As the area covered by the alluvium unit is planned for reserves, both recreational and flooding, and with no housing development foreseen, the clay of these sediments was not tested.

Clay

Clay forms no natural outcrops at Blackstone Heights. The first exposures observed were in road cuttings and sewerage and water main drains of the early subdivisions. Mapping of the clay was by default, where few or no boulders were seen. The presence of clay was indicated by the magnetometer and seismic surveys, then confirmed by drilling and trenching. The areas where clay is thickest are in the valley floors—associated with the faulting and metasomatism—with the clay generally thinning upslope.

When moist, both clays (the dark brown and yellow and white) are highly plastic and expansive, with low angles of friction and cohesion. Most clays tested have montmorillonite in their composition (Tables 6 and 7). At depth and closer to dolerite rock, a yellow-white low plasticity clay may occur.

In many of the trenches and exposures the brown surface clays merge and change gradually to the yellow-white dolerite-derived clays, with igneous texture present in these latter clays. There is little doubt that these clays are formed by *in situ* weathering of the underlying dolerite.

In other exposures the brown-orange-brown clay is a distinct surface layer above either the weathered dolerite rock or yellow-white clay. These clays are thought to have possibly been deposited, and may belong to the Launceston Beds of the Tamar Valley. Comparing the soil laboratory results of the clay from Blackstone Heights with the depositional clays of the Launceston Beds from the Legana and Windermere areas, no difference in the results could be observed. The Blackstone Heights clay was more plastic than the *in situ* clay derived from the mudstone of lower Permian age at Lilydale (fig. 12). The Blackstone Heights clay contained more montmorillonite than the clay from Windermere and Legana (fig. 10, 11).

WINDERMERE

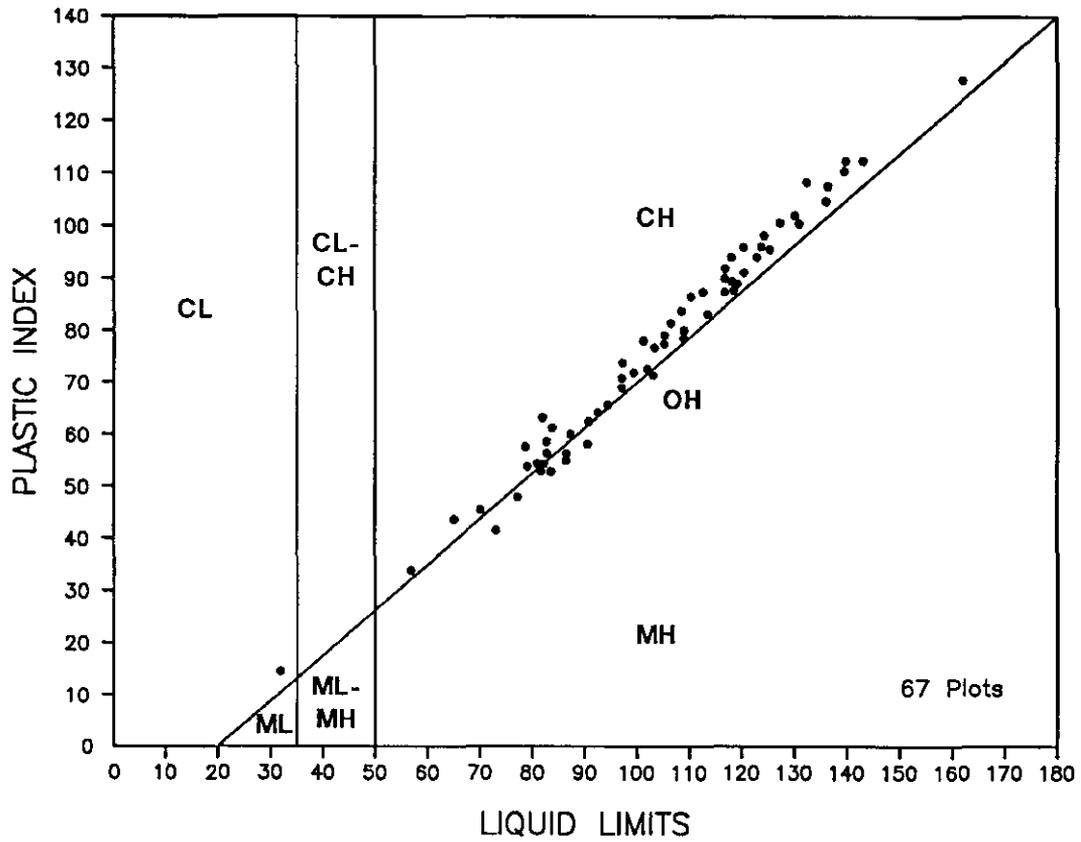


Figure 10. Plasticity chart, Windermere clay samples

LEGANA

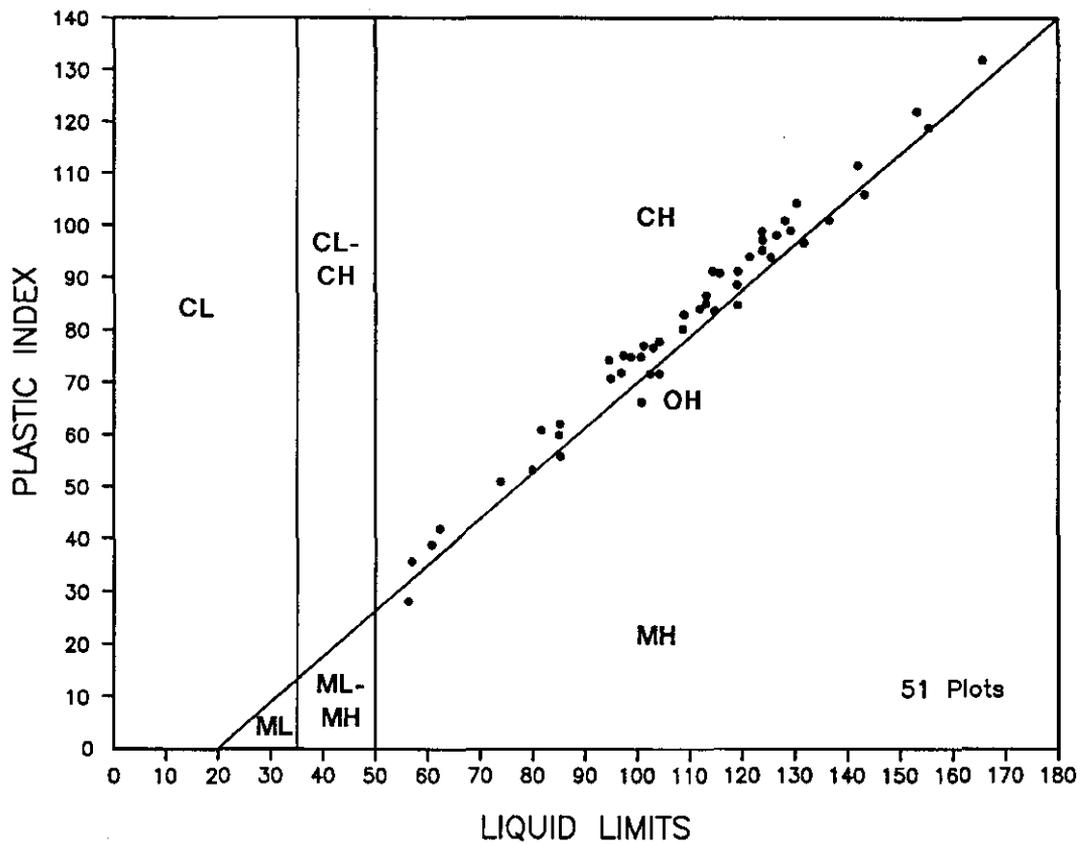


Figure 11. Plasticity chart, Legana clay samples

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LILYDALE

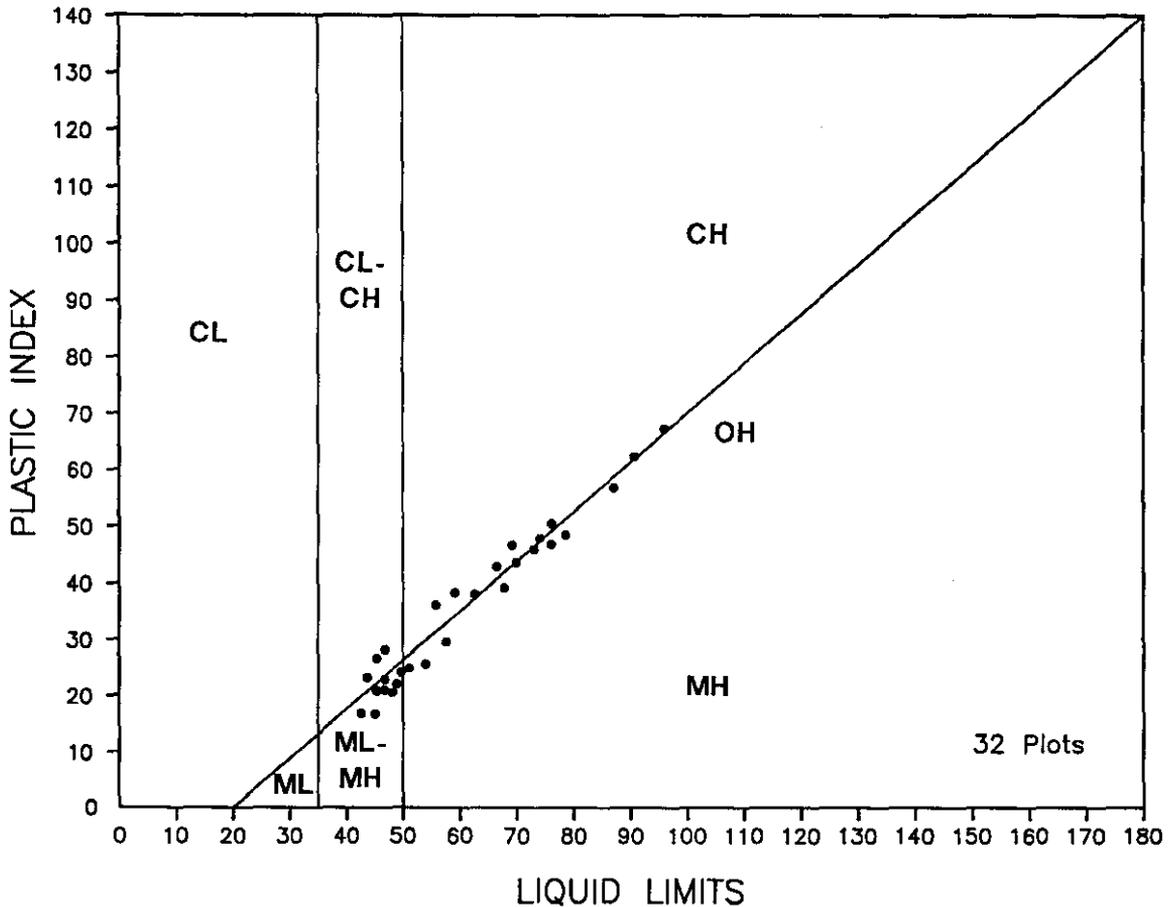


Figure 12. Plasticity chart, Lilydale clay samples

Clay and dolerite with small outcrops and boulders

This unit was exposed in the western bank of the reservoir and in the quarries at Blackstone Road and Bakers Court (Plate 7).

Similar profiles could be seen along Blackstone Road and Panorama Road, where clay changed to dolerite rock with the weathering succession, described previously, exposed (Plate 10).

Geophysically this unit was recognised by firing seismic spreads above the quarries and above Blackstone Road. It was also recognisable in the magnetometer traverses by the anomalies of small contacts coinciding with flat outcrops, particularly on wide, low ridge areas of the central block. These anomalies were less definitive on the ridges because of the talus boulder deposits but this unit is thought to occur on the slopes of Mt Leslie and Blackstone Hills.

Talus

This unit, as mapped, covers a wider range of lithologies than is normal in geological use for the term talus. It ranges from boulder-covered slopes, with little or no soil overlying small dolerite rock benches, to clay soil and subsoil with many large dolerite boulders overlying deeply weathered dolerite.

Where only boulders occur with little or no soil or clay, these deposits should more correctly be termed scree deposits. On the steeper western slopes of Blackstone Hills–Strahans Hill these deposits appear to be scree deposits, particularly on the slopes overlooking the South Esk River (Plate 11). In contrast, the western slopes overlooking Blackstone, Central

and Dalrymple Creeks, and the western slopes of Mt Leslie, are comprised of boulders and clay underlain by clay and deeply weathered dolerite (Plate 12).

Investigation trenching on the eastern slopes of Blackstone Hills has shown that surface clay with large dolerite boulders is underlain by clay and weathered dolerite, with the thickness of this weathering profile varying rapidly within short distances (Trench logs 9–11, Appendix 1).

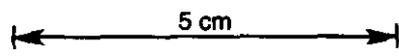
Investigations on the steep eastern slopes of Mt Leslie and Deadmans Hollow indicates that the talus is thin, resting on dolerite rock which is exposed further down the slopes overlooking the South Esk River gorge.

Dolerite Outcrops and Near Outcrops

Dolerite crops out along the ridges of Mt Leslie and Blackstone Hills, where flat and benched outcrops are separated by a thin veneer of soil and dolerite boulders. Outcrops form the near-flat ridge tops of the hills (Plate 13).

In the magnetometer profiles, the dolerite areas form high peaks and large anomalies. These areas also gave some very high seismic velocities (6000+ m/sec).

Dolerite forms the back slope of the downfaulted central block. This cap rock is now dissected, and forms a series of benched outcrops with low scarps and steep talus slopes below, overlooking Blackstone and Dalrymple Creeks (Plate 14). Other areas with extensive outcrop of dolerite are the rock benches above the South Esk River at Badger Plain and north of Dalrymple Creek. Above the low cliffs along Lake Trevallyn are rock shelves of continuous dolerite outcrops.



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ENGINEERING GEOLOGICAL PROBLEMS COMPARED WITH OTHER KNOWN CLAY AREAS

The properties of the Blackstone Heights clay, when compared with the Tamar Valley clays from Windermere and Legana, show them to be equally as sensitive to slope failure, and to be as expansive and susceptible to differential movement (fig. 8-12).

Slope failure—Blackstone Heights compared with Windermere and Lilydale clay areas

Given an adequate thickness of moist clays on the slopes of Blackstone Heights, the potential for slope failure should theoretically be as high as at Windermere or Lilydale, where similar landslide investigations have been undertaken (Telfer, 1989; Moore, 1982-88). Slope stability mapping at Blackstone Heights has shown that no active landslides occur, and the number of old landslides is few compared with either Windermere (Moore, in prep.) or Lilydale (Moore and Stevenson, 1980).

The main difference between the Windermere and Blackstone Heights areas is that there is a greater thickness of depositional clay on the slopes at Windermere. At Lilydale the *in situ* clay layer is thin but exists above the lower Permian mudstone up the entire slope. Neither of these conditions is thought to exist at Blackstone Heights. The thick clay deposits, as mapped, are confined to the valleys and lower slopes. On the higher slopes covered by the talus units, the clay/rock profile is irregular, and thick clay units are either localised or not present.

Therefore, although there is a landslide potential at Blackstone Heights it is, in the writer's opinion, lower than at Windermere. This assessment is probably also correct for other areas of Launceston and the Tamar Valley, where the thick depositional clays of the Launceston Beds are present.

In comparing the two *in situ* clay areas of Lilydale and Blackstone Heights, the potential for slope failure is considered to be lower at Blackstone Heights because the clays are not continuous upslope as they are on the long slopes at Lilydale.

Expansive clay and differential movements at Blackstone Heights

The presence of montmorillonite in the composition of most of the Blackstone Heights clays, and their high linear shrinkages, make these clays highly to extremely reactive. Their potential for house cracking is considered equal to, or even higher than, the known expansive soil areas of Launceston, such as Sandown Road, Mowbray, Legana, Newnham etc., where severe house cracking has been investigated (Moore 1983-1988).

The type of house site almost universally used at Blackstone Heights is a cut and fill site, often with a considerable amount of extra fill, comprised mainly of boulders and weathered dolerite rock. Provided the site is properly prepared by removing the original reactive clay soil, and the fill is well compacted in such sites, expansive soil movements are

reduced considerably. If the house is sited entirely on rock and not on fill, differential movements are similarly reduced. These provisions should be carried out as recommended for these problem clay sites (Site classification, Section 2, p. 10-11, Residential slabs and footings, SAA 2870-1986).

GEOLOGICAL HISTORY OF BLACKSTONE HEIGHTS AREA

Mapping and drilling indicate that the deep clay and weathering at Blackstone Heights is related to the faulting, when metasomatic alteration of dolerite occurred along these faults. This faulting is related to movement along the western margin of the Tamar Trough.

This alteration was followed by weathering, thought to be dominantly chemical weathering associated with a warm and possibly wetter climate of the Tertiary period. This weathering is different from the cold climate mechanical and iron-staining weathering of the later Pleistocene period. The older weathering caused the rotting of the dolerite, both concentrically and vertically on joints, leaving a large residue of dolerite boulders embedded in clay. When the weathering was complete no igneous texture remained, nor even small nodules of dolerite. In other exposures in these *in situ* clays the dolerite texture is retained.

Deposition of the Launceston Beds is thought to have occurred at this time in the Tertiary period. Clay of the Launceston Beds and *in situ* Blackstone Heights clays are exposed on the Southern Outlet Road south of Launceston (Plate 5). At Blackstone Heights some of the brown clays may belong to the Launceston Beds, probably being deposited as isolated pockets. Further deposition, since removed by erosion, probably occurred along this western margin of the Tamar Trough.

Later uplift and erosion stripped most of this Tertiary deposition, and what is exposed today is the base of this trough at Blackstone Heights and along much of the southern and western outlet roads. This base has an irregular weathering profile, with an old topography changing rapidly from clay to dolerite, with ridges capped by dolerite and valleys filled with clay.

The Pleistocene was a period of rapid mechanical weathering, with talus and scree boulders deposited down the slopes. These boulders cover the dolerite, and the dolerite boulders are frequently mixed with clay. On the lower slopes these deposits cover the irregular clay/rock profile. The South Esk River flowed at higher levels during the Pleistocene, and cut down the current gorge, leaving the high rock benches and flat promontories of Lake Trevallyn.

The three major engineering geology problems of Blackstone Heights are directly related to the complex geological history of the Tamar Trough. Because the area is located on the western margin of the Tamar Trough, the potential landslide risk is considered to be lower than for an area such as Windermere, which is near the centre of the Tamar Trough. At Windermere thick deposits of clay occurred. At Blackstone Heights the clays are *in situ*, localised, and thin when compared with Windermere.

SUMMARY OF THE RESULTS OF INVESTIGATIONS AT BLACKSTONE HEIGHTS

SLOPE STABILITY MAP

No active landslides have been found at Blackstone Heights. Old landslides have been found but these are few in number considering the area mapped. They vary in size and type.

The Blackstone Heights clays which have been tested have a high to extremely high plasticity, and low angles of friction and cohesive strength. Any slope above 12° with such clays has a potential to fail, and the risk of slope failure cannot be ignored.

The risk of slope failure has been evaluated by surface mapping. This involved measuring the slope angles, noting the length of slope, the drainage of slope, and its aspect, combined with the subsurface geology.

Three zones were used in the mapping:

Zone 1: Building recommended

Zone 2: Building may be recommended. Subject to investigation.

Zone 3: Building not recommended

These zones are defined, with recommendations in the text, and general slope limitations. It should be noted that these zones are at subdivisional level.

Short seismic spreads, followed by trenching, have been used as an investigation method within the Zone 2 investigation zone. Trenching alone is not an adequate method because the traxcavator bucket can be stopped by large boulders as well as rock. Some indication of the depth to rock is required. This is provided by seismic refraction surveys, with close geophone spacings. A seismic survey alone is also not an adequate investigation method. It does not indicate the surface layer lithologies or moisture content of clay, if present. It also does not accurately indicate the depth and lithologies of the intermediate velocity layer. It does, however, indicate with sufficient accuracy the depth to the higher velocity harder rock interface.

Moderately to slightly weathered dolerite is considered to be the best rock on which to found a house on steep slopes. Provided this rock is within economic depth (1.5–2.0 m), it is possible to remove the sensitive clay by cut and fill, or to use deep footings to found a house on this rock.

A generalised evaluation of the potential risk of landslides in the Blackstone Heights area was done by comparing this area with two nearby areas—Windermere in the Tamar Valley and Lilydale—where similar slope stability mapping and zoning have been undertaken by the Department of Mines.

Blackstone Heights is considered to have the lowest potential risk. This is thought to be the result of its geological history, preserving the clay *in situ* above the dolerite, and its location on the western margin of the Tamar Trough.

ENGINEERING GEOLOGY MAP

Engineering geology mapping required a considerable back up of geophysics, followed by confirmatory drilling and trenching. Trenching and drilling without prior geophysics adds little information. The map should be updated with further development.

Five mapping units were used and with further upgrading these units could be further subdivided; for example, talus into talus and scree.

The engineering geology problems associated with these mapping units are:

Alluvium—No residential development proposed, so problems are minor, such as drainage and flooding.

Clay—Expansive clays. Average linear shrinkage 25%. As the slopes are low, landslide potential is low. Engineering designed slabs are recommended.

Clay and dolerite—With an irregular clay and rock profile, differential movement is the major problem with expansive soils. Slope stability problems are confined to localised areas where the clays have an adequate thickness and moisture content. Engineer-designed slabs recommended.

Talus—Problems depend on the amount of clay within the boulders, the layer thickness, and what underlies these surface layers. If this lower layer is clay, landslides are the major risk; if it is rock then differential movements are the major risk. Boulder toppling could also be a problem. Adequate site investigations recommended.

Dolerite—Outcrop and near-outcrop. The hardness of the dolerite rock causes a high cost for footings and service trenches, and high access costs to the ridge's location. Slope failures have a low potential on the ridges. Surface run-off high. These observations do not include any dolerite-cliffed areas.

All of the engineering geology problems at Blackstone Heights; slope stability, expansive soils and differential movements; are considered controllable. This can be achieved by slope-sensitive subdivisional planning, adequate site investigation, and site inspections. To be effective, these methods need to be followed by correct site preparation, foundation designs and construction methods.

REFERENCES

- LONGMAN, M. J. 1966. One mile geological map series. K/55-7-39. Launceston. *Explan. Rep. geol. Surv. Tasm.*
- MOORE, W. R. 1965. Foundation investigations for proposed extensions, Cadbury factory, Claremont. *Tech. Rep. Dep. Mines Tasm.* 9:121–122.
- MOORE, W. R. 1968a. Site investigation of the proposed cement silos, Devonport. *Tech. Rep. Dep. Mines Tasm.* 11:71–83.
- MOORE, W. R. 1968b. Site investigation, Victoria Bridge, Devonport. *Tech. Rep. Dep. Mines Tasm.* 11:83–89.
- MOORE, W. R. 1981. Proposed landslip zoning of Wulf's farm, Browns Hill, Underwood. *Unpub. Rep. Dep. Mines Tasm.* 1981/19.
- MOORE, W. R. 1982a. Slope stability investigation of H. M. Archer's proposed subdivision at Windermere. *Unpub. Rep. Dep. Mines Tasm.* 1982/22.

- MOORE, W. R. 1982b. Slope stability investigation of land near Second River, North Lilydale. *Unpubl. Rep. Dep. Mines Tasm.* 1982/24.
- MOORE, W. R. 1982c. Slope stability investigation of a proposed subdivision at Windermere. *Unpubl. Rep. Dep. Mines Tasm.* 1982/38.
- MOORE, W. R. 1983. Subsurface geological investigation cracked houses in the Mowbray area, Launceston. *Unpubl. Rep. Dep. Mines Tasm.* 1983/24.
- MOORE, W. R. 1984. Subsurface movement in expansive clay: An alternative explanation for house cracking at Sandown Road, Launceston. *Unpubl. Rep. Dep. Mines Tasm.* 1984/59.
- MOORE, W. R. 1985a. Stability and site investigation of land at Sophie Place, Launceston. *Unpubl. Rep. Dep. Mines Tasm.* 1985/46.
- MOORE, W. R. 1985b. House cracking at Sandown Road. *Unpubl. Rep. Dep. Mines Tasm.* 1985/65.
- MOORE, W. R. 1986a. Subsurface investigation of a cracked house at Packham Street, Launceston. *Unpubl. Rep. Dep. Mines Tasm.* 1986/32.
- MOORE, W. R. 1986b. Investigation of a cracked house at Alanvale Road, Newnham, Launceston. *Unpubl. Rep. Dep. Mines Tasm.* 1986/41.
- MOORE, W. R. 1986c. Preliminary report on building cracking at the Tasmanian State Institute of Technology Campus, Newnham. *Unpubl. Rep. Dep. Mines Tasm.* 1986/68.
- MOORE, W. R. 1986d. Investigation of cracking of S. Pickett's house at Windermere Road, Windermere. *Unpubl. Rep. Dep. Mines Tasm.* 1986/83.
- MOORE, W. R. 1987. Engineering geology report on five subdivisions at the Blackstone Heights Project, Launceston. *Unpubl. Rep. Dep. Mines Tasm.* 1987/06.
- MOORE, W. R. 1988a. Investigation of cracked house in Windermere Road, East Tamar. *Unpubl. Rep. Dep. Mines Tasm.* 1988/21.
- MOORE, W. R. 1988b. Comments on the investigation of cracked buildings at the TSIT Campus at Newnham. *Unpubl. Rep. Dep. Mines Tasm.* 1988/24.
- MOORE, W. R. *In prep.* Landslides and landslide re-zoning, Windermere, East Tamar. *Unpubl. Rep. Dep. Mines Tasm.*
- MOORE, W. R.; STEVENSON, P. C. 1980. *Lilydale landslide zone maps.* Department of Mines, Tasmania.
- STANDARDS ASSOCIATION OF AUSTRALIA. 1986. *Australian Standard AS2870-1976. Residential slabs and footings.* Standards Association of Australia : North Sydney.
- TELFER, A. L. 1989. Landslides and land use planning. *Bull. geol. Surv. Tasm.* 63.

[14 March 1989]

APPENDIX 1

Engineering logs of bore holes and trenches

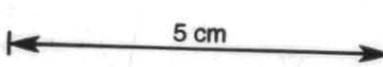
ENGINEERING LOG – BOREHOLE

borehole no. 1

sheet 1 of 1

24/58

project	Blackstone Heights	location	Panorama Road Subdivision at Southern Road entrance
co-ordinates	5073-54092	drill type	Triefus
R.L.	150	drill method	Auger
inclination	V	drill fluid	None
bearing		hole commenced	4.2.88
		hole completed	4.2.88
		drilled by	B.E. Cox
		logged by	W.R.M.
		checked by	R.C.D.

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr- ometer kPa 25 50 100 200 400	structure, geology
			S1		CH	CLAY. Dark-brown to orange-brown, highly plastic, white calcite and zeolites	D	H ↓ V		Dark brown clay
			S2	1		CLAY. Red and brown colour. White flecked and mottled.	M	St St		Red and brown clay
			S3		CH			S		watertable
			S4	2		CLAY. Red, low to medium plasticity.	VM	VS		Red clay
			S5	3	CH	Very soft with high % of water.	W			
			S6	4			V M			
			S7	5				S		
			S8	7						
						Hole stopped No more Augers Hole continued to make water for period left open and S.W.L. continued to rise.				
										

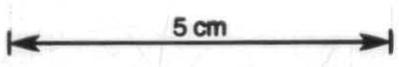
ENGINEERING LOG - BOREHOLE

borehole no. 2
 sheet 1 of 1

25/58

project	Blackstone Heights	location	Blackstone Road and junction with access track, Blackstone Heights
co-ordinates	506.4-5 409.4	drill type	Triefus
R.L.	165 m	drill method	Auger
inclination	Vertical	drill fluid	None
bearing		hole commenced	4.2.88
		hole completed	4.2.88
		drilled by	B.E. Cox
		logged by	W.R.M.
		checked by	

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr- ometer kPa 25 50 100 200 400	structure, geology
	None	None	S1	0.5		CH	CLAY. Black-dark grey. Highly plastic. Ironstone nodule and dolerite pebbles.	M	F		
							Drill stopped by dolerite boulders.				



26/58

ENGINEERING LOG - BOREHOLE

project	Blackstone Heights	location	Bay View Subdivision, Block 25 near Bayfield Rd boundary
co-ordinates	506.36-5411.0	drill type	Triefus
R.L.	145 m	drill method	Auger
inclination	vertical	drill fluid	none
bearing	-	hole commenced	4.2.88
		hole completed	4.2.88
		drilled by	B.E. Cox
		logged by	W.R.M.
		checked by	R.C.D.

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr- ometer kPa 25 50 100 200 400	structure, geology
				~	OL	SILTS. Grey, organic, fine-grained	D	Fr.		Soil
	None	None	S1 1.0		CH	CLAY. Dark grey, highly plastic, expansive. Changes to yellow in drill hole.	D	H		Exposed on road gutter. Upper brown clay.
			S2 2.0				M	St		Lower yellow clay
			S3 3.0			↓ Becoming slightly flecked with small white and brown iron stone - zeolite? - & calcite granules		V		Clay, extremely weathered dolerite
			S4 4.0			CLAY. Dark brown to orange-brown. Medium to highly plastic. Some ironstone and white flecks.	M	St.		
			S5 5.0		CH					
			S6 6.0							
			S7 7.0		CH ↓ CL	CLAY. Mottled, yellow-brown, high to medium plasticity. Some zeolite nodules and small weathered dolerite pebbles.	M	V St.		Highly weathered dolerite
			S8			Hole stopped. No more Augers.				
UNPUBLISHED REPORT 1989/06										

ENGINEERING LOG - BOREHOLE

borehole no. 4
 sheet 1 of 1
 27/58

project Blackstone Heights Mt Leslie Subdivision
location N. side Panorama Road, Block 23
 co-ordinates 5069-5410.4 drill type Triefus hole commenced 5.2.88
drill method Auger hole completed 5.2.88
 R.L. 180 m drilled by B.E. Cox
 inclination vertical logged by W.R.M.
 bearing - checked by R.C.D.

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr- ometer kPa	structure, geology
					OL	CLAY. Organic, light grey, roots	D	S		Soil
			S1 1		CH	CLAY. Light brown, highly plastic, changes to orange-brown with ironstone nodules and fragments.	M	F		Brown clay.
			S2 2							
			S3 3		CH	CLAY. Orange, highly plastic, ironstone band.	D	H		Hardpan
			S4 4		CH	As above, no ironstone band.	M	F		Orange clay
			S5 5							
			S6 6							
			S7 7							
			S8 8							
						Hole stopped. No more Augers.				

ENGINEERING LOG - EXCAVATION

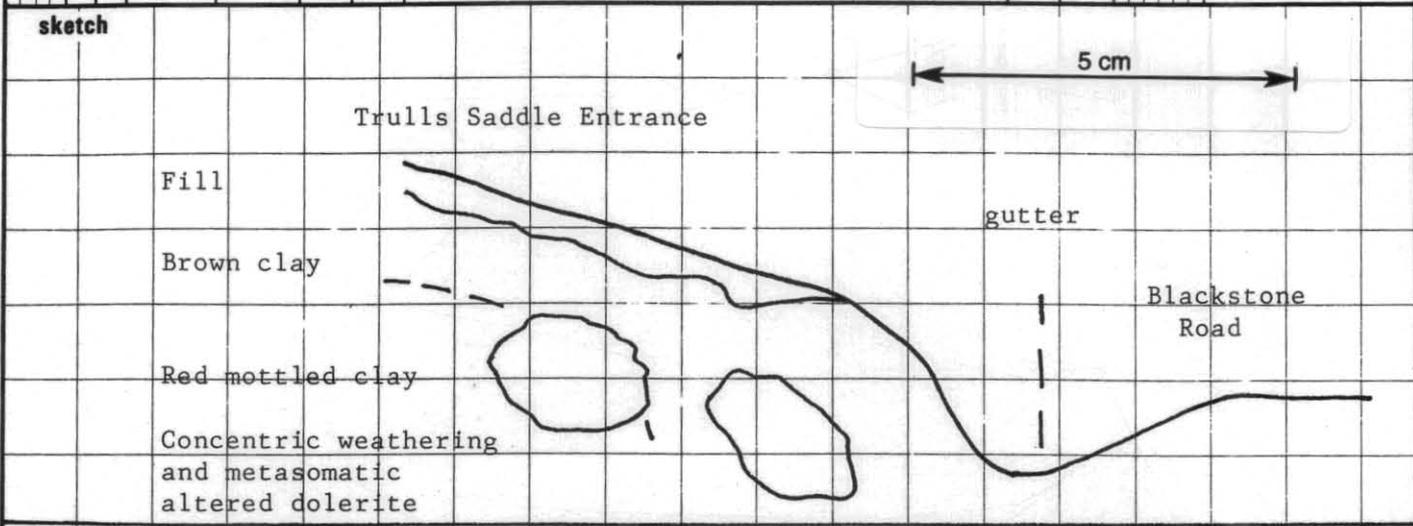
excavation no. 1

sheet 1 of 1

28/58

project	BLACKSTONE HEIGHTS	location	Trull's Saddle, Road cutting, Blackstone Road
co-ordinates	5071-54088	exposure type	Roadcut
R.L.	160 m	equipment	N.A.
excavation dimensions	2 x 2 m	operator	N.A.
		pit commenced	-
		pit completed	W. R. M.
		logged by	R. C. D.
		checked by	

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer kPa 25 50 100 200 400	structure, geology
				▲ GP	GRAVEL. Angular dolerites, un- weathered, road gravel	D	L		Fill
		S1	0.5	CH	CLAY. Dark brown, highly plastic. Ironstone nodules - some fine gravel layers. Dolerite boulders. Orange-brown	D	H		Clay Clay - extremely weathered dolerite
	None	S2	1.0	CH	CLAY Red-white, mottled and streaked low to high plasticity. Concentric weathered showed on dolerite ghost boulders - hardness increases with depth.	D	H		Extremely weathered dolerite to deeply weathered dolerite
	None	S3	1.5	CH C1					
		S4	2.0		Red-white altered and metasomatic dolerite rock	D	H		Dolerite
			2.5		Bottom of exposure				



ENGINEERING LOG – EXCAVATION

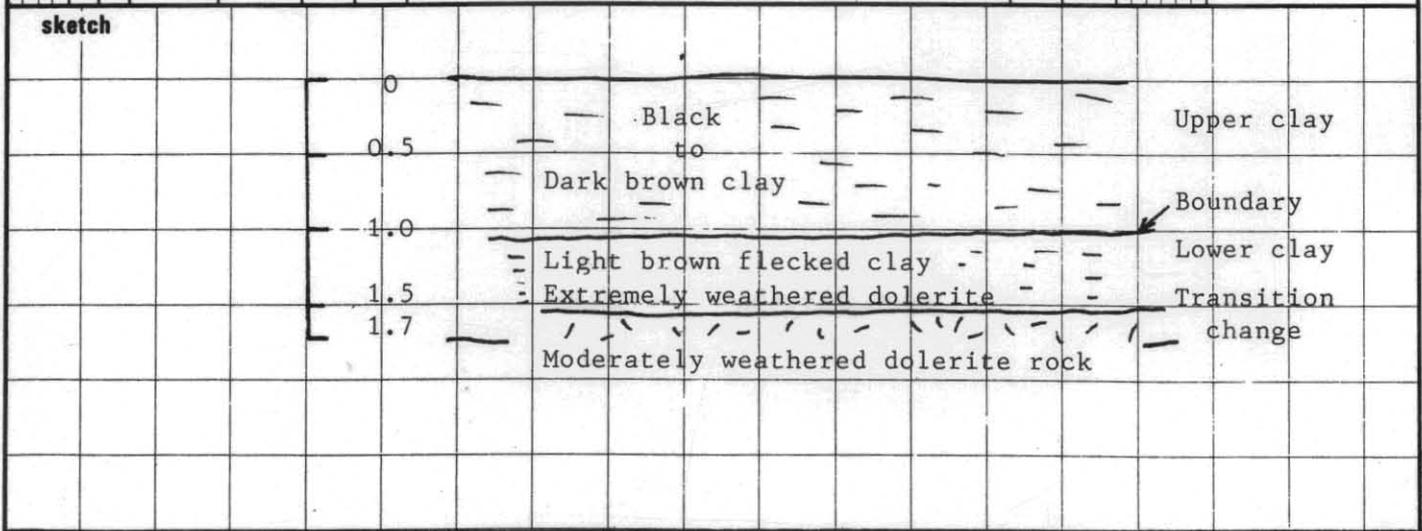
excavation no. 2

sheet 1 of 1

29/58

project	BLACKSTONE HEIGHTS	location	S. side of Blackstone Road 30 m North of BH. 2.		
co-ordinates	50636/540945	exposure type	Road drainage gutter	pit commenced	N.A.
R.L.	170	equipment	N.A.	pit completed	N.A.
excavation dimensions	gutter 1,7 m deep		operator	logged by	W.R.M.
				checked by	R.C.D.

penetration 1 2 3	support water	notes samples, tests	metres		graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer kPa				structure, geology
			R.L.	depth						25	50	100	200	
	N.A. None	S1		0.5		CH	CLAY - black, highly plastic some ironstone nodules. small dolerite pebbles. 300 Kpa	M	V					Black clay
		S2		1.0		CH	CLAY - dark brown with white flecks. calcite - zeolites etc. highly plastic. Ironstone nodules, roots 250 Kpa	M	V					No dolerite texture
		S3		1.5		CL	CLAY - light brown, white calcite - spots and zeolites common. Med-high plasticity. Ironstone nodules & grits - roots 200 Kpa	M	St					Extremely weathered dolerite
		S4			X	Jd1								
Bottom of gutter														



ENGINEERING LOG - EXCAVATION

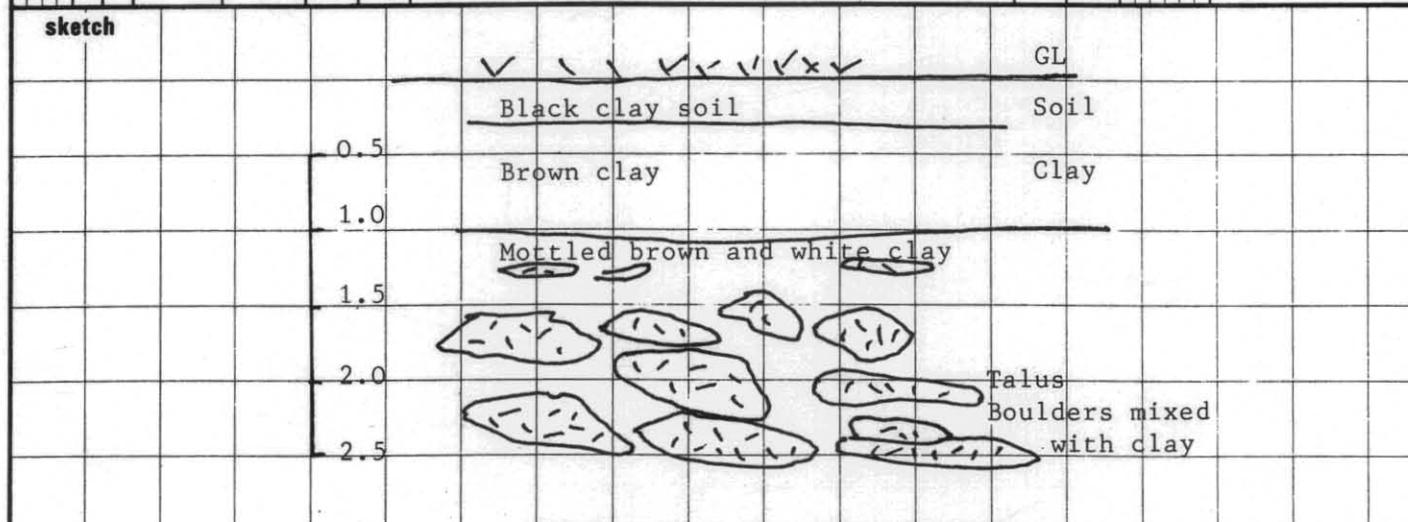
excavation no. 3

sheet 1 of 1

30/58

project	Blackstone Heights Dalrymple Subdivision	location	Above Rock Bench above Gorge in Talus between Dalrymple and Central Creek
co-ordinates	50084-54095	exposure type	Trench
R.L.	135	equipment	Traxcavator
excavation dimensions	0.5x1.5x2.5	operator	Sanieth
		pit commenced	23.6.88
		pit completed	23.6.88
		logged by	W.R. Moore
		checked by	

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer kPa	structure, geology
				OH	CLAY - black, organic, highly plastic	M	S		Soil
			0.5	CH	CLAY - dark brown, highly plastic some roots. Very few boulders	M	F		Clay
	None		S1 1.0	CH GC	CLAY AND GRAVELLY CLAY - clay - mottled white-brown (Medium to high plasticity) gravels 15% + dolerite	M	F		Transition Zone
	None		S2 1.5	GW	BOULDERS WITH CLAY - angular dolerite mixed with clay. Clay 10%-20% dark brown and mottled. Boulders 20 mm-200 mm with large boulders in trench base - but still some clay.				Talus boulders mixed with clay.
			2.0						
			2.5		Refusal - boulders. Not dolerite in situ. Bucket bouncing off boulders				



5 cm

ENGINEERING LOG - EXCAVATION

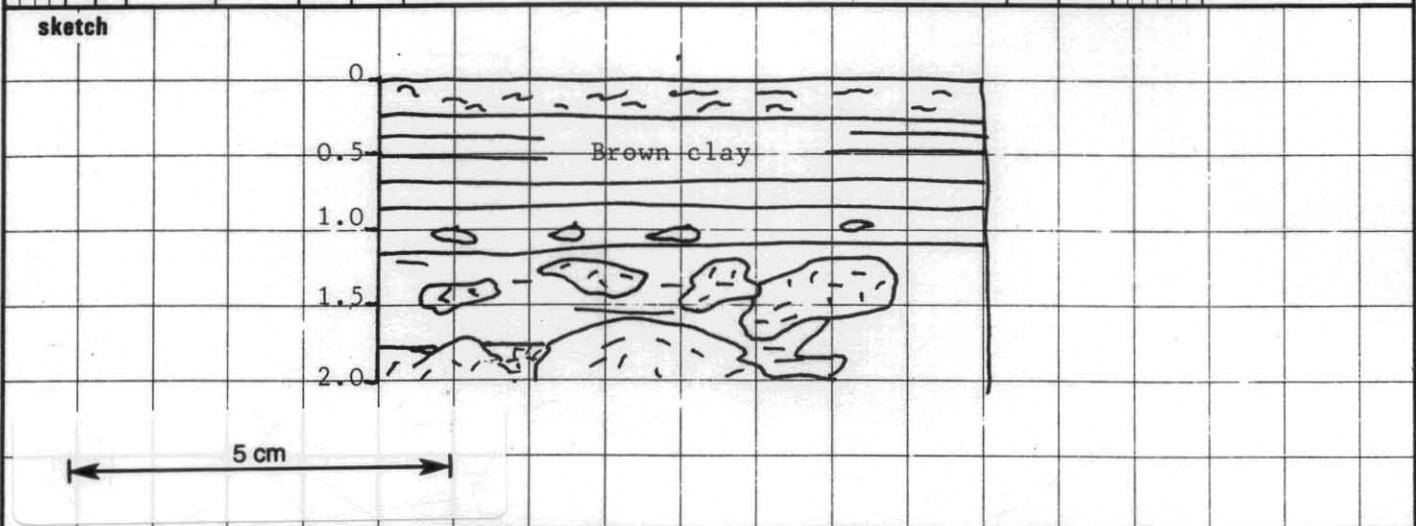
excavation no. 4

sheet 1 of 1

31/58

project	Blackstone Heights Dalrymple Subdivision	location	On boundary of talus and dolerite on Rock Bench - below Trench 3
co-ordinates	50084-54095	exposure type	Trench
R.L.	132	equipment	Traxcavator
excavation dimensions	0.5x1.5x1.8	operator	Sanieth
		pit commenced	23.6.88
		pit completed	23.6.89
		logged by	W.R. Moore
		checked by	

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer kPa	structure, geology
	None		0	OH	CLAY - black, organic, highly plastic	M	S		Soil
			0.5	CH	CLAY - dark brown, highly plastic M > PL Some roots	M	S ↓ F		Clay
			1.0		CLAY WITH BOULDERS - Clay, yellow highly plastic. Not mottled. Boulders - angular dolerite + 10 cm	M	F		Transition Zone
			1.5		BOULDERS WITH CLAY - Large dolerite boulders with clay mixed with boulders. Clay as above - >10%. Boulders large +20 cm, angular un-weathered dolerite.	M	H		Talus boulders mixed with clay
		Some water between boulders		2.0		Traxcavator stopped by boulders. Bucket bouncing			



ENGINEERING LOG - EXCAVATION

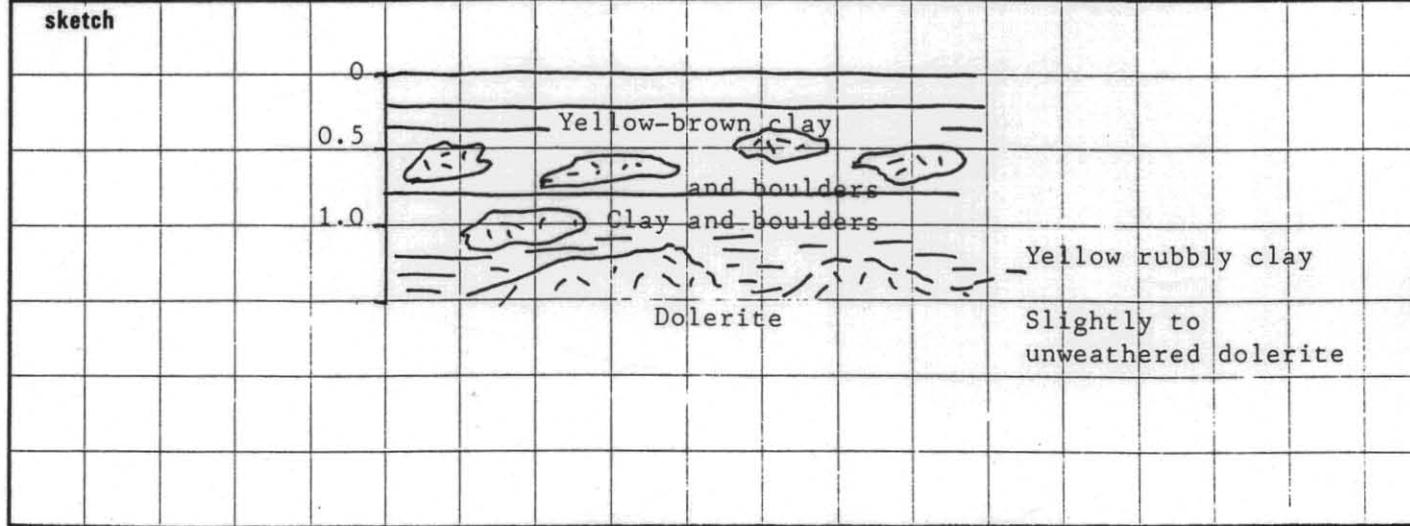
excavation no. 5
sheet 1 of 1

32/58

project Blackstone Heights Above talus slope - near boundary of
Dalrymple Subdivision location outcrop and talus - above Rock Bench

co-ordinates 50084-54094 exposure type Trench pit commenced 26.6.86
equipment Traxcavator pit completed 26.6.86
R.L. 150 m operator Sanieth logged by
excavation dimensions 0.5x1.5x1.2 checked by

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer kPa	structure, geology
									25 50 100 200 400	
	None				OH	CLAY - black, organic, med-high plasticity	M	S		Soil
			0.5		CH	CLAY WITH BOULDERS - clay, yellow-brown, highly plastic. Clay 90%. Boulders angular dolerite 10- 200 mm	M	F		Brown clay
		S1			CL	CLAY AND BOULDERS - clay, yellow, and rubbly - low-med. plasticity - shows mottled texture - becomes highly weathered. dolerite at base of trench Boulders 60%, large unweathered angular dolerite +200 mm	D	H		Yellow clay and boulders
		S2	1.0	GW						
	Made some water				Jdl	Dolerite rock concentric-ally weathered				
<p>Traxcavator stopped on what appeared to be highly to slightly weathered dolerite. Irregular surface - probably concentric-ally weathered dolerite.</p> <p style="text-align: center;">← 5 cm →</p>										



ENGINEERING LOG - EXCAVATION

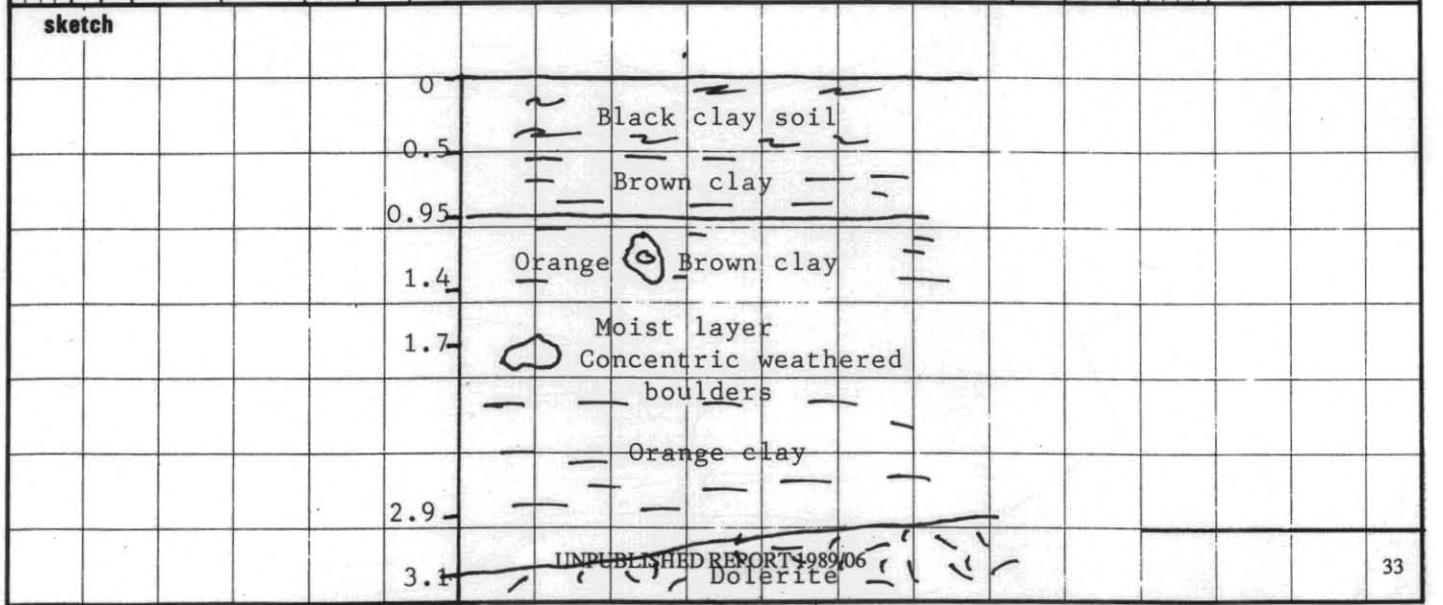
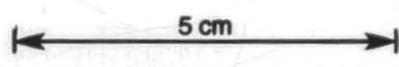
excavation no. 6

sheet 1 of 1

33/58

project	Blackstone Heights Dalrymple Subdivision	location	South-east Investigation zone (SE end of Seismic Spread 8)
co-ordinates	54089-50850	exposure type	Trench
R.L.	150 m	equipment	Traxcavator
excavation dimensions	2x1x3 m	operator	Sanieth
		pit commenced	27.10.88
		pit completed	27.10.88
		logged by	W.R.M.
		checked by	

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer kPa	structure, geology
									25 50 100 200 400	
		S1			OH	CLAY - Black, organic, highly plastic. H>PL, small ironstone nodules	M	F		Soil
		S2	1.0		CH	CLAY - brown, highly plastic, M>PL	M	S		Brown clay
		S3				CLAY - orange-brown, med-high plasticity, gritty texture, conc. weathered Jdl boulder	D	St		Orange-brown clay
		S4				CLAY - orange-brown, highly plastic	M	F		Moist zone
			2.0		CL CM	CLAY WITH BOULDERS of med. to unweathered Jdl. Ironstone grits 1-2 mm CLAY - orange, low-medium plasticity dolerite texture seen. Extremely weathered dolerite.	D	V St		Extremely to highly weathered dolerite
			2.9m			DOLERITE - slightly weathered rock. Traxcavator could not penetrate with bucket. LL PL PI LS S1 Not tested will be removed before building S2 125 27 98 26 S3 67 28 39 16 S4 128 29 99 25	D	H		Slightly weathered dolerite



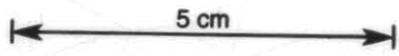
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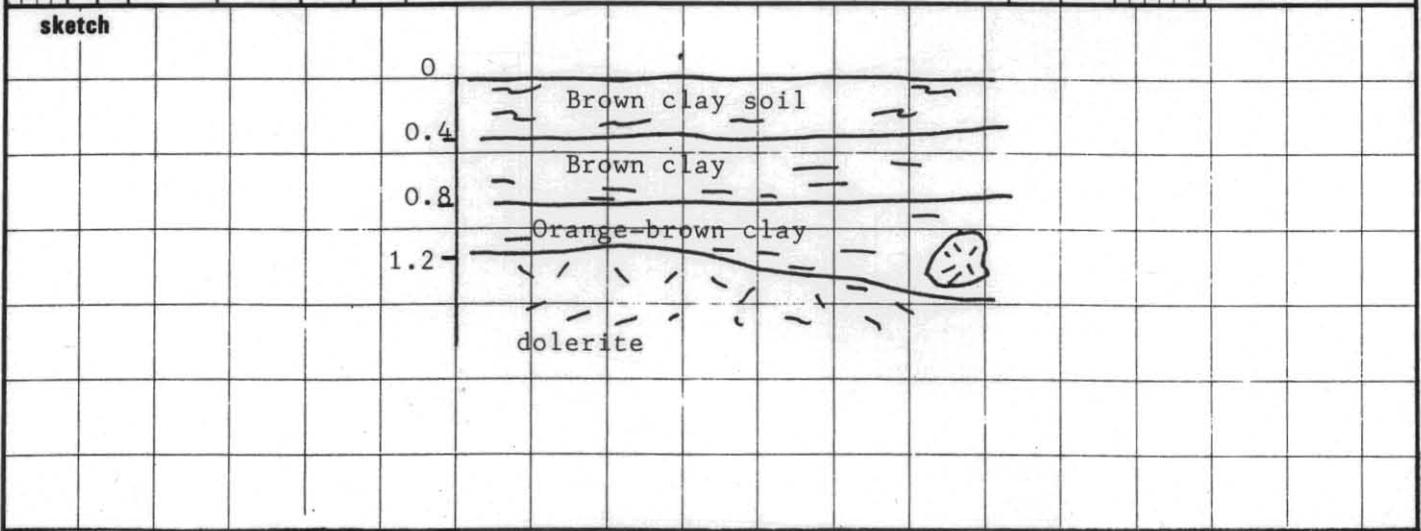
excavation no. 7

sheet 1 of 1

34/58

project	Blackstone Heights Dalrymple Subdivision	location	South-East Investigation zone Seismic Spread 7
co-ordinates	54090-50816	exposure type	Trench
R.L.	150 m	equipment	Traxcavator
excavation dimensions	2x1x2m	operator	Sanieth
		pit commenced	27.10.88
		pit completed	27.10.88
		logged by	W.R.M.
		checked by	

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer kPa	structure, geology
				OH	CLAY - black, organic, highly plastic. some roots	M	S		Soil
				CH	CLAY - brown highly plastic M >> PL	M	St		Clay
			1.0	CL	CLAY - orange-brown, low plasticity gritty texture. Banded calcite and ironstone nodules at base, some Jdl boulders	D	V St		Highly weathered dolerite
				Jdl	Slightly weathered dolerite rock	D	H		Dolerite
	None	None			Traxcavator bucket stopped at 1.2-1.5 m depth.				
									

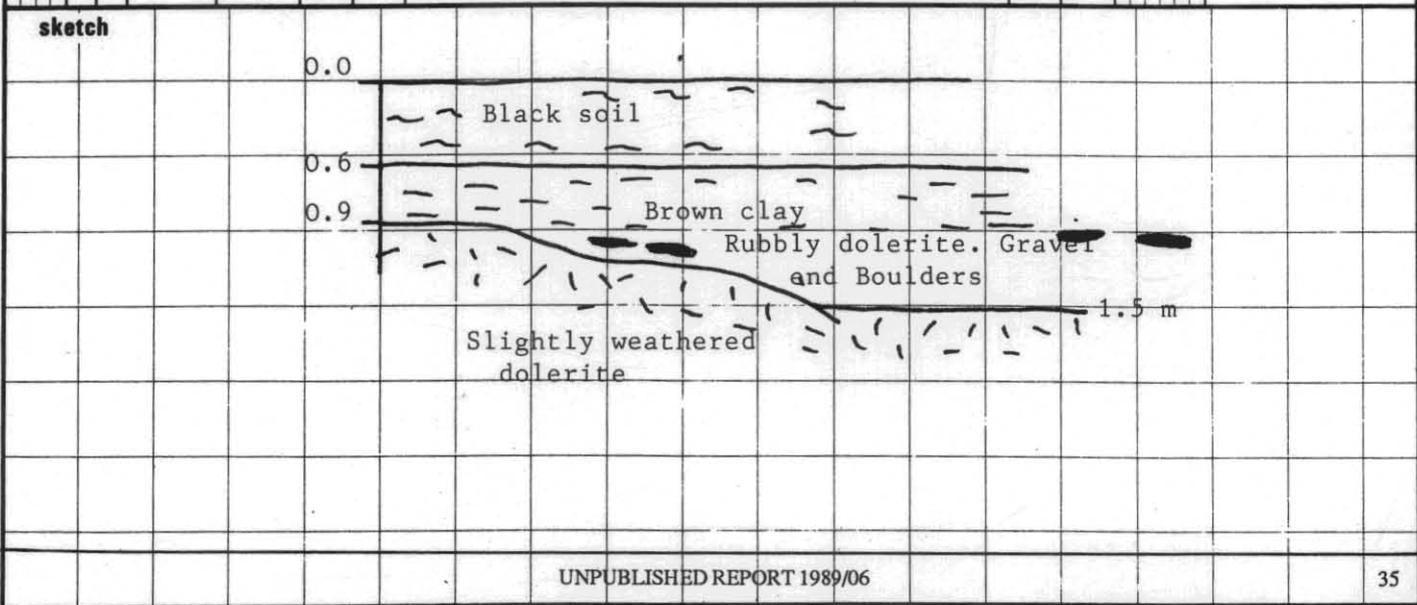


ENGINEERING LOG – EXCAVATION

35/58

project	Blackstone Heights Dalrymple Subdivision	location	SE investigation zone on spur N of seismic spread 6.
co-ordinates	54089-5085	exposure type	Trench
R.L.	150 m	equipment	Traxcavator
excavation dimensions	2x1x1.5 m	operator	Sanieth
		pit commenced	27.10.88
		pit completed	27.10.88
		logged by	W.R.M.
		checked by	

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer kPa	structure, geology
		S1		OH	CLAY - black, organic, med-high plastic.	M	S			Soil
				CH	CLAY - brown, highly plastic M > PL	M	F			Brown clay
				GW	Rubbly weathered dolerite gravel, with some silt&clay, orange-brown,	D	H			Medium weathered dolerite rock
	None			Jd1	Slightly weathered dolerite of 50 mm dolerite rock - 500 mm size, boulders angular					
	None				Step in trench 0.9N-1.5S end Traxcavator bucket stopped at 1.2-1.5 m.					Dolerite
					LL PL PI LS S4 132 30 102 27					
					← 5 cm →					



ENGINEERING LOG - EXCAVATION

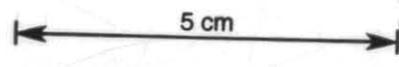
excavation no. 9

sheet 1 of 1

30/58

project	Blackstone Heights Bay View 5 Subdivision	location	Middle of seismic spread 6 Lot 64 Bay View 5 Invest. Zone.
co-ordinates	5067-54109	exposure type	Trench
R.L.	180 m approx.	equipment	Traxcavator
excavation dimensions	1.5x1x1.5	operator	B. Marsh
		pit commenced	6.12.88
		pit completed	6.12.88
		logged by	W.R.M.
		checked by	

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer kPa			structure, geology
								25	50	100	
	None		0.5	OH	CLAY WITH BOULDERS - clay - grey-brown, organic, med. to high plasticity. Boulders angular, unweathered Jdl. Some gravel at base.	D	Fb				Soil and talus boulders
	None	S1	1.0	CH	CLAY - brown, highly plastic. Few boulders present. Boulders angular, unweathered Jdl. Clay faceted and shear polished.	M	St				Faceted clay with shear polish.
			1.5	GW CL	CLAY AND GRAVEL - fine gravel, well graded, weathered Jdl. Pebbles, fine. 1-5 mm clay yellow, low to med. plasticity. Friable highly weathered dolerite	M	Fb				Gravel with clay.
			1.5	Id	DOLERITE yellow, medium weathered Bucket unable to penetrate. Refusal depth 1.5 m	D	H				Dolerite rock



sketch											
				Soil							Boulders Grey brown soil
				Clay							Clay
				Transition							Clay - highly weathered dolerite
				Rock							Med. to slightly weathered dolerite

ENGINEERING LOG - EXCAVATION

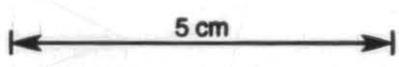
excavation no. 10

sheet 1 of 1

37/58

project	Blackstone Heights Trulls Saddle Subdivision	location	SE end of seismic spread 1. Lot 5 3 m downslope of spread
co-ordinates	5067-54089	exposure type	Trench
R.L.	210 m	equipment	Kobelco Traxcavator
excavation dimensions	6x3x1.0-1.5 m	operator	B. Marsh
		pit commenced	7.12.88
		pit completed	7.12.88
		logged by	W.R.M.
		checked by	

penetration 1 2 3	support water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetr- ometer	structure, geology
									kPa	
	None		1.0		OH	CLAY WITH BOULDERS, NORTH END - Clay grey organic, med.-high plasticity. Roots. Boulders - dolerite, large angular, unweathered	D	Fb	25 50 100 200 400	Soil and talus boulders
	None	S1			CH	CLAY - yellow-brown, highly plastic Extremely weathered dolerite.	M	St		Clay
	None					DOLERITE rock or large dolerite boulders, surface uneven Appears to be boulders. Refusal depth 1.3 m.				Large dolerite boulders
			0		OH	CLAY WITH BOULDERS, SOUTH END - Clay grey organic med.-high plasticity Boulders angular, dolerite	D	Fb		Soil and talus blds.
		S2	1.0		CH	CLAY - brown-yellow, highly plastic boulders - as above but fewer.	M	St		Clay
						Bucket unable to penetrate. Dolerite rock or large boulders Appears to be flat rock in situ. Refusal depth 1.0 m.				Dolerite rock



sketch	North End	
	Soil	
	Clay	
	Boulders or rock	
sketch	South End	
	Soil	
	Clay - with boulders	

APPENDIX 2

Results of seismic refraction spreads

4/1/58

Table 2. Long seismic refraction spreads, Blackstone Heights

Spread No.	Location	Geosporing (m)	Shot Points & Distance (m)	No. of layers	Velocity layers m/sec	Depth to Interface of Veloc. layers	Thickness of Veloc. layers (m)	Symmetry of Veloc. Plots	Stepped	Geological Interpretation of Velocity layers	Remarks
1	Mt Leslie Along track near Trig Station	7.5	N & S 7.5	3	V0 1000-1500 V1 2500-3700 V3 6000-6600	V0/V1 2.4-4.1 V1/V2 6.9-7.6	2-4 4-5	Symmetrical	Not stepped	V0 Soil & clay with boulders V1 Weathered dolerite V2 Unweathered (fresh dolerite)	V2 layer very hard
2	Mt Leslie Downslope & parallel with above track	7.5	N & S 7.5	N. End 2 S. End 3	V0 1100 V1 6400 V0 1000 V1 2300 V2 6600	V0/V1 2.7-3.6 V0/V1 2.3-4.2 V1/V2 7.0-7.6	3 2-3 4-5	Symmetrical	One step	V0 Soil & clay with boulders V1 Weathered dolerite V1 Unweathered dolerite	N. end unweathered dolerite close to surface. Weathered dolerite < 2m thick not seen seismically.
3	Mt Leslie cross spread between spreads 1 & 2	7.5	E & W 7.5	3	V0 1200-1400 V1 2900-3200 V2 4200-5400	V0/V1 2.4-3.9 V1/V2 5.5-6.3	2-3 2-4	Symmetrical	Stepped	V0 Soil and clay with boulders V1 Weathered dolerite V2 Unweathered dolerite	No account of the 3 ^o -10 ^o ground surface slope has been taken in these calculations.
4	Lake View block 40-39	5	N & S 5	4	V0 650-700 V1 1300-1500 V2 2000-3000 V3 5000-6000	V0/V1 3.0-5.9 V1/V2 9.7-12.1 V2/V3 18.6-21	3-6 3-6 6-9	Slightly asymmetrical	Not stepped	V0 Clay with large Jdl boulders V1 Decomposed dolerite conc. weathered V2 Slightly weathered dolerite V3 Unweathered dolerite	Slope on the interface and a thicker clay layers (V0) present at the south end of the spread.
5	Blackstone Road, Old Quarry	7.5	N & S 7.5	3	V0 500 V1 900-1200 V2 2000-3000	V0/V1 2.5-4.9 V1/V2 8-11	3-5 5-6	Symmetrical	Some stepping	V0 Clay V1 Highly weathered and decomposed dolerite V2 Slightly weathered dolerite	Dolerite, bed rock high velocities of [4000-6000] seen on previous spreads not found here. It appears that weathering zone is deep at this location.
6	Panorama Rd Along fence line upslope on Mt Leslie near break in slope	7.5	NW-SE NW S.P 7.5 SE S.P 15 m mid S.P. 7.5	NW End 3 SE End 3	V0 700-1000 V1 2500 V2 4500 V0 700-1000 V1 2200-2600 V2 3700-4500	V0/V1 0.82 V1/V2 4.4-5.2 V0/V1 5.0-5.4 V1/V2 11.5-11.75	1 4-5 5 6-7	Very asymmetrical slopes down to SE	No stepping	V0 Clay V1 Slightly weathered dolerite V2 Unweathered dolerite V0 Clay V0 Deeply weathered dolerite V1 Slightly weathered to fresh dolerite	Shallow clay horizon at NW end of spread with considerable thickening of this surface layer and 2nd layer at SE end of spread. This slope seen also at mid S.P.
7	Panorama Rd NW from Mt Leslie Road Jct. along front blocks	7.5	NW-SE 7.5	NW End 3 SE End 2	V0 750- V1 900-1000 V2 2200 V0 = 750 V1 = 4500	V0/V1 3.4-4.2 V1/V2 18.1-19.7 14-17 V0/V1 15.8	3-4 14-17 15-16	Asymmetrical	No stepping	V0 Clay V1 Clay highly weathered dolerite V2 Weathered dolerite V0 Clay V1 Dolerite	Deep clay layer present. Calculated depths over deepened by slope on V1 layer. Anticipated depth to unweathered dolerite in excess of 10 m at SE end of spread and 6 m NW end. Clay drilled to a depth of 7 m at this location.
8	Panorama Rd Cross spread between spreads 6 & 7	7.5	NE-SW Uphill NE 7.5 Downhill 7.5	NE End 3 SW 3	V0 800 V1 1500 V2 3200 V0 500-800 V1 1700 V2 4500+	V0/V1 = 2.1 V1/V2 15.5 V1/V2 9-11.1 V1/V2 24.8-26.4	2 14 10 aprox. 15 aprox.	Very asymmetrical interface slopes uphill	No stepping	V0 Clay V1 Weathered dolerite V2 Unweathered dolerite	Speeding up of velocities upslope towards Mt Leslie make depth calculations unreliable. This cross spread confirms thick deposits of clay along valley at Panorama Road level. The dolerite comes close to surface at break of slope probably associated with fault at foot of Mt Leslie.
9	Trulls Saddle, Near access track	7.5	NW-SE NW 7.5 SE 15	NE End 3 SE End 2	V0 1000 V1 2200 V2 3500-5000 V0 550 V1 5000+	V0/V1 2.3 V1/V2 7.5-9.3 V0/V1 6.5	V1 2.0 V2 5-7 6	Asymmetrical interface slopes down to SE	Very stepped	V0 Clay V1 Weathered dolerite V2 Unweathered dolerite	Spread crosses from dolerite rock at NW end to clay at SE end. Depths not reliable.
10	Blackstone Heights Subdivision. On high level track	7.5	NW-SE NW = SE and Mid 7.5	2	V0 750-1000 V1 2900-3500+	V0/V1 2.1-2.9	V0 2	Symmetrical	Stepped	V0 Weathered dolerite V0 Unweathered dolerite	Dolerite rock in situ - with no clay present.
11	Plateau Subdivision near dolerite bluff	7.5	E-W approx. E, W and Mid S.P 7.5	W End 2 E End 3	V0 750-800 V1 3000-5000 V0 500-700 V1 900-1200 V2 5000+	V0/V1 2.8-3.2 V0/V1 1.9-2.4 V1/V2 9.6-10.9	3 V0 2 V1 8-9	Asymmetrical interface slope down to East	Not stepped	V0 Weathered dolerite V1 Unweathered dolerite V0 Clay V1 Highly weathered dolerite V2 Unweathered dolerite	Clay overlying dolerite at East end of spread. At west end dolerite close to or at surface. Depth calculations unreliable.
12	Dalrymple Subdivision. Overlooking rock shelf above Gorge	7.5	E-W W = 15 m E = 7.5 Mid S.P. 7.5	3	V0 500-600 V1 1000-1500 V2 3500-5000+	V0/V1 1.6-2.2 V0/V1 7.2-10.2	V0 2 V1 6-8	Asymmetrical	Not stepped	V0 Clay V1 Weathered dolerite V1 Unweathered dolerite	Clay overlying weathered dolerite at east end of spread. Little to no clay overlying unweathered dolerite at west end. Depth calculations unreliable.
13	Deadmans Hollow Subd. Overlooking Gorge Blocks 4-6	7.5	NE-SW NE 15 m SW 7.5	2	V0 750-1200 V1 4000-6000	V0/V1 2.0-3.1	V0 2-3 thickening to SW end	Symmetrical	Not stepped	V0 Clay with boulders to weathered dolerite V1 Unweathered dolerite	Surface velocity layer changes from 750 m/sec at NE end - to 1100, 1200 m/sec at SW end. This higher velocity is consistent with weathered dolerite rock at ground surface.

Table 3. Weathering spreads, Blackstone Heights

Spread No.	Location & Direction	Velocity layers m/sec	Depth to Velocity Interfaces m	Symmetry	Stepped	Geological Interpretation of Velocity layer	Remarks
1	Top of hill Mt Leslie N-S	North End		V0/V1 0.8	Asymmetrical	Stepped	Bed rock of slightly weathered dolerite - slopes upward to the northend.
		V0 500					
		V1 2600				V1 Rock slightly weathered dolerite	
		South End		V0/V1 0.6			
		V0 500					
		V1 1100-1500				V1 Highly weathered dolerite	
2	Panorama Road Near junction of Mt Leslie Road N-S	V0 400	V0/V1 1.3-1.4	Symmetrical	Stepped	V0 Clay soil	Seismic section proved when drilled. No unweathered dolerite rock was encountered in drilling to depth of 7 m at this location.
		V1 1000-1200	V1/V2 4.3-5.4			V1 Clay below water table and/or extremely weathered dolerite. Clay with dolerite texture.	
		V2 1800				V2 Highly Weathered dolerite rock	
3	Blackstone Road Subdivision. Above old quarry. Now used as a rubbish tip. N-S	V0 400-650	V0/V1 1.3-1.6	Asymmetrical	Stepped	V0 Brown clay soil	Confirms the exposures in the old pit where no dolerite rock exposed. Only clay with dolerite texture.
		V1 800-900	V1/V2 4.6-4.9			V1 Brown clay and mottled clay of extremely weathered dolerite.	
		V2 1800				V2 Highly weathered dolerite	
4	Blackstone Road. Along road bank near middle access track. N-S	V0 400	V0/V1 0.4-0.5	Symmetrical	Not stepped	V0 Clay soil	
		V1 700	V1/V2 6.4-6.5			V1 White mottled clay and boulders	
		V2 1200				V2 Highly weathered dolerite.	
5	Deadmans Hollow Subdivision Blocks 5 & 6 NE-SW	SW End		Asymmetrical	Extremely stepped	SW End	At NE end of the spread only a thin layer of clay and boulders overlie unweathered dolerite. Depth calculations not reliable because of stepping.
		V0 600	V0/V1 0.5			V0 Clay	
		V1 1000	V1/V2 1.2			V1 Clay and boulders	
		V2 1800-1900	V2/V3 4.4			V2 Highly weathered dolerite	
		V3 4000				V3 Slightly to unweathered dolerite	
		NE End				V0 1000	
		V1 4000-5000			V1 Slightly to unweathered dolerite		

Table 4. Shallow seismic refraction results, Dalrymple subdivision.

Investigation Zones

Spread No.	No. of Velocity layers (m)	Velocity layers (m/sec)	Calculated thickness of velocity layers (m)	Symmetry of velocity layers	Degree of stepping in velocities	Geological Interpretation of velocity layers	Estimate of foundation depth (m)	Reliability of Seismic record	Remarks				
1	3	S.W. End		Asymmetrical Shallows to S.W. end	Stepped	V ₀ Boulders & clay V ₁ Slightly weathered dolerite V ₂ Unweathered dolerite	1 - 1.5	Reliable					
		V ₀ 800	1st 1.5										
		V ₁ 3200	2nd 2.6										
		V ₂ 5000	depth to 3rd 4.1										
		N.E. End											
V ₀ 400	1st 0.81	"											
V ₁ 2000	2nd 1.34												
V ₂ 3000	to 3rd 2.15												
2	3	V ₀ 350-400	1st 0.77	Symmetrical No slope	Stepped	V ₀ Boulders & clay V ₁ Med to slightly weathered dolerite V ₂ Unweathered dolerite	1 - 1.5	Reliable					
		V ₁ 1600-2600	2nd 1.46										
			to										
		V ₂ 3500-5000	3rd 2.2										
3	2	V ₀ 308-400	1st 0.9-1.38	Symmetrical No slope	Very highly stepped	V ₀ Boulders & clay V ₁ Dolerite	0.9 - 1.5	Medium reliability	Stepped at critical point				
		V ₁ 4000-4500											
4	3	V ₀ 400-600	1st 0.54-1.22	Slightly asymmetrical	Highly stepped	V ₀ Boulders & clay V ₁ Highly to medium weathered dolerite V ₂ Dolerite	1.5 - 2.0	Reliable	Intermediate velocity thickness to the south				
		V ₁ 1100-2000	2nd 1.85-2.33										
		V ₂ 3750-5000+	to 3rd 2.8-3.07										
5	2	N.W. End		Asymmetrical	None	V ₀ Clay with few boulders V ₁ Highly to deeply weathered dolerite	No building recommended	Reliable	Spread fired on old landslide and very wet area				
		V ₀ 500-800	1st 2.9										
		V ₁ 1600-1700											
		S.E. End											
		V ₀ 400-700	1st 2.2										
V ₁ 2500-3000													
6	3	N.W. End		Asymmetrical slope to S.E. end	Stepped	V ₀ Clay with boulders V ₁ Deeply to medium weathered dolerite V ₂ Dolerite	1.5 - 2.0	Reliable	Requires trench to check velocities and depths				
		V ₀ 400-600	1st 1.5										
		V ₁ 1400	2nd 1.75										
			to										
		V ₂ 2100-2600	3rd 2.25										
		S.E. End											
		V ₀ 200	1st 0.83										
		V ₁ 1100	2nd 1.34										
V ₂ 1900-2100	to 3rd 2.17												
7	3	V ₀ 400	1st 0.58-0.71	Symmetrical	Very stepped	V ₀ Soil and boulders V ₁ Clay to highly weathered dolerite V ₂ Dolerite	1 - 1.8	Medium reliability	Requires trench to confirm depth and Lithologies				
		V ₁ 760-1200	2nd 0.83-1.18										
			to										
		V ₂ 2100-2750	3rd 1.54-1.76										
8	3	V ₀ 600-800	1st 0.65-2.2	Symmetrical	Some stepping	V ₀ Clay and boulders V ₁ Deeply weathered dolerite V ₂ Dolerite	1 - 2+	Unreliable	Unreliability due to misfire at N. end. Requires trenching.				
		V ₁ 1500-1600											
		V ₂ 2500											

Table 5. Seismic refraction results, Trulls Saddle subdivision.

Spread No	Subdivision & Block No.	Direction	No. of Layers	Velocity Layers m/sec	Asymmetry	Stepping	Thickness of layers (m)	Geological Interpretation	Remarks
1	Trulls Saddle Lot 5	E-W	3	V0 600	Asymmetrical Thick intermediate layer NW end	Very stepped	NW End	V0 Brown Clay	So stepped Depths are not reliable
				V1 1600			Z0 = 1.81	V1 Extremely to highly weathered Jdl	
				V2 3000-5000			Z1 = 5.2	V2 Slightly weathered Jdl rock	
							TD = 6.38		
							SE End		
							Z0 = 1.18		
							Z1 = 3.32		
							TD = 4.5		
2	Trulls Saddle Lot 6	E-W	3	V0 500- 600	Asymmetrical Thicker NW end	Very stepped	NW End	V0 Clay	So stepped Depths are not reliable
				V1 900-1050			Z0 = 0.89	V1 Clay extremely weathered Jdl	
				V2 3000-3500			Z1 = 6.1	V2 Slightly weathered dolerite rock	
							TD = 7.0		
				7000-10000			SE End		
							Z0 = 0.82		
							Z1 = 3.69		
							TD = 4.56		
3	Trulls Saddle Lots 8-9	E-W	3	V0 600	-	Some stepping	Z0 = 0.98	V0 Clay	Only one end recorded Instrument malfunction
				V1 1500			Z1 = 4.0	V1 Clay highly weathered Jdl	
				V2 2800			TD = 5.0	V2 weathered dolerite rock	
4	Trulls Saddle Lots 13-14	NW-SE	2 NW end	V0 500	Asymmetrical No intermediate layer	Slightly stepped	NW End	V0 Clay	Only one end recorded Instrument malfunction
				V1 3000			Z0 = 1.27	V0 Clay	
			3 SE end	V0 1000			SE End	V1 Unweathered dolerite rock	
				V1 1400	Z0 = 0.61	V1 Unweathered dolerite rock			
				V2 3200			Z1 = 5.18	V2 Slightly weathered dolerite rock	
							TD = 5.69		
								V0 Brown clay	
								V1 Yellow clay extremely to highly weathered Jdl	
								V2 Slightly weathered dolerite rock	
5	Trulls Saddle Lots 31-32	N-S	2	V0 800-1000	Symmetrical	Stepped	Z0 = 0.71-	V0 Soil	Slightly weathered dolerite rock
				V1 3200-3400			TD < 1 m	V1 Slightly weathered dolerite rock	
				5000+					
6	Bay View 3 Lot 34	N-S	3	V0 400-500	Asymmetrical	Slightly stepped	N End	V0 Brown clay	No hard rock velocity seen on this spread
				V1 1600-2000			Z0 = 1.16	V1 Yellow clay extremely weathered dolerite	
				V2 2500+			Z1 = 3.93		
							TD = 5.09		
							S End		
							Z0 = 1.16	V2 medium weathered dolerite rock	
							Z1 = 2.83		
							TD = 4.09		

Abbreviations

V0 = Surface layer velocity
V1 = Intermediate layer velocity
V2 = Third layer velocity
Z0 = Calculated surface layer thickness
Z1 = Second layer thickness
TD = Total Depth to rock

APPENDIX 3

Plates for Blackstone Heights report



Plate 1. *In situ* clay derived from the weathering of dolerite:- the Blackstone Heights clay.

Locations: Southern Outlet Road, Launceston.



Plate 2. *Brown clay underlain by extremely to medium weathered metasomatised dolerite.*

Location: Junction of Trulls Saddle and Blackstone Roads.



Plate 3. *Kernels of unweathered large dolerite boulders surrounded by clay, Blackstone Heights.*

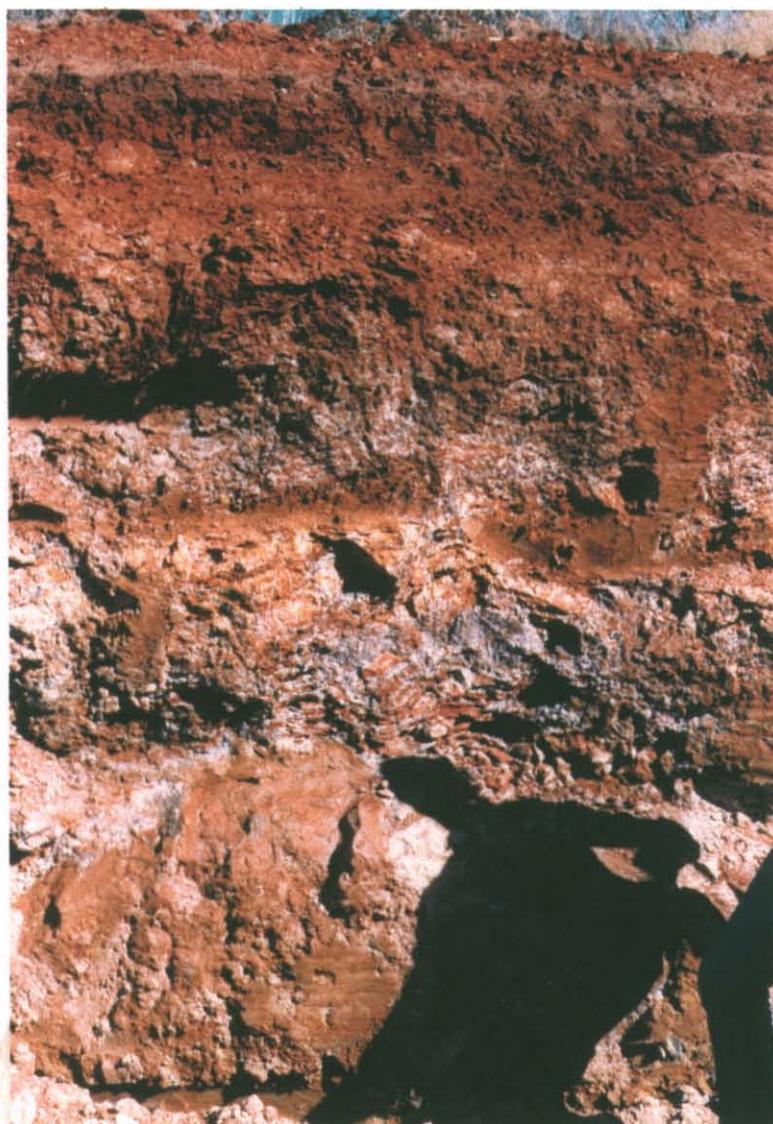


Plate 4. *Clay-rock profile in the reservoir bank, Panorama Road, Blackstone Heights.*

Lower photo shows the vertical profile of—

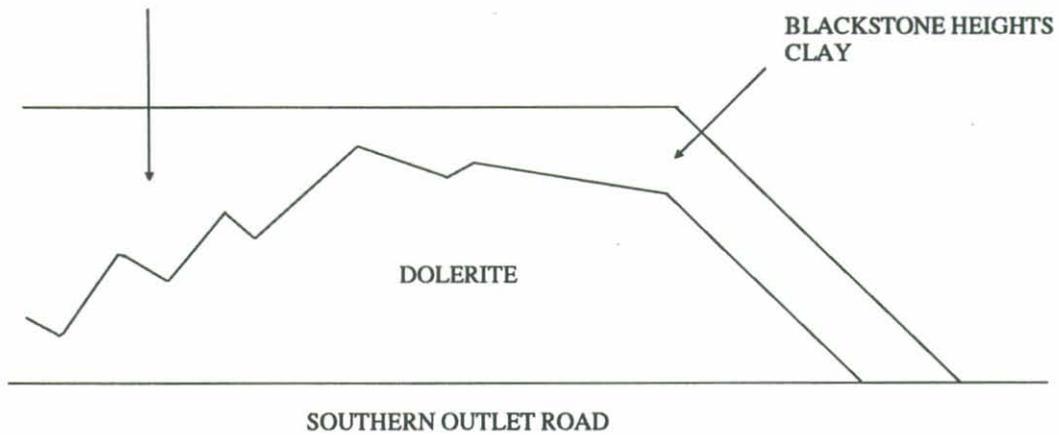
(a) Subsurface clay;

(b) White-yellow clay showing igneous texture;

(c) Weathered dolerite.



LAUNCESTON BEDS CLAY



BLACKSTONE HEIGHTS CLAY

DOLERITE

SOUTHERN OUTLET ROAD

Plate 5. *Clay-dolerite profile, Southern Outlet Road, Launceston.*

Launceston Beds upslope, Blackstone Heights clay downslope



Plate 6. Large boulders, produced by concentric weathering of dolerite, removed from a prepared house site. House site shows upper brown clay merging with lower, yellow-white clay.



Plate 7. *Irregular dolerite profile, Bakers Court quarry.*



Plate 8. *Old landslide, Central Creek. Top photo from Trulls Saddle, lower photo from Central Creek.*

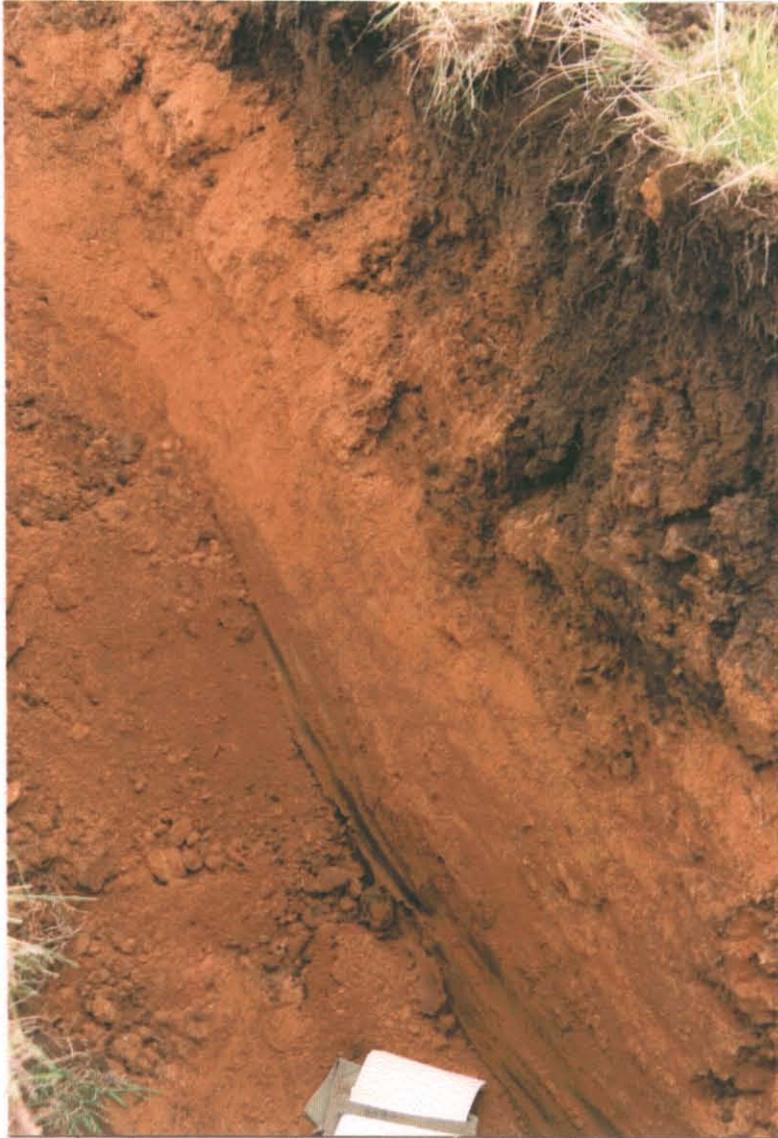


Plate 9. Clay exposed in Trench 6, Dalrymple subdivision (for log see Excavation 6).



Plate 10. Clay and dolerite with small outcrops and boulders, Blackstone Road.



Plate 11. *Talus deposits, Badger Plains Track.*

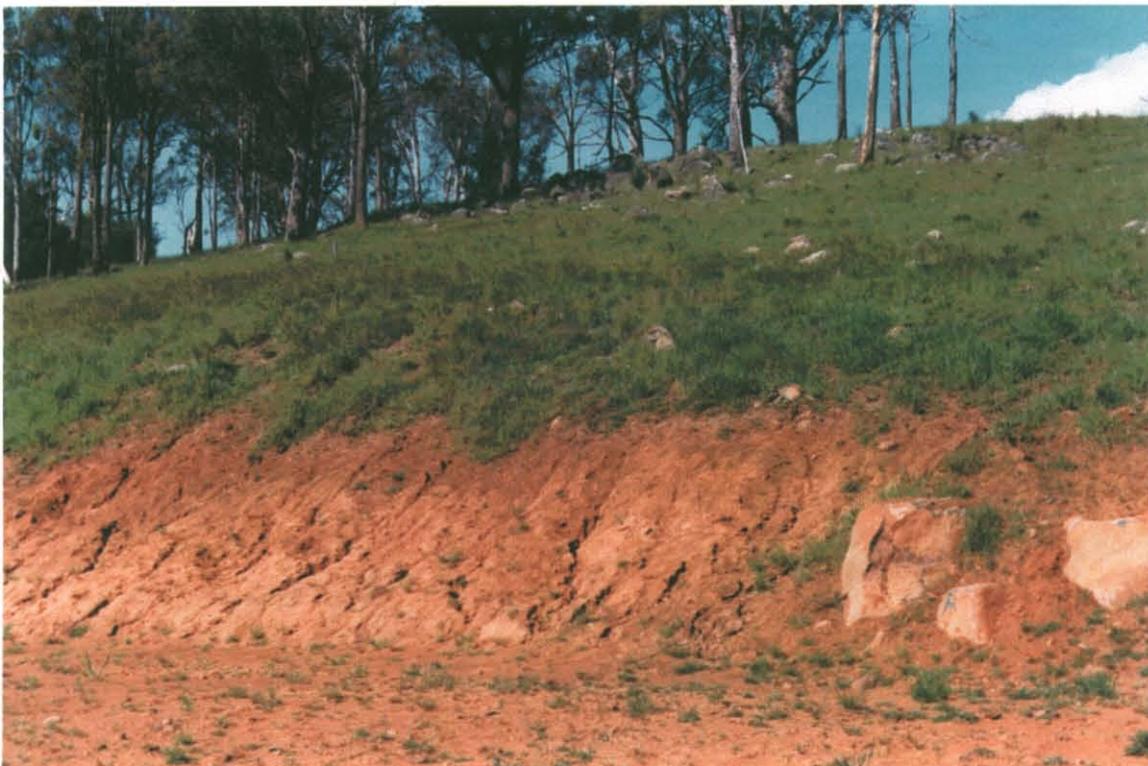


Plate 12. *Talus boulders underlain by clay and weathered dolerite.*

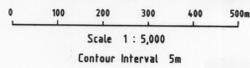


Plate 13. *Hard, high velocity dolerite capping Mt Leslie ridge at reservoir site. Dolerite velocities: $V_0=500-1000$ m/sec; $V_1=2500-3700$ m/sec.*



Plate 14. *Scarp slope, eastern valley slope of Blackstone Creek. Cap rock is dolerite, with talus front slope and clay below on lower slopes of valley.*

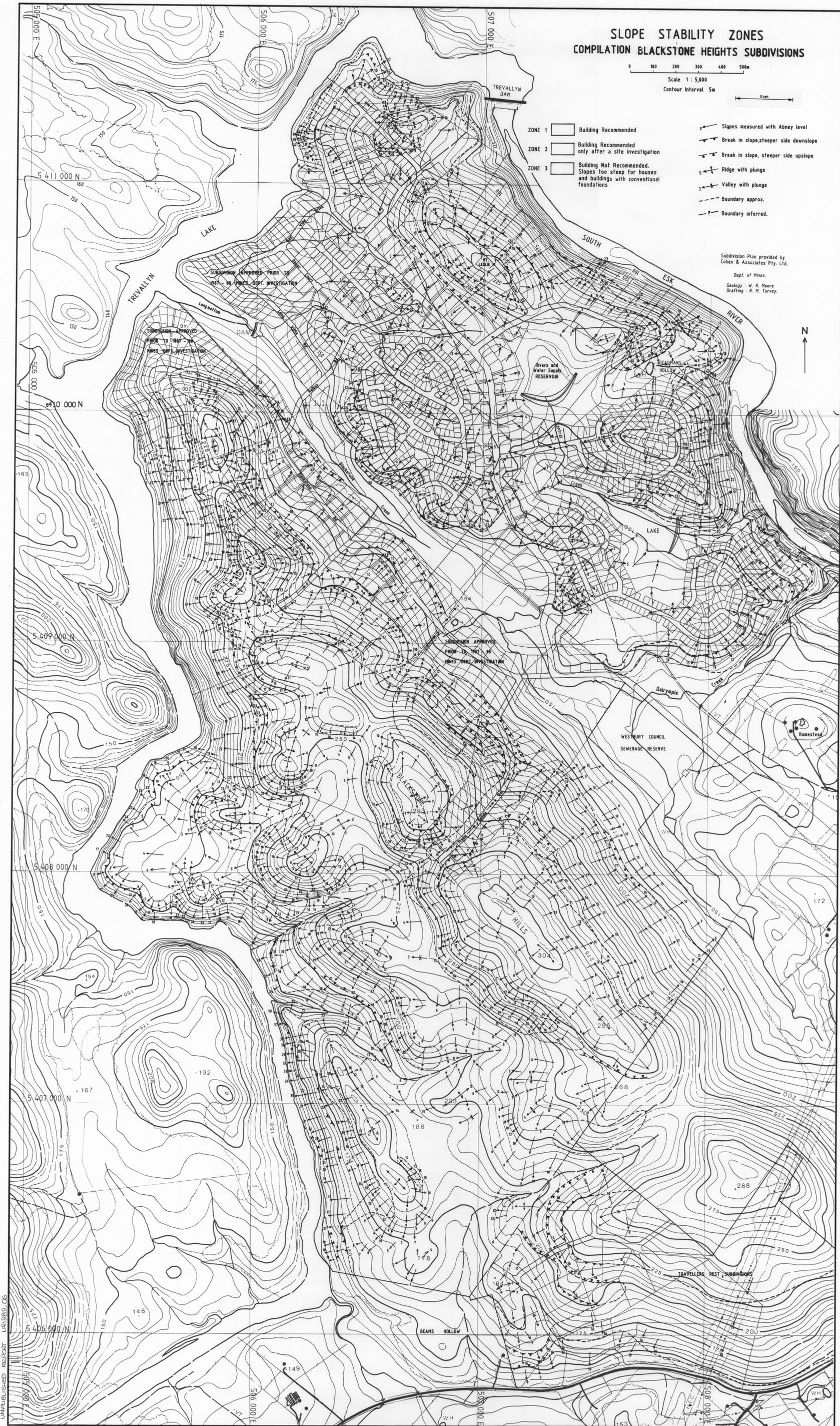
SLOPE STABILITY ZONES COMPILATION BLACKSTONE HEIGHTS SUBDIVISIONS



- ZONE 1 Building Recommended
- ZONE 2 Building Recommended only after a site investigation
- ZONE 3 Building Not Recommended. Slopes too steep for houses and buildings with conventional foundations

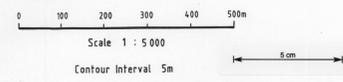
- Slopes measured with Abney level
- Break in slope, steeper side downslope
- Break in slope, steeper side upslope
- Ridge with plunge
- Valley with plunge
- Boundary approx.
- Boundary inferred.

Subdivision Plan provided by
Cohen & Associates Pty. Ltd.
Dept. of Mines.
Geology: W. R. Moore
Drafting: R. M. Turvey.



UNPUBLISHED REFLECT 140390.CE

ENGINEERING GEOLOGY COMPILATION BLACKSTONE HEIGHTS SUBDIVISIONS



- Reconnaissance mapping only - no survey control.
- Fault, downthrown side indicated.
- Magnetometer traverse
- Seismic spread - location & number (geoph. spacing 7.5m)
- " " " " " " " " (" " " " 2.5-3m)
- Seismic spread - location & number (geoph. spacing 1-2m)
- (D - Dalrymple subdivision, T - Trulls subdivision)
- Borehole - location & number
- Excavation - location & number
- Shear box sample - location
- Old landslide

Subdivision Plan base map
Cohen & Associates Pty. Ltd.

Department of Mines
Geology - W.R. Moore
Drafting - R.M. Turvey
J.H. Clarke



ENGINEERING PROPERTIES	
PI	Plasticity Index.
LL	Liquid Limit.
LS	Linear Shrinkage.
Av.	Average results.
Qu	Unconfined compressive strength (pocket penetrometer).
ϕ	Angle of internal friction (shear box).
c'	Effective cohesion (shear box).
V_s	Seismic velocity - Surface layer.
V_2	Seismic velocity - Intermediate layer.
V_3	Seismic velocity - Third layer.

UNIFIED SOIL CLASSIFICATION SYSTEM GROUP SYMBOLS AND DESCRIPTION	
GW	Well-graded gravel and gravel-sand mixtures. Little or no fines.
GM	Silty gravel, gravel-sand-silt mixture.
GC	Clayey gravel, gravel-sand-clay mixture.
SC	Clayey sand, sand-clay mixtures.
ML	Inorganic silt and very fine sand, silty or clayey fine sand, or clayey silt with slight plasticity.
CL	Inorganic clay of low to medium plasticity, gravelly clay, sandy clay, silty clay.
OL	Organic silt and organic silty clay of low plasticity.
MH	Inorganic silt, micaceous fine sandy or silty soils, elastic silts.
CH	Inorganic clay of high plasticity.
OH	Organic clay of medium to high plasticity, organic silt.

UNITS	LITHOLOGIES	ENG. GEOL. PROPERTIES	POTENTIAL ENGINEERING PROBLEMS	INVESTIGATION METHODS
ALLUVIUM	Location: Flood plain & valley floors Dominantly organic clay (CH-OH) and silts (OL-ML) Some fine to medium ironstone and dolerite gravel (IG-OH) Minor occurrence of clayey sands (Sc), silts (MH) and sandy clays (Cl)	Not tested Areas mainly non-building and recreational	EXPANSIVE SOILS: - Black clay soil - High plasticity and expansive - Ground cracking - Low bearing strength. DRAINAGE: - Clay - low permeability - Natural drainage poor - Swampy - Local flooding.*	EXPANSIVE SOILS AUGER HOLES: - If clay is deep and expansive at house site the clay should be tested in soil lab. The foundations should then be designed in accordance with a foundation engineer.
CLAY	Location: Lower slopes and valley floors Dark brown clay (CH) underlain by yellow white clay (CH) often showing igneous texture widely scattered large unweathered dolerite boulders present.	Clay - (CH) P.I. 65-123 Av. 93 L.L. 90-149 Av. 121 L.S. 19-29 Av. 25 Qu 150-400 Kpa ϕ 9 ^o -13 ^o c' 5.0-6.0 Kpa V_s 500-600m/sec	EXPANSIVE CLAY: - Outcrops and investigation indicate clays are of adequate thickness to create house cracking and even on low slopes, soil creep potential is high. Bearing strength as above. SLOPE STABILITY: - see Slope Stability Map. If slopes 12 ^o , combined with poor drainage, potential risk high. DRAINAGE: - Clay - low permeability - High storage - Effective drainage difficult in such clay.	EXPANSIVE SOILS AUGER HOLES and as above - for expansive clays - Soil lab. testing of clay, etc. SLOPE STABILITY TRENCH: - Clay shear-box tested - Slope stability analysis of entire slope length - Followed by foundation inspection and site drainage.
CLAY & DOLERITE with small outcrops and boulders	Location: Middle slopes and low flat ridges of central area Brown clay (CH) and/or yellow white clay (CH) underlain sometimes by clay with some sand (CL-ML) clay (GC) and friable rubble clay (CL-ML) mixed with large boulders of dolerite and concentric weathered dolerite.	Clay - (CH) if present as above CL - CH P.I. 69-122 Av. 94 L.L. 89-154 Av. 123 L.S. 16-24 Av. 22 Qu 150-350 Kpa ϕ 9 ^o -13 ^o c' 5.0-6.0 Kpa V_s 500-600m/sec	DIFFERENTIAL FOUNDATION MOVEMENT: - Clay and dolerite, and dolerite boulders interchange with in short distances and given certain conditions may cause house cracking. EXPANSIVE CLAY: - If house site is entirely on clay and is deep (>1.5m) - House cracking likely. SLOPE STABILITY: - See Slope Stability Map - as above if slopes 12 ^o .	SLOPE STABILITY: - Short seismic spread followed by trench plus detailed examination of foundation trenches. If clay present and deep (>1.5m) - as above for slope stability. If clay <1.5m to weathered rock, remove on cut and fill sites or foundations dug into weathered rock. DIFFERENTIAL MOVEMENT - TRENCH: Test clay, followed by house foundation inspection. EXPANSIVE SOIL - TRENCH: Test clay, followed by house foundation inspection for moisture and water.
TALUS	Location: Steep slopes, particularly slopes on Blackstone Hills and Mt. Leslie ridges. Dolerite boulders, often thick cover large areas of slopes. Lenses and pockets of clay on lower slope boulders are mixed with and overlie clay. In western section and South Esk Gorge boulder scree overlie dolerite benches.	Clay - (CH) if present as above CL - CH P.I. 15-21 Av. 17 L.L. 43-49 Av. 46 L.S. 3-10 Av. 8 Qu 350-500 Kpa V _s 600-900m/sec Weathered rock V _s 1200-1500m/sec	FOUNDATION PROBLEM: - (a) Of recognizing if foundation is on dolerite or large dolerite boulders from concentric weathering. (b) When clay pockets or lenses, and concentrically weathered boulders present, differential foundation movements - as above. SLOPE STABILITY, BOULDER TOPPING AND BOULDER AND DEBRIS SLIDES: - see Slope Stability Map. (a) Scree and rock bench areas - boulders tapping. (b) Talus areas - shallow transitional slides.	Careful house site selection - followed by seismic survey and trenching On steep slopes houses founded entirely on rock not fill. Consolidation and translational movements are possible on fill. After site selection - the house foundations when excavated require further inspection. Foundations on steeper and higher slopes - required to be keyed into rock.
DOLERITE outcrops and near outcrops	Location: Confined mainly to ridges and cliffs of Lake Trevallyn and South Esk Gorge. Outcrops: Flat or banded with intervening areas of dolerite boulders. Outcrops of dolerite to slightly weathered and unweathered dolerite. Soil layer thin and patchy.	Rock completely stained by weathering & rippled V _s 2000-3000m/sec Slightly weathered & unweathered - explosives required. Not rippled V _s 4000m/sec	LITTLE SOIL COVER AND HARD ROCK CLOSE TO SURFACE: - Ridge areas. - Digging of foundations and drains may require explosives. - High run off and little soakage. - Cliffed areas considered too steep for houses with conventional foundations.	Ridge and bench sites are costly for servicing and construction of subsurface work. Not suitable for septic tank, soakage pits etc. Steep Gorge and lake edge slopes have now been included in Council and HEC Reserves.