Tasmanian Department of Mines
Unpublished Report 1975/79

Stratigraphy and landslips in the Craigburn and Beauty Point areas

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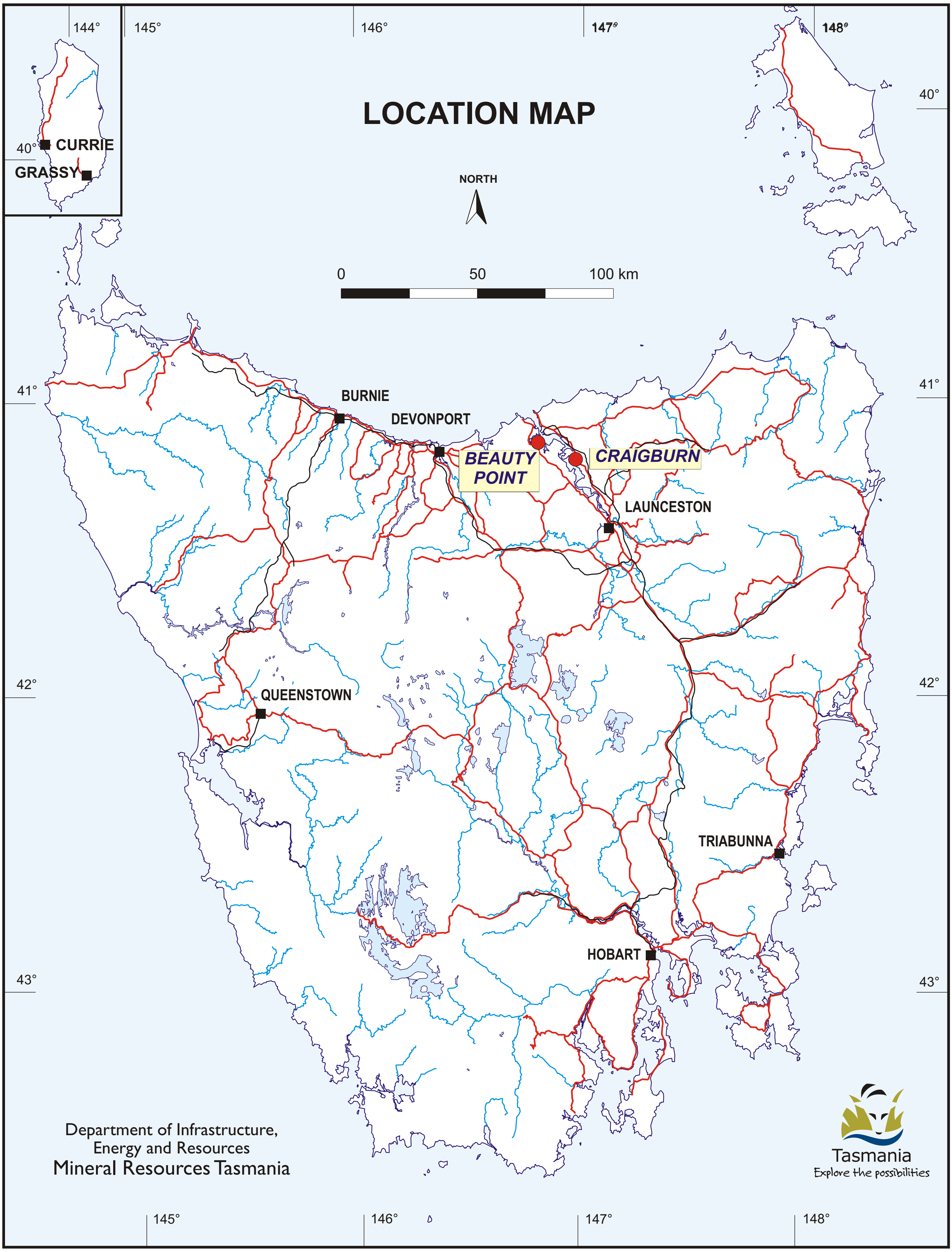

LOCATION MAP
NORTH
0
50
100 km
144°
145°
146°
147°
148°
40°
41°
42°
43°
CURRIE
GRASSY
BURNIE
DEVONPORT
BEAUTY POINT
CRAIGBURN
LAUNCESTON
QUEENSTOWN
TRIABUNNA
HOBART
Department of Infrastructure, Energy and Resources
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Explore the possibilities

Contents

Figures

Abstract

The areas around *Craigburn* and the Beauty Point town site are underlain by weakly indurated Tertiary sediments and basaltic rocks. Each area has been subject to landslip.

In the *Craigburn* area the sediments comprise a facies of well-sorted, medium-grained sand and a facies of dominantly clay-rich materials including silty and sandy clay, clayey sand and silt, sand, very minor siliceous gravel and minor sideritic rocks. These have undergone chemical weathering and there is evidence that the clay-rich materials are derived, at least in part, from sand containing a large proportion of labile constituents, probably feldspar and possibly other minerals. The ridges northeast of *Craigburn* are capped by doleritic basalt and isolated outcrops occur over the slopes. There is a lower unit of sediments at Beauty Point containing a similar range of deposits and showing a similar degree of weathering to the clay-rich facies at *Craigburn*. This unit is overlain by medium-grained basalt and isolated exposures of basalt occur on slopes underlain by the unit. Overlying the basalt is a sequence of siliceous gravel and coarse sand.

Landslips in the *Craigburn* area are tentatively grouped into a younger and an older phase. Structures of the younger phase contain fresh fractures, are related to active clay flows, and occur on relatively steep slopes associated with contemporary erosional features, namely the shore and a creek. The older phase is considered to be responsible for the disruption of the basalt horizon which overlies the sediments thus giving rise to the isolated masses of basalt on the lower slopes. Morphological features produced during the older phase include the trenches along the shoulders of the ridges. Talus on the walls of these indicate formation in Pleistocene or earlier times. Although an analogy may exist between land failure near *Craigburn* and at Beauty Point it is not obvious on the basis of observations derived solely from Beauty Point. Because of the absence of morphological development comparable with the younger structures at *Craigburn* it is suggested that failure in the currently active areas at Beauty Point is in its relative infancy and was possibly triggered by artificial factors. The terraces and trenches below the shoulder of the ridge might be comparable with the older morphological features at *Craigburn*. In each area it is suggested that any large-scale failure involved gliding of the near-surface materials over stable material rather than deep-seated rotational slip failure. It is also suggested that failure extended below present river level.

Introduction

This report is based on information collected during a brief surface geological mapping program carried out during the winter of 1974. Each area has been mapped previously by the Geological Survey (Gee and Legge, 1974) and separately by F. L. Sutherland (1971). Jennings (1964) reported on land stability at Beauty Point.

The conclusions cited in this report are ranked mainly as possibilities and some as probabilities. Thus no practical criteria are established herein whereby the type of land zonation already undertaken by the Geological Survey can be refined. To upgrade the conclusions to probabilities and proven facts would require substantial further work. It is felt that there is a reasonable chance that improved criteria would result from a detailed and comprehensive survey of the Tamar Valley.

In respect of detailed surface geological mapping the prime problem near the *Craigburn* property, on the eastern shore of the River Tamar (495 555 mE, 5 435 700 mN), and at Beauty Point on the western shore (485 000 mE, 5 443 500 mN), is lack of exposure. Contacts shown on the maps are between soil types. Because each area has been subject to landslip of unknown mechanism(s) and probably also to creep phenomena, the soils are almost certainly not in situ and, therefore, the relationship of their boundaries to the underlying deposits remains to be established. In addition it cannot be assumed that the soil composition either faithfully or totally reflects the composition of the underlying deposits and thus the stratigraphy cannot be established. For these reasons the soil boundaries do not provide a basis from which the subsurface attitude of a stratigraphic horizon or interface can be inferred. This deficiency, combined with lack of suitable outcrop from which dips and strikes can be obtained, make it impossible to prove the existence and amount of displacement of beds and thus to define the geometry of slip structures. This point is considered relevant because it is felt that the morphological features are not diagnostic in themselves of the form and mechanism of the land failure.

Part I: Craigburn

Stratigraphy

SEDIMENTS

Exposure of these sediments (fig. 1) is very poor except along the shoreline. A clay-rich facies and a well-sorted sand facies have been inferred on the basis of isolated exposures and soil type. No information was obtained concerning how the facies are related to one another but the area mapped is small and more information might be forthcoming if a larger area is investigated. An Eocene microflora was found in material collected on the north side of Spring Bay (Harris, 1968).

Clay-rich facies

Exposures of this facies comprise mainly silty and sandy clay with minor clay and clayey sand and silt. These sediments can be micaceous and are commonly mottled cream, fawn and brown. Because of widespread disruption associated with landslip, bedding is poorly preserved and no other sedimentary structures were observed. Lag of well-rounded quartz and quartzite pebbles, probably derived from the unit, were found in one very small locality. Lag derived from silty clay and consisting of hard, massive, pale grey, very fine-grained, thinly bedded carbonate material occurs along the shoreline but was not found inland. Partial analysis of the carbonate by the Department of Mines Launceston Laboratory, under the instruction of W. L. Matthews, is recorded in Table 1. This analysis indicates that the carbonate contains a little under 70% siderite. Fossils of plant fragments and of non-fragmented, large pelecypods are numerous, either in the carbonate or as lag associated with it.

Table 1

Analysis of sample of Tertiary siderite from Spring Bay

Fe (%)	29.5
Ca (%)	2.1
Mg (%)	0.75
FeO (approx. %)	42.5
CaO (approx. %)	2.9
MgO (approx. %)	1.25
$FeCO_3$ (approx. %)	68.5
$CaCO_3$ (approx. %)	5.2
$MgCO_3$ (approx. %)	2.6
Loss on ignition (%)	29.3

Sample 742020
Analayst L. M. Hay

Sand facies

There are isolated exposures of unconsolidated, medium-grained quartz sand east of *Craigburn*. The sand contains no clay material, is fairly well sorted, and varies in colour from pink to yellow to brown. No bedding was observed.

BASALT

Basalt throughout the area is of similar type. It is generally coarse grained and texturally it is a dolerite. Sutherland (1971) has described its petrography in some detail. It is an undersaturated olivine basalt.

WEATHERING EFFECTS

There is abundant evidence of chemical weathering in the sediments. Solution and redeposition of iron has been widespread and limonitic materials occur in veinlets and in bodies which range in form from highly regular to highly irregular. The form of these bodies is related to the kind of material in which they occur. In the silty and sandy clay the bodies are fairly regular and rounded, with the outer parts comprised of thin concentric shells of limonite and the inner parts comprised of fairly uniform, granular limonite commonly containing disseminated grains of fine white mica. Limonite bodies in the more sandy materials are less regular in form and the concentric shell structure is cruder. In the well-sorted sand unit they are very irregular. Some have a core with subspherical form and some show development of shells but in each case the structure is very crude.

In contrast the limonite bodies associated with the carbonate material can have strikingly regular form. Near perfect discoidal forms are common in places along the shore and are especially numerous around 495 360 mE, 5 436 860 mN. They range in diameter up to 150–200 mm and up to about 70 mm in thickness. Some consist entirely of very well developed, concentric shells of limonite. In others only the outer part consists of limonite shells and the core consists of quite fresh carbonate. The implication is, therefore, that the limonite has encroached inwards from the external surface by successively replacing, probably by alteration, thin skins of carbonate.

Blocky carbonate material about 300 mm thick occurs at this location. This material shows no tendency towards discoidal development but the outer parts do consist of very well developed, discrete shells of limonite. Although the quality of development of the limonite shells is clearly a function of rock composition the reason for the discoidal form is not clear. It may be the natural tendency of the limonite replacement mechanism to tend towards symmetrical forms, as is the case with spheroidal weathering in basic rocks. The tendency to discoids rather than spheroids may be due to the carbonate originally being thinly bedded. The fact that the long axes of fossil plant fragments and

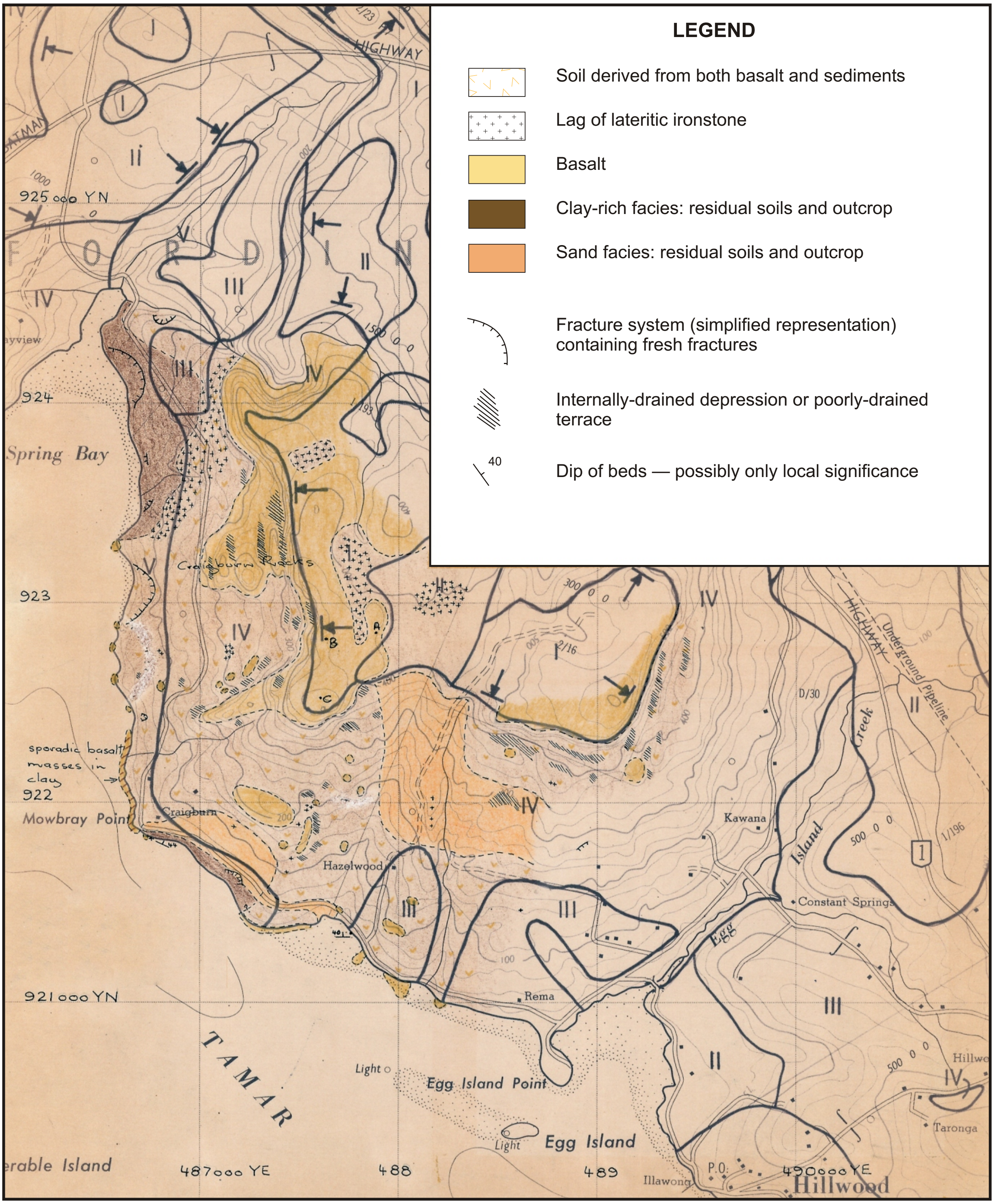

Figure 1
Geological map of the Craigburn area

shells lie sub-parallel to the planes of the discoids implies that this was the bedding direction.

Alternatively the discoid form may he inherited from a sedimentary form or even an earlier replacement form. The latter possibility arises from the fact that the abundant pelycypod fossils show the same characteristics of limonite replacement as the sideritic material. As the fossils were presumably originally calcareous it might be that the sideritic component of the materials was introduced after deposition. Because of the disruption of the surrounding silty clay there is no indication of the original stratigraphic detail.

In view of the considerable extent of chemical weathering the particular problem of the silty and sandy clays is their original composition, that is whether they were deposited as clay-rich sediments or as sediments rich in labile constituents which have been subsequently altered to clay by chemical weathering.

There are several lines of evidence bearing on the original fabric of these materials. The limonitic bodies preserve at least some of the original fabric elements. Well preserved fossil plant leaves and stems occur in limonitic material at about 495 440 mE, 5 437 960 mN. By their disposition the fossils define surfaces to which mica grains lie parallel, and these surfaces are certainly original bedding. Grains of quartz and pseudomorphed labile grains also occur. Grains such as these cannot generally be detected within other limonite bodies, although their interiors commonly have a fine granular texture and contain disseminated flakes of mica.

Fossil plant stems also occur. Although none comparable with those found at 495 440 mE, 5 437 960 mN were observed the fossils do indicate that the internal fabric of the bodies in which they occur has not been disrupted.

The granular texture of the limonite bodies might result from pseudomorphing of original labile grains. Gidigasu (1974) summarised work which indicates that alumino-ferruginous sesquioxides can coat and cement clay particles such that a pseudo-silt or pseudo-sand texture is produced. No evidence bearing directly on this problem was established. In several localities (e.g. near 495 551 mE, 5 436 311 mN; 496 295 mE, 5 435 132 mN) materials not cemented by limonite are sufficiently well preserved to show original fabric. These materials are sand containing a large proportion of labile grains which have been pseudomorphed by clay. No limonite bodies were observed but limonite veinlets are common. Fine-grained sediments which were probably originally clay-rich are associated with the sand at 496 295 mE, 5 435 132 mN. In addition to these clear examples of original labile grains being pseudomorphed, the colour mottling in the disrupted clay-rich materials is suggestive of an original granularity in many exposures.

In conclusion it can be stated that the clay-rich materials are at least in part derived from sediments consisting of labile minerals, probably feldspar and possibly some others. Longman (1966) concluded that 75% of the outcrop of Tertiary sediments in the Launceston area comprises sand in which feldspar was the main component. No estimate of the proportion of material at *Craigburn* derived from feldspathic sands can be made on the basis of information to hand.

In addition to the limonitic materials occurring either within, or as lag of, the sediments small pisoliths of limonite occur in the soils throughout the area and in places there are scattered fragments of ironstone up to 300 mm across. The ironstone can have a cellular or sponge-like framework formed by limonitic material with fine-grained, whitish, friable material occurring in the cavities. Alternatively it can consist of limonitic pisoliths ranging in size up to a few centimetres across and contained in a matrix of friable, fine-grained, angular quartz grains. In some cases the matrix contains a large proportion of clay.

Although neither solid outcrop nor a typical lateritic profile were observed the ironstone fragments are considered to have been derived from a lateritic crust because of their hand specimen characteristics. The ironstone contains basalt fragments and is, therefore, younger. Fragments of pseudomorphed, fibrous material of woody appearance were observed in the ironstone in one locality (about 495 625 mE, 5 437 775 mN) and are thought to be fossil stem fragments.

Landslips

DESCRIPTION

It is tentatively suggested that there have been two phases of land failure at *Craigburn*, an older phase and a younger phase. Morphological features ascribed to the younger phase contain fresh fractures, are associated with active clay flows, and occur on relatively steep slopes adjacent either to the shore or to a creek. The old phase is seen as having caused the present distribution of basalt masses on the lower slopes. Morphological features extant from the older phase include the trenches just below the shoulders of the ridges and probably some of the structures on the middle slopes, many of which show little indication of recent activity.

Younger Phase

The clay-rich sediments are in active failure in most places along the foreshore. They are commonly undercut such that vertical faces ranging from 0.6 to four metres in height occur along the back of the beach. These faces are collapsing both by materials falling away from them and by materials flowing out from their bases. In many places the flows extend for up to four metres out across the beach shingle and show a well developed planar fabric perpendicular to their flow direction. The bulk of the material, that is the clay component, is removed by the river as suspensoids.

Slip structures of considerable size occur on the relatively steep slopes adjacent to the shore. These are associated with the clay flows (a good example occurs at about 495 830 mE, 5 435 400 mN). A structure also occurs on the relatively steep slope adjacent to the creek at about 495 440 mE, 5 437 955 mN. Here the surface morphology of the slip structures comprises numerous individual fractures of limited displacement and length which form composite structures that in plan are semi-circular and open downslope. Many fractures are fresh and un-vegetated. The sense of movement on them is generally downslope side down. At the back of the structure, adjacent to the creek, the fractures form a graben but with maximum displacement on the up-slope fracture. Ponding and poor drainage are common in the areas between fractures but the sense of rotation of the slipped blocks is always such that their surfaces dip up-slope. Tilted trees are present in a structure at 495 364 mE, 5 436 675 mN.

Older Phase

Along the shore the basalt occurs as isolated patches resting in the clay. The patches consist of joint blocks which approximately retain their orientation one to another, with some patches elongated roughly perpendicular to the shore. Clay has intruded along many joint surfaces. Isolated patches of basalt also occur in the soils on the lower slopes of the ridge. All these exposures are of a similar type of basalt to that which occurs on the ridge tops and their present isolation is considered to have resulted from fragmentation of the perimeter of the main basalt sheet and downslope translation. Because disrupted basalt occurs on the shore, it is inferred that the structure extended below present river level.

In addition to the basalt distribution there are numerous morphological features indicative of land failure on the slopes behind the shore and below the shoulders of the ridges. Depressions or terraces that are either internally or poorly drained are the common landforms. There are spectacular examples at Craigburn Rocks where trench-like depressions transect the spur of basalt. The largest is about 350 m long by 100 m wide and up to 30 m deep. The sides and floors of the depressions are covered by scree, and the total depth of the structures may therefore be greater than the topographic depth.

Similar, but shallower, structures occur around the shoulder of the ridge above *Kawana*. On the lower slopes, which are covered by soil and basalt debris, the structures are either terraces or very shallow, semi-circular depressions rather than trenches. Their upslope sides are formed by relatively steep, low rises which curve around the structure. No fresh fractures were observed. Except in farmed areas the structures are well vegetated and no tilting of trees was observed.

FACTORS RELATING TO CAUSE AND MECHANISM

A fundamental cause of the landslips is the inadequate bearing strength of the Tertiary deposits. As discussed earlier it is likely that a significant proportion of these deposits has undergone mineralogical and probably volumetric change since deposition. Such change would produce materials of very low physical strength. The ability of the Tertiary deposits to maintain steep topography has probably been inadequate since these changes occurred. There is variation in bearing strength within the deposits, as is demonstrated by the fact that steep slopes adjacent to the shoreline have failed in particular places rather than generally. This variation might be due to inhomogeneities in either facies or water distribution.

Given the fundamental requirement of weak materials there are then other causes of landslip. In respect of the group of structures which have been classed as younger, there is a clear correlation between them and contemporary erosional features. These younger structures occur on relatively steep slopes adjacent either to the shore or to the creek, and are associated with the clay flows along the shore. Were it not prevented from accumulating, this material would form a toe to each structure. In the structure adjacent to the creek a toe has formed. Here erosion by the stream has not been rapid enough to remove the material as it has flowed out and the stream has consequently been displaced and is currently undercutting the toe material. As a group the younger structures occur on slopes at the bases of which the lateral support of the groundmass has been removed by erosion. The same erosive forces prevent accumulation of stabilising toes. Slope failure has probably been an active process in the vicinity of the shore throughout the development of the present shore platform.

Insufficient observations can be made at the surface to determine the mechanism of failure. A mechanism can only be proved if the subsurface geometry is known. It might be rotational slip (Varnes, 1958) or it may simply be collapse of the more competent surface horizons in the course of the outflow of a fluid substratum.

In respect of the older phase of land failure, the average gradient of the terrain affected is less than that affected by the younger phase, perhaps indicating failure under different conditions of materials or climate. It is thought that the materials were much the same, as failure appears to have post-dated the phase of deep weathering. This inference is based on the correspondence between the southern termination of the ironstone lag and the northernmost occurrence of basalt on the shore in the vicinity of 495 450 mE, 5 437 040 mN. Although caution should be adopted when using a lateritic horizon as a marker, the correspondence is notable and probably marks the northern boundary of the older failure. The line also corresponds roughly with the northernmost

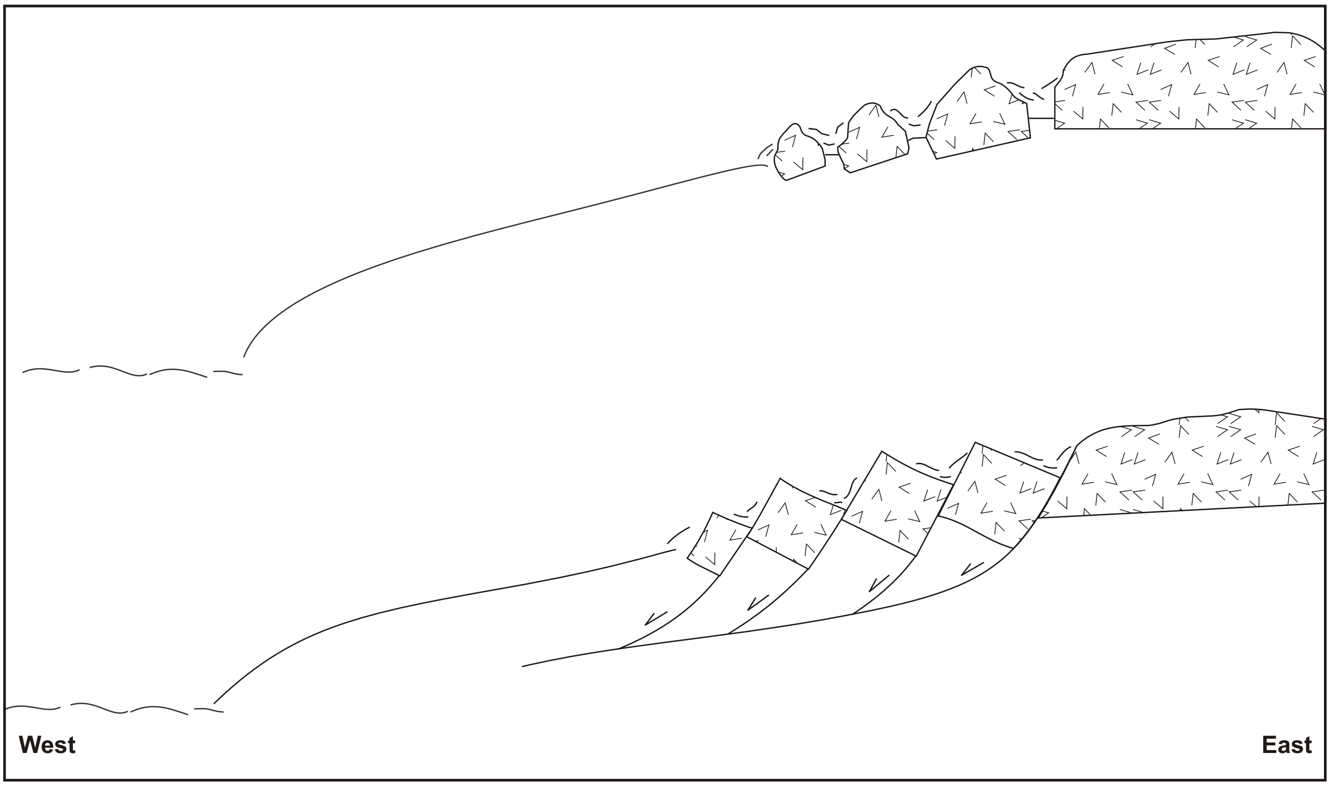

Figure 2

Diagrammatic representation of possible modes of failure at Craigburn Rocks

morphological features at the basalt perimeter. Thus the boundary of the slip transects the lateritic horizon and is, therefore, younger.

It has been indicated that fragmentation of the basalt perimeter, combined with substantial downslope translation, were processes involved in the older phase of failure. The trench-like depressions along the perimeter of the basalt are considered to indicate failure containing a component of tension. Models of two possible modes of failure are shown in Figure 2. It might be possible to distinguish between these mechanisms by carrying out a statistical survey of joint attitudes at Craigburn Rocks. If a consistent pattern shows up in the undisturbed rocks on the ridge top and a similar, but rotated, pattern shows up in the various blocks between the trenches then the sense of rotation could be determined and a preference established for one or other of the models. Sutherland (1971, plate 5) speculated that part of the spur is tilted but a careful survey of the joint attitudes would be necessary to prove this and even then caution would be necessary as the original attitude of the joints may have been related to the original attitude of the base of the basalt. On subjective assessment the sense of rotation is anticlockwise when viewed from the south thus indicating a slumping and gliding mechanism.

In themselves the trenches indicate very little translation. However some assessment can be made of this aspect based on consideration of the attitude of the base of the basalt. If the boundaries, as shown on the map of the basalt which forms the ridge top, approximate to the base of the basalt then northeast of *Craigburn* the base dips west to northwest at an inclination not much different to the average topographic inclination. Although there are local irregularities, as demonstrated by the steep easterly dip in the creek near 495 898 mE, 5 437 869 mN, there is no indication of any irregularity along the southern boundary. On the ridge above *Kawana* the base is approximately horizontal. It follows that if there is only one horizon of basalt then the exposures on the southern and eastern slopes have undergone substantial translation.

The thickness of materials involved in the older failure was probably not great because the accumulation of soil and debris on the slopes appears to be thin. This is in accord with the mechanism of failure suggested above.

FACTORS RELATING TO AGE

The structures ascribed to the younger phase of failure are considered to be young because:

1. They are associated with active clay flows.
2. They contain fresh, un-vegetated fractures.
3. Trees within the structure at 495 364 mE, 5 436 675 mN have been tilted during growth.
4. They are genetically related to modern erosional features.

As stated earlier it is considered that landslip has probably been an integral process in the formation of the present shore which commenced shortly after the present river level was established, that is, in post-Pleistocene times. Clearing and agricultural development may have accelerated land failure in modern times.

Little worthwhile knowledge was obtained from locals concerning the history of land failure in the area. Apparently failure was occurring near the shore below Craigburn Rocks in the early 1920s.

The older phase of land failure is considered to be so because:

1. The shore and some of the younger structures are superimposed on the mixed debris produced by the old failure.
2. Scree occurs on the walls of the depressions at Craigburn Rocks and is particularly well developed on the scarp at the shoulder of the ridge above *Kawana*. Geomorphologists express the view that this type of deposit is the product of periglacial conditions. Therefore, the depressions and scarp are of Pleistocene or older age. It was noted previously that the land failure appears to post-date the period of lateritisation.

A problem is presented by the structures occurring on the middle slopes, many of which are complete in themselves. As they are superimposed on the mixed materials, they were produced after translation occurred but as they contain no features indicative of recent activity they are grouped with the older phase of failure. This criterion is weak and it might be that these structures represented a mode of failure intervening between the initial major phase and the younger phase.

FURTHER WORK

1. Diamond drill hole at A (496 461 mE, 5 436 596 mN) (fig. 1);

   Objective: To establish the stratigraphy to Mesozoic basement.

2. Holes at B (496 280 mE, 5 436 502 mN) and C (496 283 mE, 5 436 228 mN) (fig. 1);

   Objective: Use A, B, and C to establish the dip of the base of the basalt and to establish the relationship of the actual base to the mapped boundaries.

3. Carry out statistical survey of joint attitudes at Craigburn Rocks;

   Objective: Establish sense of rotation of blocks.

4. Auger drill holes on the middle slopes;

   Objective: To establish the thickness of the accumulation of mixed debris.

5. Extend area of surface geological mapping;

   Objective: To establish the major and minor stratigraphic relationships.

Part 2: Beauty Point

Stratigraphy

TERTIARY

Exposure at Beauty Point is poor. As with the Craigburn map, the boundaries shown on the Beauty Point map are between types of superficial materials, and their relationship to the underlying deposits is uncertain. Two stratigraphic units are recognised. The lower unit contains sediments which on the basis of similarity of composition and weathering characteristics are correlated with those at *Craigburn*. Also present within the unit is basalt which is similar to, but finer grained than, the basalt at *Craigburn*. Overlying the lower unit disconformably is an upper unit consisting of clean, siliceous gravel and coarse sand. It has no equivalent at *Craigburn*.

LOWER UNIT

Sediments

Exposures of sediments of the lower unit comprise silty and sandy clay. Exposures are mainly on the shore and are best in the area south of the Port Dalrymple Yacht Club. The sediments are brown, yellow and light grey in colour and the colours are commonly mottled. The fabric of the materials is disrupted. Some subsurface information was procured by diamond drilling in 1962–1963. The deposits intersected were all clay-rich but a substantial proportion (?25–30%) show relict fine to medium sand grade texture. Relict grains of labile minerals are clearly evident in some sand together with quartz and mica grains.

A good example of a coarse-grained, poorly-sorted sand in which a large (?70–80%), original labile constituent has been pseudomorphed by clay occurs between 15 and 17 m in Hole 6, where a few thin horizons containing granules or pebbles of quartz were intersected. Fine white mica is common in both sand and clay. Fossils of leaves and stems are common and can be either moulds or carbonaceous remains. A few moulds of small pelecypods occur. Fossils are more common in the coarser materials and are absent from some clay.

Both fossils and mica flakes are orientated such that a strong planar fissility exists. This must define the bedding orientation which in all holes lies approximately perpendicular to the axis of the drill. As the holes were vertical the bedding in the areas drilled is approximately horizontal.

Additional subsurface information was obtained from an adit driven into the hill from the back of the beach below Crozier Street. Sideritic bands were encountered in the sediments excavated (I. B. Jennings, pers. comm.).

Basalt

Basalt crops out in several places along the upper boundary of the lower unit. The maximum exposed thickness is about 4.5 m on the scarp south of Bagot Street but neither the bottom nor the top was observed. Because the basalt has been subject to lateritic weathering followed by erosion prior to deposition of the upper unit, the original thickness might have been substantial. A thickness of the order of 15 m is indicated by discontinuous exposure near the intersection of Napier and Oxford streets and the base was not observed.

At Inspection Head a thickness of about 16.7 m of basalt is exposed, with the top not seen. The base crops out on the shore north of Inspection Head and is sub-horizontal over the few metres that it is exposed. Two diamond-drill holes were drilled in the vicinity in 1963 but neither the positions nor the altitudes of the collar points are known. One hole intersected sediments to a depth of 25.15 m, the other intersected superficial material to 4.8 m and basalt to 22.5 m. The hole was apparently stopped in basalt.

Minor exposures of basalt occur on Flinders Street, close to Ross Street, and on the shore from Inspection Head to just south of the Beauty Point jetty.

All exposures are of a uniform, fine-gained, doleritic basalt containing sparse amygdules filled by botryoidal chalcedony and other minerals. The rock is a near-saturated olivine basalt (Sutherland, 1971). Sutherland has suggested that there were two phases of basalt extrusion in the Tamar Valley separated by a period of sedimentation, and he includes the exposure at Inspection Head in the lower phase. In view of the possibility of the basalt base being controlled by pre-existing topography and the possibility of substantial fragmentation of the basalt by landslip, it is considered that there is no substantial evidence to hand justifying such a division of the Beauty Point basalt. Neither of the deeper drill holes (holes 2 and 6) intersected a lower horizon of basalt and no substantial evidence has been presented in respect of any other area in the Tamar Valley.

UPPER UNIT

The disconformity between the upper and lower units is exposed in the cutting at Bagot Street hall (fig. 3), where channels filled with poorly-sorted siliceous gravel are incised in weathered basalt. Poorly-sorted gravel containing well rounded quartz and quartzite pebbles is widespread. The gravel's finer fraction is angular, and coarse angular sand is also widespread. Better sorted medium-grained sand interbedded with gravel is exposed on the scarp in Bagot Street, and similar material occurs in Ross Street just above Flinders Street. No good sections are exposed, and the stratigraphic relationships between the various materials were not determined. The unit is considered

Figure 3

Regional map of the Beauty Point area

Qa = Low level surface covered by silt and gravel
Qs = Soil
Tg,s = Well washed gravel and sand
Tb,c = Basalt and clay, probably some coarse clastic fragments
Jdl = Jurassic dolerite
TRs = Triassic sandstone
= Low scarp

to probably be of Tertiary age because it has been deeply dissected.

QUATERNARY

Because it forms a single geomorphological unit which post-dates dissection of the Tertiary strata, the flat country around Illfraville is mapped as Quaternary. Because there is sporadic outcrop of Triassic sedimentary rocks and Jurassic dolerite along the entire length of shore which forms part of the unit's perimeter, and because there is outcrop of dolerite at the foot of the slope behind the flat country, the Quaternary deposits are thought to be thin. They consist of sand, silt and coarse gravel.

WEATHERING EFFECTS

The silty and sandy clays along the foreshore show very similar weathering characteristics to those exposed near *Craigburn*. Limonitic materials occur both in veins and in bodies which are generally of fairly regular form. Limonitic bodies of substantially larger size than any observed at *Craigburn* occur south of the Port Dalrymple Yacht Club, ranging up to one metre across and lenticular in section. Sutherland (1971, plate 1) figures a limonitic body of similar type from Ruffins Bay. The outer parts of the bodies comprise concentric shells of limonite, while the inner parts consist of granular limonite and disseminated mica. Fossil plant fragments occur.

The problem of the origin of these bodies and their relationship to the disrupted clay-rich materials in which they occur is the same as has already been discussed in respect of the bodies occurring at *Craigburn*. The proposition is that they were produced during the course of chemical weathering and preserve some aspects of the original texture which has been eliminated from the surrounding materials by subsequent disruption. The aspects preserved indicate that the original deposits consisted in part of labile minerals. This conclusion is supported by the drill hole information discussed above. Banded limonitic material was intersected at about seven metres in Hole 7.

Clay-rich materials showing relict texture are exposed in the cutting at Bagot Street hall (fig. 3), in a laneway about 200 m north of the hall, and in fractures at the top of part of the steep slope in the main slip area south of Beauty Point jetty. These materials show a sand-grade granularity and are finely mottled dark bluish-grey and white. They are massive, uniform, even grained and show no bedding structure, and contain veinlets of soft white material. Very similar material occurs in the leached zone of a lateritic profile developed on basalt and exposed near 484 776 mE, 5 443 409 mN. This profile passes from fresh basalt into textured clay-rich material and is capped by a ferruginous, pisolitic horizon which is overlain by coarse sand of the upper unit. In addition to being similar in hand specimen, the material at Bagot Street hall occupies the same stratigraphic position. These facts are considered proof that the material at the hall was produced by lateritic weathering of basalt. Pisolitic ironstone lag occurs in association with basalt lag just south of Bagot Street, but is not present in the cutting. Comparison of the sequences at the hall and at 484 776 mE, 5 443 409 mN indicates that the laterite pre-dates the upper unit and was eroded at the hall but preserved at 484 776 mE, 5 443 409 mN. Although the stratigraphic relationships are not exposed the textured clays in the other two localities are correlated with the hall exposure on the basis of hand specimen similarity. At TEMCO, Bell Bay, McLaren and Taylor (1961) found 'soft clay either blue or brown in colour and resulting from in situ decomposition of the basalt' overlying much of the basalt. Similar material was also found in places at the base. Where the base of the basalt is exposed at Inspection Head no such alteration is evident.

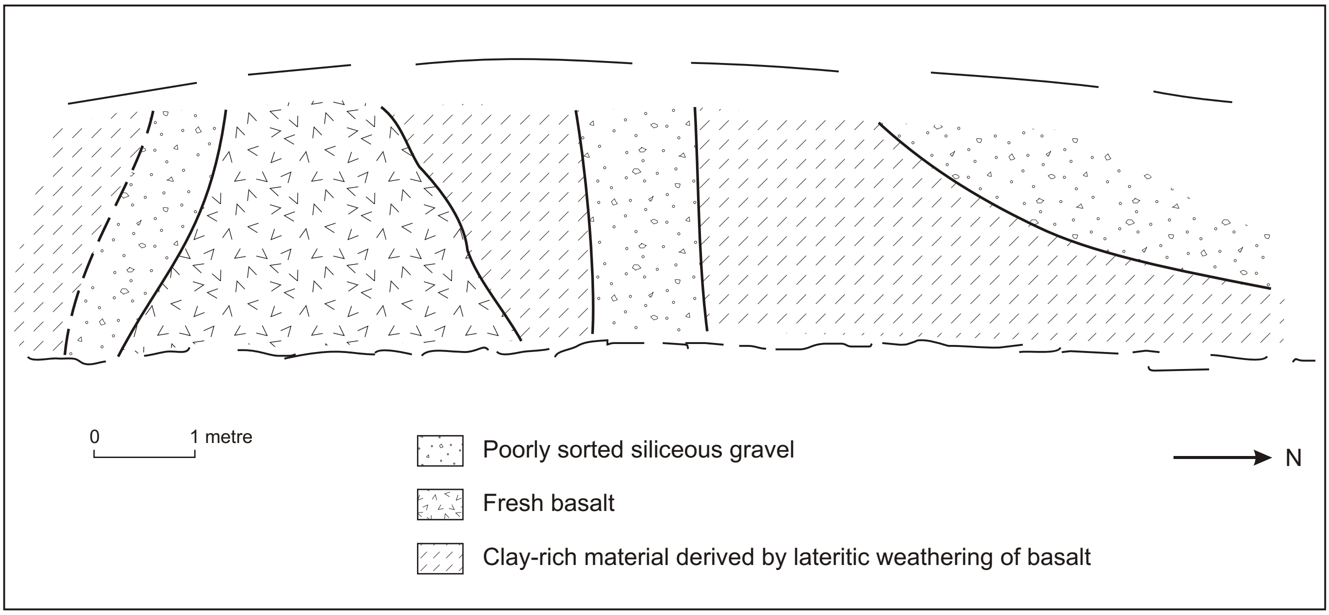

Figure 4

Relationships of rocks in cutting at Bagot Street hall, Beauty Point

Landslips

GENERAL DISCUSSION

There is some evidence that the history of land failure at Beauty Point is comparable to that at *Craigburn*. Certainly the underlying geology of each area is very similar.

The height of the undercut face at the back of the beach at Beauty Point is substantially less than near *Craigburn*, possibly because the beach has an easterly facing aspect rather than westerly. Although the disrupted clays exposed in the undercut face can be seen to have moved out over the beach shingle for up to 600 mm in several places none of the very low viscosity flows such as occur at *Craigburn* were observed. No correlation was observed between clay movement on the shore and obvious morphological features on the adjacent slopes. Although the areas which are undergoing obvious active failure are located on the relatively steep slopes adjacent to the shore, they do not show a stage of morphological development comparable with the structures adjacent to the shore at *Craigburn* and for this reason they are considered to be relatively young.

Morphological features in the main slip zone south of the Beauty Point jetty comprise fractures along the top of the slope which show little displacement, and one structure near 485 144 mE, 5 443 139 mN which shows a similar trend in development to the structures at *Craigburn*. Its upslope portion is at the top of the relatively steep slope and consists of an arcuate system of fractures on which there is downslope-side down displacement, while the downslope portion consists of a clay flow. The clay flow has its origin in a cutting beside the road which runs along the base of the slope and when active (during the winter) causes obstruction of the road and is therefore periodically removed. This artificial situation is analogous to the natural situation at *Craigburn* where natural erosion has removed the lateral constraining load at the bottom of the slope and prevents accumulation of a stabilising toe.

It is suspected that the entire failure in the main zone at Beauty Point was triggered by artificial modification of the slope. Apart from clearing of vegetation and construction of buildings, two other important artificial factors have affected the slope.

In 1886 a tramway was constructed along the middle slope to provide access to the Beauty Point jetty. The cutting would have removed the lateral restraining load from the uphill side thus probably inducing failure of the type currently associated with the road cutting. The absence of any remnants of the cutting is presumed to be a result of this failure. Also in the early days a wooden water pipe was laid from the springs near 484 965 mE, 5 442 863 mN to the jetty. Numerous maintenance problems were encountered with the pipe and leakages would have given rise to water content on the slope in excess of normal.

The second area of recent landslip activity at Beauty Point is near the intersection of Crozier and Flinders streets. This has been artificially stabilised by deep piling and no worthwhile observations were made at the location.

In addition to the zones of recent movement there are numerous morphological features on the higher slopes indicative of land failure. A scarp extends along the entire length of the shoulder of the ridge behind the township. Along its base there are internally or poorly drained, trench-like depressions and terraces. It is the view of the writer that although these morphological features are indicative of landslip they are not diagnostic of the form or extent of movement. It is regarded as essential that the subsurface geometry be established and the surface morphology interpreted in terms of this geometry. This requires the tracing of a suitable marker horizon.

On the basis of the information to hand the stratigraphy can be summarised as follows.

- A lower unit consists of sediments of fine facies and containing very little coarse material. Bedding in the unit is sub-horizontal.
- This unit is overlain by a basalt horizon with a maximum thickness of at least 15 metres. Because of deep weathering and subsequent erosion, the lateral variation in thickness of the basalt might be quite substantial.
- An upper unit of coarse facies overlies the basalt.

As stratigraphic marker horizons were not established in either the fine or coarse facies, the upper and lower contacts of the basalt are the surfaces of interest. Because of possible irregularities in their form caution should be adopted in using either to establish relative displacement. In respect of this last point consider the upper surface of the basalt. On the northwest slope of the ridge, where there are no landslip structures, the contact between the basalt-derived soils and soils derived from the upper unit varies in altitude between 41 and 44 metres. The contact can be fairly accurately located at 41 m altitude in Oxford Street and about 39.6 m near 484 776 mE, 5 443 409 mN. Thus, on a regional scale, the contact west of the scarp is flat-lying at an average altitude of about 42.6 m, and is therefore considered a useful stratigraphic marker.

Although the contact occurs at the top of the scarp, the scarp face is in most places mantled by talus derived from the upper unit, and the contact between the superficial materials does not correspond to the actual contact. The contact is exposed in the cutting at the Bagot Street hall at an altitude of 24.4 metres. This indicates a total relative vertical displacement of about 18 m in the zone between the scarp and the hall.

The surface morphology of this zone comprises a series of stepping-down terraces covered by material of the upper unit. The contact can be approximately located at the eastern end of Ross Street. Coarse materials cap the small rise and are correlated with the upper unit and basalt outcrops below the rise on Flinders Street.

This implies the contact occurs between 18.2 and 19.8 m, thus indicating a displacement of 16.7 to 24.4 m relative to the scarp. The distinctive morphology in this locality comprises a poorly drained elongate depression between the scarp and the small rise.

These observations give some indication of the magnitude of vertical displacement associated with the failure which produced the scarp. The sporadic basalt exposures on the shore and in the main slip area indicate additional vertical displacement on the lower slopes, presumably extending below present river level. The absence of basalt in drill hole 6, which was collared in the depression below the scarp, demonstrates a component of lateral translation. Further work is required to determine whether the failure involved a deep-seated rotational slip or an essentially shallow gliding mechanism.

Further work

1. A diamond-drill hole collared west of the scarp.

   Objective: To determine the stratigraphy to Mesozoic basement.
2. Additional auger holes west of the scarp.

   Objective: Confirm the attitude of the basalt surface.
3. A series of auger holes down Bagot Street and near the eastern end of Ross Street.

   Objective: To determine the form of the upper surface of the basalt.
4. A series of auger holes in the main slip area.

   Objective: To determine the lateral extent and attitude of the weathered basalt.

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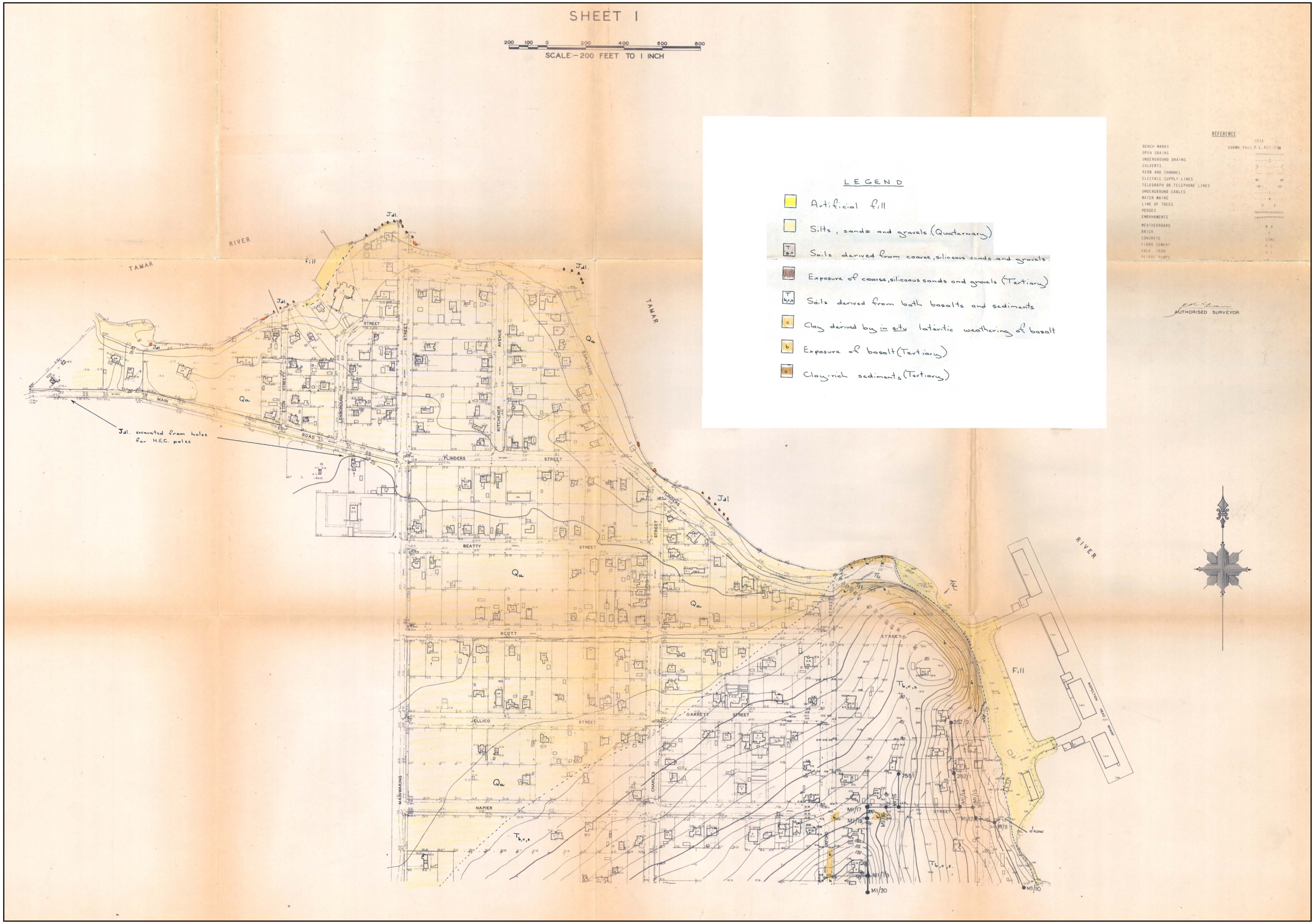
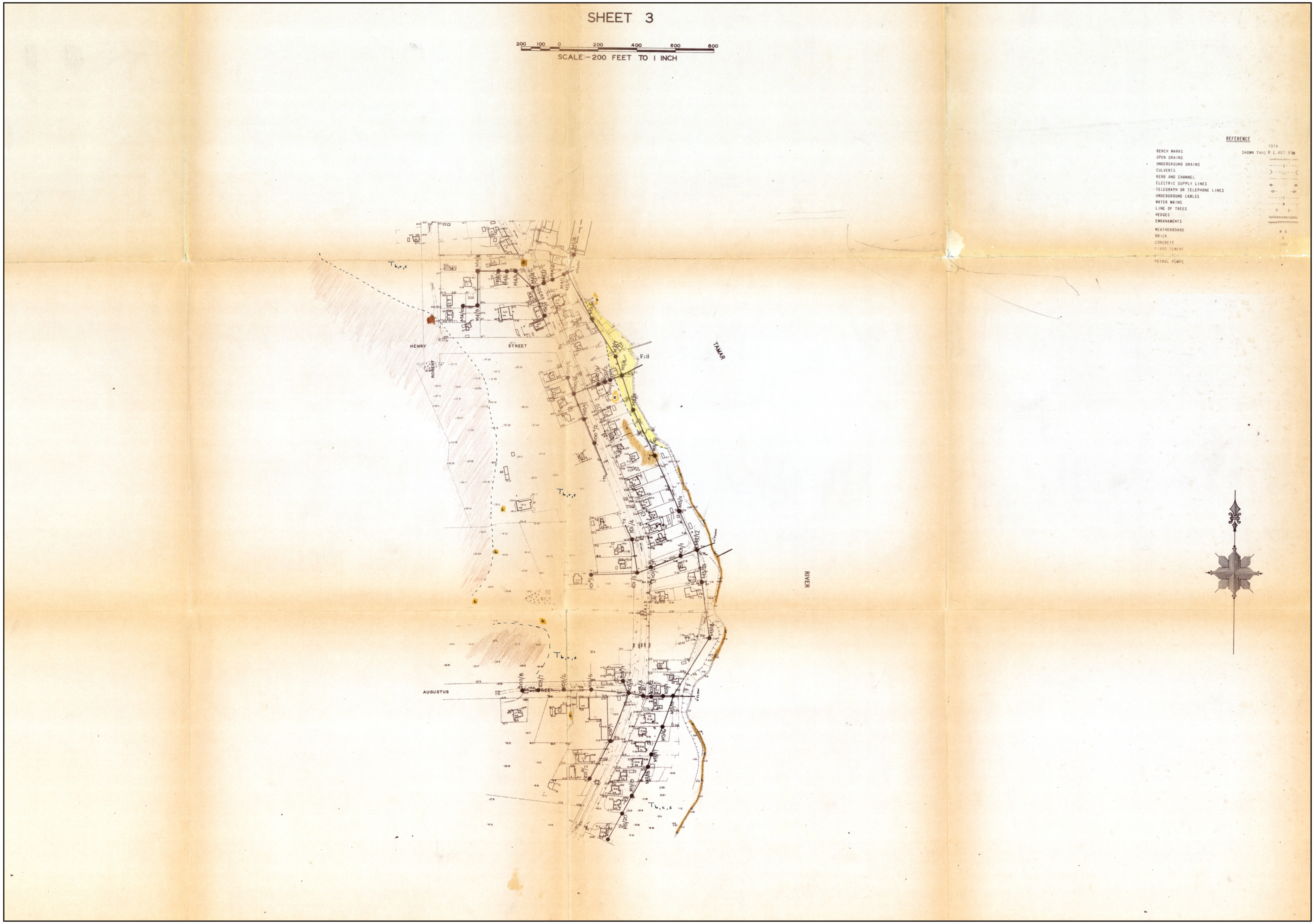
APPENDIX 1

Detailed maps, Beauty Point area


SHEET I
200 100 0 200 400 600 800
SCALE:- 200 FEET TO 1 INCH
LEGEND
Artificial fill
Silts, sands and gravels (Quatarwary)
Soils derived from coarse, siliceous sands and gravels.
Exposure of coarse, siliceous sands and gravels (Tertiary)
Soils derived from both basalts and sediments
Clay derived by in situ lateritic weathering of basalt
Exposure of basalt (Tertiary)
Clay-rich sediments (Tertiary)
REFERENCE
AUTHORISED SURVEYOR
TAMAR RIVER
TAMAR RIVER
Fill
Jdl.
Jdl. excavated from holes for H.E.C. poles
Qa
MAIN ROAD
FLINDERS STREET
BEATTY STREET
SCOTT
JELLICO STREET
NAPIER
GARRETT STREET
KITCHENER AVENUE
MAINWARING
CHARLES
ESPLANADE
Fill
Tb,c,s
M1/10
M1/20
d'FLOW

SHEET 2
200 100 0 200 400 600 800
SCALE - 200 FEET TO 1 INCH
REFERENCE
BENCH MARKS
OPEN DRAINS
UNDERGROUND DRAINS
CULVERTS
KERB AND CHANNEL
ELECTRIC SUPPLY LINES
TELEGRAPH OR TELEPHONE LINES
UNDERGROUND CABLES
WATER MAINS
LINE OF TREES
HEDGES
EMBANKMENTS
WEATHERBOARD
BRICK
CONCRETE
FIBRO CEMENT
GALV. IRON
PETROL PUMPS
NAPIER
ERNEST STREET
ROSS
CHARLES STREET
MAINWARING STREET
CROZIER
OXFORD
BAGOT
STREET
FLINDERS
ROBERT STREET
TAMAR
RIVER
Fill
Piles.
Rubble of Laterite


SHEET 3
200 100 0 200 400 600 800
SCALE:-200 FEET TO 1 INCH
HENRY
STREET
ROBERT
TAMAR
RIVER
AUGUSTUS
REFERENCE
1074
BENCH MARKS
SHOWN THUS R.L.467.97
OPEN DRAINS
UNDERGROUND DRAINS
CULVERTS
KERB AND CHANNEL
ELECTRIC SUPPLY LINES
TELEGRAPH OR TELEPHONE LINES
UNDERGROUND CABLES
WATER MAINS
LINE OF TREES
HEDGES
EMBANKMENTS
WEATHERBOARD
W B
BRICK
B
CONCRETE
FIBRO CEMENT
PETROL PUMPS