

Basalt at Breadalbane

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Date: 2008/9

Report No. UR2009_05

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General Geology

Near Breadalbane basalt is distributed over an area of about nine square kilometres. Competing land uses in the area include quarry operations and their associated buffer and future resource areas, and various residential, light industrial and rural developments. Launceston airport is also situated on the basalt.

An Ar-Ar age of 37 Ma indicates a late Eocene age for the basalt (Sutherland et al., 2006) and for the main part the basalt overlies a succession of older Eocene to Palaeocene age mudstone, siltstone and sandstone with minor lignite and conglomerate that was deposited in a graben or half-graben structure. To the west the basalt laps onto Jurassic dolerite that forms a horst structure. The same dolerite probably underlies the Palaeogene deposits within the graben.

By analogy to areas south of Perth it is possible that the basalt was once buried by sedimentary strata that were subsequently removed by erosion, but small pockets of sedimentary deposits may still exist above the basalt. These strata may include mudstone, sandstone and possibly gravel deposits.

Throughout much of the Northern Midlands these deposits are succeeded by a veneer of quartz gravel capped in places by a crust of Neogene laterite. More common is a series of younger quartz gravel terraces that descend from the level of the laterite crust towards the current river flood plains. Remnants of the quartz gravel deposits occur north of Evandale and extend towards Western Junction, but no large remnants of the quartz gravel or of the laterite have been mapped in the Breadalbane area. Unmapped small remnants of the quartz gravel or of laterite may be present, but the intense and deep weathering usually associated with the laterite surface seems to be absent from the area of the existing quarries.

In a generalised way the base of the basalt falls topographically from the exposed dolerite in the west towards the east where the valley of Rose Rivulet and its tributaries has eroded into the Paleogene sedimentary strata and the overlying basalt by backwards retreat.

The primary source of information regarding the distribution of the basalt is geological mapping by Blake (1959) and this, with scattered revisions, forms the basis of the current Prospect 1:25 000 digital geological map (Forsyth and Calver, 2003).

Estimates of basalt thickness can be made based on the structural contours drawn on the base of the basalt. To do this the elevation of the base of the basalt is determined at marginal areas and the structural contours inferred in the areas where the base is not exposed, based on a realistic model for the lower surface. The simplest model for the basalt base is a planar surface except where the control points around the periphery define some more complex form.

Additional control points come from a handful of water bores and quarry excavations where the quarries have passed through the base of the basalt and more recently from

quarry resource and planning drill holes and from two September 2008 exploration bores drilled south of the Stornoway (Raeburn) Quarry. See figure 1.

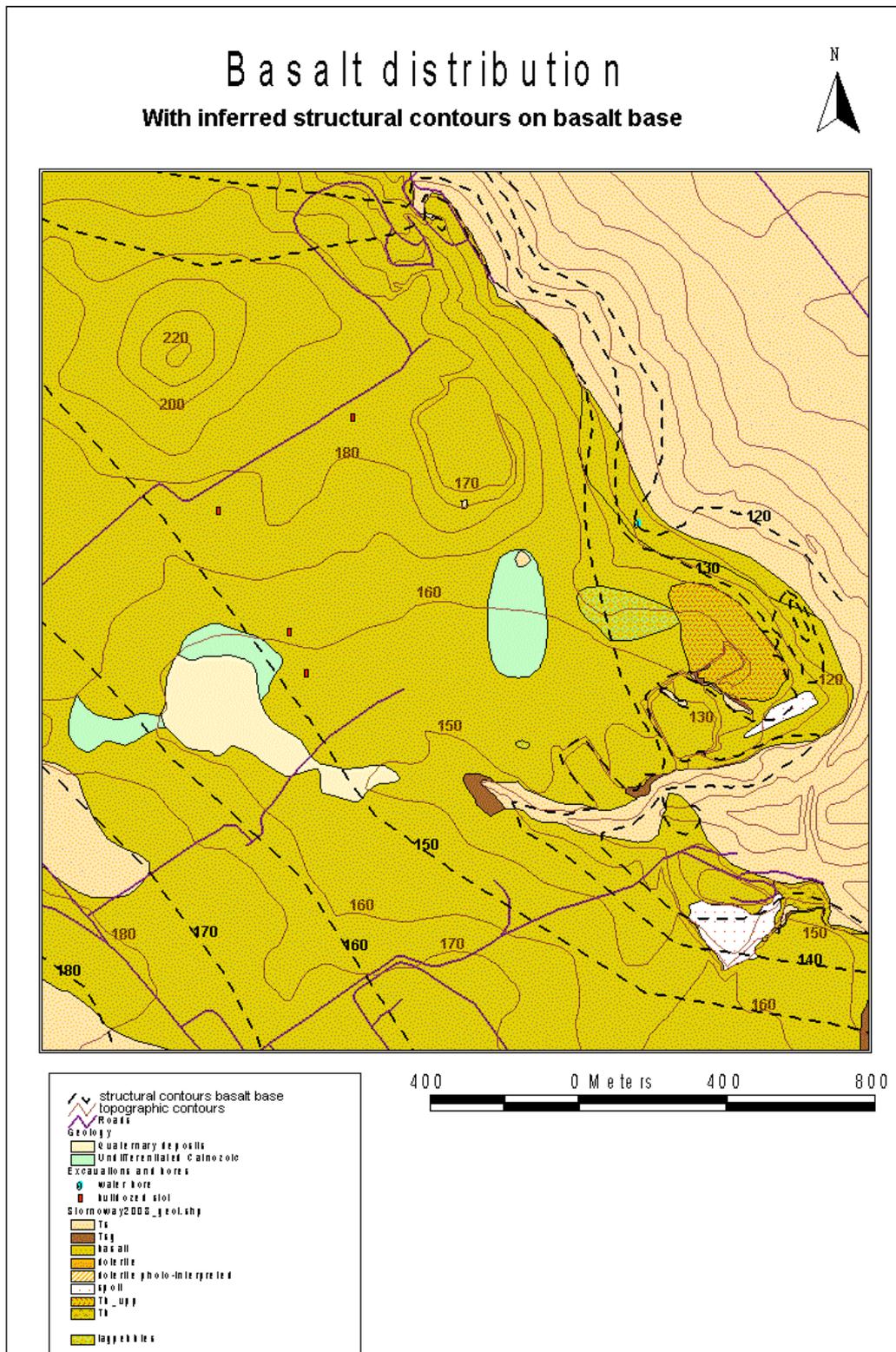


Fig.1

The basalt is not a uniform rock and this has enabled the quarry operations to produce a range of products, some derived from relatively hard unweathered basalt, to

products derived from weathered or altered rock. Contraction cooling joints occur through much of the basalt and these define columns of various diameters and inclinations. Some basalt is massive and some is vesicular or amygdaloidal containing zeolite (Sutherland, 1971). In recent years the basalt has been recognised to be a composite body composed of at least two separate lava flows with intervening sedimentary rocks including clayey siltstone, sandstone and conglomerate.

A review of the data that can be used to infer structural contours on the base of the basalt suggests that most of the data has deficiencies. Further there are indications that the basalt flowed over an eroded terrain (see also Stevenson & Jennings, 1977) and it seems likely that the eruptive vent (or vents) for the flows are buried in the same area as the flows. This probably indicates a more complex model is required to produce a realistic model of the lower basalt surface. There is too little data to build such a model.

Although some preliminary steps could be taken to reduce the deficiency of the existing data (see appendix), more drilling is probably required to provide further data that might help define the basal geometry of the basalt.

Stornoway exploration bores September 2008

Stornoway bore hole 1 [517036E 5402957N]

14m top creamy claystone

Hole1 14m driller collected sample bag - contains chips predominantly of slightly to moderately weathered basalt, plus some hard light coloured chips that may be indurated or cemented mudstone.

Hole1 16m driller collected sample bag - similar to the sample from 14 m, but contains a higher proportion of light-coloured chips.

Hole1 16.5-17 m driller collected sample bag - a slurry sample with basalt chips and light-coloured chips. Most of the latter appear to be broken mineral grains of several types.

Stornoway bore hole 2

Sample depths.

1.5 m
3 m
4.5 m
6 m
7.5 m
9 m
17 m

All sample bags from bore hole 2 contained basalt, mostly as moderately to very weathered chips. Samples from 7.5 to 17 m contained larger pebble-size rock fragments.

September 2008 geological observations of quarries and surrounding areas

Five large gravel quarries and two smaller quarry excavations exist in the area. The southernmost of the quarries (BIS S) lies south of Briarly Creek now houses the crushing plant for the BIS quarry group. North of Briarly Creek are two other quarries of the BIS group. (See fig 2.)

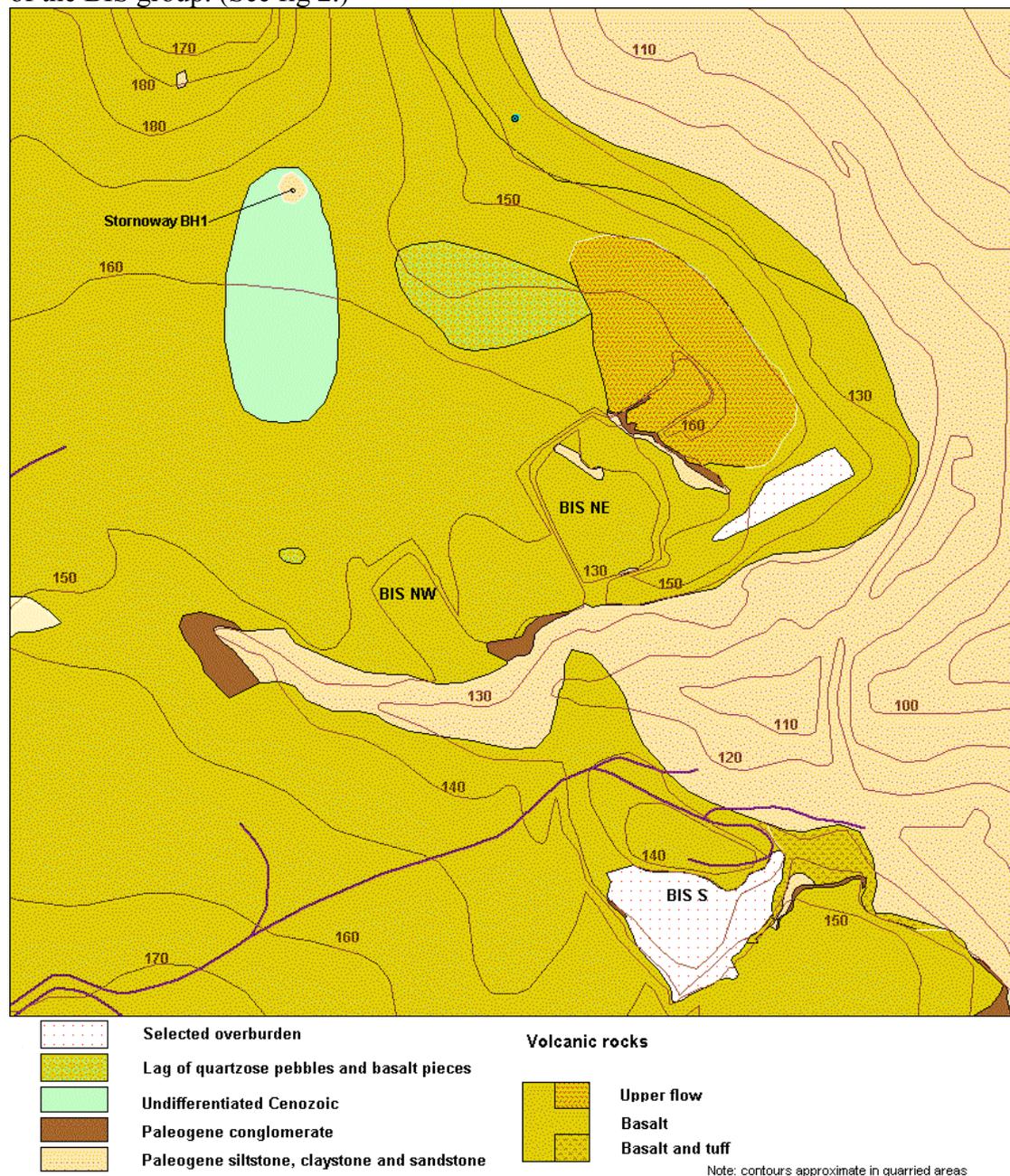


Fig. 2

The western (BIS NW) appears to be used as a storage area including stockpiles of crushed stone. The eastern quarry (BIS NE) is being actively quarried.

About one kilometre to the north east on a separate lease lies the current Stornoway quarry and a further half kilometre to the north is the dormant Mt Oriel (McGrath) quarry.

Other smaller quarries include a railway quarry east of BIS S that may either have been used as a source of materials during the original construction of the Mainline Railway or it may represent an attempt to remove material that failed in a landslide (Anon., 1976) [517890E, 5401935N]. The other small quarry occurs north of the access road to the Stornoway Quarry and is situated on the south-eastern slopes of Cocked Hat Hill [516215E, 5403523N].

With the exception of BIS NW the other four major quarries all reveal contact zones between the basalt and associated Paleogene sedimentary strata. Accurate mapping and interpretation of these contact zones is hindered by the dynamic nature of the quarry faces in an active quarry environment and especially the difficulty of establishing the topographic height of mapped features. A second difficulty arises both in the quarries and in the surrounding areas as a result of the redistribution of overburden which both obscures rock exposures and severely complicates the interpretation that might otherwise be made from the natural distribution of rock floaters.

The quarry exposures provide information about the structural form of the basalt and associated rocks and the variable nature of the rock weathering state. Some basalt is hard, grey and relatively less weathered or altered compared to other brown-coloured basalt. Some of the latter basalt is considered to have undergone alteration during the period of vulcanicity and some of the weathered/altered rocks that resemble a basalt flow instead may be tuffaceous or fragmental.

BIS NE quarry

The basalt in quarry BIS NE can be interpreted to form two 'flows' with inter-flow sedimentary strata; an upper flow in the upper level northeast corner where the flow is currently being actively worked [517600E, 5402675N] and a lower 'flow' that occurs throughout the remainder of the quarry. The lower basalt is considered to be the same basalt that occurs in BIS NW and also is considered to occur through much of BIS S.

Upper flow geology

In BIS NE the upper flow geology is relatively straight forward where the flow has been exposed. The flow base is not horizontal, but has a closer resemblance to a channel or basin shaped feature. The flow is underlain by conglomerate that rests on siltstone and lesser sandstone. Generally the conglomerate lies below the level of the September 2008 quarry floor, but rises perhaps in a south westerly direction [517500E, 5402637N] to occur above the main access road to this section of the quarry and also crosses [517560E, 5402600N] and rises above the road leading from the upper level to the natural ground east of the quarry. The conglomerate layer has

been mapped with a ribbon-like outcrop distribution that extends for about 200 m in a south easterly direction. An excavation a few metres below the upper level quarry floor indicates that the conglomerate extends at least 55 m in a north easterly direction below the basalt of the quarry floor [514545E, 5402660N]. The basalt has a well developed colonnade with an overlying irregular entablature. The form of the colonnade is assumed to mirror the base of the upper flow and mega-joints visible on aerial photographs help recognise the distribution of the upper flow outside of the quarry. The eastern extent of this flow is not known

The inter-flow conglomerate includes rounded basalt, dolerite and sedimentary pebbles and cobbles. It is possible that the conglomerate intersects the land surface north of the quarry as similar rounded clasts are dispersed in the neighbouring paddocks. The conglomerate does not appear to intersect the natural land surface along the northern side of the quarry BIS NE, but rather is terminated against other basalt in the subsurface. Further observations are required to confirm this.

Boundary zone of lower basalt and upper flow

In BIS NE the lower basalt occupies the lower levels of the quarry and along the eastern margin the basalt extends to the siltstone that underlies the conglomerate of the upper level. Here the lower basalt exhibits unusual bulbous intrusions into the siltstone [517572E, 5402587N]. These bulbous features may be interpreted as lava intrusions into wet soft sediments (F L Sutherland pers. comm.) The orientation of conspicuous columnar jointing in the lower basalt swings to a sub-horizontal direction along the northwest face of the quarry [517423E, 5402438N]. This slightly weathered basalt passes eastward into altered basalt with mineralised joints and fillings. This change occurs within a distance of a few centimetres and a columnar structure ceases to be conspicuous, but where columnar are evident they remain sub-horizontal in the altered basalt.

Spoil covers much of the quarry face east of this change, but high in the face are visible further bulbous basalt intrusions into sedimentary rocks. Further east as the conglomerate layer is approached, a large flame-like projection of siltstone is located between the conglomerate and basalt outcrop above the spoil to the west. Above the spoil, the basalt found between the bulbous basalt intrusions and the flame-like feature probably is part of the lower flow, but other interpretations may be possible.

The boundary zone between the workings of the lower basalt in the lower western part of BIS NE and the workings of the upper flow in the upper level north east corner is not fully understood. The simplest interpretation is that the lower basalt passes eastward beneath the upper flow, but rock exposures that incontrovertibly show this have not as yet been located. The presence of bulbous intrusions extending from the lower basalt into sedimentary units may have resulted from local-scale intrusions of magma into wet sediments, but may indicate a larger-scale intrusive margin. The sub-horizontal columns seen in the lower basalt near the boundary zone may indicate near vertical isotherms during magma cooling and this too could be interpreted as a result of a steep intrusive contact or a steep-sided channel fill. If a major intrusive contact is developed in the boundary zone then the interpretation of the relative ages of the upper flow and lower basalt using the theory of superposition need not apply.

Lower basalt basal contacts

The lower basalt in BIS NE exhibits three basal contacts with underlying sedimentary strata. Quarry plans indicate an RL of 122.8 m for the quarry floor so for much of the lower level quarry area the basalt base is below this RL. For a small section of the quarry face east of the main entrance to the quarry, the base lies at about 123 RL (BIS datum) and is relatively regular in form [517517E, 5420410N]. Further north in the quarry, but south of the access road to the working upper level is a large outcrop of sedimentary strata that includes both light coloured and dark carbonaceous beds [517472E, 5402556]. These strata are overlain by overburden, but in some areas broken basalt rock above the strata appears to be part of an overlying basalt body. These strata are estimated to be six to ten metres above the floor of the quarry and so the base of the basalt in this area is probably above 130 RL. A basal basalt contact 60 m to the north west was exposed and photographed by Dr F L Sutherland on 17th March 2007 [517417E, 5402591N]. This exposure was not noted during 2008, but may merely have been obscured behind a pile of overburden or possibly the exposure had become buried by overburden. Across the plane of the photograph the basal contact steps downward with a variable apparent dip of up to about forty degrees. The basal contact must also fall in a south west direction, but only the initiation of this height decrease is visible before overburden obscures the photograph view. It seems possible that this area of elevated sedimentary strata may have been continuous with that 60 m to the south east, and formerly formed a ridge of sedimentary siltstone across the quarry floor.

BIS NW quarry

The basalt base is not exposed in BIS NW, but the basal contact is exposed immediately outside of the quarry either side of the access road [517340E, 5402292N] where the basalt rests on conglomerate or at places slightly lower on sub conglomerate siltstone. Utilising the 10 m contours the elevation on the basal contact at the access road is between 130 and 140 m ASL whereas autonomous GPS elevations suggest an elevation closer to the lower end of this range or below 130 m BIS datum.

Briary Creek

A natural exposure of the conglomerate occurs in Briary Creek [516919E, 5402308N] about 450 m further west where the 10 m contours in adjacent fields indicates an elevation for the basalt base of about 145 m. The contours may not truly reflect the elevation of the creek channel and the basalt base may be lower than indicated.

BIS S quarry

Basal basalt contacts are also exposed in BIS S quarry. This quarry has a remnant bench around the rim and more centrally located 'hill' of basalt on which some of the crushing plant is located at an elevation similar to the surrounding bench. The basalt 'hill' remnant shows basalt extending to below the level of the quarry floor. This is not the case midway along the south western side of the quarry where an inclined basalt basal contact with conglomerate is exposed [517503E, 5401929N].

Autonomous GPS elevations suggest that the quarry floor is about 130 m ASL or slightly lower. The basalt base dips more steeply than the conglomerate to below the floor of the quarry along the north west trending face and rises in the opposite direction until it becomes obscured by spoil which then obscures the geology between the quarry floor and remnant bench throughout the south western corner of the quarry.

Apart from one small spoil covered interval the basalt remains continuously exposed through out the south western section of the quarry in the face above the remnant bench. Along these faces the cooling column orientation shows some gradual and some abrupt changes. It is assumed that the base of the basalt occurs beneath the spoil that covers the lower face, but this need not be so for the complete interval up to exposures of contacts between basalt and sedimentary rock about 180 m from the southwest corner along the south east face. The remnant bench falls by about 10 m elevation north easterly along this face. Near the exposed contact the basalt base must rise several metres in elevation, but the nature of this change is obscured by spoil until a series of short irregular steps in the basalt base are revealed followed by a steeply west dipping (68 degree) planar contact where the basalt base rises by several metres [517716E, 5401904N]. This sudden rise may be an intrusive edge, but could also be the edge of a steep channel or a collapsed channel margin.

The associated sedimentary deposits are of silt and clay grade, but immediately to the east a sub-horizontal conglomerate layer is overlain by basalt. The approximate elevation of the conglomerate is 145 m and assuming it is the same unit present in the west of the quarry it is significantly higher in the east. The conglomerate overlies a bed of sandstone, pieces of which can be traced discontinuously for a distance of about 65 m in a north north east direction until spoil and rehabilitation work obscures the geology at this elevation. Below the sandstone and extending to the floor of the quarry occur a variety of basaltic rock types. At the easternmost extent of the quarry floor (near 517738E 5402012N) cuttings in basalt extend northwest for about 10 m and south south west for about 45 m. The base of this basalt is below the quarry floor and probably lower than 130 m ASL. The basalt ranges from slightly to moderately weathered to almost friable material with clay? amygdules or pellets. Some friable rock could be fragmental basalt or tuff.

In this immediate area the highest exposed basaltic material is very soft and almost shaly and similar material occurs further south near the junction of the old and current access roads to the bench (517716E 5401927N) and north of the old railway quarry (517846E 5401966N) at an elevation of about 140 m ASL. The simplest interpretation is that this basalt lies below a thin sedimentary interval beneath the conglomerate. An alternative explanation is that this basalt does not extend into the cuttings to occur below the conglomerate, but instead rises steeply to overly the conglomerate in a similar way to the west dipping steep contact exposed above the remnant bench.

An exploratory drill hole located towards the centre of the quarry probably on the basalt 'hill' intersected clay below basalt at a depth of 14 m. This is considered to be at an RL of approximately 86 m based on the Brambles RL 100 position at the Crusher Pads on 1/5/1989. The elevation of the clay is estimated to be approximately 130 m ASL. An additional drill hole 70 m to the east appears to have remained in basalt to 79 m (Brambles local RL) or about 123 m ASL. The preferred interpretation is that the basalt contact on the western side of the quarry dips below the basalt

remnant in the quarry centre; alternatively the central basalt could be equivalent to the lower basalt near the south eastern part of the quarry.

Extension to railway landslide area

About 300 m south east of the quarry conglomerate is exposed above the railway cuttings at an elevation of about 130 m ASL. Nearby at a slightly lower elevation basalt agglomerate [517005E, 5401865N] is overlain by a basalt flow that descends with a north westerly component to approach railway level. Previous anonymous geological observations (Longford 1947 Run 4 photograph25748) suggests that the conglomerate is inter-bedded between two basalt flow and nearby ash and tuff beds underlie basalt [517965E 5401890N].

Surveyed drill hole information from landslide investigations (Maunsell & Partners, 1976) gives further information on the geology, but only driller's logs are available. Without further survey information it is an assumption that the elevations are with respect to AHD. Drill holes east of the railway indicate that the top of the conglomerate ranges from 131 to 134 m elevation. Aerial photo interpretation suggests that the morphology of some of the area immediately to the east of the drill holes collars may be the result of spoil dumped here during railway construction. It is possible some of the drill hole intersections are of man-made ground.

At the northern end of the old railway quarry the top of the conglomerate ranges from 134 to 140 m and towards the southern end of the quarry the conglomerate top is about 127 m. The conglomerate RL at 140 m is comparable to that in the BIS S quarry. The conglomerate at lower elevations may in part indicate fossil landslide or younger landslide displacements or other structural variability in the Paleogene strata. The base of the basalt in this area shows significantly greater variability and descends into strata below the conglomerate. The highest basalt base is about 139 m in BH18, but if the drilling records correctly identify weathered basalt then the basalt base falls by 15 m to 124 m in BH6 but rises to the north east to occur between 131.5 to 134.3 m east of the railway. Some of the completely weathered basalt noted in the driller's logs may be tuff and ash reported anonymously on the aerial photograph.

Other features

A further basalt contact is revealed in the BIS s quarry 30 metres to the south west of the steeply dipping contact with sedimentary rocks. In this instance a large mass of altered basalt several metres across forms a tall dome that extends upward from the remnant bench and is enclosed above the bench by much less-weathered basalt which forms a sharp intrusive contact on the eastern side [517690E, 5401890N]. The weathered basalt also contains vertical narrow dykes and a sub-horizontal curved sheath of the surrounding less weathered basalt. It is concluded that the alteration of the intruded basalt occurred prior to the crystallisation of the surrounding basalt. The altered basalt may belong to the interval of basalt and tuffaceous rocks found topographically lower than the conglomerate further east.

The 1947 aerial photography also reveals a light-coloured band approximately coincident with the 150 m ASL contour within the BIS S quarry. This may be a

stratiform boundary such as a flow base or sedimentary unit or a travertine layer, but now may have been completely removed by quarrying.

Mt Oriel (McGrath) quarry

Basal basalt contacts are also revealed on the quarried ridge east of the deepest part of the Mt Oriel quarry. Clayey siltstone and pebbly beds are overlain by basalt that falls in altitude from about 150 m ASL [near 516810E 5430910N] to a lower stratigraphic level below the pebbly bed at approximately 145 m ASL a lateral distance of 25 metres to the north west. Although the quarry floor descends to 140 m ASL or lower, there are no sedimentary rocks exposed in the quarry.

The basalt exposed in the south east face of the Mt Oriel quarry is of two types. Grey, slightly to moderately weathered basalt occurs in the upper face and descends into the face below this. In places this basalt type exhibits well-defined, inclined columnar jointing. Under this basalt is brown, altered basalt crossed by white mineralised joint fillings. In some areas the brown basalt is amygdaloidal and the mineral infills include natrolite (Sutherland, 1971). To the east of the altered basalt there is a change to harder more massive basalt on the ridge east of the main quarry workings. The change in basalt appearance may be entirely due to alteration, but there is a possibility two separate basalt bodies are present.

Stornoway (Raeburn) quarry and adjacent areas

Sedimentary clayey siltstone has also been intersected in the Stornoway quarry [516882E, 5403107N, ~182 m ASL], a recent exploration bore south of the quarry [517036E, 5402953N, ~166 m ASL] and probably at an electricity power pole [517032E, 5402646N, ~155 m ASL] that is situated 300 m south from the bore.

The quarry and bore hole (BH1) intersections are both of strata that overly basalt and it is not clear if the strata are part of a succession that once buried the entire volcanic interval or are part of inter-flow sedimentary intervals from which the overlying flow (s?) have been eroded. Removal of spoil from the siltstone exposed in the quarry revealed some small scale steep contacts on the western side of the outcrop. The sedimentary rocks adjacent to the contact were indurated and the basalt may be intrusive in this area. Although locally some basalt is topographically higher than the siltstone, the exposure is inadequate to determine whether the underlying basalt rises above the sedimentary rocks or whether the topographically higher basalt is part of an overlying flow. The latter seems unlikely, but the possibility should not be dismissed entirely.

The borehole intersection revealed quartz-bearing cream coloured clay below a surface scattering of basalt floaters. Weathered basalt chips were collected from 14 to 17 m depth, but as shallower samples were not collected the depth to the first struck basalt remains somewhat ambiguous.

Basalt Resource

A large area of basalt occurs in the Breadalbane-Western Junction area and probably less than 20% by area of the surface exposed basalt is contained within mining leases

1747 P/M (54 HA), 975 P/M (53HA), 869P/M (17HA), 1584P/M (18HA) and applied lease 1863 P/M (54 HA). Taken as a whole the basalt may exceed 70-80m thickness at places such as Cocked Hat Hill, but more applicable is a general thickness range of 20 – 40 m that can be estimated from previous mapping of the basalt lower surface at the periphery of the basalt and by using some water bore information.

Within the Stornoway and BIS leases the basalt thickness is similarly variable in thickness and may range approximately 10 – 40 m thickness. At the Stornoway quarry possibly 30 m of basalt may still remain beneath the quarry floor, but only the upper part of this has been tested by drilling. In the currently mined BIS NE quarry operations have reached the base of the basalt in the deepest part of the quarry.

The process leading to estimates of basalt thickness is a reasoned one, taking into account the best current information. Without subsurface information from drilling any estimate will have a degree of uncertainty.

The basalt is variable in character and this variability enables a number of different commodities to be obtained from the quarries. This variability also means the extent of any one basalt type similarly cannot be determined without knowledge of the controlling geological factors in combination with some subsurface information to place limits on the rock distribution.

In recent years the detection of sedimentary clay and gravel deposits in the currently worked BIS NE quarry has made the quarrying operations more difficult, as either the clays and gravels have to be removed as overburden or left in place preventing quarrying of any basalt beneath them. A further difficulty may arise through stock piling overburden in areas of resource. A very small area of sedimentary clay occurs on the margin of the Stornoway quarry and is not significant for current quarry operations, but may have geological significance in understanding the geometry of the basalt. The September 2008 exploratory drilling south of the Stornoway quarry has also detected thick sedimentary clay where previously basalt had been shown on geological maps.

In view of the presence of these sedimentary units the estimation of resources is further complicated as they may both reduce in volume the expected basalt resource or hinder the quarrying of existing resource. Quarry management in the short term and over the life of the leases will need to take the variability of the rock and clay distribution into account.

Notwithstanding these limitations the mining leases hold much promise to continue to be a source of basalt gravel of various types. Drilling in the Stornoway quarry indicates that basalt extends a further 18 m in depth without a basalt base being reached. A resource of similar volumetric magnitude to that already obtained from the Stornoway quarry can probably be obtained by deeper operations at approximately the existing quarry area. A similar additional resource volume could probably be obtained if the quarry could be enlarged to near the lease boundary in the eastern half 1747 P/M. Basalt also extends to the western boundary of the same lease and a thickness of 10 – 30 m might be obtainable from the western half of the lease. At some stage this could be checked by drilling and in addition augur drilling could be undertaken to define the extent of the clay found in the September 2008 Stornoway bore hole 1.

It seems likely that the basalt quarried in BIS NW will continue north into lease 1863 P/M. This basalt may be thin in the west and in moving northward from the lease boundary there is risk that clay overburden may be present and the overburden may increase in thickness northward. It is possible that a basalt volume several times that of the volume already obtained from BIS NW could be obtained from western side of 1863 P/M. Again, it would be prudent to test the overburden and basalt thickness at some stage.

Northern extensions of the basalt in the western part of BIS NE into 1863 P/M is highly likely. A thickness of 25 m of basalt with an increasing risk of sedimentary overburden some distance north of the lease boundary is a possible estimate.

The upper flow quarried in BIS NE also could be expected to continue into 1863 P/M, but the volume may be equivalent to the somewhat limited amount already mined from the upper flow in BIS NE.

Within lease 975 P/M continuing quarry operations and possible resource exploration may determine the extent of the upper flow in an easterly direction and the thickness of sedimentary units beneath the upper flow. The sedimentary units may thin or thicken. It is not yet clear if the upper flow forms all the basalt east towards the railway or whether there is in addition a lower flow in that direction. A resource may exist to the limits of the mapped basalt.

It is concluded that the area has potential to support quarry operations on a similar scale to those of the past with the exclusion of the BIS S quarry and the Mt Oriel Quarry. It is quite possible that the area may support quarry operations on a scale several times greater than the previous tonnages, but it would be prudent to undertake investigations to check for any limitations that would not permits this. If leases were granted south of the BIS S quarry, extensive basalt resources could probably be obtained from that area.

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Appendix.

Steps that could be taken to reduce the deficiency of the existing data

Steps that could be taken to reduce the deficiency of the existing data include remapping the natural and artificial outcrops of basalt and the associated sedimentary layers and more accurately locating the position of the various drill holes collars including those at the Brambles north eastern pit. Significant well exposed outcrops in the quarries and drill hole collars require better than autonomous GPS position accuracy especially regarding the measuring of RL's.

Geological mapping around the basalt periphery could be undertaken to assess how accurately the existing maps depict the lower basalt boundary. This could include more accurately locating the lower basalt boundary where this could be done and noting areas where there is insufficient information to locate the boundary. In some instances the lower basalt may prove to be absent. Autonomous GPS accuracy would probably prove adequate. The mapping could also seek possible areas of basalt discontinuity within the general area of basalt.

In the quarry areas mapping could place emphasis on determining the RL's of the basal surfaces of the two known flows and the inter-basalt strata. Mapping the orientation of the cooling columns and changes of alteration not related to surface weathering would provide useful information that may clarify the geometry of the basalt flows. Some basalt alteration is related to processes acting during or soon after volcanicity.

Outside of the quarries in the open paddocks, an attempt could be made to map the distribution of rounded clasts derived from the inter-flow conglomerate.