THE STABILITY OF SCARP SLOPES.

by

J.B.A. McKELLAR, B.Sc.

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DRAFTING, PRINTING AND PHOTOGRAPHY.

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Photos. 1 and 2 are oblique air photos. taken by the Tasmanian Govt. Film Unit.

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THE STABILITY OF SCARP SLOPES.

INTRODUCTION.

I PURPOSE: With the investigation and development of large-scale engineering projects the engineering geologist is faced with problems, the solution of which may well determine the economic feasibility of those projects. Among the most vital problems, particularly in the field of hydro-electric engineering, are those concerning the stability of slopes. The purpose of this thesis is to outline the investigation of one such problem, to state the observed facts and to offer interpretations of these facts.

II THE PROBLEM: The proposed construction of hydro-electric installations on the face of the Western Tiers of Tasmania necessitated a study of the stability of slopes on this actively retreating scarp. Abundant evidence of rock slips and extensive scree and talus deposits reflect the general instability of the Tiers face. Any structure contemplated must be located to minimise the danger of extensive rock slides from higher levels. A study of the mechanisms of retreat and an assessment of the stability of cliffs and rock-slide material is undoubtedly the major problem of the geology of this scheme.

III INVESTIGATION METHODS: The investigations were carried out in two phases:

Phase 1: The compilation of a detailed geological map with appropriate contour information over an area broad enough to include all the salient features of the Western Tiers.

Geological boundaries were plotted on aerial photos and transferred to map squares prepared from aerial photos by the Hydro-Electric Commission. At the same time barometric traverses were carried out and from these, with the help of steroscopic inspection of the aerial photos, a rough contour map was prepared.

(NOTE: After the field work was completed the Mapping Branch of the Tasmanian Lands and Survey Department produced a contour map of the southern portion of the area chosen. These contours have been substituted for the Author's in maps included in this thesis.)

The stratigraphic succession was established from field mapping and core logging of diamond drilling carried out by the Hydro-Electric Commission.

Phase 2: A close examination of structures, superficial deposits and vegetation which provides evidence of recent and imminent scarp retreat.

Plane-Table mapping of selected areas with the recording of the physical characters and disposition of scree blocks, joint patterns in outcrops and vegetation data provided the "control areas" for photo interpretation of the scarp face generally.

Diamond drill cores provided subsurface information on scree and talus deposits.

IV PRESENTATION:

The thesis is presented in three parts:

PART A: GENERAL DESCRIPTION OF THE AREA.

The location, access and climate of the area and the broader aspects of its physiography and geology are intended as a general introduction to the more detailed treatment in subsequent Parts of this thesis.

PART B. HISTORY AND CHARACTER OF THE WESTERN TIERS.

The origin and subsequent history preface a detailed description of the scarp in terms of slope elements.

PART C. STABILITY ANALYSIS OF SCARP SLOPES.

An analysis of the data presented in Part B. is attempted with a view to its general application to problems of stability of scarp slopes.

1. THE WESTERN TIERS — DRYS BLUFF.

PART A:

GENERAL DESCRIPTION OF THE AREA.

I. LOCATION AND ACCESS.

The area studied includes some twenty miles of the Western Tiers scarp bounded on the north-west by Warner's Creek and on the south-east by Woodside Creek. Map I indicates the extent of this area and the inset its location in the State. Grid lines on Map I refer to the Military Grid shown on the 4-mile State Map No. 3 of Tasmania. These grid lines also represent the boundaries of Map Squares used in the geological mapping of the area.

Access to the area may be gained via the Lake Highway in the western portion of the area and via various second class roads from the Midland Highway which lies some thirty road-miles east of the area. Within the area a system of secondary roads indicated on Map I gives access to the foot of the scarp. Only the Lake Highway in the west and the Palmer River track in the east give vehicle access to higher levels so that most of the investigations have entailed journeys on foot from the lower levels.

II. TOPOGRAPHIC DIVISIONS:

The area studied comprises three distinct topographic divisions each characterised by distinctive climatic conditions and vegetation.

1. Plateau Division:

The Plateau division extends from the depression occupied by Great Lake (Top water level 3381.8) in the south-west of the area to the edge of the scarp. The general terrain is that of a dissected plateau. Flat floored, marshy valleys separate boulder-strewn rocky ridges some of which have precipitous sides. Examination of the geological maps indicates that the disposition of the marshy valleys is controlled by structures, shear zones and faults, in the dolerite bedrock.

The vegetation of the marshy valleys is restricted to grasses and mosses while the rocky ridges support patches of stunted eucalypts. The restricted vegetation is probably a reflection of the extreme winter climate of the plateau. The precipitation is about thirty five inches per annum, part of which is in the form of snow. Because of the low winter temperatures a snow blanket is maintained for weeks at a time and only in areas sheltered by ridges can the eucalypts survive.

2. Escarpment Division:

The Escarpment Division may be defined as the area between the margin of the plateau and the one thousand feet contour. The profile of this escarpment is typically concave (photo 3), the cliffs and scree fields of the upper levels giving way to timbered slopes decreasing in grade at lower levels. Major streams incise the scarp in steep sided thickly timbered valleys but much of the drainage is effected in shallow migratory channels in the deep talus deposits on the slopes.

The climate is less extreme than on the plateau and the rainfall somewhat higher. (The limited records suggest a figure in excess of forty inches per annum.) Snowfalls occur on these slopes but the snow melts rapidly producing high run-offs and local flooding in the water-courses. The less extreme climate is reflected in the vegetation which is dense with good stands of milling timber up to the three thousand feet contour. Above the three thousand feet contour the vegetation is still thick but is somewhat stunted partly because of movements of the scree and talus and partly because of the inability of this material to support bush vegetation.

3. Lowlands Division:

The Lowlands Division occupies the north-eastern portion of the area. It includes the pediment of the scarp and the low dolerite hills north-east of the scarp-forming fault.

The climate and vegetation differ from those of the plateau and escarpment. The extremely localised showers which supplement the escarpment rainfall are absent and snowfalls are very rare. Lightly timbered grasslands and shallow migratory streams characterise the division though some degree of permanence in the stream courses exists beyond the line of the scarp forming fault where the channels are cut into the dolerite bedrock. Storms on the escarpment cause periodic flooding of the gently sloping pediment so that the agricultural use of this area is restricted to grazing.

III. GENERAL GEOLOGY:

1 Outline:

A gently dipping sequence of Triassic and Permian sediments

2. Western Tiers — Mt Blackwood (right of centre)

with an overall thickness in excess of thirty eight thousand feet is overlain by a thick, and in part, transgressive dolerite sill. The exposed upper surface of the sill has been eroded, in part by ice action and the region subjected to Tertiary block-faulting.

2. Stratigraphy.

The stratigraphic sequence is shown in the table below.

Stratigraphic Table.

System	Group	Formation	Rock Type	Thickness	
Recent to Pleistocene			Scree, Talus Alluvium Glacial Deposits		
Jurassic		Wellington	Dolerite	1000'+	
Triassic (2015')		Newtown	Sandstones, Siltstones, Shales	435'	
	Knocklofty	Tiers	Thinly bedded siltstones, Shales	385'	1580'
		Cluan	Sandstones and Siltstones	425'	
		Ross	Massive Sandstones	630'	
		Jackey	Shales	140'	
Permian (1870'+)	Ferntree	Eden	Mudstones	20'	687'
		Blackwood	Conglomerate	2'	
		Drys	Mudstones	350'	
		Palmer	Sandstones	5'	
		Springmount	Mudstones	280'	
		Risdon	Sandstone	30'	
	Woodbridge	Weston	Mudstones	30'	265'
		Dabool	Sandstones	40'	
		Meander	Mudstones	195'	
	Liffey	Creekton	Wormcast sandstones	10'	90'
		Woodside	Sandstones	35'	
		Kopanica	Shales and sandstones	15'	
		Flat Top	Sandstones	30'	
	Golden Valley	Macrae	Mudstones	115'	170'
		Billop	Sandstone	10'	
		Brumby	Marls	45'	
		Quamby	Mudstones	250' - 330'	
		Stockers	Tillitic Conglomerate	340'+	

3. Lithology.

A. Quaternary System:

Rocks of this system include superficial deposits of both Recent and Pleistocene as follows:

(1) Scree Deposits: The retreat of the Western Tiers scarp results in the formation of extensive scree fields immediately below

the dolerite cliffs on the upper slopes of the escarpment The scree material, angular blocks of dolerite up to twenty feet in diameter but usually of the order of two to five feet, has been proved by drilling to depths in excess of three hundred feet. The scree slopes approximate the angle of repose of the scree material.

(2) Talus Deposits: Below the scree line on the Tiers and on the plateau surface dolerite talus covers much of the surface. This material results from the decomposition of the dolerite and consits of residual boulders of dolerite in a heavy clay matrix.

(3) Alluvium: The alluvial fan at the base of the escarpment results from the transport of material by sheet and rill erosion from the scarp face. As well as the dolerite boulders and clays of the talus zone it contains silts and sands from the sediments at lower levels of the scarp face. The average thickness of this material is thirty feet near the base of the scarp and ten feet at the eastern edge of the area.

(4) Glacial Deposits: Throughout the Central Plateau abundant evidence of glacial action has been noted. Glacial over-deepening in zones of less resistant bedrock has produced a pattern of depressions throughout the plateau. The glacial deposits which occupy these depressions are obscured by later sediments of the lakes and marshes which have formed in the depressions. There is little doubt that Great Lake was formed in this manner by the glacial erosion of basalts and other volcanic deposits which previously occupied a depression in an older topography. The marshes adjacent to Great Lake in this area are of similar origin but the eroded material in this case was probably dolerite from shatter zones in the bedrock. The orientation and distribution of these marshes bears a close relation to the disposition of known shatter zones and major joint trends in the dolerite.

B. Jurassic System:

This is represented by dolerite which occurs as thick sills intruded at the close of an earlier period of sedimentation which is considered to have extended through the Triassic and probably into the Jurassic period. The dolerite consists essentially of plagioclase and pyroxenes. Olivine is present in small quantities and micrographic intergrowths of quartz and alkali felspar occur in small amounts. The occasional presence of amphiboles, biotite, chlorite, calcite, ilmenite, magnetite, pyrite and chalcopyrite have been noted. Grainsize varies from very fine and perhaps microporphyritic close to contacts with sediments to coarse in the central parts of the intrusions and to pegmatitic in segregations. Contact metamorphic effects of the magma were slight and restricted to narrow zones.

Jointing in the dolerite is closely spaced, the strong system of vertical joints producing a structure akin to the organ pipe structure characteristic of basalts. Major joint patterns, which can be readily determined from air photos of the exposed rock, are discussed elsewhere as are the weathering features of the dolerite. The strongly developed joint system provides ready access and considerable storage for ground water in the superficial levels of the dolerite mass. Only in shatter zones does ground water persist to greater depths.

C. Triassic System:

Overlying the Permian formations disconformably and apparently terminated by the intrusion of dolerite, the Triassic sediments were laid down in predominantly lacustrine and swamp conditions. The gently dipping sequence of Triassic formations has a maximum thickness of approximately two thousand feet in this area.

(1) Newtown Coal Measures: The Newtown Coal Measures comprise a typically fresh-water sequence of felspathic sandstones, siltstones and fossiliferous shales with occasional coal seams up to six feet in thickness. The frequent lensing out of beds makes correlation difficult, only general correlation being possible over distances in excess of two thousand feet. The maximum measured thickness (where dolerite transgression across the sequence has virtually ceased) is four hundred and thirty five feet. The base of the formation is taken as the lowest coal seam.

The contact between dolerite and sediments is a welded contact characterised by fine grained dolerite (chilled margin) and a variety of effects depending on the nature of the sediment at the contact. Thus sandstones show very little alteration while shales have a baked zone up to ten feet in thickness. On exposure the shales and siltstones are prone to slaking and disintegration.

(2) Knocklofty Group: Underlying the Newtown Coal Measures conformably is the Knocklofty Group which is nearly one thousand five hundred feet

thick and consists of thick quartz-sandstones in the lower part but becomes increasingly dominated by shales towards the top.

(a) Tiers Shale: The highest formation of the Knocklofty Group is the Tiers Shales which consists of thinly-bedded siltstones and plant-bearing shales with occasional felspathic sandstones. The maximum measured thickness of the formation is three hundred and eighty five feet. Weathering on exposure is fairly rapid and few outcrops of this formation are found in the area.

(b) Cluan Formation: Conformably beneath the Tiers Formation, interbedded siltstones and sandstones, predominantly quartzose, constitute the Cluan Formation. The maximum measured thickness of this formation is four hundred and twenty five feet. More resistant than the generally finer-grained Tiers Formation, it is characterised by fairly extensive sandstone outcrops.

(c) Ross Formation: Underlying the Cluan Formation conformably, the Ross Formation is a predominantly massive, medium-grained quartz sandstone commonly exhibiting cross-bedding. The measured thickness of this formation is six hundred and thirty feet. Outstanding characteristic is the development of lines of high cliffs on the face of the Tiers.

(d) Jackey Formation: Conformably beneath the Ross Formation fossiliferous shales and minor sandstones constitute the Jackey Formation. Very few outcrops of this formation occur. Its thickness is estimated to be one hundred and forty feet.

D. Permian System:

A gently dipping sequence of Permian formations disconformably overlies Pre-Cambrian rocks and is overlain disconformably by the Triassic system. The system is predominantly marine, the lithology being influenced by the glaciation of the adjacent land surface. The depth of the seas during sedimentation, as inferred by the grainsize of the sediments and the associated fossil types, varied over quite wide limits. Inspection of the stratigraphic sequence reveals the rhythmic nature of these changes. Thickness of the system is in excess of one thousand eight hundred feet.

(1) Ferntree Group: Underlying the Triassic sediments disconformably is a highly siliceous group consisting of alternations of conglomeratic

sandstone and mudstone with occasional erratics and a few marine fossils. The six formations which constitute the group have an overall thickness of approximately six hundred and eighty feet and have been distinguished as follows:

(a) Eden Mudstone: The topmost formation is a grey to black micaceous mudstone almost devoid of erratics and marine fossils. It is extremely fine-grained, massive and of medium hardness, and consists essentially of quartz, felspar and mica. The thickness of this formation is approximately twenty feet.

(b) Blackwood Conglomerate: This conglomerate consists of well rounded white quartz pebbles up to one inch in diameter, but largely of quarter inch diameter, in a matrix of poorly sorted sandstone consisting essentially of quartz and felspar. It is an extremely resistant formation forming well marked benches on the Tiers face. The thickness of the formation is from two to five feet. Because of its limited thickness and persistent outcrop it constitutes an excellent marker formation.

(c) Drys Mudstone: This formation consists essentially of grey micaceous mudstone. Though predominantly fine-grained, occasional bands of coarser material, in which angular grains of clear quartz are evident, occur towards the base of the formation. Erratics of slate, mica-schist and quartzite occur sporadically throughout the formation. The thickness of the formation is approximately three hundred and fifty feet.

(d) Palmer Sandstone: A poorly sorted sandstone consisting of quartz and felspar. Erratics of slate, mica-schist and quartzite up to three inches in diameter are common. It forms benches bounded by a small scarp on the face of the tiers and produces waterfalls in the streams. The thickness is approximately five feet. The mudstones immediately above and below this formation show an increase in grain-size towards this formation, but the boundaries of the sandstone are well marked. Because of its limited thickness and persistence of outcrop the formation is an excellent marker for mapping.

(e) Springmount Mudstone: A banded mudstone in which the banding results from alternation of grey micaceous mudstone and light grey quartz mudstone and the bands vary from fractions of an inch to several feet in thickness. The quartz mudstone consists of macroscopic angular quartz grains in a matrix of quartz and felspar. The essential difference between the two types of mudstone lies in the grain-size of the quartz and the presence or absence of mica. The quartz mudstone is somewhat harder than the micaceous mudstone. Occasional erratics have been noted in the formation but no fossils have been found. The thickness of the formation is approximately two hundred and eighty feet.

(f) Risdon Sandstone: The basal formation of the Ferntree Group is the Risdon Sandstone. It is a grey poorly-sorted sandstone consisting largely of quartz and felspar. Erratics are common throughout the formation and marine fossils, notably brachiopods, occur in the lower horizons. Essentially similar to the other Ferntree Group Sandstones it also forms benches on the face of the Tiers. Because of its greater thickness and therefore slower erosion the Risdon benches are generally wider than the other Ferntree benches and are normally covered with a rubble of Risdon material from the superficial weathering of the bench. Thickness of this formation is approximately thirty feet.

(2) Woodbridge Group: Conformably beneath the Risdon Sandstone and underlain by the Liffey Group the Woodbridge Group consists of approximately two hundred and sixty five feet of mudstones and sandstones. Erratics occur sporadically throughout the group and marine fossils are common, two of the formations having very rich faunas. The group includes three formations -

(a) Weston Mudstone: The uppermost formation consists of a dark grey micaceous mudstone with a rich bryozoan fauna. Several thin members of quartz mudstone with macroscopic angular quartz grains occur within the formation. The approximate thickness of this formation is thirty feet.

(b) Dabool Sandstone: The Dabool Sandstone consists of meduim quartz and felspar grains in a mudstone matrix. Erratics occur in this formation which is characterised by a rich brachiopod fauna. Like other Permian Sandstones it forms benches on the Tiers slope though these are not as extensive because of the generally higher resistence to erosion of the Woodbridge Group mudstones. The formation has an average thickness of forty feet.

(c) Meander Mudstone: The Meander Mudstone is the basal formation of the Woodbridge Group lying conformably between the Dabool Sandstone and the Liffey Group. Like the Springmount Mudstone of the Ferntree Group, it is a banded mudstone with alternating layers of dark grey micaceous mudstone and light grey quartz mudstone, the latter predominating.

Occasional erratics and minor beds of marine fossils occur throughout the formation. The average thickness is one hundred and ninety five feet.

(3) Liffey Group: The Liffey Group which underlies the Woodbridge Group conformably consists predominantly of well sorted quartz sandstones with minor interbedded shales. Fragmented plant fossils have been found in the shales and worm casts are numerous in one formation. Erratics are absent in this group. The average thickness of the group is ninety feet and thicknesses of the four formations which constitute the group are extremely variable.

(a) Creekton Sandstone: The Creekton Sandstone is a medium grained quartz sandstone characterised by an abundance of worm casts. The characteristic worm-cast structure and the limited thickness of the formation (eight to ten feet) make it an excellent mapping formation.

(b) Woodside Sandstone: The Woodside Sandstone is a massive well-sorted white to cream quartz sandstone with occasional lenses of conglomerate, particularly near the top of the formation. The massive sandstone forms near-vertical cliffs along stream courses and with other members of the Liffey Group forms a fairly persistent scarp on the lower levels of the Tiers face. The average thickness of this formation is thirty five feet.

(c) Kopanica Shales: The Kopanica Formation consists essentially of grey shales with thin bands of white sandstone. The grey shales contain plant fragments and carbonaceous bands. The thickness of this formation is variable ranging from fifteen to thirty feet over short distances.

(d) Flat Top Sandstone: The basal formation of the Liffey Group is a massive, barren, well-sorted quartz sandstone very similar to the Woodside Sandstone except that conglomeratic horizons appear to be absent. The thickness of this formation is variable, ranging from fifteen to thirty feet.

(4) Golden Valley Group: The Golden Valley Group underlies the Liffey Group conformably; richly fossiliferous in part it also contains numerous erratics in certain horizons and generally represents a diversity of lithological types. The average thickness of this group is one hundred and seventy feet.

(a) McRae Mudstone: These mudstones, the upper part of which are predominantly micaceous mudstones while the lower part are quartz mudstones, underlie the Liffey Group conformably. Few erratics and occasional marine fossils occur in this formation which has a thickness of one hundred and fifteen feet.

(b) Billop Sandstone: The Billop formation is a medium-grained quartz sandstone containing numerous erratics (to six inches in diameter) and marine fossils, principally brachiopods. The formation forms broad benches towards the foot of the Tiers. These benches are frequently covered with gravel formed from the erratics within the formation. Thickness of the Billop Sandstone is ten feet.

(c) Brumby Marls: The basal formation of the Golden Valley Group is a marl with rich marine fauna. Bryozoans predominate at the top of the formation but towards the base brachiopods (particularly Stropholosia) are the most common fossil type. A wide range of range of rock types is actually represented in the various horizons of this formation which includes mudstones, marls and limestones. Thickness of the formation is forty five feet.

<u>(5) Quamby Formation:</u> Underlying the Golden Valley Group conformably, black micaceous mudstones of the Quamby Formation occur. Bands of erratics and fossil detritus occur frequently near the top of this formation, but these bands become more widely spaced in the sequence as the lower limit of the formation is approached. The thickness of this formation varies throughout the area from two hundred and fifty to three hundred and thirty feet.

<u>(6) Stockers Tillite:</u> This probably represents the basal formation of the Permian sequence, being underlaid conformably by rocks of Pre-Cambrian age a few miles to the east of this area. In the area under discussion the basement rocks are not exposed and have not been encountered in drilling which has proved the thickness of the Stockers formation to three hundred and forty feet. The tillite is characterised by faceted erratics, which range up to three feet in diameter, and are set in a matrix of micaceous mudstone. There are lenses of mudstone in which few erratics occur while in other places large erratics represent a considerable proportion of the rock mass. While the erratics represent a large range of rock types there are zones where particular types predominates.

4. Structure.

A. Tectonic History:

The prolonged period of sedimentation during the Permian and Triassic was terminated by widespread injection of dolerite probably of Jurassic age. Following the intrusion of dolerite and persisting until the early Tertiary a period of peneplanation produced a lateritised and bauxitised surface of low relief. Violent block faulting associated with the Tertiary Epeirogeny dismembered the peneplain. The central plateau was formed fringed by a scarp with a relief of two thousand feet. East of the area further faulting in the same sense increased the relief of the central plateau mass over the midland mass to well over three thousand feet.

The Tertiary basalts and related rocks found to the south and west of the area may have extended into this area only to be removed by ice action during the Pleistocene glaciation of the area.

The pattern of marshes, the presence of glacial-type deposits in these depressions and vast accumulations of large, angular dolerite boulders in parts of the area suggest that a major ice sheet moved southwards across the area during the Pleistocene glaciation. Glacial over-deepening occurred along shear zones in the dolerite surface on the site of the present marshes. The extensive, shallow depression occupied at present by Great Lake may well owe its origin to glacial erosion.

The passing of the glacial period saw the development of a system of minor streams draining the Plateau surface into Great Lake. As the catchment boundary of the lake corresponds closely with the Plateau margin plateau drainage plays little part in the incision of the scarp.

As the scarp fringing the Plateau retreats the products of its erosion form a broad, gently sloping alluvial fan at the base of the scarp. These deposits are constantly being reworked and removed by stream action as evidenced by the almost complete lack of weathering in the underlying rock.

B. Permian Sedimentation:

Several features of the Permian sedimentation have topographical expression and are worthy of note in a structural appraisal.

The alternations of fine-grained, low-strength sediments ~~produces~~ and coarse-grained resistant sediments produces a benched or tiered slope, the coarse-grained sediments of higher erosion-resistance forming benches while the finer sediments occupy the steep intervening slopes. Passing upwards through the sequence there is a general decrease in thickness of coarse-grained formations. The topographical effect of this is that the benches become less pronounced at higher levels.

C. Triassic Sedimentation:

The shales and sandstones of the Triassic sequence produce effects similar to the Permian "benching". The sedimentation pattern bears a close relation to the intrusion form of the injected dolerite. Thus a strong sandstone horizon will direct the intruding dolerite and restrict its transgression through the sedimentary sequence. No such control is exerted by the finer sediments. Thus in those formations of the Triassic where sandstones predominate dolerite injection conforms with the sedimentary bedding while in those formations where shales predominate the form of the intrusion is irregular and discordant intrusive boundaries are common.

D. Dolerite Intrusion:

The dolerite has been injected into the sediments as a vast sill-like intrusion, frequently transgressing across the bedding in a shelving form. The upper surface of the intrusion has been exposed and eroded throughout this area. The lower surface of the sill-like intrusion may occur in the sedimentary sequence anywhere above the Ross formation. Thus its tranggressions through the sedimentary sequence total approximatly twelve hundred and fifty feet. The maximum measured thickness of the dolerite sill is in excess of one thousand feet though great variations of thickness result from the transgressive nature of its lower boundary and the erosion of its upper surface.

As mentioned earlier, where the dolerite intrudes a predominantly sand-grade formation the pure sill-form of the intrusion may be retained over an extensive area. Thus the dolerite-sediment contact low in the Cluan formation extends, without major transgression from Drys Bluff (Map Square 4786) southward to the Palmer Track (Map Square 4785) and in the area east of the Tiers fault no transgressions from a similar horizon have been noted. Where the lower surface of the intrusion occurs in the Tiers or Newtown formations (both predominantly shale deposition), the contact is irregular and frequent shelving of the contact across the sedimentary sequence occurs. The dolerite-sediment contact may cut across the stratification at any angle but there appears to be some preference for a slope of five to fifteen degrees.

At only two known points in the area is there evidence of dolerite intrusion into sediments stratigraphically lower than the Cluan formation. In the north-west of Map Square 4686 a steep transgression of dolerite through the Permian sequence was mapped. In the north-west of Map Square 4786 an area of dolerite talus suggests the presence of a dolerite intrusion through the Permian sediments. These two intrusions may well be "feeders" of the sill dolerite higher in the sedimentary sequence.

E. Faulting:

The Tertiary epeirogeny produced a network of faults and shear zones. separating tilted blocks. There is some tendency towards a general south-west dip of the sediments in this area. However, divergence in the direction and amount of the dip indicates that the various blocks were tilted independantly during the epeirogeny. To accommodate this tilt-variation the faults between blocks are often complex, a number of sub-parallel faults and crush zones representing the overall displacement between contiguous blocks. Further adjustment between blocks has been attained in wide zones of shearing which show little evidence of any associated vertical movement of either bounding block.

Because of the closeness and complexity of faulting a given fault is rarely constant in throw or direction. The throw of one fault of a system may be transferred via a transverse fault to another member of the system. An example of this may be seen in the Tiers Fault near the north-east corner of Map Square 4885. Here the throw on a north-north-west trending fault is transferred along a transverse fault trending west-north-west to another member of the north-north-west system. The tendency is also reflected in the marsh deposits, as in Map Square 4785.

As far as can be ascertained all faults are normal and near-vertical. According to their direction the faults in this area may be grouped into four systems.

(i) A system trending north-north-west conforms with the major trend of faulting recognised over much of the old "structural core" of

Tasmania. In this area the trend is not nearly as pronounced. The major fault of the area, the Tiers Fault, belongs to this system as do some minor faults and shear zones.

(ii) A system trending east-north-east are the most numerous and also the most persistant laterally though the throws rarely exceed two hundred feet. There is a tendency, if only slight, to a radial arrangement about a centre west-south-west of the area. This is well illustrated by the faults and shears of Map Square 4785.

(iii) A minor system trending north-north-east consists of members of small throw and restricted lateral persistance. An interesting development in the shear patterns is evident on Map Square 4785 where a combination of shears trending north-north east and those trending east-north-east produce a resultant lineation north-north-west. As this direction coincides with Trend (i) it suggests that there may be a structural weakness in the basement rocks in this direction.

(iv) A fourth system, not well represented numerically in this area but including a major fault between Cluan Tier and Drys Bluff (Map Square 4786), trends west-north-west. This system is best developed in the north of this area.

From a regional view-point the fault evidence suggests that the area is perhaps marginal to the ~~Pre~~-Cambrian "core" of Tasmania and that it lies east-north-east of this core. In support of this theory we have the north-north-west trend less strongly developed than in other areas to the south and south-west, the tendency to a radial arrangement about a point west-south-west of this area and quite a strong development in the north of this area of a west-north-west system.

PART B.

HISTORY AND CHARACTER OF THE WESTERN TIERS.

I. ORIGIN AND RETREAT OF SCARPS:

1. Formation of Scarps:

Based on their formation mechanism three major types of scarp may be recognised within the area.

A. Fault Scarps.

B. Fault-Line Scarps.

C. Stream-Cut Scarps.

A. Fault Scarps:

The north-north-west trending scarp extending from the southern boundary of the area to Drys Bluff is a typical Fault Scarp. During the Tertiary epeirogeny the Central Plateau area was upfaulted some three thousand five hundred feet relative to the lowest blocks of the midlands east of the area under discussion. Movement took place along a series of faults trending north-north-west. The major fault of this system, with a throw in excess of two thousand feet, is the Tiers Fault indicated on Map I. As no other persistent fault of similar trend occurs between the Tiers Fault and the present scarp it may be assumed that the Tiers Fault is primarily responsible for the formation of the scarp. The retreat suffered by the scarp generated by the Tiers Fault and the subsequent erosion of the area across which retreat has taken place has produced the present scarp with a relief in excess of three thousand feet. The presence of remnants of the dolerite cap on the downfaulted block east of the Tiers Fault indicates that other fault-scarps to the east did not retreat to and amalgamate with the Tiers Fault Scarp. Thus the formation of the present scarp may be related solely to the Tiers Fault.

A fault-scarp with a relief in excess of a thousand feet was formed by the Cluan Fault which separates the Cluan Tier block from the adjacent Central Plateau Blocks. This scarp has been accentuated in the region of Drys Bluff by the down-cutting of the Liffey River along the fault zone. The relief between the floor of the river and Drys Bluff is now in excess of three thousand feet.

Fault Scarps formed on faults of smaller throw have been obliterated in most areas though remnants of these scarps may be found on the areas of dolerite.

B. Fault-Line Scarps:

When, through prolonged action of erosive forces, the down-faulted block stands at a higher level than the complimentary up-faulted block the scarp separating the two levels is termed a Fault-Line Scarp. The western slopes of the Dolerite hills east of the Tiers Fault constitute such a scarp. The dolerite capping of the downfaulted block has proved more resistant than the Permian sediments exposed by the retreat of the Tiers Fault Scarp and a Fault-Line Scarp with a relief of up to five hundred feet has resulted.

Erosion of the fault zone of the Cluan Fault by the Liffey River has produced a scarp on the southern margin of Cluan Tier. This scarp, with a relief of one thousand feet may be termed a Fault-Line Scarp though it may be better classified as a Stream-Cut Scarp.

C. Stream-Cut Scarps:

A lineation parallel to the Cluan Fault (trend west-north-west) follows Jackey Creek and a "reach" of the Liffey River. Although no faulting has been detected along this line it obviously represents a zone prone to erosion and is probably akin to the shear zones mapped elsewhere in the area. Stream incision to depths in excess of two thousand feet along this zone has produced similar scarps on either side of the incision. Although these scarps may be related to the Tectonic pattern (the Jackey Lineation) they were not formed at the time of, nor as a result of, faulting. They were formed as a result of stream incision and may be termed Stream-Cut Scarps.

2. Age of Scarps.

A. Fault Scarps.

Since the faulting displaces the dolerite and older rocks of the area it may be assigned to what is generally accepted as the Tertiary Faulting of Tasmania. The most recent contribution to the dating of this faulting is that of Gill and Banks (1956, p.12.) The presence of Trisacites (presumably pre-Yallournian) in Launceston Group Sediments which post-date the initiation of Tertiary faulting suggests to these authors that the main scarp-forming faulting is probably Eocene in age.

B. Fault-Line Scarps and Stream-Cut Scarps.

The nature of formation of these scarps precludes the dating of their initiation. It is sufficient to note that in their present form they are considerably younger than the Fault Scarps in this area.

3. Climatic and Erosional History.

The major geological events of the area may be summarised as follows:

A. Faulting.

B. Sedimentation in fault troughs.

C. Basalt Effusion.

D. Lateritisation.

E. Glaciation.

These events will be used as a basis for discussion of the climatic and erosional history of the area.

A. Faulting.

The duration of faulting is not known with any certainty. While the main scarp-forming faulting is probably Eocene in age it is probable that it continued during the deposition of the Launceston Group. Faulting has displaced some of the Launceston Group beds, as seen in the excavation for the Trevallyn Power Station. Rapid erosion could be expected on the newly formed scarps. The presence of coarse boulder beds, considered by Carey (1947, p. 37) to be redistributed earthquake debris very near the base of the section, suggests severe erosional conditions.

B. Sedimentation:

The sediments of the Launceston Group show evidence of a number of climatic cycles. Carey (1947, p. 40.) points out that seams of lignite characteristic of the early part of the lake sequence and horizons of laterite and ferruginous sandstone which occur particularly in the later phases of the sequence, probably represent definite phases in the climatic oscillations. The abundant fossil plants of the sediments belong to genera which, today, are characteristic of warmer and more humid climates.

The available evidence for the upper limit of sedimentation is scant. Gill and Banks (1956, p. 12.) showed that marine transgressions deposited limestones of Upper Oligocene to Lower or perhaps Middle Miocene age at

Marrawah. Valleys eroded in similar limestones at Irishtown (within twenty five miles of Marrawah) contain sands, gravels and lignites with a Tertiary flora which disappeared from S.E. Australia by the end of the Pliocene. These sediments, therefore, probably fall within the range Lower Miocene to Pliocene. Since sediments of a similar type occur in the Launceston Group and since climatic conditions suitable for the depostion of (say) lignite would hardly be restriced to an area which excluded the topographically similar Launceston basin (within one hundred miles of Irishtown) it seems reasonable to suppose that some, at least, of the Launceston Group sediments are of similar age. On these grounds we may assume that sedimentation in the Launceston basin persisted at least until the Miocene.

Oscillations in the climate will have produced a variety of erosional conditions. However the presence of over a thousand feet of sediments with evidence of rapid accumulation suggests generally severe erosional conditions during deposition.

C. Basalt Effusion:

Sedimentation in Lake Launceston was terminated by the pouring out of basalt from scattered foci. Gill and Banks (1956, p.12) have given the known limits of basalt effusion as Lower Oligocene and Middle Pleistocene. In view of the foregoing remarks on the age of the Launceston Group and the topographical evidence - the complete erosional obliteration of many volcanic features - the dating seems rather conservative. Miocene - Pliocene seems a reasonable assumption. (The upper limit of this range is supported further in subsequent paragraphs).

D. Lateritisation and Bauxitisation.

Basalt flows in the Launceston basin overlying Launceston Group sediments have been bauxitised. (Edwards. 1955, p. 20). Further, quite extensive deposits of laterite underlain by "grey billy" have been noted on the margins of the Launceston basin at levels comparable with that of the uppermost Launceston Group sediments. The thickness of laterite and "grey Billy" west of the H.E.C. Transmission Camp, Cressy, is in excess of thirty feet. This evidence suggests that following the basalt effusion a prolonged period of lateritisation occurred. Whitehouse (1951) suggests that lateritic processes operated in Australia during an interval that covers parts of both the Miocene and Pliocene periods.

If we assume that a particular laterite-forming climatic zone was involved and that the southern limit of this zone migrated northwards during the Miocene - Pliocene time interval it is apparent that the Tasmanian lateritisation occurred in the earlier part of this range.

Hanlon (1933) summarised the current views on the climatic and topographic conditions favourable for lateritisation. The most suitable climate is a warm one with a variable incidence of rainfall not sufficient to support dense perennial vegetation. A topography approaching peneplanation with mechanical erosion at a minimum is most suitable.

E. Glaciation:

Overlying the laterites and bauxitised basalts are the post-basaltic gravelly sands known as the Brickendon Sands. Stephens, Baldwin and Hocking (1942, p.11.) consider these represent gravel terraces of the Pleistocene glaciation. Near the foot of the Tiers a small plateau (487E853N) with a sloping surface, no doubt represents a remnant of an earlier face of the retreating scarp. This plateau ("talus flatiron") is capped with very large angular blocks of dolerite underlain by pisolitic laterite. The size (up to ten feet in diameter) and extreme angularity of the dolerite is suggestive of glacial deposition.

The presence of presumably glacial deposits underlain by laterite suggests that erosion was not severe in this area between the period of lateritisation and the onset of glaciation. The only evidence so far produced for the dating of the onset of glaciation in Tasmania is a radio-carbon dating by Gill (pers. com. 1956) of a sample from varves of the Linda Valley in western Tasmania. This gives an age of twenty six thousand years for these deposits.

The degree of glaciation is a matter of importance in assessing the prevailing erosional conditions. The plateau surface in the area studied bears little resemblance to the more typical glacial terrain to the west of this area. Nevertheless, certain features suggest the presence of an ice sheet in the area studied. The broad, marshy depressions, the rounded ridges with a suggestion of plucked faces and the accumulations of angular dolerite boulders suggest the presence of an ice sheet. Certain features of the scarp margin, notably the major joint "trenches" and the "benched" scarp rim (Fig. 6, Photos. 4&5) suggest ice action. It seems probable, therefore, that glacial conditions or, at the very least, periglacial conditions, persisted in this area.

On the evidence in other parts of S.E. Australia it seems that the Quaternary included, in addition to frigid phases, certainly one arid phase and possibly three or four such phases. Crocker (1941), Browne (1945), Crocker and Wood (1947) and Gill (1955) support the presence of at least one arid phase during the Quaternary. Gill (1955, p. 204) proposed the name Post-Glacial Thermal Maximum for this phase for which radio carbon determinations give an age of five thousand years. Butler (1956), on the evidence of "Parna" sheets on the Riverina Plain, suggests the presence of four periods of widespread and intensive aridity each preceded by a humid phase. The Post-Glacial Thermal Maximum represents the most recent of these. Sprigg (1952, p. 102) has summarised the geochronology of the Quaternary and indicated possible ages for glacial and interglacial phases based on the Milankovitch Astronomical Theory. It will be noted that the evidence of interglacial high shore lines supports the presence of three interglacial phases and a post-glacial phase as suggested by Butler.

The evidence so far noted of Quaternary aridity in Tasmania is restricted to the presence of lunettes similar to those described by Hills (1940) in Victoria. These lunettes are evident on the eastern margins of swamps on remnants of the youngest sediments of the Launceston Group.

If we accept the Quaternary record as suggested by Butler (1956) for Victoria as equally applicable to Tasmania it is evident that the Quaternary has been a period of repeated wide climatic variations. The erosion conditions were severe during glacial phases and the fluctuations from humid to arid conditions would materially accelerate the scarp retreat.

An interpretation by Gill (1955, p. 205) of climatic conditions in S.E. Australia following the Post-Glacial Thermal Maximum suggests that a wetter period corresponding to the "Little Ice Age" of Matthes was succeeded by a general movement of climate towards a warmer and drier phase. The present climate is incorporated in this trend. Gill's dating of the end of the Post-Glacial Thermal Maximum is four thousand years before the present.

4. Summary of Erosional Phases During Scarp Retreat.

Phase I.

During the period of faulting rapid erosion of the newly formed scarps resulted in accumulations of earthquake debris. Initial rapid retreat of the scarps occurred with a decreasing rate of retreat as the scarp faces assumed a more stable form.

Phase II.

During the period of deposition of the Launceston Group the general prevailing pluvial conditions promoted fairly rapid erosion of the scarp as instanced by the huge quantities of sediments (thicknesses in excess of a thousand feet have been measured) deposited in a comparatively short time interval.

Phase III.

Following the basalt effusions which marked the close of deposition of the Launceston Group a prolonged period of lateritisation and bauxitisation occurred. During this period mechanical erosion was apparently at a minimum and scarp retreat would have been slow. It is even possible that the scarp reached a stable state for the conditions then prevailing.

Phase IV.

The onset of glaciation and subsequent climatic oscillations ranging from frigid periods to interglacial arid periods must have promoted rapid erosion and retreat of the scarp face. This phase includes the Post-Glacial Thermal Maximum.

Phase V.

A climatic phase wetter than at present succeeded by a trend towards a warmer and drier climate was probably reflected by a slowing down of the retreat of the scarp.

5. Rates Of Retreat Of Scarps.

The history of retreat of the various scarps which constitute the Western Tiers will be considered in an effort to determine the rates of retreat under the different climatic and erosional conditions outlined in the preceding section.

A. Scarp formed by the Tiers Fault:

The mean position of the present scarp rim may be represented by a straight line between Drys Bluff and Mt. Blackwood. The distance between this line and the Tiers Fault, representing the total retreat of the scarp, is approximately thirty thousand feet. This retreat occurred during the period covered by the five erosion phases outlined earlier.

Not enough evidence is available for the determination of the volume of earthquake debris in the Launceston Group and hence the amount of retreat during Phase I.

Calculation of the total amount of retreat during Phase I and Phase II depends on determination of the margin of the Launceston Group sediments. Stephen, Baldwin and Hosking (1942, Fig. 1.) indicate that the boundary of the Tertiary basin was close to the foot of the Tiers. This location is confirmed to some extent by soil tests on clay samples from Palmer Rivulet. Samples were collected at the confluence of Palmer Rivulet and Brumby Creek and at a number of points upstream as far as the six hundred feet contour. All these samples showed precompression and a fair agreement as to the thickness of overlying sediments originally present. The figures suggest that the surface of the original sediments was some seven hundred feet above sea level. This figure is in reasonable agreement with the known upper levels of the Launceston Group. The possibility that pre-compression phenomena were due to desiccation cannot be overlooked but the general agreement of levels and the previous work of Stephens, Baldwin and Hosking support the hypothesis of compression due to loading. The proven western limit of pre-compressed clays, presumably belonging to the Launceston Group, is the point where Palmer Rivulet crosses the six hundred feet contour. This provides a retreat of the foot of the scarp of some thirteen thousand feet from the Tiers Fault. The period of this retreat is of the order of thirty million years (Mid Eocene to Early Miocene are the limits chosen). The rate of retreat is therefore of the order of one foot per two thousand, three hundred years. Obviously this figure represents nor more than the order of the real rate of retreat.

It has been suggested that during Phase III comparatively little mechanical erosion occurred. The presence of several large floaters (three feet in diameter) of "grey billy" in the bed of Palmer Rivulet one thousand feet downstream of the six hundred feet contour suggests that strong lateritisation occurred in this vicinity. The pisolitic laterite overlying Permian Mudstone and underlying dolerite blocks on the talus flatiron (853N487E) suggest that the lower slopes of the scarp itself were lateritised. This occurrence supports the view that mechanical erosion of the scarp during this phase was slight. It should be noted that since the overlying dolerite blocks rolled from the top of the scarp the talus flatiron was incorporated in the scarp face when these blocks were deposited. It follows that the "talus flatiron" did not exist as such, offering a protected environment for the formation of the laterite, during Phase III.

The large angular dolerite blocks which cap the talus flatiron mentioned above and a similar talus flatiron to the north (856N482E) have been assigned to Phase IV. Their size and angularity completely unlike any dolerite blocks found on the present scarp face at similar levels, suggest an origin during conditions of extreme mechanical erosion. Their similarity to dolerite boulder accumulations found on the Central Plateau and generally attributed to ice or frost action suggests that their emplacement occurred during the period of glaciation. Since these dolerite blocks immediately overlie laterite they may be assigned to the first stages of extreme mechanical erosion. The retreat of the scarp face from its position when these blocks were deposited to its present position may be calculated. If parallel retreat is assumed (constancy of slope of the scarp face is maintained in parallel retreat) the amount of retreat is the distance between similar levels on the "talus flatiron" and the scarp face proper (See Fig.10.) This distance is of the order of three thousand feet. The inception of Phase IV may have been as recent as the only radio carbon dated glaciation of Tasmania, namely twenty six thousand years ago. Even if the beginning of the Pleistocene (six hundred thousand years ago) is taken as the beginning of Phase IV the rate of retreat of the scarp for phase IV and V is of the order of one foot per two hundred years. Compare this rate of retreat with the rate calculated for Phases I and II, (one foot per two thousand, three hundred years), or for the average retreat from formation of the scarp (at least sixty million years ago) to the present - an average rate of the order of one foot per two thousand years. These comparisons indicate that retreat during Phase IV and V is far more significant than any previous retreat. While no division between Phase IV and Phase V is possible on present evidence the generally milder climate during Phase V and the much shorter duration of this Phase - four thousand years (Gill 1955, p.205) - suggests that Phase IV is the dominant Phase of scarp retreat.

B. Scarp formed by the Cluan Fault.

In the case of the Cluan Fault the scarp produced had a relief of about one thousand feet, only about half the relief of the scarp formed by the Tiers Fault. The down-faulted block (Cluan Tier) remained at a level some thousand feet above the lowland surface to the north and east. The effect of this elevated block at the foot of the newly formed scarp was probably reflected in a slower retreat since it would affect drainage from the scarp face.

More effective in retarding the retreat in comparison with that from the Tiers Fault was the physical nature of the scarp formed. The Tiers Fault exposed dolerite and underlying sediments. Removal of the more easily eroded sediments would cause collapse of the dolerite and retreat rate would be governed by the rate of erosion of the sediments. The Cluan Fault, on the other hand, exposed only dolerite - the underlying sediments were at a lower level than the surface of the down-faulted block. In this case retreat would be governed by the rate of erosion of the dolerite, a much more resistant rock than the sediments which controlled the Tiers Scarp. These factors, then, explain the small retreat (less than nine thousand feet) from the Cluan Fault to Drys Bluff.

The physical nature of the scarp face and the drainage control on the lower slopes, while paramount in the case of water erosions, would be less effective in the case of erosion by ice and frost. These agents acted predominantly on the rim of the scarp during Phase IV. No evidence of glacial topography could be found on the scarp face and it seems possible that while an ice cap may have existed on the plateau surface the tongues of ice which over-ran the plateau margin melted on the upper slopes of the scarp face. If such tongues of ice over-ran the rim of the plateau they would be most effective in plucking the well-jointed dolerite from the plateau edge. There is evidence to suggest this theory.

Inspection of Map I indicates that in the immediate vicinity of Drys Bluff the plateau has a raised rim. The Drys Bluff promontory surface is, in fact, shaped like a half saucer. It is possible that ice action produced this form and it is almost certain that no ice over-ran the plateau rim in this vicinity. Inspection of the plateau rim immediately to the south-west of Drys Bluff (4720E 8620N) on Map I and Map Square 4786 reveals a different picture. Not only is there no raised rim in this vicinity but broad marshes extend to the plateau margin. Beyond this point broad fields of dolerite boulders extend towards the Liffey Valley on a general slope of eleven degrees. This slope is well below the natural angle of repose of such accumulations. All these conditions could be explained by the over-running of the plateau margin by a tongue of the ice sheet. It will be noted that the direction of movement of these tongues of ice need not conform with a general widespread movement of the ice sheet. The movement of isolated tongues over the rim of the scarp - purely local movement - would be expected. Such movements would provide stress-relief in the ice cap mass. This would also explain the lack of persistence down the scarp face of these tongues. Relative positions of the raised rim scarp and the depressed swampy rim with respect to the Cluan Fault indicates the relative amounts of retreat at those points. Acceptance of the ice erosion hypothesis would strengthen the argument that Phase IV was the dominant erosion phase in the history of the scarp retreat.

C. Scarps formed by Stram Incision:

Stream incision along a lineation coinciding with the present course of Jackeys Creek and a reach of the Liffey River has produced scarps to the north and south of this lineation. It is important to realise that no appreciable vertical movement occurred along this lineation. Erosion directed by the lineation produced the scarps. The relief of the scarps (two thousand feet) is similar, the same sequence of rocks is involved but their attitude relative to the scarp differs. Thus while the sediments of the northern scarp dip outward from the scarp those of the southern scarp dip inwards. (See section on Map Square 4686).

The retreat of the northern scarp measured normal to the lineation is some nine thousand feet. This is a similar amount of retreat to that at Drys Bluff. Yet the latter was produced by faulting and is therefore considerably older than this northern scarp. This suggests that retreat conditions were more favourable in the period common to both scarps, namely, the later period embracing Phase IV. The prospect of ice tongues operating on the northern scarp is remote since it is an isolated fragment of the plateau the total area of which is no more than five times the area of that portion shown on Map Square 4686.

The retreat of the southern scarp, measured normal to the lineation, to the promontory just west of the lake highway is eight thousand feet. This promontory has a raised rim similar to that at Drys Bluff so that ice-tongue action is not suspected. The agreement in amount of retreat of the north and south scarps suggests that the effect of the different dips of strata ~~selective~~ relative to the scarp face is of little significance. If the retreat of the southern scarp is measured where ice tongue action could have operated, namely in the south west corner of Map Square 4686, a figure of nineteen thousand feet is obtained. However the possibility of a similar, though weaker, lineation along Worners Creek nullifies this evidence.

A striking feature of this area is the limited catchment area and the low stream flows of Jackeys Creek. Under the present climatic conditions the catchment area, even with the addition of the headwaters of the Liffey which may have been captured from the Jackey drainage system, would not provide sufficient water to erode the valley to its present depth. In an earlier section it has been suggested that climates up to the beginning of Phase III were not unlike the present climate as regards rainfall. Phase III was apparently considerably drier. Phase IV, with huge volumes of water available from the ice cap appears to be the only Phase with far greater stream flows than the present. It seems, therefore, that much of the stream-incision occurred during Phase IV. A similar argument could be applied to the stream-incision of the Cluan Fault Zone. The comparatively late exposure of the sediments on the up-faulted block has produced a scarp similar in relief and physical composition to that produced in the early Tertiary by the Tiers Fault. The difference in amount of retreat of the now similar scarps suggests that they have assumed that similarity comparatively recently. This is in accordance with the earlier suggestion that their m arked physical differences at the time of origin explain the difference in their rate of retreat up to the beginning of Phase IV.

D. Fault-Line Scarps:

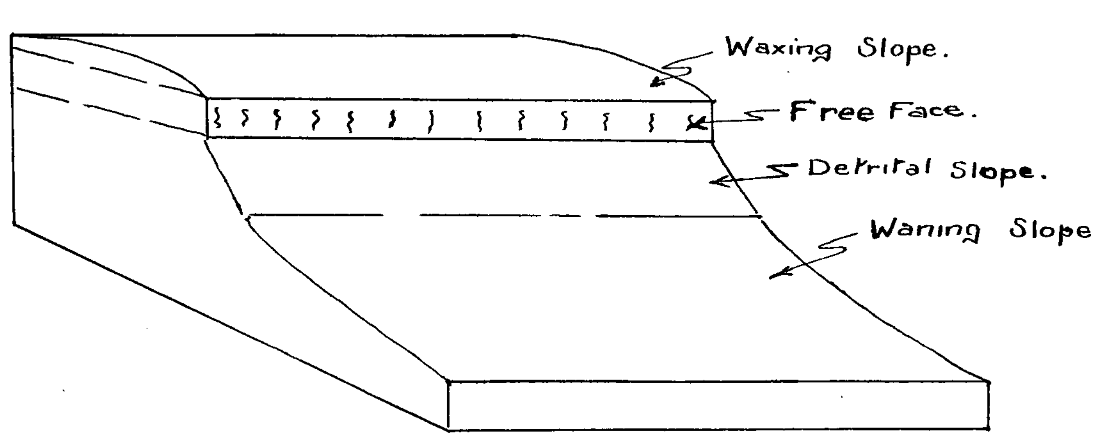
The fault-line scarp immediately to the east of the Tiers Fault reaches its maximum developement in Macrae Hills (Centre-ground right-hand margin of photo.1. and Map 1.). Even though it is thought to have existed at least since Phase III, since laterite deposits occur on the western flanks of the southern extension of this scarp (east of the area under discussion), there has been very little retreat of this scarp. The sediments underlying the dolerite are not exposed along the fault-line so that retreat depends on dolerite erosion. It has been suggested in the case of the Cluan Scarp that dolerite erosion is best effected by ice and frost action. The paucity of dolerite erosion in this area which was almost certainly free of ice or prolonged frosts throughout its history could be taken as support for the effectiveness of ice and frost erosion.

II. NATURE OF SCARP IN TERMS OF SLOPE ELEMENTS:

Having studied the origin and retreat of the various scarps which constitute the Western Tiers it is now intended to discuss these scarps in terms of their slope elements and combinations of these elements which constitute what may be termed "unit scarps".

1. Slope Elements.

In his paper on landscape evolution King (1953) describes four elements which may occur in hillside slope. These he terms waxing slope, free face, detrital slope and waning slope (including the pediment). These elements are illustrated in the text figure below.



This terminology fits the Western Tiers picture perfectly as do King's qualifying remarks, a precis of which follows:

Each or any of the elements may be suppressed.

Each element may evolve more or less independently.

The most active elements are the free face and debris slope.

When the free face and debris slope are inactive the waxing slope becomes strongly developed and may meet the waning slope. The resulting concavo-convex slope is a degenerate form.

2. Scarp Elements.

The essential elements in the scarp-form are the free face and detrital slope. These elements are best developed in regions of moderate to high relief where a cliff-forming rock is underlain by a less resistant material.

3. The Tiers - a "Multiple Scarp":

A. Constituents:

The combination of critical slope elements, suitable relief and favourable juxtaposition of hard and soft strata occurs on the Western Tiers not singly but a number of times. The combination is represented not only by the cliff-forming dolerite overlying weak Upper Triassic sediments but by all those cliff-forming sandstone formations of the Triassic and Permian overlying shales and mudstones of appreciably less resistance to erosion. Thus the Ross sandstone, the Liffey sandstone and to a lesser degree the thinner Permian sandstones represent laterally persistant free faces on the Western Tiers slope. The Western Tiers is therefore a "multiple scarp" the units of which vary markedly in character and magnitude.

B. Profile and Drainage:

The slope elements (free face, talus slope and waning slope) which produce the smoothly concave profile of the unit scarp are repeated for each unit of the multiple scarp. The result is a "scalloped" profile with a series of benches on the multiple scarp face - hence the name "Tiers." (See Fig. 10).

The repetition of free-faces modifies the drainage pattern usually associated with scarp slopes. Drainage of a steep slope when the slope itself represents the entire catchment is usually effected by an anastomosing system of channels and rills with frequently changing courses. No deep incision of such a slope occurs. In the case of a multiple scarp of similar grade the repetition of rock outcrop in the form of free faces of the various unit scarps has a restricting influence on the drainage form. Water gaps form in these outcrops which restrict the lateral migration of superficial drainage channels. The result is a system of permanent channels traversing the entire face of the Tiers at more or less regular intervals producing deep incisions in the line of the scarp. (It should be noted that very little Plateau drainage is carried on the face of the Tiers.) Buttress-like interfluves extending from the top of the face to points on the pediment well beyond the general line of the base of the Tiers indicate the permanance of the drainage form.

C. Interaction of Unit Scarps:

In spite of the variations in magnitude and character of the unit scarps involved their rate of retreat is sensibly the same since the Tiers scarp, as a whole, has retreated. It is reasonable to suppose that the retreat of any unit is governed to some extent by the retreat of adjacent members. For instance, collapse of a section of Ross sandstone cliff has two immediate effects.

(a) It removes the toe of the slope above accelerating the scarp retreat cycle in the unit immediately above (dolerite).

(b) It introduces greater loading, in the form of blocks from the cliff collapse, on the unit immediately below precipitating failure in that unit.

The effect of this contemporaneous collapse of a number of units is to maintain uniform retreat over the whole scarp face.

III. COMPOSITION AND RETREAT MECHANISMS OF UNIT SCARPS.

I. Dolerite Scarps:

The dolerite "sill" which caps the Permo-Triassic sedimentary sequence and forms the surface of the plateau in this area provides the free-face of a scarp which dominates the Western Tiers. The dominance of this unit is due not only to the thickness of the dolerite or its position at the top of the succession of unit scarps which constitute the Tiers, but to a number of features of the unit

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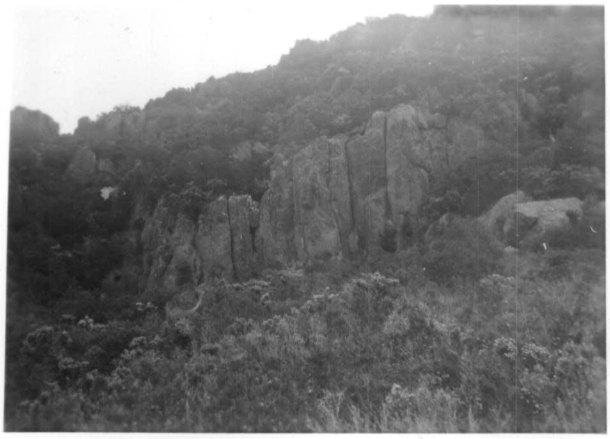

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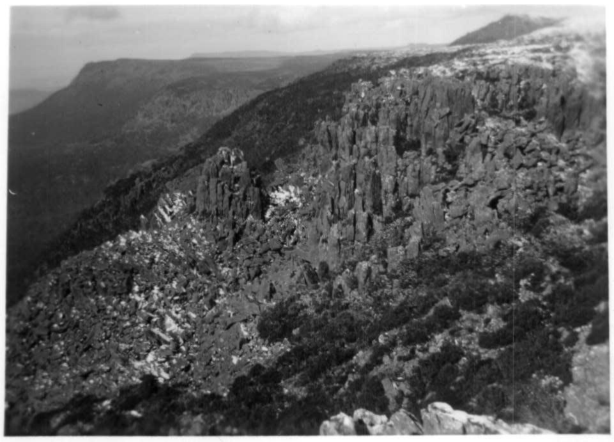


which will emerge in the following discussion.

A. Waxing Slopes.

The waxing slope is not well developed in areas where a free-face is present. The high resistance to erosion and the active retreat exemplified by the free-face hinders the development of a typically convex waxing slope. Where the free-face is absent, however, the waxing slope may constitute a large proportion of the unit. In the fault-line scarp east of the Tiers Fault the free-face is rarely developed and the convex slopes of this scarp represent the ultimate development of the waxing slope.

Certain features of the waxing slope in its poorly developed form on the plateau rim are worthy of note. In some areas trenches have developed along major joints. These trenches are roughly rectangular in cross section, generally up to six feet in depth and up to ten feet in width. At the point where the joint intersects the free-face the dimensions may be considerably greater (See Figs. 4&6 and Photos. 4&5). These trenches may persist well beyond the limits of the waxing slope.

Associated with the joint trenches and restricted to the same areas are features which constitute a stepped margin to the plateau. These features are illustrated in Fig. 6 . Each "step" is level, bounded by major joints and backed by dolerite cliffs. (Photo.) Originally it was thought that these steps had been parts of the plateau surface which had subsequently dropped but a thorough search revealed no evidence of movement on the bounding joint planes. It seems more likely, in view of their association with the trenches that they are the result of erosion processes. They may well be connected with tongues of ice which, it has been suggested, overran the plateau margin. Preferential erosion of the joint zones by ice action could produce the joint trenches and ice action is known to have a step-forming action on slopes. Johnson (1904), Andrews (1910) and Matthes (1930) are among those who have advanced hypotheses as to the nature of the process whereby the steps are produced. Matthes (p.89, 1930) describes in some detail the process whereby moving ice excavates. The ice, taking advantage of existing fractures in the rock, dislodges joint blocks, particularly those with one face unsupported, as in a cliff face. In this manner the joint blocks above a well developed horizontal joint plane (now representing the "tread" of the step) could be dislodged and carried some distance down the face of the Tiers. The complete absence of trenched joints and stepped margins at points where the plateau has a raised rim (as at Drys Bluff) suggests that the "trenches" and "steps" are due to an erosion process rather than a structural relation between dolerite and underlying sediments. The structure relations are apparently constant over long distances of the rim while the erosion processes may well have varied widely over the same distances.

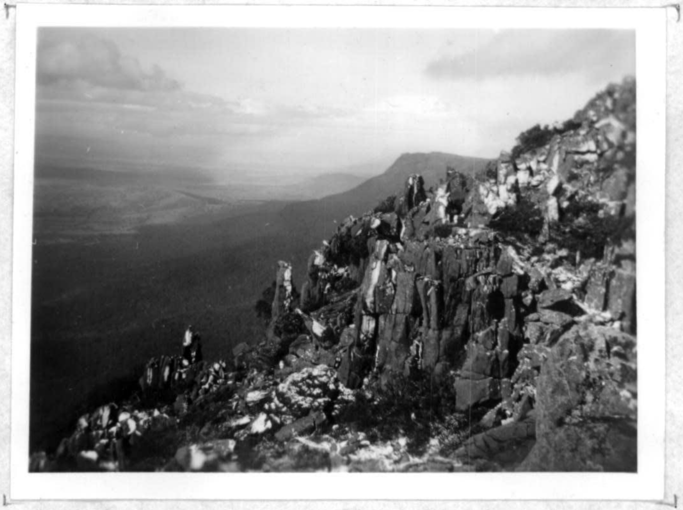
B. Free-Faces:

The free-faces of dolerite form a wall of varying heights up to nine hundred feet (Drys Bluff) along much of the scarp rim. The slope of these cliffs varies considerably and of those measured no relation between hieght and slope could be established. A series of near-vertical joint faces separated by ledges of varying width make up these slopes and it is possible that some relation exists between joint-spacing and cliff-slope.

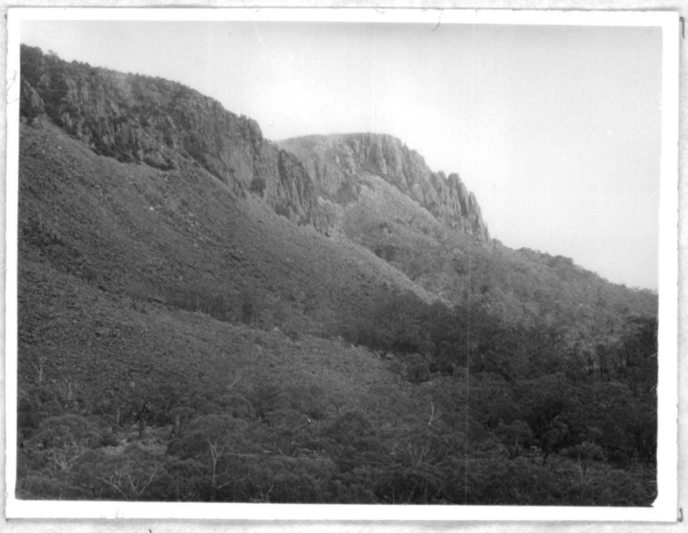
A prominent feature of the cliffs is the strongly developed vertical joint system. This feature is developed almost to the stage of the well known "Organ-pipe" structure of basalts though the jointing is not as regular as in the better examples of that structure. The effect of this pronounced jointing is to make the rock particularly prone to frost action during the winter months. (How much more prone to ice plucking!) The thaw of frost-filled joints loosens and precipitates many individual joint blocks on to the scree slopes below the cliffs.

As well as the vertical system (evident in Photos. 6 & 12) several other joint systems are apparent. A fairly well developed near-horizontal system may be discerned in Photos. 6 & 7 while in Photos. 16 & 18 a few strongly developed oblique joint planes may be seen. All these joint systems play an important part in the retreat of the dolerite scarp and any retreat mechanism proposed must be reconcilable with such systems.

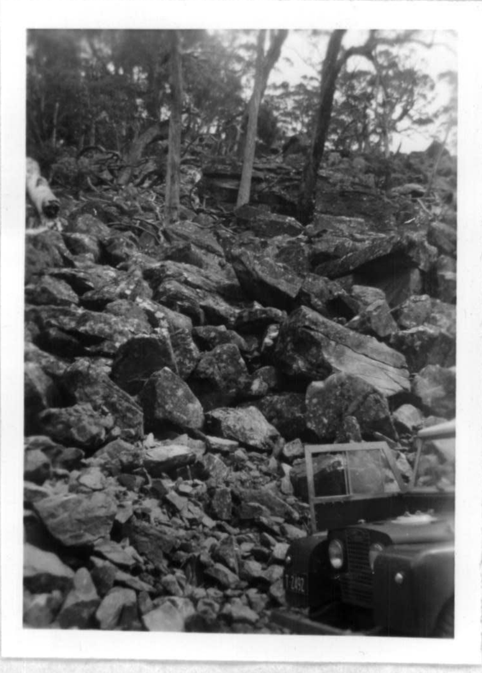
7. (TEXT 33)



8. (TEXT 34)



9.



10. (TEXT 37)

11. TEXT 41.

C. Detrital Slopes:

The features of the detrital slopes and of the vast accumulations of rock slide material which constitute those slopes are the key to the retreat mechanism of the dolerite scarp. The months of field observation, of plane tabling under difficult topographical conditions and trying weather conditions have produced many ~~much~~ valuable data on the surface features. Plane tabling of a large area of the detrital slopes and plateau margin was ~~were~~ carried out by the author on a scale of forty feet to one inch. Ten foot contours were plotted but on reduction of the scale for inclusion in this thesis (Fig. 4) only fifty foot contours were plotted so that geological features were not obscured by contour detail.

Only in the enlargement of one portion of the area (Fig. 6) have the ten foot contours been retained. In other areas (Figs. 1 & 3.) fifty foot contours only were plotted. The areas chosen for plane tabling were so chosen because they included detrital-slope features common to many areas of the Western Tiers. There has been no attempt to choose rare or unusual features nor has there been any attempt to avoid areas with mystifying or apparently contradictory features. It is felt that the areas chosen include reasonable examples of all the known features of these deposits. These "type areas" will be described in turn and an interpretation of their features attempted. Their general location is shown on Map I.

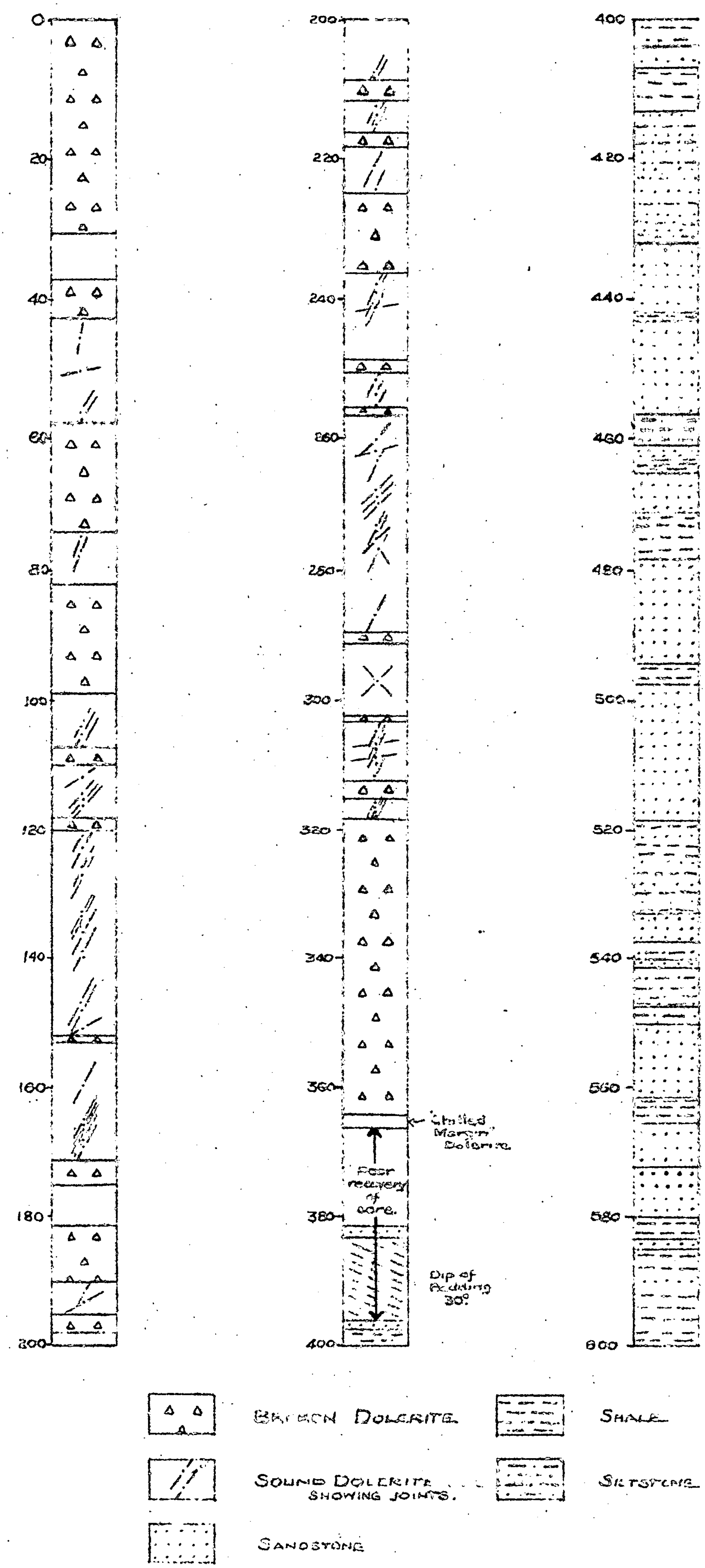
Type Area I (Fig. 1)

Dolerite cliffs some two hundred feet high extend from the eastern margin of the area to within five chains of the western margin. A gap in the dolerite cliffs is occupied by a scree-filled depression through which flows a creek which drains a broad shallow depression on the plateau surface. Immediately below the cliffs scree fields composed of angular blocks of dolerite up to two feet in diameter rest at the angle of repose of that material (25deg.) The gap in the cliffs and the scree slopes are shown in photo 8 . Beyond the toe of the scree slopes gentler slopes extend to the northern margin of the area. Most of this area is occupied by tree-covered 'talus'. (The term 'talus' is applied to boulders

FIG.2.

CORE LOG – DRILL HOLE 5019.

(TYPE AREA I)



in a matrix of clay derived from the weathering boulders.) A small proportion of the area is occupied by ploughed fields - accumulations of angular boulders without a clay matrix and therefore devoid of vegetation. A number of depressions, steep-sided and up to ten feet in depth and elongated parallel to the scarp, are evident. Mounds of similar dimensions and disposition but bearing no obvious relation to the depressions are also indicated. It was noticed, however, that the mounds were composed of larger blocks of dolerite than the rest of the area and there was a suggestion of a preferred orientation of these blocks normal to the scarp slope.

A ridge parallel to the slope extending westward from the section line just south of the three thousand five hundred foot contour is composed of a large mass of dolerite in which the prominent jointing, vertical when the mass was in situ, dips towards the cliffs at an angle of sixty degrees.

A vertical diamond drill hole (D.H. 5019), in the location shown, penetrated rock slide material and the underlying sediments for a depth of six hundred feet. The log of this hole is shown in Fig. 2 . Features of the core indicated on this log are:

(i) The alternations of sound and broken rock both showing little signs of weathering.

(ii) The overwhelming majority of joints dipping at or near sixty degrees.

(iii) The presence of a 'chilled margin' representing the lower edge of the dolerite sill.

(iv) The zone of poor recovery of sediments immediately below the 'chilled margin' including fragments in which the bedding direction indicates a displacement of some thirty degrees from their original position.

(v) The sound, fresh and undisturbed condition of sediments below three hundred and ninety six feet.

Interpretation.

As indicated on the section the angles of dip of predominant jointing in the drill hole agree with those on the ridge north of the drill hole. It seems reasonable to assume that the direction of this dip, indeterminate in the case of the drill hole, is also coincident.

It appears, therefore that a large mass of dolerite has hinged outward from the cliff face about an axis parallel to the cliff face and near the base of the hinged mass. The shattered zones which alternate with zones of sound rock in the drill hole are interpreted as zones of movement (crush breccias) between contiguous blocks which constitute the hinged mass. (A simple parallel is obtained when a bookend is removed from a row of books so that the books tilt away from the remaining bookend.) Some of the sediments underlying the dolerite may have adhered to the dolerite mass since the measured angle of dip of beds in the zone three hundred and eighty four to three hundred and ninety six feet is the complement of the angle of prominent jointing in the tilted block, just as the angle of dip of the undisturbed sediments (two to three degrees) is approximately the complement of the angle of pronounced jointing (near-vertical) in the dolerite cliffs. The zone of poor recovery may result from crushing of the less competent of these sediments during movement.

Several explanations as to the cause of the movement of a large mass of dolerite in this manner may be offered:

(i) The Triassic sediments which underly the dolerite are notably weak and prone to slaking on exposure. Furthermore, certain layers contain Halloysite. Grim (p.18, 1950) points out that any change of moisture content of material containing this clay mineral would cause a great change in properties of the material - an unplastic material may well become plastic. It seems feasible, therefore, that a radical change in properties of the underlying sediments, brought about by their change in environment as the scarp face retreats to them, may cause plastic flow in these sediments. The great bed of dolerite may squeeze out certain layers of the sedimentary 'pile' supporting it and precipitate failure in the dolerite mass. Such a squeezing-out, at a maximum at the scarp face and diminishing inwards, would produce a wedge down which the overlying mass may slide. The zone of poor recovery may occur in sediments disrupted initally by plastic flow of supporting layers and subsequently by the over-riding, sliding mass.

Against such a hypothesis is the restricted width of the halloysite layers. Individual layers are, at most, a foot thick and the total thickness of halloysite would not constitute one per cent of the Upper Triassic sediments. Nevertheless, failure of a limited number of layers may introduce stresses in the sediment pile sufficient to precipitate failure in other layers. Clay minerals other than halloysite constitute a considerable portion of these sediments which are notorious for their disintegration behaviour on exposure (or on drastic change of environment.) The fresh undisturbed character of sediments below three hundred and ninety six feet precludes the existence of deep-seated planes of movement causing cliff collapse.

(ii) A second explanation involves the movement of ice over the scarp rim. The broad shallow depression on the plateau drained by the creek on the western margin of this area may well owe its origin to ice action. An ice-tongue slowly over-running the scarp may well initiate outward rotation on marginal masses of dolerite. Once the movement is initiated gravity will complete the operation. Against this hypothesis is the overall depth of the mass. It seems that the mass would have to be unusually free of horizontal and oblique joint systems for a force applied at the plateau level to rotate a block of such depth.

The smaller mounds may be of similar origin to the ridge just described. The suggestion of a preferred orientation in their constituent blocks supports this similarity.

The depressions could be interpreted as tension zones in the talus mass caused by the irregular downslope migration of this mass. Alternatively they may be regarded as a type of sink-hole. Quite strong flows of underground water move down-slope on the zone of contact between the talus deposits and the underlying sediments. Photo. 10 shows water emerging from this zone where it is intersected in a cutting. Such underground flows may well remove sufficient material from the talus sole to cause subsidence of its upper surface. Such an explanation, however, does not explain the general orientation of the depressions parallel to the scarp.

The ploughed fields may represent zones of movement in the talus. As in the case of the depressions the movement could be caused by sub-surface erosion, by general downslope migration of the talus mass or by a combination of these. Further discussion of these features will be included in the interpretation of other areas where more evidence is available as to their origin.

Type Area II (Fig. 3)

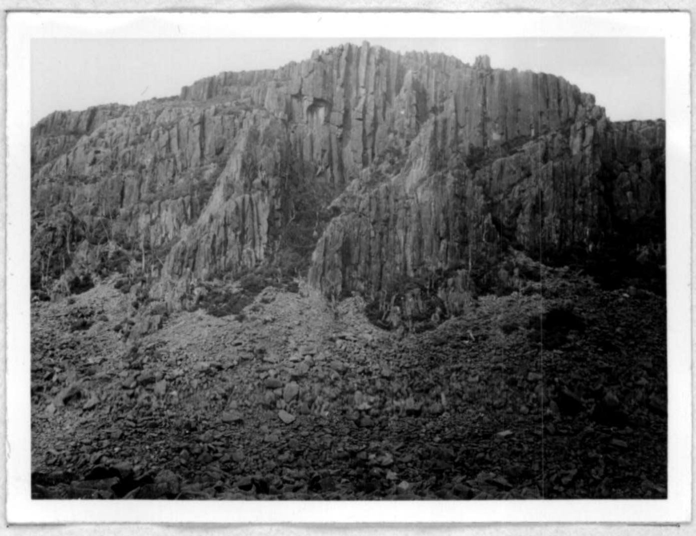
This area includes Mt. Blackwood, the cliffs, up to four hundred feet in height, bordering this eminence and a debris slope displaying two new features of particular interest.

A small round hill located on the section line is composed of dolerite blocks in which the prominent joint-dip direction is normal to and away from the cliffs. This jointing is shown in Photo. 13 in which the seated figure gives an indication of the size of the blocks. Photo. 14 illustrates the relation of the hill and neighbouring scree slope. It is apparent that this hill represents a coherent mass which has moved from its original position en-masse. It is not an accumulation of blocks which have fallen at different times. The rotation of this mass, as instanced by the disposition of prominent jointing, is in the opposite sense to that of the hinge-block described from Type Area I.

An interesting interpretation based solely on the direction of rotation is that a "slip-circle" is involved. Movement along a slip-circle would have to be appreciable to produce the observed amount of rotation. While it is conceivable that a slip-circle may form in weathered rock-slide material containing an appreciable proportion of clay it seems unlikely that a slip-circle would develop in the heterogeneous sediment pile underlying the dolerite sill. Movement along such a surface would involve the shearing of quite competent sandstone horizons (see core log - D.H. 5019) as well as the dolerite. (No slip-circle movement could be accomplished along a surface coinciding with joint planes in the dolerite over the full thickness of the dolerite since considerable curvature of the sliding surface is demanded if rotation is to be effected.)

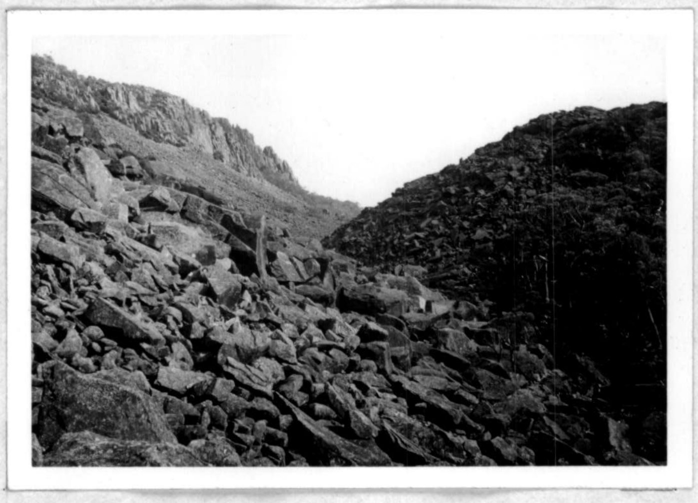
Perhaps a more feasible interpretation is a movement along a plane surface represented by a member of the oblique joints system in the dolerite. Photos. 12 & 16 show the strong development of such a system in the cliffs at this point and sliding may well occur along such a plane. Photo. 18 illustrates sliding along such a plane of a considerable mass of dolerite. Crushing in the vicinity of

12. (TEXT 38)



13. (TEXT 38)

14. (TEXT 38)



15. (TEXT 39)

the plane is evident. A remarkable feature is that the disposition of the joint planes indicates that no rotational movement has occurred. (Location of feature: 4793E. 8535N.) Another example of sliding on a plane within the dolerite is shown in Photo. 17 (Location 4019E. 8496N.) In this case there is some backward tilting of the blocks above the plane. The fact that backward tilting occurs suggests that the movement is rapid. It will be noted that the plane of failure is steep so that rapid movement would be expected.

Consider now the extensive ploughed field of Type Area II (Photo. 15). This broad area has a very low general grade and an extremely irregular surface-a "choppy sea" surface in which the waves have an amplitude of two to five feet. Dolerite blocks of sizes up to ten feet are chaotically distributed. Parts of the surface are sufficiently mature to support stunted trees. In other parts the boulders are lichen-covered while yet other areas are occupied by brown, lichen-free boulders which would indicate comparatively recent redistribution. A number of trenches paralleling the scarp line are present.

The whole aspect of this surface is one of movement, - a rock glacier of complex internal stresses providing zones of tension (trenches) and of compression (mounds). Yet this area is completely surrounded by timbered slopes devoid of evidence of recent movement. Possibly the oscillations which disrupt this surface are caused by groundwater. This flat area may provide a trap for groundwater. The only permanent stream in this area, apart from two which have a plateau catchment of several square miles, emerges on the slope at the three thousand foot contour below this ploughed field. Drilling results in other areas indicate that while considerable groundwater flows occur at the base of the rock-slide accumulations groundwater does not occur in any quantity above this level. If local conditions here cause the groundwater table to fluctuate within the rock-slide mass the associated swelling and contraction of clays in the zone of fluctuation may well cause disruption of the surface.

In considering the origin of this broad, gently sloping mass of rock debris lying at the foot of a four hundred foot cliff it is interesting to compare many of the smaller rock-falls described and photographed by Howe (1909) in the San Juan Mountains. Howe suggests that the triggering mechanism for the catastrophic collapse required to produce the broad, gently sloping mass of rock-slide material is provided by earthquake waves.

It should be noted that jointing in the three mounds beyond the limits of the ploughed field indicates a "hinge-block" origin, similar to that described for Type Area I, for these features. This suggests that the two principal features in this area, the outward-dipping block and the gently-sloping ploughed field are not related to persistent mechanisms of retreat.

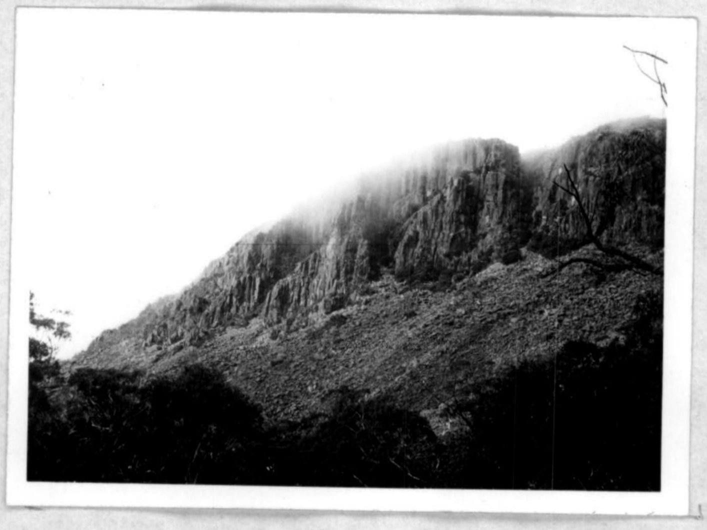
The small "ploughed field" to the north-west of the main field has little in common with the latter. It is a steeply and evenly sloping mass of lichen-free blocks produced by slope adjustment on the flanks of the hinge-blocks immediately to the south. Such slope-readjustment with the production of minor ploughed fields is a common feature on the larger "hinge-blocks" of Type Area III.

Type Area III. (Figs 4 to 9 inclusive)

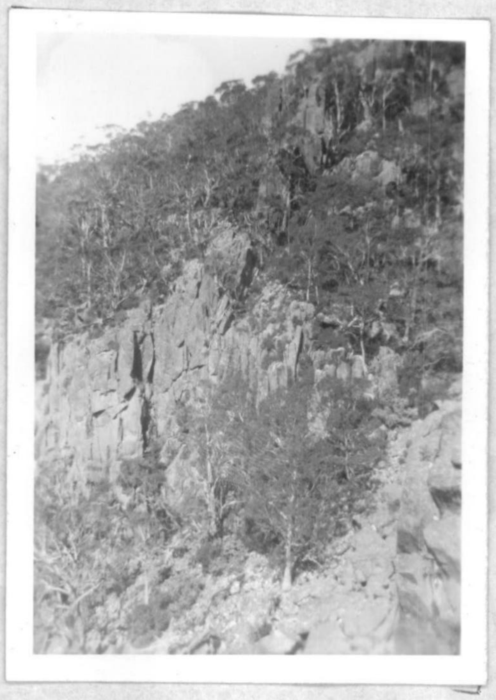
This area embraces the full width of the detritus slope from the comparatively small cliffs bordering the plateau to the toe of the rock slide accumulations resting on outcrops of the bedrock sediments. Section A.B. (Fig. 9) shows the relative magnitude of the cliffs and the detritus slopes and the irregular profile of the slope. The outstanding surface features of this slope are the "hinge-block" (or "rotated-block") cliffs and the associated ploughed fields.

The "hinge-block" cliffs consist of huge masses of dolerite in which the prominent joint planes dip towards the cliffs. As shown in Sections A.B. and C.D., the angle of dip for any given section decreases as distance from the cliff increases. Since this angle of dip is a measure of the rotation suffered by the block it follows that the blocks furthest from the cliff line have suffered the greatest rotation for any particular section normal to the slope. Photos. 19 to 23 show features of these cliffs. The cliff face is formed by what may be termed the basal planes of dolerite prisms which constituted the sill. Even though the masses have rotated through as much as

16. (TEXT 38)

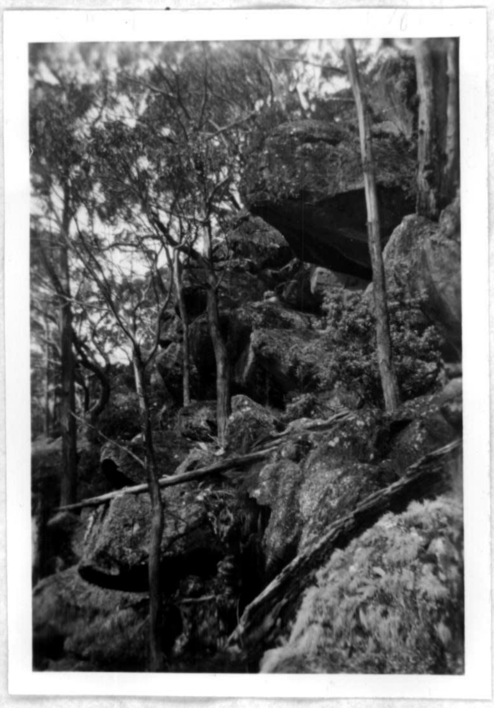


17. (TEXT 39)

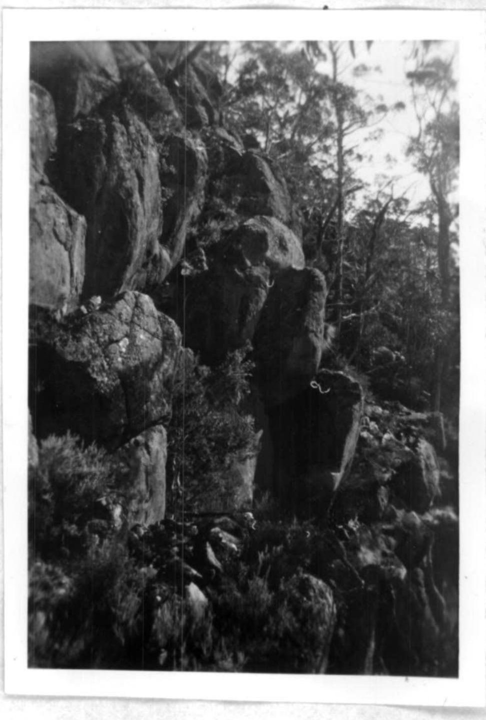


18. (TEXT 38)

19. (TEXT 40)



20 (TEXT 40)



21. (TEXT 40)

22. (TEXT 40)

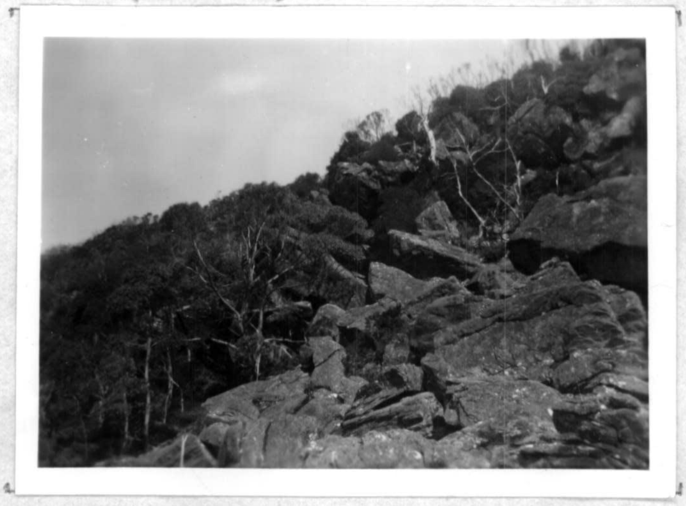
23. (TEXT 40.)

24. (TEXT 42)

25. (TEXT 43)

26. (TEXT 43)

27. (TEXT 43)



ninety degrees there is still a strong coherence between constituent blocks. There can be no doubt that the mass moved as a whole. It should be noted that these hinge-blocks have suffered far less shattering than the outward-dipping block in Type Area II. The inference in that case was that the movement was catastrophic. It may be inferred here that the coherence of these "hinge-blocks" points to a more sedate rotation. A significant feature of hinge-blocks in this area and in all other cases studied is that they do not exist at levels below the base of the sill. The lowest hinge-block (SectionCD.) noted is on the three thousand one hundred foot contour The dolerite

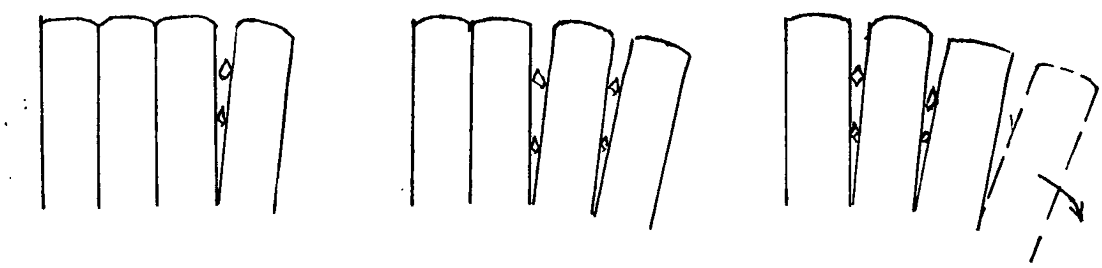
2,920 sediment or contact established in drilling D.H. 5033 is at R.L.3920 feet. This could be taken to indicate that there is very little downslope-sliding of the block during rotation.

There is a tendency towards alinear arrangement of hinge-blocks. A line of hinge-block cliffs extends eastwards from D.H. 5085 for a distance of twenty five chains. The line crosses the slope contours obliquely. The dip of blocks throughout this line is roughly constant. (A"scatter" of readings between seventeen and twentyfour degrees was obtained with no apparent relation between dip and contour level within this range.) It may be significant that this line is almost parallel to the plateau rim.

The mechanism of retreat which produces these hinge-blocks has been discussed in connection with Type Area I. The two suggested mechanisms - (i) plastic flow of underlying sediments (ii) rotation of marginal blocks by ice overrunning the scarp rim - may be further considered here. A study of drill cores reveals that the dolerite contact occurs much lower in the sedimentary sequence in this area than in Type Area I. The Cluan Formation sediments underlying the dolerite at this point are not known to contain Halloysite and generally contain a much lower proportion of clay mineral sediments than do the Tiers Formation sediments which underlie the sill in Type Area I. The likelihood of plastic flow of sediments is therefore greatly reduced in this area.

Now consider the alternative (Ice Tongue) mechanism. Looking southward from the plateau margin (on section line A.B.) the plateau presents a remarkably level surface the only serious interruption of which are the steep sided peaks of Brady's Lookout. The view is shown in Photo. 11 . There is nothing in this aspect to conflict with the presence of an ice sheet in this area during the Pleistocene. The trenched major joints belonging to the S.S.E. system and the stepped-rim have been mentioned earlier as possibly of glacial origin. The evidence of an ice tongue at this point, while not strong, is worthy of consideration. While it is considered that such an ice tongue could cause outward rotation of marginal blocks the obvious objection is that such blocks would scarcely persist to great depths in view of the horizontal joint systems. It has been suggested earlier that the scarp face may have assumed a stable form in the period prior to the glacial phase. If we assume that the dolerite section of the scarp face was a fairly even slope devoid of major cliffs and free of rock slide material - similar in fact to the present slopes in the western corner of this area and those on the upper part of section C.D. - the ice tongue may well produce the effect displayed in the hinge-block areas. Working from the bottom of the dolerite slope successive blocks need not persist greatly in depth. The resulting surface of undisturbed dolerite would be a sloping plane roughly parallel to the present surface. A seismic traverse carried out along the line of drill holes by the Bureau of Mineral Resources suggested that this was, in fact, the attitude of the dolerite basement beneath the rock slide material. Section E.F. (Fig. 7) along this line indicates the only known points on this basement (at the surface and in D.H. 5033). A study of joint directions in core from D.H. 5033 (Fig. 8) suggests that above five hundred and thirty eight feet successive blocks tilt to a greater and greater extent. Above three hundred and eighty feet (about R.L. 3100) the prominent direction was near-horizontal. Is it only chance that the level coincides with the lowest level of hinge-blocks in this area?

Another possible mechanism may be mentioned. A small scale mechanism operating on individual joint blocks on the cliffs today may be termed a cumulative wedging mechanism. The joint separating a marginal block from the cliff is opened by frost action. On thawing, fragments of rock drop into the open joint. These fragments wedge the joint open and successive freezing and thawing may increase the wedging effect. At successively later stages joint blocks behind the marginal one may undergo similar wedging. It will be seen that the wedging effect is cumulative. That is to say the outermost block is rotated through an angle equal to the sum of the wedge angles on all joints behind that block. This process is illustrated in the text figure below.



If this mechanism is applicable on a larger scale (the scale of the hinge-blocks) it would produce the rotation direction observed in the hinge-blocks. Weathering along major joints with the production of clay may offer a more feasible alternative than the frost action observed in the small scale example. The swelling of this clay when wet or simply the increased volume on formation and the fact that there would be a decreasing weathering effect with depth may provide the wedge mechanism. The clay zone between four hundred and forty and four hundred and fifty feet in D.H. 5033 (Fig. 8) could be interpreted as such a wedge filling. The appeal of the "cumulative wedging" mechanism lies not only in the existence of a known small scale counterpart but in the fact that it explains slow outward-rotation of masses which would preserve their cohesion - a feature observed in the hinge-blocks. Further, it explains the increasing amount of rotation of blocks with increasing distance from the present scarp rim. It should be stressed that initiation of the rotation is all that is required of any mechanism - once the centre of gravity is moved beyond the base of the mass its rotation will proceed under the effect of gravity.

The "ploughed Fields" associated with the hinge-blocks are the second feature of the area worthy of note. Inspection of the area indicates the juxta-position of rotated-block cliffs and ploughed fields. The example chosen for detailed description is that shown on a larger scale in Fig. 6 . Photo. 24 gives an indication of the surface composed of lichen-free blocks. The group of trees on the skyline are growing on the "island" shown in the plan. Collapse of the rotated-block cliffs was accompanied by slumping of the rock slide material over a wide area. The bulging of contours round the down-slope tongue of the ploughed field and the dropped level of its up-slope limits are characteristic of slumping in homogeneous unconsolidated materails. The island, representing part of the pre-slump surface stands high above the surrounding new surface. Photo. 25 shows the margin of the "field". Some lichen is evident on blocks and exposed roots can be seen. The absence of these over most of the surface is evidence of the amount of disturbance of the mass. Photo. 27 (taken on another ploughed field) shows the slumped field in the foreground and the unbreached portion of the rotated-block cliff in the background. Photo. 26 shows a large eucalypt buried to the full depth of its trunk by a slumped mass of dolerite blocks.

The causes of collapse of the cliffs could be numerous. The cliffs, retaining walls of great thickness and sound structure, do not apprear prone to undercutting. The presence of smaller cliffs on the lower levels without associated ploughed fields suggests that collapse may be due to forces operating down-slope from behind the cliffs. These forces may be associated with the extreme climatic conditions of the upper slopes. The upper slopes on which the ploughed fields occur are frequently snow covered during winter while slopes lower down are free of snow accumulation.

An interesting feature of the lower slopes is the bench development. The general slope is interrupted by flat benches bordered on the down-slope side by a steep slope. These features may be local slumps of superficial material brought about by saturation of clays which constitute a large proportion of the surface layers of the rock slide material.

The area with the heavy timber cover is significant. To the north and south of this zone the rock slide material over-rides the Ross Sandstone cliffs. Talus "rivers" several thousand feet wide and up to fifty feet deep extend to the foot of the scarp. (See Map Square 4385). No doubt there is a slow migration of talus material down these "rivers" fed from the surface of the upper slopes. The heavy timber marks an island between these two "rivers". This island is a stable area the surface of which contributes little to the "flows" of the "rivers".

Subsurface Investigation:

Diamond drilling in the locations indicated (Figs.4,7,8&9) provided subsurface information on the rock slide material. Unfortunately D.H. 5085 has not yet been drilled. The information, plotted on Section E.F. (Fig. 7) and shown in some detail on core logs (Figs.8&9), indicates the extent in depth of these deposits. Unfortunately the section is oblique to the slope so that some value, from the academic viewpoint, is lost. The drilling was extremely difficult, as can be imagined, due to frequent movements of dolerite blocks and cavings of clay sections. Of the two materials penetrated in the rock slide zone almost all of the dolerite was recovered while almost all the clay was lost. On plotting the recoveries an interesting feature emerged. There is a suggestion of zoning as indicated on Section E.F. (Fig. 7.). The upper zone penetrated in 5033 gave a core recovery of 85% obtained principally from long "runs" of sound rock extending down to two hundred and thirty four feet. Thereafter a zone of crushed rock with good recovery was succeeded by talus penetration with decreasing recoveries. From two hundred and eighty three feet to three hundred and twenty feet no recovery was obtained. Between three hundred and twenty feet and the next zone of no recovery at four hundred and forty one feet the overall recovery was 70% though the centre portion of this zone gave practically full recovery. In D.H. 5032 clay layers were penetrated at fifty five feet and at one hundred and ninety one feet. The zone between these layers, including some long "runs" of good recovery, gave an overall recovery of 70%. Between two hundred and seven feet (bottom of clay layer) and two hundred and eighty nine feet the recovery dropped to 40%. In D.H. 5030 a clay layer occurred at thirty three feet. Below this layer the recovery in the rock slide zone was 40%. The pattern suggests that recoveries fall off with depth. Could this be interpreted as evidence of successive rock-falls separated by a time interval during which clay formed on the

FIG. 8.

CORE LOG – DH 50.53.
(TYPE AREA)

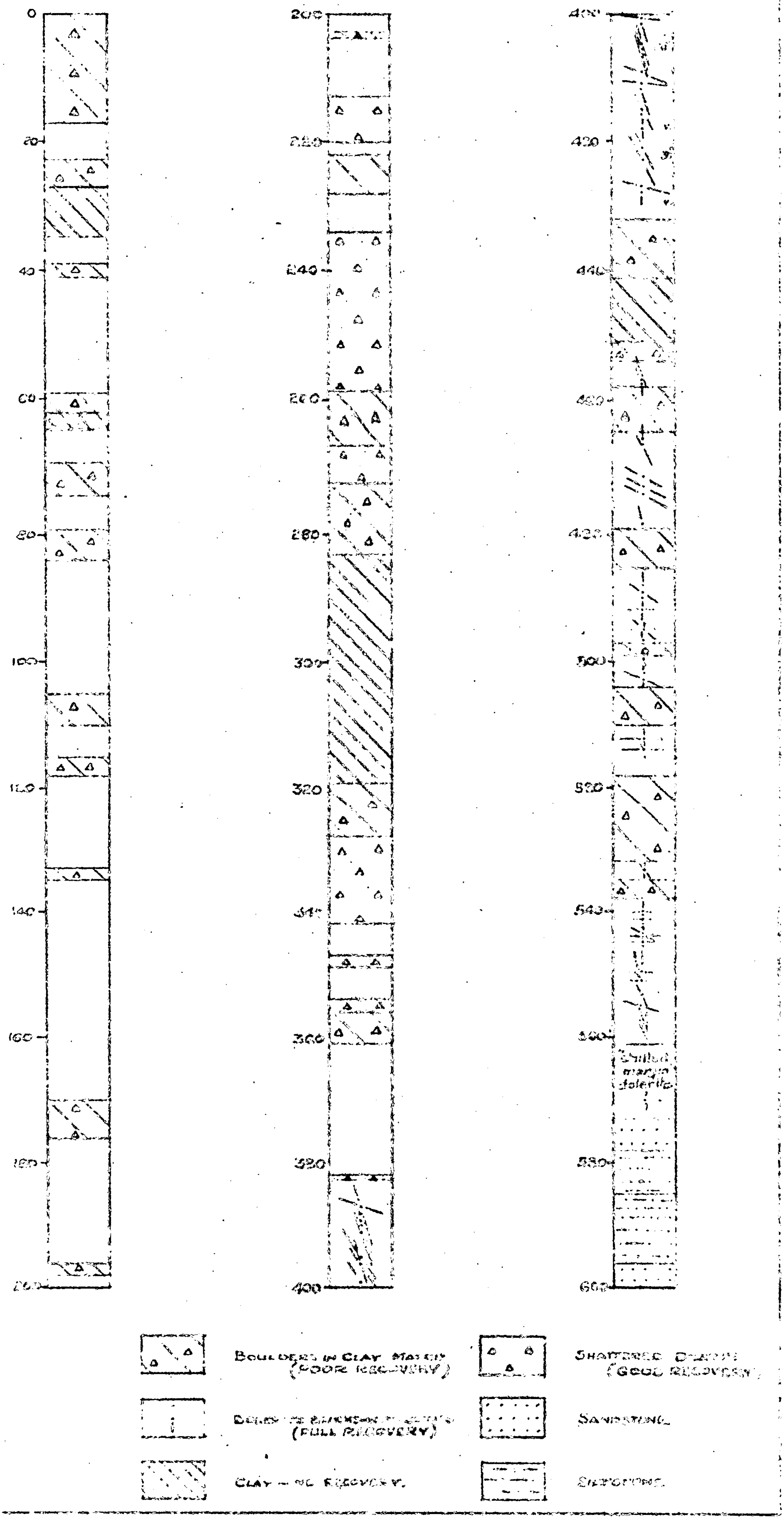
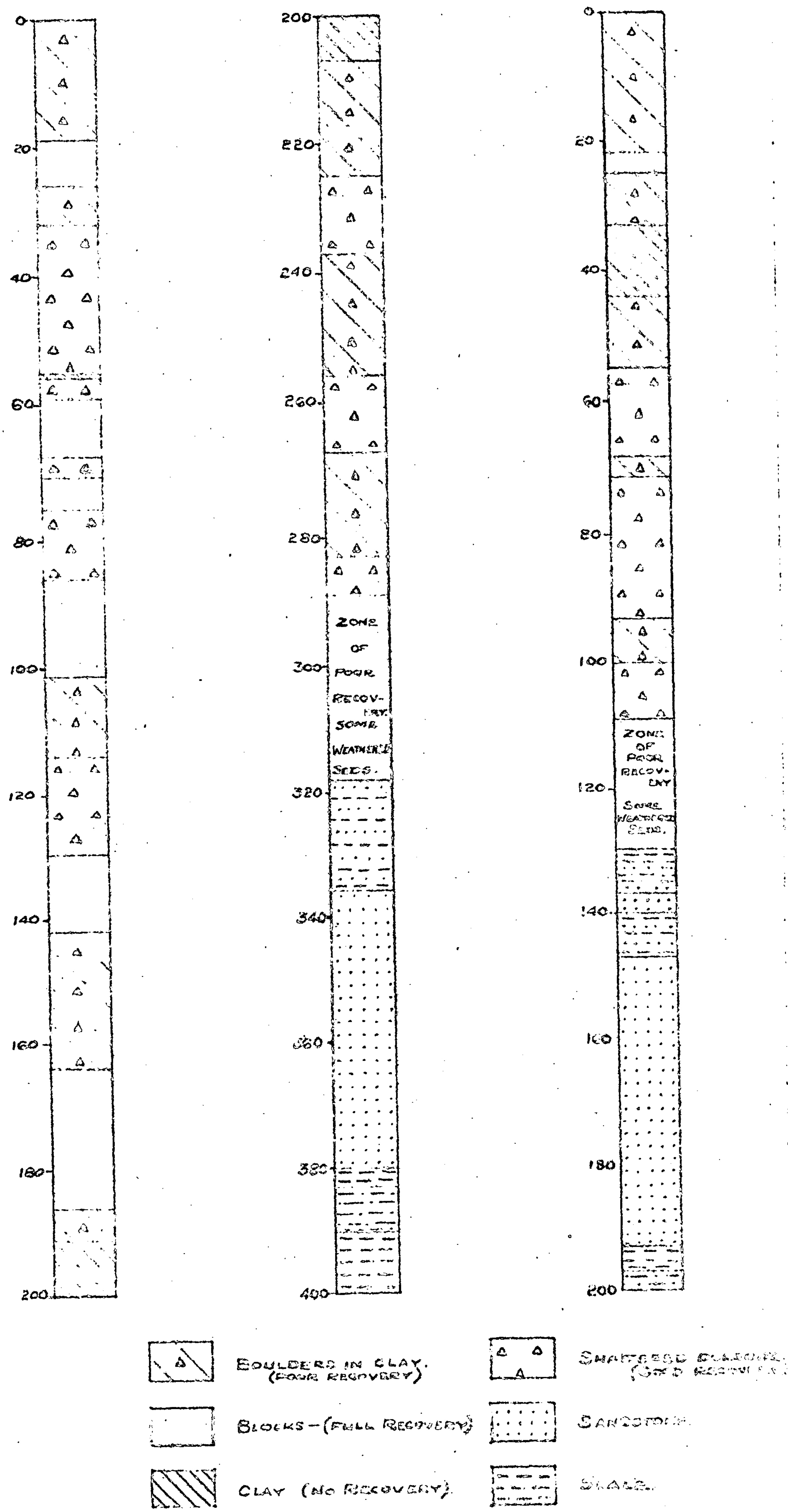


FIG. 9.

CORE LOG – DH.5032.

(TYPE AREA III.)



surface - a surface buried and preserved by the subsequent fall? On the evidence available it can be no more than a suggestion. Matthes (p.106, 1930) points out that excavation of talus in the Yosemite Valley revealed four distinct layers of rock debris separated by layers of earth matter containing roots and stumps. The flatness of the layers indicated on the section E.F. could be explained by the obliquity of the section to the slope. However, the second zone in D.H. 5033, exhibiting steep-angle predominant jointing is against the theory - at least as far as percentage recovery zones is concerned. It will be remembered also that an alternative (one of many) explanation of the clay layer below this zone has already been given.

The shape of the base of the rock-slide material and the distribution of loads suggests that movement of the entire mass could take place. The zone of weathered sediments with its high water content would provide a lubricated sole plane along which the overlying mass could slide. No definite evidence of such movement has come to light. Evidence against movement, at least on this section is seen in the zone of heavy timber. At D.H. 5031 the rock-slide zone is twenty four feet thick. The timber in this vicinity includes trees eighty feet high with a butt diameter of five feet. Test pits indicate that the root systems of these trees penetrate the underlying sediments. Movement of the rock-slide mass would cause either tilting of the trees or banking up of boulders against their up-slope side. Neither of these features ~~are~~ is evident. Again, any appreciable movement should be evident at the upper limit of the rock-slide material. Yet along this line no evidence of general subsidence of the rock-debris mass could be found. If movement occurred it would surely be evident at the contact between slide material and dolerite (in situ) where no cliffs and no obscuring scree are present.

2. Sandstone Scarps:

A number of strong sandstones of the Permo-Triassic sequence form free faces of the sandstone units of the multiple scarp.

A. Ross Unit.

The Ross Sandstone forms persistant cliffs on the scarp face

(See Photos. 1&2) immediately below the dolerite units. The regular joint system of this massive sandstone produces roughly equidimensional blocks up to twenty feet square. Detritus from these cliffs together with dolerite detritus which has over-run the cliffs forms accumulations up to fifty feet thick at the base of these cliffs.

Underlying the Ross Sandstone are the soft micaceous shales of the Jackey Formation. The erosion of these shales, at a faster rate than the massive sandstone above them, causes failure in the shales at the base of the cliffs and collapse of the sandstone joint blocks.

The mechanism of retreat of all sandstone units is a periodic one in which the following stages may be recognised :

(i) Detritus accumulations on the slope below the cliff are removed by water erosion

(ii) The exposed shale formation erodes to a steep slope near the cliff with the upper part attaining a slope which conforms with the face of the cliff.

(iii) Yielding of the shales along fracture surfaces oblique to the bedding and the collapse of joint blocks of sandstone supported by those shales above the plane of fracture.

(iv) The cliff-collapse material forms detritus accumulations at the foot of the cliff.

The retreat of sandstone units at present is very slow. Few areas were seen where cliff faces of fresh rock indicated recent collapse. Few areas were discovered where the underlying slope-formation was exposed at the base of the cliffs. The dense scrub which flourishes in the protected environment at the foot of the cliffs impedes the erosion of the detritus. Koons (1955) carried out measurements of slope angles on the bare slope-forming rock below cliffs in the arid regions of the south west United States, and established that a reasonable constancy of this angle (thirty four to thirty eight degrees) exists for a number of rock types. Because of the limited number of sub-talus slopes exposed no survey of this kind could be carried out but the available slopes did fit the range suggested.

B. Liffey Units.

The Liffey Group consists of two similar sandstones of similar thickness separated by shales. The two sandstones represent the free-face of two units. Underlying the upper sandstone are soft, freshwater shales of the Kopenico Formation while the lower sandstone rests on marine mudstone (Macrae Formation) of a much more resistant character. This arrangement gives an opportunity of studying the effects of slope-forming rock on retreat rates of scarps. The effect is considerable. The upper scarp has retreated far beyond the lower unit where both are present as active scarps. Even more significant is the fact that while the upper unit provides a fairly continuous line of cliffs on the Tiers Face the lower unit is apparent only at a few points on the entire line of the Tiers. The difference in slope formation is sufficient to cause the upper unit to be actively retreating while the lower unit is dormant.

C. Minor Sandstone Units.

Four minor sandstone of restricted thickness (up to thirty feet) form the free-faces of units within the Permian sequence. The slope-forming rock supporting the sandstone in each instance is a mudstone, the strength and erosion susceptibility of which are not very different from those of the overlying sandstones. The difference is sufficient, however, to produce the typical scarp form of free-face and detritus slope and for the production of flat benches on the sandstone units.

An interesting contrast between the behaviour of closely spaced pairs of units, the Risdon and Dabool units on the one hand and the two Liffey units on the other, may be noted. In the case of the former pair the slope-forming formations are similar while in the latter case they are markedly different. The Risdon and Dabool units are equally well developed though usually both are not represented on the same section. The contrasting behaviour of the two Liffey units has been discussed in the previous section.

3. "Talus Flatirons":

Several "talus flatirons" have been mentioned in connection with the history of retreat of the scarp. They are shown on

Map Square 4889 as deposits of "talus" surrounded by Golden Valley Group sediments. The more easterly one can be seen as a low sloping plateau in the middle-ground on the right-hand margin of Photo. 2. Fig. 10 indicates the general dimensions and topographical form of the more typical western one.

"Talus flatirons" characteristic of western Grand Canyon as described by Koons (1955) are somewhat different from the Western Tiers "flatirons" in section but this difference is explained by the much steeper slopes of the Grand Canyon scarps. Their origin and history - remnants of a previous scarp face left behind by a retreating scarp and protected from erosion by a detritus cover more resistant than the underlying rock - are similar to those of the Western Tiers examples and the term "talus flatiron" suits the local example admirably.

In view of their function as a record of an earlier scarp face they are most significant features in any study of scarp retreat.

PART C.

STABILITY ANALYSIS OF SCARP SLOPES.

I. STABILITY COMPARISON WITH OTHER SLOPE FORMS:

For any given relief, the scarp form, exemplified by a free-face and detritus slope, represents the ultimate in activity. The strongly concave profile is the hall-mark of this form just as the convex profile reflects degeneracy of mechanical erosion and concomitant stability of the form. The convex element (waxing slope) may suffer superficial instability in the form of hill creep but this element is not affected by catastrophic rock-slides. Any stability comparison between slopes should therefore be made, in the first instance, on the basis of relative developments of convexity or concavity of the upper parts of those slopes.

II. FACTORS AFFECTING THE RETREAT RATE OF SCARPS:

From the discussion included in earlier parts it will be realised that innumerable factors govern the rate of retreat of scarps. Only the more important ones which are widely applicable are treated here.

1. Nature of the Cliff Forming Rock:

A comparison of the dolerite unit and the Ross Sandstone unit, which are of similar thickness and underlain by similar formations highlights the importance of this factor. Dolerite, an extremely strong rock in its unjointed form is reduced to a form susceptible to mechanical erosion by the strong development of jointing. The Ross Sandstone, by comparison, is a weak rock yet its widely spaced joints do not assist mechanical erosion to the same degree.

The appreciably higher specific gravity of the dolerite results in increased loading on the slope-forming formation for the same thickness of cliff-forming formation. In considering loading at the scarp face it is necessary to take into account the lateral support available to the marginal blocks. The strong vertical jointing of the dolerite reduces the lateral support to these blocks.

The nature of the cliff-forming rock naturally dictates the nature of the rock slide material which, by virtue of its erosion-susceptibility affects the retreat of the scarp.

2. Nature of the Slope-forming Rock:

The nature of the slope-forming rock is as vital a consideration as the nature of the cliff-forming rock. The combination of a strong rock underlain by a weak rock is the pre-requisite of scarp formation.

Characters of slope-forming rocks which favour scarp formation are low shear strength, a capacity for rapid physical change on change of environment and a high susceptibility to weathering or erosion.

The effects of the slope-forming rock on scarp behaviour has already been noted in the case of the two Liffey Group scarps.

3. Climatic Environment:

The behaviour of similar scarps under different climatic conditions will be strikingly different. The type and amount of rainfall is an important factor in determining the erosion rate of scarps. Extremes of climate may introduce factors such as frost action. Type and persistance of vegetation, a function of the climatic environment, may play an appreciable part in determining the rate of retreat of a scarp.

The climatic factor must be considered, not only in comparing scarps in different areas but also those at different levels of a multiple system. The general climate on the dolerite scarp is much more extreme than that on lower members of the system.

In considering the past history of a scarp a knowledge of the past climate is essential to a full assessment of that history.

4. Position in a Multiple System:

In a multiple scarp such as the Western Tiers the position of a unit scarp in the system is of importance. It determines the amount of water available for transport of detritus from that unit and also the amount of detritus introduced from higher levels. The dolerite may well present a very different aspect if it occurred some distance down the face and was overlain by several sandstone units.

III. THE NATURE OF RETREAT MECHANISMS:

In the assessment of stability the characters of the retreat mechanism are vital. What may be termed constant, small-scale mechanisms - those involving the production of scree slopes at the foot of cliffs - may move significant amounts of material. But however significant these mechanisms may be in the scarp retreat their very constancy permits their evaluation in terms of slope stability and retreat rate.

The behaviour of the larger-scale periodic mechanisms is more difficult to assess. A study of the retreat cycle followed by an assessment of the stage of the cycle reached may allow the prediction of a period of time before the catastrophic stage is reached.

The possibility of large-scale constant mechanisms cannot be overlooked. The cumulative wedging mechanism suggested for the dolerite hinge-blocks may represent this type. While ultimate proof of such mechanisms may require strain measurements within the rock-slide mass the realisation of the possibility is important.

In the present case the realisation that evidence existed for such a mechanism resulted in the relocation of all proposed excavations to points below the limits of rock-slide accumulations.

ACKNOWLEDGMENTS

Much of the material used in the composition of this thesis was collected in the course of geological duties for the Hydro-Electric Commission and the author wishes to express his gratitude to that organisation for permission to use the material for this purpose.

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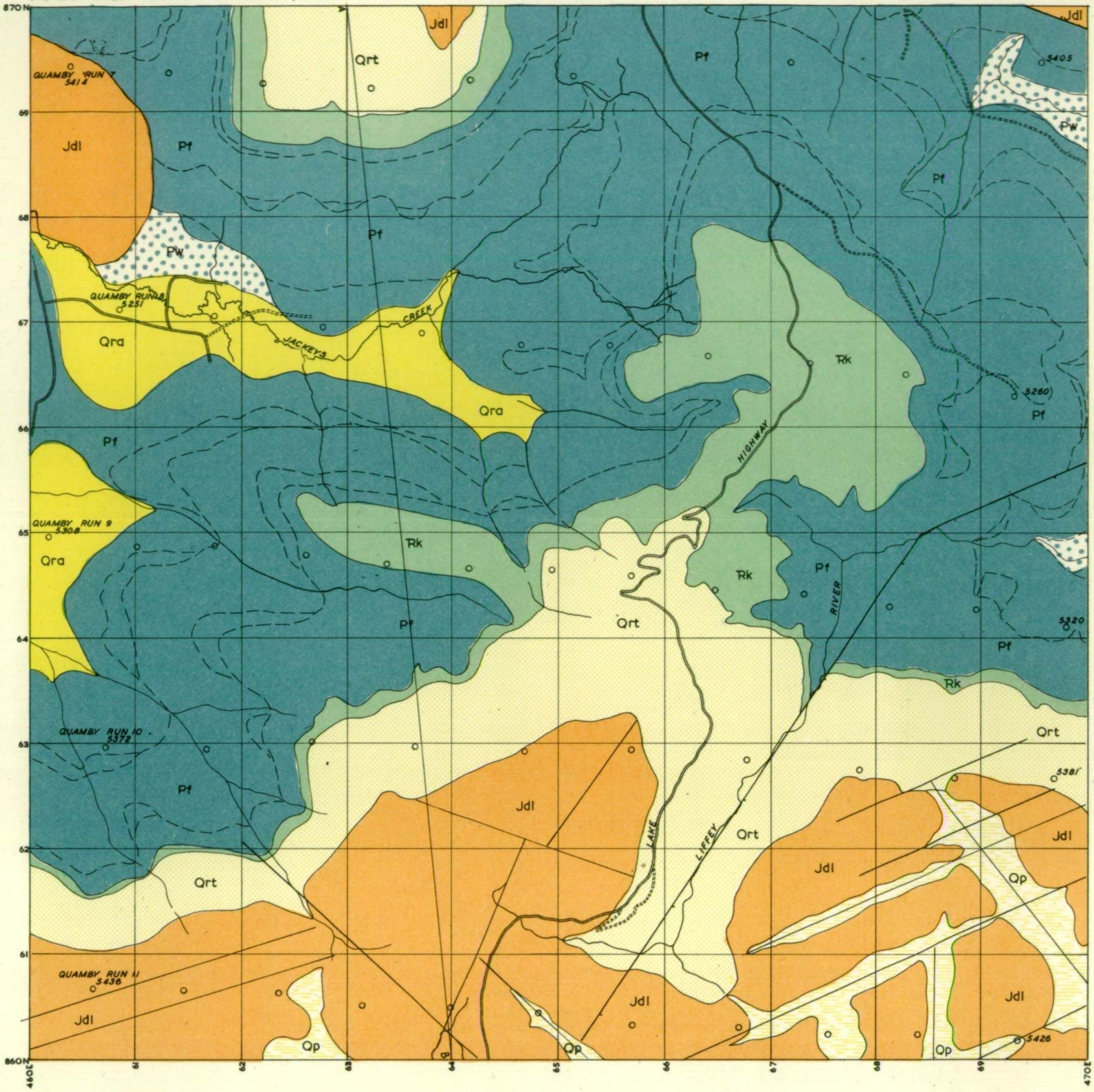
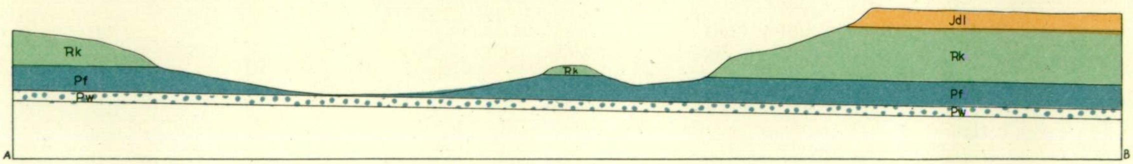
JACKEY





Quaternary System

- Qra ALLUVIUM
- Qrt TALUS
- Qp MARSH DEPOSITS

Jurassic System

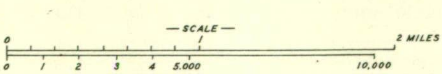
- Jdl DOLERITE

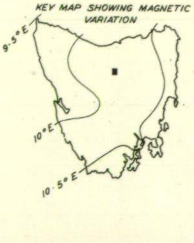
Triassic System

- Rk KNOCKLOFTY SANDSTONES AND SHALES

Permian System

- Pf FERNTREE GROUP
- Pw WOODBRIDGE GROUP
- Pl LIFFEY GROUP
- Pgv GOLDEN VALLEY GROUP





Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Forestry Dept. Origin of co-ordinates 400,000 yds West and 1,800,000 yds. South of True Origin of Zone 7.

MAPPED AND COMPILED BY
J.B.A. McKELLAR APRIL 1956

- FAULT
- LINEAR
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  - FORMATION
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- TRACK

GEOLOGY OF JACKEYS CREEK AREA
MAP SQUARE 4686

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2. STRATIGRAPHIC TABLE:

SYSTEM	GROUP	FORMATION	ROCK TYPE	THICKNESS
Recent to Pleistocene			Scree, Talus Alluvium Glacial deposits	
		EROSION INTERVAL STRONG EPEIROGENY AND FAULTING PENEPLANATION AND UNCONFORMITY		
Jurassic			Dolerite	1000'+
Triassic		New Town	Sandstone, Shales, Coal	435'
		Tiers	Siltstone, Shale	385'
		Cluan	Sandstone, Siltstone	425'
		Ross	Massive Sandstones	630'
		Jackey	Shales	140'
		DISCONFORMITY?		
Permian	Ferntree	Eden	Mudstones	20'
		Blackwood	Quartz Conglomerate	2'
		Drys	Mudstone	350'
		Palmer	Sandstone	5'
		Springmount	Mudstone	280'
		Risdon	Sandstone	30'
	Woodbridge	Weston	Bryozoan Mudstone	30'
		Dabool	Brachiopod Sandstone	40'
		Meander	Mudstone	195'
	Liffey	Creekton	Wormcast Sandstone	10'
		Woodside	Sandstone	35'
		Kopanica	Shale and Sandstone	15'
		Flattop	Sandstone	30'
	Golden Valley	MacRae	Mudstone	115'
		Billop	Brachiopod Conglomerate	10'
		Brumby	Fossiliferous Limestone, Marl	45'
		Quamby	Mudstone	330'
		Stockers	Tillitic Conglomerate	340'+

3. LOCALITIES OF SPECIAL INTEREST:

Type locality of Jackey Formation; track 4664E. 8657N.
Weston Formation fossil locality; road-cut 4683E. 8700N.
Risdon exposures in Liffey Falls 4695E. 8649N.
Triassic sequence Jackey to Newtown; Road-cuts on Lake Highway
Dolerite — sediment contact; Road Quarry 4656E. 8614N.

4. DOLERITE INTRUSION CENTRE:

Extensive dolerite outcrops in the north-east of the Map Square suggest a dolerite intrusion centre in this vicinity.

5. SCARP FORMATION:

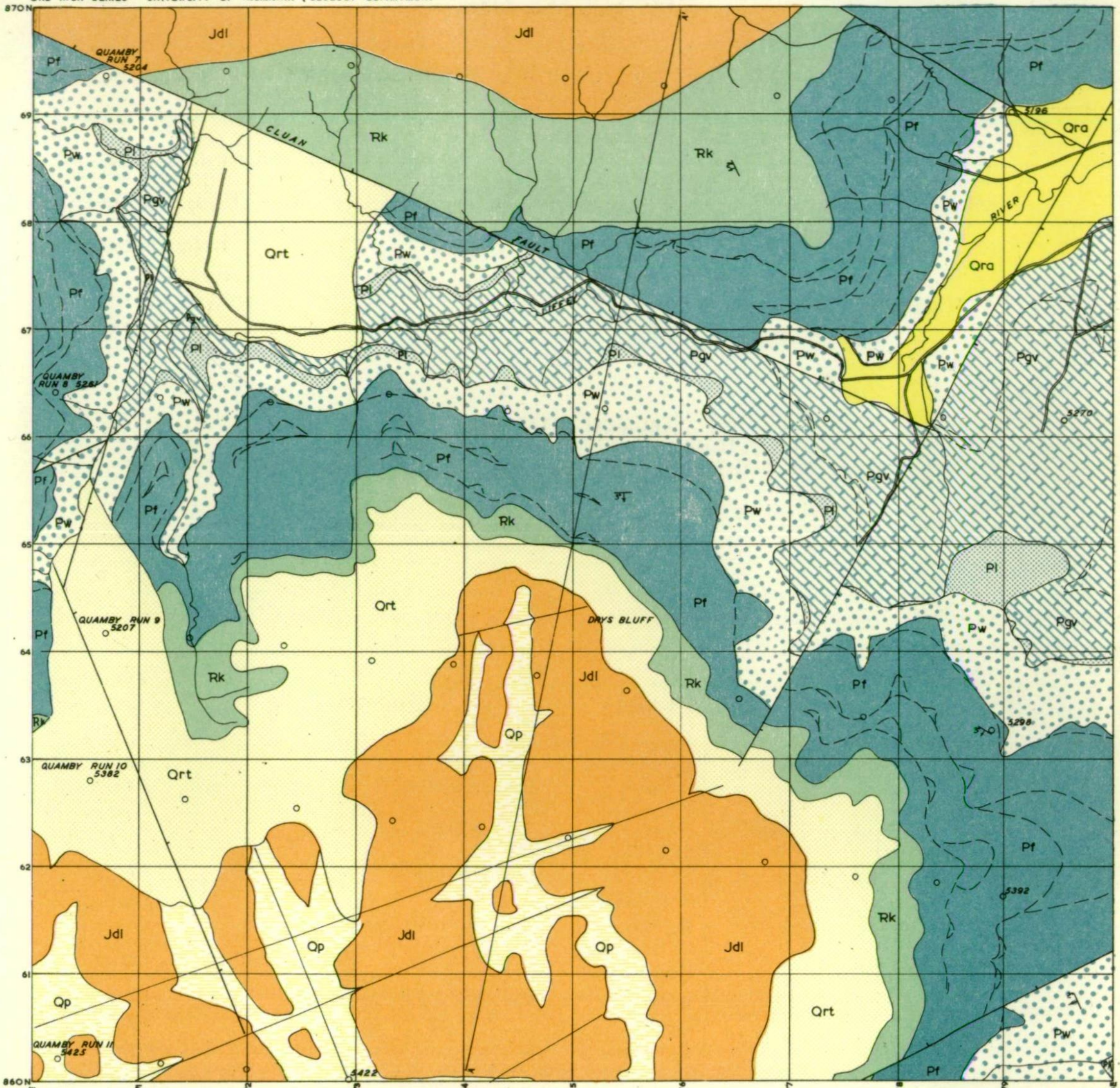
Stream erosion of a probable shear zone along Jackeys Creek has produced the opposing scarps of Quamby Bluff and Western Tiers. No appreciable fault movement was involved in the formation of these scarps.

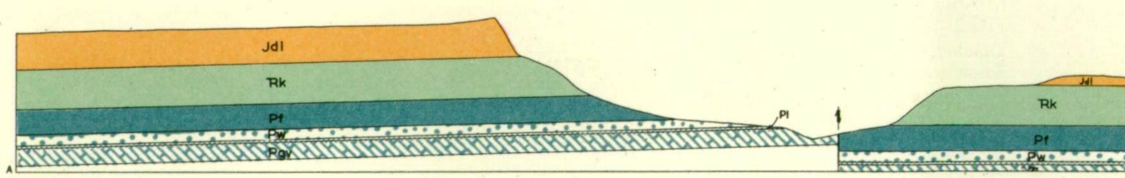
GEOLOGY OF TASMANIA

DRYS BLUFF

4786

ONE INCH SERIES – UNIVERSITY OF TASMANIA, GEOLOGY DEPARTMENT





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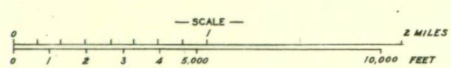

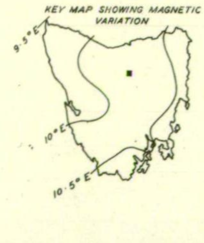

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3. LOCALITIES OF SPECIAL INTEREST:

Liffey Group exposures in Liffey Valley.
Dolerite — sediment contact exposed 4757E. 8638N.
Brumby fossil locality — on track 4743E. 8674N.

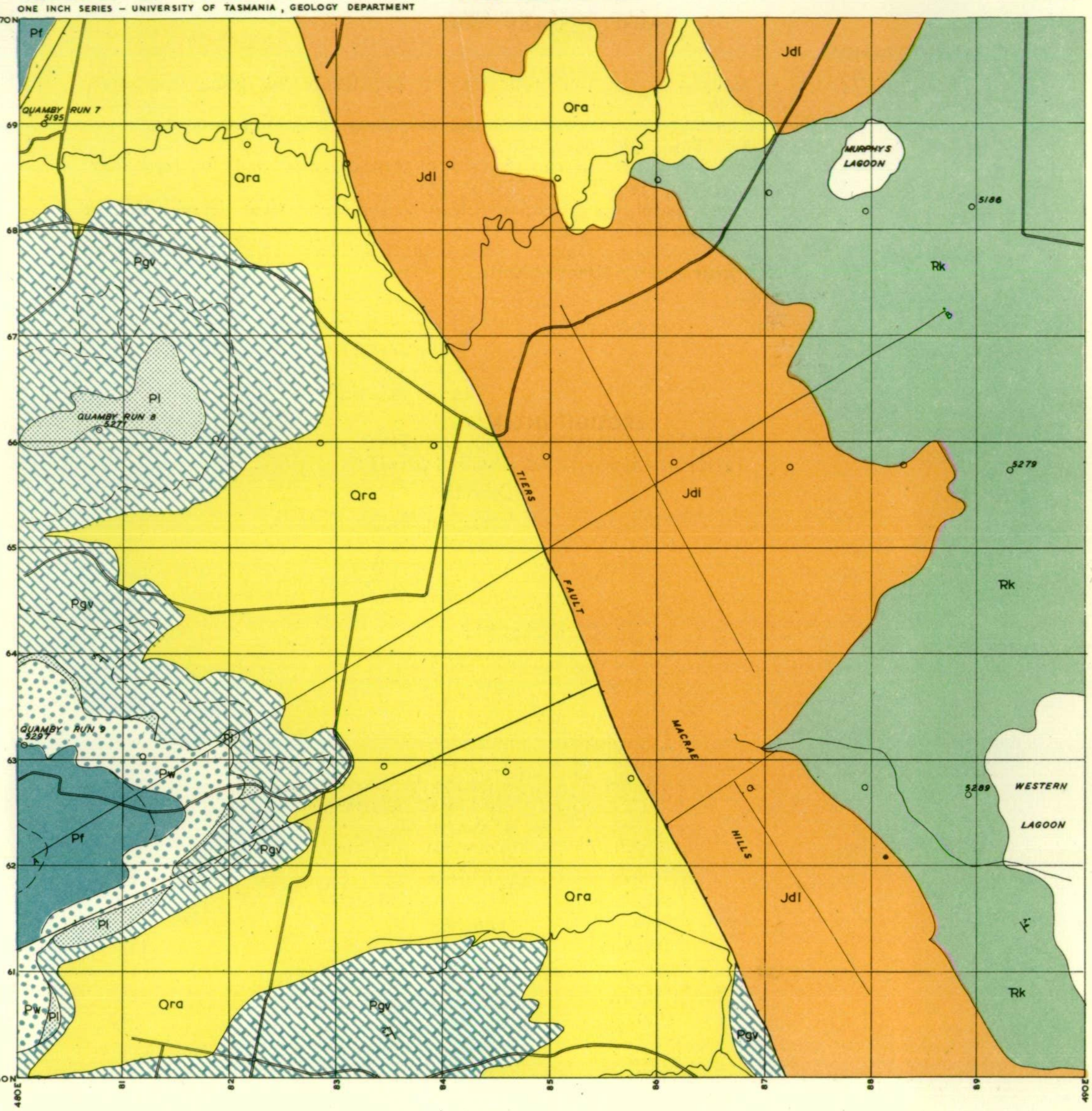
4. DOLERITE INTRUSION CENTRE:

Extensive talus deposits including large masses of dolerite in the region surrounding E472. N868 suggests the presence of a centre of intrusion of the dolerite.

5. SCARP FORMATION:

The original Fault Scarp of the Cluan Fault has been transformed by stream erosion of the fault-zone into the opposing fault-line scarps (Resequent and Obsequent) of Drys Bluff and Cluan Tier.

MACRAE



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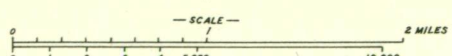

Compilation from Aerial Photographs.
Trigonometric Station Control by courtesy Forestry Dept.
Origin of co-ordinates 400,000 yds West and 1,800,000 yds South of True Origin of Zone 7.

MAPPED AND COMPILED BY
J.B.A.McKELLAR *APRIL 1956*

- FAULT
- LINEAR
- BOUNDARIES
- GROUP
- FORMATION
- FAULT BLOCK TILT
- ROAD
- VEHICULAR TRACK
- TRACK

GEOLOGY OF MACRAE HILLS AREA
MAP SQUARE 4886

1. BIBLIOGRAPHY:

CAREY, S. W., 1947 — Geology of the Launceston District. **Rec. Queen Vic. Mus., Launceston,** pp. 31-46.

VOISEY, A. H., 1949 — Geology of the country around the Great Lake, Tasmania. **Pap. Proc. Roy. Soc. Tas.,** 1948, pp. 95-103.

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		EROSION INTERVAL STRONG EPEIROGENY AND FAULTING PENEPLANATION AND UNCONFORMITY		
Jurassic			Dolerite	1000′+
Triassic		New Town	Sandstone, Shales, Coal	435′
		Tiers	Siltstone, Shale	385′
		Cluan	Sandstone, Siltstone	425′
		Ross	Massive Sandstones	630′
		Jackey	Shales	140′
		DISCONFORMITY?		
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		Blackwood	Quartz Conglomerate	2′
		Drys	Mudstone	350′
		Palmer	Sandstone	5′
		Springmount	Mudstone	280′
		Risdon	Sandstone	30′
	Woodbridge	Weston	Bryozoan Mudstone	30′
		Dabool	Brachiopod Sandstone	40′
		Meander	Mudstone	195′
	Liffey	Creekton	Wormcast Sandstone	10′
		Woodside	Sandstone	35′
		Kopanica	Shale and Sandstone	15′
		Flattop	Sandstone	30′
	Golden Valley	MacRae	Mudstone	115′
		Billop	Brachiopod Conglomerate	10′
		Brumby	Fossiliferous Limestone, Marl	45′
		Quamby	Mudstone	330′
		Stockers	Tillitic Conglomerate	340′+

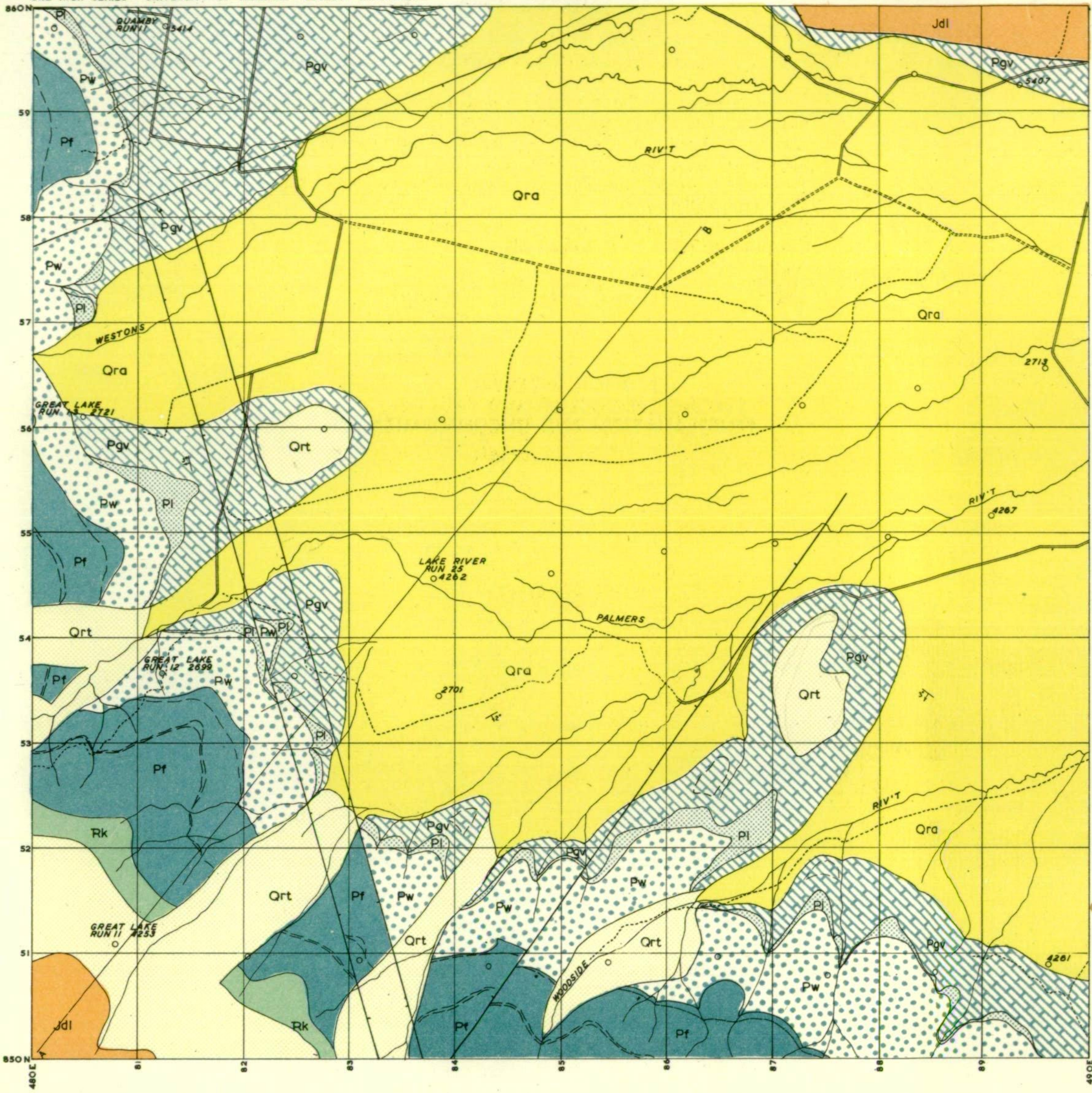
3. LOCALITIES OF SPECIAL INTEREST:

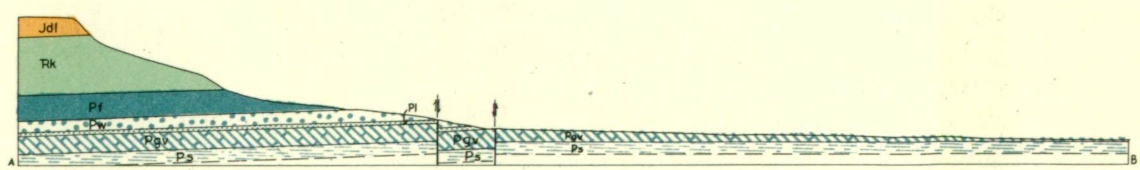
Type Section of Brumby Formation; Steep Slope	4817E. 8618N.
Billop Formation fossil locality; Bench	4825E. 8628N.
"Sulphur Springs"; centre of open paddock	4837E. 8640N.

4. SCARP RETREAT:

The Tiers Fault produced a scarp with a relief of some 2000 feet. Subsequent retreat and erosion of this scarp has produced the resequent fault-line of the Western Tiers and the obsequent fault-line scarp of MacRae Hills.

PALMER





Quaternary System

- Qra ALLUVIUM
- Qrt TALUS
- Qp MARSH DEPOSITS

Jurassic System

- Jdl DOLERITE

Triassic System

- Rk KNOCKLOFTY SANDSTONES AND SHALES

Permian System

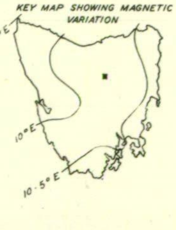
- Pf FERNTREE GROUP
- Pw WOODBRIDGE GROUP
- Pl LIFFEY GROUP
- Pgv GOLDEN VALLEY GROUP
- Ps STOCKERS

— SCALE —

0 1 2 MILES

0 1 2 3 4 5,000 10,000

KEY MAP SHOWING MAGNETIC VARIATION



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J.B.A. McKELLAR APRIL 1956

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GEOLOGY OF PALMER RIVER AREA
MAP SQUARE 4885

1. BIBLIOGRAPHY:

CAREY, S. W., 1947 — Geology of the Launceston District. **Rec. Queen Vic. Mus., Launceston,** pp. 31-46.

VOISEY, A. H., 1949 — Geology of the country around the Great Lake, Tasmania. **Pap. Proc. Roy. Soc. Tas.,** 1948, pp. 95-103.

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		Springmount	Mudstone	280'
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	Woodbridge	Weston	Bryozoan Mudstone	30'
		Dabool	Brachiopod Sandstone	40'
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		Kopanica	Shale and Sandstone	15'
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		Billop	Brachiopod Conglomerate	10'
		Brumby	Fossiliferous Limestone, Marl	45'
		Quamby	Mudstone	330'
		Stockers	Tillitic Conglomerate	340'+

3. LOCALITIES OF SPECIAL INTEREST:

Type Locality Palmer sandstone; waterfall 4816E. 8519N.
Type locality Kopanica Shales; waterfall 4803E. 8573N.
Dabool fossil locality; creek bed 4807E. 8543N.
Brumby Formation fossil locality; creek bed 4823E. 8546N.
Billop Formation fossil locality; bench 4875E. 8518N.
Stockers Formation exposure; creek bed 4878E. 8538N.

4. SCARP RETREAT:

Interesting features of the retreat of the Western Tiers Scarp are the broad, sloping, alluvium covered pediment, the talus "rivers" on the Tiers slopes and the talus "flatirons" about the points 4875E. 8535N. and 4825E. 8557N. Outward-hinging cliff blocks of dolerite at 4815E. 8501N. represent a significant mechanism of retreat.

5. DIAMOND DRILLING:

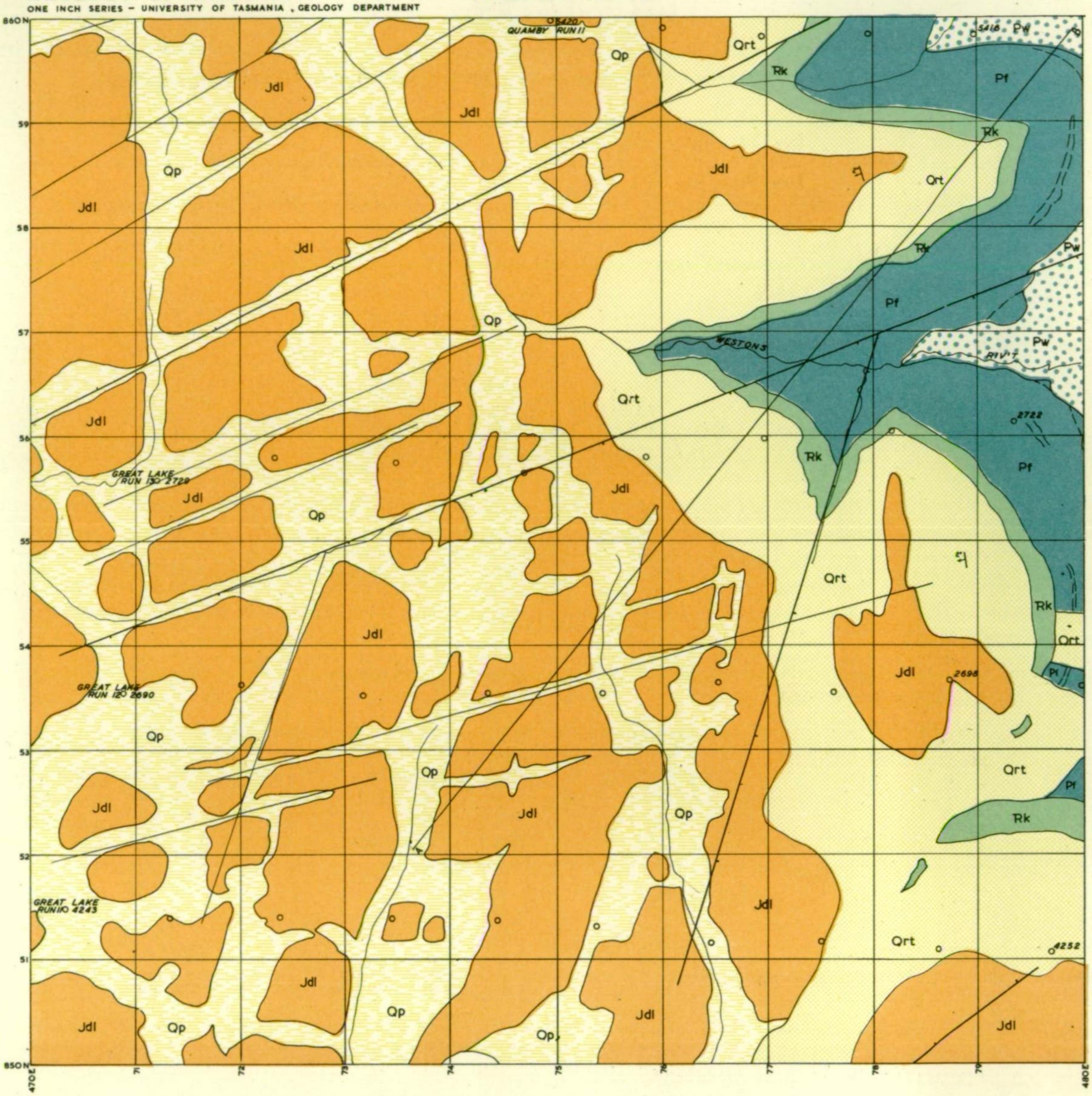
An extensive programme of diamond drilling by the Hydro-Electric Commission over the south-western portion of this sheet is recorded in Commission files.

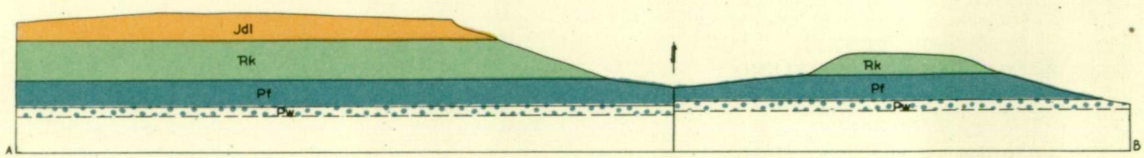
GEOLOGY OF TASMANIA

ONE INCH SERIES – UNIVERSITY OF TASMANIA , GEOLOGY DEPARTMENT

WESTON

4785





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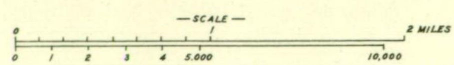

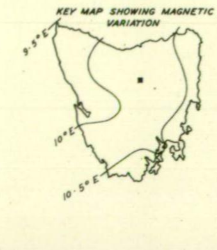

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J.B.A.McKELLAR APRIL 1956

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GEOLOGY OF WESTON CREEK AREA
MAP SQUARE 4785

1. BIBLIOGRAPHY:

CAREY, S. W., 1947 — Geology of the Launceston District. **Rec. Queen Vic. Mus., Launceston,** pp. 31-46.

VOISEY, A. H., 1949 — Geology of the country around the Great Lake, Tasmania. **Pap. Proc. Roy. Soc. Tas.,** 1948, pp. 95-103.

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		Brumby	Fossiliferous Limestone, Marl	45'
		Quamby	Mudstone	330'
		Stockers	Tillitic Conglomerate	340'+

3. LOCALITIES OF SPECIAL INTEREST:

Type Locality of Weston Formation; Creek bed	4785E. 8597N.
Outward hinging of dolerite cliff blocks	4791E. 8512N.
Slip-circle collapse of dolerite cliff	4796E. 8512N.
Joint-plane slipping of cliff blocks	4792E. 8535N.

4. PLEISTOCENE GLACIATION:

The pattern of marsh deposits on the plateau surface suggests glacial over-deepening of shear zones in the dolerite.

5. DOLERITE TRANSGRESSION:

Field evidence suggests a transgression of the lower surface of the dolerite mass along a line trending N.E. from the point 477E. 850N. North-west of this line the intruded rock is the Cluan formation while south-east of the line the intruded rock of the dolerite is the Newtown Formation.