THE DUNDAS GROUP IN THE QUEENSTOWN AREA

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(With 1 Plate and 4 Text Figures)

ABSTRACT

Reconnaissance geological surveys of the Dundas Group in the Queenstown area reveal that the sequence contains a suite of volcanic rocks including potassic rhyolites, quartz keratophyres, andesites, basalts and associated pyroclastics in additon to the sedimentary rocks, which are mainly paraconglomerates, greywacke sandstones and slates. The potassic rhyolites are confined to a narrow zone between Mt. Sedgwick and South Darwin and are flanked by lavas which vary from rhyolites to basalts but which generally contain a relatively high soda content. Viewing the West Coast as a whole this variable zone has a western limit beyond which the lavas are mainly of basic type and commonly spilitic.

The rock types which make up the Darwin Granite body are briefly described and it is noted that chemically they resemble members of the volcanic suite. The age of the granite is verified as pre-Junee Group.

It is suggested that the formation names previously proposed for the Dundas Group in this area are invalid.

INTRODUCTION

Geologists have been attracted to the Queenstown area ever since gold was first discovered there in 1883 by a prospecting syndicate. The clearing of the thick rain forest and the development of the associated copper deposits that followed the initial discovery soon revealed the complexity of the local geology, which became the subject of numerous technical reports. Of the scientists who visited the field in its early years, Professor J. W. Gregory was the first to extend his survey beyond the mine leases and his geological map published in 1905 remained the principal reference for many years. The Tasmanian Mines Department gradually developed its activities on the Lyell and the nearby Jukes and Darwin fields and by the middle 1930's an approximate picture of the geology had been obtained. However, not until Bradley began his work in 1950-51 had any attempt been made to produce a general geological map of this part of the West Coast, despite its obvious economic importance.

This pioneer work was followed in 1954-56 by a more detailed survey of the area by the writer on behalf of the Mt. Lyell Mining and Railway Co., as part of a new approach to the solution of the problems of ore deposititon at Mt Lyell. The area then investigated included that part of the West Coast Range between Mt. Sedgwick and South Darwin, involving about 200 square miles of rugged terrain (Fig. 1). Aerial photographs of scale 1 inch = 1320 feet were used for mapping so that the survey was of a reconnaissance nature and hence by no means a complete study; similarly the petrographic work must be regarded as essentially preliminary. The specimen numbers quoted refer to the rock and slide catalogue of the Mt. Lyell Mining and Railway Co., Queenstown.

Discussion in this paper is confined to the Dundas Group which is of particular interest in that it is host to the Mt. Lyell copper deposits and contains a variety of rock-types which have puzzled geologists for many years. The Group was defined by Elliston (1954) as the sequence of sediments and volcanics exposed near Dundas township, underlying the Junee Group and overlying the Carbine Group (Precambrian). As a result of regional mapping programmes by private enterprise, Government departments, and the University of Tasmania, the extent of the Dundas Group outcrop on the West Coast has been determined approximately, correlations being made largely by lithology and continuity of outcrop but occasionally on palaeontological evidence. Those fossils collected to date show a range from the *Ptychagnostus gibbus* Zone to the *Glyptagnostus reticulatus* Zone, or approximately Upper Middle Cambrian to basal Upper Cambrian (Banks, 1956). No fossils have been found near Queenstown and correlation is made by continuity of outcrop from areas to the north, by lithology, and by relationships to overlying beds. The base of the Group is not exposed in this area.

The sediments of the Dundas Group are thought to have been deposited in a geosynclinal basin which extended over at least western Tasmania and part of Victoria (represented there by the Heathcotian Series) and the abundance of volcanics has led to the use of the term eugeosyncline (Kay, 1947) for the basin of deposition.

A feature of the Dundas Group on the West Coast is the development of a considerable thickness of dominantly volcanic material along the West Coast Range. This was recognised by Carey (1950, 1953) and further emphasised by Campana *et al.* (1958) in their subdivision of the Group into a "bedded series" and a "volcanic assemblage". The latter is particularly well exposed in the Bulgobac-Pinnacles-Rosebery-Mt. Tyndall area and forms a sharply defined N-S zone of dominantly volcanic rock, while the Dundas Group to the west is essentially a sedimentary sequence.

Elliston described considerable thicknesses of agglomerate and tuff in the succession at Dundas but these beds are now recognised as non-pyroclastic and it is clear tht the type section belongs to the " bedded series ".

South of Mt. Tyndall the volcanic assemblage of Campana *et. al.* is difficult to distinguish as its percentage of sedimentary rocks increases and lavas become ubiquitous. As a general rule all Dundas Group sections south of the latitude of Mt. Sedgwick contain roughly equal proportions of volcanics and sediments.

The volcanic zone between Bulgobac and Mt. Tyndall is interpreted (Carey, 1950) as marking a line of volcanoes in the Cambrian eugeosyncline and Campana *et al.* have related this zone of volcanic activity to the early phases of rift valley formation.

No fossils have been reported in the volcanic zone and its stratigraphic relationship to the bedded series is unknown.

PREVIOUS STUDIES AND PRESENT VIEWS

Gregory's (1905) descriptions of the Dundas Group rocks in the Queenstown area, including chemical analyses and petrographic data, are still referred to. Of the earlier contributions from the Tasmanian Mines Department the most useful accounts of the Cambrian rocks are those by Twelvetrees (1900) and Hills (1914) on the Jukes-Darwin mining district and Hills (1927) on the Lyell field. Nye, Blake and Henderson (1934) completed a generalized survey of the area north of Mt. Jukes and their views on the origin of the Cambrian rocks were opposed to those expressed by Hills. Although later workers on the Mt. Lyell leases (e.g. Edwards, 1939; Conolly, 1947; Alexander, 1953) followed Nye *et al.*, recent work confirms Hills' conclusions that the Cambrian rocks are largely of volcanic origin.

Hills and Carey (1949) and Carey (1953) discussed problems of West Coast geology and Banks (1956) included local information in his summary of the Dundas Group in Tasmania. The regional geology has been dealt with at length by Bradley (1954, 56, 57) and summarized by Wade and Solomon (1958).

The earlier geological opinions on the nature of the Dundas Group in this area varied from intrusive complexes with sedimentary roof-pendants (e.g. Nye, Blake and Henderson; Edwards; Conolly), to volcanics with minor sediments (e.g. Hills 1914, 1927) while others have suggested combinations of these extremes (e.g. Gregory, 1905). In 1953, Carey obviously considered that many of the so-called pyroclastics were greywackes and he stressed the sedimentary nature of the Group as a whole; he also heralded and supported the work of Bradley, who introduced a new approach when he postulated that many of the igneous rocks were a result of metasomatism of greywacke sediments and basic lavas, the metamorphic processes being a Tabberabberan age and related to sulphide mineralization. He envisaged the extensively developed quartz and feldspar porphyries (the term porphyry is used in this text to describe a rock showing porphyritic texture) as originating by " porphyritization ", involving growth of feldspar and quartz *in situ*, whereas all earlier workers had considered these rocks to be igneous. He was supported by Scott (1954) though she suggested the metasomatism only affected basic lavas and was of late Cambrian age. These views have been criticised by Banks (1956) and Wade and Solomon (1958) and it is now suggested that the Dundas Group in the Queenstown area comprises a suite of only slightly metamorphosed lava flows (varying from rhyolites to basalts), agglomerates, tuffs, conglomerates, sandstones and slates. This is very similar to the description given by Hills 45 years ago.

Bradley's views were accepted by other workers (e.g. Carey 1953, p. 1109) probably largely because severe alteration of the Dundas rocks was obvious near the Lyell deposits and it seemed reasonable to assume a more " regional " metasomatism involving porphyritization and granitization. However, Cambrian sequences in areas further afield, where there is no obvious metamorphism, contain identical porphyries and there is no reason to believe these are metasomatic. Examples include the Cambrian rocks in the D'Aguilar Range (south of Macquarie Harbour), on the High Rocky Point-Point Hibbs coastline, and in the Tullah-Mt. Farrell area. Those on the Southern Ocean coast are somewhat lenticular bodies interbedded with sediments(and pyroclastics ?) and varying from a few inches to several hundred feet thick. They are fine grained, porphyritic, locally vesicular and a few exhibit scoriaceous tops. The evidence is overwhelmingly in favour of these rocks being lava flows. The Tullah and D'Aguilar Range bodies are less well exposed but they appear to be concordant igneous porphyries.

Further and more direct evidence that the Queenstown porphyries are igneous is provided by the discovery in them of high-temperature quartz crystals (see p. 4). Several of these porphyry occurrences (e.g. the Lynch Creek area) are lenticular, concordant, vesicular and amygdaloidal, fine grained, associated with pyroclastics and similar to lavas of other areas, so that they are almost certainly volcanic. However, some of them (e.g. in the West Queen River and near Little Owen) have elliptical, almost circular outcrops and show discordant contacts; these are either intrusions, or volcanic necks, or steep-sided Peléan-type domes of viscous lava, burial of which by ash and sediment has produced pseudo-discordant relationships at their margins.

The majority of the porphyries are very probably lavas, judging by field relationships, similarities to other flows, and both macro- and microscopic textures, but there may be instances of intrusive bodies.

VOLCANIC ROCKS

Lavas

The principal lava-types observed in the Queenstown-Darwin area are as follows:

Spherulitic potash rhyolites

On Mt. Darwin, Intercolonial Spur, Whip Spur and Mt. Sedgwick (Fig. 1) are found distinctive massive outcrops of closely jointed, pink haematitic

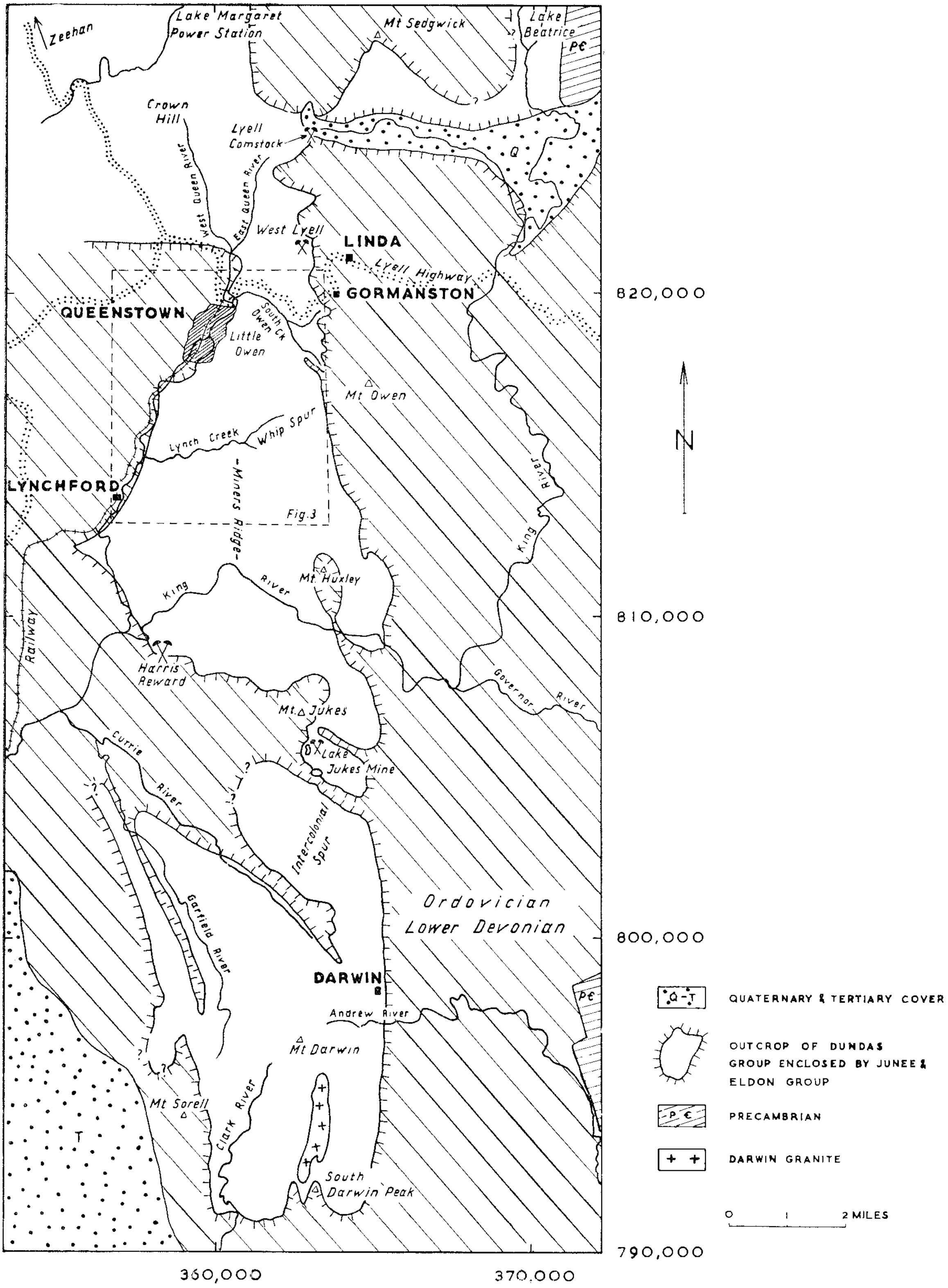


FIGURE 1.—The Queenstown Area.

feldspar porphyry (D 32, 33). The outcrops of these porphyries, in plan, vary from those which are almost circular (e.g. Whip Spur and Mt. Sedgwick) to those with one dimension much greater than the other (e.g. Intercolonial Spur). Possibly the former represent volcanic necks of Peléan cores while the latter are flows. The groundmass of these porphyries is aphanitic and the pinkish feldspar laths are up to 3 mm. long and very sparsely distributed. In places, and particularly south-east of Mt. Sedgwick, the rock is laced with haematite magnetite veins which are up to two feet wide, generally lenticular and of random orientation.

Microscopic study of typical porphyries on Mt. Darwin and Intercolonial Spur show the phenocrysts to be subhedral laths of plagioclase feldspar (albite ?) many of which show slightly corroded margins. Alteration of some crystals is slight, but in others it is so intense that the crystal is merely an outline in a microcrystalline "felt" of sericite, calcite, &c. The groundmass, which may form more than 90% of the rock, is composed mainly of rather crudely developed spherulites generally less than 0·5 mm. diameter. These usually possess a core of clear quartz and often a rim of quartz or dark brown haematitic (?) "dust" (Fig. 2). Notable features of the chemical composition of a typical sample of this rock are the high silica and potash percentages (73·4% SiO_2, 8·0% K_2O—see Table 1, No. 1). Sodium-cobaltinitrite stain tests (Chayes, 1952) gave negative reactions on the phenocrysts and strong indications of positive reactions throughout the groundmass. Though the fine grain of the base reduces the certainty of the latter observation, the stain results and the chemical analysis together suggest that much of the groundmass material is potash-feldspar.

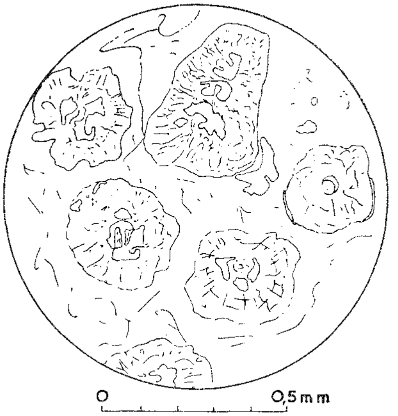


FIGURE 2.—Spherulitic forms in potash rhyolite, Mt. Darwin. Clear material in the spherulites is quartz.

Similar rock (Q 75) forms a bold outcrop at the head of Whip Spur (see Figs. 1 and 3). Albite (?) phenocrysts up to 2 × 1 mm. in size occur in a microcrystalline feldspathic ground mass in which spherulites abound; these are less than ⅓ mm. diameter, consist of radiating fibres and have a thin dark circumference like many of those described from Mt. Darwin. Once again the base reacts positively to potash stain tests. A fine banding which shows on some weathered faces is interpreted as flow banding.

An interesting variant (D25) acts as host to the Lake Jukes copper orebody. It is a dense, mottled, pink and grey "felsite" similar to the porphyries just described but differing in locally showing micrographic texture between quartz and potash (?)-feldspar. Hills (1914) describes the rock as a granophyre. The texture may be primary but could also result from reconstitution of a spherulitic base during mineralization. Breccias and banded rocks associated with this and other potash rhyolites are described under the heading "Pyroclastics" on p.

The outcrops of the pink rhyolites are confined to a narrow zone roughly coincident with the axis of the West Coast Range between South Darwin and Mt. Sedgwick, and the only other occurrences known to the writer are at Red Hills, South Mt. Farrell and near Lake Rolleston, all within the West Coast Range. This localization suggests the existence of a narrow zone of distinctive volcanic centres in Cambrian times from which acid, potash-rich lavas were erupted. It is significant that a major part of the only granite of proved Cambrian age in the Queenstown area is of similar composition to these rhyolites and is intruded into them.

Quartz keratophyres

Quartz-feldspar porphyries outcrop in the West Queen River, at Harris' Reward pack bridge (over the King River), in the Garfield River, west of Mt. Sedgwick, north of Darwin and at many other places within the area under discussion. Outside the area, similar rocks occur near South Mt. Farrell, Lake Dora and over a wide area north of Boko Siding on the Emu Bay Railway.

The boundaries and precise shapes of these quartz porphyry outcrops are always difficult to define though generally the bodies conform to the local structural trend. The porphyry exposed in the West Queen River has an elliptical outcrop roughly concordant with the regional strike but its southern margin appears to cut across steeply dipping sandstone beds. This porphyry (Q31) is pink or grey in colour with phenocrysts of both clear quartz and feldspar set in an aphanitic groundmass. Thin section study reveals that the quartz phenocrysts show some well-defined crystal faces but most are corroded and embayed and frequently contain inclusions of the ground mass. A few of the crystals show fuzzy, poorly defined boundaries.

Bradley (1957) has discussed similar observations on this and other quartz porphyries and he considers they indicate that the phenocrysts have grown *in situ* by a metasomatic process involving solid diffusion. Actually all the features described are typical of present-day and ancient acid eruptives, the corrosion, embayments, &c., being attributed to reaction between developing quartz crystals and the residual liquids. Proof of their igneous origin has been provided by Dr. E. Williams who has shown me etched basal sections of quartz crystals from West Coast porphyries that clearly display the cracking and heterogeneous twinning typical of the high temperature form. The feldspars of the West Queen River porphyry occur as hypidiomorphic crystals in approximately equal quantity to the quartz, the phenocrysts of the two minerals forming 60% of the typical rock. Few feldspar crystals show embayments or inclusions but many are markedly zoned, a feature which is often highlighted by alteration of the core to chlorite and the rim to sericite (?). Some of the crystals are clear, unaltered albite but the majority are clouded by alteration products and appear to have a composition of about Ab_{90}. Ferromagnesian minerals are very scarce though chlorite and haematite confined in idimorphic lath outlines suggest that some ferromagnesian mineral was once present in the rock.

The groundmass is a microcrystalline aggregate of feldspar, chlorite, and haematite of which the texture is obscured by alteration products.

A feature of these quartz porphyries and also the feldspar porphyries (keratophyres) is the presence in irregular patches of chlorite-albite (Ab_{98}) aggregates some of which occur isolated in the groundmass but many of which are clearly replacing altered feldspar laths. Many are only visible under the microscope but others are seen in outcrop as vughs partially filled with albite, chlorite and epidote. The albite is characteristically confined to the rim while the ferromagnesian minerals fill, or partially fill, the core. A specimen in the Mt. Lyell Mining and Railway Company's collection, presented by Professor J. W. Gregory in 1903, is a feldspar porphyry from the East Queen River with a vugh several centimetres across lined with albite, epidote and quartz. There is every gradation between typical zoned amygdales and irregular "clots" derived from feldspar alteration and they are all regarded as expressions of late-stage gas action (i.e. deuteric phenomena). The albite of this phase is usually pink or brown in colour and appears fresh and unaltered under the microscope.

A chemical analysis of a large specimen of typical West Queen River porphyry is given in Table 1, No. 3; in conjunction with the petrographic data it suggests the rock should be identified as a quartz keratophyre. The latter term is used to denote a rock with the chemical composition of a sodic rhyolite but with abundant albite or oligoclase and a very small percentage of primary ferromagnesian mineral, which is altered to chlorite. It is distinguished from keratophyre by abundant free quartz and consequent higher silica percentage. Gregory (1905, p. 57) described a quartz-feldspar porphyry from the Lyell Comstock tram line as a diabase porphyrite. However, his petrographic description and the chemical analysis he provided (see Table 1, No. 4) suggest he had examined a rhyolitic flow.

A striking quartz keratophyre (Q22) outcrops in a small quarry west of the Zeehan road three miles from Queenstown. It is a pink-brown porphyry containing prominent amygdales lined with albite and filled with chlorite and occasional specks of galena. The majority of the phenocrysts are of altered plagioclase feldspar in laths up to 4 mm. long, the remainder being of corroded quartz crystals and irregular, rounded masses of chlorite with dark rims which may represent altered feldspar crystals. The chlorite shows the dark blue or rich brown interference colours typical of pennine. The groundmass is a microcrystalline aggregate of quartz and feldspar, speckled with pyrite grains and containing rare apatite crystals.

A slightly different variety of quartz porphyry outcrops on the tram line between the upper and lower power houses at Lake Margaret. It varies in colour from grey-blue to yellowish grey and contains phenocrysts of quartz, feldspar, and chlorite up to 4-5 mm. diameter. The idiomorphism of the quartz crystals and zoning in the feldspars are visible in hand specimen.

Sodi-potassic rhyolite

Half a mile south of the upper zig-zag on the Lyell-Comstock tram line and on the west side of the East Queen River, there are bold outcrops of grey feldspar porphyry (Q23), parts of which show banding. Colours of individual bands vary from pale to medium grey and hence they are not particularly distinct; they vary from a few millimetres to a few centimetres in thickness and are impersistent.

Many of the phenocrysts, which average 2 mm. across show vestiges of multiple twinning but they are so clouded by alteration products that identification is difficult; extinction angle measurements indicate a composition of about Ab_{88}. They are enclosed by a quartzose (?) microcrystalline ground mass.

This rock was described by Bradley (1954, p. 223) as a soda trachyte but chemical analysis (Table 1, No. 5) of a specimen reveals a high silica content (72·9%) and roughly equal amounts of soda and potash, so that the term sodi-potassic rhyolite seems more appropriate until more definite petrographic data are available.

Keratophyres

Sodic feldspar porphyries of various types occur throughout the Dundas Group and are the most common of the lava-types in the Queenstown area. They are particularly well exposed at several places along the Lyell-Comstock tram line, on the Zeehan road, east of Mt. Sorell, and north and east of Mt. Jukes. Similar rocks make up the bulk of the "volcanic assemblage" (of Campana *et al.*, 1958) which outcrops between Rosebery and the Sterling River Valley, and between Farrell Siding and Tullah.

Deeply weathered lavas of this type occur at the northern end of the Queen River gorge where they are interbedded with beds of slate several feet thick; at their base the flows have picked up and incorporated fragments of the underlying sediments. Along the Lyell-Comstock tram line the lavas are interbedded with conglomerates, pyroclastics and thin beds of banded slate.

These porphyries (Q15, 26, 27, 29, &c.) are characterised by subhedral feldspar laths up to 1 cm. long, very fine or microcrystalline matrices, and "clots" of albite-chlorite crystals which are taken as evidence of deuteric action. The feldspar phenocrysts are generally intensely altered, either to albite-chlorite, or to a dense brown "felt", but examination of fresher remnants indicates a composition near Ab_{90}. Small amounts of calcite have been observed as an alteration product of feldspar. Augite and hornblende laths, generally considerably chloritized, and embayed quartz crystals rich in inclusions are rare constituents. The groundmass in some thin sections is speckled with haematite and apatite crystals are observed occasionally.

Most of the feldspar porphyries can be classed as keratophyres, assuming that term to include trachytic rocks characterised by a relatively high soda content, the presence of abundant albite or oligoclase and intense alteration of what little ferromagnesian mineral may have been present in the rock. In this area there are all gradations to sodic rhyolites on the one hand and to albite andesites on the other, with the result that there are considerable ranges in the chemical composition of the keratophyres. The analysis of the feldspar porphyry given in Table 1, No. 6 is typical of a rather more basic variety and on chemical composition alone would be described as a trachy-andesite. It is transitional between the true keratophyre and the hornblende andesite in that it contains laths of hornblende and augite up to $1 \times \frac{1}{4}$ mm. in size and partly altered to chlorite.

Augite Trachyte (?)

East of the Queenstown-Lynchford road (see Fig. 3) the grass-covered hills display tors of feldspar-pyroxene rocks and on some of the tor faces can be seen haphazardly distributed fragments of sedimentary rocks and basic lavas.

This rock has a rudely equigranular, more or less reticulated texture, with a grain size of about 1 mm. and sparse interstitial material. The feldspar content varies from 30% to 90%, the remainder of the rock being composed of augite (diopside ?), quartz and the microcrystalline base. The feldspars occur as stumpy subhedral laths, only slightly altered and with a composition of Ab_{98}. The augite crystals are anhedral, fractured, and partially altered to chlorite and locally form 30% of the rock. Clear albite veinlets traverse the rock and albite-chlorite aggregates (amygdales ?) are common.

From petrographic data, Twelvetrees (1902, p. 282) considered the rock to be extrusive and described it as a syenite porphyry. Bradley (1954) included it in his "Lynch Conglomerate" formation and considered it to be a sediment derived from weathering of underlying basalts. He inferred an unconformity at its base.

The outcrop (Fig 3) is nearly two miles long and relatively narrow and it is clearly concordant with contiguous beds. From the evidence outlined it is impossible to differentiate between suggestions that the rock is a crystal tuff, a lava, or a sill, but it is most unlikely to be a sediment. Its texture is rather similar to that seen in tuffs near Lyell Comstock described on p. 43.

South-east of Little Owen there outcrops a rock of similar composition but with a more pronounced porphyritic texture; on its northern margin it is interbedded with sandstones and tuffs but the major part of the outcrop shows discordant relationships to the neighbouring rocks. This occurrence therefore has more the features of an intrusion and may represent a section through a volcanic cone.

The only other example of this rock-type with which I am acquainted occurs as boulders on the side of the Zeehan-Comstock road nine miles from Zeehan. The boulders are in Pleistocene moraine and are derived from the plateau south of Mt. Dundas. One of them contains randomly oriented fragments of finely banded siltstone that appear to have been hornfelsed at their margins by baking. The inference is that the host rock was hot and probably fluid.

In summary then, the available evidence suggests that this rock-type may occur as an intrusive, a pyroclastic or as a lava flow. In all probability all these modes of occurrences exist and they are clearly interconnected. Uncertainty as to its exact nature makes it difficult to define the rock but tentatively it is named after the lava-type of similar composition; several occurrences of other lava-types may similarly be actually intrusive or in part pyroclastic.

The chemical composition of a sample gathered 500 feet east of Lynch Creek bridge is given in Table 1, No. 7. Although clearly related to the keratophyres and andesites of the area it is a distinctive rock type and warrants a particular term. Despite the abundance of albite and high soda content, the presence of augite invalidates the term keratophyre and augite trachyte is preferred.

Andesites

Many of the hill-tops in the Comstock-Crown Hill area are capped by tors of hornblende and augite porphyry. These rocks are typically grey or pinkish-brown in colour and composed of phenocrysts of feldspar and ferromagnesian minerals (up to $3 \times 1\frac{1}{2}$ cm.) set in an aphanitic ground mass. Similar rocks occur as boulders in the Lake Margaret moraine and outcrop west of Mt. Tyndall.

The texture of these porphyries (Q1, 7*a*, 7*b*, 8, 9, &c.) varies from seriate to porphyritic and the dominant mineral is feldspar occurring as phenocrysts and in the very fine grained groundmass. It is generally clouded and partly chloritised but remnants of multiple twinning are discernible and extinction angle measurements indicate a composition of Ab_{70}. Zoning is common, many crystals showing a clear albite fringe enclosing a core of altered Ab_{70} feldspar.

Hornblende occurs as pale green crystals, usually deeply embayed and containing "inclusions" of the ground mass; in some cases the crystal is more of a skeletal framework. Some have a dark rim and a core of chlorite, others are represented by chlorite-haematite aggregates.

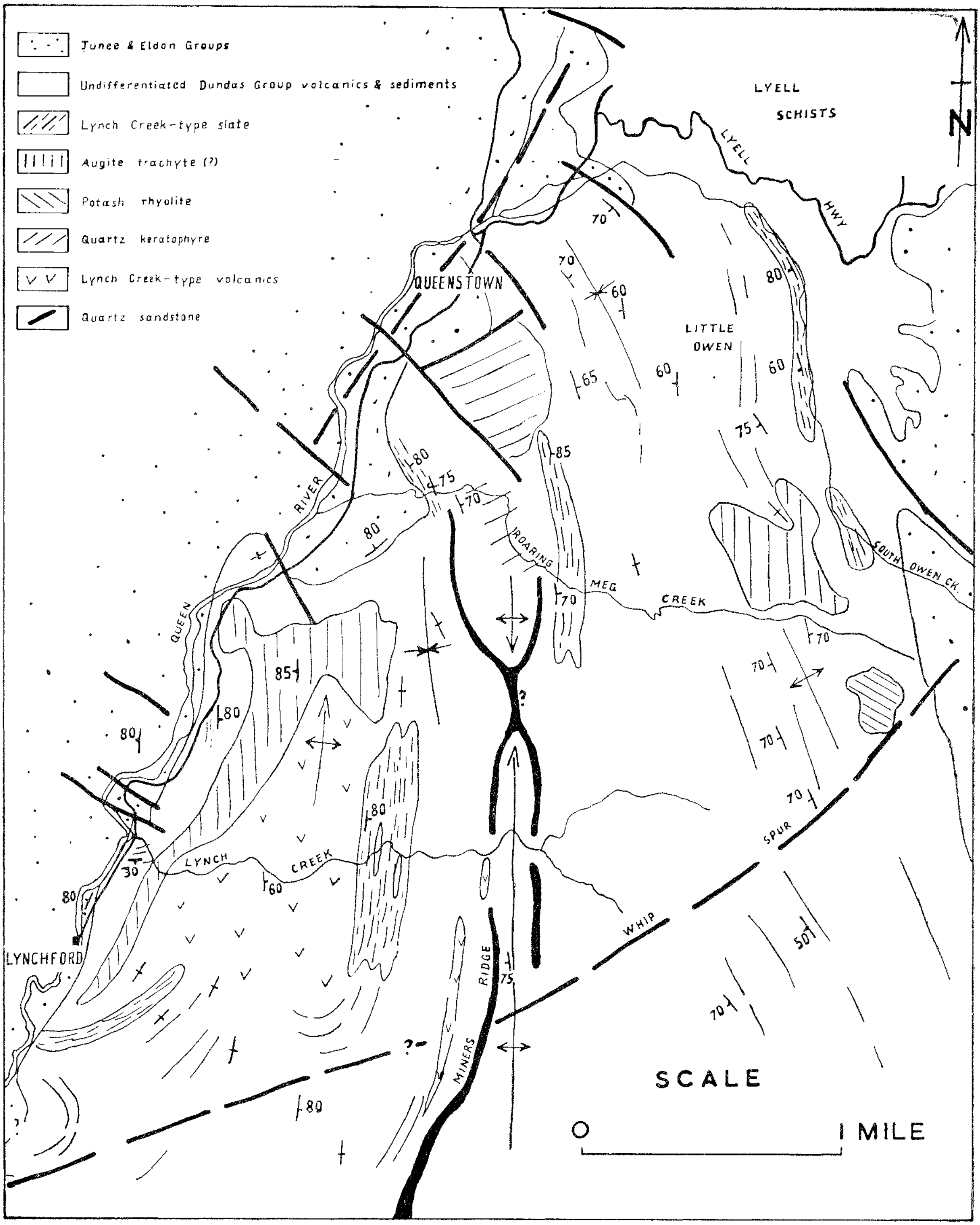


FIGURE 3.—Geological Map of the Lynch Creek Area.

There is every variation from hornblende porphyry without augite to augite porphyry with little hornblende; the total percentage of ferromagnesian minerals is constant and thus where there is much of one mineral there is little of the other. The augite (diopside ?) occurs as cracked and poorly formed crystals, generally partly chloritized.

Quartz occurs sparsely in the form of shards or in clusters of fragments showing unit extinction (presumably representing a fragmented crystal). The remainder of these rocks is usually made up of a dark, partly feldspathic matrix, fragments of feldspar-pyroxene lava, and ragged crystals of calcite. Albitization of these rocks varies from slight to intense, a more severe case being illustrated in Plate 1, Fig. 1. Here the albite replacement has proceeded to such a degree that a brecciated appearance has resulted. The isolated blocks of hornblende porphyry average 3 dm. across and are separated by pale albite rock containing some hornblende crystals. Some of the thin sections show irregular replacement zones of albite and one contained in addition a number of dilatational veinlets. A specimen taken on the west slope of Crown Hill contained in the groundmass tiny (0·1 mm.) spherulites of radiating albite (?) fibres; the spherulites gave the typical "cross-figure" when rotated between crossed nicols. Near the summit of Crown Hill the porphyries show banding, "pebble" outlines and inclusions of sediments or tuffs.

Chemical analysis of typical slightly albitized hornblende porphyry from Crown Hill (Table 1, No. 8), taken in conjunction with petrographic data suggests a suitable name for the rock is a hornblende (or augite) andesite.

Scott (1954) regards these andesites as originating by metasomatism of basic lavas, the hornblende crystals growing out of chlorite which has developed through breakdown of pyroxene. I was unable to establish definitely the relationships between hornblende, augite and chlorite but gained the impression that chlorite formed from both augite and hornblende. Probably the chloritization and albitization are deuteric or secondary phenomena and are obscuring the magmatic hornblende-augite relationships. Scott (1954, p. 141) discusses at length the parallelism of hornblende laths in a boulder of andesite observed by Banks in the Margaret moraine. The orientation of the laths is at an angle to the cleavage and she is unable to explain the feature by her metasomatic theory for the development of hornblende. In all probability it is a primary flow phenomenon.

Basalts

Basalts outcrop along Lynch Creek, between 1000 and 4500 feet east of the Lynch Creek bridge (see Fig. 3). Individual flows are limited in extent, in both horizontal and vertical direction, and they are associated with tuffs, siltstones and volcanic breccias. Red and brown clays are exposed along Lynch Creek in the walls of open cuts made during the pursuit of quartz-gold veins. These clays are probably tuffs and perhaps lavas that have been altered as a result of the mineralization, and since deeply weathered.

The lavas (Q82, 83, 88) are grey-green in colour and porphyritic, with phenocrysts of dark green pyroxenes up to 2 cm. long and smaller pale grey feldspar laths, set in an aphanitic ground mass. The pyroxene occurs in euhedral crystals, is only slightly chloritised and has been identified by Scott (1954) as diopside. Although Scott describes the feldspar laths as albite I found they were so altered that identification was difficult and that what few measurements could be made indicated a composition of about Ab_{60}. The relatively low soda percentage in these rocks (Table 1) fails to support Scott's determination.

Some specimens gathered from the volcanic sequence contain hornblende laths and are not unlike the hornblende andesites of the Crown Hill area.

The Lynch Creek lavas are associated with lenses of breccia; this is usually very coarse grained and consists of fragments of basalt embedded in a basaltic matrix which usually shows evidence of having "attacked" the fragments. These lava fragments differ from the matrix and also the majority of the flows in being markedly vesicular and amygdaloidal. The amygdales are spherical, up to 5 mm. in diameter, and are made up in the following ways:—

(*a*) Lined with albite enclosing a zone of haematite and a core of chlorite.
(*b*) Lined with calcite enclosing a chlorite core.
(*c*) Filled completely by calcite.
(*d*) Lined with chlorite enclosing a calcite core.

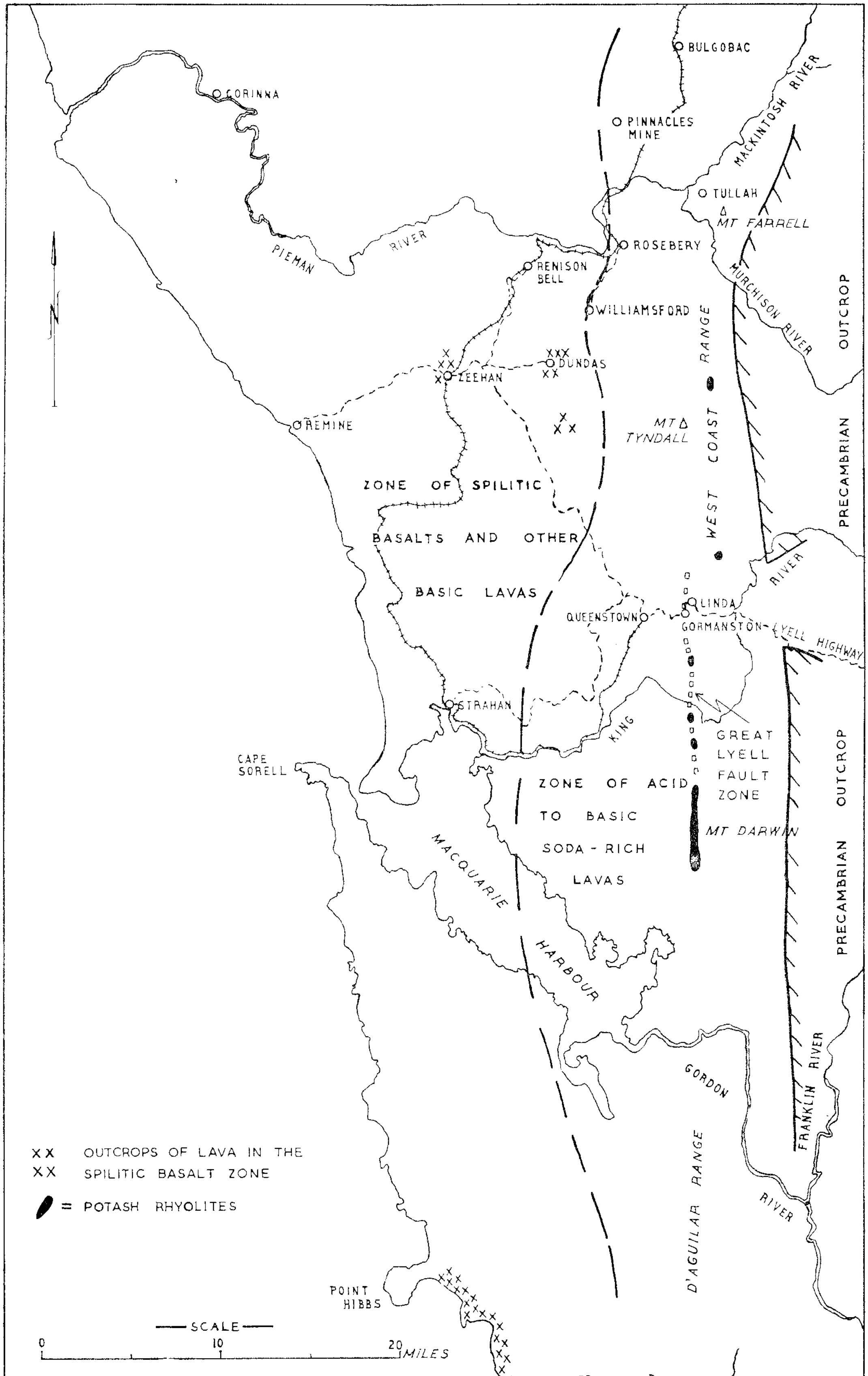
The breccias are thought to have originated by the process of "autobrecciation" whereby the chilled gas-laden crust on a mobile lava becomes broken up by, and incorporated into, the still molten rock beneath.

A variation (Q96) of the normal porphyritic texture is seen in a flow outcropping on the west flank of Miners Ridge; it is about 50 metres thick and extends for several hundred metres. The lava is composed of diopside and feldspar but has a roughly equigranular texture with augite granules set in a lattice-work of fine feldspar laths. A chemical analysis is given in Table 1, No. 12, along with others of the Lynch Creek basalts (Nos. 10 and 11).

Another suite of basalts with which I have a brief acquaintance occur outside the area now under discussion but are of some interest as regards distribution of lava types. They outcrop on the Southern Ocean coast between Point Hibbs and High Rocky Point and consist mainly of spilitic basalts and associated tuffs and breccias, very well exposed in steep cliffs. The flows vary from a few inches to over 100 feet thick, are fine grained apart from local coarser zones, and are dark or medium grey in colour. While some flows are homogeneous others are severely brecciated, resulting in a "conglomerate" of lava fragments in a lava base, similar to those described from Lynch Creek.

The commonest type is a grey porphyry with feldspar phenocrysts and dark euhedral augites set in an aphanitic, dark ground mass. The feld-

FIGURE 4.—Distribution of lava-types in the Dundas Group.➔


BULGOBAC
CORINNA
PINNACLES MINE
MACKINTOSH RIVER
TULLAH
MT FARRELL
PIEMAN
RIVER
ROSEBERY
RENISON BELL
MURCHISON RIVER
WILLIAMSFORD
OUTCROP
DUNDAS
ZEEHAN
WEST COAST RANGE
MT TYNDALL
REMINE
ZONE OF SPILITIC BASALTS AND OTHER BASIC LAVAS
PRECAMBRIAN
RIVER
LINDA
QUEENSTOWN
GORMANSTON
LYELL HIGHWAY
STRAHAN
KING
GREAT LYELL FAULT ZONE
CAPE SORELL
ZONE OF ACID TO BASIC SODA-RICH LAVAS
MT DARWIN
PRECAMBRIAN OUTCROP
MACQUARIE HARBOUR
GORDON
FRANKLIN RIVER
D'AGUILAR RANGE
RIVER
XX OUTCROPS OF LAVA IN THE
XX SPILITIC BASALT ZONE
= POTASH RHYOLITES
POINT HIBBS
SCALE
0
10
20 MILES
WANDERER
RIVER

spars are slightly chloritized, euhedral, albite crystals generally less than 1-2 mm. long; similar feldspar is discernible in the groundmass either as scattered tiny laths or forming a microcrystalline lattice of laths with interstitial pyroxene granules.

Amygdales are seen occasionally in thin sections and are usually circular or lenticular in shape, consisting of clear albite enclosing a central zone of chlorite.

These basalts have strong spilitic affinities and are similar to spilites described by Scott from King Island, Penguin, and Zeehan. Some of these have " pillow " structures and are in all probability of submarine origin.

Summary of Lava Descriptions

The Queenstown area exposes a continuously variable series of volcanic rocks ranging from basalts through andesites to rhyolites. The alkali content is equally variable, potash-rich rhyolites being associated with soda-rich keratophyres and relatively alkali-poor basalts. Apart from the potash-rhyolites the dominant primary feldspar type varies from Ab_{60} to Ab_{98} in composition and the rocks have undergone varying degrees of albitization. Though these rocks were predominantly extrusive the discordant contacts mentioned in a few cases suggest some of the occurrences are actually intrustive, in the form of small sills, plugs, or vent-fillings.

Association of the lavas with slates and sandstones suggests the environment was at least temporarily aqueous and it probably ranged in place and time from terrestrial to marine.

Distribution of Lava Types

A notable feature of lava distribution in the Queenstown-Darwin area is the concentration of the potash rhyolites along a narrow N-S belt which coincides with the axis of the West Coast Range and locally with the Great Lyell Fault Zone. (see Solomon, 1959, p. 36). The Darwin Granite, of very similar composition, also occurs along this fault zone between Mt. Darwin and South Darwin (Fig. 4).

Away from this belt the lavas vary from basalts to rhyolites but are characterized by dominance of soda over potash.

Viewing the West Coast as a whole, a tripartite division of lava types can be recognised:—firstly the narrow, relatively insignificant potash rhyolites occurring within a wider zone of variable but soda-rich volcanics, which in turn is flanked on the west by a still wider area in which the majority (say 80%) of the lavas are basic and sodic (see Fig. 4).

The central acid to basic zone in the Queenstown area has a poorly defined western boundary partly due to lack of exposure but to the north, and particularly in the Rosebery district, the western edge is sharp and coincides with the bedded series—volcanic assemblage interface. The volcanics here and to the north are made up of similar lavas to those seen near Queenstown. West of Rosebery and Williamsford, the lavas of the basic zone are subordinate to sediments and are largely basic in character (e.g. the Curtin Davis Volcanics and the Montana Melaphyre, Elliston, 1954, and Scott, 1954) and only rare acid lavas have been recorded (e.g. at Montana, Twelvetrees and Ward, 1910, p. 19). In the Point Hibbs-High Rocky Point area the percentage of lavas in most of the Cambrian sequence is greater than that of the sediments but the dominance of basic types is maintained.

Cause of the Distribution

Again insufficient is known of the Cambrian palaeogeography and tectonic environment to be certain of the cause of the lava distribution described.

An important feature, however, is that the lava zones are roughly parallel to the western margin of the Precambrian outcrop, a relationship which appears to be continued north-east of Bulgobac (Fig. 4). The present Precambrian limit roughly coincides with the Cambrian margin of the Tyennan Block, a relatively stable area which Carey (1953) considers to have had a considerable influence on Palaeozoic sedimentation and tectonics and which was very likely exposed during the Cambrian. The narrow zone of volcanoes that are assumed to have built up the " volcanic assemblage ", and another related to the potash rhyolite distribution, are both parallel to the Tyennan Block margin and may be imagined as lines of off-shore volcanoes in the Cambrian depositional area. These volcanic lines roughly coincide with major Devonian structures such as the Great Lyell Fault Zone and probably are expressions of Cambrian movement along these features, which also appear to be influenced by the Tyennan Block.

Albite in the Lavas

Scott (1950) has described albite in ophitic texture with diopside in Cambrian basalts from King Island and this is strong evidence that albite occurs as a primary mineral. The presence of fresh albite in tuffs north of Queenstown (see page 43) suggests the mineral formed at an early stage in crystallization and the fresh albite crystals in the augite trachytes, and also in some of the quartz keratophyres, has the appearance of a primary mineral.

The existence of rims off clear albite on more calcic feldspar indicates a phase of albite formation related to soda-enrichment of the residual material of the cooling flow. Albitization of an even later phase is seen in the veinlets and the chlorite-albite aggregates; these are observed mainly in lava flows but the presence of similar features in pyroclastic rocks indicates the mobile material circulated beyond the limits of the flows. The continuity between the chlorite-albite " clots " and amygdales suggests this late albitisation is related to the release of volatiles from the lava.

It is accompanied by chloritization of both primary feldspars and ferromagnesian silicates.

Scott (1954) considers the albitization to be part of a widespread late Cambrian metasomatism involving not only albite introduction but also chloritization, silicification and carbonation. Actually chlorite and albite are the only replacement minerals of Cambrian age in the Queenstown area and their mode of occurrence suggests they are of igneous origin. With regard to the source of the soda in the porphyries she concludes (p. 144) that it is derived from connate waters trapped in the lower levels of the eugeosynclinal sediments. I would prefer to leave the problem with Turner and Verhoogen (1951, p. 210), who state when discussing olivine basalt magma: "Differentiation of the magma, assimilative reaction with rocks situated in the basal levels of the geosyncline, concentration of magmatic water rich in soda, and chemical activity induced by entrapped sea water and rising connate waters squeezed up from deeply buried sediments, are all factors of possible significance in evolution of spilites and keratophyre".

The albite described above is a pinkish brown in colour and easily recognizable. Albite with a reddish tinge is often seen in quartz veins in the schists at Mt. Lyell and in the vicinity of other sulphide deposits; the veins are clearly post-schistosity and related to Devonian mineralization and this albite is perhaps derived by solution from soda-rich Dundas Group lavas and tuffs.

PYROCLASTIC ROCKS

Agglomerates (fragments over 32 mm. diameter.)

Conglomeratic and breccia lenses are a feature of the Dundas Group in the Queenstown area. When the constituents are entirely of igneous origin, then the rock is probably the result of autobrecciation or may be a true agglomerate, particularly if associated with lavas. Many of the lenses show no stratification or sorting and could be products of the nuée ardente type of eruption. For instance, coarse breccias occur in the potash rhyolite assemblage on Mt. Darwin and also in the granophyric host to the bornite veins at Lake Jukes; generally the fragments vary from a few cm. to a few decimetres across, are angular to subangular, and of similar composition to the matrix. There is little or no stratification and the fragments are randomly orientated.

Apart from these breccias, which are fairly certainly of volcanic origin, there are many which contain varying percentages of sedimentary material such as siltstone and sandstone fragments. These could be volcanic, or pyroclastic rocks deposited in water or sedimentary rocks and proof of volcanic origin must depend on the recognition of volcanic glass; this, of course, is completely devitrified and in most cases it is impossible to decide whether the deposit is pyroclastic or whether it is reworked volcanic material. In the environment envisaged by the writer both types might be expected for the frequency of volcanic material suggests the Queenstown district in Cambrian times was one of considerable volcanic activity with eruption taking place from numerous centres of ephemeral nature. The constantly changing conditions would result in re-working of both land- and water-deposited pyroclastic and igneous material and would produce a complex, rapidly varying suite of sedimentary and volcanic rocks.

A typical conglomeratic rock (Q78) that is probably of mixed origin outcrops near the head of Whip spur some hundred metres west of the pink rhyolite. It occurs as lenses associated with finely banded mudstones and lavas and consists of coarse fragments of feldspar porphyry and sandstone and smaller quartz pebbles in a confused matrix of albite crystals, chlorite, and microcrystalline quartz (?) and feldspar (?). There is little stratification and the framework is disrupted. Veinlets and replacement zones of clear albite are common.

Tuffs

Again it is difficult to differentiate between sediments and volcanic deposits but there are a number of rock types that can be described as tuffs with reasonable certainty. For instance, at 8263/3584, on the Lake Margaret tram line west of Crown Hill (Fig. 1) is a distinctly banded rock (Q11) with an average grain size ½ mm. and a texture typical of orthoquartzites (equidimensional grains with an interstitial cement forming say 8-10% of the rock). It is composed of subangular grains of albite, quartz and hornblende (in order of abundance) and microcrystalline interstitial matter. The presence of banding, the texture and the anomalous composition (a high percentage of quartz compared with the local lavas) suggest the rock may be a tuff.

Similar remarks apply to a rock (Q17) forming tors above the northern zig-zag on the Lyell-Comstock tram line. It is mottled or rudely banded in pinks and dark greens, the bands being several inches thick, and it is interbedded with sandstones and paraconglomerates (i.e. conglomerates with disrupted framework and high matrix-pebble ratios). The rock has a granular texture, an average grain size about 1 mm. and is composed of quartz and fresh albite with sparse, fine grained, interstitial material which is locally chloritic (giving the dark green colour).

SEDIMENTARY ROCKS

The relative proportions of sedimentary and volcanic rocks in the Cambrian sequence near Queenstown vary considerably and can only be determined approximately due to difficulties in identification. General field observations indicate that the proportion of sediments varies from a little above, to a little below, 50% in any square mile.

Conglomerates

The problems of identifying sedimentary conglomerates have already been discussed and rocks which are probably volcanic have been described. Those with more obvious sedimentary affinities are typified by the following examples:—at 8218/3588 there are outcrops of a deeply weathered, grey, feldspathic breccia-conglomerate containing fragments, sometimes "shard"-like, of slates and sandstone. The framework is disrupted and the distribution of fragments is chaotic, indicating rapid sedimentation.

Lenses of conglomerate occur in fine, grey sandstone in the Queen River gorge (south of Lynchford); an interesting type consists of small (up to 5 × 15 mm.) ovate pebbles of grey chert or very fine quartzite lying with long axes on the bedding planes, the plentiful interstitial material ranging from pebble size to microscopic and comprising "chert", quartz and rounded fragments of keratophyre. The source of the siliceous pebbles could be Cambrian chert beds, but none are known in this area and it is more likely that they are derived from Precambrian material.

A paraconglomerate containing sandstone lenses outcrops half a mile north-west of the Lyell Comstock open cut and immediately north of the mottled tuff described on p. 43. It is composed of fragments of volcanic and sedimentary material of Cambrian origin but in addition contains rounded pebbles of vein quartz identical with those which form the bulk of the Owen Conglomerate. It is thus very similar to typical Jukes Conglomerate but is almost certainly a member of the Cambrian sequence. Similar rocks occur throughout the Dundas Group (e.g. Elliston's Razorback Formation at Dundas) and grade, with increasing quartz pebble content, to siliceous breccias and conglomerates almost identical with beds in the Owen Formation. Thus there is good evidence that a Precambrian quartz-rich source was intermittently feeding material in limited amounts into the Cambrian eugeosyncline. Density currents sweeping off the Precambrian shoreline (to the east?) and also off the unstable volcanic belt probably carried much of the material into the "bedded series" depositional area.

The similarity of many of these Cambrian paraconglomerates to the Jukes Conglomerate renders impossible the positive identification of the latter formation by lithology alone.

Sandstones

Several greywacke sandstones outcrop in the Queenstown-Darwin area. They are variable in character, lenticular, "dirty" or "muddy", and again it is often difficult to differentiate between greywacke sandstone and tuffaceous sandstone. Thin beds outcrop north-east of Lynchford and a considerable thickness may be seen east of Little Owen (see p. 46).

The one exception to the greywacke-type sandstones is the clean, quartz sandstone (Q101) which outcrops along the crest of Miners Ridge east of Lynchford (Fig. 3). It is about 100 feet thick and can be traced for four miles; its grain size varies between ½ mm. and 1/30 mm. and it consists entirely of subangular quartz grains apart from a small number of biotite flakes aligned parallel to the poorly developed cleavage. It is interbedded with slates and is of some importance in that its prominent outcrop makes it a useful marker horizon for determining structure.

Mudstones and Slates

These beds consist of finely, irregularly alternating bands of coarse siltstone (or very fine sandstone) and claystone. The claystone bands are thickest and consist of argillaceous material studded with quartz grains of silt grade; the narrower siltstone bands are usually composed of angular and subangular quartz grains of silt grade. Locally a tendency to grading is seen and the bands look similar to varves. Very fine ripple markings and erosion of tops of layers are seen occasionally and good examples of slump structures on a small scale outcrop on Whip Spur (see also Bradley 1954, p. 223). An indication of the frequency of banding is given by measurements made on the polished face of a specimen in the Mt. Lyell Mining and Railway Company's geological museum; in a nine-inch section the frequency of bands varies from one band per inch to 35 bands per inch.

Bradley (1954) has described these beds as exposed in Lynch Creek and termed them the "Miners Slates". As a cleavage is developed in the rock the lithology is correctly named but the Miners Ridge, from which the term is derived, is actually due to the quartz sandstone already described. "Miners Slates" (see p. 46) outcrop over a wide area as isolated lenses which merge along strike to other Dundas Group rocks, these facies variations render suspect the use of the slates as marker beds and suggest that mud and silt developed in local, ephemeral basins through a considerable range of the Cambrian.

The principal accessible exposures are along Lynch Creek, in the Queen River gorge, and along South Owen Creek (east of Queenstown). The most continuous outcrop mapped so far is in South Owen Creek, where the slates have been traced for 1½ miles with a fairly constant thickness of 300 feet. They outcrop either in low rises or in stream beds depending on the relative resistance of the propinquent beds. Rather similar finely banded rocks outcrop over a wide area around the junction of the Garfield and Currie rivers (Fig. 1) but the stratigraphic position of these beds is not known (they may, in fact, be of Silurian age).

The slates of the Tullah area and of the Rosebery and Hercules mines are very similar in lithology to the Lynch Creek slates.

STRUCTURE

Determination of structures in the Cambrian rocks is hampered by rapid lithological changes along strike and the consequent lack of "marker horizons", and also by the fact that few of the rock types display identifiable bedding planes.

However, the presence of relatively persistent units east of Lynchford has allowed at least a partial portrayal of the fold styles in that area. The folds are only slightly asymmetrical, have steeply dipping limbs, and wave lengths averaging about 4000 feet. The axial trend in this district is 180° and there are fairly frequent changes in the direction of plunge. East of Queenstown the folds have NW trending axes and they plunge NW (Fig. 3). The north point shown on Fig. 3 is magnetic with declination 10° E.

Folds on these trends affect the Junee and Eldon Groups and clearly belongs to a Devonian orogeny, yet there is good evidence that faulting, uplift and erosion affected the Cambrian sequence prior to deposition of the Junee Group. The presence of pebbles of Darwin Granite and Dundas lavas in the Jukes Conglomerate and the history of the development of the Jukes Trough (or Owen Rift valley), in which the Owen Conglomerate was later deposited, clearly indicate major faulting on N-S trends followed by erosion of elevated areas (see Bradley, 1954, 56; Wade and Solomon, 1958; Campana *et al.*, 1958). A good example is the uplift and erosion of the Darwin Granite late in the Cambrian and prior to deposition of the Owen Conglomerate. This tectonic phase has been termed the Jukesian Movement by Carey and Banks (1954). Clearly defined and indisputable unconformity between the Junee and Dundas Groups has not been proved on the West Coast, to the writer's knowledge, but it has been inferred at several places. A very strong indication of unconformable relationships in the Queenstown district is found near Lynchford, on grounds of discordance of lithology trends and observed dips (Fig. 3) and also at Mt. Sedgwick, where the base of the Jukes Conglomerate appears to cut through part of the Cambrian sequence. Yet at Mt. Misery (three miles east of Zeehan) the Gordon Limestone-Owen Conglomerate-Dundas Group succession is apparently conformable and Carey and Banks (1954) describe other areas showing a similar relationship.

As Bradley (1954, p. 205) has already pointed out the unconformity at Mt. Jukes described by Hills (1914) is actually a contact between gently dipping Junee Group conglomerates and Dundas lavas with a steeply dipping cleavage but in which no stratification is visible. A similar relationship is seen at the north end of Mt. Huxley where the basal beds of the Jukes Conglomerate and the underlying rocks of the Dundas Group are so sheared and altered that it is impossible to investigate the Dundas-Junee interface.

A complicating factor in determining Cambrian-Ordovician relationships is the likelihood of the interface acting as a décollement surface during Devonian folding, thus possibly producing "pseudo-unconformities". The chances of such a process taking place are increased in the areas where there are thick wedges of Owen Conglomerate that locally deflect and modify the Devonian stresses. Banks (1956, p. 204), by "unfolding" the unconformities he has observed and studying the residual pre-Junee dips, has concluded that the intensity of Jukesian folding varied from place to place. The force of his argument is reduced if it is accepted that décollement development is a real possibility.

In summary, there is evidence that faulting and unheaval preceded Junee Group deposition but the extent and precise nature of the movements is unknown. The variation in relationship between the Junee and Dundas Groups tends to support Banks' view of localised zones of tectonic activity but study of this tectonism is possibly hampered by décollement surfaces.

METAMORPHISM

As a general rule the Cambrian sequence has been only slightly metamorphosed for if the effects of weathering and albite metasomation are omitted, the rocks have undergone little change. Locally, however, the Cambrian beds have undergone severe alteration as a result of the embayment of sulphides, mainly pyrite and chalcopyrite. This alteration involved sericitization, chloritization, propylitization and hydration and the resulting rocks are described as sericite and chlorite schists. At Mt. Lyell the process reached a peak and the West Lyell open cut area is the centre of an aureole of alteration extending outwards for three-quarters of a mile. As described in Wade and Solomon (1958) the auerole is very crudely zoned, the central sericite zone passing out to chlorite-rich areas and then to rocks that have undergone milder alteration which is included in the term propylitization.

Typical of the early, propylitic stage of alteration is a sheared feldspar porphyry (Q64) from the upper reaches of South Owen Creek. The feldspar phenocrysts are roughly aligned with the cleavage and are also slightly rounded, giving a poorly developed augen structure. The ground mass is a quartzose (?) microcrystalline aggregate almost obscured by thick sheaths of sericite (?) which lie parallel to the cleavage. Alteration of phenocrysts is in some cases slight but in others the feldspar is almost totally replaced by calcite growing from the crystal centres in reniform masses with dark rims. The initial phase of this alteration process is seen as the development of tiny calcite rhombs with parallel orientation throughout the feldspar crystals. Many other cases could be described but the complete treatment of the various types of hydrothermal alteration is the subject of another study.

The mineralization with which this metamorphic aureole is associated is of Devonian or Carboniferous age, as the sulphides are later than the Devonian cleavage and locally replace Junee Group rocks, and the remnants of basal Permian beds in the area are relatively undisturbed, have no cleavage and are unmineralized.

Other important areas of hydrothermal alteration apart from West Lyell are concentrated on the N-S line of copper deposits that mark the Great Lyell Fault Zone between Comstock and South Darwin.

Kaolinization of quartz porphyries is described by Bradley (1954, p. 233) near the Hospital at Queenstown and has been noted by the writer both south and north of Queenstown in small irregular zones. The alteration affects the entire rock apart from the quartz crystals and the result is a whitish or greenish clay that is studded with the residual quartz phenocrysts. The process appears to have no relation to mineralization and might in fact be a deuteric effect. It is selective in that if affects some porphyries but not others, yet no differences in environment, either structural or sedimentary, are discernible. Bradley, however, relates the kaolinisation to NE faults which he believes to be major controls over ore deposition.

STRATIGRAPHY

The frequent lithological variations, the difficulties in elucidating structures and lack of fossils have prevented the establishment of a stratigraphic succession for the Group in this area. However, Bradley (1954, p. 221) has suggested the following sequence in the Lynch Creek area (youngest at the top):

	feet.
Lynch Conglomerate	3,000
Battery Volcanics	4,000
Miners Slate	3,000
TOTAL	10,000

The recent field work suggests that this successsion has been measured across an anticline in which the Lynch Conglomerate and the "Miners Slate" occupy opposing limbs of the fold and are thus roughly equivalent (Fig. 3). The mapping has also shown that the lithologies change rapidly along strike and any sequence is therefore of only very local significance; this is at variance with the data on Bradley's maps which show the beds extending north and south of the type section for considerable distances. Part of Bradley's metasomatic hypothesis (1954, p. 224) is based on his belief that he could observe gradational metasomatism of the Lynch Conglomerate and Battery Volcanics along strike from Lynch Creek to Roaring Meg Creek. Actually the beds are not continuously exposed as his maps indicate, due to structural contortions (Fig 3); and in any case I would attribute the rock-type variations to original facies changes.

With regard to the terms Lynch Conglomerate, Battery Volcanics and "Miners Slates" the new structural picture renders suspect the proposed age relationships between these units, and other field evidence shows that whatever relationship may exist is likely to be a really restricted one. The rock types of the Dundas Group in this area, both volcanic and sedimentary, were almost certainly laid down in localized and ephemeral depositional environments and it is doubtful if contemporaneous depositon of any one rock type or particular association of rock types over a wide area ever took place. This being so, it would seem unwise at this stage to assign formational names to individual members of particular sequences that have been measured in this area and it is suggested that Bradley's terms be discarded. The terms he used are also unsatisfactory for other reasons, viz.:—

Lynch Conglomerate: I have been unable to match the description given for this formation with field observations and suspect that a considerable proportion of it is occupied by augite trachyte or trachytic tuff, which Bradley considered to be a conglomerate. This formation has been correlated with the Sorell Conglomerate and the Dora Conglomerate but the former is clearly part of the Jukes Formation and similar remarks probably apply to the Dora Conglomerate. The structural interpretation shown on Fig. 3 suggests the Lynch Conglomerate is equivalent in part to the Miners Slate and also that it is overlain unconformably by the Junee Group, both observations being at variance with Bradley's description.

Battery Volcanics: The age relationships are suspect and the locality name is unfortunate in that the "Battery" (of the King River Gold Mining Co.) is now non-existent and its position is seldom shown on published maps, new or old.

Miners Slates: Again the proposed stratigraphic relationship to the basalts is questionable and again the locality name could be improved; Bradley used the prefix "Miners" under the impression that the slates outcropped on Miners Ridge but as has already been mentioned (p. 44) this feature is due to the presence of a sandstone bed. In Wade and Solomon (1958, pp. 374-375) the terms Lynch siltstones and Miners sandstone (the capital 'S' in the 1958 text is a typographical error) were used as strictly lithological terms but this form of nomenclature is not now considered to be satisfactory, mainly because these terms are so similar to formation names and these carry so many implications. If it is desired to refer to the lithologies described under the terms Battery Volcanics and Miners Slates, and it is often convenient to do so during field work, then such terms as Lynch Creek-type volcanics and Lynch Creek-type slates could be used; similarly Crown Hill-type andesite, Whip Spur-type rhyolite, &c.

THICKNESS OF THE DUNDAS GROUP

The only reliable reasurements available have been made near Little Owen and on Lynch Creek. The former area was mapped in conjunction with work on the Mt. Lyell Mine leases on a scale of 1″ = 100 ft. and the measurements obtained are as follows: —

	feet.
Conglomerates (?), pebbly sandstones and sandstones, probably partly volcanic, outcropping near Little Owen summit	1,000
Greywacke sandstones and tuffs, and augite trachyte (?)	700
Lynch Creek-type slates, exposed along South Owen Creek	300
"Dirty", fine grained sandstone	500
	2,500

The rocks east of the Lynch Creek bridge are relatively undisturbed and they give the following sequence, measurements being by tape and level:—

	feet.
Gordon Limestone	600
Owen Conglomerate (?): Grey-brown quartzite	6
Jukes Conglomerate (?): Grey to purple sheared paraconglomerate with pebbles of porphyry and sediments, and a few of quartz	100-150

	feet.
Dundas Group: Poorly exposed section; mainly finely and regularly banded pale grey shaly sandstone with lenses of paraconglomerate. Also lenticular quartz porphyry lavas, part kaolinised	300
Augite trachyte (?)	250
Basalts, tuffs and breccias	plus 1000

Total of Dundas Group exposed—1550 feet.

While drawing horizontal sections through the area it was found necessary to assume a thickness of at least 4,000 feet for the Group and generally a figure of twice this was used.

Hills (1914) suggests a thickness of 21,000 feet in the Jukes-Darwin area but he points out that the beds may be repeated by folding.

THE DARWIN GRANITE

The Darwin Granite is the only large intrusive body in the area and it is of Cambrian age. Despite Bradley's assertions that it is Devonian, the occurrence of granite pebbles in the Jukes Conglomerate at South Darwin and at Mt. Sorell is clear proof that it is older than the Junee Group. The basal part of the Jukes Formation at South Darwin contains numerous and distinct sub-angular fragments (up to 24 × 30 cm.) of pink granite, white granite and haematitic material, together with smaller pebbles of quartz and chert (Plate 1, Fig. 2). The pebbles and fragments are clearly defined in a matrix of granitic detritus. In the Jukes Conglomerate exposed on the east face of Mt. Sorell the pebbles of granite and haematitic material are fewer in number and smaller in size.

The granite occurs as a vertical tabular body aligned north-south and extending from Mt. Darwin to South Darwin. Its outcrop is roughly three miles long and half a mile wide. The adjacent rocks to south and east contain pebbles of granite and are therefore younger but to the west and north consist of the pink potash rhyolites and tuffs, pre-granite in age.

The granite body is complex, being composed of parallel sheets of differing composition with a predominance of granitic types, chief of which are a pink orthoclase-quartz rock and a white plagioclase-quartz rock.

The *pink granite* (D42) forms a long line of tors on the eastern side of the Mt. Darwin-South Darwin Spur. It is coarse-grained and has a texture that is typically granitic, being not seriate yet not quite equigranular; intercrystal boundaries are commonly sutured. The mineralogy is simple, the only conconstituents being pink orthoclase, colourless quartz and pale green altered plagioclase feldspar and generally the mineralogical composition is orthoclase > quartz > plagioclase. However, in places the quartz content exceeds that of the feldspars and they occur in approximately equal quantity so that these varieties should be termed adamellites.

The orthoclase is fresh and most sections under the microscope show a fine, wispy cleavage; they often exhibit relatively coarse ("vein") perthitic texture, the orthoclase enclosing parallel tongues of plagioclase (albite ?) in which multiple twinning is perpendicular to the length of the tongues. Quartz crystals are finely fractured and show undulose extinction. The plagioclase is considerably altered to chlorite, kaolin and other minerals and its composition is difficult to determine but the few reliable measurements indicate a composition of Ab_{92}. Ferromagnesian minerals are rare and consist of ragged crystals of biotite and chlorite. The two available chemical analyses (Table 2, Nos. 1 and 2) resemble those of potassic granites.

The *white granite* (D40) occurs on the west flank of the pink variety; it is coarse-grained, locally almost pegmatitic, and is composed entirely of equal percentages of altered, cloudy plagioclase feldspar and colourless quartz. Alteration of the feldspar hampers identification but it appears to be oligoclase; its alteration products are whitish in colour in contrast to the greens of the plagioclase in the pink granite. The crystals are loaded with inclusions of quartz, suggesting it crystallized after that mineral. As with the pink granite, sutured crystal boundaries are characteristic. A chemical analysis of a specimen of this granite type, given in Table 2, No. 3, shows a reversal of the K_2O/Na_2O ratio of the pink variety.

Workings for haematite and copper minerals in the granite prove that the alteration of the feldspars in both types extends many feet below the surface, indicating that it is not a weathering effect.

Within the granite complex are thin sheet-like tongues of sedimentary material trending parallel to the length of the granite. Between the pink and white granites is a long zone of schists showing patchy mineralization and in the pink granite occur dark-grey, sharply defined, hornfelsic lenses not unlike Lynch Creek-type slates; Bradley (1954, p. 325) emphasises the alternation of granite and hornfels by giving details of a traverse across the complex.

The outer margins of the granite are unfortunately not now exposed but Hills (1914) states that the "boundary-line between granite and the felsites which it has intruded is sharp and well-defined. This line of contact has been opened up in several places by trenching, and the granite can there be seen in contact with the felsite, being quite as coarse-grained as in the interior of the mass, no transition into finer grained varieties being observable at the margins". Certainly the felsites on the western side of the granite show little alteration that can be ascribed to granite intrusion, unless the unduly heavy haematite-magnetite veining is related to the granite.

A feature of the Darwin Granite is the complete lack of apophyses and aplite or pegmatite veins. This and other points such as the lack of contact matamorphism, complex composition and the tabular shape serve to distinguish it from the massive, irregularly shaped and monotonous stocks and batholiths of Devonian age such as occur at Mt. Heemskirk and Mt. Meredith. The Murchison Granite, which outcrops in the gorge south of Mt. Farrell, is similar in form to the Darwin Granite and even more variable in composition.

Though it has not been studied in detail, sufficient is known to indicate that it too contrasts with the Devonian granites and may well be of Cambrian age.

Bradley (1954) has suggested that the Darwin Granite is a replacement of sedimentary rocks but the evidence he presents, and the evidence since gathered by the writer, is insufficient to provide a conclusion on the mode of emplacement. However, the similarity in composition between the pink Darwin Granite and the potassic rhyolites, and between the white granite and the keratophyres suggests a genetic relationship. It is highly probable that the granites and the lavas represent the intrusive and effusive phases of a single late (?) Cambrian unwelling of acid magma, and that the granite core of the volcanic pile rose up at a late stage to become emplaced among the products of the earlier eruptions.

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TABLE I

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	73.44	73.76	70.60	72.7	72.88	56.80	58.6	61.58	58.08	46.72	47.6	50.6
TiO_2	0.33	0.12	0.40	..	0.37	0.35	n.dt.	0.49	0.42	0.48	..	0.5
Al_2O_3	14.18	11.98	13.31	15.6	13.76	17.11	15.7	16.96	16.32	18.25	17.7	20.3
Fe_2O_3	1.46	1.14	1.54	Fe: 4.2	0.89	2.12	8.9	1.75	2.00	2.38	13.7	10.7
FeO	0.55	2.40	2.36	..	3.44	5.26	n.dt.	2.85	5.53	7.73	n.dt.	n.dt.
Mno	Tr.	..	0.05	..	0.02	0.28	n.dt.	..	0.12	0.07	n.dt.	n.dt.
MgO	0.43	0.76	1.75	0.9	0.94	3.61	3.6	3.67	3.98	7.81	6.55	4.4
CaO	—	0.32	1.68	0.4	0.16	4.20	2.8	6.28	7.32	7.86	8.2	6.6
Na_2O	0.16	0.53	4.44	2.8	2.86	4.47	5.8	3.94	2.16	2.64	2.0	2.3
K_2O	8.05	7.38	2.03	0.8	2.63	2.75	1.8	1.28	1.30	1.32	1.3	1.8
H_2O+	1.38	1.65	1.46	..	2.04	2.58	1.0 (total H_2O of 6, 7)	1.30 (total H_2O of 8, 9)	2.74	0.11	1.5 (total H_2O of 10, 11)	1.9
H_2O-	0.08	0.10	0.06	..	0.06	0.04			Nil	4.43		
P_2O_5	0.10	0.16	0.08	..	0.09	0.35	n.dt.	..	0.18	n.dt.	..	..
CO_2	0.38	—	0.73	..	0.31	0.44	0.7	0.25	0.38	—	0.6	0.4
S	Tr.	0.09	0.07	..	Tr.	Nil	n.dt.	..	Nil	—	—	—
Other Consts.	..	0.09	..	1.2	(Ig. Loss)	..	..	..	..	..	..	..
SO_3	..	..	..	..	..	..	..	..	..	..	1.1	1.0
Total	100.54	100.48	100.56	98.6	100.45	100.36	98.9	100.35	100.53	99.80	100.25	100.5

1. Potash rhyolite, Intercolonial Spur (near Mt. Jukes). Analyst: Tasmanian Mines Department, 1956.
2. Potash rhyolite, Cwm Caregog, Snowdon. Analyst: R. J. C. Fabry as qoted by Williams (1927, p. 368).
3. Quartz keratophyre, West Queen River. Analyst: Tasmanian Mines Department, 1956.
4. Analysis of rock from Lyell-Comstock tram line described by Gregory (1905) as "diabase porphyrite". Analyst: A. S. Wesley (quoted in Gregory, 1905).
5. Sodi-potassic rhyolite,-Lyell Comstock tram line. Analyst: Tasmanian Mines Department, 1956.
6. Keratophyre, Lake Margaret tram line. Analyst: Tasmanian Mines Department, 1956.
7. Augite trachyte (?), near Lynchford. Analyst: Mt. Lyell Co., Assay Office, 1954.
8. Hornblende andesite, Crown Hill. Analyst: Tasmanian Mines Department, 1956.
9. Hornblende andesite, Mount Shasta, California (H. N. Stokes), as quoted in Hatch, Wells, and Wells, 1949, p. 271.
10. Augite basalt from Lynch Creek, South Queenstown. Analyst: B. Scott (Unpublished Ph.D. thesis, University of Tasmania, 1953).
11. Augite basalt from Lynch Creek. Analyst: Mt. Lyell Co., 1956.
12. Basalt near Miners Ridge, east of Lynchford. Analyst: Mt. Lyell Co., 1956.

TABLE 2

	1	2	3
SiO_2	74.96	71.9	76.92
TiO_2	0.13	n.dt.	0.19
Al_2O_3	13.55	14.7	14.07
Fe_2O_3	0.79	3.6	0.43
FeO	0.71	n.dt.	0.64
MnO	0.01	n.dt.	Tr.
MgO	0.48	0.6	0.25
CaO	0.16	0.5	0.16
Na_2O	2.33	1.9	3.24
K_2O	5.57	4.7	2.61
H_2O+	0.86	0.6 (H_2O+ and H_2O- combined)	1.84
H_2O-	0.16		Nil
P_2O_5	0.05	n.dt.	Tr.
CO_2	0.30	0.4	0.06
Total	100.06	98.9	100.41

1. Pink granite, South Darwin. Analyst: Tasmanian Mines Department, 1956.
2. Pink granite, South Darwin. Analyst: Mt. Lyell Company, Assay Office, 1955.
3. White granite, South Darwin. Analyst: Tasmanian Mines Department, 1956.

Plate I.

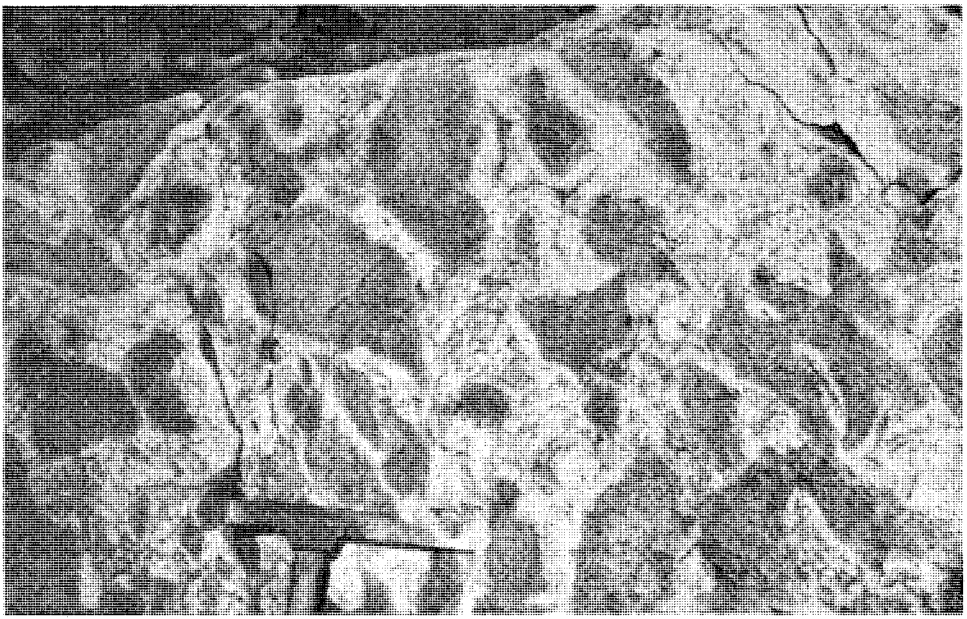

Fig. I.—Albitised hornblende andesite from Crown Hill. The pale grey rock is largely fresh albite, the darker grey is hornblende-feldspar porphyry.

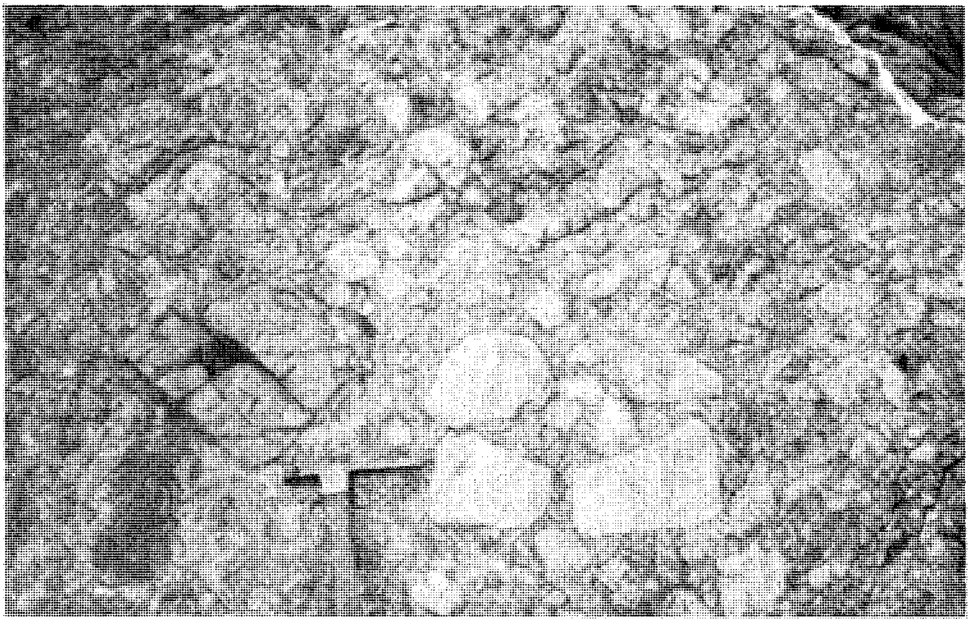

Fig. II.—Jukes Conglomerate, South Darwin Peak. The boulders to the right of the hammer are pink granite; the large one to the left is haematitic schist. The lack of contrast between boulders and the matrix is due to inadequate lighting of the subject at the time of photography.