COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF SUPPLY AND SHIPPING.

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS.

REPORT No. 1948/7.
(Geol. Ser. No. 3).

GEOLOGICAL RECONNAISSANCE OF THE PROPOSED HYDRO-ELECTRIC WORKS IN THE KOSCIUSKO AREA BETWEEN WASTE POINT AND KHANCOBAN.

by

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Geologists.

CANBERRA, A.C.T. JULY, 1948.

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PART I.

SUMMARY OF THE GEOLOGY AND ENGINEERING GEOLOGY.

by

L.C. Noakes.

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I. INTRODUCTION.

The first geological reconnaissance of the proposed diversion of the Snowy River to the Murray Valley was undertaken by the Bureau of Mineral Resources, Geology and Geophysics late in 1946.

This work was followed by more detailed work in the summer of 1947-48 when field parties carried out a reconnaissance of a strip of country covering the approximate route which the main tunnel is expected to follow. The writer was in charge of the investigation in 1946, but, due to illness, was unable to participate in the field work during the summer of 1947-48.

The eastern party, under the leadership of Mr. C.W. Ball, covered the main tunnel line from the proposed intake, near the junction of the Snowy and Thredbo Rivers, west to the Geehi River. This party also carried out a geological investigation of the Spencer's Creek dam site, and made a reconnaissance along the line of the two smaller tunnels between Spencer's Creek and the Snowy River.

The western party, led by Mr. W.B. Dallwitz, carried out a reconnaissance along the tunnel line from Khancoban to the Geehi River.

Most of the country covered by these parties is rugged and relatively inaccessible, but traverses have now been made along the greater part of the main tunnel line. Both parties extended their traverses into the Geehi Valley, but unfortunately, owing to bad weather, neither party reached the Geehi River itself. The geology of this critical section across the Geehi River had therefore to be interpreted from air photographs. Aerial photography has also been used to extend the geological boundaries determined in the field.

Part I of this report deals briefly with the geological work accomplished during the two field seasons and provides a summary of the engineering geology of the main and subsidiary tunnel lines. Parts II and III consist of the geological reports by the leaders of the two field parties. Mr. Ball left the Bureau for an oversea appointment in February, 1948, and the brevity of his report (Part II) is due to the lack of time before his departure.

II. PREVIOUS GEOLOGICAL WORK.

The results of the previous geological reconnaissance by the Bureau of Mineral Resources, Geology and Geophysics, are contained in a "Preliminary Report on the Proposed Hydro-Electric Works in the Kosciusko Area" by L.C. Noakes (1946). This report was included in the folio of Technical Reports on the Snowy River Diversion to the Murray River Valley issued by the Department of Works and Housing in 1947.

Some amendments and corrections can now be made to the earlier geological work, but, in general, the conclusions reached in regard to engineering geology have been confirmed by the later field work.

The principal amendments to the earlier work are as follows:-

(1) The geological boundaries west of the Geehi River, which were based on aerial photography, needed

correction, so that the proportion of metamorphics and granitic rocks outcropping along the main tunnel line has been amended. Previous figures indicated that the proposed main tunnel would traverse granite and gneissic granite for 25 miles and metamorphic rocks for 4 miles, in a total distance of 29 miles. The amended figures show that the tunnel should traverse granitic rocks for $21\frac{3}{4}$ miles, schistose metamorphics for $3\frac{1}{2}$ miles, and unsheared metamorphics for $2\frac{3}{4}$ miles in a total distance of 28 miles.

(ii) The suggested location of faults in the Bogong and Geehi Valleys has been amended.

(iii) A re-interpretation of the geology of the Geehi Valley, in the vicinity of the proposed tunnel line, has been made from the aerial photographs.

(iv) The narrow belt of metamorphics trending north-east from Mount Kosciusko, which appeared to lens out south of the tunnel line, has been traced to the north across the line of the tunnel.

(v) Additional faults have been mapped, both from the field work and from the aerial photographs, particularly in the vicinity of the Main Divide and at the eastern end of the main tunnel line.

III. GENERAL GEOLOGY.

a. Waste Point to Geehi River (See Plate 1).

The work of C.W. Ball and party confirms that the main tunnel line east of the Geehi River, and the subsidiary tunnel lines in the Kosciusko area, lie, for the most part, in medium to coarse-grained granite and gneissic granite.

No major variations in the composition of these rocks have been noted along the tunnel lines. In many places they contain xenoliths or inclusions, and dykes of aplite and hornblende porphyrite are common, particularly along the main tunnel line east of Island Bend. The granite has been well jointed, and in most places shows some degree of gneissic structure, particularly to the west of the Snowy in the vicinity of the Main Divide.

The western limit of the granite is marked by a narrow belt of metamorphics about $\frac{1}{2}$ to $\frac{3}{4}$ of a mile wide, which runs north-east from Mount Kosciusko and crosses the main tunnel line mid-way between the Main Divide and the Geehi River. In this locality the belt of metamorphics is $\frac{1}{4}$ mile wide, and consists of phyllite and schists with vertical schistosity.

West of the metamorphics is a belt of acid gneiss which appears to be older than the granite and gneissic granite to the east. The relationship of the gneiss to the metamorphics outcropping along the western side of the Geehi Valley is not certain, but the air photographs suggest that a major normal fault parallels the Geehi River on the eastern side, and marks the contact between the gneiss to the east and the metamorphics on the west. According to this interpretation, the Geehi River, in the vicinity of the tunnel line, would lie in metamorphics on the down-throw side of the fault.

b. <u>Geehi River to Swampy Plain River (See Plate 2).</u>

The metamorphics mapped by W.B. Dallwitz and party on the western side of the Geehi River, consist of phyllite and schists, and seem comparable in grade of metamorphism to the schists and phyllite found in the narrow belt of metamorphics east of the river.

West of the Geehi River, low-grade schists and phyllite form a belt, approximately 2½ miles wide, which trends in a north-easterly direction. The rocks consist of a variety of low-grade schists, phyllite, some hornfels and sheared tuff. Small bodies of sheared prophyry are found in the metamorphics, and unsheared lamprophyre, probably in dyke form, has been introduced after the host-rock was sheared. The internal structures of the metamorphics are not known, but they have been jointed and sheared with schistosity striking about north-east and dipping north-west at 60 to 65 degrees.

Near the eastern edge of the Grey Mare Range, the schists give way to granitic rocks which outcrop for about 2¼ miles to the west, into the Bogong Valley and almost to the Creek itself. The eastern boundary of the igneous rock runs in a north-easterly direction and is marked by a narrow contact zone in which the metamorphics have been silicified.

W.B. Dallwitz suggests that these granitic rocks may be divided into at least two groups - a body of acid granodiorite (Trondhjemite) outcropping along the Grey Mare Range, and an admixture of granodiorite, adamellite and granite west of the Grey Mare Range. Between the two, lies a zone of xenoliths - quartzite and schist - up to ½ a mile or more wide which outcrops along the western side of the Range. In general, these granitic rocks are not gneissic, although some gneissic foliation appears in the eastern portion of the composite mass.

About ½ a mile east of the Bogong River, in the vicinity of the tunnel line, the granitic rocks give way to metamorphics which outcrop for about 3 miles to the west, across the Bogong Valley and over Scammel's Spur.

In the Bogong Valley, north and south of the tunnel line, these metamorphics are probably faulted against the granitic rocks to the east by major normal faults. The trend of these faults across the line of the tunnel is not plain in the air photographs and it is not certain whether the contact crossed by the tunnel ½ a mile east of the Bogong Creek is a fault or not.

The metamorphics are unsheared and consist of low-grade hornfels, impure quartzite and silicified shale. Small outcrops of phyllite, acid tuff and agglomerate have been noted. The hornfels and quartzite are strongly jointed and appear hard, massive rocks below the zone of weathering. The silicified shale is also jointed but tends to part along the bedding planes as well. The internal structures of the metamorphics are not known, but field evidence indicates that they have been folded.

About ½ a mile west of Scammel's Spur, along the tunnel line, is the contact between these metamorphics and the Khancoban granodiorite. The contact trends in a northerly direction and follows the western slope of The Razorback.

West of this contact, the tunnel line is mainly in granodiorite - unsheared, jointed and similar, from an engineering point of view, to the granite of the Kosciusko block. Dykes of porphyry, lamprophyre and dolerite intrude the granodiorite in the vicinity of the tunnel line and altered porphyry and rhyolite, found near Khancoban, probably represent a large inclusion.

c. Age of the Rocks.

The schistose metamorphics found in the Geehi Valley and in the narrow belt to the east of the Geehi, are probably Ordovician, but the unsheared metamorphics found in the Bogong Valley are younger and may be Silurian in age.

The granite and gneissic granite found on the Kosciusko Plateau are part of the Berridale batholith of late Devonian age. The Khancoban granodiorite and the granitic rocks between the Bogong and Geehi Rivers are probably contemporaneous with the Berridale granite, but the gneiss outcropping on the eastern side of the Geehi Valley may be older.

IV. STRUCTURAL GEOLOGY (See Plate 3).

The major structural features in the area consist of block faulting and warping which took place about the end of the Tertiary era. An old land surface was uplifted slowly but unevenly, to give rise to the present relief of the Kosciusko area. The broad structure of the uplift seems reasonably clear, as remnants of the older land surface can be traced from the Berridale area westward over the Kosciusko plateau and down into the Murray Valley, but many of the details of the structure, as it affects the geology of the main tunnel line, cannot be elucidated without close geological mapping. It is suggested, at this stage of the investigation, that the major structural features along the main tunnel line, from east to west, are:-

(i) A meridional warp-zone, with step faults dipping east, for some 3 miles west of the intake of the tunnel.

(ii) A major block fault along the upper Snowy Valley, which, with similar block faults trending north-east along the Thredbo Valley and along the valleys followed by the Kosciusko Road above the Hotel, complicates the structure of the Kosciusko block.

(iii) Minor step faults dipping east in the vicinity of the Main Divide.

(iv) A major fault zone along the Geehi Valley with major displacements to the west.

(v) Similar normal faults along the Bogong Valley with displacements to the west.

The significance of these structures, from the view point of the engineer, is apparent, as tension faults are likely to provide channels for ground water and may be accompanied by a zone of shattered rock.

Although reconnaissance has indicated the probable position of some of these major and minor faults, the tracing of the fault pattern in detail is beyond the scope of reconnaissance.

The exact position of faults is difficult to determine on both sides of the divide. On the rugged western side, where the structure should be relatively easy to follow, the outcrops are obscured by scree and undergrowth, and on the eastern side the country consists mainly of granite, so that these major faults are not represented by a change of rock type or structure across the fault zone. Moreover, most of these normal faults will be found along valleys but, in many of the valleys on the Kosciusko plateau, outcrops along the valley floor are masked by fluvo-glacial material. However, the structural pattern can be worked out by detailed investigations along the tunnel line, together with geological and physiographical mapping on a regional basis.

Pre-Tertiary structures will be found in the metamorphics outcropping in the Geehi and Bogong Valleys, but the pattern of folding and faulting in these rocks can only be worked out by detailed mapping.

V. ENGINEERING GEOLOGY.

a. General.

The proposed tunnels from the Jindabyne storage west to Swampy Plain River will be approximately 28 miles long. Approximately 21¾ miles will traverse igneous rocks, which are mainly granitic, 3½ miles will traverse schistose metamorphic rocks and the remaining 2¾ miles will lie in unsheared metamorphics. The principal problems in the engineering geology are considered to be:-

(i) Driving and maintaining the tunnel in weak or shattered rocks.

(ii) Controlling or handling the inflow of water during construction.

(iii) Preventing leakage of water from certain sections of the tunnel when in operation.

(iv) Precaution against damage to works and tunnel by seismic activity.

These problems are, to a large extent, interdependent and will only be encountered over certain sections of the tunnel line, depending on the type or rock, the type and extent of fracturing in the rock, the rainfall, and the position of the tunnel relative to the surface and the water table. There is little possibility, within metamorphics, of the occurrence of permeable beds which could function as aquifers, so that rock fractures will provide the only significant source of ground water.

The first three problems may involve grouting, lining or other permanent support. The evidence collected on the fourth problem is, as yet, not conclusive. Apparently no earth-tremors have been noticed by the inhabitants on either side of the main divide and, although the area is sparsely populated, this indicates that seismic activity, at least during the last forty years, has been very small. On the other hand, a map produced by the Commonwealth Meteorologist about 1910 (Griffith and Taylor, 1910), shows a number of epicentres in a meridional belt extending from about Island Bend, on the Upper Snowy, east to Berridale. The location of these epicentres cannot be regarded as accurate, but some degree of seismic activity could be expected in the Kosciusko area. All that can be said at this stage of the investigation, is that there is no evidence of significant seismic activity in the immediate past, but an investigation of seismic activity should be made if detailed work on the hydro-electric project is undertaken.

Sections of the main tunnel line in which difficulties may be expected are:-

(i) Where the tunnel lies in the zone of surface weathering above the water table, it will probably need permanent support. The possibility of significant loss of water from the tunnel, when in operation is limited to such sections and to the pressure tunnels leading into the power stations. In these sections, lining may have to be used as a permanent support and as a conduit for the water.

(ii) In the immediate vicinity of major fault zones, support may be necessary and inflow of water is likely to increase.

(iii) Where the tunnel traverses rock which lies below, but close to the water table, the inflow of water from joints and fracture planes is likely to reach a maximum. Such sections together with the major fault zones should constitute the wettest parts of the tunnel.

(iv) In sections of the tunnel which have backs of 2,000 feet or more, rock temperatures will be high and ventilation problems will become greater. It is impossible to estimate rock temperatures in the deeper parts of the tunnel, and there are no mine workings in the area from which data on temperature gradients could be obtained. The section of the tunnel with backs of more than 2,500 feet, lies entirely in granite, and there is no evidence to suggest abnormal conditions such as thermal waters, which could produce unusually high rock temperatures and a temperature gradient less than 100 feet per degree Fahrenheit.

It is interesting to note that the temperature gradients in at least three tunnels in the European Alps - Simplon, St. Gothard and Mont Cenis - were abnormal, and ranged from 72 feet to 84.7 feet per degree Fahrenheit, (Peele 1944). This was apparently due to the presence of thermal waters, which were encountered in driving the tunnels.

b. Main Tunnel.

1. Waste Point to Geehi River.

From the intake at the eastern end, the tunnel will lie in granitic rocks for about 16 miles to the Geehi Valley. The granitic rocks are well jointed and show a varying degree of gneissic structure which, however, strikes approximately at right angles to the direction of the tunnel. Dykes of aplite and porphyrite and quartz veins are found in the granite, but their contacts appear to be silicified or "frozen", so that, below the water table, these dykes should not cause trouble. However, these dykes should be mapped in detail as some of them may be accompanied by narrow fracture zones which would act as channels for ground water. Xenoliths or inclusions in the granite are common in surface outcrops, but at the depth of the tunnel, few inclusions are expected.

The salient features of the engineering geology in this section are as follows; (See Plate 3):-

1. From the intake the tunnel will lie in the zone of weathering for $\frac{1}{4}$ to $\frac{1}{2}$ a mile and the remainder

of the tunnel, from the intake to the Bogong Valley, will lie below the water table.

2. The tunnel will traverse a warp-zone with faults for, perhaps, 3 to 4 miles from the intake. The worst conditions for inflow of water and for shattered rock are likely to be met in the first two miles.

3. Beyond this point, for nearly 13 miles, the tunnel will lie at least 1,000 feet below the water table and very little permanent support should be necessary. Seepage from joints is to be expected, but fault zones are the only likely source of significant supplies of water. It is probable that even major fault zones will not produce much water at depths of over 1,500 feet, but it would be wise to expect at least an initial flow.

4. As it may not be possible, in some cases, to project faults accurately from the surface to the line of the tunnel at depth, exploratory holes may have to be drilled from the tunnels, ahead of construction, as a precaution against breaking into fault zones with a considerable initial flow of water.

5. The tunnel will probably intersect a major fault 1,000 feet below the Snowy Valley at Island Bend, and at least an initial flow of water is to be expected.

6. At present, no estimate can be made of the quantity of ground water likely to be picked up in any section of the tunnel, but as soon as sections of the main or subsidiary tunnels are driven, it will be possible to collect data on water flow as a basis for predicting water conditions in the deeper portions of the tunnel.

7. High rock temperatures will prevail for at least 3 miles along the tunnel below the Main Divide. There is no evidence that these temperatures will be unusually high and the temperature gradient should not be less than 100 feet per degree Fahrenheit.

8. The tunnel will probably cut through a belt of schist and phyllite about 1.7 miles east of the Geehi River. The width of the belt at the level of the tunnel is not known, and may be more than the quarter of a mile found on the surface. At this point, the tunnel is approximately 2,500 feet below the surface and no support should be needed, particularly as the tunnel will lie at a high angle to the schistosity. Occurrences of rock burst or "kicking rock" are possible in this section, but the danger will be at the headings not along the walls of the tunnel. The nature of the contacts either side of the metamorphic belt is not known, but little trouble need be expected at this depth. West of the schist, the tunnel will traverse acid gneiss and will lie at a high angle to the gneissic foliation. At a depth of more than 2,000 feet, the gneiss should hold satisfactorily and produce little ground water.

9. The tunnel will probably strike a major fault zone about ½ to ¾ of a mile east of the Geehi River. If this is the true position of the main fault zone,

the tunnel will have nearly 2,000 feet of backs and the zone should be crossed with less trouble from shattered rock and water inflow than if it had been encountered nearer the surface. However, the fault zone may be very wide, with a number of sub-parallel fault planes as the surface exposure suggest, and it would be wise to expect serious difficulties in this section of the tunnel.

10. West of the fault zone, schist and phyllite will be encountered. The tunnel will pass about 350 feet below the Geehi River and this is likely to be the wettest section in the main tunnel. Fortunately, the tunnel will lie at a high angle to the schistosity, but at this stage, it would be wise to anticipate the need for permanent support and increased water flow at least within 500 feet of the water table.

11. Detailed geological mapping of the Geehi Valley will be required before the best route for the tunnel can be decided.

2. Geehi River to Swampy Plain River.

The salient features of the engineering geology of the main tunnel line west of the Geehi are as follows:-

1. West of the Geehi River the tunnel will lie in schists and phyllite for about 2½ miles. Permanent support may be necessary for the first ½ mile, but the remainder of this section is expected to stand well.

Water inflow is expected to be greatest in the first ½ mile, and ground water may increase again about 1½ miles west of the Geehi. These sections, in which inflow of ground water is likely to be significant, aggregate about a mile, and the remaining 1½ miles should be relatively dry. Rock bursts could occur in headings in this section, but it is not likely to be a constant feature.

2. Two and a half miles from the Geehi River the tunnel enters granitic rock and, for 1¾ miles to the vicinity of the Bogong surge tank, construction should be straight-forward. The surge tank and pressure incline will lie in massive rocks, but the flow of ground water will have increased. It may be necessary to line the pressure incline and particularly the pressure tunnel leading into the Bogong Power Station. Detailed geological mapping of faults and rock types in the Bogong Valley will have an important bearing on the final location of the tunnel and power station.

3. West of the Bogong Creek, the tunnel will traverse unsheared but folded metamorphics - mainly hornfels, quartzite and silicified shale - for about 2½ miles. A significant flow of ground water may be expected for the first ½ mile, but, farther west, water problems should be limited to possible faults within the formation. Permanent support will be required for a short section at the intake end, but most of the tunnel should stand satisfactorily. Detailed geological work is required to indicate the best route for the tunnel and to provide an estimate

of the length of the tunnel in which support will be nedessary.

4. The tunnel should enter the Khancoban granodiorite approximately $2\frac{1}{4}$ miles from Bogong Creek and tunnelling should be straight-forward with little water and no need for support for about a mile. The flow of ground water will gradually increase over the next section, of nearly $\frac{3}{4}$ of a mile, to the provisional surge tank. Permanent support should not be necessary except, perhaps, at the surge tank itself.

5. The provisional layout of the tunnel shows a pressure incline for $\frac{1}{2}$ a mile west of the surge tank. The flow of ground water will decrease with depth and the incline should need no support. However, lining may be necessary to conserve water.

6. West of the incline the tunnel will be a pressure tunnel until the Khancoban power house is reached. There should be no problems in driving this section of the tunnel and little support should be required for about $1\frac{3}{4}$ miles, until the tunnel approaches to within 100 feet of the surface, about $1\frac{1}{2}$ miles east of Swampy Plain River. However, at least the greater part of the tunnel east of the eventual power house will have to be lined to prevent the escape of water. It may be possible to change the layout and the route of the western end of the main tunnel to decrease the length of pressure tunnel leading into the power station, and hence decrease the length of tunnel in which lining would be required.

c. Snowy River Auxiliary Power Scheme.

This scheme involves three dams, approximately 9 miles of tunnel and between 50 to 60 miles of water race to be constructed mainly within the water shed of the Snowy River above its confluence with the Eucumbene. With the exception of some miles of water race, all of these works will lie in granite within the Kosciusko block.

The recent geological work by C.W. Ball and party was limited to the Spencer's Creek Dam Site and the two tunnel lines, but notes on the race lines and other dam sites were included in the report of the first geological reconnaissance in 1946 (Noakes, 1946).

1. Spencer's Creek Dam Site.

A plane table survey has been made of that portion of Spencer's Creek in which a dam site is required, (see Plate 4).

The Creek flows in a "U"-shaped glaciated valley in which the floor and lower slopes consist of fluvo-glacial material with very few outcrops of the granitic basement.

The granitic bedrock should provide suitable foundations for a dam, but the broad cross-section of the valley and the depth of the fluvo-glacial material are costly disadvantages. One possible site near the Kosciusko Road has been drilled, and although detailed results are not to hand, it is understood that bedrock was recorded in several drill holes nearly 100 feet below stream level in the floor of the valley. The depth of fluvo-glacial material on the floor of the valley should decrease downstream and it is recommended that holes should be drilled at intervals down the valley to test for a more economical site.

2. Tunnels.

(a). Spencer's Creek Tunnel.

A tunnel is to be constructed from the main storage at Spencer's Creek for approximately 5 miles to the valley of Piper's Creek where a power station will be installed. The tunnel will lie in jointed coarse-grained granite and gneissic granite in which dykes of aplite, veins of quartz and inclusions of metamorphic rocks will probably be encountered.

There is no evidence to suggest the presence of major faults along the tunnel line, but minor faults will probably be found in detailed mapping. The tunnel will be driven approximately parallel with the gneissic structure in the granite. This could lead to a higher percentage of overbreak in driving and the need for more support in the shallower sections of the tunnel, but, in general, the gneissic structure, which has not been strong enough to influence topographical development, is likely to have little effect on tunnelling operations.

The proposed tunnel will have backs ranging from 200-900 feet, and there should be very little need for support except across possible faults, and in the intake and outlet sections. On the provisional route, shown on Plate 1, the tunnel will lie below the water table for most of the distance, but the quantity of water encountered during construction should be readily handled.

(b). Piper's Creek Tunnel.

A second tunnel about 5½ miles long is proposed from the Snowy near Piper's Creek to Digger's Creek. The tunnel will lie entirely in granite and gneissic granite and from an engineering point of view should be very similar to the Spencer's Creek tunnel. No faults have so far been located along the line of the tunnel, but some minor fractures are to be expected. For the greater part of the distance, the tunnel will have backs of about 800 feet, and, therefore, support should be necessary only at the intake and outlet sections.

This tunnel should be similar to the No. 3 tunnel at the Kiewa Hydro-Electric Project in Victoria as regards rock formations, rainfall and depth below the surface. It is interesting to note that, at Kiewa, ground water entering the mile-long No. 3 tunnel was handled by two Worthington pumps with a three inch delivery.

VI. FUTURE GEOLOGICAL INVESTIGATION.

The geological reconnaissance of the proposed hydro-electric works in the Kosciusko Area is almost complete. The geology of the Geehi Valley has yet to be checked in the field, field work is required along the race lines, and a proposed dam site in the vicinity of Island Bend, on the Snowy River, has yet to be inspected, but none of these investigations is of vital importance.

If the plans to divert the Snowy River to the Murray Valley are to be implemented, detailed geological investigations will be required, and the following recommendations are submitted with regards to the course which these investigations should follow:-

(i) Detailed geological mapping on a scale of 500 feet to the inch should be carried out along all tunnel and race lines.

(ii) A regional investigation of topography, geology, geomorphology and limits of glaciation should be undertaken and maps compiled on a scale of 2 inches to the mile. All of this information will be essential to enable the geologist to interpret correctly the results of the detailed mapping.

(iii) The sites of surface works such as dams, weirs, power stations, etc., should be mapped in detail on a scale of 50 or 100 feet to the inch.

(iv) Engineering geology maps on a scale of 1 or 2 inches to the mile should also be compiled to cover those areas from which supplies of rock material may be drawn for engineering construction.

(v) Geological investigation should also include inspection of all tunnelling or hydro-electric works in process of construction in Australia. Special attention should be paid to the Kiewa Hydro-Electric Project in Victoria where the general geology shows marked similarity to that of the Kosciusko area. Inspections should also be made of mines in selected mining areas, particularly in the eastern portions of New South Wales and Victoria, where metamorphic rocks, similar to those found in the Kosciusko area may be inspected at various levels in underground workings.

CANBERRA, A.C.T.
July, 1948.

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Geologist.

PART II.

GEOLOGICAL RECONNAISSANCE FROM WASTE POINT TO THE GEEHI RIVER.

by

C.W. Ball.

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I. SUMMARY.

1. Twenty-four miles of the proposed tunnel lines were examined and this included sixteen miles of the main tunnel line. Field evidence suggests two possible faults, one near the main tunnel entrance at Waste Point, and the other approximately half a mile west of Windy Creek.

2. Faults have previously been inferred (Noakes, 1946), along the valley of the Thredbo and Snowy Rivers and also along the line of cols extending from the Chalet to Hotel Kosciusko. Lining of tunnel walls will probably be necessary in the vicinity of any faults which may be encountered.

3. The subsidiary tunnels and all of the main tunnels to within 2 miles of the Geehi River will be driven in granite or gneissic granite containing xenoliths and igneous dykes.

In general, the joints in the granitic and gneissic rocks especially should be fairly tight and the rocks will ensure hard driving and need little support.

4. The exact nature of the contact between the granitic gneiss and schists in the Geehi Valley could not be determined owing to the surface weathering of the schists. However, it is quite likely that the steeply dipping band of schists will extend down to the level of the tunnel.

II. INTRODUCTION.

This report sets out the results of reconnaissances of the proposed hydro-electric tunnel line from Waste Point on the Snowy River just above its junction with the Thredbo River, to the Geehi River, and of the proposed subsidiary tunnel lines from Spencer's Creek and Piper's Creek to the Snowy River; and also of a contour survey of the Spencer's Creek dam site.

The field work was carried out from 18th December, 1947, to 18th January, 1948, by the writer with the assistance of four University Geology students, Messrs. J. Baird, J.N. Casey, F.G. Carroll and E.K. Carter. Field traverses are plotted on Plate 1, which shows the directions of jointing and foliations in the granitic and gneissic rocks. Plate 1 is based on preliminary contoured maps produced by the Survey Directorate, Department of the Army. However, contour maps are not yet assembled east of Island Bend, on the Snowy River, and Plate 1 has been completed from the aerial photographs.

III. GENERAL GEOLOGY.

Granitic and gneissic rocks are the prevailing rock types in the area surveyed. The grainsize, texture and gneissic structure of the rocks vary considerably from place to place. Intrusions of aplite and hornblende porphyrite and rarely lamprophyre were seen in the field. They are particularly abundant in the portion of the tunnel line near Waste Point. Xenoliths, or inclusions of foreign rock, are common in the granite and gneissic rocks. Some of the xenoliths consist almost entirely of biotite, others consist of fine-grained dioritic rock, felspar, porphyry and banded quartzite. The xenoliths are commonly drawn out into a lenticular shape and as such tend to be orientated parallel to the foliation of the granitic and gneissic rocks. Generally the xenoliths are about 6 inches in diameter, but in many cases they are 3 feet or more across.

To date no thin-sections have been prepared for petrological study, but 81 specimens of typical rock types have been collected and labelled for future reference.

a. Faulting.

Two possible fault zones were found in the field viz. the fault zone associated with aplite breccia in sub-division A-B of the Waste Point-Island Bend section, (see Plate 1) and the fault which intersects the Island Bend-Geehi River tunnel line less than ½ mile west of Windy Creek. Field evidence, so far, does not indicate any other faults in the vicinity of the tunnel lines, but it is possible that a fault along the Upper Snowy River and one along Windy and Guthega Creeks, may exist. Their possible occurrence has been inferred from air photographs and from physiographic evidence. Other probable faults, determined from aerial photographs are shown on Plate 1. Three of these lie within three miles of the eastern end of the tunnel line and the remaining two crossing the tunnel line on the main divide about one mile east of Windy Creek. The direction of Digger's Creek has, in all probability, been controlled by joint planes and no fault could be detected in the field.

No evidence of faulting on the line from Bett's Camp to Hotel Kosciusko was obtained. Nevertheless it is possible that faulting may have occurred along this line which is parallel to the inferred Thredbo fault.

b. Joint Planes.

Extreme care has been taken in recording wherever possible observations of strike and dip of joint planes. The majority of these have been plotted on Plate 1. The joint planes have exercised a very strong influence on the drainage pattern of streams in the area of the elevated Kosciusko area. It is considered that joint planes have exercised a controlling influence on the directions of Spencer's Creek, Farm Creek, Perisher Creek and Digger's Creek. A graph has been prepared (see Plate 5), to show the most prevalent directions of jointing.

Flat jointing was also almost universally present, but has not generally been specially recorded.

IV. DETAILED GEOLOGY.

a. Tunnel Line from Waste Point to Island Bend.

This section of the tunnel line was examined very closely from 17th December to 22nd December. Field evidence, strongly indicative of faulting near the tunnel entrance, is described below, but no other faults were encountered. It is suggested that the line of Differ's Creek from Hotel Kosciusko to the Snowy River may have been the result of the Creek following joint planes, and no field evidence was found to suggest a fault.

Field study of the texture and structure of the granitic rocks indicated a progressive increase in metamorphic effects westerly along the tunnel line.

DIAGRAM SHOWING

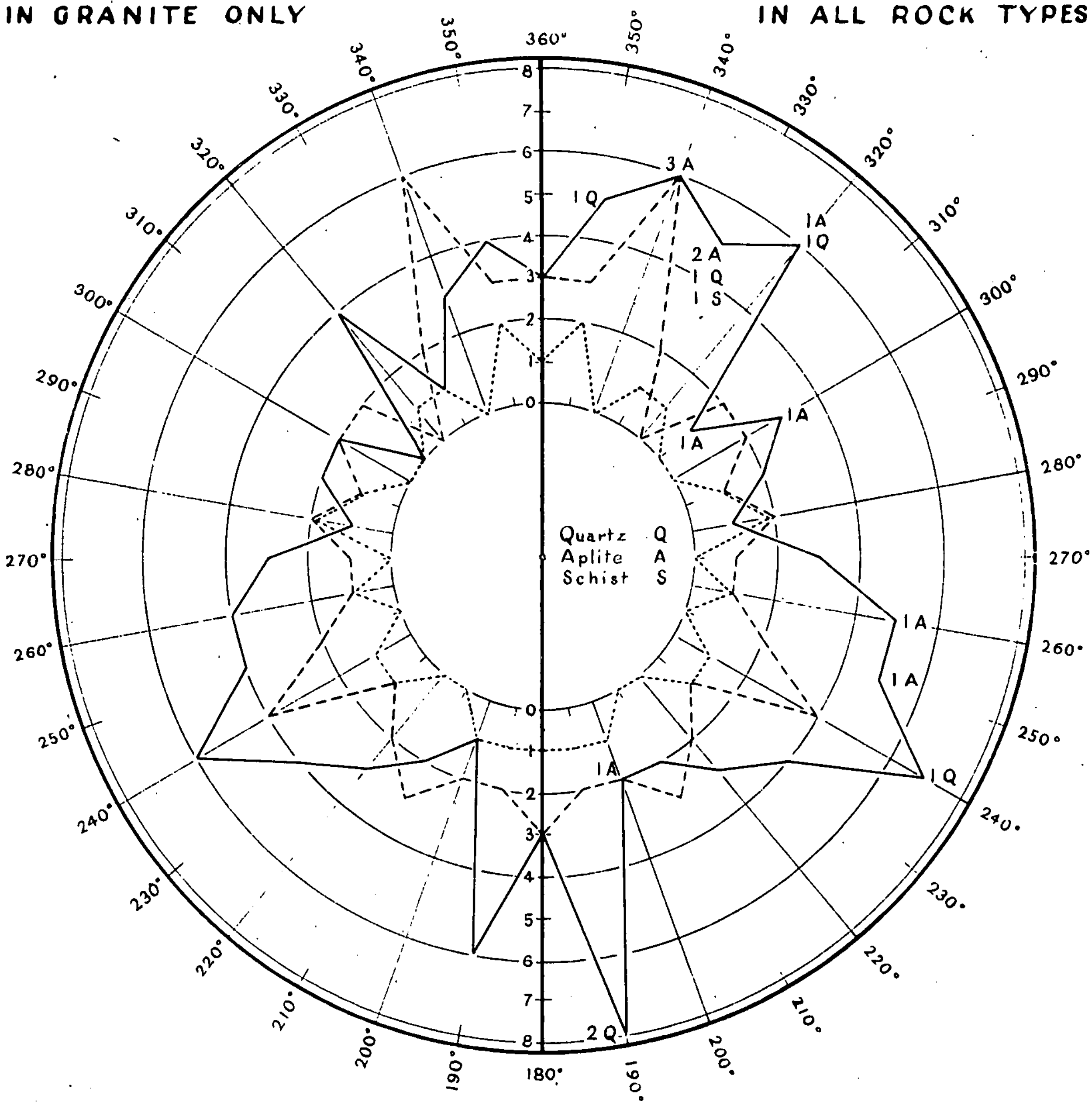
STRIKES OF JOINTS

IN THE

KOSCIUSKO AREA

STRIKES OF JOINTS IN GRANITE ONLY

STRIKES OF JOINTS IN ALL ROCK TYPES



Bearings are true and to nearest 10°

Jointing in Rocks from Waste Point to Island Bend ————

Jointing in Rocks on Spencer's - Perisher Cks & Piper's - Digger's Cks Tunnel Lines ------

Jointing in Rocks on Island Bend - Geehi River Section ....

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS
JULY 1948

N42/5
W.T.C.

Granitic rocks preponderate throughout the tunnel line, but in sub-division A-B of the Waste Point-Island Bend Section, aplite and hornblende porphyrite dykes (in many cases of considerable dimensions), are conspicuous.

In view of the possible fault and the large number of dykes of aplite and hornblende porphyrite in the first mile of the proposed tunnel line from Waste Point with shallow cover, it would be advisable to have a detailed geological map of this portion on a scale of, say, 100 feet to 1 inch.

For convenience in describing the general geology, the section of tunnel line from Waste Point to Island Bend has been divided into three sub-divisions, A-B, B-C and C-D.

1. Sub-Division A-B.

This sub-division of the tunnel line traverses coarse-grained biotite granite which is intruded by dykes of aplite and hornblende porphyrite. Several of the spurs in the eastern portion have cores of aplite which has commonly proved to be more resistant to weathering than the granite.

Granite outcrops at the proposed tunnel entrance which is at an elevation of approximately 2,975 feet above sea level.

Two large outcrops of brecciated aplite were located. The first of these is 15 feet wide. It was traced over a length of more than 200 feet. As it lies within a large mass of aplite which is 180 feet wide, it is highly possible that the brecciation has been caused by large-scale faulting movements. The strike of the breccia zone is 30 degrees*.

Approximately 1 mile to the west of the faul zone a well defined gully runs parallel to the fault zone. On physiographic grounds an inferred fault is postulated along the gully (see Plate 1).

The granite is strongly jointed, the principal joints observed being as follows:-

Strike of Joint.	85°	115°	2°	63°	120°	40°	150°
Dip of Joint	85°N	Vert.	85°W	75°N	23°	85°NW	70°SW

Strikes and dips of aplite dykes have been noted as follows:-

Strike	155°	18°	65°	100°	30°
Dip	-	85°E	85°N	80°S	-

* Throughout the report all strikes of joints, gneissic structure, faults, etc., are given as magnetic bearings.

2. Sub-Division B-C.

Coarse biotite granite, foliated biotite granite and gneiss predominate along the tunnel line in this sub-division, but north of the tunnel line a minor area of mica schist and phyllite was noted (see Plate 1). A few small outcrops were observed over a width of 90 feet. The schistosity had a strike of 90 degrees and a dip to the south of 75 degrees. The field relationships of the schist and phyllite with respect to the adjacent gneiss and aplite could not be determined.

Joint planes observed in the granitic rocks have the following strikes and dips:-

Strike	135°	45°	103°	5°
Dip	65°SW	74°NW	Vert.	71°W

Flat joints were also observed.

3. Sub-Division C-D.

In this, the most westerly sub-division of the Waste Point-Island Bend section, gneissic granite and gneiss are the principal rock types. However, for half a mile east of Island Bend, fine to medium-grained biotite granite is found.

Hornblende porphyrite and aplite dykes are shown on Plate 1. These strike diagonally across the tunnel line. Some of the aplitic dykes have been affected by the dynamo-metamorphism which produced the gneissic structure, and such aplites have suffered fairly intense shearing.

Xenoliths are fairly common in the gneissic granite and consist of angular and lenticular fragments composed almost entirely of biotite, biotite-felspar rock and, rarely, banded quartzite.

Strikes and dips of joint planes in the granitic and gneissic rocks have been noted as follows:

Strike	43°	155°	130°	50°	53°	15°	70°	166°	68°	167°	160°	37°
Dip	Steep	Steep	Steep	-	70°W	-	80°N	Vert	-	12°W	Vert.	Vert

Strikes of gneissic foliation were observed as follows:-

Strike	14°	35°	2°	20°
Dip	-	-	73°E	-

b. Tunnel Line from Island Bend to Geehi River.

With field headquarters established at White's River Hut on the Munyang River, the party was able to cover this section of the tunnel line on horseback on 18th and 19th January. Two parties operated with Messrs. V. Russell and H. Mansfield of Adaminaby as guides.

The contour map (Plate 1) indicates the rugged nature of the country traversed. Access was further hampered by boggy ground due to the recent melting of snow.

East of Windy Creek granitic rocks preponderate. However, to the west of Windy Creek metamorphic rocks such as schists, phyllite and quartzites, constitute a large proportion of the surface outcrops. The geology of the tunnel line will, therefore, be discussed with reference to traverses east and west of Windy Creek.

1. <u>Section of Tunnel Line East of Windy Creek</u>.

The granite is for the most part coarse-grained and is generally strongly gneissic.

Joints observed in the field are plotted on Plate I and are tabulated below.

Joints	Strike	105°	0°	55°	15°	70°	140°	160°	171°	92°	158°
	Dip	-	Vert	60°S	Vert	-	-	57°W	52°W	86°N	84°E

The strike and dip of foliation in the gneissic granite is indicated in the following table:-

Strike of foliation of gneissic granite	20°	16°	7°	177°	12°
Dip " "	-	Vert	67°E	-	-

On the eastern slopes of Disappointment Spur gneiss has been observed. This would appear to be collinear with the zone of strongly gneissic granite occurring at the junction of Piper's Creek and the Snowy River.

2. <u>Section of Tunnel Line West of Windy Creek</u>.

A fault along Windy Creek has been postulated from air photographs by L.C. Noakes, but no field evidence could be obtained in support of this inference. Where Windy Creek was crossed no outcrops occurred and on each bank talus exists to a height of 170 feet above the steam bed. The outcrops observed above the talus at Windy Creek consist of coarse gneissic biotite granite with foliation striking 20 degrees.

On the north-south ridge immediately west of Windy Creek the granite is strongly gneissic and contains xenoliths of porphyry, banded quartzite (silicified slate) and schist.

At a point 1,900 feet west of Windy Creek and 600 feet north of the tunnel line an ironstained zone was detected in the gneissic granite and this is regarded as a possible fault. The zone is 6 feet wide and was traced over a length of 50 feet. Its strike is 141 degrees and dip 80 degrees north-east.

Two outcrops of metamorphic rocks were mapped approximately midway between Windy Creek and the Geehi River, and form part of a narrow belt of metamorphics trending north-east. The first outcrop was crossed about 1,700 feet south of the tunnel line. It consists of phyllite, and the planes of schistosity strike 6 degrees and dip vertically. These metamorphic rocks strike towards a zone of metamorphic rocks which could be observed approximately 1 mile to the south of our track. The second outcrop of metamorphic rocks occurs just north of the tunnel line and comprises grey slate, phyllite and banded quartzite. Only floaters were observed, but they were traced at very close intervals up a spur.

West of the first belt of metamorphics, gneiss outcrops strongly. It is very strongly gneissic and is notable for the abundance of white mica as well as quartz, felspar and biotite. Strong joints were noted with strikes of 128 degrees and 44 degrees. The former joint system had a dip of 33 degrees south-west. A higher grade of metamorphism appears to have been involved in production of this gneissic granite than that which affected the bulk of the granitic mass to the east.

Near the end of the traverse westerly to the Geehi River, floaters of sedimentary metamorphic rocks were observed. These included chlorite-schist, fine spotted schist, phyllite, quartz-sericite-schist, quartz-actinolite-hornfels and andesine-quartz-hornfels.

c. Spencer's Creek Dam Site.

The Spencer's Creek Dam Site was surveyed by plane-table from 3rd to 8th January, 1948. The portion of Spencer's Creek extending for about one mile north from the Kosciusko road and the David Moraine lies in a glacial valley. It has the typical "U"-shape, with steeper slopes on the western side. The greater part of the valley that was surveyed is covered by sandy soil and granitic boulders. Very few outcrops were observed in the area contoured. Those marked on the plan (Plate 4) consist of fresh gneissic granite which is strongly jointed.

The following table indicates the strikes and dips of joint planes in outcrops of gneissic granite observed in the valley of Spencer's Creek.

Joint	90°	140°	150°	7°	45°	145°	0°
Dip	77°N	75°SW	83°SW	45°W	85°N	77°S	

The gneissic foliation has a strike of 7 to 15 degrees and dips steeply (dips varying from 80 degrees east to vertical). No outcrops could be detected in the creek bed, but large lbocks of gneissic granite up to 20 feet across are very common. No estimate can be given of the thickness of fluvio-glacial material covering the bedrock, and this can only be determined by boring or shaft sinking.

The David Moraine is exposed in two road cuttings shown in the plan (Plate 4). Large boulders of granite are embedded in coarse buff-coloured sand derived from from granitic rocks. The granite is gneissic in part and contains xenoliths. Rarely pebbles of quartzite and nepheline tinguaite have been found in the David Moraine. The summit of the David Moraine is estimated to be roughly 5,840 feet above sea level.

Datum for elevations is the road mileage post, K 7 (seven miles by road from Kosciusko summit). The elevation marked on the post is 5,772 feet. This post is situated on a col which is the lowest point on the western side of the contoured portion of Spencer's Creek Valley.

The axes of three possible dam sites have been marked on the plan (Plate 4). Final selection must obviously await the results of the proposed drilling tests which should permit the delineation of bedrock contours.

d. Tunnel Line from Spencer's Creek Dam Site to Piper's Creek.

This tunnel line runs north-easterly for a distance of approximately 5 miles to the valley of Perisher Creek. It is shown on Plate 1.

The predominant rock type is coarse gneissic granite, the foliation of which generally has a strike of 15 to 20 degrees. The strike and dip of joint planes observed in the field are indicated on Plates 1 and 5. Xenoliths of bedded quartzite and dioritic rock are quite common. Large floaters of white quartz carrying black tourmaline crystals occur on the west flank of The Paralyser. On the east slope of The Paralyser, approximately 6,000 feet from Bett's Camp on a bearing of 315 degrees, large boulders of gneissic granite (not in place) contain veins of quartz up to 1 foot in thickness.

At a point about 2,100 feet west-north-west of the summit of the Blue Cow, joints with flat easterly dips were noted in the granitic rock.

1. Faulting.

No evidence of faulting could be detected in the field, and no sign was found of the inferred fault which L.C. Noakes in 1946 suggested might exist along Farm Creek. The direction of Farm Creek between the Paralyser and Blue Cow Creek has been influenced by strong joint planes which strike 176 degrees and 165 degrees. This is obvious from a close study of the jointing shown on Plate 1 in the vicinity of Farm Creek.

Likewise the lower section of Perisher Creek has been influenced by a joint system in the granitic rocks which strikes in a northerly direction (see Plate I).

e. Tunnel Line from Piper's Creek to Island Bend.

Throughtout the greater part of its length the tunnel line is through medium-grained foliated biotite granite. About ½ a mile west of Scrubby Creek the gneissic structure becomes more pronounced and the texture coarser. A belt of strongly gneissic granite about 900 feet across occurs in this sector, but otherwise the rock encountered along the tunnel line lacks strong gneissic structure. The jointing observed in the field is shown in Plate I. Xenoliths, composed of banded gneiss (felspar and biotite) and micro-diorite, are abundant at the western end of the tunnel line.

GEOLOGICAL RECONNAISSANCE FROM THE GEEHI RIVER TO THE SWAMPY PLAIN RIVER AT KHANCOBAN.

by

W.B. Dallwitz.
Petrologist.

TABLE OF CONTENTS.

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I. SUMMARY.

1. The topography of the area has been influenced by Kosciuskan block faulting, type of rock, jointing, schistosity and relatively high rainfall.

2. New evidence for possible glacial action between the Grey Mare Range and Bogong Creek is discussed.

3. The rocks along the course of the tunnel line are divisible into five zones - the Khancoban granodiorite; low-grade hornfelses, quartzite and shales, from The Razorback to Bogong Creek; granodiorite, adamellite and granite on the western slopes of the Grey Mare Range; trondhjemite on the Grey Mare Range; schists and phyllite on the eastern face of the Grey Mare Range and in the Geehi Valley. The main characteristics of these zones and the known structures within them are described.

4. The proposed tunnel line will pass through the following approximate thicknesses of rock; schistose rocks, 13,050 feet; igneous rocks, 42,120 feet; unsheared metamorphic rocks, 14,580 feet. Engineering aspects of construction, water problems, permanent support and lining in critical sections are discussed.

5. Suggestions on the course of future geological investigations are made.

II. INTRODUCTION.

The field work on which this report is based was done between February 4th and 19th of this year. In addition to the writer, the field party consisted of K.R. Fleischman and student geologists J. Baird, J.N. Casey and W.N. MacLeod.

Three successive camps were set up at The Black Creek, Bogong Creek and The Pinnacle. Men and equipment were transported to and from camp sites by horse, arrangements for which were in the hands of Mr. H. Barlee of Khancoban.

Aerial photographs were used throughout to establish locations in the field.

The topographical details of the geological plan and section (Plate 2) accompanying this report are taken from preliminary contour maps prepared by the Survey Directorate, Department of the Army.

Because of the short time available to do the field work, it was found to be much simpler to locate outcrops and cover the necessary ground by traversing ridges rather than streams, though water courses were visited wherever possible to study the rocks in their less weathered states.

Owing to four days' almost continuous rain and fog, field work from Camp 3, near The Pinnacle, was confined to about two hours on one day and about four hours on another, with the result that a length of $1\frac{1}{4}$ miles of tunnel line between point 102 and the Geehi River was not mapped.

All bearings mentioned in this report are true.

Previous work on the whole hydro-electric project in the Kosciusko area was covered in a report by L.C. Noakes (1946).

III. TOPOGRAPHY.

The factors which have had an important bearing on the development of the topography of the area are faulting, type of rock, jointing, schistosity, and relatively high rainfall (30 inches annually at Khancoban and about 45 inches at the Geehi). The Kosciuskan epoch of uplift and block-faulting is the most important of these, because it has been the major influence in stream rejuvenation and in determining the relief of the area as expressed particularly in the Grey Mare Range and Scammel's Spur; at the same time the Bogong and Geehi valleys have apparently been largely localized by the fault-zones. With the exception of the Grey Mare Range and some of the more gentle slopes immediately to the east of Khancoban, sharp ridges and steep hillsides are characteristic.

a. Relief.

In the area covered by the plan the vertical range is from over 5,400 feet at The Twins to under 1,000 feet. Along the tunnel line itself the variation is from just over 5,000 feet on the Grey Mare Range to just under 1,000 feet at the western end of the tunnel on the Swampy Plain River.

b. Drainage.

In the granodiorite east of Khancoban the directions of many of the streams are determined by major joints.

Near the junction of the hard hornfels and quartzites and the Khancoban granodiorite is The Razorback, which runs parallel to the contact for at least 5 miles and forms a strong divide from which headwaters of streams flow west towards the Swampy Plain River and east towards Khancoban Back Creek. It is possible that the course of this divide is dependent on the general north-south strike of the bedding, but a more important factor in determining its presence is the fact that the rocks near the granodiorite are largely hard hornfelses and quartzites, formed by contact metamorphism.

The position of the creek running south-west into Bogong Creek from station 12A2 (Plate 2) is determined by a probable fault; the virtually straight course of the upper part of this creek west of The Twins is almost certainly due to strong jointing in the granodiorite of that area.

The Grey Mare Range possibly owes its lack of "sharpness" to its being a part of the semi-mature land surface which was developed between the time of Kosciuskan block faulting and the onset of the Pleistocene glaciation.

In the schist country between the Grey Mare Range and the Geehi, the directions of ridges and streams are determined mainly by schistosity, though jointing has controlled the development of the streams flowing south, east, south-south-east and south-east. The course of the Geehi itself happens to follow approximately the direction of schistosity though part of it has probably been strongly influenced by the major normal fault postulated a short distance to the east.

The Swampy Plain River at Khancoban is approaching maturity, more so as it nears its junction with the Murray. All the other streams are youthful and fast flowing, though their profiles may flatten on the upstream side of rapids which owe their origin either to hard rock bars or to locally rapid back-cutting, which is gradually working upstream and was initiated during the Kosciuskan epoch of block faulting and consequent stream rejuvenation.

As would be expected, marked differences exist between even the youthful streams, so that the larger ones, such as the Geehi, Bogong Creek and Khancoban Back Creek, have grades much gentler than those of their tributaries. For example, a tributary which enters Bogong Creek at point 69 (Plate 2) falls 1,500 feet in about the same plan distance as the Bogong falls 400 feet.

c. Glaciation.

The Grey Mare Range was undoubtedly ice-covered during the last ice age. That some ice-movement took place there is proved by the finding of a facetted pebble of gneissic leuco-granite near Camp 3, at an elevation of 5,000 feet.

Previous workers in the Kosciusko area have come to the conclusion that evidences of glacial action extend down to about 4,500 feet (David, 1908, pp.662-3). David, Helms and Pittman (1901) also state that the glaciers appear to have "descended 500 to 800 feet lower on the eastern fall of the main divide than on the western" (p. 63).

Between the Grey Mare Range and Bogong Creek there are some interesting features which have not been closely examined but which, nevertheless, seem to suggest that glacial action may have extended down to well below 2,200 feet. The straight south-west trending valley immediately to the west of The Twins (Plate 2) has the appearance of a hanging valley, though, perhaps, it is not sufficiently U-shaped in cross section. However, viewed in profile, it is distinctly flattish between the 3,600 and 4,000 foot contours, and then rises steeply to 5,000 feet. Between the 3,600 and 3,400 foot contours there is another sharp drop. The whole structure is reminiscent of that of two hanging valleys on Mount Black and Bald Hill near Rosebery, Tasmania. Downstream from the 3,400 foot level, at station 12A2 (Plate 2) a ridge about 15 feet high and 60 feet wide follows the valley upstream in an almost straight line for approximately 1,000 feet. This ridge is made up of piled boulders of granodiorite and similar rocks, and has every appearance of being of morainal origin.

At the junction of this creek and Bogong Creek the pile of boulders still persists, and forms the left bank of Bogong Creek for a distance of some hundreds of feet, possibly as much as 600 feet. These boulders consist almost entirely of granodioritic and granitic rocks both massive and gneissic, and they rest on a basement of sedimentary rocks - mostly indurated shale. The ridge traversed from point 72 to station 11A16 consists of quartzite, silicified shale and hornfels, yet only three or four boulders of quartzite and shale were seen at 69. The explanation of this circumstance is, apparently as follows:-

> The valley from some distance (probably the 3,400 foot contour) east of station 12A2 to Bogong Creek is broad - it is at least 300 feet wide at station 12A2 - and in this respect it is quite different from that of the Bogong and other creeks in the neighbourhood. The stream follows a very sinuous course over the suggested morainal material, and numerous low mounds in the valley have given rise to swampy areas because of their effect in impeding drainage and seepage towards the main stream. At point 69 a very small tributary enters on the right bank of the main channel from a level several feet above that of the latter; probably similar streamlets, which slowly drain the swampy areas, exist farther upstream also; one such was noted near station 12A2. The paucity of boulders of

sedimentary rocks at point 69 is due to the fact that blocks shed from the ridge on the right bank rarely reach the main channel, but are largely held up on the relatively flat, swampy stretch which probably nearly everywhere intervenes between the bottom of the steep slope and the stream itself.

A pile of granitic boulders was found near point 67; along the traverse it extends about 70 feet south of there and 230 feet north. On either side of the pile quartzite and indurated shale occur in situ, and scattered pebbles of granite rest on these rocks. This mound may owe its origin to the transport southward of boulders from points 68 and 69. An interesting fact is that between points 68 and 66 the valley of the Bogong is much broader than usual; this, too, may be due to glacial action.

IV. DESCRIPTIVE GEOLOGY.

From west to east the rocks crossed by the proposed tunnel line are divisible into five zones, as shown on Plate 2:

a. Granodiorite from Khancoban to The Razorback.
b. Low-grade hornfelses, quartzites and silicified shale from The Razorback to beyond Bogong Creek.
c. Granodiorite, adamellite and granite, from near Bogong Creek to just below the crest of the Grey Mare Range.
d. Trondhjemite (a rock similar to granodiorite), on the crest of the Grey Mare Range.
e. Low-grade schists and phyllite from near the beginning of the eastern fall of the Grey Mare Range to the Geehi.

Probable faults and the extensions of geological boundaries established in the field were plotted by L.C. Noakes from a study of aerial photographs.

a. Granodiorite.

This rock covers the greater part of the area between The Razorback and the Swampy Plain River. It consists of about 45 per cent. plagioclase, 40 per cent. quartz, 8 per cent. biotite, 5 per cent. orthoclase and 2 per cent. other minerals. Its average grainsize is of the order of 2.5 mm., though many grains are up to 4 or 5 mm across.

The accessory minerals are muscovite, epidote, zoisite, chlorite, colourless sphene, apatite and zircon in decreasing order of abundance.

The granodiorite is generally massive, though a few specimens showed slight directional structure.

Some variations of grainsize and mineral composition were noted in parts of the granodiorite mass, particularly in specimens 30, 31 and 32, near its eastern boundary. The first two of these are somewhat pegmatitic and contain large porphyritic crystals of potash-felspar; number 31 is also unusually rich in quartz. Number 32 has been sectioned; it is a medium-grained rock carrying porphyritic microperthite crystals up to 1.5 cm. long. All three rocks are adamellites rather than granodiorite. Between station 5A1 and point 13 a floater of adamellite with pink potash-felspar was found.

Veins of muscovite-aplite from an inch or two up to several feet wide are very common in the granodiorite. The largest aplite dyke seen was at point 23; it is about 3 feet wide, strikes 160 degrees and dips vertically. In one place (28a) biotite-aplite was found.

Small biotite-rich xenoliths, usually only an inch or two across, are also common in the granodiorite.

A notable feature in this western area is the presence of large lamprophyre dykes, which appear to follow certain joints along part of their length. The boundaries of two of them have been approximately marked from aerial photographs, but it was not possible to determine the positions of the ends of the dykes. The two dykes shown on the plan are by no means the only ones to be expected, because floaters of similar rock were found between station 6B1 and point 21 and also at point 6 (Plate 2).

The lamprophyres show considerable variation in grainsize and in mineral content, even over a distance of a few yards. Their essential minerals are green hornblende and acid plagioclase (albite to acid oligoclase), and their petrographic name is spessartite. Some specimens are fine-grained, others medium-fine and a few are medium-grained.

Several fairly large xenolithic bodies of altered porphyry and autometamorphosed rhyolite were found in the granodiorite within a mile of the point where the tunnel line crosses the road. Both types of rock have suffered silicification and other changes through contact with the granodiorite. The true relationships of the different masses towards one another are not known. Specimen 1 is a granite-porphyry, 2 and 2a are toscanite or adamellite-porphyry and 3 and 4 are extensively autometamorphosed banded rhyolites.

That rocks similar to toscanites 2 and 2a are to be found among the intruded rocks of this area is shown by the presence of dacite near the propsed Geehi dam site (see Appendix to report by C.W. Ball, 1947).

Another outcrop of porphyry, probably in the form of a dyke, was found about 1,700 feet south-south-east of Camp 1 at station 27 (Plate 2). This rock is a felspar-quartz porphyry, and is much less altered than are porphyries 1, 2 and 2a.

A dyke of bytownite-dolerite occurs at point 15; its strike is probably determined by a joint. The outcrop, which was 60 to 75 feet wide, was traced for a short distance only.

The account of the Khancoban granodiorite and the rocks associated with it, may be concluded by mentioning the finding of a floater of spotted hornfels at point 21 and another of metamorphosed impure felspathic sandstone at point 6a. They show that xenoliths of altered sedimentary rocks may also be expected in the granodiorite.

b. Low-grade hornfelses, quartzites and silicified shale.

In general, these rocks are characterized by hardness, lack of regional cleavage and strong jointing. Their hardness is due to the low-grade thermal metamorphism to which they have been subjected.

It is difficult to tell from weathered specimens (e.g., 37, 37a, 37b, 46) collected on ridges or hillsides whether some of the rocks are best described as quartzite or or as sandstone. However, all fresh rocks of this type found in creek beds were undoubted quartzites; this suggests that the rocks listed are probably weathered quartzites. Weathering would not normally affect quartzite to the extent that some of the rocks of this belt have been attacked, but the explanation lies in the circumstance that all of the quartzites examined microscopically are impure - they contain appreciable quantities of one or more of such minerals as sericite, chlorite and felspar, which have allowed easier attack by the agents of weathering than if they were pure quartzites. Originally they were argillaceous and/or felspathic sandstones. Some of the quartzites are carbonaceous (e.g., 42 and 48). Specimens 40, 41 44 (cherty), 46, 47, 52, 55, 59, 63, 66, 71, 72 and 73 are representative of the impure quartzites. White vein quartz is abundant in most of these rocks, and it occurs also in the silicified shales.

Hornfels was noted particularly towards the western part of the area under discussion. Among the types are quartz-sericite-chlorite-biotite hornfels (24, 24a, 33), quartz-sericite-biotite-chlorite hornfels (33a, 34), quartz-sericite-biotite hornfels (25, 26), quartz-sericite-biotite-felspar sandstone-hornfels (38) and spotted scapolite-biotite hornfels (53). Hornfelses probably derived from siltstones (e.g., 36, 38b, 50) and spotted hornfelses not examined microscopically also occur (e.g. 38b, 50 and at 11A14).

Silicified or indurated shales were found in numerous places, namely at points 43, 43a, 51 (siltstone), 54, 57, 58, 60, 61, 65, and 66a, and between and at stations 11A15 and 11A16.

At station 6A5, where the tunnel line crosses The Razorback, phyllite was found in situ. This is the only known occurrence within the belt of hornfelses, etc. of a relatively soft rock showing cleavage. The presence of phyllite probably explains the existence of the broad saddle in The Razorback ridge near this point.

Specimen 70 is an acid tuff. A small outcrop of conglomerate occurs in Bogong Creek downstream from Camp 2.

The saddle between The Lookout and Scammel's Spur was traversed only on horseback; outcrops and floaters suggest that is consists of quartzite.

The eastern boundary of the belt of hornfelses, etc. is probably largely determined by faults within the area covered by Plate 2.

c. Granodiorite, adamellite and granite.

It is impossible to say with certainty, on the basis of the little evidence at hand, of what kind of rock the greater part of this belt is composed. Microscopic examination of the only sectioned specimens (69, 75, 79, 81) more or less representative of the area showed that two were granodiorites, one was an adamellite and remaining one a granite. Specimen 69 was not in situ, but was collected from the pile of boulders situated near Bogong Creek and already mentioned under the sub-heading "Glaciation". However, judging from outcrops between The Grey Mare and Pretty Plain Hut the type of rock represented by specimen 69, a medium-grained melanocratic granodiorite, is fairly general for the whole mass. Specimens 117 and 118 from the western fall of The Grey Mare Range are very similar to 69, differing only in being gneissic and of coarser grainsize.

Although specimen 69 is a granodiorite, it is quite different in appearance from the Khancoban granodiorite. The percentage mineral composition of the two rock-types is also different. Most variation is shown in the biotite-content (20 per cent. as against 8 per cent. for the Khancoban rock).

Specimens 75, 79 and 81 are, respectively, biotite-rich adamellite, biotite-rich granite and quartz-rich granodioritic rock. Specimens 79 and 81 are unusual in that they contain 5 to 10 per cent. or more of pinite, which is probably an alteration product of cordierite.

Characteristic of most of the rocks from point 75 to point 84 are the numerous xenoliths of vein quartz, which are usually about an inch in diameter. In places, however, they are much larger; thus, specimen 88 is a partly granitized xenolith, portion of which consists of a piece of quartz now measuring 5" x 4" x 1" to 1½", though it has obviously become detached from a larger mass. Specimens 82 and 121 show quartz xenoliths in probable granodiorite.

Some floaters of gneissic rocks were found at station 12A3, and it is possible that such rocks are more abundant near the western margin of this belt than present knowledge suggests. However, it is known that a zone from 2,000 feet to at least half a mile wide along its eastern boundary carries abundant xenoliths in all stages of assimilation. The rocks in this strip are fairly commonly somewhat gneissic. Among the xenoliths are such rock-types as quartz-mica schist of various kinds, sandstone, quartzite, chlorite schist and quartz-sericite schist. Specimens 85, 87, 87a, 87b, 97, 97a, 98, 99, 119, 120, 122, 123 and 124 are representative of them. Specimen 83 is a dolerite floater, but it is not known whether it is a xenolith or part of a dyke (c.f. specimen 15). Close to the ultimate eastern margin, which is gradational, there are gneissic rocks intermediate between the contaminated varieties making up this belt and the trondhjemite to the east of it.

Specimens 76, 77 and 78 are altered lamprophyres, and they represent a dyke within the granodiorite, etc. The trend of the dyke can be picked up on aerial photographs, because it outcrops more strongly than do the surrounding rocks; however, it could be followed for only a short distance. It will be seen that it is approximately parallel to the straight valley west of The Twins, and its direction has, therefore, probably been determined by a major joint.

Specimen 80 (a floater) represents a hybridized rock which is best described as a medium-grained uralitized quartz-mica gabbro, and probably occurs as a dyke within the granodioritic mass.

The granodiorite, adamellite, granite, xenolithic and other rocks just described are discussed in more detail in the Appendix.

d. Trondhjemite.

Though aplitic and especially pegmatitic phases are strongly developed in many parts of this belt of rocks, the dominant rock type here is leuco-adamellite or trondhjemite. In some places, for example on The Pinnacle itself, gneissic foliation is marked, but in general the trondhjemite has only faint traces of directional structure.

Time was too short to make a proper study of the variations within the rock mass exposed on The Grey Mare Range, but one specimen (96) was selected for closer examination. This is almost certainly not typical of the whole mass, which is described more fully in the Appendix.

The eastern boundary (which probably follows the direction of schistosity in the Geehi schists) of the trondhjemite belt lies about 60 feet west of point 113 and was also observed from horseback at The Twins, where an outcrop of schistose rocks can be easily distinguished at a distance.

Aerial photographs leave some doubt as to whether the extreme southern part of the trondhjemite mass as shown on Plate 2 does actually consist of that rock; there is a possibility that granodiorite comes in there, and accordingly query marks have been placed on the plan.

e. Low-grade schists and phyllite.

From a study of aerial photographs it is virtually certain that these rocks extend from the farthest point reached (102) to beyond the Geehi River. Accordingly they have been shown on the plan as bridging the gap between that point and the Geehi.

The rocks of this belt have been subjected to low-grade regional metamorphism, and they comprise sericite-quartz schists (100 a (in part), 102 (in part), 105 and 106), phyllite, (108, 108a, and 108b; between stations 17A4 and point 112; phyllite and fine-grained sericite-quartz schist between stations 17A3 and 17A4), quartz-sericite schist (100a (in part) and 104 (in part)), siltstone-schist (102 in part), quartz-chlorite-schist (104 in part), andesine-hornblende-epidote schist (100), hornblende-epidote-plagioclase-quartz granulite (101), banded plagioclase-hornblende-quartz-epidote-magnetite-biotite schist (103), probable plagioclase-actinolite hornfels (110), sheared and silicified acid tuff (112) and silicified phyllite (113). This last rock is close to the trondhjemite-contact, and it, no doubt, owes its silicification to this circumstance. Some of these specimens were not in situ, but they serve to show the types of rocks in this area. Quartz veins are very common in the schist at and between points 105 and 107.

Within the schists two small outcrops of sheared porphyry (107 and 109) were found. Specimen 107 is a felspar-quartz porphyry and 109 is a quartz-felspar porphyry, very similar to 107. It is impossible to say whether these represent flows, sills or dykes, but, in any case, they pre-date the shearing.

Specimen 111 is a weathered lamprophyre which macroscopically resembles specimen 20b in the Khancoban granodiorite. This rock has not been involved in the shearing, and is almost certainly genetically connected with the lamprophyre represented by specimens 76, 77 and 78 which were collected within the granodiorite mass on the track taken to The Pinnacle.

f. Supplementary Notes.

The return to Khancoban from The Pinnacle was made on horseback via the Grey Mare Range, Pretty Plain Hut, Broadway Top and Bradley's Gap. Certain broad geological features were noted on the way, and these will now be briefly described.

About half a mile beyond the Grey Hill and 4½ miles from the Pinnacle the bridle track passes from trondhjemite into the granodioritic belt lying to the west of it. Xenoliths, predominantly of quartzite, are very plentiful over a wide zone, and the conspicuous inclusions of vein quartz noted west of The Pinnacle are also present. A very large block of quartzite, probably not less than 150 feet wide, occurs about half way between the Grey Hill and The Grey Mare. The granodiorite is not sensibly gneissic and is very similar to specimens 68 and 69 collected near Bogong Creek. It continues with very little variation to within 1½ miles of Pretty Plain Hut where sedimentary rocks again appear. On the western flank of the north-south trending range west of the Pretty Plain Hut a probable coarse fault-breccia was seen. The course of the fault-zone which was marked by low, jagged outcrops could be easily traced by eye across hills and valleys for a thousand feet or so. If the fault were of Kosciuskan age it would not normally be expected to stand out in this way, but a possible explanation is that it may have followed a Palaeozoic fault connected with the folding and uplift of the sediments. Itsstrike is 190 degrees, and, in view of this, it is interesting to note that it could approximately follow the Bogong Creek valley and connect with one of the faults shown as forming the eastern margin of the hornfelses, quartzites and silicified shale. Further mention will be made of this matter in connection with the subject of faulting.

Sedimentary rocks continue to Broadway Top (on The Dargals Range), down The Long Spur and to within about 1,200 feet of the west-flowing tributary of Khancoban Creek (i.e., near the foot of The Long Spur). At this point granitic rock, possibly of the type mapped west of the Grey Mare Range trondhjemite appears again and continues for about ¼ mile along the track, where sediments again outcrop. Three hundred to four hundred and fifty feet farther west these give place to uralitized gabbro, which continues to outcrop for about half a mile. Thereafter sediments again appear and persist all the way down the track, past the Khancoban Creek crossing, over Bradley's Gap and along a disused cutting to where the track emerges into a broad, settled valley about 2 miles past Khancoban Creek crossing.

All of the sedimentary rocks are of the hornfelsic type mapped on The Razorback and in the vicinity of Bogong Creek; they are in no way schistose and are, therefore, not to be correlated with the Geehi schists.

g. Structural Geology.

The most important structures are normal faults of Kosciuskan (late Tertiary) age. The eastern boundary of the belt of hornfelses, quartzites and silicified shale is shown as being largely determined by two such faults. It is by no means improbable that the fault shown as merging into an approximate geological boundary at a point about ¼ mile east of point 66 actually continues northward along this line, and so becomes a branch of the fault marked between point 68 and station 12A2. This latter fault, about 1½ miles northward along its course from the point to which it has been plotted on Plate 2, again enters the valley of Bogong Creek and follows it for some miles; it may then connect with the probable fault found west of Pretty Plain Hut (see under f. above). Actually, this fault determines the course of the upper part of Bogong Creek. On the aerial photographs it cannot be traced southward of the point shown. When more work is done in the area it should be possible to establish the existence (or non-existence) and the position of the fault in the vicinity of the tunnel line, for it is shown as intersecting Bogong Creek no fewer than five times.

The course of the probable fault shown about a quarter of a mile east of point 66 on Bogong Creek has possibly been controlled by the original contact between the granodiorite and the horfelsic rocks. Numerous west-flowing streams intersecting the suggested fault line should give ample opportunity to verify its existence (or otherwise) and to plot its course and dip accurately. It may be that this fault carries on southward for some miles, taking the place of the other suggested fault after the latter peters out about half a mile south of the tunnel line on Bogong Creek.

Both of the faults just discussed, being on the western side of the Kosciusko horst, will almost certainly have steep westerly dips.

It is clear that the relative relief of the Grey Mare Range, Scammel's Spur and of the Main Divide are attributable to Kosciuskan uplift and normal block faulting (Plates 1 and 2). Their influence on the profile section along the tunnel line is shown in Plate 3, where the successive steps downward from the Main Divide to the Grey Mare Range and to Scammel's Spur are clearly marked. These major faults will probably be found to consist of a number of planes along which movement has taken place, so that a zone of shattering up to 100 or more feet wide may be expected. The Geehi and Bogong valleys have been largely cut down along these two fault zones.

In the Khancoban granodiorite up to five joint directions were noted in a single outcrop (near point 27). Five joints are also shown at point 14, but these were actually measured on two outcrops about 220 feet apart. In the vicinity of the tunnel line the major joints strike at approximately 45 degrees and 130 degrees, and the directions of some of the streams are determined by them. This is especially noticeable in the cases of three streams near stations 5A3 and 5B2 and point 16, respectively, and also in the case of a stream flowing almost along the tunnel line from station 5B5 towards the road.

Both strike and dip of the two lamprophyre dykes and of the porphyry dyke at point 27 are probably controlled by joints.

Although reasonable correspondence between the strike-directions of the dominant and even the minor joints is common, their dips are variable. Thus, for the north-east trending joints, individual dip readings were 70 degrees north-west and 88 degrees south-e st, and for those with a south-west trend they were 85 degrees north-east, 60 degrees north-east and 85 degrees south-west. Similar variations were noted in the minor joints also.

In the belt of hornfelses, quartzites and silicified shale, the joints were found to be much less consistent in both dip and strike than in the granodiorite. This suggests that the metamorphic rocks behaved less as a uniform body during the operation of tectonic stresses than did the granodiorite. It is to be expected, therefore, that these rocks will have suffered considerable contortion and probably minor fracturing and faulting as well. From the point of view of the engineering geologist this is an important factor, and very close mapping will be necessary to allow an estimate of the relative proportions of competent and incompetent beds to be made.

Although the measurements taken show that the average strike of the bedding is 167 degrees and that the dip, on the whole, is steep to the west, minor folds and contortions were noted in several places, and at point 66 a east-pitching anticline is exposed over a distance of about 75 feet on the bank of Bogong Creek. From this evidence it is clear that repetition of beds will be found within this zone. In general, the competent and incompetent beds will be folded together, as in the case of the alternating bands of quartzite and silicified shale at point 66, but where thick beds of these rocks occur, it is to be expected that the shale will have yielded by folding and the development of joints and fracture-cleavage, whereas the quartzite will have yielded by folding and the development of joints, tension-cracks (on anticlines), and even by shattering and minor faulting under some circumstances. Fracture-cleavage in shale was noted at point 61 and also at point 66 in portions of some shale bands.

Little bedding was seen in the quartzites, but it was more conspicuous in some hornfelses and shale-bands. The siltstone-hornfels (36) at The Lookout and the shale at point 66 break along the bedding-planes.

The joint-systems in different outcrops of the hornfels-quartzite-shale belt are not as regular as those in the granodiorite. All readings, except those taken by Baird and Casey along Bogong Creek, have been shown on Plate 2. These latter are confined to a small area, and they are set out below:-

Point	Strike	Dip		Remarks.	
54	30°	85°NW	Major.	Quartzite.	
	85°	80°S	Minor.	Quartzite.	
Near 54	50°	60°NW	Minor.	Silicified	shale.
	130°	Vert	Major.	"	"
	150°	30°NE	Minor.	"	"
	170°	70°W	Major	"	"
55	80°	75°S		Impure	quartzite.
	180°	30°E		"	"
56	100°	80°S	Minor.	"	"
	165°	80°W	Major	"	"
	175°	15°E	Major	"	"
Between 56 and 57.	85°	65°S		Quartzite.	
	90°	85°S		"	
	180°	80°W		"	
57	130°	60°N		Silicified	shale.
	170°	75°W		"	"

From these readings it is clear that there is some correspondence between strikes of joints in the same types of rock. The quartzites have, apparently, behaved differently under stress than have the silicified shales. Aerial photographs show that the dominant joints near Camp 2 strike approximately south-south-east and east-north-east to east.

In some outcrops in Bogong Creek it was noticed that water was seeping down certain of the steeper joints and finally escaping along a flat dipping joint. For example, at point 66 the following readings were taken:-

Joints:	a.	Strike	10°	Dip	85°E.	
	b.	"	30°	"	15°NW.	
	c.	"	70°	"	87°NNW.	(Major).
	d.	"	115°	"	85°NNE.	
Bedding (apparent)		"	75°	"	40°S.	

Water was seeping along d, b and the bedding.

Due to the presence of different rock types, the strikes of joints generally show so much diversity that their influence in forming stream-patterns is not strong. No trends as obvious and striking as those in the granodiorite are apparent. It is not unlikely that the original attitudes of the joints have been disturbed by Kosciuskan faulting.

Very few joint-readings were taken in the granodiorite-trondhjemite complex east of the Bogong. Those joints striking about 65, 100 and 120 degrees have had most influence on the directions of streams. Gneissic banding (average strike 35 degrees, dip 85 degrees west), which is parallel to the contact between granodiorite and trondhjemite, is developed in such a small area, and then not strongly, that it has had **no visible** influence on topography.

In the Geehi schists the dominant physical features, the dissected ridges, are parallel to the average strike (30 degrees dip, 62°W) of the schistosity. These ridges and the streams parallel to them are so marked that the effect of jointing is masked. Nevertheless, there are water-courses which follow joints striking 92, 130, 150 and 175 degrees. At point 100, a stream flowing parallel to schistosity changes its course to follow one of these major joint directions (strike 175°).

Bedding was noted in quartz-sericite schist at point 104, but the outcrop had been disturbed by downhill creep, and no measurements were taken. No statement can, therefore, be made regarding the fold structures in this belt of schists, though it is probable that, if they are folded and not merely tilted, the folding will be sharp and more less isoclinal. Crumpling and minor contortions are almost certain to be found also. Furthermore minor or major faulting dating from pre-Tertiary diastrophism may be expected, as also may minor faults of Kosciuskan age.

V. ENGINEERING GEOLOGY.

The main problems in the engineering geology of the proposed tunnel line have been outlined by Noakes (1946).

From the Geehi River to the Swampy Plain River the following approximate thicknesses of rocks will have to be excavated (see Section, Plate 2):

Schists, etc.	13,050 feet.
Trondhjemite	3,270 "
Granodiorite, etc.	9,480 "
Hornfels, etc.	14,580 "
Granodiorite	25,680 "
Lamprophyre	1,200 "
Rhyolite	780 "
Porphyry	1,710 "

Reduction to significant rock types gives the following figures:

Schistose rocks	13,050 feet.
Igneous rocks	42,120 "
Unsheared metamorphic rocks	14,580 "
Total :	69,750

As far as the Geehi schists and phyllite are concerned, the problems of excavation, construction and maintenance will be vastly lessened because the course of the tunnel will cross the direction of schistosity at an angle of about 65 degrees. The amount of overbreak will be very much less than it would be if the tunnel were to be more or less parallel to the strike of the schists. However, the schists, etc. are strongly jointed in addition, so that overbreak and danger of loose blocks may be expected on the roof of the tunnel, particularly where joints dip at a shallow angle; similarly, overbreak may be expected on the walls of the tunnel in places where joints are approximately parallel to its course. However, possible problems due to jointing cannot be adequately assessed until the spacing of the joints has been investigated. With closer spacing difficulties would be greater.

Rock-bursts could occur near the western boundary of the Geehi schists; however, the backs here are only about 1,500 feet, so that the danger is possible rather than probable, and is, in any case, lessened because the tunnel crosses the direction of schistosity.

In two sectors of this belt water problems may arise from possible minor faults, from open joints and from the schistose nature of the rocks. These sectors, which are marked on Plate 3, are:-

a. At the Geehi (backs about 370 feet) and for about half a mile west of the stream.

b. In the vicinity of the valley (backs over 500 feet) 1.375 miles west of the Geehi for a length of about half a mile.

Elsewhere within the schists the tunnel will be well over 500 feet below the suggested water table, and, therefore, joints and minor fissures should be tight, though if a major fault of Kosciuskan age were found it would possibly yield a strong flow of water. Permanent support may be necessary in the vicinity of the Geehi if the rocks are found to be shattered due to faulting (Plate 3). Possible faults (over-thrust, reverse and normal) and shears associated with the early history of these rocks may be found, but they should cause less difficulty than the late-Tertiary faults.

No rocks which are likely to act as aquifers were found within the Geehi schists.

With the exception of the plagioclase-hornblende-schists and any hard siliceous bands or silicified zones these rocks should provide easy tunnelling.

Unless Kosciuskan normal faulting, at present unsuspected, is present, no difficulties are envisaged in the trondhjemitic/and granodioritic belts in the vicinity of the Grey Mare Range until the tunnel approaches the surge tank (250 feet below water table) and pressure incline about one mile east of Bogong Creek. At this point the flow of water will probably begin to increase, though the rocks themselves should be fresh and should stand well. The pressure incline and that portion of the tunnel between it and the power station, which will, presumably, be near Bogong Creek, will almost certainly have to be lined because the natural hydrostatic head will not be great enough to prevent leakage. The upper part of the surge tank itself may need support.

Elsewhere the tunnel is so far beneath the surface that it should be relatively dry. The dyke of lamprophyre (points 76 to 78, Plate 2) and a body of gabbro at point 80 will not give rise to problems even if the tunnel intersects them, because the contacts will be silicified and hard ("frozen").

No difficulties are to be expected within the zone of xenoliths at the granodiorite-trondhjemite contact, mainly because backs there are 2,000 feet.

The extent of possible overbreak in the granodiorite-trondhjemite complex cannot be estimated at this stage; it will depend on the spacing and attitudes of joints.

The western boundary of the complex may be determined by a fault, so that precautions will be necessary thereabouts. The probable fault in Bogong Creek will have no effect on the construction of the tunnel itself; however, the fault zone may have to be excavated and grouted on the hillsides to prevent leakage from the Bogong storage-basin.

Within the hornfelses, quartzites and silicified shale near Bogong Creek, water problems will almost certainly assume prominence over a tunnel length of about one mile (see Plate 3). Elsewhere the tunnel will be at least 1,000 feet below the surface, so that the workings should be relatively dry. No rock which is likely to act as an aquifer was found in this belt, so that water should not be troublesome in places where the tunnel line is more than 500 feet below the water table unless a major normal fault is discovered. Although many of the quartzites become rather friable on weathering, in outcrops of fresh rock in stream beds they were everywhere highly silicified and lacking in intergranular pore spaces.

Lining may be necessary in some section of that part of the tunnel extending from the eastern boundary (possible fault) of the hornfelses, etc. to the outlet of the tunnel at Bogong Creek; permanent support may have to be provided for about a quarter of a mile west of the portal on the right bank of the Bogong. Both of these parts of the tunnel are in the near-surface zone, where a strong flow of water and weakness in the arch of the tunnel may be anticipated.

Folding and minor faulting are to be expected throughout these rocks, and if they are under strain the possibility of rock bursts should be taken into account under Scammel's Spur and The Razorback, though the backs here are only 1,750 feet, and the possibility must be considered remote. Unless major faulting is revealed by detailed mapping the greater part of the hornfelses, etc. should present no abnormal difficulties in working.

Overbreak may be a problem, particularly in the silicified shales, because, in addition to breaking along rather closely spaced joints, they will also tend to break along the bedding.

Pyrite was noted in hard quartzite at point 56 and pseudomorphs of limonite after pyrite in specimen 64. This mineral, if occurring in disseminated form only, should cause no trouble at any stage in the history of the tunnel.

The exact nature of the contact between the hornfelses, etc. and the Khancoban granodiorite is not known. There is no evidence to suggest that it is a faulted one, because the most highly metamorphosed rocks found occur on the western slopes of The Razorback, as would be expected for a normal intrusive contact. However, it is not impossible that a subsequent fault may have followed the boundary. The latter is shown as dipping steeply east on Plates 2 and 3; the easterly dip could be much more gentle than shown, thus reducing the thickness of hornfels, etc. to be excavated.

Within the Khancoban granodiorite water problems should not be very great, partly because rainfall decreases towards the west. Joints are not closely spaced, and, therefore, overbreak should not be excessive.

The inflow of water will gradually increase from a point about 3,700 feet south-east of the surge tank, where the backs are about 500 feet, attain a maximum at the surge tank itself (backs 250 feet), and gradually decrease down the pressure incline (see Plate 3). However, in the absence of known faults, there is no reason for anticipating a strong flow. Lining of part or all of the pressure incline and of the pressure tunnel between it and the power station must be allowed for; within that section of the tunnel which lies up to half a mile north-westward of the bottom of the incline lining may not be needed, but if the power station is to be west of this point it will almost certainly be necessary to line the tunnel from there onwards in order to prevent leakage. Part of the surge tank may need support.

Water is to be expected again at a point nearly 2¼ miles south-east of the Swampy Plain River (see Plate 3), and the inflow will probably increase as the tunnel approaches the surface further along its course. Again, however, it should be possible to cope with the inflow without difficulty. Permanent support or lining (see above) will almost certainly be necessary over that portion of the last 1 2/5 miles of aqueduct which will not take the form of an open channel.

The lamprophyre dyke situated about three miles from the final outlet of the tunnel should not occasion any difficulty, as the tunnel will be at least 750 feet below the surface at that point. The more westerly lamprophyre dyke also should not cause concern, as the tunnel will intersect it 250 feet below the water table. It was found from a study of specimens collected at the surface, that the lamprophyres weather with at least as much, if not more, difficulty than does the granodiorite. Possible porphyry dykes, such as that at point 27, will not present any special problems.

The xenolithic bodies of porphyry and rhyolite will have hard, "frozen" contacts, and the rocks themselves will also be very hard below the zone of weathering. No difficulties, apart from hard driving, need be anticipated where the tunnel intersects them. The same applies to any xenoliths of sedimentary rocks which may be found.

GENERAL CONSIDERATIONS.

Grouting may be necessary, both to improve working conditions and as a permanent measure, in those parts of the tunnel where the inflow of water is excessive. It may also have to precede lining or to supplement permanent support of structurally weak rock across the tunnel arch.

It is not possible to estimate at this stage the quantities of water which may have to be handled in any part of the tunnel. The possibility of a strong flow of water should be anticipated from the fault zones; in general, this flow will be a maximum when first tapped and will then gradually diminish and tend to become constant. Apart from faults the greatest flow of water may be expected where the tunnel is below, but close to the water table. Elsewhere even small seepages will aggregate into a fairly strong flow over a considerable length of tunnel. However, from present knowledge, it cannot be anticipated that the inflow will anywhere be so great that it cannot be pumped satisfactorily, especially if warning of major increases is got by drilling ahead of excavation.

In the igneous rocks there should be little trouble in driving and maintaining the tunnel. In general, the metamorphic rocks will present greater problems, particularly on account of jointing, schistosity, variation in the hardness of different beds, local shattering (in the quartzites and hornfelses of the Bogong Valley), and minor or major faults within or at the borders of the different masses. Fault- or shatter-zones will almost certainly have to be supported, and they will have to be lined where there is a possibility of leakage of water.

VI. FUTURE GEOLOGICAL WORK.

To make it possible to specify more accurately the problems in engineering geology which will have to be met during the construction of the hydro-electric works, it will be necessary to make a regional geological survey of a large tract of country on either side of the propsed main tunnel line. The width of the strip to be mapped cannot be determined at present; it will have to be sufficient to allow, as far as possible, the solution of allrelevant problems, particularly those connected with Kosciuskan block faulting. This mapping should be on a scale of 2 inches to the mile.

More detailed mapping along the actual course of the tunnel will be necessary on a scale of, say, 500 feet to the inch.

At the Bogong dam site even closer mapping on a scale of about 50 feet to the inch will be called for. The same applies to other places where key structures are contemplated.

During the progress of the detailed work it may be necessary to diamond-drill, sink shafts, drive adits or dig trenches at critical points, particularly where the positions of important contacts and fault zones must be established. Exploratory shafts and adits will, at the same time, furnish valuable evidence on the flow of ground water and on the need for support or lining in certain sections of the tunnel.

The detailed work must, among other things, aim at determining the fold structures within the metamorphic rocks. If these and the fault-pattern can be elucidated, it may be possible to change the course of the tunnel in order to avoid unfavourable sections of ground and also to estimate the proportions of different rock types which the tunnel will intersect, so that cost and problems of working, support, lining, etc. may be, to some extent, anticipated. Within the hornfelsic zone, on a count of collected specimens alone, the percentage of hornfels and quartzite is 75 and that of silicified shale is 25, but it is certain that close mapping will make it necessary to change these figures.

Regional and detailed mapping will also make it possible to more accurately project faults, rock-contacts, and dykes from the surface to the tunnel line. Faults will be more difficult to detect in the granitic rocks than in the metamorphic, so that particular care in investigating any evidence which even remotely suggests faulting will have to be exercised within the igneous masses.

Although, in the proposed position of the tunnel line, no difficulties may be anticipated from possible glacial valleys, the possibility of breaking into such valleys at points where the tunnel approaches the surface must be closely checked. This applies, of course, more particularly to the works on the eastern side of the Main Divide, but if the suggested evidence for possible glaciation west of The Grey Mare Range is found to be correct, the problem may have to receive attention in parts of the area described in this report.

CANBERRA, A.C.T.
July, 1948.

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Petrologist.

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PART IV.

APPENDIX.

by

W.B. Dallwitz.

PETROGRAPHY AND PETROLOGICAL NOTES.

Originally it was intended to deal briefly with the petrology of the area covered by Plate 2 only, because the writer has not visited the country which is covered by Plate 1. However, it appeared likely that there would be some relationship between the Berridale bathylith in the east and the smaller igneous masses in the west, so that it was decided to spend a little time in examining representative specimens of the rocks collected by C.W. Ball and party.

In general, the plutonic igneous rocks shown as occupying that section of Plate 1 which lies east of the long, narrow belt of metamorphic rocks appear to be divisible into two main groups. The first of these comprises the coarse-grained types which are usually somewhat gneissic and occupy the major part of that area; the second is represented by medium-grained, massive plutonites which outcrop probably as relatively small bodies within the gneissic rocks in the eastern part of the area. In Plate 1 and in Parts I and II of this report "granite" has been used as a field name to include both of these types of rocks.

Nine rocks representative of the "granite" have been sectioned. On the basis of a single section of each, five of these were found to be coarse granodiorite (though one was close to adamellite), three medium-grained granodiorite (one of these bordered on adamellite) and one was coarse, gneissic granite. Four of the coarse granodiorites are gneissic in varying degree, but the medium-grained granodiorites show no trace of gneissic structure.

Comparison of the sectioned rocks with other specimens collected in the area suggests that the body of coarse, gneissic granodiorite owes its origin to granitization in situ, and that the medium-grained massive granodiorite represents a mobilized fraction of the larger mass, and has been intruded into the latter as a discordant stock or, perhaps, a small bathylith. It is impossible to say, from the evidence at hand, whether there is more than one body of medium-grained granodiorite, though it is clear that the main tunnel line intersects two occurrences, which may be either separate masses or lobes of a single mass. One of these is in the neighbourhood of Waste Point and the other near Island Bend; a large body of coarse granodiorite intervenes between the two, and apparently outcrops again within half a mile south of Island Bend, though nothing is known of the distribution of the two rock types in the vicinity of Waste Point.

On the western fall of the first ridge west of Windy Creek coarse, gneissic granite was found. This rock consists essentially of perthite, plagioclase, quartz (showing mortar structure) and biotite, and contains accessory sericite, black iron ore, chlorite, zircon and apatite. It appears, therefore, that the graniti ed mass is richer in potash near its contact with metamorphosed sediments. Evidence that this happens elsewhere also will be mentioned below.

The coarse, gneissic granodiorite consists essentially of zoned, subhedral plagioclase, anhedral orthoclase, perthite or microcline in variable amount, quartz and biotite. The accessories are sericite, chlorite, apatite and zircon, and one specimen (from Daner's Gap) contains pyrite, black iron ore and blue tourmaline in addition. The plagioclase is generally fresh, but may be moderately saussuritised in some places; it is unusually basic for a rock of this type, as the composition of the cores of the crystals is $An_{50} \pm 5$. Strong strain shadows and mortar structure are developed in the quartz, which generally has a bluish tinge in the hand specimen. Pleochroism in the biotite is from dark or medium red-brown to pale buff or buff.

The essential constituents of the medium-grained granodiorite from near Waste Point are subhedral, zoned plagioclase (An_{50}), quartz and biotite, and the accessories are orthoclase or microcline, chlorite, black iron ore, apatite, epidote, zircon and lawsonite. The near-adamellite from Island Bend has two generations of subhedral to euhedral plagioclase (about An_{42}) and contains large areas of anhedral microperthite which enclose crystals of plagioclase. The quartz is semi-vitreous and shows strain shadows, but no mortar structure. Pleochroism in the biotite is from very dark chocolate brown to brownish yellow. (These medium-grained granodiorites resemble the Khancoban granodiorite).

The significant differences between the two types of granodiorite may now be tabulated as follows:

<u>GRANITIZED IN SITU.</u>	<u>MOBILIZED FRACTION.</u>
Coarse-grained	Medium-grained.
Generally gneissic	Massive
Plagioclase An_{50}	Plagioclase An_{45}.
Mortar structure in quartz	No mortar structure in quartz.
Biotite pleochroic from red-brown to buff.	Biotite pleochroic from very dark chocolate brown to brownish yellow.

Biotite and zircon are generally more plentiful in the original granitized rock than in the mobilized fraction; black iron ore is invariably present in the latter, but was found in only one specimen out of the five coarse ones.

The listed features of the suggested mobilized fraction are consistent with what would be expected. Most interesting is the increase of depth of colour in its biotite, a circumstance which points to relative richness in iron; similar enrichment of pyroxene and olivine in iron, during the progress of crystallization of dolerite and gabbro, have been established by many workers. This enrichment is reflected also in the presence of small amounts of black iron ore in the medium-grained granodiorites, whereas it is almost completely excluded in the coarse granodiorites.

Lamprophyre similar to that found in the Khancoban granodiorite occurs as dykes in this eastern area; it is not known to the writer whether the dykes are confined to one type of granodiorite or not. Tertiary dykes, dykes of aplite and hornblende porphyrite and numerous xenoliths are known to occur, but they will not be discussed beyond mentioning that the xenoliths seem to be largely of the biotite-rich type, and were, presumably, derived from argillaceous sediments, and that the marginal effects are almost identical with those observed in the zone of xenoliths bordering the Grey Mare Range trondhjemite; these effects are, in some instances, rather characteristic, and may be recognized at once.

The relationship of the "acid gneiss" shown on Plate 1 to the coarse granodiorite on the east is not known; only three specimens of rocks collected within its borders are at hand. One of these is a coarse, gneissic leucogranite from the summit of Mount Kosciusko. Microscopically it is found to consist of perthite, acid plagioclase and quartz (showing mortarstructure), with accessory biotite and sericite. The perthite is so rich in plagioclase that the rock may prove to be an adamellite on analysis. A specimen very similar to this was collected on the tunnel line between the long, narrow metamorphic belt and the most westerly fault shown on Plate 1. On Mount Townsend, the locality of the third specimen, strongly foliated, medium-grained, porphyroblastic granodioritic gneiss outcrops. This rock contains red-brown biotite, but is quite different in appearance from the coarse, gneissic granodiorite described earlier; however, it could conceivably be part of the ultimate western border-zone of that mass which has been partially "granitized". In that case the narrow belt of metamorphic rocks would be a roof-pendant or large xenolith, and it is interesting to note that granite occurs on either side of the belt - at Mount Kosciusko and about half a mile west of the Geehi schists near the tunnel line, and also west of Windy Creek, as previously described. The suggestion is that more or less true granite (gneissic) has, for some reason connected with the composition of the metamorphics, formed on either side of them during the progress of the granitization. These ideas are put forward tentatively only; they obviously need checking in the field, but it is felt that they are, at least, feasible.

The composite granodiorite-trondhjemite mass on and west of the Grey Mare Range is an interesting one. The granodiorite observed north of the limits of Plate 2 is much more uniform than that seen on the traverse from Bogong Creek to The Pinnacle, where the rocks show even more sign of contamination than do those in the north, with the result that granite and adamellite in addition to granodiorite were found. An unusual feature of some of the rocks is the presence of considerable quantities of pinite, presumably formed from cordierite; this shows that contamination by argillaceous material has been extraordinarily strong, particularly in the south.

The typical granodiorite of the north is unlike that at Khancoban and also unlike either of the two types of granodiorite in the Snowy River area (Plate 1). It differs from the Khancoban granodiorite in being much richer in biotite, and in the pleochroism of the biotite; from the coarse, gneissic granodiorite of the east in being medium-grained and generally not gneissic, and from the medium-grained granodiorites of the east in the same way as it does from the Khancoban granodiorite. On the whole, however, there is more similarity between the granodiorite on the western slopes of the Grey Mare Range and the coarse, gneissic granodiorite of the east than between the former and either of the other two granodiorites mentioned. The main points of similarity are:

1. Pleochroism of biotite - red-brown to buff in the Snowy River area, light red-brown to pale yellow west of the Grey Mare Range. This shows that the mica is relatively rich in MgO.

2. Percentage of biotite.

3. Similar marginal alteration around some types of xenoliths.

In spite of these similarities it is not possible to postulate with confidence similar modes of origin for the two granodiorites. In fact, it is easier to correlate the Grey Mare Range granodiorite with the Khancoban granodiorite for the following four reasons:-

1. Lack of evidence of granitization in the western part of the Geehi schists and in the eastern part of the Bogong hornfelses, etc.
2. General lack of gneissic structure.
3. Random orientation of most xenoliths, which is contrary to what would be expected under conditions of granitization, which give rise to lenticular residuals of country rock oriented parallel to gneissic banding.
4. Lack of mortar structure in quartz.

The explanation of the greater biotite content of the Grey Mare Range granodiorite and of the relative richness of the biotite in MgO, as reflected in its pleochroism, may lie in the evident strong contamination of this rock, a contamination which is really a retrogression towards the composition of its possible parent, the coarse gneissic granodiorite east of the Main Divide.

In view of the difficulties mentioned above, the question of the rock's origin must be left undecided.

The trondhjemite of the Grey Mare Range and the wide zone of xenoliths in the granodiorite to the west of it pose interesting problems.

Normally it would be expected that xenoliths would be most profuse in the neighbourhood of the Geehi schists. As this is not so, it must be assumed that the trondhjemite was emplaced approximately along the original contact of the granodiorite and the Geehi schists. Barrow (1893, pp. 334-335) suggested a mechanism whereby this could occur. If, at a late stage in the formation or crystallization of the granodiorite, ~~sufficiently strong~~ pressure were exerted from the west, relief would be found in the east. By a filter press action any residual liquor in the granodiorite would be squeezed out and be emplaced in the east in a zone presumably best determined by some strong, discordant feature - in this case the contact.

If the above mechanism is the correct explanation of the origin of the trondhjemite, it is highly probable that the plagioclase of the latter would be more albitic than that of the granodiorite. This is actually found to be so, the anorthite percentage being 35 to 40 in the granodiorite and 25 to 30 in the trondhjemite.

As mentioned under IVd. of Part III of this report, the single specimen of trondhjemite which was sectioned was not typical of the mass as a whole. On the basis of its suggested origin, it could be that the average composition of the mass is that of a leuco-adamellite. Specimen 96 is a coarse-grained rock consisting of about 50 per cent felspar, 45 per cent quartz and 5 per cent chlorite, which is accompanied by a little epidote and leucoxene. The bulk of the felspar is partly saussuritised plagioclase (An_{25-30}). Pegmatitic phases of the trondhjemite are strongly developed in many places.

For the Khancoban granodiorite an origin similar to that suggested for the Waste Point and Island Bend granodiorites is postulated. It is, therefore, considered to be a subsequent bathylith representing a mobilized fraction of the coarse-grained, gneissic, synchronous granodiorite of the Berridale bathylith. Macroscopically and microscopically the Khancoban rock is similar to the medium-grained granodiorites from Waste Point and Island Bend, for the anorthite content of the plagioclase lies between 45 and 50 per cent., the quartz is strained but is generally free from mortar structure, and the biotite is pleochroic from very dark nigger brown to brownish yellow, with no suggestion whatever of the red-brown colour of the biotite in the coarse, gneissic granodiorite.

It is interesting to note that near The Razorback the granodiorite gives place to adamellite, in which porphyritic crystals of microperthite up to 1.5 cm. long are prominent. The plagioclase of the adamellite is more albitic than that of the granodiorite, and carries between 25 and 30 per cent anorthite. Enrichment in potash in the vicinity of metamorphosed sediments was noted also in the case of the gneissic granodiorite east of the Main Divide.

Associated with the Khancoban granodiorite are large lamprophyre dykes. The lamprophyre consists essentially of green hornblende and plagioclase (albite to acid oligoclase). This rock type shows considerable variations in grainsize in different parts of the dykes.

The plagioclase grains are, in general, equidimensional and are commonly free from twinning; twin-lamellae, when present, are nearly always rather broad. The hornblende tends to occur as euhedral to subhedral, elongated crystals, which are fairly commonly twinned, in some instances repeatedly. Two generations of hornblende are present, though they are not easily distinguishable in the fine-grained specimens. Epidote and chlorite were found in every slide examined, but the proportion of these minerals in different specimens is very variable, as it depends on the degree of alteration of the amphibole and plagioclase. Some of the hornblende crystals are 4 to 6 mm. long and about 0.75 mm. wide; in the coarsest lamprophyre (20 b) the crystals are stumpy and tabular (2 to 2.5 mm. long and 1 to 1.5 mm. wide) rather than elongated. Orthoclase was identified in specimen 5, and it is probably present as an accessory in all of these rocks. Tremolite was associated with chlorite in specimen 12 and possible lawsonite with hornblende in specimen 20 b. Other minerals present in small amounts are black iron ore, limonite and apatite.

The petrographic designation of the lamprophyre is spessartite. As mentioned in Section IV of Part III of this report, similar rocks occur in the granodiorite, etc west of the Grey Mare Range and in the Geehi schists.

The xenolithic, autometamorphosed, banded rhyolites outcropping within 1 mile of the road at Khancoban are of interest. In specimen 3 the bands are pink and greyish white and in specimen 4 they are buff and pale grey. The banding is generally irregular, in some places very much so, especially in specimen 4. Alteration has been so intense that all traces of resemblance to ordinary felsitic rhyolite have been completely obliterated. These rocks are now composed of rounded masses (1 mm. or more across) and bands of clouded orthoclase of nodular to tabular form set in a network of tabular grains of quartz which has associated with it a little chlorite. In specimen 4 the quartz is coarser and the chlorite more plentiful than in specimen 3. A few rounded embayed, porphyritic grains of quartz occur in both rocks.

Before dismissing the igneous rocks some reference will be made to three basic rocks represented by specimens 15, 80 and 125.

Specimen 15 represents a narrow dyke of bytownite dolerite (see Plate 2). The essential minerals are zoned bytownite ($Ab_{25}An_{75}$ for cores of grains), monoclinic pyroxene partly converted to hornblende, and chlorite formed from both the pyroxene and the amphibole. Black iron ore, epidote, leucoxene, pyrite and apatite in needle form are the accessories.

Specimen 80 (a floater) consists essentially of pale brown amphibole, ‐ townite (about Ab_{15}, An_{85}) and subordinate biotite.

The bytownite shows sieve structure, the inclusions being blebs of quartz; these blebs are commonly in optical continuity over several grains of the host and even with quartz which is interstitial between the grains of plagioclase. A little finely divided zoisite has been formed in the felspar.

The amphibole, which has probably been derived from monoclinic pyroxene, is bleached in many places and appears to have been converted to tremolite in others.

Pleochroism in the biotite is from light red brown to yellowish white. A little chlorite is associated with the mica.

Apart from quartz the only accessory is black iron ore.

This rock is evidently a hybrid and not a normal basic type. It is best described as a medium-grained, uralitized, quartz-mica gabbro, and it apparently occurs as a dyke in the granodioritic mass west of the Grey Mare Range (see Plate 2).

Specimen 125 represents the uralitized gabbro to which reference was made under IV f. of Part III of this report. It consists essentially of unaltered bytownite ($Ab_{21}An_{79}$), tremolite and diallage. Brown hornblende and ilmenite are the only primary accessories. Small quantities of limonite and leucoxene are also present.

In both specimens 80 and 125 the bytownite has weathered by solution, and the rocks have a characteristic pitted appearance.

The constant features of all three of these rocks are that they are basic, contain bytownite and have been uralitized in varying degree. This concordance suggests that they are all genetically related, and, although the date of their emplacement is unknown, it is thought probable that they were intruded in the Palaeozoic at a date very little later than that of the emplacement of the granodiorites, etc.

The metamorphic rocks have been described in Sections IV b. and IV e. of Part III of this report, but one or two points of interest may be made here.

Cordierite and/or andalusite might have been expected in the low-grade hornfelses of the Razorback (Plate 2), but none has been found as yet; apparently the sediments were too low in alumina to allow the early formation of these minerals.

In the Geehi schists (Plate 2) the andesine-hornblende-epidote schist (100), the hornblende-eipidote-plagioclase-quartz granulite (101), and the banded plagioclase-hornblende-quartz-epidote-magnetite-biotite schist (103) probably represent metamorphosed intermediate or basic lavas (andesite or basalt).

Rocks similar to these were found also in the long, narrow belt of metamorphics west of Windy Creek (Plate 1); two sectioned specimens were fine-grained quartz-actinolite-(? plagioclase) hornfels and banded andesine-biotite-quartz granulite.

CANBERRA, A.C.T.
July, 1948.

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REFERENCE.

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RECONNAISSANCE GEOLOGICAL PLAN AND SECTION
OF THE COUNTRY BETWEEN
WASTE POINT AND GEEHI RIVER
KOSCIUSKO AREA
FOR THE
SNOWY RIVER DIVERSION SCHEME
Scale : 2 inches to 1 mile
Miles ½ 0 ½ 1 1½ 2 Miles
Contour Interval 200 feet
Grid from Preliminary Army Map, Kosciusko
Geology by C.W. Ball, J. Baird, F.G. Carroll, E.K. Carter and J.N. Casey
Topography from Preliminary Army Maps, Kosciusko and Berridale
REFERENCE
Schists & phyllite
Acid gneiss
Granite, gneissic granite & differentiates
Aplite
Geological Boundaries
Definite
Approximate
Faults Definite
Inferred from air photographs
Jointing
Jointing, Vertical
Schistosity
Schistosity, Vertical
Gneissic foliation
Gneissic foliation, Vertical
Roads
Tracks
Traverses
SNOWY RIVER
GEEHI RIVER
THREDBO RIVER
WASTE POINT
ISLAND BEND
HOTEL KOSCIUSKO
MT TATE 6783
BLUE COW 6518
THE BACK PERISHER 6816
THE PERISHER 6742
THE PARALYSER 6518
MT GUTHRIE 6346
CHARLOTTE'S PASS
TWYNAM
LITTLE TWYNAM
Blue Lake
Hedley Tarn
Club Lake
CARRUTHER'S PEAK 7043
MT TOWNSEND 7238
Lake Albina
MT NORTHCOTE 6992
MUELLER'S PEAK 6944
SEAMAN'S HUT
KOSCIUSKO 7316
THE CHALET
WILSON VALLEY HUT
DISSAPPOINTMENT SPUR
MAIN DIVIDE
TUNNEL LINE
PROPOSED DAM SITE
Munyang River
Guthega R
Pound's Ck
Spencer's Ck
Blue Cow Ck
Perisher Ck
Diggers Ck
Sawpit Creek
Wright's Ck
Windy Ck
Munyang R
Finns R
Snowy R
Diggers Ck
Geehi R
Heights along this sector from Army 4 mile maps
6000' 5000' 4000' 3000' 2000' 1000'
SECTION ALONG TUNNEL LINE
Vertical Scale not exaggerated
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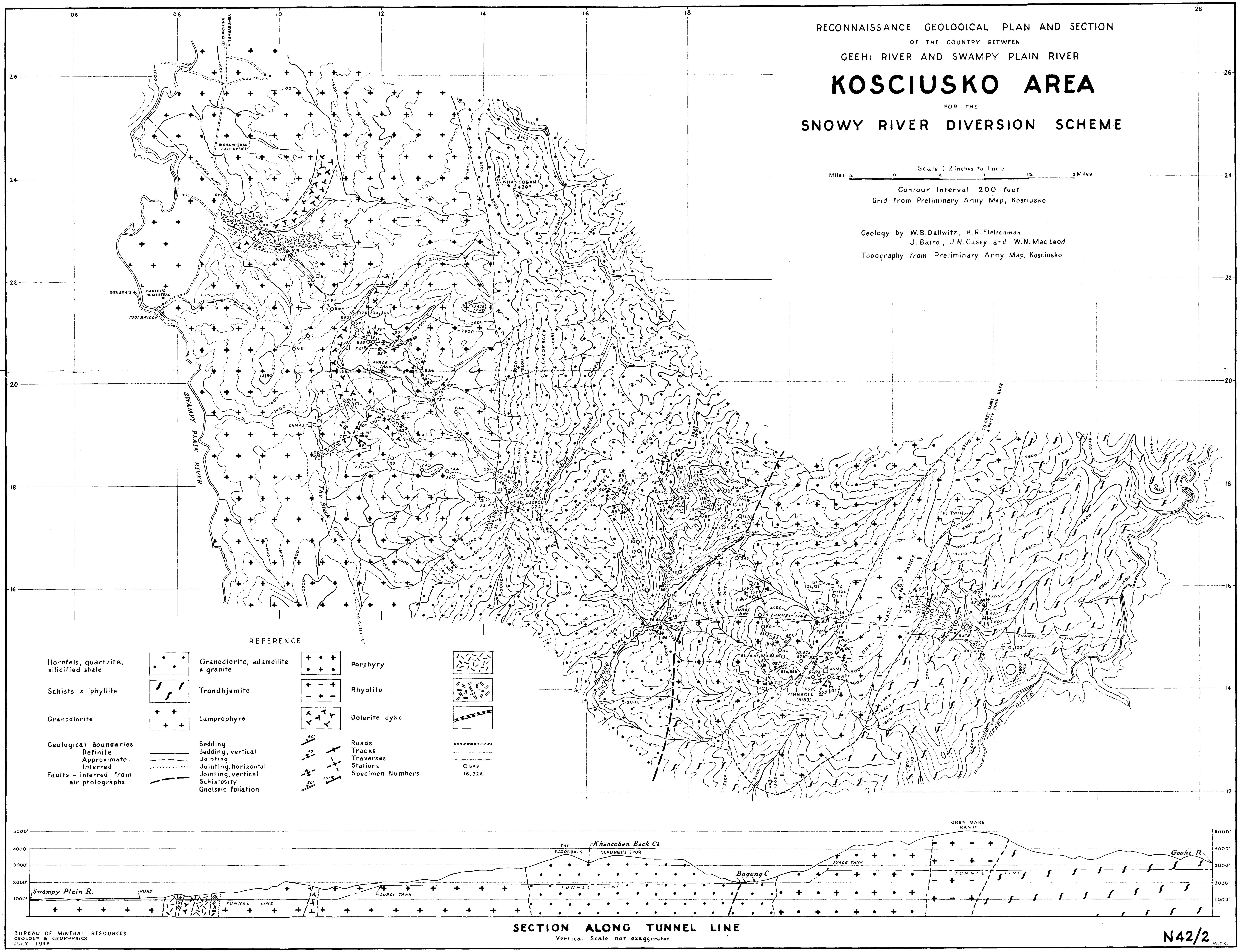
GEOLOGY AND GEOPHYSICS
JULY 1948
N42/1
W.T.C.



RECONNAISSANCE GEOLOGICAL PLAN AND SECTION
OF THE COUNTRY BETWEEN
GEEHI RIVER AND SWAMPY PLAIN RIVER
KOSCIUSKO AREA
FOR THE
SNOWY RIVER DIVERSION SCHEME
Scale : 2 inches to 1 mile
Miles ½ 0 ½ 1 1½ 2 Miles
Contour Interval 200 feet
Grid from Preliminary Army Map, Kosciusko
Geology by W.B. Dallwitz, K.R. Fleischman, J. Baird, J.N. Casey and W.N. Mac Leod
Topography from Preliminary Army Map, Kosciusko
REFERENCE
Hornfels, quartzite, silicified shale
Schists & phyllite
Granodiorite
Granodiorite, adamellite & granite
Trondhjemite
Lamprophyre
Porphyry
Rhyolite
Dolerite dyke
Geological Boundaries
Definite
Approximate
Inferred
Faults - inferred from air photographs
Bedding
Bedding, vertical
Jointing
Jointing, horizontal
Jointing, vertical
Schistosity
Gneissic foliation
Roads
Tracks
Traverses
Stations
Specimen Numbers
SWAMPY PLAIN RIVER
KHANCOBAN POST OFFICE
TUNNEL LINE
BARLEE'S HOMESTEAD
BENSON'S
FOOTBRIDGE
KHANCOBAN 3429'
LARGE TORS
SURGE TANK
CAMP
THE RAZORBACK
Khancoban Back Creek
THE LOOKOUT 3721'
SCAMMEL'S SPUR
The Black Creek
TO GEEHI HUT
Bogong Creek
THE PINNACLE 5183'
GREY MARE RANGE
THE TWINS
TO GREY MARE & PRETTY PLAIN HUTS
GEEHI RIVER
GREY MARE RANGE
THE RAZORBACK
Khancoban Back Ck
SCAMMEL'S SPUR
Swampy Plain R.
ROAD
Bogong C
SURGE TANK
TUNNEL LINE
Geehi R.
SECTION ALONG TUNNEL LINE
Vertical Scale not exaggerated
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KOSCIUSKO AREA

GEOLOGICAL SECTION

ALONG THE

PROPOSED MAIN TUNNEL LINE

SNOWY RIVER DIVERSION SCHEME

SHOWING

A RECONNAISSANCE VIEW OF CERTAIN ENGINEERING PROBLEMS

Horizontal Scale : 1 inch to 1 mile

Vertical Scale : 1 inch to 2,500 feet

Hornfels, quartzite, silicified shale

Schists & phyllite

Granite, gneissic granite & granodiorite

Granodiorite, adamellite & granite

Rhyolite

Trondhjemite

Acid gneiss

Lamprophyre

Porphyry

Geological Boundaries, Approximate
Geological Boundaries, Inferred
Faults
Tunnel Line
Likely position of Water Table
Significant inflow of water probable — W
Permanent support possibly necessary — PS
Lining possibly required — L
High rock temperatures — HRT

Engineering Geology by L.C.Noakes & W.B.Dallwitz
Heights from Preliminary Army Map, Kosciusko, except where otherwise stated

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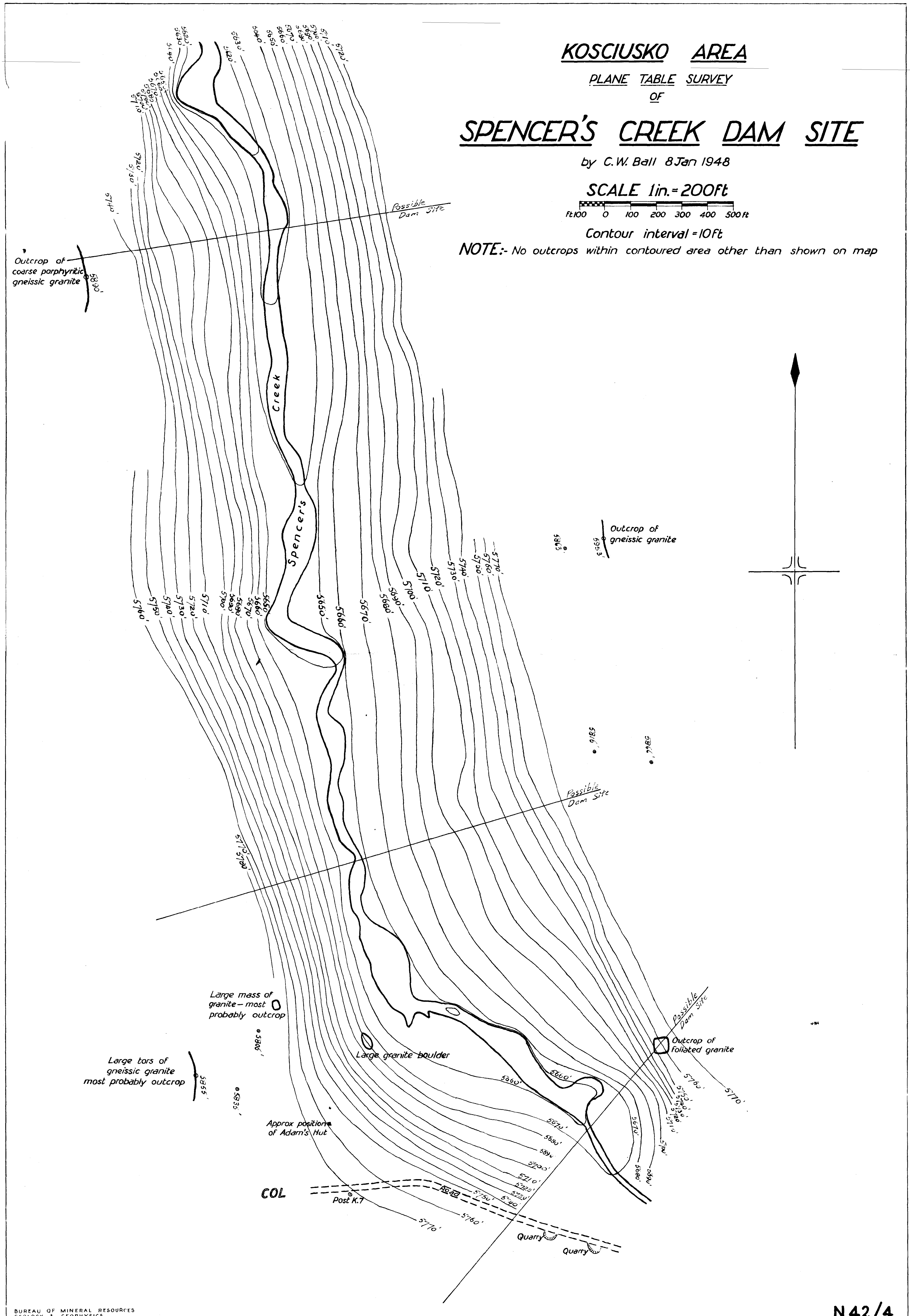
KOSCIUSKO AREA
PLANE TABLE SURVEY
OF
SPENCER'S CREEK DAM SITE
by C. W. Ball 8 Jan 1948
SCALE 1in. = 200ft
Ft100 0 100 200 300 400 500ft
Contour interval = 10ft
NOTE:- No outcrops within contoured area other than shown on map
Outcrop of coarse porphyritic gneissic granite
Possible Dam Site
Spencer's Creek
Outcrop of gneissic granite
Possible Dam Site
Large mass of granite – most probably outcrop
Large tors of gneissic granite most probably outcrop
Large granite boulder
Possible Dam Site
Outcrop of foliated granite
Approx position of Adam's Hut
COL
Road
Post K.7
Quarry
Quarry
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N 42/4