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GEOLOGICAL RECONNAISSANCE OF THE PROPOSED HYDRO-ELECTRIC WORKS IN THE TUMUT-UPPER MURRUMBIDGEE RIVER AREA.

by

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I. SUMMARY.

An area of about 300 square miles has been geologically surveyed in the Upper Murrumbidgee - Tumut River area. The object of the work was to investigate dam sites and tunnel lines in connection with a Hydro-Electric Scheme by which it is proposed to transfer water from the Murrumbidgee River into the Tumut River.

Topographically the area may be divided into three sections :- the Bimberi highlands; the broad, gentle depression or warp drained by the Murrumbidgee river; and the markedly dissected portion drained by the Tumut and the Yarrangobilly rivers.

Silurian sediments underlie Devonian sediments unconformably. Granodiorite porphyry and adamellite intrusives, and dacite and basalt flows have been mapped.

Two proposed dam sites were examined. At No. 4 dam site on the Murrumbidgee River the rocks consist of steeply dipping interbedded quartzites and slates, which should present few difficulties in dam construction. The other site, No. 3, at Lobb's Hole on the Tumut River, lies mainly in granitic rocks. The proposed tunnel line from the Murrumbidgee river to the Tumut river will pass through approximately $6\frac{1}{4}$ miles of Silurian sediments and $4\frac{3}{4}$ miles of Devonian sediments. The contact is probably a faulted unconformity. The major problem in constructing the tunnel line is likely to be control and handling of inflowing water, particularly in Devonian sediments where porous beds will probably be encountered. Many sections of the tunnel line may need support, but a more detailed geological survey will be necessary before tunnelling conditions can be predicted.

II. INTRODUCTION.

The Snowy River Investigations Committee, on which the Commonwealth and the States of New South Wales and Victoria are represented, decided that an alternative or supplementary Hydro-Electric Scheme to the original Snowy River Scheme, should be investigated in the Tumut Valley area. Under this new scheme it is proposed to develop power in the Tumut Valley by bringing in water, by means of tunnels and water-races, from the Eucumbene River, a branch of the Snowy River, from the Upper Tooma River, and from the Upper Murrumbidgee River.

The scheme will involve the construction of five dams :

No. 1 on the Eucumbene River near Adaminaby.
No. 2 on the Tumut River, about 19 miles upstream from Lobb's Hole.
No. 3 on the Murrumbidgee River at the "Gulf".
No. 4 on the Tumut River at Lobb's Hole.
No. 5 on the Tumut River at Blowering.

The geological reconnaissance of the area, in which the dams and tunnels are to be constructed, has been shared by the Bureau of Mineral Resources, Geology and Geophysics and the Geological Survey of New South Wales. Geologists from the Geological Survey of N.S.W. have mapped the southern portion of the area, and have examined Dam Sites 1, 2 and 5 and the country along the proposed connecting tunnels. Geologists from the Bureau of Mineral Resources have mapped the northern portion of the area, and this report sets out the results of that survey, with special reference to the geology of Dam Sites 3 and 4 and of the tunnel line from the Upper Murrumbidgee River to Middle Creek. This tunnel is divided into two sections, one between the Upper Murrumbidgee storage and Power Station No. 3, and the other between Power Station No. 3 and Power Station No. 4. (See Plate 1).

The country surveyed is approximately 300 square miles in area. The results have been plotted on the Snow Leases Map, Lithograph No. 1, of the Lands Department of New South Wales.

Aerial photographs were available of the southern portions of the area examined by the Bureau. The topographic detail of the Snow Leases map was found to be accurate and the map formed a useful base on which to plot the geology of both photographed and unphotographed portions of the area.

Some five weeks were spent in the field. Personnel of the party were J.F. Ivanac, geologist in charge, J.E. Glover, W.A. McKinnon and J.J. Veevers.

III. TOPOGRAPHY.

The area examined consists of an elevated plateau which is being actively dissected by a rejuvenated drainage system. This drainage system embraces parts of the Tumut, Murrumbidgee and Yarrangobilly rivers. (Plate 1).

In the area covered by the plan the vertical range is from 6,267 feet above sea level at Mt. Bimberi to 1,620 feet at the Lobb's Hole dam site. Along the tunnel line itself the range is from just under 4,100 feet at the eastern entrance to the tunnel on the Murrumbidgee river to approximately 2,000 feet at the western end.

The view from Mt. Bimberi, looking west-south-west, shows :

(a) the surrounding highlands which include Mt. Morgan (6,147 feet) and Half Moon Peak (5,340 feet);

(b) the broad gentle depression or warp drained by the Murrumbidgee River;

(c) the markedly dissected portion drained by the Tumut and the Yarrangobilly rivers.

The discussion of the topography therefore naturally falls under the following heads :-

(a) Bimberi area and highlands above 5,000 feet;

(b) Murrumbidgee Valley;

(c) Tumut-Yarrangobilly river area.

(a) Bimberi Area.

This highland area averages 5,500 feet above sea level and is snow-covered during the winter months.

Vegetation is very dense on the steep mountain slopes, but is sparsely distributed on the summits, where snow gums and snow grass represent the major tree and plant cover.

No well-defined drainage pattern exists in this portion; cascades, rapids and waterfalls are common along stream courses.

The Murrumbidgee river cuts across the southern edge of these highlands in a steep sided gorge.

(b) Upper Murrumbidgee Valley.

i. Murrumbidgee River.

The broad and gentle warp which forms the valley of the Murrumbidgee river in this area trends from north-west to south-east through the highland area. This sector is separated from the Yarrangobilly-Tumut area by a north-south divide which joins Gooandra Trig. and Rules Point and thence continues in a north-westerly direction through Yarrangobilly Trig. Station.

The average height of the Upper Murrumbidgee section is between 4,000 and 5,000 feet. A few residuals of the highlands are present, such as Mt. Yarrangobilly (5,339 feet), Mt. Nungar (5,611 feet), Mt. Nattung (5,309 feet), and these serve as indicators of a once extensive upland area.

Land forms are mostly rounded hills trending in a north-south direction parallel to the strike of the country rocks. There are very few abrupt scarps. Valleys are flat-bottomed and contain a superficial veneer of alluvium and detritus, probably deposited during a lacustrine cycle when the river was temporarily dammed.

The Murrumbidgee river, unlike the Tumut river flows in a general southerly direction. Its overall course was determined by an older drainage system which existed before uplift to the present level took place. Before the uplift, the southerly flowing headwaters of the Snowy were separated from the Murrumbidgee by a divide which was situated to the north of the present divide. The tilting of the Monara peneplain enabled the capture of the Snowy headwaters by the Murrumbidgee. This explains the south-easterly direction of flow of the Murrumbidgee in the locality, and its sudden reversal to the north in the vicinity of Cooma. (Süssmilch, 1909).

In many places the river transgresses the structural trend of the Silurian rocks and may be considered an antecedent stream. However, numerous right-angle bends in the river's course are due to the influence of the prevailing north-south trend of the country rocks.

In the alluviated valleys in the upper reaches of the river the gradient is gentle. In this portion the river has numerous meanders in its course. Billabongs and cut-off meanders are common, but are developed only on a small scale. The alluviated part of the Murrumbidgee river extends upstream from the Gulf (at Dam site No. 3 - Plate 1). From the Gulf to Yaouk the Murrumbidgee flows through disconnected steep-sided gorges, one of which, Yaouk, is very well-defined. This latter gorge is in hard granite which has been resistant to lateral planation by river action and through which the river has maintained a fairly straight course.

ii. <u>Other Streams</u>.

Nungar and Tantagara Creeks are strike streams which drain into the Murrumbidgee river. These rivers have courses which were alluviated possibly by the formation of lakes when the Murrumbidgee River was temporarily dammed. The courses of these creeks are marked by numerous meanders and billabongs.

(c) <u>Tumut-Yarrangobilly River area</u>.

The rivers in this area are actively degrading their valleys as evidenced by the numerous rapids and waterfalls, and the fact that terraces and river valleys are not alluviated. Valleys are V-shaped, very steep sided, and thickly clothed with vegetation. Hill crests are generally flat topped in marked contrast to the steep fall of the valleys.

The flattened hill crests represent remnants of an old plateau level which sloped westwards.

i. <u>Yarrangobilly River</u>.

This river flows south for part of its course along the contact of the Silurian limestone and the overlying Devonian sediments. The limestone is very cavernous and numerous underground streams drain into the Yarrangobilly river.

Near the Yarrangobilly Caves the river turns south-west, and thence flows into the Tumut river. Throughout the whole of its course downstream from the caves the river transgresses the structural trend of the Devonian. North of the caves the river has cut through Devonian shales and slates and in places exposed the underlying Silurian metamorphics.

ii. <u>Tumut River</u>.

The Tumut river is an old stream which has been rejuvenated by the Kosciuskan uplift. Incised meanders are common features, and have resulted in the formation of asymmetrical valleys, due to meanders accentuating erosion on alternate banks of the river.

(d) Conclusions.

The marked variation in land forms is the most significant feature to the engineer. In the Murrumbidgee valley area road construction will be on a comparatively mature land surface, with a considerable thickness of surface soil cover; crab-holes (shallow surface soil depressions) are common features; swamps are numerous along the valleys; snow covers most of the area during the winter months.

In the Tumut-Yarrangobilly area roads will have to be cut in steeply sloping hillsides where soil cover is very thin; roads should be constructed so as to minimise the risk of damage by landslip and flow under the very wet climatic conditions; landslides have been noted along the course of the Yarrangobilly river.

IV. GENERAL GEOLOGY.

In the area covered by the survey, Silurian se[illegible] underlie Devonian unconformably. Granodiorite, porphyry a[illegible] adamellite intrusions and dacite and basalt flows were map[illegible]

A. Geological Succession:

The generalised geological succession may be li[illegible]ed as follows :

Post Tertiary	:	Faulting and uplift.
Tertiary	:	Basalt flows overlying river deposi[illegible]
?	:	Porphyry
Devonian	:	(Dacite flows (Marine Limestones (Interbedded continental sediments an[illegible] (lava flows.
?	:	Granodiorite and Adamellite
Silurian	:	(Limestones (Interbedded lightly metamorphosed (sediments.

B. Silurian.

The Silurian sediments comprise a group of steep[illegible] dipping sedimentary rocks which have been subjected to lo[illegible] regional metamorphism. These rocks have a predominant nor[illegible] south strike. They are partly marine and partly volcanic [illegible] origin. The rocks may be divided into two groups (1) Metamorphics; (2) Limestones.

(1) Metamorphics: The main rock types are quartzites, phyllite, compacted siltstone, tuffaceous rocks and slate. A sample taken from $1\frac{1}{2}$ miles west of Dam Si[illegible] No. 4 is apparently a felspathized argillaceous sediment.

In general, samples sectioned show evidence of marked volcanic activity associated with normal ma[illegible] sedimentation.

The granites and porphyries which intrude the Silurian strata have, in common with the tuffs of th[illegible] Silurian pyroclastics, a predominantly granodio[illegible] composition. This granodioritic affinity between the intruded and intrusive rocks is one of the most significant results obtained from a microscopic examination of specimens from the area.

(2) Limestones: The limestones form a belt 4,000 feet wide, and extend northward from the Yarrangobilly Caves for an indeterminate distance. The rock is very massive in appearance, white, reddish grey and grey, with a texture which varies from finely crystalline to compact. The limestone is extremely cavernous and contains the famous Yarrangobilly Caves. West-flowing streams in this locality pass through the limestones through caves and other channels.

The limestone is richly fossiliferous and several characteristic Silurian fossils were collected. No detailed descriptions of the fossils are yet available. Types recognized among among the fossils collected are:-

Conchidium Knightii, the corals Favosites, Halysites, Heliolites, brachiopods and crinoid stems.

C. Devonian.

The western part of the area - west of a line running north-south from Yarrangobilly River and east of the Tumut River (Plate 1) - is occupied by Devonian sediments which unconformably overlie the rocks of Silurian age. The reconnaissance has shown that the Devonian sediments are more flatly dipping than the Silurian strata. In both periods vulcanism was associated with sedimentation.

The main rock types in the Devonian are fossiliferous limestone, conglomerate, shale, hornfels, tuffaceous sandstone, grit, compacted volcanic ash and dacite flows. The conglomerate pebbles, both large and small, are well rounded.*

The grits under the microscope consist mainly of poorly cemented angular fragments of glassy, cryptocrystalline and fine-grained material, which may contain partly resorbed quartz and felspar phenocrysts. Many of these fragments bear a marked resemblance to the granodiorite-porphyry intrusives of the Silurian.

The continental conditions of deposition (Garretty, 1936), of some Australian Devonian formations, bringing about oxidation of their iron content, has, in many places, imparted them a reddish colour. Some of the Devonian rocks of the area under consideration are no exception in that iron-rich cementing material and iron stains have combined to give them a red appearance. Conglomerate, grit, sandstone and some of the clay slates are the types chiefly affected.

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* Andrews (1901) noted quartzitic breccias associated with conglomerates in the Ravine area but, during the recent reconnaissance, breccias were not found with the conglomerates in other areas and are unlikely to be encountered in the engineering works.

The main features observed in thin section of the Devonian rock samples are :-

(1) The tuffaceous origin of a large proportion of the rocks.

(2) The wide range of grain size of the rocks, which include limestone, slate, sandstone, grit and coarse conglomerate, indicating considerable variation in conditions of deposition.

(3) The red coloration of many of the sediments, which possibly points to the prevalence of continental conditions over earlier parts of the period of sedimentation. No marine fossils were found in these sediments. The fossiliferous limestone, which is stratigraphically at the top of the local Devonian sequence, is of course marine.

The geological succession from east to west is as follows :-

Quartzites with interbedded slates.
Yellow sandy slate, sandstone, and argillaceous slate
Slate with conglomerate beds.
Interbedded conglomerates, lavas, tuffs, red cherty slates.
Limestones and calcareous sandstones.

The significant structural features of these rocks are the marked jointing in quartzites, the jointing and cleavage of the slates, and the porosity of the tuffaceous rocks.

Time was not available to estimate accurately the thicknesses of the various formations. However at Yan's homestead, Ravine village, four miles south-east of Lobb's Hole (Plate 1), the limestone beds were measured and shown to be at least three hundred feet thick. This limestone proved to be very fossiliferous and contained well-preserved specimens of typical Devonian types such as Orthis, Spirifer bisulca, (?) Acrospirifer and indeterminate Rhynchonellids.

In the New South Wales Geological Survey Bulletin No. 25, (Carne and Jones, 1919), an analysis of this limestone is given as follows :-

Constituents	$CaCO_3$	$MgCO_3$	Al_2O_3 Fe_2O_3	Gangue	HO
Percentage	76.03	0.93	5.60	16.74	0.70

Descriptions of typical Devonian rock types are given in Appendix I.

D. Igneous Rocks.

1. Granite.

The Silurian sediments include two meridional bands of acid igneous intrusive to which the field name of granite has been given. A sample (G5) from the easterly band - a band which is thought to be continuous with the Bimberi granite to the north - has been determined as a granodiorite, probably of hybrid origin. Andesine is the dominant felspar.

One sample (V21) of the western or Boggy Plain granite was determined as an adamellite. A second sample (V26) proved to be a granodiorite of somewhat more basic composition than the granodiorite G5 from the Bimberi band. All three samples contain abundant andesine.

Insufficient thin section work has been done to determine what part, if any, contamination and differentiation have played in the determination of the final composition of the two masses. The presence of a felspathized sediment in the western portion of the rock outcrops of Silurian age indicates the possibility of granitization. No metamorphic effects on the invaded sediments were observed. The combination of field relationships, strike and mineralogical composition of the two intrusives suggests that they are contemporaneous.

2. Porphyry.

Three approximately parallel bands of intrusives have been designated by the field name of porphyry. These bodies strike in a general north-south direction and in most places their boundaries conform to the strike of the Silurian sediments.

The two easterly intrusive bodies are composed of granodiorite porphyry (J61, J47* - see Appendix I). However, a sample from the southern portion of the easternmost intrusion, has the composition of an augite lamprophyre (J71). It is possible that this may be a gabbroic xenolith and that the sample is not a true indication of the rock mass over a wide area.

The westernmost of the three porphyry bands differs markedly from the granodiorite porphyry in texture and appearance - it is a granophyric adamellite (J28), or acid granite.

All samples from the three intrusives with one exception contain abundant andesine. The exception is J71 (augite lamprophyre) in which the plagioclase has the composition bytownite.

The three bands are similar in field occurrence, trend and composition. Furthermore, they have much in common with the so-called granites. Further petrological work would no doubt do much towards establishing the relationship and origin of these intrusive bodies.

The adamellite appears to intrude Silurian rocks only whereas the granodiorite porphyry intrudes both Silurian and Devonian sediments.

3. Lavas.

(a) Dacite - Dacite flows cover an extensive area in the western part of the region mapped, where they overlie the Devonian beds; no accurate measurement could be made of their thickness but they are estimated to be at least 75 feet thick.

Macroscopically the rocks are greyish-pink and purplish-grey with porphyritic felspar crystals set in either a fine grained or felsitic groundmass. Phenocrysts may be as much as 7 mm. long. Several distinct flows are suspected but time was not available to confirm this.

The age of these lavas is uncertain but it is thought that they might be of Devonian age.

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* This number refers to specimens collected and described in the Appendix.

(b) Olivine Basalt.- Gooandra Trig. is the approximate centre of the largest basalt capping in the area, and other small and relatively insignificant outcrops have been noted elsewhere. Basalt has been extruded as successive flows to form fairly clearly defined terraces, which are best exposed in the country between Gooandra Trig. Station and Gooandra Creek. The rock is dark grey, hemicrystalline and porphyritic with phenocrysts of olivine set in a glassy to cryptocrystalline groundmass.

The flows overlie Tertiary river deposits and are thus of similar age to those at Kiandra, where rich deposits of alluvial gold were worked in the early part of the century.

E. Structural Geology.

The structural relationship between the different rock groups is shown in the section on Plate I. The reconnaissance provided no opportunity for detailed structural mapping but the following salient features were noted:- The Silurian rocks have been subjected to low-grade regional metamorphism and the less competent beds folded into steeply pitching minor anticlines and synclines. Dips are steep, and there is a predominant north-south strike.

The overlying Devonian has been folded into broad anticlines and synclines faulted by both north-south and east-west faults. Contact with Silurian is most likely unconformable and this contact is probably a thrust plane along which movement took place during the compression of the Devonian sediments. The dip of the Devonian sediments is very variable, but on the average is less than 30 degrees.

The porphyries and granites have well defined contacts. Contact metamorphic effects are almost unnoticeable. Surface outcrops show that they are concordant with the intruded rocks. The granite outcrops at the surface represent lenses and cupolas probably derived from an underlying deep-seated mass.

Basalts and dacites are flow rocks and unconformably overlie the older formations.

Block faulting associated with the Kosciuskan uplift has been in part responsible for the present topography.

V. ENGINEERING GEOLOGY.

A. Dam Site No. 3*(Plate 3).

(1) The Proposed Dam.

Dam Site No. 3 was surveyed by plane table on a scale of 100 feet to an inch. This dam site is in the steep-sided valley 300 feet east of the eastern extremity of Kelly's Plain. The Murrumbidgee River abruptly changes its course from a north-south to an east-west direction near the proposed dam site, and passes from a broad, flat valley to a steep-sided gorge. The gorge is V shaped with steeper slopes on the northern side. The proposed retaining walls runs approximately at right angles to the river's course.

The rocks exposed at the dam site are interbedded slates and quartzites, which dip steeply to the west. The prevailing strike is north-east/south-west with minor deviations from this direction (see Plate 3). The slates have been folded in some places to form minor anticlines and synclines with vertical pitch. Thrust faulting is apparent in some places. The forces which folded the slate have compressed what was originally fine and medium-grained sandstone to quartzite. Both slate and quartzite have been injected with quartz veins which have caused silicification on a minor scale, but have, nevertheless, helped to make the rocks more structurally sound. A contact between porphyry and fine-grained slate was noted 1,000 feet upstream from the dam site.

The quartzite is the most suitable rock in which to construct the dam and the retaining wall can be built into the structure of the rock itself. Two possible sites for retaining walls have been suggested (Plate 3), but some costeaning will be necessary to determine the best position. The suggested wall sites lie approximately parallel to the strike of the rocks and have a maximum length of 800 feet.

The type of rock underlying the soil cover on the upstream site is uncertain but this will be revealed by costeaning. Quartzite forms an almost continuous outcrop on the southern bank and may be concealed by the soil on the northern side. If this is so, the suggested western better situated than the eastern site wall because the latter is close to the contact of resistant quartzites and easily eroded slates, and would be on the hanging wall side of a minor strike fault.

The depth of soil cover on those areas not marked as outcrop on Plate 3 ranges up to ten feet.

The quartzite is strongly jointed and three systems of joints have been observed.

(a) Joints which strike north 40° east, and dip 55°-70° to the north-west. These are the most prominent joints and are approximately parallel to the bedding.

(b) Joints which are almost at right angles to the bedding but may dip either north or south, at angles between 60° and vertical.

(c) Numerous other joints not so consistent as (a) and (b). These lesser joints are, in someplaces, strongly curved.

Most of these joints appeared to be fairly tight at water level, but some grouting may be necessary in order to seal major joint openings when the dam is constructed.

One of the important features noted was the plucking of the quartzite from along intersecting joint planes. This is due to the erosive power of stream water by its penetration along open joints. This plucking will have to be considered either in spillway construction, or in the location of flood gates, as this form of erosion is bound to be accelerated under increased water pressure.

Pools along the river have been closely mapped, as these indicate the less resistant strata, namely, slates and quartzitic slates. Water from either spillway or flood gates should not be allowed to fall directly on to any of these softer formations, as considerable erosion is likely to result.

Seepages have been observed on the banks of the river but are of no significance.

(2) Aggregate.

Samples of blue and fine-grained grey quartzite were collected from the dam site and will be submitted for testing.

Microscopically, the quartzites consist of an interlocking mosaic of quartz grains, some of which show strain shadows. No cryptocrystalline silica was noted in thin section. The percentage of quartz is as high as 98% and seldom less than 90%.

Deposits of river gravel were examined over a length of two miles from the dam site to a point two miles upstream. The deposits are sporadic in occurrence but have an average thickness of 18 inches. A twenty-pound sample has been collected for testing. Detailed mapping would be necessary to prove the extent and quantity of these deposits.

(3) Access to Dam Site.

The best route to the Dam Site is from Adaminaby to the Circuits Hut (Plate 1) and from there to the site. At present the vehicle track is almost unserviceable but could be readily improved.

(4) Storage Area.

Regional work has shown that the storage area will lie entirely within Silurian quartzites, slates and tuffaceous rocks which are steeply dipping and have a general north-south strike. These sediments have been intruded by quartz-felspar-hornblende porphyry. No limestones have been observed in the storage area, and no problem of leakage is likely to arise.

There is no possibility of leakage from the reservoir to valleys outside the catchment area as at no place will the limit of the storage lake approach the boundary of the catchment area.

Several fences and two huts will be submerged. The portion of the telephone line between Adaminaby and Currango Homestead which lies in the catchment area will have to be moved.

Strong winds, which are common at the No. 3 Dam Site, may cause wave motion in the reservoir which will undercut the steep northern banks. This may cause minor landslips and points to the necessity of a cautious selection of building sites.

B. Dam Site No. 4 (Plate 4).

(1) The Proposed Dam.

A possible site for the proposed Dam No. 4 on the Tumut River was surveyed by plane table. This site is about half a mile downstream from the Yarrangobilly-Tumut River junction.

The valley is asymmetrical with a steep spur on the western and vertical cliffs on the eastern side. In the area surveyed, the Tumut River is degrading its course and there is little thickness of superficial rock material in the river bed. The bedrock exposed in the river is unweathered porphyry which has been determined as granophyric adamellite.

The steep cliffs, on the eastern bank of the river, are comparatively unweathered and will provide a suitable abutment for the retaining wall. The western bank is covered by soil and dense vegetation and the depth of weathering is not known. Pits and costeans will be necessary to establish the depth to solid rock on this side of the river.

Joints are numerous in the granite rock and diverse in both strike and dip. They are plotted on the accompanying plan and are listed below for reference :-

STRIKE	47°	47°	156°	157°	175°	145°	35°	35°	155°	65°	110°
DIP	V-80N	85N	60S-V	70E	50E	70W	55E	50W	60W	60E	50S

The relative importance of parallel joint systems varies from place to place; although numerous the joints appeared to be comparatively tight at water level. However, some grouting will be necessary to seal open joints which may be encountered during dam construction.

It is proposed to construct the dam wall to a height of two hundred feet above the river bed. This will necessitate a wall with maximum length of 1,500 feet.

For a dam 150 feet above river level, a maximum wall length of 900 feet would be required, but a low saddle on the western side of the dam, about 145 feet above river level, will have to be closed by a vertical wall about 10 feet high. However, this saddle may form a suitable site for a spillway. The depth of weathering that will be found in the vicinity of the saddle is not known.

(2) Construction Materials.

(a) Aggregate. A twenty-pound sample of granophyric adamellite was collected for testing as an aggregate for concrete. This is the principal rock at the dam site. There are no obvious reasons why it should not be suitable for use as aggregate.

(b) Sand. Extensive deposits of pure white and yellow sand are present at Lobb's Hole and a channel sample was collected from over a vertical distance of five feet.

This sample, which was examined microscopically to determine its suitability as a cement sand, appeared, before washing, as a micaceous, strongly iron-stained sand. Boiling with hydrochloric acid was necessary before any grain count could be made. A count undertaken after washing with HCl and the removal of very fine material by decantation revealed the following :-

Quartz	50%
Dark, cloudy grains.. ..	49%
Mica, hornblende, etc. ..	1%

It seems reasonable to assume that the majority of the cloudy grains are strongly kaolinised felspars. Quartz is angular, and no chalcedonic or cryptocrystalline varieties were observed.

In view of its relatively low quartz content and the high proportion of kaolinised felspars, the sand is probably not of high quality for concrete work.

(3) Access to Dam Site.

Tracks could be built to the dam site from :-

(a) Tumbarumba: It has been reported that fishermen have driven vehicles to within half a mile of Lobb's Hole.*

(b) Lobb's Hole Turnoff via Log Cabin (Plate 1). A track was originally in existence through this area but is now partly overgrown. This appears to be the better track and should be investigated.

(4) Storage Area.

The rocks which underlie the storage area consist of Silurian tuffs, felspathized tuff and slate, intruded by granitic rocks, and overlain unconformably by Devonian quartzite, slate, conglomerate, tuffaceous rocks and limestone.

None of these rock formations or accompanying structures are likely to give rise to leakage from the storage area. The limestones are an isolated outcrop about three miles upstream from the dam site, and although they could give rise to leakage from one valley to another within the storage, they do not persist in depth or in outcrop beyond the limits of the storage.

Landslips have been noted along the steep banks of the Yarrangobilly River but these were only minor occurrences. The increased height of the water level in the valleys when the dam is completed may cause some of the steep slopes to become unstable.

The reservoir will be mostly on State lands and only one or two small private holdings will be submerged.

The old Copper Mines near Ravine Village will be covered by water. The ore bodies are relatively small. Reports (Carne 1908) show that the ore is a chalcopyritic lens which occurs over a length of 1,300 feet. The width of the lens ranges from 8-18 inches.

An average sample (Carne 1908, p.386) returned -

Copper	..	..	8.25 per cent
Gold	..	..	2 dwts. 4 grs.
Silver	..	..	8 dwts. 17 grs.

It is reported that the deposits cannot be worked at a profit because of inaccessibility, high working cost, and narrowness of the mineral veins.

C. Tunnel Lines.

(1) General.

The proposed tunnels from the Upper Murrumbidgee River storage west to Middle Creek will be approximately 11 miles long. Approximately $6\frac{1}{4}$ miles will traverse Silurian metamorphics intruded by a narrow body of granite, and $4\frac{3}{4}$ miles will be in Devonian quartzite, sandstone, tuff, shale, slate and lava.

* The fishermen's track, unfortunately, comes out at the edge of a gorge 1,500 to 2,000 feet above the river.

The principal problems in engineering geology are considered to be -

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

(ii) Controlling and handling inflow of water during construction.

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

These problems will only be encountered in certain sections of the tunnel line and depend on the type of rock, the extent of fracturing in the rock, the rainfall and the position of the tunnel relative to the surface and to the water table. They may involve grouting, lining or some other permanent support. The effects of these factors relative to the two main portions of the tunnel line are discussed in the succeeding section.

On inquiry, it was found that none of the local residents had experienced earth tremors at any time. However post-granodiorite intrusion movement may have developed fractures in the surrounding country rock.

(2) Murrumbidgee River - Power Station No. 3.

From the intake point at the eastern end, the tunnel will be for 6 miles in Silurian quartzite, sandstone, slate, tuffs and phyllite, $\frac{1}{4}$ mile in hornblende granodiorite, and $\frac{1}{2}$ mile in Devonian quartzite and slate. The Silurian rocks are steeply dipping with a meridional strike, and will cross the line of tunnel at right angles. The rocks are well jointed and show particularly strong joints parallel to and at approximately right angles to the bedding. These rocks are intruded by a lenticular hornblende granodiorite mass and contacts appear to be silicified or "sealed".

The tunnel will cross the Devonian quartzite and slate at right angles to the strike. These rocks dip west at 25^{o} to 30^{o} and unconformably overlie the Silurian metamorphics. The contact is probably a fault and a detailed investigation of this structural feature will be necessary.

The salient features of engineering geology in the section between the Murrumbidgee River and Power Station No. 3 are as follows :-

(a) From the intake the tunnel will probably lie in the zone of weathering for about $1\frac{1}{2}$ miles, where lining will be necessary to prevent leakage.

(b) Beyond this point, for nearly $5\frac{1}{4}$ miles, the tunnel will be below the water table from 100 to 500 feet beneath the zone of rock weathering, and without detailed mapping it will be necessary to estimate the amount of support required. Seepage from joints from along contacts between soft and hard rocks and from any major fault zones are the likely sources from which water will enter the tunnel in the Silurian rocks.

(c) The final $\frac{1}{2}$ mile of the tunnel will lie in Devonian sediments, which dip at 25-30 degrees approximately in the direction of the tunnel line. About half of this distance will be in the weathered zone and will probably need permanent support.

The presence of porous beds is not improbable, as they have been observed in other Devonian sections. Detailed geological mapping should prove or disprove the existence of such beds. Seepage is to be expected from joints and fault zones, but the volume of water struck in the tunnel is not expected to be large.

(d) The tunnel will probably intersect the faulted unconformity between Devonian and Silurian sediments about 1 mile east of Yarrangobilly River (see Section Plate 1). There is liable to be a significant inflow of water along this contact, which should dip westwards. Detailed work in this vicinity and possibly some drilling may be necessary. The tunnel may have to be lined in this section.

(e) The probable fault shown about 1 mile west of Tantangara Creek may be only a minor strike fault, but further investigation will be necessary.

(f) It is suggested that an investigation be made of water flow conditions in Mr. Conelson's Blue Creek Copper Mine (Plate 1). This mine is situated in gently dipping Devonian slates which are very strongly jointed. A copper mineral, namely, chalcopyrite, occurs in quartz lenses which fill fractures in the slates. The initial fractures appear to have been formed as tension fractures in the nose of a minor fold.

The water flow was mainly along joints, but was not significant. However, it is reported to increase markedly in the winter time when the rainfall is much higher. It was noted at the time of the investigation that the inflow of water decreased with distance into the hillside.

(g) The outcrop of Silurian limestone terminates $1\frac{1}{2}$ miles north of the proposed tunnel line, where it is overlain by Devonian slate and tuffaceous rocks. Pitch of the bedding of Silurian slates, which lie immediately below the limestone, is 50°S. It is probable, therefore, that the limestone either terminates $1\frac{1}{2}$ miles north of the tunnel line, or pitches at approximately 50° South, in which case it would still not intersect the proposed tunnel line.

(h) Detailed geological mapping of this tunnel line will be required to select the best route for the tunnel and to outline in more detail the engineering difficulties that are likely to be encountered.

(3) Power Station 3 - Power Station 4.

This part of tunnel line will lie entirely within interbedded Devonian quartzite, sandstone, tuffs, slate, conglomerates and lava. The beds are of varying thickness and have been folded to form a broad basin-like structure (see Section Plate 1). Dips of the sediments vary from 10-30 degrees. The strike of these rocks is approximately 45° to the line of the proposed tunnel.

No limestone will intersect the tunnel line.

The salient features of engineering geology of this portion of the tunnel line are as follows :-

(a) Water inflow into the tunnel line during driving is likely to be a significant problem in this area, particularly as some of the Devonian rocks are porous and likely to act as aquifers. Sediments which outcrop in the Yarrangobilly Valley dip 25-30 degrees south into the proposed tunnel line and may bring in water from the Yarrangobilly River.

Inflow of water may be expected from faults and from joints, many of which are strongly developed.

(b) Lining or permanent support may be necessary over a considerable distance of this tunnel line.

There will probably be a large inflow of water where the tunnel passes beneath the Yarrangobilly River. Permanent support will be necessary in this section.

(c) Before the exact position of the tunnel line is decided, detailed geological mapping will be essential. Structure contour maps of selected beds such as quartzite should be compiled in an attempt to confine the tunnel for the maximum distance in a suitable formation.

D. Other Sources of Constructional Materials.

Possible sources of materials, for cement making and for concrete aggregates, were briefly examined.

(1) Cement. Examination of the Yarrangobilly limestones and of slate and clayey slate deposits in the same locality suggests that it might be possible to establish a cement works in the construction area. Both rock types will have to be thoroughly sampled and tested. Analyses of the limestone (Carne and Jones, 1919) show that the constituent percentages are as follows :-

$CaCo_3$	$MgCo_3$	$MnCO_3$	Fe_2O_3 Al_2O_3	Organic Matter	Gangue
98.07	0.80	0.04	0.84	Nil	0.54
98.12	0.80	0.04	0.44	Nil	0.78

If the slates and clayey slates are found to be suitable coal alone would have to be transported to the area for use in cement production.

(2) Aggregates. Possible sources of concrete aggregates other than those investigated at the dam sites were briefly examined and samples of the following were collected :-

(a) Olivine basalt: Two localities are suggested, one at New Chum Hill near Kiandra and the other near Gooandra Trig. Site. At New Chum Hill there are large heaps of basalt boulders, in convenient piles, suitable for immediate use in a rock cracker without preliminary quarrying. These rocks were stacked by miners engaged in search for gold in deep leads underneath the basalt. This deposit is 11 miles from Dam Site No. 3 and 13 miles from Dam Site No. 4.

A considerable thickness of basalt is available near Gooandra Trig. site and a suitable site for a quarry could be easily selected.

For cartage of materials, the temporary road which runs from Rules Point almost to the No. 3 dam site could be used. However part of this road will be useless after the reservoir fills. About five bridges or fords will have to be built along this track.

(b) Sand: At New Chum Hill near Kiandra, the face of an open cut was observed, which showed basalt overlying Tertiary sand and river deposits. A cross section (Plate 2), copied from New South Wales Geological Survey Report No. 10, shows that a thickness of up to 45 feet of sand is present.

A sample collected was fairly fine grained, and of uniform grain size. The grains were angular, and not affected by ironstaining - they were counted under the microscope without any preliminary washing, with the following results.

Quartz	63%
Felspar (converted partly or wholly to kaolin)	36%
Chlorite, etc.	1%

No chalcedonic or cryptocrystalline quartz was observed, and there is no apparent reason why this sand should not be a suitable source of material for concrete.

VI. FUTURE GEOLOGIC INVESTIGATION

Future geologic investigation should include -

(i) a detailed survey of the tunnel line on a scale of say, 500 feet to the inch;

(ii) compilation of a plan of the Murrumbidgee-Tumut area showing the sources and quantity of suitable rock materials for engineering construction;

(iii) a detailed survey of power station sites;

(iv) a general survey of proposed water race lines.

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APPENDIX I.

DESCRIPTION OF ROCKS IN THIN SECTION.

DEVONIAN SEDIMENTS AND VOLCANICS.

Specimen No. V.39 ✠

(5¾ miles east-south-east of No. 4 Dam Site).

In the hand specimen the rock is reddish-brown, not particularly friable, coarse but fairly even-grained. Quartz grains and occasional mica flakes can be determined with the naked eye.

In thin section, quartz, which in some cases shows strain shadows, is present as grains which are commonly enclosed in larger fragments of light-coloured microcrystalline material, evidently of volcanic or intrusive origin. In places the quartz is partly resorbed into the enclosing groundmass, which commonly contains opaque iron ores.

Also present are yellow grains composed largely of sericitic and argillaceous material, and a few grains of muscovite and chlorite. In some cases the borders of the grains are outlined by black cementing material which is reddish in reflected light. This cement is very sparse. The reddish colour of the rock in hand specimen is presumably due to these iron stains.

The percentage composition of the rock is difficult to assess accurately. Large quartz grains probably make up 70 per cent. of the whole.

The rock is a tuffaceous grit.

Specimen No. J.21

(4 miles east of No. 4 Dam Site).

Macroscopically the rock is red, coarse, granular, but even-grained and slightly friable. The colour of the individual grains varies from black, through red (which is dominant) to white.

Microscopically, quartz appears as phenocrysts in individual glassy to cryptocrystalline fragments. These fragments are quite angular and quartz has, in places, been resorbed into them. Some of the material of the groundmass is composed of tiny lathes of felspar, some of microspheralitic quartz which gives a poor cross under crossed nicols, and some of dark, ashy material.

The cementing material is generally ironstained, and is probably argillaceous. It is not abundant.

Quartz comprises about 30 per cent. of the rock, the remaining 70 per cent. being cryptocrystalline and glassy material, ash, cement, etc. The mineralogical composition of the rock, and its texture, shows that it is a tuffaceous grit.

✠ Note: Numbers refer to samples collected in the field. The position of all these samples is plotted on the plan of the Murrumbidgee-Tumut area. (Plate 1).

Specimen No. J.50.

(4 miles south-east of Jounama Homestead).

In the hand specimen the rock is hard, blue-grey and very fine-grained, with conchoidal to subconchoidal fracture.

In thin section the rock can be seen to contain fine grains of angular quartz and occasional felspar, quite fresh in appearance, scattered throughout a brown, very fine-grained argillaceous base. Black iron ores are also present.

The rock is too fine-grained for a completely satisfactory determination by microscopic methods, but appears to have been originally a volcanic ash. It is used as a surface cover for roads in the Yarrangobilly area.

Specimen No. J.43A

($3\frac{1}{4}$ miles north-north-west of Jounama Homestead).

Macroscopically, the rock is hard, greenish, and evengrained, with fairly well-defined lamination. Angular quartz and mica may be seen with the naked eye.

Thin section examination shows that the quartz makes up about 70 per cent. of the rock. It is very angular, often has strain shadows, and shows all gradations between medium and fine-grained fragments. The matrix is composed essentially of the fine quartz and sericite.

Also present are black iron ore grains, chlorite, sericitized felspar, occasional thin flakes of biotite and very rare grains of tourmaline.

This rock is a fine-grained quartz-rich hornfels.

Specimen No. J.43B.

($3\frac{1}{4}$ miles north-north-west of Jounama Homestead).

Macroscopically the rock is pink, fine-grained, fairly soft, argillaceous and well laminated.

Thin section examination shows that a fine matrix of argillaceous material, stained brownish red due to iron oxidation, makes up 75 per cent. of the rock. Quartz, as small angular grains, a little felspar, occasional black iron-ore grains and sericite shreds comprise the remaining 25 per cent.

The rock is a clay slate.

Specimen No. J.80.

($1\frac{1}{4}$ miles south-west of Jounama Homestead).

In the hand specimen the rock is grey, non-friable and even-grained, with white grains of quartz and felspar, and dark grains of ferromagnesian and ashy material.

Thin section examination shows that the rock is made up of fragments of microcrystalline, cryptocrystalline and glassy material, very similar in appearance to the groundmass of the Silurian granodiorite porphyries to the east. The fragments are sometimes grey and contain numerous small felspar lathes.

Quartz grains occur in the fine-grained fragments as phenocrysts which may show strain shadows and partial resorption. Andesine, strongly sericitized, and chlorite, derived from euhedral ferromagnesian crystals, are also present as phenocrysts in the fine grained angular fragments.

Other material noted is chlorite, ilmenite altered to leucoxene, ash and a little argillaceous matter.

The percentage composition is as follows -

Quartz grains	50
Andesine grains	10
Chlorite, ilmenite	3
Fine-grained to cryptocrystalline material and ash	37.

The rock is a tuffaceous grit.

Specimen No. J.55

(3½ miles south-east of Jounama Homestead).

Macroscopically the rock is grey, closely compacted, and finely and evenly grained. It is composed of quartz, dark grey grains and occasional flakes of mica.

Microscopic examination shows that quartz is prominent as angular fragments, which make up about 40 per cent. of the rock. Larger fragments of grey cryptocrystalline material, commonly containing tiny sub-parallel lathes of felspar, and inclusions of iron ore, make up about 59 per cent. of the rock. The cementing medium is mainly micaceous and argillaceous. An occasional grain of calcite may be seen.

This rock is a tuffaceous sandstone.

SILURIAN SEDIMENTS.

Specimen No. J.77

(No. 3 Dam Site).

The hand specimen is hard, grey, medium to fine grained and non-friable, consisting of cemented quartz grains.

Quartz, the dominant constituent of the rock, occurs as anhedral interlocking grains which form a mosaic structure. Some of the quartz grains are components of wider vein like intrusions which pervade the rock. Much of the quartz - possibly 50 per cent. - is very finely divided and interstitial and is associated with sericite.

Magnetite as small grains and a few zircons, as small euhedral crystals, are scattered throughout the slide.

The percentage composition is as follows :-

Quartz	93
Sericite	6
Accessories	1.

The interlocking mosaic structure of the sample and the dominant percentage of quartz indicate that the rock is quartzite.

Specimen No. J.69.

(5 miles north-east of No. 3 Dam Site).

This rock is blue, fine-grained and well compacted, and consists of at least 90 per cent. interlocking quartz grains.

The microstructure is an interlocking mosaic of angular quartz grains, commonly with strain shadows. The quartz grains show considerable variation in size and some quartz is very finely divided.

Sericite is fairly abundant, while square, strikingly euhedral grains of pyrite are present. A few flakes of muscovite may be seen.

The percentage composition is as follows :-

Quartz	90
Sericite	9
Pyrite	1.

This rock is a slighly impure quartzite.

Specimen No. J.79

(No. 3 Dam Site).

In the hand specimen the rock is light grey, medium grained, uniform and non-friable.

Under the microscope it appears as an interlocking mosaic of angular quartz grains, some of which show strain shadows. Apart from quartz, the only minerals present are a few shreds of biotite and muscovite and odd grains of black iron ore. Reddish iron stains are present in places.

The percentage composition of the quartzite is as follows -

Quartz	98
Mica, iron ore	2.

The interlocking structure of the rock, and its high quartz content, shows that it is a quartzite.

Specimen No. J.78.

(No. 3 Dam Site)

Macroscopically the rock is blue-green, very fine grained, soft, argillaceous and well bedded.

Microscopic examination shows that the fine grained matrix of the rock is made up of finely divided quartz with sericitic and chloritic material. Iron stains are common.

Ilmenite is present as occasional grains which have been altered to leucoxene.

The percentage composition is difficult to assess accurately, but the finely divided quartz probably makes up at least 50 per cent. of the rock.

This rock is a fine-grained silt stone.

Specimen No. V.11.

(6 miles west-south-west of No. 3 Dam Site).

In the hand specimen the rock is hard, dark grey, fine grained and uniform, with conchoidal fracture.

The matrix is very fine-grained, and contains small angular fragments of quartz and subhedral fragments of plagioclase. The long axes of the quartz fragments are sub-parallel in general, but numerous grains show no such orientation. Black iron ore, clearly not of detrital origin, and a few flakes of biotite are present.

The very fine-grain of the rock renders determination difficult. It is probably a hornfels derived from dacitic volcanic ash.

Specimen No. J.24.

(4½ miles south-south-east of No. 4 Dam Site).

Macroscopically this is grey, non-friable and argillaceous with a schistose appearance. Quartz, felspar and ferromagnesian minerals can be seen in the hand specimens.

In thin section, quartz is present as large irregular grains often showing undulose extinction, and as fine irregular veinlets which pervade the rock. The plagioclase is subhedral to euhedral and seems to have grown by some process of felspathization. It is part altered to sericite.

Chlorite is abundant. Leucoxene, derived from skeletal ilmenite grains, is present and the rock is in places coloured by reddish brown iron stains.

The percentage composition is as follows :-

Quartz	60
Felspar	25
Chlorite	12
Leucoxene	3.

The mineral content, and the appearance of the plagioclase, indicates that the rock is a felspathized argillaceous sediment.

Specimen No. J.57A.

(8 miles west of Currango Homestead).

Macroscopically the rock is hard, green, and fairly uniform with faint bedding.

In thin section the base of the rock appears very fine-grained and tuffaceous - it is made up of epidote, orthoclase, leucoxenised ilmenite and abundant chlorite. Scattered throughout the base are angular fragments of quartz and felspar which have no general orientation.

The rock is a trachyte or andesite tuff.

Specimen No. J.57B.

(8 miles west of Currango Homestead).

The hand specimen is grey-green, soft, well laminated and very fine grained.

Thin section examination emphasises both the bedding and the fineness of the constituent grains. Chlorite is abundant, while quartz and plagioclase occur as fresh and very angular fragments. Ilmenite seems totally converted to leucoxene. The percentage composition has been estimated as follows -

Quartz	47
Chlorite	40
Plagioclase	10
Leucoxene	3.

This rock is a trachyte or andesite volcanic ash.

Specimen No. J. 1.

(Gooandra Trig. Station).

The hand specimen is porphyritic, with small scattered olivine phenocrysts in a very fine-grained, dark coloured ground mass.

The micro-structure is hemicrystalline and porphyritic, with phenocrysts of olivine in a brownish groundmass which shows gradations between microcrystalline and glassy. Tiny grains of plagioclase, olivine and iron ore may be distinguished in portions of the ground mass. The remainder is made up of brown, glassy and cryptocrystalline material.

The euhedral phenocrysts of olivine, which show a rough parallelism, may be altered to brown iddingsite.

The percentage composition of the rock is as follows -

Olivine phenocrysts	5
Groundmass	95.

This rock is an olivine basalt.

Specimen J. 90.

(3¼ miles west-north-west of Jounama Homestead).

Macroscopically this is a somewhat indistinctly banded, greyish-pink rock carrying porphyritic crystals of felspar up to 2.5 mm. long in a fine-grained groundmass.

In thin section the banding shows up very faintly and then only between crossed nicols. This is due to the fact that the groundmass is largely spherulitic. The spherules average 0.15 to 0.2 mm. in diameter and are composed of clouded plagioclase. Rather scattered, irregular grains of interstitial quartz, of grainsize similar to that of the spherules, make up between 5 and 8 per cent. of the rock.

Granules of black iron ore are fairly evenly distributed, though in some places rows of granules are arranged in a radiating manner within spherules. Small quantities of limonite and leucoxene are present.

With the exception of one grain of embayed quartz the only porphyritic crystals noted were felspar; they make up about 10 per cent. of the rock. No trace of ferromagnesian could be found. Among the felspars plagioclase predominates it anorthite content is 34 per cent. and it shows slight alteration to sericite and kaolin. A very small percentage (probably less than 3 per cent.) of clouded crypto-perthite is also present. Both felspars are subhedral and are fairly commonly in glomero-porphyritic aggregates.

The rock is a spherulitic dacite.

Specimen No. J. 91.

(3¼ miles west-north-west of Jounama Homestead).

Macroscopically this rock consists of purple-grey apparently felsitic groundmass in which are set porphyritic crystals of felspar of various sizes up to 6 or 7 mm. No sign of flow-banding is evident. The ratio of groundmass to porphyritic crystals is about 4 to 1.

About 90 per cent. of the groundmass is clouded plagioclase; most of it averages about 0.15 mm. in grainsize though, in some parts, it grades down to 0.02 mm. or lower.

The plagioclase is untwinned; the individual grains interlock and their shapes are quite irregular. Black iron ore in rods, granules, and strings of granules, dusty haematite and a little quartz make up the rest of the groundmass. A few veinlets and pockets of quartz with haematite and magnetite are present.

The phenocrysts of plagioclase ($Ab_{70}An_{30}$) are generally only very slightly altered to sericite and kaolin; a few of them, however, are extensively replaced by black iron ore and haematite. Some of the crystals have been rounded by corrosion, but most of them are subhedral. A few glomero-porphyritic groups of plagioclase grains were noted.

Porphyritic quartz makes up probably only about 2 or 3 per cent. of the whole. The grains are generally rounded through corrosion.

Black iron ore surrounded by haematite is the only primary accessory.

The rock is a porphyritic dacite.

These two rocks, J. 90 and J.91, differ in colour, structure, texture, percentage of felspar phenocrysts and in composition of plagioclase; furthermore, J.90 contains a little potash felspar, whereas J.91 does not. However, the field evidence shows that they are both volcanic rocks, and they were collected within about 25 feet vertically of each other. It is virtually certain that each rock represents a separate flow.

PORPHYRIES.

Specimen No. J. 71

(1¼ miles south-south-west of Dam Site No. 3).

Macroscopically this rock is grey, massive and porphyritic, with phenocrysts of felspar and a ferromagnesian mineral.

In thin section it is holocrystalline and porphyritic, with phenocrysts of plagioclase and monoclinic pyroxene in a groundmass of quartz and felspar.

The plagioclase, which has been determined as bytownite, is euhedral to subhedral, with occasional rounded residua which are bordered by quartz containing a felted mass of small, less basic plagioclase crystals. The bytownite is strongly sericitized.

Monoclinic pyroxene has been converted to actinolite and then to chlorite in places. In some cases biotite seems to have formed directly from the pyroxene, and may be altered again to chlorite.

Black iron ore, which forms about 1 per cent. of the rock, has been partly altered to leucoxene.

The sample has been tentatively called an augite lamprophyre, largely because of the subhedral and euhedral outline of both the plagioclase and pyroxene phenocrysts. Nevertheless the basic composition of the plagioclase suggests strongly that the rock may be a gabbroic-xenolith in the porphyry intrusive. Sample J.61, taken farther north in the same intrusive, is a normal granodiorite porphyry.

The percentage composition of J.71 is as follows -

Phenocrysts	(Pyroxene	20
	(Plagioclase	20
Iron ore and leucoxene		1
Groundmass		59.

This determination shows that the sample is an augite lamprophyre.

Specimen No. J. 61.

(1¼ miles north-north-west of Currango Homestead).

In the hand specimen this sample is grey-green, massive and porphyritic with clearly discernible phenocrysts of quartz and felspar.

Microscopically it is hemicrystalline and porphyritic with phenocrysts of quartz (often showing resorption), felspar, and a ferromagnesian mineral which has been completely serpentinized. The altered ferromagnesian is quite euhedral in outline, and may commonly contain pleochroic haloes due to zircon inclusions. The plagioclase phenocrysts, determined as andesine, are sericitized, and ilmenite has been converted to leucoxene.

The groundmass, which is felspathic and silicious, is sufficiently fine-grained in places to be classed as cryptocrystalline.

The percentage composition of the rock is as follows -

Phenocrysts	Quartz	12
	Serpentine	12
	Felspar	11
Accessories (Zircon, ilmenite)		2
Groundmass		63.

This sample is a quartz-felspar porphyry.

Specimen No. J.28.

(No. 4 Dam Site).

This rock is massive, crystalline, pink and apparently even-grained, with visible grains of felspar, chlorite and quartz.

Under the microscope it is holocrystalline and pseudoporphyritic, with euhedral phenocrysts of quartz in a groundmass of micrographically intergrown quartz and orthoclase. The felspar is sericitized, and chlorite, apparently an alteration product of large grains of some ferro-magnesian mineral, is also present.

The groundmass is somewhat richer in orthoclase than quartz - these minerals have obviously crystallized out simultaneously. All orthoclase is stained a light yellow brown, presumably due to the concentration of iron in the final stages of consolidation of the magma.

The percentage composition of the rock is as follows -

Phenocrysts.	Andesine	38
	Quartz	5
	Chlorite, possibly from a ferromagnesian phenocryst	2
Accessories (Iron ore, apatite)		2
Orthoclase-quartz intergrowth		53.

The type of mineral content present indicates that the rock is a granophyric adamellite.

Specimen No. J.81.

(No. 4 Dam Site).

This rock is essentially similar to J.28 (described above) except that hornblende, altered in places to chlorite, occurs as occasional grains 4 mm. in diameter. The percentage composition is as follows -

Phenocrysts	Andesine	35
	Quartz	9
	Hornblende	5
Accessories	.. ..	1
Quartz-orthoclase intergrowth	.. ..	50.

Specimen No. J.47.

($4\frac{1}{4}$ miles east-north-east of Jounama Homestead).

In the hand specimen this rock is grey, massive and porphyritic, with phenocrysts of quartz and felspar in a fine groundmass.

The micro-structure is porphyritic and holocrystalline with subhedral, sericitized and zoned andesine, and quartz, commonly partially resorbed, as the most prominent phenocrysts. Actinolite, subordinate in amount to the quartz and felspar, is associated generally with chlorite and epidote.

The groundmass, which is silicious and felspathic, is microcrystalline, and shows the remnants of what were apparently once perlitic cracks. These are now filled with dusty material and chlorite. The general appearance of the groundmass indicates that it may have once been glassy, and that devitrification has since taken place.

Accessory apatite, as six-sided crystals, and ilmenite, usually altered to leucoxene, constitute about 2 per cent. of the rock. The overall percentage composition is as follows -

Phenocrysts	Felspar	1
	Quartz	9
	Ferromagnesians ..	5
Accessories	.. .. ..	2
Groundmass	.. .. ..	73.

This rock is a quartz-andesine-porphyry.

GRANITES.

Specimen No. V.21

(6 miles south-west of No. 3 Dam Site).

Macroscopically this sample is light grey, holocrystalline, massive and coarse grained. Quartz, felspar and a ferromagnesian constituent can be distinguished in the hand specimen - the rock has a slightly gneissose appearance.

Microscopically the rock is holocrystalline with an allotriomorphic granular texture. The plagioclase, probably an intermediate andesine, is altered to sericite, and, on the whole, seems somewhat more euhedral than the orthoclase. Biotite, as irregular flakes, and hornblende as subhedral elongate grains, both contain numerous inclusions of accessory iron ore. Apatite is a rare accessory.

The percentage composition of the rock is as follows -

Quartz	35
Plagioclase	32
Orthoclase	28
Biotite	5
Hornblende	1
Accessories	1

This rock is determined as an adamellite.

Specimen No. G.5.

(5 miles east-north-east of No. 3 Dam Site).

In the hand specimen G.5 is a coarse, uneven-grained grey rock containing quartz, felspar and aggregates of biotite grains.

Microscopically the sample is holocrystalline and allotriomorphic granular, with considerable variation in grain size.

Plagioclase, altered considerably to sericite, is the dominant constituent of the rock - its composition is that of an intermediate andesine. Alkali felspar is represented by microcline perthite, and makes up only 5 per cent. of the whole.

Biotite is characteristally present as clots or aggregates and is very fine grained - it commonly contains pleochroic haloes due to accessory zircon. Some biotite is altered to chlorite.

The coarse, uneven nature of the constituent grains together with the biotite clusters, gives the specimen an unusual appearance. The texture is certainly not typical of that produced by the normal crystalline of an igneous mass - it suggests rather, a hybrid origin for the rock.

The percentage mineral composition is as follows :-

Plagioclase	48
Quartz	38
Microcline	7
Biotite	6
Accessories	1.

The presence of these minerals indicates that the specimen collected is a granodiorite.

Specimen No. V.26.

(6 miles west of No. 3 Dam Site).

This rock is massive, grey and fine-grained, with a slightly gneissic structure. Quartz, felspar and a ferromagnesian mineral may be distinguished in the hand specimen.

Under the microscope the rock is holocrystalline and even-grained, with an allotriomorphic granular texture.

Plagioclase, often fairly euhedral, has the composition of a sodic andesine. It often shows zoning, and is partly converted to sericite.

Hornblende is fairly abundant as elongate, tabular and subhedral grains which are in some cases partly altered to chlorite. Both sphene and epidote are generally associated with the hornblende, which also contains numerous inclusions of opaque iron ore.

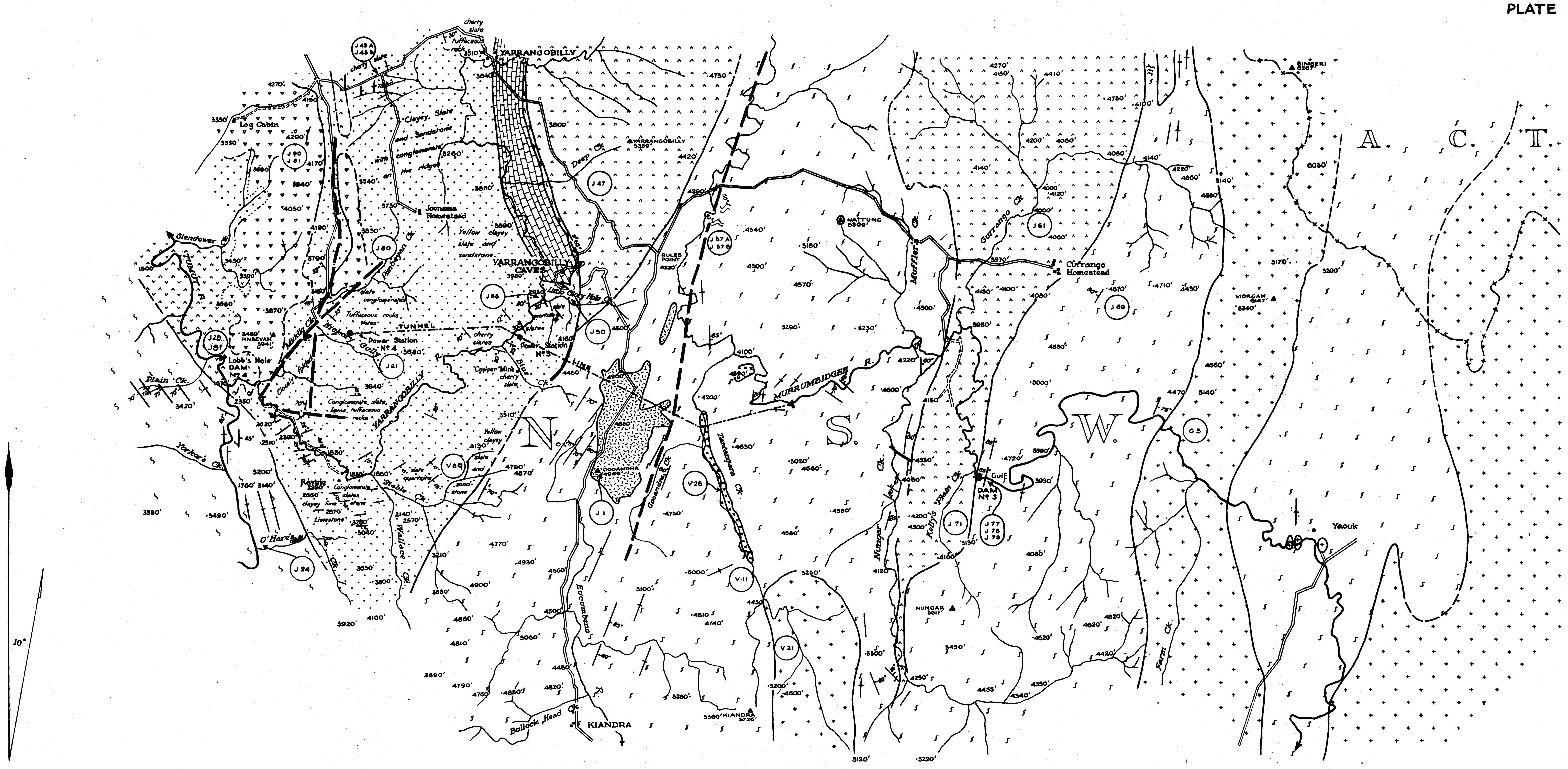
Quartz is present mainly as small, anhedral grains which occur interstitially.

The percentage composition is as follows -

Plagioclase	77
Hornblende	10
Quartz	10
Ilmenite and leucoxene	2
Epidote	1
Apatite, sphene, zircon	1.

This rock is a hornblende granodiorite.

PLATE I

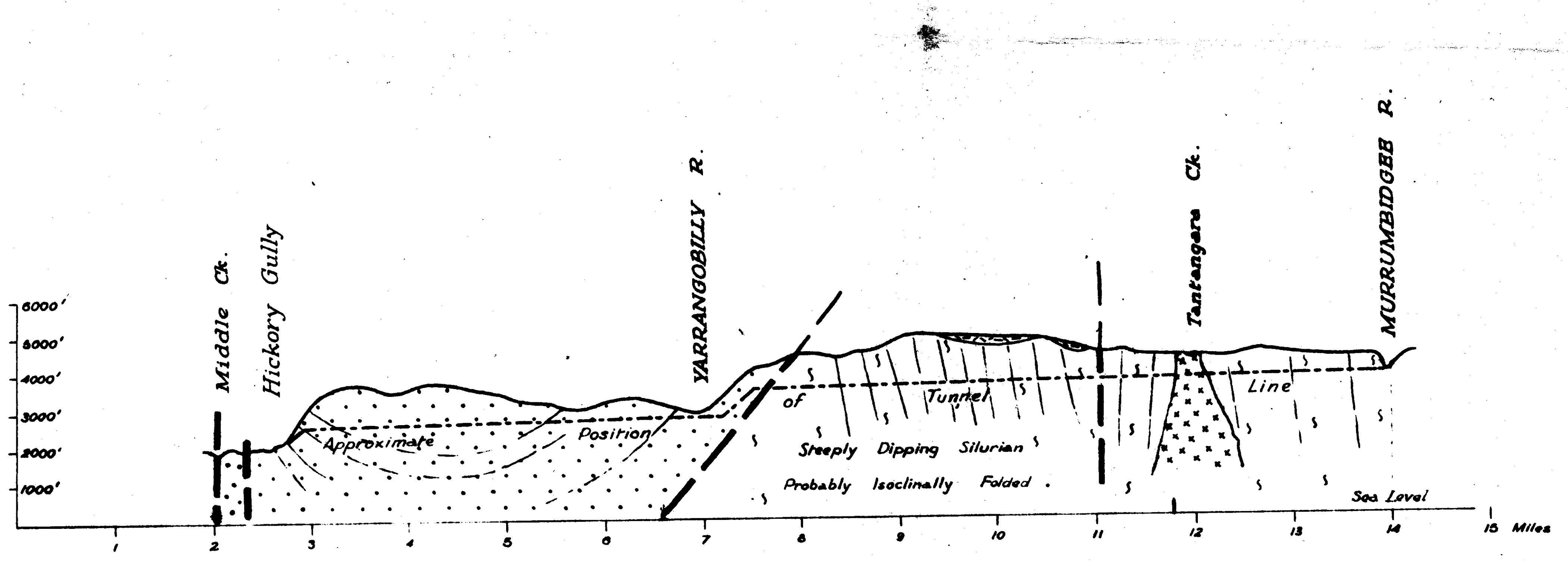


MURRUMBIDGEE - TUMUT RIVER POWER SCHEME

RECONNAISSANCE GEOLOGICAL MAP

Geology by J.F.Ivanac, J.E.Glover, W.A.McKinnon, & J.J.Veevers

MILES 2 1 0 1 2 3 4 5 6 7 8 MILES



GEOLOGICAL SECTION ALONG PROPOSED TUNNEL LINE

LOOKING NORTH

Heights From 'Snow Leases' map.

TERTIARY	*Olivine Basalt.*		*Dacite*
DEVONIAN	*Quartzite, Slate, Tuff, Sandstone, Conglomerate, Lavas, Limestone.*		*Porphyry* / *Granophyric Adamellite*
SILURIAN	*Limestone.*		*Hornblende Granodiorite*
	Metamorphics.		*Biotite Granodiorite*
	Probable Fault		*Bedding Dip & Strike* (Vertical)
	Minor Folds		
	Rock Samples (See Report Appendix) J45		

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WD. March '49.

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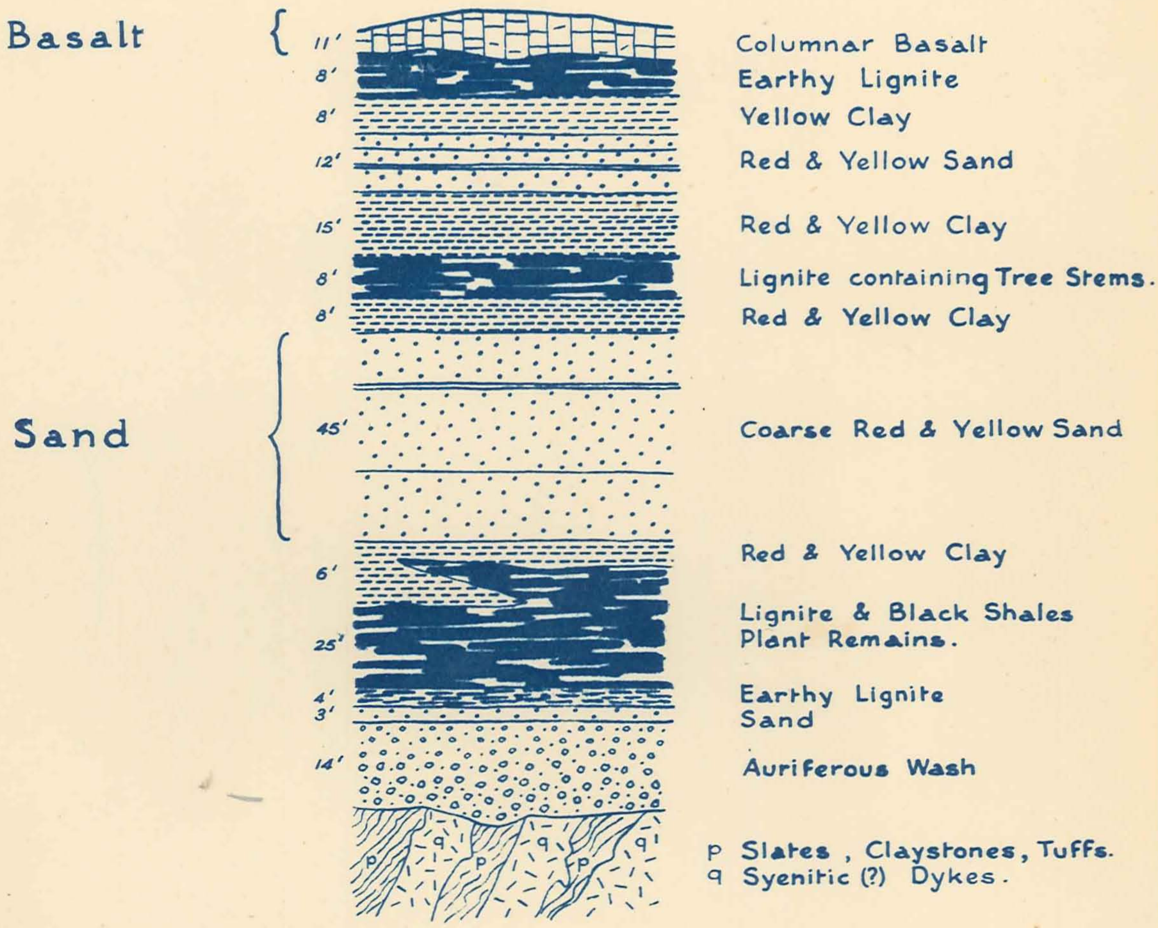
PLATE 2



SECTION OF WORKING FACE NEW CHUM HILL, KIANDRA LEAD

SHOWING 45 FT. SAND & 11 FT. BASALT

Traced from Report on Kiandra Lead by E.C. Andrews (1901)

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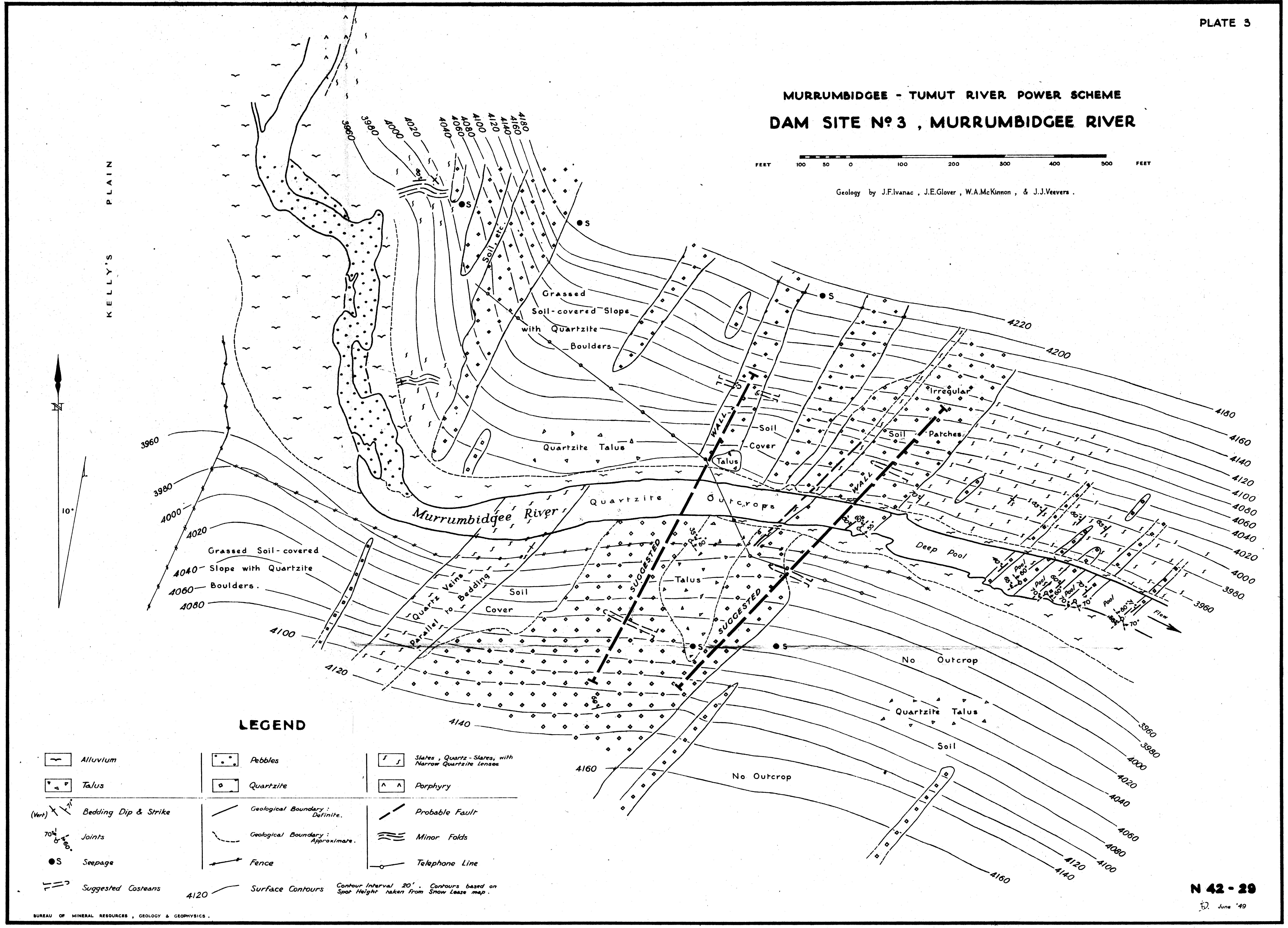
N 42-28

J.D. JUNE '49


MURRUMBIDGEE - TUMUT RIVER POWER SCHEME
DAM SITE Nº 3, MURRUMBIDGEE RIVER
FEET 100 50 0 100 200 300 400 500 FEET
Geology by J.F.Ivanac, J.E.Glover, W.A.McKinnon, & J.J.Veevers.
KELLY'S PLAIN
N
10°
Murrumbidgee River
Grassed Soil-covered Slope with Quartzite Boulders
Grassed Soil-covered Slope with Quartzite Boulders.
Soil etc.
Quartzite Talus
Quartzite Outcrops
Talus
Soil Cover
Irregular Soil Patches
WALL
SUGGESTED
Quartz Veins Parallel to Bedding
Soil Cover
Deep Pool
Pool
No Outcrop
Quartzite Talus
Soil
No Outcrop
Flow
LEGEND
Alluvium
Talus
Pebbles
Quartzite
Slates, Quartz-Slates, with Narrow Quartzite Lenses
Porphyry
(Vert) Bedding Dip & Strike
Joints
Seepage
Suggested Costeans
Geological Boundary: Definite.
Geological Boundary: Approximate.
Fence
Surface Contours
Contour Interval 20'. Contours based on Spot Height taken from Snow Lease map.
Probable Fault
Minor Folds
Telephone Line
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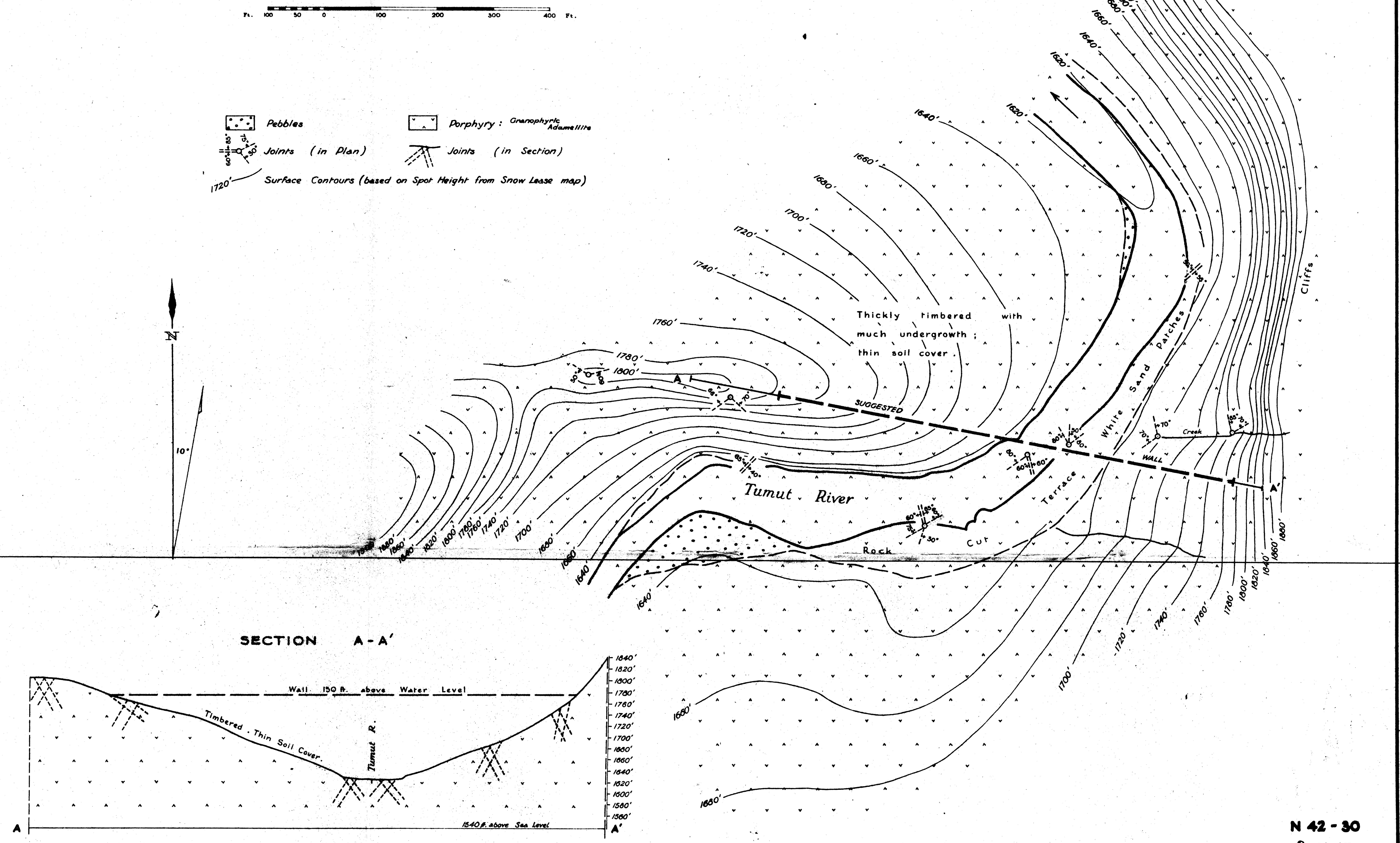
June '49

PLATE 4

MURRUMBIDGEE - TUMUT RIVER POWER SCHEME

DAM SITE No 4, TUMUT RIVER

Geology by J.F.Ivanac, J.E.Glover, W.A.McKinnon, & J.J.Veevers.



N 42 - 30

July '49.

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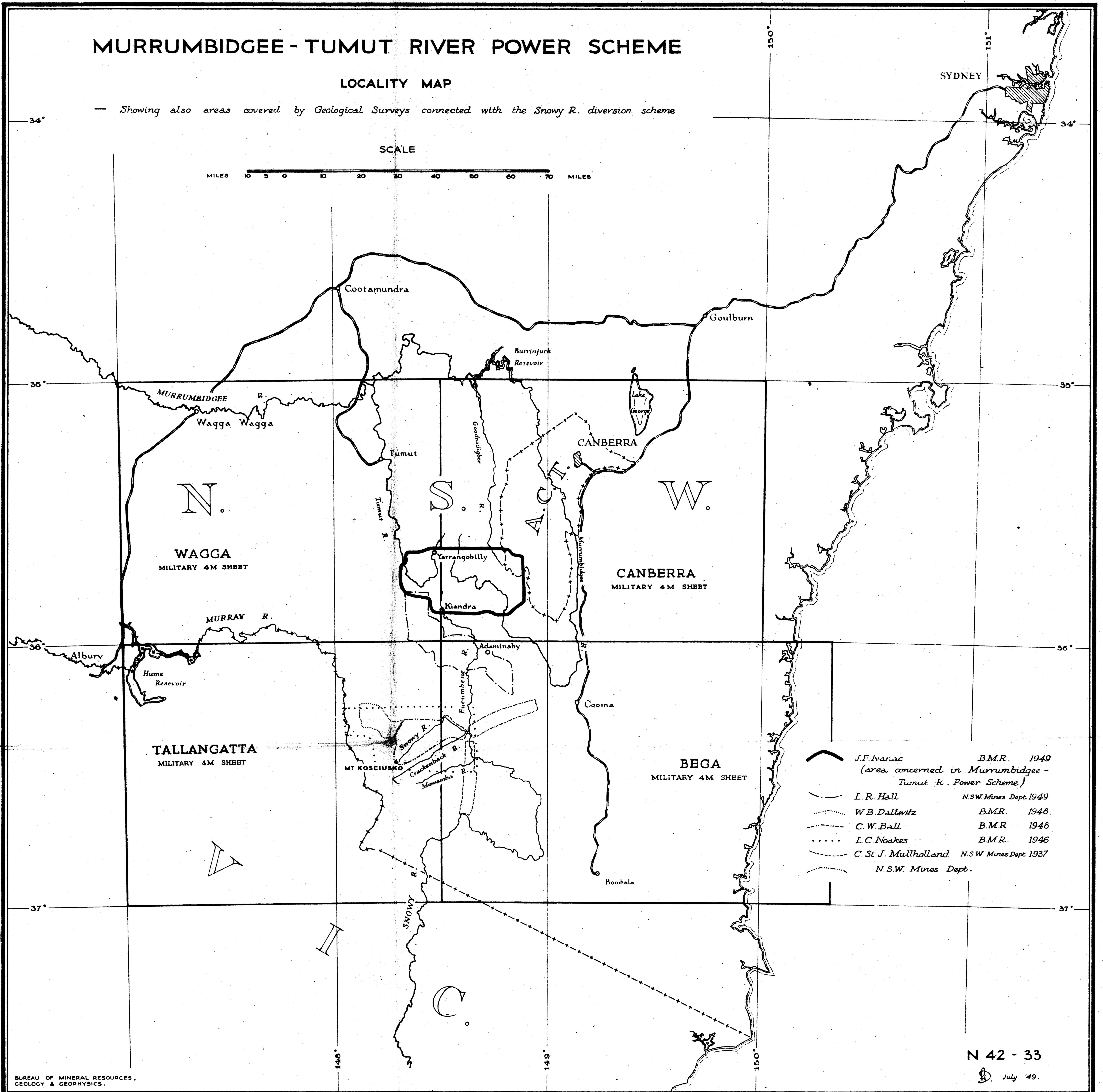
MURRUMBIDGEE - TUMUT RIVER POWER SCHEME
LOCALITY MAP
— Showing also areas covered by Geological Surveys connected with the Snowy R. diversion scheme
SCALE
MILES 10 5 0 10 20 30 40 50 60 70 MILES
SYDNEY
Cootamundra
Goulburn
Burrinjuck Resevoir
MURRUMBIDGEE R.
Wagga Wagga
Lake George
CANBERRA
Tumut
Goodradigbee R.
A.C.T.
N. S. W.
Tumut R.
Murrumbidgee
WAGGA
MILITARY 4M SHEET
Yarrangobilly
Kiandra
CANBERRA
MILITARY 4M SHEET
MURRAY R.
Albury
Hume Resevoir
Adaminaby
Eucumbene R.
Cooma
Snowy R.
TALLANGATTA
MILITARY 4M SHEET
MT KOSCIUSKO
Crackenback R.
Mowamba R.
BEGA
MILITARY 4M SHEET
J.F. Ivanac B.M.R. 1949
(area concerned in Murrumbidgee - Tumut R. Power Scheme)
L.R. Hall N.S.W. Mines Dept. 1949
W.B. Dallwitz B.M.R. 1948
C.W. Ball B.M.R. 1948
L.C. Noakes B.M.R. 1946
C. St. J. Mullholland N.S.W. Mines Dept. 1937
N.S.W. Mines Dept.
Bombala
SNOWY R.
V I C.
34° 35° 36° 37°
148° 149° 150° 151°
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July '49.
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