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DAM SITES IN THEUPPER COTTER VALLEY BETWEEN BUSHRANGERS AND COLLINS CREEKS.

by

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MINERAL RESOURCES SURVEY.

DEPARTMENT OF SUPPLY & SHIPPING.

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Report No. 1946/12.

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I. SUMMARY.

1. Four possible dam sites were examined along the Upper Cotter River between Bushrangers and Collins Creeks.

2. The geology of the area consists of an older formation of phyllite, the Franklin formation, and a younger formation of quartzite, the Tidbinbilla quartzite, separated by a major normal fault. Both formations have been intruded by biotite granite.

3. The suitability of the area for the construction of a dam has been examined with regard to seismic activity, the effect of loading due to impounded water, and the possibility of leakage of water from the storage. The investigation of seismic activity in the Australian Capital Territory is not yet complete, but the available evidence suggests that earth tremors in the Cotter River area are likely to be of low intensity, and that, although it is possible, it is unlikely that movement will take place along the Cotter fault.

4. Consideration of these regional factors indicates that the dam should be constructed at as great a distance as possible from the Cotter fault and in such a position as to impound the minimum depth of water over the fault zone. Site B is therefore considered the best site for a retaining wall.

5. The geological feature of each of the four sites have been briefly discussed, and the order of preference established as B, C, A, D.

6. Engineering geology at Site B has been discussed in detail and there appear to be no serious disadvantages to the construction or maintenance of a stable dam at this site.

7. The supply of rock suitable for use as aggregate has been investigated. Quartzite, river gravels and porphyritic granite should all be suitable for this purpose, and adequate supplies of these rocks occur in the vicinity of Site B.

8. There are no readily available supplies of natural sand along the Cotter River in this area, but limited quantities can probably be obtained by screening the river gravels in the flats and terraces. Artificial sand could be prepared from quartzite by grinding, washing and screening.

II. INTRODUCTION.

A. GENERAL.

In November, 1945, the Department of Works and Housing requested that a Geological Survey be made of a section of the Upper Cotter Valley in which it is proposed to construct a dam. Four provisional sites had been selected in 1908 by surveyors of the Lands Department of New South Wales, and these and any other possible sites were to be examined.

A preliminary examination, in conjunction with Mr. Thornton, Superintending Civil Engineer of the Department of Works and Housing, was made on 3rd December. The field work was subsequently carried out by Messrs. Noakes, Dimmick and Hawkins who spent nine days in the area from 11th to 19th December, 1945.

This report deals with the geology of the area examined with special reference to possible dam sites. The section on general geology has been made more detailed than is strictly necessary from an engineering point of view because no previous geological work has been carried out in the area. The report is also intended as a basis for future regional work in the area lying west of the Murrumbidgee River where little is known of the geological structure and stratigraphical sequence.

B. LOCATION AND ACCESS.

The Cotter River forms part of the Murrumbidgee watershed. It rises between Mounts Kelly and Bimberi in mountainous country near the southern border of the Territory, and flows north for about 35 miles to its confluence with the Murrumbidgee 10 miles west of Canberra. The existing dam is situated on the Cotter River about 1½ miles from its junction with the Murrumbidgee. The stretch of the river which includes the new dam sites extends over approximately 4 miles of the Upper Cotter River, between Bushrangers and Collins Creeks, and due west of Mount Tidbinbilla. (See Plate 1).

This section of the Cotter Valley lies in rugged country in which there are no roads or established tracks. The nearest road is that which runs from Uriarra to Mount Franklin and follows the Cotter-Goodradigbee Divide. This road gives access to the western side of the Upper Cotter Valley. A graded horse or tractor road has been constructed from Bendora, a forestry camp 6 miles north of Mount Franklin and about 42 miles by road from Canberra, down a prominent spur into the Cotter Valley. This track ends at a hut about (half a mile) west of the mouth of Bushranger Creek and approximately 570 feet above the Cotter River. Supplies and equipment can be taken as far as this hut - by motor truck to Bendora, thence by tractor and sledge down the graded track - but beyond the hut transport is at present limited to packhorses. Considerable difficulty would be encountered in moving pack horses downstream but a rough pack track has been established upstream for approximately 2¾ miles to the mouth of Cow Flat Creek and horses could be taken farther upstream, at least to the vicinity of site D. A loaded pack horse takes approximately 1 hour to travel from the hut to Cow Flat Creek.

C. MAPPING.

The only base map of the area available was the Feature Map of the Australian Capital Territory, on a scale of a little over 2 miles to the inch, but this scale was too small and the map too inaccurate for use as a base map for geological work on the Cotter River. A base map of the relevant section of the Cotter Valley was therefore constructed from aerial photographs supplied by the Department of the Interior. The map was prepared directly from air photographs, without adjustments in scale due to variations in topography, and should therefore be regarded as a preliminary one. The scale was calculated to be 1,660 feet to the inch.

The geology of the area was mapped on to air photos in the field and transferred to the base map which is reproduced in Plate 1. It was not possible to cover the whole of the area, even in reconnaissance, and the geological boundaries established by field work were extended later by studying the air photographs. Boundaries determined from air photographs have been denoted by broken lines on Plate 1 to distinguish them from boundaries established by field work.

Prospective dam sites, selected in 1908, are shown on Plate 1, and lettered A, B, C, D, from north to south. On account of the scarcity of place names in the area, these site s will frequently be used in the report as points of reference.

Detailed plans of the Cotter River betwen possible sites A and D had been compiled by the New South Wales Land Department in 1908, and copies of these plans were used in detailed mapping along the course of the River. Reduced levels for points on the River and at the dam sites were taken from these plans and used for correcting numerous barometric traverses. Site B was mapped in detail by plane table and stadia and a detailed plan and section of the site appear in Plate 2.

III. PHYSIOGRAPHY.

The Cotter River flows through the mountainous country occupying the southern half of the Australian Capital Territory and bounded on the east and north-east by the Murrumbidgee River. There is a marked change in topography at the Murrumbidgee River, south of the Cotter Junction. Moderately dissected uplands occur on the eastern side of the river, but give way to rugged mountain country on the west. This abrupt change, although partly due to differential erosion, is generally accepted as evidence of block faulting which commenced in Tertiary time. The Murrumbidgee River is believed to mark the trend of a major normal fault with the upthrown block to the west-south-west and the down thrown block to east-north-east (Griffith Taylor, 1910).

Over most of its course the Cotter River lies in a valley gorge with the overlapping spurs and steep river sides common to youthful streams. The topography is, therefore, in many places emminently suitable for the construction of dams. However, the fall of the river is steep, approximately 45 feet to the mile, above Bushrangers Creek, and this, in conjunction with the youthful valley, would limit the storage capacity of the dam.

The straight northerly course of the Cotter River has been determined mainly by the northerly strike of the metamorphic rocks which it has eroded and partly by the northerly trend of a major fault which can be traced along the centre of the valley for at least 4 miles.

IV. GENERAL GEOLOGY.

A. INTRODUCTION.

The geological units mapped in the Upper Cotter Valley include phyllite, found on the western side of the valley and younger beds of quartzite, which outcrop east of the Cotter River. The quartzite has been faulted down into the phyllite along the Cotter Fault, which, in this area, closely follows the course of the Cotter River. Both phyllite and quartzite have been intruded by small bodies of granite.

Since no previous geological work had been carried out in the Upper Cotter Valley, it was necessary to name the igneous and metamorphic units which outcrop in the area.

This has been done in accordance with the system of classification and nomenclature of rock units prepared by Geological Societies in America in 1932 (Bartrum, 1939).

To avoid any confusion, the units mapped and named are set out below:-

Franklin formation:	A formation of metamorphic rocks consisting of phyllite, with some interbedded quartzite, which outcrops along the Cotter-Goodradigbee Divide and on the western side of the Cotter Valley for at least 10 miles north of Mount Franklin.
Tidbinbilla Quartzite:	A formation composed of quartzite, with rare bands of silicified shale; which extends over the eastern side of the Cotter Valley in the vicinity of Mount Tidbinbilla. The formation extends for at least 5 miles north and south of Mount Tidbinbilla and has been faulted down against the Franklin formation along the Cotter Fault.
Bendora granite:	A sill or elongated stock of biotite granite intruding the Franklin formation near Bendora, which lies on the Franklin road 6 miles north of Mount Franklin.
Cow Flat granite:	An apophysis or elongated stock of biotite granite which intrudes the Tidbinbilla quartzite along the Cotter River in the vicinity of Cow Flat Creek.

B. METAMORPHIC ROCKS.

(1) Franklin Formation - Phyllite of the Franklin formation and intrusive granite occupy the entire western side of the Cotter River Valley, between Bushrangers and Collins Creeks. On the east phyllite is bounded sharply by the Cotter fault. On the west phyllite outcrops on the Cotter-Goodradigbee Divide and undoubtedly continues westwards into the eastern side of the Goodradigbee valley. The formation originally consisted mainly of shale, but it has been altered into sericite phyllite in which a prominent flow cleavage has been developed. Thin sandy beds were interbedded with the shale in some places and these have been converted into sheared quartzite. The alteration of the rocks is mainly due to regional metamorphism but the grade of metamorphism is not high.

In thin section the only metamorphic mineral present is sericite which has formed in needles and clusters oriented in the plan of the flow cleavage. Quartz is present in small lenses which form typical augen structure in the rock.

Flow cleavage or schistosity is the prominent structure in the phyllite. The relationship of bedding to schistosity was determined only in a few places. Between the Cotter River and the Goodradigbee Divide, bedding and schistosity appeared comparable in strike and dip in several places but at one point on the Franklin road, about 2 miles north of Bendora, schistosity dipped 80 degrees west with a north-south strike, but beddings, with the same strike, dipped only 50 degrees to the west.

The strike of the schistosity varied little from north-south in all of the outcrops that were examined, and dips, over most of the area, were consistently to the west at angles ranging from 50 to 60 degrees. Phyllite at Mount Agnes on the Cotter-Goodradigbee Divide dipped at a high angle to the east, however, and there was evidence at other places to the north to suggest a reversal of dip in the vicinity of the divide which may therefore, lie near the axis of a major syncline.

The age of the Franklin formation is not known, but by general comparison with rocks of known Age in the Canberra District they are probably Silurian or Ordovician. The closest comparison is afforded by the slates and phyllites found south of Queanbeyan which are known to be of Upper Ordovician Age and on this account a tentative estimate of Upper Ordovician Age for the Cotter phyllites seems reasonable. No fossils were found during the recent field work and it is probable that metamorphism has destroyed any organic material in the rocks.

(2) Tidbinbilla Quartzite - The Tidbinbilla quartzite (and some intrusive granite) occupies the entire eastern side of the Valley between Bushrangers and Collins Creeks, and extends eastward from the Cotter fault to a contact with granite approximately 2 miles east of the Cotter-Paddy's River Divide.

The formation originally consisted of sandstone with some calcareous phases and a few thin shaly bands. Thermal metamorphism produced by intrusive granite has altered the rocks to massive quartzite in which silicified shaly bands can, in places, be discerned. In many places all trace of the original bedding planes has been obscured, but in some outcrops bedding is still discernible.

In thin section the rock consists of a mosaic of recrystallised quartz in which traces of the original grains can be seen. Some metamorphic minerals have been produced. They occupy interstitial spaces in the quartz mosaic and constitute from 20 to 30 per cent. of the rock. The rock shows no directional structures and alteration is to be attributed to thermal metamorphism.

The grade of metamorphism decreases away from the granite contact. Quartzite from site C, some 600 feet from the granite contact showed the highest grade of metamorphism observed. Metamorphic minerals included chlorite and a high-grade metamorphic mineral. This was not identified, but it resembled altered biotite. A bounder of quartzite from Cow Flat Creek also showed a comparatively high grade of thermal metamorphism. Approximately 30 per cent. of the rock consisted of metamorphic minerals including chlorite and a mineral which probably belongs to the epidote group. Another boulder from the same source showed a lower grade of metamorphism in which chlorite appeared to be the only metamorphic mineral produced. In some places adjoining the granite contact, notably at site A, intense silicification of the quartzite has taken place and the rock has been converted into massive quartz.

The possibility of calcareous rocks occurring in the Tidbinbilla quartzites warrants special consideration since the presence of these rocks might give rise to serious engineering problems. The presence of calcareous sandstone and possibly limestone on certain horizons in the formation has been inferred from the appearance of the rocks exposed in the river ½ mile upstream from site C.

Selected specimens of quartzite from this locality were subjected to quantitative acid tests, which would remove any calcite, dolomite or iron oxides present, but the highest loss by solution amounted to only 1.1 per cent. Furthermore no calcite could be discerned in this sections. Similar quantitative tests were carried out on selected fragments of quartzite, with a dolomitic appearance, taken from gravels at the mouth of Cow Flat Creek, but these showed a maximum loss by solution of only 2.6 per cent.

It is concluded that if any calcite or dolomite were originally present in some bands of the rock most of it has been replaced by silica or converted into metamorphic minerals.

Although there may be thin calcareous bands in the Tidbinbilla quartzite there is no evidence of significant beds of limestone. No caves or solution holes were observed and no incrustations of any sort were noted in dry stream channels or around pools in quartzite country. No boulders of limestone were observed in the stream gravels examined.

The Tidbinbilla quartzite has been gently folded along a north south axis and, dips consistently to the west at angles ranging from 15 to 40 degrees and averaging 20 to 25 degrees. The examination of the quartzite was admittedly a cursory one and bedding could rarely be discerned, but there was no evidence of a reversal of dip either in the outcrops examined or in the aerial photographs of the area. T he quartzite was stongly jointed after silicification and most of the joint planes are vertical or steeply inclined.

Slight changes in structure were observed in places where the quartzite terminates against the Cotter Fault. In some places, notably at site A, the dip steepens close to the fault and many reach 40 degrees, but at exposures between sites C and D, the quartzite has apparently been dragged up against the fault and becomes horizontal, or even dips slightly to the east, within 60 feet of the fault. In the vicinity of site C, the quartzite shows more shattering in proximity to the fault than elsewhere. The relationship of the Tidbinbilla quartzite to rocks of known age elsewhere in the Canberra area has not been determined, but the formation is probably of Upper Silurian or Devonian age.

C. IGNEOUS ROCKS.

The igneous rocks found in the area consist of two separate intrusions, the Bendora granite and the Cow Flat granite.

(1) Bendora Granite. This granite outcrops on the western side of the Cotter Valley midway between the Cotter River and the Cotter-Goodradigbee Divide. It outcrops as a lenticular mass approximately 4 miles long, with a maximum width of 1½ miles. It is elongated in a north-south direction, and appears to be generally concordant with the structure of the phyllites.

The rock is a biotite granite consisting of quartz, orthoclase, a little plagioclase (acid andesine) and biotite. No ferromagnesian mineral other than biotite has been found in the rock.

In hand specimen the rock shows incipient gneissic banding and in thin section shows further evidence of strain in broken and strained quartz crystals.

The intrusive is probably a sill or elongated stock, and was intruded at a time when stress was still operative.

(2) Cow Flat Granite. The Cow Flat Granite outcrops along or adjacent to the Cotter River between sites A and C. The granite forms an irregular lenticular intrusion into the Tidbinbilla quartzite. It is elongated in a north-south direction and partly truncated on the western side by the Cotter Fault. The outcrop is a little over three miles long and up to approximately ¾ mile wide.

The intrusion consists mainly of acid biotite granite, in which most of the felspar is orthoclase and the only ferro-magnesian mineral is biotite. Porphyritic granite, with prominent crystals of quartz, felspar and biotite is common, particularly near the margins of the intrusion. Unlike the Bendora granite the rock is massive and has no gneissic banding.

At site A the Cow Flat Granite is only 1,000 feet wide and dips west with the quartzite, but near site B is approximately ¾ mile wide, and the east wall of the granite appears to be vertical.

An irregular tongue of granite extends up Cow Flat Creek, eastward from the main body. Farther east a large mass of very coarsegrained biotite granite outcrops about two miles east of Mount Tidbinbilla, in the Paddy's River Valley, and extends eastward to the Murrumbidgee River. This distribution of biotite granite east of the Cotter River indicates that the Cow Flat granite is probably a major apophysis or stock-like instrusion connected in depth with the batholith that outcrops to the east.

The relationship between the Bendora granite and the Cow Flat granite is obscure, but the chemical and mineralogical similarity of the two instrusions and the additude of the fault indicate that the two granites may have been part of the same intrusion before faulting took place. Furthermore, the difference in structure and texture between the two intrusions suggests that, if they were contemporaneous, the Cow Flat granite consolidated at a relatively higher level in the intruded rocks. The age of the granites is not known but it seems likely that they were introduced late in Devonian time when major granitic intrusions are known to have taken place.

D. STRUCTURAL GEOLOGY.

(1) General. The area examined is too small to provide an interpretation of the broad structures in the Cotter River District. However, it appears that bodies of granite have been intruded through older steeply folded phyllite of the Franklin formation, into overlying beds of sandstone which were converted into the Tidbinbilla quartzite. Subsequently a meridional fault developed, which caused downward movement of considerable magnitude in the eastern block. Subsequent erosion has apparently removed all trace of the quartzite on the upthrow block, immediately west of the fault, and has left quartzite abutting phyllite along the outcrop of the fault.

(2) The Cotter Fault. The Cotter Fault is the most important structural feature in the area. The fault has been traced from site A, near the mouth of Bushrangers Creek for about 4 miles to the south to a point about ½ mile north of the junction of Collins Creek with the Cotter River. Over most of this distance the fault lies along the Cotter River whose course and position has largely been determined by the line of weakness provided by the fault.

In view of the importance of this fault in the selection of dam sites in the area it is as well to state briefly the geological facts which indicate that faulting has taken place. These may be summarised as follows -

(i) Quartzite dipping at 25 degrees to the west outcrops on the eastern side of the Cotter Valley, but, at the fault line, about phyllite which dips steeply to the west.

(ii) Where the contact between the two formations is clearly exposed (notably ¼ mile south of site A and also ¼ miles upstream from site C), they are separated by a zone of shattered rock up to 120 feet wide.

(iii) The trace of the contact of the two formations on the surface is virtually a straight line regardless of topographical relief, indicating that the contact is close to vertical.

(iv) The quartzite shows alteration due to moderate thermal metamorphism - the phyllite shows alteration and structures predominantly due to moderate regional metamorphism.

(v) No quartzite referable to the Tidbinbilla quartzite has been foun west of the fault zone and no phyllite has been found east of the fault zone.

(vi) The Cow Flat granite which intrudes the Tidbinbilla quartzite has been traced up to, but not across, the fault zone, and no definite contact metamorphic effects have been detected in pjyllite of the Franklin formation adjacent to this granite.

As already indicated the dip appears to be vertical or very nearly so, and this suggests a normal fault which probably dips very steeply to the east. The throw of the fault, i.e. the vertical downward displacement of the downthrow block, cannot be determined, but the fact that no Tidbinbilla quartzite has yet been found in the Cotter Valley west of the fault suggests a throw of considerable magnitude.

The age of the Cotter Fault has not been established, but it is probable that major movement commenced in Tertiary time, and may have been roughly contemporaneous with movements along the Murrumbidgee and Cullerin Faults.

There is no marked topographical expression of the Cotter Fault, but this may be accounted for by the difference in the rate of erosion of phyllite on the upthrow block, and quartzite on the opposite side of the fault.

V. ENGINEERING GEOLOGY.

A. POSSIBLE DAM SITES.

The problems involved in selecting suitable dam sites in the Upper Cotter area fall into two groups - regional problems which apply to the area as a whole and, therefore, effect all possible dam sites, and local problems which are concerned with the details of the individual sites. It is proposed to deal firstly with the regional problems before discussing the merits of individual sites.

1. Regional Problems.

(a) Seismic activity - The stretch of river in which it is proposed to build the new dam lies adjacent to the Cotter Fault, and is approximately 12 miles west of the supposed Murrumbidgee Fault. It is therefore obvious that, if movement took place along either of these faults, earth tremors would be set up which might effect the stability or efficiency of a retaining wall. Furthermore, comparatively recent faults are known elsewhere in the Canberra-Goulburn district, such as the Cullerin fault at Lake George, and the district is subject to occasional earth tremors.

The question of epicentres of seismic activity in the Australian Capital Territory has been referred to Father O'Connell of the Riverview Observatory at Sydney, but unfortunately his report will not be available for some time. The following remarks and conclusions may therefore require some modification when more detailed information is available.

The only information on the position of epicentres in the Canberra-Goulburn district appears on a map published in 1910 (Griffith, Taylor, 1910). This map shows 40 epicentres within a radius of approximately 70 miles of the Upper Cotter Valley, but the number and intensity of tremors which have originated from each epicentre is not shown. Sixteen of the 70 epicentres are distributed around Lake George, and in the area between Lake George and the Capital Territory. Four epicentres are shown distributed along or close to the Murrumbidgee Valley for approximately 50 miles north of the Territory, and 15 epicentres are shown around the headwaters of the Murrumbidgee and Snown Rivers. Three epicentres are shown west of the Murrumbidgee near the lower Goodradigbee River, and two occur farther west in the Tumut Valley. No epicentres are shown within the boundaries of the Territory.

However, since the nearest recording seismographs were in Sydney and Melbourne the location of epicentres in the Canberra-Goulburn district was probably subject to an error of up to 20 to 30 miles or more, and the map of epicentres referred to above, therefore, may be inexact. Even if allowance be made for an error of 20 to 30 miles in the position of epicentres on the map, there are only four epicentres whose correct position might lie in the Australian Capital Territory. Two of these could be placed in the Murrumbidgee Valley, one in the Cotter Valley and one could be placed in either Valley.

The only conclusions which might be drawn from Griffith Taylor's map are -

(i) Seismic disturbances have originated in the Canberra-Goulburn district in recent years and similar disturbances must be expected in the future.

(ii) From the distribution of epicentres it appears that earth tremors are more likely to originate in the Lake George district or in the headwaters of the Snowy and Murrumbidgee Rivers than at any other place within a radius of 100 miles of Canberra.

(iii) Epicentres shown near the head of the Murrumbidgee and again along the Murrumbidgee north of the Capital Territory suggest that earth tremors may originate from the Murrumbidgee fault zone, particularly to the north and south of the Territory.

(iv) There is little or no evidence to indicate that seismic disturbances have originated from the Cotter fault.

The only information at present available on the intensity of the tremors which have occurred in the Territory is based on verbatim reports by several residents of long standing. Earth tremors were felt in Canberra in 1930; 1934 and 1944. All of these tremors were apparently of low intensity and probably of the order of 3 on the Rossi-Forel scale. These tremors have occurred since the present Cotter dam was completed in 1915, and have apparently caused no damage. The wall of this dam now shows some horizontal and vertical cracks, but it is believed that seismic activity has not been a factor in their formation.

The conclusion is therefore, reached that the Upper Cotter area will undoubtedly be subject to earth tremors from time to time. Based on experience over a limited period, these will in all probability be of low intensity. A major earthquake is, of course, possible but there is no record of such an earthquake in the history of the Territory.

In view of the expected low intensity of earth tremors and the relatively small size of the dam to be constructed, it should not be necessary to carry out detailed seismic investigations of the foundation rocks. However, the dam should be built in a solid homogeneous rock formation to minimise shock, and should be placed at as great a distance as possible from the Cotter fault, to avoid building in shattered rock.

(b) <u>Loading due to Water Storage.</u>

If a dam is constructed at any of the possible sites, a body of water will be impounded in the valley for some miles upstream from the dam. The rocks underlying the storage area will thereby be subjected to a loading whose magnitude, at any one place, will depend on the depth of impounded water. The maximum loading would normally occur on the immediate upstream side of the dam. As a result of this loading, stresses will be set up in the underlying rocks which may cause the strata to bend on an exceedingly small scale.

Evidence obtained in the Burrinjuck storage area indicates that bending or some very small deflection of strata probably does take place under water loading. At Burrinjuck, three pendulums were installed in tunnels in three positions near the edge of the impounded water and continuous records taken of their movements over at least eight months. All three pendulums showed some movements which appeared dependent on the rise and fall of water in the storage area (Cotton, 1915). Furthermore, the depths of water at the time of the observations were not great and ranged from 22 to 80 feet above the old stream bed.

Further evidence on the effect of water loading is provided by seismological records taken, over a period of years, at the Boulder Dam in the United States of America. These records show a large number of very small shocks which were almost certainly caused by small adjustments in the strata due to water loading.

If there were no adverse geological structures in that portion of the Upper Cotter valley under discussion the effect of loading by impounded water could be dismissed as insignificant, but the presence of the Cotter fault and the fact that the weight of impounded water will fall on the downthrown block adjacent to the fault makes the question worth considering. It is conceivable that if the fault blocks involved were not in equilibrium, but under considerable stress, a very small additional stress might constitute a "trigger" action and cause slight adjustments along the fault. The resulting earth tremors might be too small to damage structures, but any movement along the fault might cause serious leakage from the storage area.

The pressure on the underlying rocks exerted by the impounded water at any one place can be calculated, but there is no way in which the effect of this pressure can be accurately assessed. However, in view of the lack of direct evidence of instability in recent years, and the comparatively small area over which water will be impounded, it is unlikely that the stresses set up could be sufficient to cause movement along the Cotter fault.

(c) Leakage of Water from the Storage Area.

In general, water may escape from a storage area by channels provided by faults or joints, by sink holes and solution cavities developed in rocks such as limestone, and by absorption into dry, proous strata in areas where the water table is well below the level of the impounded water.

If the proposed dam is constructed at a place between the mouths of Bushranges and Collins Creeks on the Upper Cotter River, the storage area involved will not include any significant thickness of strata in which solution channels could develop.

Significant loss of water is likely by absorption into strata outcropping on the valley sides. The present water table would normally be at stream level, or lie slightly below it, and slope upwards from this level at an angle somewhat lower than that of the valley sides. A small loss of water from the storage area would result if the level of water in the storage rose at a greater rate than that of the water table. Water would then pass into the adjacent rocks, particularly into the phyllite, until the level of the water table was raised to that of the water impounded. However, loss of water from the storage, in normal seasons, should be temporary and relatively small.

The possibility of water escaping by joints and faults is more serious. Both the quartzite and the granite are jointed and water would tend to penetrate joint planes and particularly those in the quartzite. These joint planes are not continuous open cracks, however, and loss by this means, should be negligible except, perhaps, at the dam site itself.

On the other hand the Cotter fault might provide channels along which significant leakage could take place. Regardless of where the dam is placed in this section of the river, some water will be impounded over portions of the Cotter Fault, and leakage might take place into the fault zone, or into the zone of shattering which in places accompanies it. This could eventually increase the rate of circulation of meteoric water already occupying interstitial spaces along the fault zone, and lead to the development of springs along the fault zone, outside the storage area. However, there are probably no cavities or wide cracks along the outcrop of the zone, and, therefore, water entering it would have to force its way through very small openings against the pressure of the meteoric water which those openings already contained. Under these conditions, the force of friction would greatly reduce the initial pressure of the impounded water, and thus restrict its rate of entry into the zone.

The amount of water which could pass into the fault zone and escape from the storage would depend on the ease with which it could enter and circulate along the fault zone and on the hydrostatic head operative between the points of intake and outlet.

Field evidence provides two significant facts bearing on the circulation of water along the fault. In the first place, no springs have been found along the outcrop of the fault or in its vicinity. Admittedly, the inspection was made after several comparatively dry seasons and no springs were found elsewhere in the valley, apart from one at Bendora, close to the Cotter-Goodradigbee divide, (see Plate 1). However, the absence of springs from the fault zone means there is no direct evidence at present to suggest free and regular migration of water along the fault.

In the second place, the tightness of the fault zone varies along the strike of the fault. The fault zone has been eroded more easily in some places than in others and the relief of the fault should therefore, reflect the degree of compaction of the fault zone itself. The best example of this occurs downstream from Site D, where the river follows the fault zone for half a mile and then swings shaply to the east into the quartzites above site C. The fault zone is exposed on the bend of the river, and is approximately 120 feet wide. It consists of fragments and blocks of quartzite and phyllite in compacted clay and soil. Penetration of the quartzites by the river was no doubt encourages by joints and shattering, but the fault zone must nevertheless have provided greater resistence to erosion at this point than it had done farther upstream. A similar example of differential erosion of the fault zone occurs at site A.

Thus, the fault zone is tightly compacted, at least near the surface, in those sections where the fault leaves the stream bed and outcrops across spurs, but is less well compacted along those sections of the fault which outcrop in or adjacent to the stream bed and at a elvel comparable with that of the river. Serious leakage into the fault zone is therefore most likey to occur in those sections where the fault outcrops along the river-above site A, in the vicinity of the Top Flats, and again above site C. The chances of leakage appear greatest in the last section, above site C, and part or all of this would underlie the water impounded by a re aining wall at sites B, C or D. If water were impounded by a wall at sites B or C, leakage along the fault might be prevented by the relatively tight fault zone immediately north of the critical sections, but, if leakage did occur, the most likey place along the fault for escaping water to emerge would be along the fault in the vicinity of the sharp bend in the river ½ mile below site B. Water would escape from the storage although it would eventually be collected in the existing Cotter dam.

The difference in elevation between the point at which water would enter the fault and the point at which it would emerge below site B is approximately 100 feet. If 100 feet of water were now impounded over the critical section above site C, it would be equivalent to doubling the hydraulic head between the points of potential intake and outlet. This increase in hydraulic head might eventually cause some leakage from the storage, but if water is not at present escaping down the fault, it is unlikely t at significant losses would occur.

Therefore, in view of the lack of evidence of recent disturbances, the absence of springs and the apparent tightness of at least some portions of the fault zone, it is considered that the circulation of meteoric water is sufficiently restricted and the fault zone itself sufficiently compact to prevent the deveopment of serious leakage, at least under the pressures likely to be involved. However, some small leakage may develop in time and the depth of water to be impounded over critical portions of the fault should be regarded as an important factor in the selection of a site for the dam.

(d) Summary.

Consideration of the regional problems indicates two important factors in the selection of a dam site in the Cotter River between Bushrangers and Collins Creeks. Firstly, the site should be as far removed as possible from the Cotter Fault, and, secondly, the minimum depth of water should be impounded over critical sections of the fault zone.

The most suitable site, from a regional viewpoint, is, therefore, site B.

2. The Sites.

The possible dam sites, lettered A to D on plate 1, were selected by surveyors of the Lands Department of New South Wales in 1908, and no additional sites worthy of mention were found during the recent survey.

For convenience, the sites will be discussed in the order D, A, C, B, which is the reverse order of suitability.

(a) Site D (See Plate 1).

Site D is the most southerly of the dam sites and is considered the least suitable for the following reasons -

(i) The site is farthest upstream and would have the smallest catchment.

(ii) The site would probably provide the smallest storage.

(iii) The retaining wall would straddle the Cotter fault with consequent risk of (a) damage if any movement occurs and (b) leakage, unless the zones of weakness were adquately sealed.

(iv) The retaining wall would lie in partly shattered rock, the strength of which is not known.

(v) The western buttress would lie to phyllite, which is inferior to quartzite or granite as a foundation rock.

(vi) The greatest depth of water would be impounded over a critical section of the fault zone above site D with additional risk of water leakage.

(vii) It is the least accessible.

Furthermore the site has no advantages which other sites do not possess. For these reasons the construction of a dam at site D would be inadvisable.

(b) <u>Site A (See Plate 1)</u>.

Site A is the most northerly site and would provide the maximum storage on account of the comparatively wide valley extending upstream from the site. It is nearest the present Cotter Dam and would therefore entail the minimum expenditure on road and pipe line up the Cotter Valley.

The disadvantages of the site are as follows -

(i) The retaining wall would parallel, and lie within 250 feet of the fault zone on the downthrow side, and, therefore, would be subject to damage if movement occurred. Furthermore, the maximum depth of water would be impounded over a critical section of the fault zone lying immediately upstream from the site and this would involve risk of leakage.

(ii) The rocks at the dam site consist of quartzite and granite. These would provide suitable foundations from the point of view of strength, but they are strongly jointed. The joining has probably been accentuated by movement in the rocks adjacent to the fault and some grouting might be necessary to prevent leakage through the foundations.

(iii) The elevation of site A is insufficient to allow water to gravitate to all reservoirs at Canberra.

Site A is therefore not considered suitable for the construction of the dam.

(c) <u>Site C (See Plate 1)</u>.

Site C lies in quartzite and provides the most restricted gorge between Bushrangers and Collins Creeks. The elevation is 2,425 feet above sea level and is sufficient to gravitate water to Canberra. The quartzites provide suitable foundation rocks and supplies of aggregate.

The site is subject to the following disadvantages -

(i) Site C provides the smallest water storage but one.

(ii) A critical section of the fault zone lies ¼ mile upstream from the site and a considerable depth of water would be impounded over this section with consequent risk of leakage.

(iii) The site is close to the fault, and, therefore, subject to damage should any movement take place. If the retaining wall were constructed to a height of 200 feet the western buttress would probably lie within 500 feet of the fault zone.

(iv) The quartzite contains strongly developed joint planes which dip at angles ranging from 25 degrees to vertical. Movement during faulting has probable caused slight adjustments to take place along some of the joint planes and this has resulted in an increased tendency for the rock to break into blocks and fragments. The course of the river at site C and immediately above was determined by the strike of the two principal joint systems found in the quartzites. The strike of the first ranges from 35 degrees to 15 degrees and the strike of the second ranges from 240 degrees to 300 degrees. The fact that the river has carved its valley through these quartzites rather than along the fault zone is a clear indication that because of the joint planes the quartzite is vulnerable to water action and the foundation of a dam to be constructed at site C would therefore, require very careful examination and probably some grouting to prevent leakage along the joints.

(v) Access to site C would be comparatively difficult, particularly above Cow Flat Creek.

It is concluded that a dam could be constructed at site C, but the site offers several disadvantages which can be avoided or reduced by selecting a site farther downstream and at a greater distance from the fault.

(d) Site B (See Plates 1 and 2).

(i) Summary. This is considered the most suitable site for a dam between Bushranges and Collins Creeks.

A retaining wall at site B would impound water in the valley of Cow Flat Creek as well as in the Cotter Valley, and would provide a larger water storage than sites C or D. The foundation rocks consist of massive granite in which weathering and jointing should present no difficulties and the site is situated at the greatest distance from the fault. The gorge at site B is not as restricted as that of site C, but is suitable for a retaining wall at least 180 feet high.

The elevation of the site is sufficient to allow gravitation to Canberra although the hydraulic head would be 45 feet lower than that at site C. Supplies of aggregate are readily available and access to the site is comparatively easy.

The principal disadvantage of the site is that water will be impounded over the critical section of the fault zone above site C, but the depth of water would be considerably lower than that impounded over the same section by a wall at site C, and the risk of leakage is less than at any other site. The second disadvantage may lie in the elevation of the site which is lower than sites C and D. The detailed geology of the site will be discussed in the succeeding sections.

(ii) Foundations. SITE B is in the Cow Flat granite and the rock types are coarse-grained biotite granite and a porphyritic phase of the same rock. The approximate distribution of these types is shown on Plate 2. The eastern wall of site B consists mainly of the coarser grained granite. The same rock outcrops over the lower 40 feet of the western wall but uphill it grades into porphyritic granite, which outcrops over the remainder of the western side.

The coarser grained granite is composed of quartz, felspars and biotite in the approximate proportions of 35, 60 and 5 respectively. The quartz crystals show some fracturing and shadow extinction, but strain was not excessive and there is no evidence of crushing or banding in the rock. Approximately 60 per cent. of the felspars show some alteration to kaolin and saussurite, and much of the biotite is altered by weathering to chlorite.

The porphyritic granite is composed of quartz, felspars and biotite in the approximate proportions of 45, 55 and 10 respectively. Phenocrysts of quartz, felspar and biotite are set in a finely crystalline ground mass of quartz and felspar. Phenocrysts show some evidence of strain but no crushing and banding has been induced in the rock. The alteration of biotite to chlorite is well advanced but is not as complete as that observed in the coarser granite. The felspars show some alteration tokaolin and saussurite, but the alteration is noticeably less than that observed in felspar in the coarser granite and only affects 30 to 40 per cent. of the crystals.

In hand specimen the coarser granite is a hard even-grained rock when fresh but near the surface it weathers comparatively easily to a friable rock, then to soft earthy material and finally to a sandy soil. The degree of weathering varies from place to place and may depend on variations in the grain size or in the felspar content of the granite. The porphyritic granite appears to be tougher than the coarser variety and is considerably more resistant to weathering. Both rock types show an uneven and fairly rough fracture which should bond well in concrete.

Both the granite and the pyrophyritic granite are suitable foundation rocks. The degree of alteration of minerals in the fresh rock should have very little effect on its strength. The proportion of platy minerals such as biotite is too small to effect shearing strength and there is no noticeable crushing or banding in the rock.

(iii) Weathering. In both granitic types weathering consists mainly of the alteration of felspars and biotite. This alteration is pimarily due to surface agencies and not to chemical processes originating within the body of the granite or dependent on igneous emanations. Complete weathering of the rocks will, therefore, be restricted to a shallow zone near the surface beneath which comparatively unaltered granite will be found. The lower limit of the zone of weathering in any one place is established by the water table so that, in general, depth of weathering will increase with elevation above the stream bed.

The distribution and relative intensity of weathering at site B is shown in Plate 2. Three types of surface disintegration were recognised -

(a) Outcrops of granite which have been weathered into tors and rounded blocks by spalling and disintegration along joint planes.

(b) Thin mantles of granite scree consisting mainly of numerous small fragments and boulders of granite.

(c) Deeply weathered granite and granite soil with relatively few fragments of solid rock.

Plate 2 shows that the zone of weathering on the western side of the site consists mainly of granite scree and must be very shallow. On the eastern side, massive granite outcrops over the lower portion, but a patch of deeply weathered granite occurs between two ridges of granite tors towards the top of the ridge. This is the only place at site B where the depth of the weathered zone cannot be determined, within close limits, without recourse to drilling. Two pits approximately 8 feet deep have been sunk in this weathered material, but they did not reach unaltered rock. The outcrops of massive granite lower down on the eastern side, and the outcrops of granite tors north and south of the weathered material indicate that the depth is not likely to be more than about 15 feet. Elsewhere on the site, the depth of weathering products will be less than 6 feet in most places.

(iv) Jointing. No faults were found at site B, but the granite and porphyritic granite are jointed. The joints are not closely spaced and, judging by the surface outcrops, should not give rise to leakage problems.

The strike and dip of major and minor joint planes are shown on Plate 2. There are two major joint systems. The strike of the first system ranges from 315 to 340 degrees and the joint planes dip to the east at angles which usually range from 70 to 85 degrees. A dip of 25degrees to the east was observed on one of these joints on the western bank of the river, but elsewhere no dips lower than 70 degrees were recorded. The strike of the second major system ranges from 256 to 280 degrees and dips are to the south at steep angles ranging from 50 to 80 degrees. One joint plane, apparently belonging to this system, was observed dipping south at 10 degrees on the western bank of the river, but similar low angle dips were not apparent at other places. Minor joint planes noted on the western bank of the river showed strikes ranging from 145 to 200 degrees with both easterly and westerly dips which ranged from 55 to vertical.

None of these joints should cause engineering difficulties with the exception of the two low angle joint planes noted above. Joint planes which dip at an angle lower than that of the valley side are undesirable since they may cause rock slips during excavation and could affect the stability of the foundation. The distribution of low-angled joints will need investigation, but they are not widely developed in the outcrops at the site.

B. SOURCES OF AGGREGATE.

1. General.

The essential properties required in a rock to be used as aggregate in concrete may be summarised as follows -

(a) The rock should be massive and have a high compressive strength. The presence of soft alteration products is, therefore, undesirable.

(b) The rock should not contain structures such as schistosity or lamination, or a high proportion of platy minerals such as mica, as these would reduce the shearing strength of the material (Haff, 1942).

(c) The rock should contain a little or no sulphide minerals, such as pyrite.

(d) The rock should contain a minimum of minerals likely to enter into expansive reaction with the cement used in the concrete. Minerals and rocks most likely to enter into expansive reactions in concrete comprise opaline silica, rock glass, cryptocrystalline ground mass material, gypsum, olivine and its alteration prod ucts, altered felspar, microcline-perthite felspar and zeolite minerals (Alderman, 1943).

(e) The rock should break with an uneven fracture and present few smooth crystal faces on the fracture surface.

The country rocks in the vicinity of the dam site consist of phyllite, quartzite and granitic rocks. The phyllite may be eliminated as a source of aggregate on physical properties alone. The rock usually shows strong schistosity and breaks into smooth-sided, tabular fragments. The quartzite and the porphyritic granite should both provide good aggregate. Some of the coarse-grained granite should also make good aggregate, but weathering is usually more pronounced in the coarser granite and careful selection would be necessary. Stream gravel should also provide suitable aggregate but the proportions of phyllite and granite boulders would need to be determined.

2. <u>Sources of Aggregate at Site B.</u>

The sources of aggregate near site B include quartzite, granitic rocks and stream gravels. No phyllites outcrop at the site or in its vicinity.

(a) <u>Quartzite.</u> The nearest outcrop of quartzite occurs at the eastern edge of the granite, about ½ mile east of site B, and about 200 feet east of the alluvial terraces at the mouth of Cow Flat Creek. Access to the quartzite could be obtained up Cow Flat Creek or up a small stream about 500 feet to the north. The rock could be quarried from the steep hill sides and, in proximity to the granite, would consist of highly silicified quartzite. No specimens were examined from this locality, but boulders and fragments of quartzites in the flats to the immediate west indicate that the rock should consist of about 70 per cent. silica and 30 per cent. metamorphic minerals. The metamorphic minerals may consist entirely of chlorite or may include varying proportions of higher grade metamorphic minerals such as epidote. The higher grade metamorphic minerals, with the exception of biotite, should be acceptable, but chlorite is a platy mineral with a cleavage similar to that of mica and is undesirable for both physical and chemical reasons. However, the effect of 20 to 30 per cent. of chlorite in the quartzite should be negligible since the chlorite is disseminated in a mosaic of quartz which constitutes 70 per cent. of the whole rock. Negative crystals of pyrite were found in quartzite near site C, but the mineral is comparatively rare. The presence of pyrite at site C has given rise to ferruginous soil cover and therefore, any quartzites which are covered by red soil should be examined for pyrite, before being used as aggregate.

An alternative source of quartzite lies about 1½ miles north of site B where quartzites form a cliff along the eastern margin of the Top Flats. The rock could be easily quarried and considerable quantities of scree are also available along the base of the cliff. So far as is known, the rock would be essentially similar to that available at Cow Flat Creek.

With regard to physical strength and mineral assemblage, the quartzites would provide the best rock for aggregate.

(b) <u>Granite.</u> Granite and porphyritic granite are the most readily accessible sources of aggregate at site B. Porphyritic granite outcrops over most of the western side of the site, Coarse granite outcrops in the river bed and in places on both sides of the gorge.

The porphyritic granite is the more suitable rock for aggregate. It is a tough rock and should crush into rough angular fragments. Felspar and biotite are present, but neither mineral is likely to cause trouble. Felspar amounts to approximately 50 to 60 per cent. of the rock, but over 80 per cent. of the felspar is orthoclase which does not weather as readily as the plagioclase variety. About 25 per cent. of the felspars show some signs of alteration, mainly to kaolin but this does not imply that 25 per cent. of the mineral is extensively weathered and therefore comparatively weak. It is difficult to determine the actual proportion of felspar which has been completely weathered, but it is certainly less than 25 and probably less than 10 per cent. Thus a maximum of 5 to 10 per cent. of the whole rock might consist of soft kaolinised felspar. The specimens examined were taken from surface outcrops and the degree of weathering should decrease with depth. The biotite originally present in the rock has been almost completely altered to chlorite but, since the biotite probably constitutes less than 5 per cent. of the rock, the effect of this alteration should be negligible. The ground mass constitutes about 20 per cent. of the rock, and is finely crystalline. It consists of quartz and felspar and contains no trace of rock glass. The specimens examined contain no trace of sulphide minerals such as pyrite or any other features likely to be undesirable in an aggregate.

The coarser grained granite is usually more weathered, than the porphyritic variety. Felspars constitute about 60 per cent. of the rock, but about 80 per cent. of the felspar is orthoclase. Approximately 60 per cent. of the felspars show traces of weathering and although the actual proportions of soft kaolinised felspar cannot be determined, it would not exceed 15 to 20 per cent. of the rock in the specimens examined. Biotite constitutes about 5 per cent. of the rock, but has been almost entirely altered to chlorite. However, portions of the coarser grained granite have been more extensively weathered than the specimens from which thin sections were cut and, therefore, if any coarse granite is to be used as aggregate, it will be advisable to select the least weathered patches.

(c) Stream Gravels. Large supplies of stream gravels could be obtained from the Top Flats, which extend to within ½ mile below site B, and from the flats and terraces at the mouth of Cow Flat Creek, immediately south of the site. Small quantities could also be obtained from the present river channel.

Gravels from the flats at the mouth of Cow Flat Creek would probably be the best gravels for aggregate, although the quantity available here would be comparatively small and of the order of 90,000 cubic yards*. These gravels consist of quartzite and granitic types and contain very little phyllite Much of the quartzite toward the western side of the flats has suffered little water action and has the angularity of scree. Both granite and porphyritic granite are represented in the gravels but both types should be suitable for aggregate, since fragments of weathered granite would normally disintegrate during river transport, and not appear in gravels.

The gravels in the Top Flats consist of quartzite and granitic types, with some phyllite shed from the western side of the river. The proportions in which these rock types occur has not been determined, but the amount of phyllite present is probably small. Much of the quartzite will have the angularity of scree and the granitic types should be similar to those found at Cow Flat Creek. The quantity of gravel available in the Top Flats will be of the order of 200,000 cubic yards.*

C. SOURCES OF SAND.

There are very few beaches along the Upper Cotter River, and no readily available supplies of natural sand have been found. Natural sand could be obtained by screening and washing river gravels from the flats and terraces. The proportion of clean sand available in the flats has not been determined. The quality should be satisfactory, although samples should be examined to determine the proportion of felspar present.

Artificial sand could be made by grinding and screening quartzite, but no other local rock should be used for this purpose.

If sand is made from quartzite, care should be taken to remove the fine fractions and the rock flour. The chlorite present should pass out in the fines but the final sand should be examined for chlorite content. Quartzite for making sand could be obtained from quarries or by sorting the river gravels.

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* Based on assumption that gravel constitutes 40 per cent. of alluvial material by volume.

D. LOCATION OF ROADS AND BILLETS.

A road following the Cotter Valley should be constructed in the granite, wherever possible. Much of the granite is weathered near the surface, can readily be excavated, and provides a source of fine quartz gravel.

After a road had reached site A, the best location would lie along the belt of granite, immediately east of the site, to the northern end of the Top Flats. From here to site B, the road could be constructed along the Top Flats and then across the granite slopes north of site B.

Suitable locations for billets could be found along the Top Flats or on the granite slopes between the upper limit of the Flats and siteB.

VI. RECOMMENDATIONS.

The following recommendations are submitted -

(1) Site B is recommended as the most suitable site for a dam on the Upper Cotter River between Bushrangers and Collins Creeks.

(2) If it is decided to construct a dam at site B, the possibility of leakage along the Cotter fault should be further investigated. The fault zone should be examined by trenching across it in several places, and by sinking at least one shaft, at sites to be selected along the fault zone.

(3) A shaft or bore in the fault zone north-west of site B, in which the level of the water table can be determined, should be maintained throughout the construction of the dam and for some years afterwards, to provide a record of movements in the water table and a check on leakage from the storage area. Complete rainfall records should also be taken and correlated with movements in the water table.

(4) If site B is selected, this Branch should be consulted in the selection of sites for exploratory bores and shafts in the foundation rocks.

(5) When excavating work is commenced at site B, this Branch should examine the excavations from time to time to check on the petrology of the rocks and to map structures. A very detailed examination of the completed excavations should also be made.

(6) With regard to sources of aggregate, it is recommended that this Branch make a detailed examination of all proposed quarry sites. If stream gravels are to be used, an examination of the flats and terraces should be made to determine the proportions in which the various rock types are present, and the proportion of undesirable material.

(7) A geological survey should be made of any areas through which it is proposed to construct roads, canals or pipe lines.

(8) If a site other than B is preferred, a detailed geological examination of the site should be made.

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APPENDIX 1.

DESCRIPTION OF ROCK SLIDES.

SLIDE NO. 1.

Locality : ½ mile east of Bendora, Cotter River.

Appearance : Dark holocrystalline rock, containing quartz, white felspars and dark ferromagnesian minerals with gneissic banding.

Texture : Holocrystalline - granitic.

Mineral Content : Quartz, felspars (mostly orthoclase) and plates of biotite.

Quartz forms 60 per cent. of the rock. The crystals show shadow extinction and are also cracked, indicating strain.

Felspars form about 30 per cent. of the rock. About 10 per cent. of the crystals show traces of weathering, mainly to kaolin, although in places saussurite is also present. The proportion of orthoclase to plagroclase is about 4 to 1. The plagroclase appears to be oligoclase.

Biotite crystals are fresh, but are twisted and distorted due to strain. The mineral forms about 10 per cent.

Apatite is present by a few small grains.

Name: Biotite granite.

SLIDES NO. 2 & 3.

Locality : West of the Air Gap, Cotter River.

Appearance : A brown phyllitic rock, showing flow cleavage.

Mineral Content : Quartz is confined to small lenses or "augens" throughout the rock. Sericite is abundant, and smaller quantities of chlorite, magnetite, and possibly biotite are present. The rock is stained with limonite.

Quartz: The quartz in the "augens" has been recrystallised, and generally shows shadow extinction due to strain.

Sericite is the most abundant mineral. The individial needles are very small and oriented in the plane of the flow cleavage.

Chlorite is present in very small crystals in parts of the rock.

Magnetite is well represented in certain bands in the rock; it is partly weathered to limonite which stains parts of the rock a deep brown.
Weathered Biotite may be present, for in places, the brown material shows faint pleachroism.

Name: Sericite phyllite.

SLIDE 4.

Locality : Boulder from Cow Flat, Cotter River.

Appearance : Brown, fine-grained metamorphic rock, slightly weathered.

Mineral Content : Recrystallised quartz and metamorphic minerals, which show no directional structures.

Quartz has been recrystallised into a mosaic in which the shape of some of the original grains can be discerned. Quartz constitutes about 70 per cent. of the rock.

Metamorphic Minerals constitute about 30 per cent. of the rock and occur in small crystals and aggregates. Minerals not definitely identified, but almost 60 per cent. of the metamorphic material is probably a mineral of the epidote group, and the remaining 40 per cent. consists largely of an altered mineral which may be altered biotite.

Name: Quartzite.

SLIDE No. 5.

Locality : Boulder from Cow Flat, Cotter River.

Appearance : Dark fine-grained metamorphic rock.

Mineral Content : The rock is composed chiefly of recrystallised quartz, with smaller quantities of chlorite, and a few flakes of partly weathered biotite(?).

Quartz forms 70 per cent. of the rock, and has been recrystallised into a mosaic.

Metamorphic Minerals. Chlorite is the prominent metamorphic mineral and constitutes about 30 per cent. of the rock. A few small weathered crystals of biotite may also be present. Rock shows no evidence of directional structures.

Name: Quartzite.

SLIDE No. 6.

Locality : Western bank of Cotter River at Dam Site C.

Appearance : Dark fine-grained metamorphic rock.

Mineral Content : A mosaic of recrystallised quartz grains, containing interstitial chlorite and probably biotite.

Quartz. Original quartz grains have been recrystallised into a mosaic which constitutes about 80 per cent. of the rock.

Metamorphic Minerals. Chlorite constitutes approximately two thirds of the metamorphic minerals. Other minerals present have not been definitely identified, but include mica and probably some cordierite.

Name: Quartzite.

SLIDE No. 7.

Locality : Upper portion of western wall, Dam Site B, Upper Cotter.

Appearance : Light coloured porphyritic rock with phenocrysts of quartz and felspar, in a felsitic groundmass.

Texture : Holocrystalline - porphyritic.

Mineral Content : Phenocrysts of quartz and felspar and probably biotite in groundmass of quartz and felspar.

Phenocrysts constitute approximately 80 per cent. of the rock.

Quartz occurs in hypidiomorphic crystals - some with slight corrosion at the edges. Many had been cracked by strain. Quartz crystals constitute approximately 45 per cent. of the phenocrysts.

Felspar. Both orthoclase and plagioclase present in proportions of approximately 5 to 1. Both show some degree of weathering to kaolin and saussurite - the latter largely confined to plagioclase felspar. Approximately 24 per cent. of all felspar phenocrysts show evidence of weathering (20 per cent. of orthoclase crystals and 40 per cent. of plagioclase crystals).

Weathered biotite may be present in two places but alteration is almost complete.

Groundmass. Consist of finely crystalline quartz and felspar and constitutes about 20 per cent. of the rock. Quartz and felspar occur in approximately equal proportions. No rock glass occurs in the groundmass.

Name : Porphyritic granite.

SLIDE No. 8.

Locality : Lower 40 feet of western wall, Dam Site D, Cotter River.

Appearance : Light coloured rock composed of quartz, felspar and altered ferro-magnesian minerals.

Texture : Holocrystalline - granitic.

Mineral Content : Quartz, partially weathered felspar and chlorite.

Quartz constitutes about 35 per cent. of the rock. Most of the crystals show fractures and some shadow extinction due to strain.

Felspar constitute about 60 per cent. of the rock. Orthoclase and plagioclase occur in the proportions of 4 to 1, and about 60 per cent. of all felspars show evidence of alteration - mainly to kaolin.

Chlorite, derived from biotite, constitutes about 5 per cent. of the rock.

Name : Biotite granite.

SLIDE No. 9.

Locality : Eastern wall, Dam Site B, Cotter River.

Appearance : Light coloured igneous rock with phenocrysts of quartz and felspar.

Texture : Holocrystalline and porphyritic.

Mineral Content : Phenocrysts of quartz, felspar and biotite in a fine groundmass.

Phenocrysts constitute about 70 per cent. of the rock.

Quartz in hypidiomorphic crystals forms about 60 per cent. of the phenocrysts. The larger crystals show cracks from strain and some crystals show corrosion at the margins.

Felspar - mainly orthoclase - form about 30 per cent. of the phenocrysts. Approximately 40 per cent. of all felspars show some degree of alteration to kaolin.

Biotite forms about 10 per cent. of the ph enocrysts and is extensively atered to chlorite. Some of the crystals are bent and strained.

Groundmass constitutes about 30 per cent. of the rock and is composed of quartz and felspar in approximately equal proportions. Some of the felspars show evidence of weathering to kaolin, but alteration is not extensive.

Name : Porphyritic granite.

PLATE I.

GEOLOGICAL PLAN
- OF -
PORTION OF UPPER COTTER VALLEY
(BASED ON AERIAL PHOTOGRAPHS)

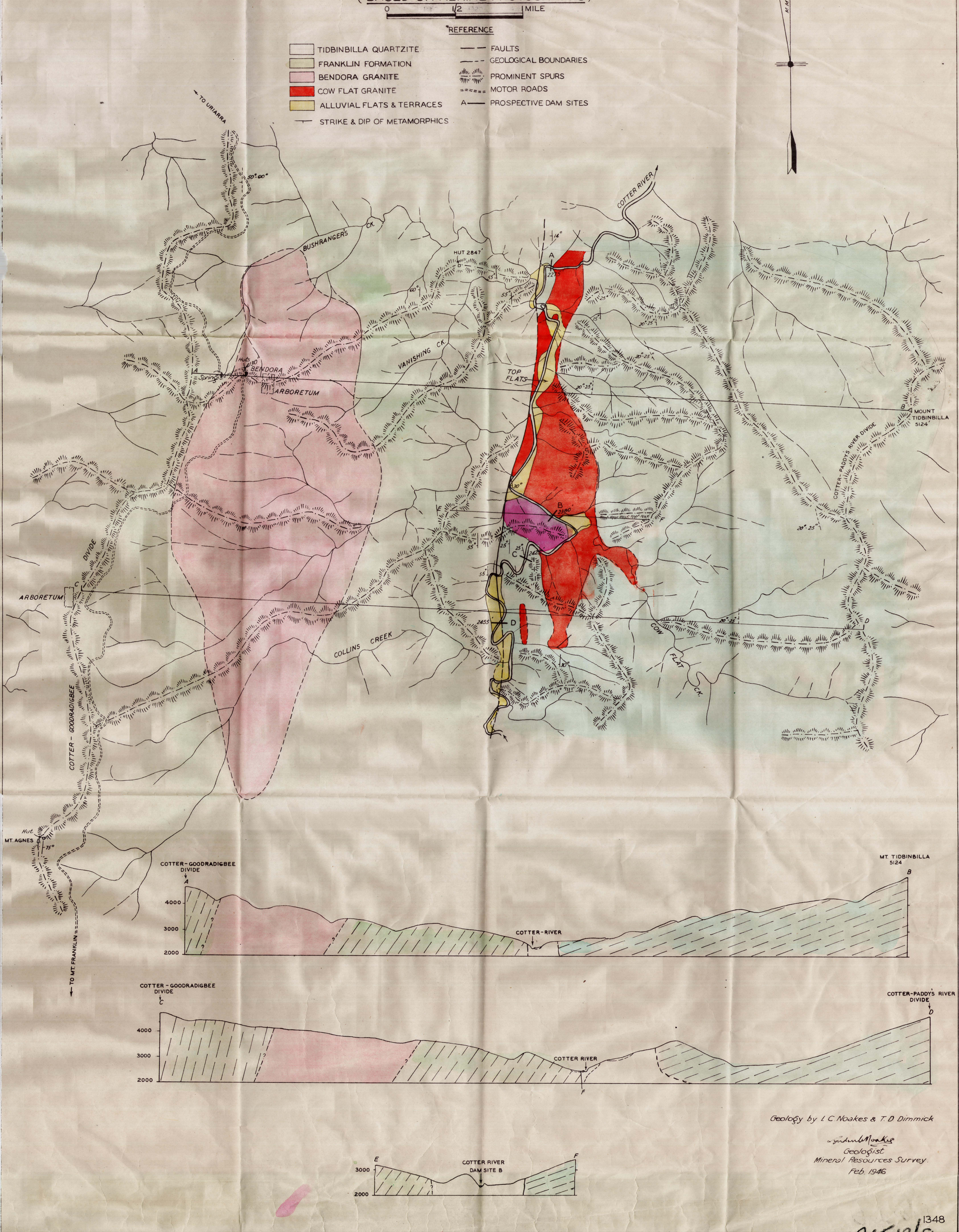

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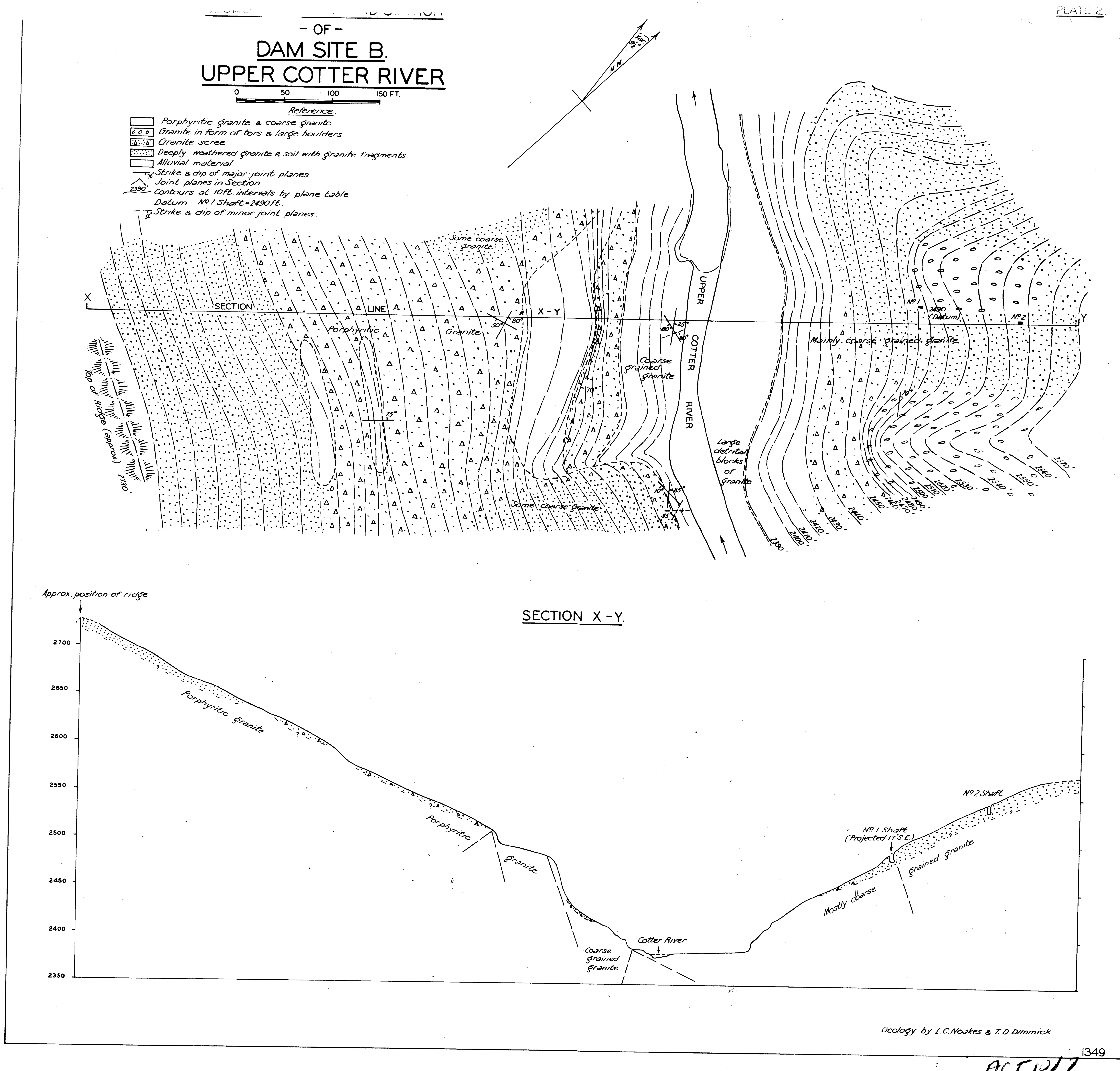
PLATE 2.



1349

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