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THE EDITH RIVER URANIUM-BEARING AREA

by

N. H. Fisher.

CANBERRA.

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Illustrations

Plate 1. Edith River Area, Northern Territory, showing location of uranium-bearing deposits, Scale 2.11 ins = 1 mile.

Plate 2. Uranium-bearing area Edith River, Northern Territory - Plane Table Survey Scale 1 in. = 200 ft.

SUMMARY

In the Edith River area uranium occurs as meta-autunite associated with apatite and hematite in narrow siliceous reef formations which are in part brecciated and mylonized. The reefs, which dip steeply west and strike mostly north-north-west, occur over a length of about 3 miles in a north-south, sheared greisenized, zone in granite. Two main types of granite are present, a coarse grained granite and a finer-grained adamellite, which is intrusive into the coarse granite. In places partial digestion of the coarse by the fine granite has produced a porphyritic "hybrid" granite. All granites except the greisenized granite of the sheared zone give high background counts, 2 to 3 times as high as that of the sediments of the Brocks Creek group into which the coarse granite is intrusive.

Within the reef formations the distribution of uranium-bearing material is patchy. In many places the best geiger readings are obtained where cross reefs or fractures with a north easterly strike cut the main reefs. Surface samples were taken across most places where significant Geiger readings were obtained and all returned less than .1% U_3O_8. Commercial production from the field will only be possible if the grade of the original ore has been greatly affected by surface leaching and a site was selected for a shaft to test the primary ore.

THE EDITH RIVER URANIUM-BEARING AREA

SITUATION etc.

The area which has been shown to be uranium-bearing (up to August 21st, 1952) is from one to five miles south of the Edith River and from ¼ to 1 mile east of the Darwin-Birdum Railway line near the Edith River Siding. It can be reached either from the Stuart Highway at a point about 27 miles by road from Katherine, or from the Mt. Todd road (Plate 1) which joins the Stuart Highway from the east about 32 miles from Katherine. In a direct line the area is 22 miles north-west of Katherine airport.

The presence of radioactive minerals was established by a party known as the Y.M.C.A. syndicate, consisting of Messrs. Young, Mazlin, Cousin and Atkinson, who have been engaged upon the erection of a battery (Plate 1) near Mt. Todd to treat tin ore from the Horseshoe Creek tin deposits.

A plane table survey on a scale of 200 feet to an inch was made of the mineral-bearing area; representative samples were cut across the most significant exposures and all the reef formations tested thoroughly by Geiger Counter (ratemeter type). Geiger counts obtained in the field were correlated with radiometric assay results so that a fairly thorough assessment is possible of the uranium content of all the reef outcrops mapped. Roughly, a count of 3 times background corresponded to a radiometric assay of .03 percent U_3O_8, five times background .05% U_3O_8 and so on.

The writer records his thanks to Mr. W. Macdonald, Inspector of Mines, Northern Territory and Mr. Cousin for providing information about the location of the mineral deposits and the points where radioactivity had been detected and his appreciation of the efforts of B.P. Walpole and B. Drew, Bureau of Mineral Resources, in completing in 2 days the plane-table survey of three miles of mineral-bearing country; also his thanks to W.B. Dallwitz for carrying out the petrological examinations and for his assistance in elucidating problems concerned with rock and mineral occurrence.

GENERAL GEOLOGY

The area is occupied by granite and constitutes the southern extension of the main mass of what Noakes (1949) has called the Cullen Granite. Metamorphosed sediments of the Brocks Creek group of Pre-Cambrian age, into which the granite is intrusive, outcrop at the southern end and to the east of the uranium-bearing area (Plate 1). Two distinctive varieties of granite are present, a coarse-grained and a fine-grained granite. The fine-grained granite (adamellite) is the later of the two and is intrusive into the coarse-grained. In places the contact is sharp and well-defined, in others a transition zone exists in which the granite is of a hybrid character with coarse phenocrysts in a fine ground-mass, seemingly the result of partial digestion of the coarse-grained granite by the fine. Results of petrological examination of the granites (Specimens A203, A202, A213) by W.B. Dallwitz are given in Appendix I.

OCCURRENCE OF URANIUM

The uranium-bearing deposits occur along a sheared zone in the granite (Plate 2) which extends southwards for over two miles from the original discovery. The zone is generally 300-400 feet wide and the granite within the zone has been altered to greisen to a greater or less degree (Specimens A222,226, 204). No relative displacement appears to have taken place on either side of the sheared zone. Near Deposit B (Plate 2), for instance, the contact of the fine-grained and coarse-grained granite crosses the sheared zone. In the neighbourhood of Deposit E, the zone is bounded by coarse-grained granite on the east and hybrid granite on the west, but as a rule the sheared zone does not necessarily coincide with lithological boundaries. More detailed mapping of a wider area would no doubt give further interesting information on the granite relationships.

Along the sheared zone, which strikes north-south, numerous narrow siliceous reefs and zones of shearing in the granite occur. Most of these strike at 338 degrees (north-north-west) so that they are arranged en echelon within the main zone of shearing. Dip is usually at 80 degrees to the west. Some of the siliceous reefs swing from the north-north-easterly strike at their northern end to a strike of 3 to 10 degrees, at their southern end. A set of cross-reefs ranges in strike from 26 to 75 degrees. Near the southern end of the mapped area (Plate 2) the sheared zone seems to lose its identity. In this area individual reefs, ranging in direction of strike from 320 to 335 degrees, occur outside the sheared zone (or its continuation along the strike).

Some of the reefs are in part brecciated and in places, principally those striking north-north-west, have reddish hematitic material associated with them. It is this hematitic material that carries the radioactive mineral, and high Geiger counts can generally be obtained where it is present. Radioactivity occurs as a rule only at certain places within the reef formation, commonly where the north-north-west reef is cut by a cross-fracture belonging to the north-easterly striking series.

The radioactive mineral, which occurs mainly as a facing along cracks and partings in the hematite-bearing sections of the reef formations, has been determined by W.B. Dallwitz as meta-autunite. It fluoresces a bright yellowish-green colour and shows up extremely well in the outcrops, where present, at night under ultra-violet light. However, because of the manner of distribution of the meta-autunite, examination under ultra-violet light gives an exaggerated impression of the amount of uranium present.

Study of the ore in thin section, of which detailed results are given in Appendix 2, has shown that most of the reddish hematite-bearing material actually consists of apatite. Fluorite is present in some of the reefs, mostly in segregations of fairly coarse grain-size, but is not normally associated with the uranium-bearing sections.

The sequence of geological events that are relevant to the formation of the primary mineral deposits appears from the field evidence to have been as follows:

1. Intrusion of the coarse-grained Cullen granite into the sediments of the Brocks Creek Group.

2. Intrusion of the finer-grained granite into the coarse-grained.

3. Formation of main north-south zone of shearing in the granite, accompanied by the development of the complimentary smaller shear zones striking mainly north-north-west.

4. Conversion of the granite along the shear zone, particularly the finer-grained variety, into greisen.

This was probably contemporaneous with 3.

5. Introduction of silica with the formation of narrow quartzose reefs along the complimentary shear zones.

6. Further movement causing brecciation and mylonization in places of the reef formations.

7. Further mineralization with hematite, apatite, more silica, primary radioactive minerals, and fluorite.

Determination of the distribution of radioactive minerals is made complicated by the high geiger count obtained in the granites. Wherever tested, the granites, coarse-grained, fine-grained and hybrid, gave a uniform count with the ratemeter used of 140 to 160 counts per minute. Sediments of the Brock's Creek Group gave a background of only 60 to 80 counts per minute. The greisenized granite of the sheared zone in which the reef formations occur gave a background of about 100 counts per minute and this is the reading that is taken as "background" in this report. Any count above this along the reef formations indicated the presence of radioactive minerals. This was checked by examination at night under ultra-violet light. Highest readings obtained were about 10 times background, in one spot only, and in a few places 6 to 8 times background. Readings above the 100 count background were obtained on 14 of the individual reef formations, but radiometric assay results of all samples taken were low. None exceeded 0.1 per cent. U_3O_8. Details are given in the next section.

The extent to which leaching may have affected the reef formations is extremely important. Surface samples are all low-grade and the primary ore would have to be several times richer to be minable. Evidence from surface exposures does not particularly favour this possibility. The hematitic material with which the meta-autunite is associated is fairly dense and it does not appear likely that leaching agents could have penetrated right through it, so that some at least of any original radioactive mineral that it may have contained should still be present. Most of the meta-autunite seen is along cracks and partings, and cut sections of the hematitic material show very little fluorescent mineral under ultra-violet light. The meta-autunite is confined mainly to the hematite-bearing sections of the reef formations whereas if the primary ore were rich, one would expect the secondary minerals to be distributed over other parts of the reef and into the adjacent country rock. Comparatively little detrital material exhibiting radioactivity is found near the reefs.

It is also possible that the apatite which constitutes the bulk of the hematitic material may have acted as a precipitating agent and that the present distribution of meta-autunite is a reflection of this rather than of the original distribution of primary radioactive mineral.

In any case it is essential that sufficient work should be done to determine the grade of the primary ore and the character of the mineralization.

Two of the specimens collected of the granite showed specks of fluorescence under ultra-violet light similar to that of the reef formations, which suggests that the radioactivity of the granite may be due to a disseminated uranium content.

The distribution of radioactivity along the sheared zone is also significant and indicates that the uranium content of the greisenized granite of the sheared zones, which gives so much lower a count than the granites elsewhere, may have been concentrated during the process of greisenization into the reef formations.

Individual uranium-bearing reef formations.

The individual reef formations or groups of reef formations have for convenience been lettered from north to south, Deposits A to H.

Deposit A.

This is the original discovery. A well-defined zone of shearing up to 60 feet wide extends for over 1,000 feet on a bearing of 338°. Geiger readings usually about twice background but rising in spots to 4 or 5 times background are obtained at intervals for about 400 feet in the central and northern part of the shear zone in a mineralized formation up to 5 feet wide. Narrow transverse quartzose reefs near the southern end and near the middle of the shear zone, striking about 30°E, are associated with sections giving high geiger readings. Outcrop samples were taken across the reefs at places of highest geiger readings as follows. For position of samples refer to Plate 2.

Sample No.	Width of Sample, inches	Geiger Reading X Background	Radiometric Assay % U_3O_8
A225	42	2½	.06
A223	36	2	.02
A224	16	up to 10	.05

Six samples were taken by the discoverers from this deposit near samples A223 and A225. Of these, three returned less than .01 percent. U_3O_8, one .03 percent. one .07 percent and one .107 percent.

Deposit B.

The second group of deposits is about 1,000 feet south of Deposit A. It consists of a number of quartzose reefs of which the northernmost strike at 337 degrees and the remainder at about 11 degrees. All dip steeply west. Readings about twice background can be obtained in several places. This group of deposits crosses a well-defined contact between the coarse and the fine-grained granites. No samples were taken but from the geiger readings the U_3O_8 content of the reef outcrops nowhere exceeds .ol percent.

Deposit C.

This deposit is situated also near the junction of fine and coarse-grained granite, ½ mile south of Deposit A. It is a strongly outcropping quartzose formation, brecciated in part, with some hematite-bearing material which gives geiger readings up to 4 or 5 times background. Length is 300 feet and width up to 10 feet. Strike ranges from 340 to 10 degrees and dip is steep to the west.

Three samples were taken from the outcrops. From north to south these returned:-

Sample No.	Width of Sample, inches	Geiger Reading X Background	Radiometric Assay % U_3O_8
A207	30	2	Less than .01
A206	24	1½	" " .01
A205	30	4	.04

Deposit D.

The deposits referred to this group are long, narrow, siliceous reefs, commonly about 1 foot wide. They dip steeply west and strike ranges from 335 to 355 degrees. At one point only a geiger reading 2½ times background was obtained.

Deposit E.

The presence of uranium minerals has been established in two formations, which strike generally about 345°.

In the northerly one, high geiger readings (5 times background) were obtained where the reef is broken at two places by small cross-faults. The reef is in general only 1 to 2 feet wide but on either side of the more northerly break, it bulges to 10 feet wide. The reef bulges also at the southern break. Samples A208 and 209 were taken at these bulges.

In the southern deposit high geiger readings (up to 6 times background) can be obtained on poorly exposes hematite-bearing material along the western side of a zone of shearing which ranges in width up to 40 feet. The eastern side of the shear zone is marked by a straight steeply-dipping quartz reef. Both this reef and that of the more northerly deposit contain patches of fluorite, mostly yellow in colour, though some purple fluorite is also present.

Two samples were taken in each deposit from the places giving the highest geiger readings.

Sample No.	Width of Sample, inches	Geiger Reading X Background	Radiometric Assay % U_3O_8
A208	42	$2\frac{1}{2}$ - 5	.01
A209	54	2 - 4	.03
A210	18	6	.06
A211	24	7	.06

Deposit F.

On surface indications this deposit is the most promising so far located. It consists of a quartzose reef formation, hematite-bearing in places, about 700 feet in length, with a sharp bend about the middle. The northern part strikes at 340 degrees and the southern part at 27 degrees. Dip is steep to the west. Geiger readings up to 8 times background were obtained at sporadic intervals along the whole length of this formation. Near the southern end the reef crops out prominently as a hematite-bearing quartz breccia formation 2 to 3 feet wide. South of this is a lens of hematitic lode, up to five feet wide, which gives geiger readings above background continuously for a length of 50 feet. In the central part of this lens the reading is 7 to 8 times background and this was the site recommended for sinking a shaft to test the ore at deeper levels. Samples from 5'6" and 7'6" depth in this shaft returned .12% U_3O_8.

Four outcrop samples were taken from the southern "leg" of Deposit F. (Plate 2).

Sample No.	Width of Sample inches	Geiger Reading X Background	Radiometric Assay % U_3O_8
A215	24	$3\frac{1}{2}$	.04
A216	25	5 - $7\frac{1}{2}$	.08
A217	21	6 - $7\frac{1}{2}$	.09
A218	18	3	.01

About 1,000 feet north of Deposit F, geiger readings 2 to 3 times background were obtained over about 20 feet length of a narrow steeply west-dipping reef. Sample A214 over 32 inches (geiger reading twice background) returned less than .01% U_3O_8.

South of Deposit F the main sheared zone in the granite within which Deposits A to F occur becomes less well-defined, partly because the area is flat and soil-covered, the only outcrops being large rounded isolated boulders of coarse granite.

Deposit G is outside the sheared zone and 600 to 800 feet west of it and Deposit H is about the same distance to the east of the continuation of the zone, which, however, was not traced as far as this.

Deposit G.

This is a straight siliceous reef which cuts across an old deviation road made when the Stuart Highway was under construction. It is about 750 feet long, with a prominent quartz outcrop at the southern end. It strikes for the most part 333° and dips west at 70-75 degrees. Granite adjacent to the reef is sheared. Geiger readings above background were found at only two places on this reef. The principal one is associated with a small cross-fracture, on the southern side of which counts generally not more than twice background can be obtained for about 10 feet.

Deposit H.

Two reefs, which may be continuous under soil cover, were mapped in this area, which marks the southern margin of the granite. The reef stops abruptly at the contact of the granite with the metamorphosed sediments - mudstone shale etc. - of the Brocks Creek Group. The northern reef, which is not well exposed, is generally less than 2 feet wide, strikes 320 to 335 degrees, and contains fluorite in places. Geiger counts of 3 times background were obtained at a small cross-fault; elsewhere the count did not exceed 1½ times background.

The southern reef, which terminates at the contact of granite and sediments, is up to 4 feet wide and gives similar geiger readings except at one point, where 5 times background was obtained. One sample, A219, was taken from the northern and one, A221, from the southern reef (Plate 2).

Sample No.	Width of Sample inches	Geiger Reading X Background	Radiometric Assay % U_3O_8
A219	16	2½ - 3	.01
A221	32	1½	.01

Other Deposits.

Outside the area of Plate 2 radioactivity has been shown to occur in sheared granite, near the Mt. Todd road, about 3,000 feet north of Deposit A. A sample taken of this material over a width of 12 inches, geiger reading twice background, returned a radiometric assay value of less than .01 percent. U_3O_8.

RECOMMENDATIONS

a. Prospecting.

It was suggested to the finders of the deposits that a shaft should be sunk at the site indicated on deposit F. In view of the low uranium content of surface samples and the desirability for determining the grade of the primary ore, it is recommended that the Commonwealth Government, from funds provided for the development of resources of radioactive minerals, should finance the sinking of this shaft to the extent of, in the first instance, 120 feet of shaft-sinking and/or driving at £5 per foot shaft sinking for the first 20 feet and £7 per foot below that depth.

Second preference of site for shaft sinking would be at Deposit A, at the original discovery. This site is to be commended mainly because of its lower elevation (about 50 feet lower than on Deposit F). Primary minerals should be met at a shallower depth.

Because of the patchy distribution of radioactive minerals at the surface, diamond-drilling cannot be regarded as a suitable means of exploring the deposits, at least until driving in the primary zone has established whether the ore is more continuous there than on the surface.

b. Reward.

Assay results of all samples taken so far are so low that it cannot be said that the deposits contain "uranium ore sufficient to be of economic importance". However the discovery has established the existence of radioactive minerals over a considerable area and further prospecting is definitely justified (a) for further deposits of uranium ore (b) to determine whether the primary ore may be of sufficiently high grade to be of commercial importance. The discovery therefore fulfils the requirements of Clause 3 of the conditions for the grant of rewards for discovery of uranium ore and it is recommended that a reward of £500 should be paid immediately to the discoverers. The matter should be further considered when the grade of the primary ore is known.

REFERENCES.

Noakes, L.C., 1949: A Geological Reconnaissance of the Katherine-Darwin Region, Northern Territory. Comwlth. of Aust. Bur.Min. Res.Geol & Geophys. Bull. 16.

APPENDIX I.

PETROLOGICAL NOTES ON ROCK SPECIMENS FROM THE EDITH RIVER AREA, N.T.

Petrography.

No. A203. Coarse-grained Granite - the "Cullen Granite".

In the handspecimen flesh-coloured to pinkish white felspars, semi-vitreous quartz, and very subordinate biotite are distinguishable. The felspars, in general, and the rock as a whole, are coarse-grained; some unusually coarse, porphyritic felspar crystals measure 2 cm. or more across. A single fleck of a bright yellowish-green-fluorescing mineral - probably meta-autunite - appears on the specimen.

Microscopically the texture of the rock is seen to be typically granitic.

Perthite is the most abundant felspar; acid plagioclase and microcline perthite are also present, but, because the rock is so coarse-grained, it is impossible to assess, from a single slide, the relative proportions of potash-felspar and plagioclase. The rock can probably be named granite, but more extensive examination may show that it is closer to adamellite in composition. The large porphyritic crystals consist of potash felspar, and are anhedral and interstitial. Plagioclase probably crystallized earlier, and occurs in subhedral grains. Potash felspar is slightly kaolinized; plagioclase is fairly strongly sericitized and kaolinized.

In some places, plagioclase in perthite is in optical continuity with an adjacent plagioclase crystal. Most plagioclase grains are bordered by a narrow shell of clear, unaltered albite.

The quartz shows moderate strain-polarization and it contains fluid inclusions arranged in several planes.

Biotite is partly altered to chlorite and sphene. Pleochroic haloes surround minute, dark, elongated grains which can not be identified. Grains of a mineral resembling zircon, but having fairly low double refraction, are included in the biotite; these grains are commonly bordered by pleochroic haloes. A single grain of apatite, and another of an unidentified mineral (possibly coloured apatite, or axinite), which is pleochroic from brownish purple to light brown, and has a low first order interference colour, are also associated with the biotite.

Muscovite is found in association with biotite and felspar, but is quite sparsely distributed.

Calcite is of rare occurrence.

Fluorite occurs as crack-fillings in potash felspar, and as abundant small flecks in plagioclase; some is also associated with biotite and quartz. Nearly all of it is colourless, but where contiguous with biotite it is coloured purple.

No. A202. Medium-grained adamellite.

This rock consists, macroscopically, flesh-coloured felspar, semi-vitreous quartz, biotite, and muscovite. A single porphyritic crystal of white felspar measuring over 1 cm. in length is present, and a few porphyritic grains of slightly smoky quartz up to 0.75 cm. long are distributed through the specimen. Ignoring these few larger grains, the average grainsize is between 0.5 and 1 mm.

Microscopically the essential minerals are seen to be felspar quartz, and biotite. The rock is moderately even-grained.

Potash felspars represented comprise microcline, microcline perthite, orthoclase, and perthite; these are slightly kaolinized. The soda-lime felspar (an acid plagioclase) is generally zoned, and is moderately sericitized and kaolinized. Potash felspars and plagioclase are present in approximately equal proportions, thus placing the rock in the adamellite division. One porphyritic crystal of plagioclase measuring about 6 mm. in length appears in the slide; this crystal has been stronly sericitized and kaolinized, and is also impregnated with limonite.

The quartz is more strained than that in specimen No. A203.

Some of the biotite books are partly altered to chlorite; others have been completely changed to that mineral. Pleochroic haloes surround minute, unidentifiable grains in the mica. Muscovite is subordinate to both biotite and chlorite.

A little purple fluorite is associated with biotite and chlorite, and flecks of colourless and purple fluorite are included in the felspars.

Calcite is a rare accessory.

No. A213. Porphyritic ("hybrid") granite.

Macroscopically this rock has the appearance of being a mixture of specimens Nos. A202 and A203.

Set in a matrix closely resembling the adamellite (specimen No. A202) are large porphyritic crystals of microcline perthite and books of biotite; one crystal of microcline perthite is over 3 cm. long. Part of the specimen is coated with a thin, discontinuous film of probable meta-autunite, visible only under ultra-violet light.

In the thin section examined, no porphyritic crystals appear, and, accordingly, the rock is rather closely similar to specimen No. A202. However, plagioclase is somewhat less plentiful than in that specimen, and muscovite is more plentiful. Fluorite, also, is present somewhat lesser quantity. Most of the muscovite is identifiable as the variety damourite, by virtue of its having a small, but variable, optic axial angle.

No. A222. Sericitized adamellite.

In the hand specimen this rock appears to have a grainsize similar to that of specimen No. A202. However, porphyritic crystals of quartz are absent. Pink felspar, quartz, yellowish masses of sericite, hematite, and muscovite are identifiable.

No plagioclase remains in the slide; this mineral has, apparently, been replaced by fine-grained sericite; microcline and orthoclase appear to have escaped alteration. Former biotite is probably represented by masses of compact hematite; only one or two very small flakes of the mica remain unaltered.

No. A226. Greisen.

This specimen is macroscopically somewhat similar to the last; the main difference is that no pink felspar remains. It, therefore, consists almost entirely of yellow masses of sericite, and quartz. Some porphyritic quartz grains are present (c.f. specimen No. A202). Bleached biotite and flakes of muscovite are also distinguishable.

Greisenization has advanced a stage further than in specimen No. A222: potash felspars, as well as plagioclase, have been completely replaced by fine-grained sericite. However, by contrast with that rock, some biotite remains, but it has been severely bleached.

Distinct masses of hematite are absent, but as in specimen No. A222, granular hematite is distributed throughout the sericite; thin films of hematite also lie along the cleavage of muscovite books. The mica has a smaller optic axial angle than that normally observed, and is, therefore, a damouritic variety.

The degree of strain in quartz in this specimen, as well as in Nos. A213 and A222, is similar to that in specimen No. A202.

<u>No. A204. Greisen.</u>

Macroscopically this rock consists almost entirely of quartz and greensih grey sericite. Some of the quartz has been either introduced, or else segregated into schlieren during the progress of autometamorphism.

In thin section, quartz, sericite, muscovite, and damourite are found to be virtually the only minerals present. The whole rock has been reconstituted. The masses of sericite noted in the earlier stages represented by specimens No. A222 and A226 have been recrystallized on a coarser scale, and have partly lost their characteristic shapes (pseudomorphous after felspars), due to their having been attacked by solutions, and affected by shearing. All of the mica has a yellowish tinge, and is noticeably pleochroic.

The quartz is characterized by strain shadows stronger than those noted in any of the other five specimens.

Leucoxene and limonite are the only accessories.

<u>Petrogenesis.</u>

The main granite mass in the area is the coarse, porphyritic type known as the Cullen Granite (specimen No. A203). This granite, probably at a late stage in its cooling, has been intruded by a medium-grained adamellite (specimen No. A202). The adamellitic magma was most likely derived from one or both of the following sources:

(a) From the deeper portions of the granite batholith itself - in which case its emplacement would probably have been brought about by shearing (see also under b).

(b) From residual liquors present in the granite at a late stage in its crystallization; if such liquors contributed to the formation of the adamellite, they would probably have been expressed as a result of contraction during the cooling of the granite magma, or, more probably, as a result of a shearing movement within the granite. The fact that quartz is more strained in the adamellite and greisens derived therefrom, than in the granite, favours the latter idea.

Mild shearing stress probably continued during the solidification of the adamellite, thus imparting strain to the crystallizating quartz.

To what extent the adamellite owes its explacement to metasomatic processes is not known; from an examination of specimen No. A213, it seemed likely that the coarse, porphyritic crystals of microcline perthite are virtually all that remains of the original granite, and that the matrix of those crystals has been reconstituted, probably with material additions, to give rise to the rock-type represented by that specimen.

Both the Cullen Granite and the adamellite are characterized by the presence of small quantities of fluorite, and by being radioactive; this evidence tends to support the suggestion that they are co-magmatic. The source of their radioactivity has not been established with certainty; the best that can be said at present is that the radioactive substances are probably included in biotite, which contains minute grains centred in pleochroic haloes. A secondary uranium mineral, probably meta-autunite, occurs as encrustations on specimens Nos. A203 and A213.

Hydrothermal, autometamorphic processes which were active in certain localized places within the adamellite have led to the formation of greisen. Plagioclase was the first mineral to be attacked (specimen No. A222), and potash felspars succumbed next (specimen No. A226); the final product is a rock consisting virtually entirely of quartz and white micas. Iron-bearing solutions, where present locally in sufficient quantity, brought about the replacement of biotite by hematite (specimen No. A222).

In a sheared portion of the greisen (specimen No. A204), quartz appears to have been partially segregated from the mica (or, perhaps, some quartz has been introduced), and muscovite, sericite, and damourite have recrystallized as coarser aggregates which have, to some extent, lost the pseudomorphic shapes observable in specimens Nos. A222 and A226; in those two rocks the outline of former felspar grains are quite well preserved.

The fact that a large quantity of felspar has been converted to white micas shows that water played a dominant role in the transformation of adamellite to greisen.

It has been observed in the field that the greisen masses, by contrast with the adamellite and the granite, are virtually non-radioactive. Thus it appears probably that, concomitantly with the process of greisenization, the radioactive elements have been removed from the altered parts of the adamellite, possibly to be redeposited in the lode-shears occurring within the greisen.

The lode materials and the post-greisenization processes which led to their formation, are described and discussed in Appendix II of this report.

(W.B. Dallwitz)
<u>Petrologist.</u>

APPENDIX II.

RADIOACTIVE LODE-MATERIALS FROM THE EDITH RIVER AREA, N.T.

Petrography.

Macroscopically the uranium-bearing rock has a strongly brecciated appearance, particularly on weathered surfaces, where elongated, angular fragments of quartz and siliceous rock stand out in relief as a result of differential solution of the matrix in which they are embedded. Some of the fragments as a whole are pale grey to greyish yellow, and are slightly, but unevenly, stained by limonite and hematite. Their sizes, in the specimens studied, range from microscopic up to about 6 cm. by 1 cm.

The general colour of the specimens is pale red (about 5R6.5/2), as defined on the "Rock-color Chart" of the National Research Council, Washington, D.C., U.S.A. Mottling, in various shades of yellow-grey, light pinkish grey, and dark yellowish orange, is conspicuous, and is due partly to the light-coloured fragments, and partly to irregular staining resulting from weathering. A few thin, white, veinlets, nowhere more than 1 mm. wide, are present; parts of them are lightly stained by limonite and hematite.

It is not possible to ascertain, from a visual examination of the hand-specimens, the nature of the relatively soluble matrix in which the fragments are embedded. It is strongly stained by hematite, and small pockets and veinlets of micaceous hematite are visible in a few places.

Veins of quartz up to 2 cm. wide have been injected into the rock after brecciation. Some of these veins carry a few platy or needle-like limonitic and hematitic pseudomorphs measuring up to 2 cm. in lenght, and 1 to 2 mm. in thickness.

Discontinuous films and patches of light-yellow-green fluorescing meta-autunite (see below) show up on the broken surfaces of the specimens under ultra-violet light. Only comparatively rarely can any trace of this mineral be seen in ordinary light; the films are evidently extremely thin, and the individual particles microscopic, so that they are masked entirely by hematite, except where they are thicker, and the grains more crowded. Examination of cut surfaces shows that the meta-autunite is confined almost entirely to small cracks and crevices. By contrast, certain specimens from the oxidized portion of White's Deposit, Rum Jungle, N.T., were found to have a fluorescing radioactive mineral more or less evenly distributed throughout the rock.

Two thin sections have been prepared for study.

One (Specimen No. A212) represents a rock consisting essentially of angular fragments of strained and partially recrystallized quartz set in a matrix of (generally) fine-grained apatite, and subordinate fine-grained quartz and hematite. A few flakes of white mica and bleached biotite, and numerous small flecks of sericite are unevenly distributed through the slide. Several veinlets of quartz are also present.

The apatite has unusually low refractive indices, about 1.595 . Reference to Palache, Berman, and Frondel (1951, pp. 878-889) suggests that it is the variety hydroxyl-carbonate-apatite, for which the indices 1.603 and 1.598 have been recorded. A qualitative chemical test on crushed matrix gave a strong phosphate reaction, and marked effervescence took place during solution in nitric acid.

The second slide (Specimen No. A228) presents a remarkable appearance. Shattered fragments of mylonitised quartz and greisen (the stratified fragments noted in the handspecimens) are set in a matrix of apatite and hematite. The hematite, though more abundant than in specimen No. A212, makes up not more than about 20 per cent. of the matrix; its degree of concentration varies greatly from place to place in the slide. A little of it has penetrated the mylonites also. The mylonitised greisen consists of alternating thin layers and elongated augen of quartz and sericite; some of the quartz is finely comminuted, and some is drawn out into long, strained streaks which are optically continuous over cross-sectional areas covering the full length of the mylonite fragments and measuring up to 8 mm. by 0.75 mm. This latter condition suggests that the mylonite was formed while the greisen was still at a sufficiently high temperature to allow some of the quartz to recrystallize coarsely after the dynamic stress had substantially subsided.

Limonite is a somewhat rare accessory.

The apatite is generally coarser-grained than that in specimen No. A212, the average dimensions of the prisms being about 0.3 mm. by 0.1 mm. The prisms are length-fast, and many of them show basal cleavage; some of the cleavage-planes are filled with hematite. As far as can be gauged, the apatite is biaxial, with a small optic axial angle.

In one part of the slide every apatite prism is bordered by a thin shell of a colourless to murky white mineral of higher double refraction, and appreciably lower refractive index. These shells are everywhere of remarkably uniform thickness. Nearby the same mineral occurs, together with microcrystalline apatite, in a veinlet traversing both the mylonite fragments and the matrix; it is probable that this is part of one of the white veinlets noted in the hand-specimen. Tests carried out on grains in the thin section show that the refractive index of the mineral is slightly above that of quartz, that the grains are biaxial negative with a moderate optic axial angle, and that the maximum interference colour is reddish purple, indicating that the double refraction is about 0.019. These properties, considered in conjunction with its intimate association with apatite, point strongly to the probability that the mineral is variscite ($(Al, Fe''')PO_4.2H_2O$; $y = 1.570-1.587$; $B = 1.565-1.583$; $d = 1.550-1.562$).

Small quantities of very unevenly distributed interstial quartz and sericite are associated with the apatite and hematite. A few small quartz veins traverse the slide, and some quartz in a few fragments of mylonitized greisen has recrystallized with an imperfect comb structure, the long axes of the quartz grains being arranged perpendicularly to the banding in the rock.

Petrogenesis.

From the above observations, the following stages in the evolution of the ore-bearing rock can be deduced. These events succeeded the greisenization of the adamellite, which was described in Appendix I.

1. Quartz was introduced into the greisen, probably along a shear-zone. The evidence for the introduction of quartz at this stage rests on the observation that quartz is considerably more plentiful than mylonitized greisen in the two slides examined, and appears also to be so in the available hand specimens.

2. Mylonitization of the quartz and the greisen took place. Where dynamic metamorphism was less intense, breccia was produced instead of mylonite.

3. The mylonitized rock - and very likely the breccia as well - was brecciated.

4. A minor, secondary brecciation then took place. This brecciation, and possibly that belonging to stage 3 also, appears to have been contemporaneous or penecontemporaneous with the next event - mineralization - because many of the brecciated fragments of mylonite formed at the third stage have been so slightly separated during the minor brecciation that it is easy to visualize groups of them as being parts of a formerly-existing larger fragment of mylonite. The small mylonite fragments, as well as the larger ones, are embedded in a matrix consisting of the gangue minerals listed under stage 5.

5. Most probably the primary uranium mineral, from which the meta-autunite was subsequently derived, was now precipitated. Gangue minerals deposited at the same time were abundant apatite, hematite, and a little quartz; it is not, as yet, known whether they replaced a previously-existing matrix, or crystallized directly.

6. Secondary recrystallization of some of the quartz, and formation of late quartz veins took place.

All six of these events most likely occurred before the rock had completely cooled.

Finally meta-autunite resulted from the weathering of the primary uranium-bearing mineral. How much, if any, of it has been removed from the outcrops by weathering remains to be discovered.

From the general appearance of the rocks, but particularly because of the presence of some micaceous hematite, it is thought unlikely that the hematite in them has been derived from iron-bearing sulphides by weathering. It is more probable that the hematite is a primary mineral.

THE URANIUM-BEARING MINERAL.

The uranium-bearing mineral, whose mode of occurrence has already been described, is coloured lemon yellow, and is very soft.

As only extremely little of it could be obtained for testing, the identification rests almost entirely on optical tests. Positive chemical tests, and determination of specific gravity, were out of the question.

Following are the optical data obtained on suitable cleavage-flakes. Most cleavage pieces were unsuitable for optical determinations, because they were found to consist of aggregates of slightly disoriented, lenticular or cigar-shaped units.

Colour:	Pale yellow.
Refractive index:	Approximately 1.600
Optic axial angle:	Very small; the interference figure given by cleavage flakes is noticeably uncentred.
Optical sign:	Biaxial negative.
Interference colours:	Almost isotropic in cleavage flakes; yellow or abnormal white or bluish grey in other orientations.

The mineral is soluble in warm, dilute hydrochloric acid.

The refractive indices are considerably above those usually given for autunite (= 1.577; = 1.575; = 1.553). However, autunite with such indices is, apparently, extremely rare, and according to George (1949) meta-autunite is the common natural form. Autunite contains about 12 H_2O, whereas meta-autunite contains 8 or less H_2O, and has = 1.595-1.613; = 1.595-1.610; = 1.585-1.600; (-)2V = 0-45°.

On the basis of refractive index, optic axial angle, optical sign, colour, fluorescence, and solubility, the Edith River mineral can, with reasonable certainty, be diagnosed as meta-autunite; because of the abundance of apatite in the rock it is not likely to be anything but a phosphate.

George (loc.cit.) states that he has measured refractive indices within the range given for meta-sutunite in so-called autunite from many localities in the world. Palache, Berman, and Frondel (1951, p.985), on the other hand, maintain that meta-autunite does not occur "as a primary deposit in nature, although most museum specimens of autunite if exposed to a warm, dry atmosphere, rapidly alter to meta-autunite I".

A comparison.

It is probable that this find is, in one respect, so far unique among the radioactive deposits of the world; it is unique in the very high percentage of apatite which is present in the gangue, and in the mode of occurrence of the apatite.

Uranium deposits contained in granitic rocks are, with few exceptions, not of particularly good size and grade, and this one at Edith River may, therefore, conform to the almost general rule.

It is of interest to note that some comparison can be made between these lodes and certain uranium-bearing deposits at Goldfields, near Lake Athabaska, Saskatchewan, Canada. These have been described by Conybeare and Campbell (1951).

These authors found that red rocks occurring along faults and shear-zones in Pre-Cambrain granitic rocks are more radioactive than others in the area. The degree of radioactivity is not uniform over the exposed parts of the zones, but the lowest readings obtained with Geiger-Müller counters were two or three times those obtained over neighbouring soda-rich granites and granodiorites. The red radioactive rock contains stringers of pitchblende, and oxidation products of pitchblende are locally abundant in solution-cavities. Megascopically the rock is stated to show a marked resemblance to reddish cherty rock associated with pitchblende deposits at Great Bear Lake, Canada. This reddish rock ranges in character from protomylonite, through mylonite, to ultramylonite. Coarse-grained varieties resemble breccia, with the texture of building stucco; the angular constituents are not rock fragments, but subhedral felspar crystals. Hematite has thoroughly permeated both fine and coarse-grained red rock, and especially the felspars. Adhering to the surfaces of felspar crystals, and lining interstices filled with calcite, chlorite, and quartz, are clusters of euhedral crystals of specularite. It is considered by the authors that hematite was introduced by solutions that rose along the mylonite zones. The uranium mineralization is not of payable grade.

To summarize, the similarities between the Goldfields deposits and those in the Edith River area are as follows:

1. Occurrence in shear-zones in granitic rocks; in the Canadian locality, the granite, an albite-bearing variety, has been formed by partial replacement of a bedded series.

2. Mylonitization along shear-zones.

3. Presence of primary hematite.

4. Presence of radioactive minerals.

5. Carbonate-bearing apatite at Edith River may be considered the equivalent of calcite at Goldfields.

As compared with the Canadian occurrences, several additional stages of development are recognizable in the Edith River rocks, and the gangue minerals are different. Possibly pitchblende will be found in primary material there.

Christie and Kesten (1949), in writing on the same area, state that the best pitchblende deposits are found in dark-coloured mafic rocks or altered carbonate rocks, rather than in quartzites or granite gneisses. Thus, on the Martin Lake property, pitchblende occurs in basalt, rather than in arkose; in the Gil group of pitchblende showings, it occurs in amphibolite, but not in quartzite. Elsewhere in the area, uraniferous veins are found in fine-grained chlorite-epidote rocks, or in dolomitic bands, or breccia-zones with carbonate cement. Thucholite is common in some of the deposits. Hematite is invariably one of the gangue minerals. High assay returns in gold and platinum are reported in some lodes. The deposits are believed not to be genetically related to any exposed intrusive rocks in the area.

The authors recommend that, in the area studied, major and minor geological breaks should be checked for radioactivity. Red hematite stain in country rocks, including red felspars in granite or gneiss, or a cherty-looking red alteration product, are favourable signs. Special attention should be paid to basalts, amphibolites, greenstones, or any other type of mafic rocks, particularly near their contacts with other formations. Carbonate bands or zones in sedimentary rocks are also stated to be favourable.

Kidd and Haycock (1935) refer also to the presence of hematite (including specularite) in some of the pitchblende deposits at Great Bear Lake, Canada. Fracture- and shear-zones are the loci of mineralization there.

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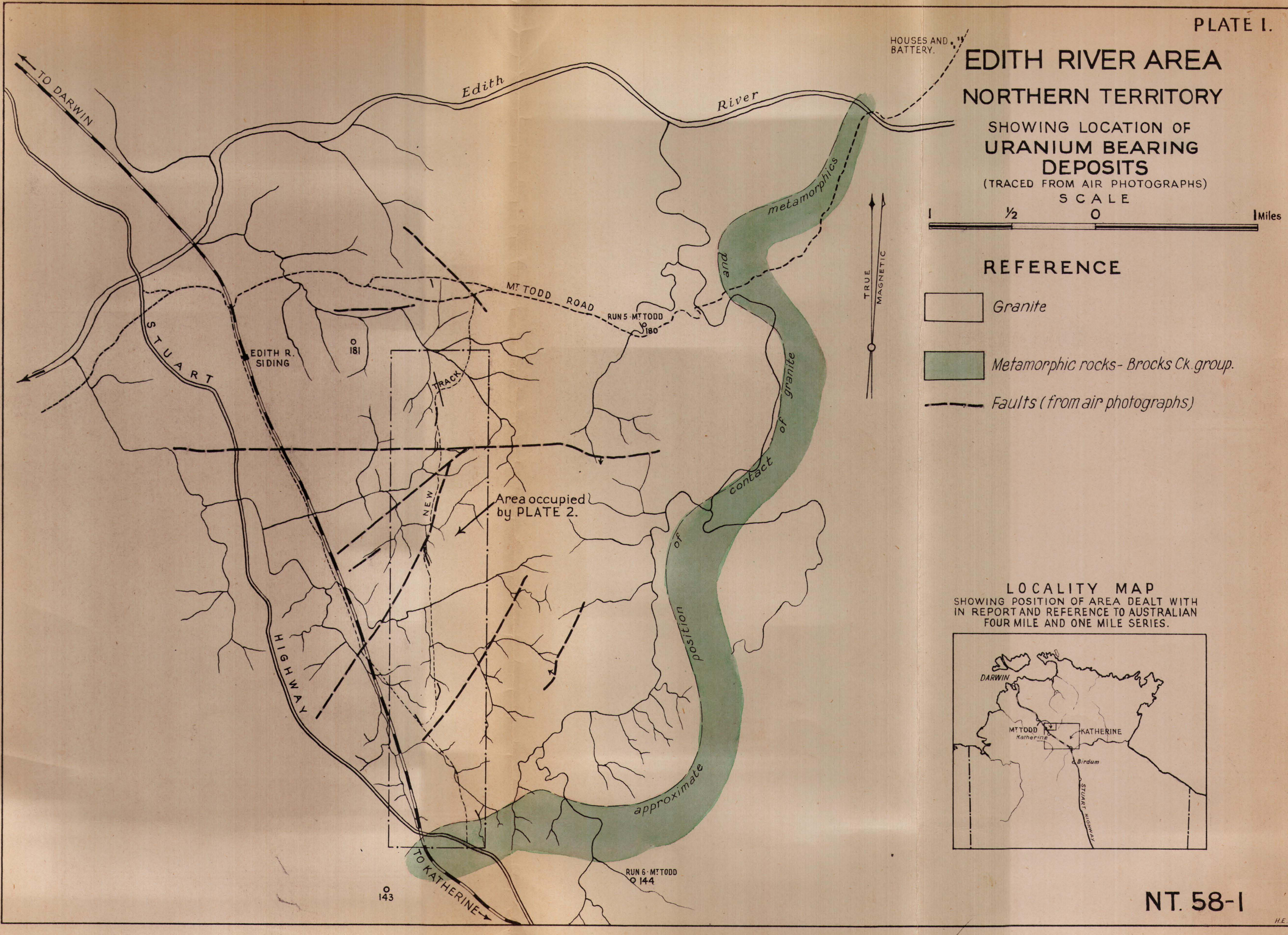
PLATE I.
EDITH RIVER AREA
NORTHERN TERRITORY
SHOWING LOCATION OF
URANIUM BEARING
DEPOSITS
(TRACED FROM AIR PHOTOGRAPHS)
SCALE
1 ½ 0 1 Miles
REFERENCE
Granite
Metamorphic rocks - Brocks Ck. group.
Faults (from air photographs)
TRUE
MAGNETIC
HOUSES AND BATTERY.
Edith River
TO DARWIN
MT TODD ROAD
RUN 5 · MT TODD
180
181
EDITH R. SIDING
STUART HIGHWAY
NEW TRACK
Area occupied by PLATE 2.
approximate position of contact of granite and metamorphics
RUN 6 · MT TODD
144
143
TO KATHERINE
LOCALITY MAP
SHOWING POSITION OF AREA DEALT WITH IN REPORT AND REFERENCE TO AUSTRALIAN FOUR MILE AND ONE MILE SERIES.
DARWIN
MT TODD
Katherine
KATHERINE
Birdum
STUART HIGHWAY
NT. 58-1
H.E.S.


PLATE 2
URANIUM-BEARING AREA
EDITH RIVER
NORTHERN TERRITORY
PLANE TABLE SURVEY - August 21-22, 1952
by N.H. Fisher, B.P. Walpole and B. Drew.
SCALE
200 100 0 200 400 600 800 1000 FEET
Reference
Coarse-grained granite
Fine-grained granite (adamellite)
"Hybrid" granite
Brock's Creek group - Metamorphosed sediments of Pre-Cambrian age.
Strongly sheared granite
Lode formations, dip.
Uranium-bearing sections at surface.
Geiger readings more than 3 times background.
Stations and points fixed by plane-table survey
Sample No. - Width - % U_3O_8.
Sample for petrological examination
Contours - approximate heights above sea-level from point on Stuart Highway and Railway at south end of area.
STUART HIGHWAY
SITE RECOMMENDED FOR SHAFT
Approximate boundary of sheared zone in granite
FLUORITE
A
B
C
D
E
F
G
H
TRUE
MAGNETIC
NT 58-2