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GEOLOGY AND MINERAL POTENTIAL
OF THE TIPPERARY STATION AREA,
NORTHERN TERRITORY

by

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SUMMARY

This appraisal describes the geology and mineral potential of several Northern Territory Exploration Licence (E.L.) areas which cover parts of the northern end of the Daly River Basin and of the south-western corner of the Pine Creek Geosyncline. Title to the tenements, which total 4,066 km$^2$ in area, is held by the Suttons Group of Companies. Because the areas are all within Tipperary Pastoral Holding, which also belongs to the Group, the tenements are not subject to Aboriginal land claims; also, the Station owns a good range of equipment of which good use could be made in mineral exploration operations.

Farm-in partners are currently sought to assist in continued exploration of these tenements.

The tenements are regarded as highly prospective for base-metal mineralization, and there is also potential for uranium mineralization, particularly in view of some of the preliminary results obtained from an airborne radiometric and magnetic survey already completed by Suttons. Other exploration already commissioned by the Group, and completed, comprises an aerial-photograph scale (ca. 1:88,000) photogeological interpretation of the region (in which the results of the airborne survey have been partly incorporated) and a report containing a general assessment of the tenements, prepared by Suttons' consultant geologist.

The tenements (Drawing 2, which overlays Drawing 1 on which solid geology is shown) are over comparatively undeformed Adelaidean to Ordovician strata within the Daly River Basin; there are also some relatively small exposure areas of the folded and faulted Lower Proterozoic rocks of the Pine Creek Geosyncline. The south-west corner of the Geosyncline is largely covered by the Daly River Basin, but the probable (now faulted) western margin of the Geosyncline against the partly-Archaean Litchfield Block is visible west of the tenements (and one E.L. extends onto the Block). The Block contains also Carpentarian granites, smaller plutons of which are seen within and near the tenements, intruding the Lower Proterozoic rocks of the Geosyncline and in turn overlain unconformably by the sediments of the Daly River Basin.
There are numerous historic mining areas within the rocks of the Pine Creek Geosyncline adjacent to the tenements, but no mining is known to have been carried out within the Licence areas. The Lower Proterozoic rocks of the region contain base-metal and uranium mineralization in the form of strata-bound deposits in metasediments or as subvolcanic copper-zinc occurrences. Some mineralization in the region accompanied intrusion of the Carpentarian granites and pre-dated the Daly River Basin sequence covered by most of the Licences. Minor mineralization in copper, manganese, and barite-fluorite-lead-zinc has, however, been recognised in these younger rocks, and recent lead-zinc discoveries may very possibly be indicative of the presence of economic mineralization.

Some relatively small uranium orebodies are known in the Lower Proterozoic rocks adjacent to the tenements, and more may remain to be discovered in these rocks within the tenements themselves. The unconformity between the Upper and Lower Proterozoic sedimentary sequences of the Pine Creek Geosyncline is present within E.L. 1359, and the two sequences are separated by a faulted contact within E.L. 1598. This unconformity is a locus of uranium mineralization in the Alligator Rivers field on the eastern side of the Geosyncline, and thorough exploration of the unconformity should be carried out for possible analogues of the uranium orebodies, large and small, known to the east. These situations are assessed in the discussion of potential for uranium mineralization.

The Middle Cambrian Tindall Limestone of the Daly River Basin sequence is of considerable interest because of its potential for stratigraphically-controlled base-metal mineralization. Four minor, separate occurrences of barite and fluorite, with minor sphalerite and galena, were quite recently discovered by the Northern Territory Geological Survey in the middle to upper part of this formation, and it has been suggested that this mineralization may be part of a Mississippi Valley-type deposit within the Limestone. The possibility should be investigated by follow-up exploration, and a field programme has been suggested. The known base metal occurrences are quite close to a subcircular structure, identified as a dome 5 km across, within the Limestone, and it is suggested that this feature may prove to have acted as a locus for the mineralization or to have a similarly close association with it.
1. INTRODUCTION

The Suttons Group of Companies holds title to a number of Exploration Licence (E.L.) areas, substantially coincident with the Pastoral Lease area of Tipperary Station in the Northern Territory of Australia. Tipperary Pastoral Lease also is owned by the Group, and the E.L.'s were taken up in 1977 and early 1978 with a view to retaining at least partial control of any mineral deposits within the property. Because of the presence of the Pastoral Lease, the tenements are not subject to Aboriginal land claims. Tipperary Pastoral Lease and the E.L.'s are outlined in Drawing 2, which is presented as a transparent overlay of comparison with solid geology (Drawing 1).

Suttons initiated mineral exploration activities within the E.L. areas by carrying out a substantial airborne magnetic and radiometric survey, and a photointerpretation of the area, in 1977 - 78. Suitably competent farm-in partners were subsequently sought by the Group to participate in vigorous follow-up exploration of the tenements.

In June 1978, Mobil Energy Minerals Australia Incorporated ("Mobil") took up an interest in the north-western tenements, including an area under E.L. Application only, and these areas are no longer available for participation by other parties. However, the Group continues to seek a partner or partners to participate in the remaining tenements, which are fully-granted Exploration Licences covering an area of 4,066 km² (Table I).

The tenements cover ground in the western parts of Australian National Grid map sheets SD/52-8 ("Pine Creek"; Malone, 1962) and SD/52-12 ("Fergusson River"; Pontifex and Mendum, 1972), with the greater part falling within the northern, Pine Creek, sheet. One tenement (E.L. 1597) extends west to overlap onto map sheet SD/52-11 ("Port Keats"; Morgan, 1972).

Primary access to the tenements is gained via the supply track serving Tipperary Station (13°44'S., 131°02'E.) from the all-weather Stuart Highway near Mount Shoobridge. From Tipperary itself, well-maintained station tracks offer ready access to most parts of the Licence areas.
<table>
<thead>
<tr>
<th>E.L. NO.</th>
<th>NAME</th>
<th>AREA (km²)</th>
<th>LICENCE</th>
<th>DATE GRANTED</th>
<th>ANTICIPATED EXPENDITURE REQUIREMENT, 1978-79 ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1355</td>
<td>Tipperary</td>
<td>1226.2</td>
<td>Suttons Motors (Darwin) Pty. Ltd</td>
<td>8.VII.77</td>
<td>20,000</td>
</tr>
<tr>
<td>1357</td>
<td>Daly River</td>
<td>865.9</td>
<td>Sydney Motor Auctions Pty. Ltd</td>
<td>8.VII.77</td>
<td>20,000</td>
</tr>
<tr>
<td>1358</td>
<td>Fish River</td>
<td>494.0</td>
<td>Autopool Pty. Ltd</td>
<td>8.VII.77</td>
<td>12,000</td>
</tr>
<tr>
<td>1359</td>
<td>Noltenius</td>
<td>946.1*</td>
<td>Gilbert and Roach Pty. Ltd</td>
<td>8.VII.77</td>
<td>20,000 (whole E.L.)*</td>
</tr>
<tr>
<td>1484</td>
<td>-</td>
<td>113.0</td>
<td>Suttons Motors (Chullora) Pty. Ltd</td>
<td>6.III.78</td>
<td>#</td>
</tr>
<tr>
<td>1597</td>
<td>Chilling Creek</td>
<td>248.7</td>
<td>Autopool Pty. Ltd</td>
<td>8.VII.77</td>
<td>6,000</td>
</tr>
<tr>
<td>1598</td>
<td>Allia Creek</td>
<td>132.6</td>
<td>Autopool Pty. Ltd</td>
<td>8.VII.77</td>
<td>3,000</td>
</tr>
<tr>
<td>1724</td>
<td>-</td>
<td>39.9</td>
<td>Suttons Motors (Chullora) Pty. Ltd</td>
<td>6.III.78</td>
<td>#</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4066.4</td>
</tr>
</tbody>
</table>

* 247.8 km² (20.75 percent) of the 1193.9 km² E.L. 1359 was farmed out to Mobil Energy Exploration Australia Limited in June 1978, and it is not now available to other partners.

# to be advised.
There are relatively few impediments to off-road travel by four-wheel-drive vehicles within the tenements. Much of the area consists of undulating plains covered by open forest or scrub; sparse rocky hills are rarely higher than about 15 m above the soil flats, and occasional mesas have scarp faces up to about 6 m high. In the north of E.L. 1359, at the northern end of the group of tenements, a more rugged uplands topography has a relief of up to 60 m, with steep-sided hills and long ridges separated by narrow valleys. A partially dissected tableland, in which deep erosion has created rough rocky hills, falls within some of the most westerly tenements, but in general this tableland is excluded from the licence areas. Scarp faces are not generally present on the eastern side of the tablelands adjacent to the tenements.

The monsoonal climate of the region produces an annual rainfall in excess of 1000 mm, restricted to the wet season of November to April. During this period, mineral exploration activities are not practicable.
2. GEOLOGICAL CONTEXT

Walpole et al. (1968) provide a comprehensive account of the geology and mineral deposits of the region.

The tenements cover part of an area in which two distinct episodes of Proterozoic sedimentation occurred; one Lower Proterozoic in age, the other Upper Proterozoic (Adelaidean) (Enclosure 1). Between the two sedimentation episodes, a phase of granite intrusion took place in Carpentarian time. The second phase of sedimentation continued, after a hiatus marked by substantial basaltic volcanism, until the Lower Palaeozoic (Ordovician).

The tenements are predominantly over rocks of the Adelaidean to Ordovician Daly River Basin, which is a trough aligned north-west to south-east. The north-western end of the trough, near Rum Jungle, is just outside the tenement areas. The Basin widens rapidly towards the south-east, where it extends well beyond the area described.

The strata within the Daly River Basin unconformably overlie those in the south-western part of the Lower Proterozoic Pine Creek Geosyncline. While they effectively mask the south-western limits of the Geosyncline, enough Lower Proterozoic rocks are exposed immediately west of the E.L. areas to indicate the probable position of the Geosyncline's western margin against the metamorphic and intrusive Litchfield Complex, about 40 km west of Tipperary Homestead. However, the original western margin of the Geosyncline remains ill-defined because the present western margin of the Lower Proterozoic sediments is faulted along most of its length (Giants Reef Fault) or masked by later rocks. Also, the Litchfield Complex contains the Archaean migmatites, schists and granulites (Hermit Creek Complex) as rafted inliers among granites. While some of these granites are Archaean, the Litchfield Complex (wholly identified as Archaean on Enclosure 1) also contains Carpentarian granites and the two intrusive phases are not easily distinguished in outcrop.

Plutons of Carpentarian granite, again similar to the granites in the Litchfield Complex, intrude the Lower Proterozoic sediments of the Pine Creek Geosyncline. Like the Lower Proterozoic sediments, these intrusions are unconformably overlain by the strata of the Daly River Basin.
3. GEOLOGY OF THE TENEMENTS

Stratigraphic units cropping out within and near the tenement areas are summarized in Table II. The following brief descriptions include the distribution of each unit within the group of tenements.

3.1 ARCHAEOAN BASEMENT: HERMIT CREEK METAMORPHIC ROCKS

The Hermit Creek Metamorphic Complex includes migmatites, granulites, gneisses and schists which, although formerly metamorphosed to amphibolite grade, have suffered retrograde metamorphism to greenschist facies. The age of the retrogression is likely to be that of the 1800 m.y. prograde metamorphism of the sediments of the Pine Creek Geosyncline. Archaean granites have intruded the metamorphic rocks, but they are not easily distinguished in the field from the later granites of the Litchfield Complex, within which the Archaean rocks are now enclosed as rafts, inliers or pendants. For clarity, the entire Litchfield Complex outcrop area is identified as Archaean in the geological map accompanying this appraisal (Enclosure 1).

Neither the Archaean rocks nor the main massifs of the Litchfield Intrusive Complex crop out extensively within the available Sutons E.L. areas, but they are close to them on their western side and the westernmost E.L. (1597) extends onto the Litchfield Complex. To the north of the tenements, Archaean rocks are seen in the Rum Jungle and Waterhouse Complexes, which are mantled gneiss domes forming inliers within the Pine Creek Geosyncline. Rocks of the Rum Jungle Complex have been dated at 2550 m.y. (Walpole et al., 1968). On the eastern side of the Geosyncline, analogous inliers of Archaean rocks crop out, indicating that the Geosyncline is shallow, and probably underlain everywhere by a continuous Archaean Shield with an irregular palaeorelief surface.

3.2 LOWER PROTEROZOIC: PINE CREEK GEOSYNCLINE

In their comprehensive review of the sediments of the Pine Creek Geosyncline, Walpole et al. (1968) defined four time-rock groups which reflect conditions of sedimentation in different parts of the geosyncline. Sedimentation, in turn, reflected the structure and palaeorelief within the composite trough.
<table>
<thead>
<tr>
<th>AGE</th>
<th>UNIT</th>
<th>SYMBOL</th>
<th>LITHOLOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAINOZOIC</td>
<td>(Three post-Cretaceous erosion cycles)</td>
<td>Ez, Ezl</td>
<td>Mud, silt, colluvium; thin sand; etc.</td>
</tr>
<tr>
<td></td>
<td>Mullaman Beds</td>
<td>Klm</td>
<td>Detrital and late laterite</td>
</tr>
<tr>
<td>CRETACEOUS</td>
<td></td>
<td></td>
<td>Sandstone; shale, conglomerate, porcellanite; much lateritization</td>
</tr>
<tr>
<td>ORDOVICIAN-</td>
<td>Daly River Group</td>
<td>Olo,</td>
<td>Silicified limestone; chert bands</td>
</tr>
<tr>
<td>CAMBRIAN</td>
<td>Ooloo Limestone</td>
<td>e/olj</td>
<td>Ferruginous sandstone, siltstone with halite pseudomorphs; silicified and dolomitic limestone; marl</td>
</tr>
<tr>
<td></td>
<td>Jinduckin Formation</td>
<td></td>
<td>Black crystalline limestone; chert bands and nodules; some clastic interbeds</td>
</tr>
<tr>
<td></td>
<td>Tindall Limestone</td>
<td>emt</td>
<td></td>
</tr>
<tr>
<td>LOWER CAMBRIAN</td>
<td>Antrim Plateau</td>
<td>Ela</td>
<td>Basalt, dolerite, tuffaceous sandstone; basal arkosic quartzite</td>
</tr>
<tr>
<td></td>
<td>Volcanics</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Witch Wai, Jarong</td>
<td>Elw</td>
<td>Conglomerate, sandstone</td>
</tr>
<tr>
<td></td>
<td>Conglomerates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADELAIDEAN</td>
<td>Tolmer Group</td>
<td>Rug</td>
<td>Ferruginous sandstone; siltstone; silicified limestone, marl; halite pseudomorphs</td>
</tr>
<tr>
<td></td>
<td>Waterbag Creek Formation</td>
<td>Euh</td>
<td>Dolomite, dolomitic limestone; locally silicified</td>
</tr>
<tr>
<td></td>
<td>Hinde Dolomite</td>
<td></td>
<td>Quartz-sandstone; minor siltstone, shale</td>
</tr>
<tr>
<td></td>
<td>Stray Creek</td>
<td>luy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandstone Member</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Depot Creek</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandstone Member</td>
<td>Euo</td>
<td>Quartz sandstone, locally silicified</td>
</tr>
<tr>
<td></td>
<td>Bulidiva Sandstone</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(TABLE II (Continued))

<table>
<thead>
<tr>
<th>AGE</th>
<th>UNIT</th>
<th>SYMBOL</th>
<th>LITHOLOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>EARLY CARPENTARIAN INTRUSIVE ROCKS</td>
<td>Reynolds River</td>
<td>Ege</td>
<td>Granodiorite to granite</td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soldiers Creek Granite</td>
<td>Egs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Titree Granophyre Granite</td>
<td>Egi</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Litchfield Complex Granite</td>
<td>Egl</td>
<td></td>
</tr>
<tr>
<td>LOWER PROTEROZOIC</td>
<td>Zamu Complex</td>
<td>Edo</td>
<td>Dolerite</td>
</tr>
<tr>
<td>intrusive contact</td>
<td></td>
<td></td>
<td>Quartz-sandstone</td>
</tr>
<tr>
<td></td>
<td>Chilling Sandstone</td>
<td>Elh</td>
<td>Intermediate to acid lavas and tuffs</td>
</tr>
<tr>
<td></td>
<td>*Berinka Volcanics</td>
<td>Eli</td>
<td>Greywacke, siltstone, greywacke-siltstone</td>
</tr>
<tr>
<td></td>
<td>Burrell Creek Formation</td>
<td>Elb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Noltenius Formation</td>
<td>Eln</td>
<td>Quartz-greywacke, siltstone, conglomerate</td>
</tr>
</tbody>
</table>

ARCHAEOAN

|                      | Hermit Creek Metamorphics  | Ah     | Migmatite, quartzite, granulite, schist. |

*Not known within Exploration Licence areas described in this report. Acid volcanic rocks, not shown on published maps, are present in the vicinity of the Daly River copper mine.
On and near Tipperary Station, the exposed sediments of the Pine Creek Geosyncline belong to the Finniss River Group. They are the Noltenius and Burrell Creek Formations, which are believed to represent the second phase of sedimentation into the geosyncline; to be derived from source areas west of the trough; and to be restricted to the geosyncline's western side. Initial sedimentation in the western part of the trough near the tenements resulted in deposition of the Batchelor Group (derived from the west) and of the Goodparla Group (derived from the east). Following uplift on the western side of the fault zone (Giants Reef Fault) believed to form the western margin of the geosyncline, the rocks of these two earlier depositional facies were then overlain, partially disconformably and partially gradationally, by the sediments of the Finniss River Group.

The rocks of the Finniss River Group are tightly folded, and faulting is common within them. They were regionally metamorphosed to greenschist facies at approximately 1800 m.y.; within E.L. 1359, locally higher grade metamorphism produced mica-schist and andalusite-mica-schist.

Walpole et al. regarded the Noltenius Formation as the near-shore facies of Finniss River Group sedimentation. It contains cobble and pebble conglomerates, greywacke and quartz greywacke, and siltstone and claystone. It appears to grade laterally eastwards into the relatively distal sediments of the Burrell Creek Formation, which is composed of generally fine-grained greywacke and siltstone, with neither conglomerate horizons nor conspicuously graded bedding. However, more recent investigations in the Rum Jungle area have shown that the Burrell Creek and Noltenius Formations are not simple divisions of the Finniss River Group, but they are complexly interbedded and grade imperceptibly into each other (Ingram et al, 1974). This situation is probably found also in the northern part of E.L. 1359 and the eastern part of E.L. 1598, the only parts of the tenements in which the Finniss River Group is exposed.

Near the Suttons tenements, the Noltenius Formation grades upwards into the Chilling Sandstone, which in this area, is regarded as part of the Pine Creek Geosynclinal sequence. (Farther west, there is a sharp facies change between the Noltenius Formation and the Chilling Sandstone on the Chilling Platform, outside the geosynclinal limits). The Chilling Sandstone is a typically medium-grained, ripplemarked quartz sandstone containing rare pebble conglomerate horizons, and like the Finniss River Group its provenance was west of the Pine Creek Geosyncline.
The Berinka Volcanics, which crop out near but not within E.L. 1597, are believed to be intercalated within the Noltenius Formation although the relationship has not been conclusively demonstrated. The volcanic rocks include intermediate to acid flows and pyroclastic horizons.

The sediments within the Pine Creek Geosyncline have been intruded by Lower Proterozoic basic sills and other minor intrusions, most of which are now seen as amphibolite following low-grade regional metamorphism. Part of only one restricted exposure of these Zamu Complex rocks is inferred within the tenements from photointerpretation; it is at the eastern edge of E.L. 1598.

As noted above, the Finniss River Group is exposed within the northern part of E.L. 1359, where both the Burrell Creek Formation and the Noltenius Formation, as mapped in the 1960's are present. Chilling Sandstone, in association with relatively subordinate exposures of rocks of the Noltenius Formation, crops out in E.L. 1597; Noltenius Formation is also exposed in the eastern part of E.L. 1598 in association with the photointerpreted exposure of basic intrusive rocks of the Zamu Complex.

3.3 EARLY CARPENTARIAN GRANITES

Rather small plutons of granitic rocks of early Carpentarian age are present within E.L. 1359, and others are partially within E.L.s 1358, 1597 and 1598. These rocks are generally massive and coarse-grained or porphyritic, the main local exception being the Titree Granophyre of southern E.L. 1597. The intrusions which were intruded discordantly or partially concordantly into the rocks of the Pine Creek Geosyncline, have been isotopically dated at 1760 m.y. by Compston (Walpole et al., 1968, p. 286).

The relatively extensive granite mass of the Litchfield Complex, flanking the tenement areas to the west, is regarded as partly an early Carpentarian intrusion like the smaller bodies. However, it contains rafted Archaean migmatites, and this massif contains Archaean granites as well as the Carpentarian material. In Enclosure 1, the Litchfield Complex is identified wholly as Archaean, to simplify the presentation of surface geology.
3.4 DALLY RIVER BASIN

The Daly River Basin contains Adelaidean (upper Proterozoic) to Ordovician sediments, the former resting with marked unconformity on the sediments of the Pine Creek Geosyncline and the Carpentarian granites intruding them. Within the relatively undeformed and unmetamorphosed Daly River sediments, unconformities are present above the Adelaidean sequence and above the Lower Cambrian Antrim Plateau Volcanics.

The Adelaidean rocks, constitute an arenite-carbonate-lutite assemblage known as the Tolmer Group. The basal Buldiva Sandstone is a shallow marine deposit, subdivided into the underlying Depot Creek Sandstone Member and the overlying Stray Creek Sandstone Member; the latter contains interbedded lenses of siltstone which are not present in the lower unit. Both members are up to about 300 m thick. In spite of the large time-break inferred at the unconformity below these rocks, there are only rare conglomeratic lenses in the Depot Creek Sandstone Member, and those that are known are all at the base of the sequence and contain only pebbles of local origin. The Buldiva Sandstone is overlain by the Hinde Dolomite, a generally massive dolomite noted for its content of algal structures (Collenia); the dolomite is up to 60 m thick. It is succeeded by the Waterbag Creek Formation, the highest in the Tolmer Group. It consists of up to possibly 150 m of ferruginous sandstone and variegated siltstone with lenses of silicified limestone and marl. The sandstone and siltstone contain halite pseudomorphs.

The Tolmer Group crops out very extensively in E.L's 1357 and 1358, and also in the western part of E.L. 1359.

The unconformity above the Waterbag Creek Formation is marked by occasional pockets of boulder-conglomerate up to 10 m thick, below the Lower Cambrian Antrim Plateau Volcanics. One such pocket of Witch Wai Conglomerate is partially within E.L. 1357, and another (Jarong Conglomerate) is adjacent to E.L. 1598. The Antrim Plateau Volcanics are composed of massive and vesicular tholeiitic basalts, there are some intercalated sandstones, and volcanic conglomerate, conglomerate or arkose have been noted from place to place at the bottom of the volcanic succession.
Up to 60 m of volcanics appear to be present near the Suttons Group tenements, although thicknesses elsewhere may be much greater (about 1000 m); the basalts crop out very extensively south of the E.L.s. Their eruptive centres are not known but they may be localized along the Halls Creek Mobile Zone, where the greatest thicknesses of lava are present.

The Antrim Plateau Volcanics are extensively exposed in E.L.s 1357, 1358, and western E.L. 1359.

Sedimentation in the Daly River Basin was completed after the eruption of the Volcanics by the subsequent deposition of the Cambrian to Ordovician Daly River Group. The basal member of the Group, the Middle Cambrian Tindall Limestone, is a fine-grained to coarsely crystalline limestone up to 150 m thick, containing lenses of sandstone and siltstone and also beds and lenses of chert. It is succeeded by the siltstones, ferruginous sandstones, and carbonates of the 200 m thick Jinduckin Formation, and these in turn are overlain by flaggy silicified limestone (Ooloo Limestone) which has a similar thickness.

The Daly River Group forms large exposure areas within E.L.s 1355, 1357, and 1358, and it extends north into E.L. 1359 and east into E.L.s 1484 and 1724.

3.5 MESOZOIC TO RECENT ROCKS

Throughout the Suttons Group tenements, generally horizontally stratified sandstones, siltstones and shales of Cretaceous age remain as mesas. It is believed that there is a passage upwards from freshwater to marine sediments in these strata, which unconformably overlie the older rocks. From place to place, there is a considerable variation in the levels of the surfaces covered by these Mullaman Beds. Since the Mesozoic, the area has been subjected to at least three erosional cycles, with consequent deep weathering of the near-surface rocks (weathering may be expected to have affected most exposures not subjected to active erosion, to depths of up to 100 m). Laterite and soil profiles, and alluvium, colluvium, talus and sand accumulations, have developed, probably mostly during the Quaternary.
4. MINERALIZATION

Three instances of minor surface mineralization are known within the tenement areas.

4.1 BARITE-FLUORITE-LEAD-ZINC

The Northern Territory Geological Survey reports (Lau, 1977) four separate occurrences of barite and fluorite, with minor sphalerite and galena, within an area of about 2.5 km x 1 km, about 15 km south of Tipperary Homestead. These occurrences are within the Middle Cambrian to Lower Ordovician Daly River Group. Although outcrop in the general vicinity is generally poor, it is believed that the occurrences are in the middle to upper part of the Middle Cambrian Tindall Limestone (Enclosure 6).

The mineralization is concentrated in veins in limestone. Sphalerite occurs as crystals in calcite veining at Location 1, which covers also a probably subhorizontal showing of coarse barite extending for 150 m along a slope. This barite float assayed 59% BaO, 2.4% SrO, and there is some evidence that silicification of the limestone is associated with this mineralization. Location 2 features similar coarse-grained barite. At Location 3, veins of fluorite containing intergrown barite and some calcite, contain rare crystals of pyrite with galena; at this location also, there is an exposure of massive fine-grained quartz containing intergrown fluorite and barite. Fluorite occurs within vein calcite at Location 4.

4.2 COPPER

Minor copper mineralization is known near the bottom of the Antrim Plateau Volcanics, 21 km west-north-west of Tipperary Homestead (Walpole et al., 1968, p. 99). Malachite and azurite occur in basalt near the contact with underlying ferruginous sandstone, probably belonging to the Waterbag Creek Formation. Similar small copper shows are not uncommon outside the tenements, in places where the bottom of the volcanics is exposed; also Traves (1955), describing an area well to the west of the Suttons tenements, records minor copper mineralization within the main mass of the lava pile.
4.3 MANGANESE

E.L. 1724, in the north-east of the group of tenements, probably covers some of the small manganese prospects recorded by Walpole et al. (1968, p. 232) in the Green Ant Creek area. These occurrences are irregular bodies of low-grade manganese ore at the unconformity below the Cretaceous Mullaman Beds, where they overlie steeply-dipping siltstones and greywackes of the Burrell Creek Formation. Walpole et al. indicate that the mineralization probably formed by replacement of siltstone horizons in the Burrell Creek Formation, suggesting that it is pre-Cretaceous in age. A total of 540 tons of ore was taken from this field for use at the Rum Jungle treatment plant, but the occurrence is believed to lack any present or future economic potential.
5. EXPLORATION BY SUTTONS GROUP OF COMPANIES

Suttons initiated its exploration of the tenements by commissioning the following investigations, which necessarily (and advantageously) covered also ground between and adjacent to the E.L.s:

(i) Geological photointerpretation (J.B. Jeppe, R. F. Loxton, Hunting and Associates);

(ii) Airborne magnetic and gamma-radiation survey (Aero Exploration Pty. Ltd.);

(iii) Consultant's general assessment (Barrie, 1978).

5.1 GEOLOGICAL PHOTINTERPRETATION

J. B. Jeppe of R. F. Loxton, Hunting and Associates, was commissioned to prepare a photogeological study of the area of Tipperary Pastoral Holding. The exercise was carried out in order to provide a detailed information base for the planning of mineral exploration in the area, and also for the planning of agricultural and pastoral development. The study, covering 5,600 km², used Division of National Mapping RC9 black-and-white photography (1962; 1:88,000), covering the area (detailed on Enclosure 2 of this report) in four sheets. The work was principally directed towards differentiation of the Cambro-Ordovician strata, rather than the relatively minor outcrop areas of Middle and Upper Proterozoic rocks. While field checking remains to be carried out (as at July, 1978), the maps have been re-assessed to include the Aero Exploration geophysical results; they appear to form a significant contribution to available knowledge of the regional geology of the tenements.

5.2 AIRBORNE MAGNETIC AND GAMMA-RADIATION SURVEY

This survey was flown by Aero Exploration Pty. Ltd. (partly owned by the Suttons Motors Group) under the general direction of John Barrie, then consultant to the Group. Equipment specifications were as follows:

**AIRCRAFT**
- Twin Pioneer

**MAGNETOMETER**
- Varian V85, resolution 0.1 gamma
The survey was flown in September and October 1977. Information was produced along a total of about 14,500 line-km, on about 150 flight lines (of which 130 lines cover the Suttons tenements including those taken up by Mobil). Nominal altitude over ground surface was 300 ft. (90 m). Flight lines were spaced at a nominal half-mile (800 m) with 25 percent allowance for quarter-mile (400 m) fill-in flight lines, which were subsequently flown along the edge of the Daly River Basin, over the Upper Proterozoic exposure areas, and along the Giants Reef Fault.

The data collected in 1977 comprise:

- Complete magnetic-tape records
- Complete print-out of magnetic tape
- Analog profiles for magnetometer, altitude, and gamma-radiation channels
  - total count, thorium, uranium, potassium (TC, Th, U, K)
- Detailed magnetic profiles of most lines
- Flight-line plots on 1:88,000 black-and-white aerial photographs

Some data have been affected by equipment malfunction. During only the early part of the survey, test runs showed that the Th channel responded to a U source, and that the U channel responded to a K source (responses were also obtained in the correct channels). The Doppler navigation equipment failed on several occasions, at which times sampling occurred at 1-second intervals instead of intervals (ranging from 0.7 to 1 second) depending on aircraft speed.

5.2.1 GAMMA-RADIOMETRIC RESULTS

The data on profiles and magnetic tape are "raw". Background correction was applied to the gamma-radiation channels by zeroing them at 2,000 ft. (600 m) altitude relative to ground level, but compton-scatter and altitude corrections have not been applied to the collected information.
Preliminary subjective analysis of the radiometric information is presented on Enclosure 4. This plot of U and U(+Th) anomalies is derived from the radiometric profiles, with some account being taken of ground-clearance effects. These anomalies include U peaks, superimposed on the local U background, which are too large to be explained as compton-scattered Th peaks. (For data collected during periods of equipment malfunction as described above, the same criterion is applied, except that the peaks selected are too large to be explained as compton-scattered Th + K peaks.)

The following observations are of interest:

(i) Different rock-types generally have different characteristic radiometric-background signatures. These background levels agree with those shown on the B.M.R. reconnaissance radiometric maps.

(ii) Some Carpentarian granites are characterized by high background U, Th and K.

(iii) Very small, but persistent, U anomalies are present along the unconformity between Upper and Lower Proterozoic successions.

(iv) The anomaly identified (*) on Enclosure 4 is unusual in that Th and U have positive peaks while K has a negative peak; TC shows no anomaly.

(v) The anomaly identified (#) on Enclosure 4 occurs over an area of anomalous reflectance on black-and-white aerial photographs.

5.2.2 MAGNETIC RESULTS

Magnetic data were collected on all flight lines. (The magnetic information collected on early flight lines is shown on charts separate from those on which radiometric and altitude data are presented.) The magnetic data have been subjected to preliminary examination, with observation of background levels, changes in background levels and zones of magnetic noise. The available information correlates well with magnetic-profile data published by the B.M.R.
POTENTIAL FOR ECONOMIC MINERALIZATION, AND SUGGESTED FOLLOW-UP EXPLORATION

The Suttons Group tenements are surrounded by historic mineral fields and prospects, except towards the south-east, where Lower Palaeozoic sediments (which form the top of the Daly River Basin sequence) mask the older formations. Lower Proterozoic strata are virtually the exclusive hosts of the mineralization in these occurrences near the tenements; taken clockwise from the south-west, the more important fields are Fletchers Gully - Buldiva (gold, tin, barytes); Daly River (silver-lead-zinc, copper); Mount Tolmer South (copper); Waterhouse (iron, uranium) with, beyond it, the economically important Rum Jungle uranium, copper, and silver-lead-zinc mines; Adelaide River and George Creek (uranium) and the Brocks Creek - Mount Shoobridge areas (uranium, tin, copper, manganese, silver-lead-zinc and iron).

Apart from the Rum Jungle operations, which are comparatively well removed from the Suttons Group tenements, these mining fields are characterized by small deposits of high enough grade to allow profitable extraction by small parties. Most orebodies were worked by individual prospectors or small gouging parties who exploited zones of near-surface secondary enrichment. Virtually without exception, the mineralization at these prospects is situated within and close to shear zones or joints in Lower Proterozoic rocks close to exposed Carpentarian granites. At some prospects, the mineralization is associated with a pegmatite or quartz reef or dyke within the fracture; it is very likely that the Carpentarian intrusions were the source of the mineralization in such cases. However, some of these mineralized veins may contain metals remobilized from stratabound deposits in Lower Proterozoic sediments. At a few mines such as those forming the Howley Group (gold) in the Brocks Creek field, the control of mineralization appears to be a stratigraphic one, the host rocks again being Lower Proterozoic in age; the ore is contained in favourable horizons which have not been obviously affected by nearby shearing nor intrusion.
The Suttons tenement areas, and indeed the whole Daly River Basin, were avoided by the early prospectors because they contain younger, relatively unstressed rocks. In these rocks, the structurally-controlled orebodies typical of the region could not be present under any circumstances; the rocks are younger than the granites which either were the source of mineralization, or remobilized mineralization in the older strata. The shorter histories of these rocks also mean that structural traps, into which mineralization might be concentrated, are relatively rare in them.

All but the very largest of the operations developed within the mining fields adjacent to the Suttons tenements would be unattractive as a modern primary exploration target, which is required by economic conditions to be a long-term mining venture based on high tonnages.

The available parts of the Suttons Group tenements mostly cover Upper Proterozoic to Lower Palaeozoic rocks within a relatively undisturbed sedimentary sequence. If mineralization is contained in parts of this Daly River Basin succession, it is likely to be stratigraphically controlled. Mineralization under stratigraphical control can be large-scale and high-tonnage.

The tenements also cover significant areas of Lower Proterozoic sediments and Carpentarian granites, particularly in the northern part of E.L. 1359 and the whole of E.L. 1597. The Lower Proterozoic rocks form worthwhile target areas for uranium and base-metal mineralization under either stratigraphical or structural control.

So far as is known, no systematic exploration for larger-scale metallic mineralization has ever been carried out within the northern Daly River basin, although it has been investigated without success for the presence of phosphate deposits (Barrie, 1978, p. 34).

Appraisal of the available information suggests that the tenement areas have worthwhile potential for uranium mineralization; only slight potential for copper mineralization; and a potential for lead-zinc or other base-metal mineralization which is of distinct interest.
6.1 URANIUM

There is fair potential within the tenements for orebodies exactly analogous to the major uranium orebodies of the eastern side of the Pine Creek Geosyncline ("Alligator Rivers Field"). These orebodies are contained within carbonate-carbonaceous-terrigenous sediment assemblages within the Koolpin Formation and its stratigraphic equivalents. Not only is there an association of mineralization with carbonaceous schists at Jabiluka, Ranger and Koongarra, but also the same association is noted in most of the smaller uranium orebodies known within the Pine Creek Geosyncline. It seems likely that primary sedimentary concentration of the uranium occurred in local sea floor depressions where reducing conditions, conducive to preservation of organic carbon, contrasted with a more generally oxidizing environment. Whatever the cause of the association, there has been no significant movement of uranium away from the carbonaceous facies within and near the top of the Goodparla Group. Carbonaceous horizons may be present within the Lower Proterozoic rocks of the tenements (the Finnis River Group, cropping out within E.L.s 1359, 1597 and 1598), and vigorous exploration for these potential host rocks should be carried out in these areas. Certainly, past geological exploration in the region has not been sufficiently intense to conclusively show that these rocks are not, in fact, present.

Nabarlek uranium orebody, in the eastern part of the Geosyncline, is believed to have formed because uranium was mobilized from its original carbonate-carbonaceous host rocks into a higher structural trap by relatively high-grade metamorphic conditions. Small-scale analogues of Nabarlek are present in the Finnis River Group (they include Adelaide River and George Creek), but the small reserves present at these obviously structurally-controlled orebodies make them unsuitable primary targets of an exploration campaign. If located during exploration for larger targets, they could be profitably exploited, however. As in the case of the carbonaceous horizons in the Lower Proterozoic strata, it is possible that further exploration of the area, using modern instruments and techniques, may locate a suitably large structurally-controlled uranium concentration.
Within E.L. 1359, small uranium anomalies appear to be associated with the radiometric boundary which marks the unconformity between the Upper Proterozoic and the Lower Proterozoic rocks. While these anomalies are likely to be caused by accumulation of supergene uranium on or near the unconformity, they should be checked on the ground in case there are unmapped favourable (carbonate-carbonaceous) Lower Proterozoic rocks below the unconformity. (It is now considered that the unconformity itself has little to do with the genesis or localization of the orebodies of the Alligator Rivers Field, despite the fact that the known orebodies are close to the unconformity. The main requirement for ore formation is now believed to be a carbonate-carbonaceous host rock associated with a tectonic feature to assist in ore localization.)

The Upper Proterozoic shallow-water sandstones, siltstones and dolomites do not at first appear to be prospective from the distribution of gamma-radiation anomalies (Enclosure 4). The sediments have a low total-count background, and several of the comparatively very sparse uranium anomalies within their outcrop-area are associated with thorium. Nevertheless, it is recommended that attention be given to ground examination of the sandstone-siltstone facies of the Depot Creek Sandstone Member of the Buldiva Sandstone, at the base of the Upper Proterozoic succession. The Member contains interfingering or lenticular contrasting shallow-water marine facies; it is adjacent to an unconformity; and, as a result, this formation is one of the more likely, among those present within the tenements, to contain peneconcordant uranium mineralization. The sediments which are higher in the local Upper Proterozoic succession are regarded as being relatively much less prospective; the Hinde Dolomite is clearly without potential, and the Waterbag Creek Formation is thought to contain too high a proportion of carbonate-facies rocks.

Although the red-bed, terrestrial and shallow-water facies of sediments deposited below and within the Lower Cambrian Antrim Plateau Volcanics would form very suitable host rocks for peneconcordant uranium mineralization, occurrences (as presently mapped) are too restricted to be of significant importance. It is therefore recommended that an early attempt be made to check in the field that these lithological units are of such limited extent, while at the same time all exposures are checked for surface-radiometric anomalies.
While many of the uranium (with thorium) anomalies recorded on the Antrim Plateau Volcanics are quite possibly the result of lateritic accumulation, there is a significant concentration of these anomalies close to the Dorisvale Fault (Enclosure 1). The fault line should be checked on the ground in case it formed a channelway for mobile uranium (and indeed, possibly for the volcanic rocks themselves, which have no known eruptive centres) during the Cambrian.

Lithologies within the Middle-Cambrian-to-Ordovician Daly River Group are not prospective for the presence of contained sedimentary uranium; carbonates are present throughout, and only the central Jinduckin Formation could be considered as a potential host. It is of shallow-water marine origin and it contains silstones and sandstones, so that permeability traps might be present within it. A number of small gamma-radiometric anomalies have been distinguished within its outcrop-area, and these will have to be checked, although they may well result from local redistribution and surface concentration of uranium. This is particularly the case over the calcareous units, where fine weathering products with a relatively high uranium content could well have collected in karst depressions.

The Lower Cretaceous Mullaman Beds are not considered to be prospective, because they are likely to be oxidised throughout their thickness.

In summary, the Lower Proterozoic metasediments form important target areas despite their relatively small area of exposure within northern E.L. 1359. In this area, particular attention should be paid to both the Upper and the Lower Proterozoic rocks close to the unconformity between them. Field work should also be directed towards checking that the Lower Cambrian red beds within and below the Antrim Plateau Volcanics are not more extensive than their presently mapped distribution, because this lithology is highly prospective for sedimentary uranium deposits. There is some concentration of uranium (plus thorium) anomalies within the volcanic rocks near the Dorisvale Fault, and it is recommended that the fault line be investigated in case the volcanics (with entrained uranium) were erupted through it. Lastly, the Upper Cambrian to Ordovician Daly River Group contains a number of radiometric anomalies within the tenements, and some exploration of this succession is warranted although published accounts of lithologies within it are not noticeably favourable for uranium mineralization.
6.2 COPPER

The presumably minor occurrence of copper oxides within the lowest part of the Antrim Plateau Volcanics 21 km west-north-west of Tipperary Homestead (Walpole et al., 1968, p.99) merits some investigation. It is entirely likely that the occurrence is both local and weak. Its origin may be obvious (for instance, a hydrothermal vein containing minor mineralization), in which case further work would not be justified. A disseminated occurrence, however, should be checked for extent by chip- or soil-sampling as appropriate, at intervals along strike; this sampling should be carried out also in the underlying arenites of the Waterbag Creek Formation, which are probably more attractive potential host rocks. The target here would be mineralization deposited from hydrothermal solutions, a possibility which probably depends on the presence nearby of an eruptive centre for the Antrim Plateau volcanism.

The Lower Proterozoic rocks of the tenements should be explored for analogues of the subvolcanic copper-zinc mineralization of the Daly River area.

6.3 LEAD-ZINC

Strata bound lead-zinc mineralization is known in the Lower Proterozoic metasediments of the region, and these rocks merit exploration for base-metal deposits.

Lau (1977) reported four minor occurrences of fluorite and barite veining, some with associated lead and zinc sulphides, about 15 km south of Tipperary Homestead. They are in the middle to upper part of the Middle Cambrian Tindall Limestone, as mapped (Enclosure 6).

In his description of these occurrences, Lau proposes a Mississippi-Valley-type origin for the mineralization. There is therefore a possibility that these occurrences may reflect the subsurface presence of substantial mineralization, and it is recommended that this possibility be investigated further, as a matter of urgent priority.

Immediately to the north-west of Lau's reported mineralization, there is a well-defined circular structure roughly 5 km across within the Tindall Limestone. This structure was detected by J.B. Jeppe (R.F. Loxton, Hunting and Associates) in his photogeological interpretation of the area. Barrie
identifies the structure as dome-like in his report on the mineral potential of the tenements (Barrie, 1978, p.33). This structure is of obvious interest as a possible locus of mineralization, being large enough to contain, or be otherwise associated with, large tonnages of mineralized ground.

While a depressed structure could be reasonably interpreted as a probable collapse structure caused by dissolution of subsurface carbonate rocks, the origin of a dome form remains more conjectural. The presence of a basement high, at possibly no great subsurface depth, is one possible reason. Among the otherwise unstressed rocks of the Daly River Basin, laterally-directed pressures cannot be considered as a cause. A diapiric origin, although unlikely because no post-Cambrian intrusives are known in the area, cannot be excluded because the underlying Tolmer Group contains carbonate rocks and others which possibly tend weakly to evaporite facies. However, a purely diapiric origin seems unlikely because of the containment of the Tolmer Group below 60 m of Antrim Plateau basalts.

Barrie (1978) recommends that the circular structure be investigated by drilling forthwith, in order to determine the subsurface stratigraphy, structure, and extent of associated mineralization. However, the present writer would prefer that considerable preliminary follow-up work be carried out before drilling took place, in order that informed drilling should be carried out on the most advantageous sites.

The recommended preliminary follow-up includes geochemical and geophysical investigations, and it would proceed as follows:

(i) A semi-regional geochemical stream-sediment survey to be carried out over the Tindall Limestone and adjacent rocks. This survey would be directed towards location of as many occurrences of surface mineralization, similar to those found by Lau (1977), as possible; it might directly indicate a stratigraphic control of mineralization, or this might have to be inferred from the distribution of surface occurrences; and it could confirm the importance of Jeppe's circular structure as either a locus or a source of mineralization.
The above distinction is an important one in this context. The structure is of undeniable importance, and it could easily form a structural situation in which substantial mineralization accumulated, perhaps in the ring-fractures themselves. (Barrie’s proposed drilling programme would test this directly.) However, the fractures may equally well have acted as conduits for mineralizing fluids which subsequently migrated outwards into the country rocks, or inwards into the core of the structure. In the latter case, the structure would have a genetic and a spatial relationship to the ore, while itself remaining quite possibly wholly unmineralized.

(ii) A rock-chip or C-horizon geochemical survey to be carried out on stratigraphic horizons, or structural features, indicated as possibly acting as loci of mineralization by the stream-sediment survey. This would allow delineation of those parts of the horizons or structures which are most likely to contain the highest grade of mineralization.

It should be noted that it is firmly recommended that these geochemical surveys be planned and supervised by a competent geochemist, so that maximum benefits be gained from them. It is envisaged that suitable orientation surveys would be carried out to allow selection of the most appropriate sampling methods, sample fractions, and radicals sought.

(iii) Induced-polarization surveys to be carried out over those localities indicated by the geochemical surveys as having the highest potential for economic mineralization.

Other geophysical techniques might be applied at this time, but it seems likely that induced polarization would be most successful in this environment.

(iv) Rotary open-hole drilling to be carried out at sites selected using the information obtained in the follow-up surveys.

It is recommended that if the programme proceeds to the drilling stage, one diamond-cored hole be drilled through the entire Tindall Limestone thickness, so that a stratigraphic description can be obtained. This should allow some measure of informed correlation between the holes drilled in the main open-hole programme.
REFERENCES


APPENDIX 1

EQUIPMENT AVAILABLE AT TIPPERARY STATION

A very substantial range of equipment which would be potentially useful in all surface phases of a mineral-exploration operation is held at Tipperary Station. The following list, provided by Mr. Frank Coyne of the Suttons Group of Companies, is indicative only of the range of equipment which could be readily made available for use in exploration of the tenements. In effect, only the heaviest equipment is listed, and it is likely that if any smaller equipment is required, then it too could be provided from the Station inventory.

2 Caterpillar tractors, D7
1 Caterpillar front-end loader, 0.75 yd$^3$
1 Caterpillar grader, 12E
1 Caterpillar grader, 12F
1 International mobile crane, tractor-mounted, 5-ton
4 Semi-mobile lighting plants
Several water pumps, various capacities
General camp equipment
APPENDIX 11

PUBLICLY-AVAILABLE INFORMATION ON
SUTTONS GROUP TENEMENTS

Relevant public information on the Suttoms Licence areas and the surrounding region mostly originates from the Bureau of Mineral Resources ("BMR"): 

(i) Tenement-definition maps (1:250,000 "Pine Creek - Katherine"; Northern Territory Administration Mines Branch);

(ii) Aerial photographs (KL7 series of the 1950s, RC9 series of the 1960s; Department of National Resources, Division of National Mapping ("DNM");

(iii) Topographic editions of the three relevant Australian National Grid ("ANG") 1:250,000 map sheets, SD/52-8 ("Pine Creek"), SD/52-11 ("Port Keats") and SD/52-12 ("Fergusson River") (DNM);

(iv) Geological editions of the three relevant ANG 1:250,000 map sheets (BMR);

(v) 1:500,000 geological maps, "Katherine-Darwin area" and "Victoria River Region" (BMR);

(vi) 1:63,360 geological maps as follows (BMR):

(vii) Total magnetic-intensity ("TMI") contours, ANG 1:250,000 map sheets SD/52-8 and SD/52-12 (BMR);
(viii) TMI contours and radiometric-anomaly locations ("RAL"), 1:253,440, Darwin-Anson Bay area (BMR, maps G 226-1 and G 226-2); and Moyle River-Muldira Creek region (BMR, maps G 241-1 and G 241-2);

(ix) TMI contours and RAL, 1:63,360, "Mount Hayward" (G 168-2), "Reynolds River" (G 165-2), "Tipperary" (G 170-2) (BMR);

(x) TMI contours and geology, 1:31,680, Daly River area, map D 52/B 144 (BMR);

(xi) Gamma-radiation profiles (total count, uranium, thorium, potassium), ANG 1:250,000 sheet areas SD/52-8 and SD/52-12 (BMR);

(xii) Bouger gravity, point readings and contour editions of the three relevant ANG 1:250,000 map sheets (BMR);

(xiii) BMR Bulletins and Reports as follows:

- Bulletin 49 The Cambrian Geology of Australia
- Bulletin 82 Geology of the Katherine-Darwin region
- Bulletin 168 The Precambrian geology of the Victoria River Region
- Report 89 Geological relationships of the Rum Jungle Complex, N.T.
- Report 90 Middle Proterozoic volcanic rocks in the Katherine-Darwin area, N.T.
- Report 139 Daly River detailed aeromagnetic survey, N.T.

Enclosures 3 and 5 of this report are derived from the published magnetic and radiometric information specified above.
COMPILATION SHOWING (a) TOTAL COUNT CONTOURS, AND (b) DISCRETE URANIUM AND THORIUM ANOMALIES WITHIN SUTTON GROUP E.L.'s

Enclosure 3

SCALE 1:250,000

NOTE: OVERLAY TO ENCLOSURE 1

LEGEND

- U (pectral ratio 10 times background)
- Th (pectral ratio 5 times background)
- Area of high background

Date: 12-3-89 - Drawn by: D.C.
COMPILATION SHOWING URANIUM AND THORIUM ANOMALIES,
INTERPRETED FROM RAW (UNCORRECTED) PROFILE DATA
Enclosure 4

NOTE: OVERLAY TO ENCLOSURE I

LEGEND

- U anomaly: 1 to 5 times background
- Th anomaly: > 10 times background
- U associated with Th, but > 5 times Th
- Amenity interpreted from poor quality radiometric data line test

SCALE 1:250,000

APPROX SCALE: 1:80,000

LEGEND

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ENCLOSURE 6
OPEN FILL

AN APPRAISAL OF THE MINERAL POTENTIAL OF

TIPPERARY STATION, N.T.

CR 78/150B

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Appendix I Pine Creek, N.T., 1:250,000 Geological Series Explanatory Notes (only the front cover is copied).

Appendix II Photogeological Study Tipperary Station, Northern Territory
AN APPRAISAL OF THE MINERAL POTENTIAL OF
TIPPERARY STATION, NT

INTRODUCTION

For a large pastoral holding such as Tipperary Station an understanding of the rock, soil and landforms is fundamental to effective planning, both short term and long term. The earth sciences - geology, geophysics, geochemistry and geomorphology - provide the basic data for the total coordinated management of a pastoral holding.

Mining has long been an important part of activity in the 'top end' of the Northern Territory and is particularly so at present with the intensity of exploration for uranium. Technology developed for uranium exploration has diverse other applications and the technique of airborne geophysical survey is particularly useful in delineating (mapping) many of the characteristics of the earth's surface and near surface materials, all of which relate to pastoral activity.

This report focuses data from the earth sciences into an appraisal of the mineral potential of Tipperary Station so that pastoral and mining industries can operate discretely and so that pastoral planning can take advantage of the techniques developed for mineral exploration.

TECHNIQUES AND SOURCES OF INFORMATION

The principal ingredients used in this study are the historical record, aerial photographs, geology, geophysics and experience. The historical record is that of minerals at large but particularly of the Katherine-Darwin Region (the Pine Creek Geosyncline). Principal sources of information used were Bulletin 72 of the Bureau of Mineral Resources, The Australian mineral industry - the mineral deposits; edited by I.R. McLeod (1965); Bulletin 82 'Geology of the Katherine-Darwin Region, Northern Territory; by B.P. Walpole, Crohn, P.W., P.R. Dunn, and M.A. Randal; and The mines and mineral deposits of the Katherine-Darwin region'; by P.W. Crohn; (1968); and Explanatory Notes to the Pine Creek, Fergusson River, Port Keats, and Cape Scott 1:250,000 map sheet areas.
The air photographs used were Australian Government RC9 photography for Fergusson River, flown in 1962, and Pine Creek, flown in 1969. The quality of these photographs is a considerable improvement on the earlier K17 photography used for the geological mapping carried out by the Bureau of Mineral Resources (B.M.R.) during the 1950's.

The geology of Tipperary is shown on B.M.R. geological maps of the Pine Creek, Fergusson River, Port Keats and Cape Scott 1:250,000 sheet areas and is summarized on the 1:500,000 geological map of the Katherine-Darwin Region. A large portion of the property is also covered by a series of special 1:63,360 geological maps. All this work is essentially outcrop mapping and shows large areas of undifferentiated alluvium, soil, swamp deposits, sand and ferruginous gravel over unspecified bedrock. The explanatory notes for the Pine Creek sheet, currently out of print, have been reproduced in Appendix I.

A geological map is an essential base on which to consider and relate the mineral potential of an area. In order to extend the information on existing mapping, photo-geological mapping using modern RC9 photography was commissioned from Loxton, Hunting, and Associates with particular attention to the extensive soil covered areas of the Daly River Basin. The maps and summary report of this work are shown in Appendix II. The work appreciably extended the distribution and detail of the principal Cambrian-Ordovician rock units.

Background geophysical data for the Tipperary area on B.M.R. maps is that of the helicopter reconnaissance gravity survey carried out in 1967 and the magnetic and radiometric work flown in 1974. The gravity data has had direct application to this appraisal and the magnetic contours have been used as a control to the regional distribution of magnetic anomalis. The radiometric data has little value since it was flown too high with too small a crystal detector.

The principal geophysical data used was that collected by Aero Exploration from an airborne geophysical survey during the latter part of 1977. The work was carried out using a Varian proton precession magnetometer and a radiometric system incorporating an 1100 inch crystal
detector. The large crystal area provides sufficient sensitivity to use the data as a very effective mapping tool.

Analogs of the radiometric data showing ground clearance, magnetic variation, total count gamma radiation and those portions of the gamma spectrum due principally to thorium, uranium, and potassium sources were studied. The principal features of the signatures of this data were delineated and plotted on enlarged air photographs at a scale of approximately 1:22,000.

Experience derived from over 10 years regular use of a scintillometer as a mapping tool was applied to assess the significance of the data and to correlate it to the field and photo-geological mapping, thereby producing a feature or work map of Tipperary. This map is essentially a map of bedrock geology.

In addition to this basic collation of information the airborne data has a primary importance in showing up anomalies as provocation for new interpretations, additional study in specific areas and ultimately delineation of exploration targets.

ROCKS AND MINERALS OF COMMERCIAL VALUE

This section comments on some of the characteristics and uses of industrial rocks and minerals as well as their known occurrences, and by simple extrapolation speculates on their occurrence at Tipperary. This is useful in showing the diversity of rocks and minerals and serves as an introduction to a perspective of the mineral industry.

NATURAL ABRASIVES

Natural abrasives found on or in the earth include minerals and rocks which may be used in their natural condition without chemical or physical treatment. They range from the hardest known substances to some of the softest, and from some of the rarer and more precious minerals to rocks of which there is an unlimited supply.

Various forms of silica used as abrasives are available in every State of the Commonwealth and commercial production is largely governed by local demand. Tipperary has large resources of sand, sandstone and quartzite but they are more likely to be useful as construction materials than as abrasives.
ALUMINIUM

Although aluminium is a major constituent of many rocks, particularly clays and shales, the only commercial source is bauxite, an aluminium-rich form of laterite produced by weathering of rocks under special climatic conditions. In general bauxite used as a source of aluminium contains 50 to 55 percent alumina and must conform to other specifications regarding composition.

Laterite occurs at many places in the Northern Territory, but is typically too ferruginous or too siliceous to be considered as an ore of aluminium. The laterite deposits on the Depot Creek and Chilling Standstones at Tipperary are most unlikely to have a marketable alumina content and the quantity available is too small to be economic. Very minor use may be made of this material in road construction.

ANTIMONY

Much of the Australian antimony output has been a by-product of the extraction of other metals, mainly gold and lead. Antimony is not known in the Tipperary region and no reason has been found to suggest its existence.

ARSENIC

Arsenic is generally produced in the form of arsenious oxide, known as 'white arsenic' or simply 'arsenic'.

Most of the Australian output of arsenic has been as a by-product of gold mining; very little arsenic was mined for its own sake. No deposits are known in the Tipperary region.

ASBESTOS

The term 'asbestos' is commercial rather than mineralogical. It is applied to varieties of several minerals which are characterized by a very fibrous habit and a well developed prismatic cleavage, so that thin flexible fibres are obtainable.

Commercial deposits of the minerals occur in serpentinites and metamorphic rocks associated with dolomites and are made up of veins which are rarely more than a couple of inches wide.
Perhaps the only possible place for asbestos minerals to occur on Tipperary is in the area of the Hermit Hill complex.

BARITE

Barite, also known as barytes, is naturally occurring barium sulphate. Most commercial barite deposits are formed by precipitation of the barium sulphate from circulating solutions. The barium may be of magmatic origin, or may have been dissolved from pre-existing rocks by circulating ground water.

The principal use of barite is in oil-well drilling muds to increase the density of the mud when high gas pressures have to be controlled.

Barite of good quality has been reported from the Fletcher's Gully area, south of the Daly River, but the size of the deposit is not known. An analysis of hand-picked crystals believed to be from this deposit showed a barium sulphate content of 95.90 percent.

Several parallel barite lodes crop out about 10 miles west of Dorisvale homestead, near Tipperary's southern border. The lodes are up to 20 feet thick; some can be traced for 200 feet. These deposits should be examined with a view to assessing their potential and the potential for additional deposits in Tipperary. A possible market may be the oil drilling activity on the North West Shelf. Transport could be by water over the tidal section of the Daly River.

BENTONITE AND FULLER'S EARTH

Bentonite and Fuller's Earth are composed mainly of the clay mineral montmorillonite, a hydrous aluminium silicate.

The principal use of swelling bentonite is as a bonding agent in foundry sands, but it is also of particular use in engineering for sealing porous substances from the flow of liquids, as in dams, earthworks, excavations etc, and in drilling muds. Fuller's Earth and activated clays are used almost exclusively for the cleaning and clarification of mineral, vegetable, and animal oils.
Although no bentonitic material has been recorded in the Tipperary region deposits may occur in the Cambrian sediments. The possibility of a market for such material, however, is remote.

BERYLLIUM

The important source minerals of beryllium are beryl, bertrandite, phenacite, chrysoberyl and helvite. Beryllium is used principally as an alloying ingredient to confer strength and hardness on otherwise soft and ductile metals and alloys.

The beryl produced in Australia is largely a by-product or co-product of mining of other minerals such as felspar, mica, tantalite-columbite, and spodumene.

Beryl crystals have been recorded from Kelly's tin mine, near Wolfram Creek, 28 miles east-south-east of Pine Creek. Beryl is found in minor quantities in many pegmatite dykes in other parts of the Northern Territory, but no large concentrations have been reported. On Tipperary the Reynolds River, Soldiers Creek and Allia Creek granites may contain some beryl but probably in uneconomic amounts.

BISMUTH

Bismuth is only rarely mined for its own sake. Bismuth minerals are associated with ores of molybdenum, tungsten or tin, and to a lesser extent, lead, copper, cobalt, nickel, gold, silver, and arsenic; most of the world's production is a by-product of the processing of base-metal ores. Unless it is present in quantities large enough to be economically separated, bismuth is an undesirable impurity in an ore, as small amounts are difficult to separate during refining.

An estimated 1.3 tons of bismuth was won from the Mount Ellison Copper mine at Brocks Creek, about 25 miles northeast of Tipperary and Bismuth minerals were present in the Rum Jungle uranium ore. Any occurrence of bismuth in the Tipperary area is more likely to be a nuisance than of any value.

CADMIUM

No ores of cadmium, in the usually accepted sense, are known. Cadmium occurs chiefly in the mineral sphalerite (zinc sulphide), in which a small percentage of the zinc can be replaced by cadmium.
The principal use of cadmium is in electroplating such common articles as bolts, nuts, screws, etc., for which purpose it competes with zinc because the cadmium coating needs to be only a third as thick and the rate of deposition is nearly double. Since cadmium is exclusively derived from lead-zinc ores the potential for the element to occur in Tipperary parallels that for lead and zinc which follow.

CHROMIUM AND CHROMITE

Several chromium salts occur naturally, and chromium is a minor constituent of many minerals, notably rutile and ilmenite, but the only commercial source of chromium is chromite. Chromite deposits are nearly always associated with ultrabasic rocks, particularly serpentinites, but these are not known and are unlikely to occur at Tipperary.

CLAYS

The term 'clay' cannot be precisely defined, owing to the wide variety and complexity of clays and the clay minerals, but in general terms, clay is an earthy mineral aggregate, which is plastic when wetted, rigid when dry, and vitreous when fired (burnt) at a sufficiently high temperature. Shale (and less commonly slate, phyllite, etc), particularly in the partly weathered state, can be used instead of clay. These rocks are essentially clays that have been consolidated under pressure, and which, when pulverized and wetted, become plastic.

Geologically, clays are of two general types - residual or transported; all clay is of secondary origin, that is, it has been formed by the alteration of some other rock. Clays may be found in a variety of forms - as a soft paste, soft solid (known as mudstone when harder and more consolidated), or as a laminated rock (shale).

Apart from the various clay materials used in the heavy clay (ie brick, tile, and pipe-making) industry the principal industrial clays are kaolin (china clay), ball clay, and fireclay.

In Australia, rocks of almost every geological age make some contribution of raw materials to the ceramic industry. The major use of clay materials is in the production of building bricks and tiles. Relatively large quantities of pottery clay and other clays are used also in the production of ceramic ware, white ware, earthen and stone ware, and terra cotta ware. Considerable quantities of clay are used in cement-making and in the paper industry.
Localities for the production of clay depend on demand rather than the availability of deposits; for the most part clay deposits are worked close to market centres and deposits of good quality may remain unexploited because there is no local demand. The possible extent and use of clay deposits around Darwin has been investigated but with no prospective result. Clay deposits on Tipperary are widespread particularly in the Cambrian sediments. An investigation of these deposits would be worthwhile if any particular market potential could be identified.

BLACK COAL

Coal is a stratified carbonaceous rock formed by accumulation of vegetable matter and its subsequent alteration by decay and a certain amount of heat and pressure. Coal is always associated with sedimentary rocks, forming beds ranging in thickness from a fraction of an inch to many feet. Such a bed or group of beds one above the other and separated by a small thickness of shale or sandstone (dirt bands or partings), constitutes a seam.

The only known occurrence of black coal in the Northern Territory is near Port Keats, west of Tipperary, where bores in presumably Permian strata penetrated several seams which were too thin to be workable. In terms of geologic time the rocks on Tipperary are mostly too old to be coal bearing and those that are young enough did not have the conditions necessary to produce accumulations of organic matter.

COBALT

Cobalt minerals are seldom found in sufficient quantity to be mined for cobalt alone, and most of the world's production is as a by-product of copper, lead-zinc, and nickel mining.

The only known cobaltiferous deposit in the Northern Territory is at Rum Jungle where copper, lead, nickel and cobalt occur, mainly as sulphides, in association with the uranium deposits.

COPPER

Copper is the most important of the non-ferrous metals in quantity and value of world production. Copper occurs in various
parts of the world as native copper, but its most important source is in copper sulphide ores. The most important primary copper mineral is chalcopyrite, but many orebodies contain copper in complex sulphides of copper and other metals. Minerals produced by oxidation of the sulphide minerals formed rich ore in the upper parts of many deposits. Copper has numerous valuable properties that, individually or in combination, give it a wide variety of uses.

Occurrences of copper minerals are widely distributed throughout Australia, chiefly in rocks of Precambrian and Palaeozoic age. More than 2000 tested and worked deposits of copper have been recorded, but most of these consist of small bodies of rich oxidized ore (such as those near the Daly River) which have been, or would be, quickly worked out - most of the deposits have produced less than 50 tons of copper.

Copper was discovered in the Daly River area in 1884, and mined on a small scale intermittently until 1918. The total recorded production is about 7000 tons of ore. The deposits occur at irregular intervals over a distance of about 8 miles and appear to have been small leucocratic bodies in shear zones in steeply-dipping slate. The principal mine, the Daly River copper mine, about 2 miles north of the Daly River Police Station, produced about 6000 tons of ore averaging approximately 20 percent Cu. Today small mines such as these suffer from the capital cost of infrastructure needed to bring them to production and the cost of transport to market. However they are important in being a record that copper exists in the area and hence enhance the possibility that much larger deposits may be found.

DIATOMITE

Diatomite is an extremely light weight sedimentary rock composed largely or wholly of skeletal remains of minute aquatic plants called diatoms, which are related to algae.

The commercial value of diatomite is mainly due to its unique microscopic structure, and also to its chemical inertness, which in turn is due to the fact that it is composed almost entirely of silica.

Almost all deposits in Australia are associated with Tertiary volcanic rocks, chiefly basalts, either in depressions in the lavas or interbedded in them. All other Australian deposits are sub-Recent
to Recent in age and are associated with lakes, swamps, or springs. The geologic conditions on Tipperary during the Tertiary to Recent time period were not favourable for the development of diatomite deposits.

FELSPAR AND CORNISH STONE

'Felspar' is the general name for a group of abundant rock forming minerals which are usually potassium, sodium, or calcium aluminium silicates. Most of the felspar produced in Australia is used in glass manufacture; the remainder is used in the ceramic and abrasives industries. Although felspar is a common rock forming mineral in the several bodies of granitic material in Tipperary deposits of commercial grade would most likely be associated with pegmatites which have not been noted in significant quantities. However the felspar potential might be reconsidered in conjunction with beryl.

FLUORSPAR

The mineral fluor spar, or fluorite, is naturally occurring calcium fluoride. It is a glassy translucent to transparent mineral with a wide range of colour; apple-green and violet varieties are common in Australia.

Most of the fluor spar produced is used by the foundry and steel trade. Moderate quantities are used in the ceramic and glass industries and the remainder in the manufacture of hydrofluoric acid and other chemicals.

Fluorspar deposits as such are not known to occur in the Tipperary region but deposits may have been formed in the Hind Dolomite from volcanic activity during formation of the Antrim Plateau Volcanics. Fluorite mineralisation has been noted in the Cambrian carbonate sediments in association with barite and lead-zinc mineralisation. Investigation may reveal the presence of much more of the mineral.

GEMSTONES

Minerals with special qualities of beauty, rarity, and durability, and used for personal adornment and decorative purposes, come under the general classification of gemstones. Public fashion and taste, which are subject to continual variation and differ from country to country, are important factors in determining the use of a mineral as a gemstone.
Although it appears unlikely that gemstones occur on Tipperary Station the gravels associated with the granite bodies and any gravels associated with the Antrim Plateau Volcanics should be checked out by simple sieve technique to concentrate the heavy mineral fraction. Agate may also occur in the volcanics as well as in association with any chert (silica) bands, nodules or concretions in the Cambrian calcareous and dolomitic sediments.

GOLD

Most of the gold mined occurs in native form, but it is invariably alloyed with silver and, in some cases, other metals. The proportion of silver is usually 5 to 15 percent; gold from some areas contains as little as 50 percent pure gold. The size of the grains ranges from very fine particles almost invisible to the naked eye to nuggets weighing many pounds. Because of its chemical inertness gold is not destroyed by weathering and accumulates in the soil near gold-bearing rocks as eluvial deposits. Such gold is eventually carried into streams where it forms alluvial (placer) deposits. Alluvial deposits and deep leads (deposits formed by burial, of gold-bearing alluvium under barren alluvial material or lava flows) were prolific sources of gold in the past.

Gold has little direct application in industry. It is used mainly for monetary purposes to provide backing for paper currency and in international financial transactions.

Gold was the most valuable mineral product in the early years of mining in the Katherine-Darwin region and the main gold producing areas were the Pine Creek Diggings, the Union Reefs, the Burundie area, and the Brocks Creek area. Gold was reported at Fletchers Gully on Tipperary in 1905, but the history of the field has been one of continual closing and reopening. The gold occurs in quartz reefs filling fissures and tension cracks associated with faulting in the Noltenius Formation. Records indicate production of at least 3000 oz of gold.

GRAPHITE

Graphite, also known as plumbago or black lead, is one of the naturally occurring crystalline forms of carbon.
In 1924, 2.65 tons of graphite were taken from the Golden Dyke mine area, about 30 miles east of Tipperary. The ore probably came from a belt of graphitic slates known to outcrop in the area. The occurrence of good-quality graphite has been reported at Finniss River, north of Tipperary, and graphitic material is known to occur also in lower Proterozoic sediments in the Mt Shoobridge area immediately east of Tipperary. Graphitic material may occur in similar sediments on Tipperary but the apparent absence of any market opportunity does not preclude incentive to search for it because it can be a significant indicator for uranium deposits.

GYPSUM

The mineral gypsum is hydrated calcium sulphate and is widely useful because of its peculiar property of losing three quarters of its combined water on the application of moderate heat, and its ability, when cooled and made plastic by admixture with water, to be spread, cast or moulded to any desired surface or form, and finally to resume its original composition by 'setting'. Gypsum is an important ingredient in cement manufacture and is used as a fertilizer and conditioner for soils. Calcined gypsum has wide application in the building industry as plaster board and allied products.

Semi arid conditions which are usually required for the formation of gypsum deposits, may have existed during deposition of the Jinduckin Formation. Although no report of the occurrence of gypsum is known it does not eliminate the possibility of its occurrence because it may not be readily identified and therefore missed in studies to date.

IRON

Iron is used on a far greater scale and over a far wider range of applications than any other metal, principally for structural material, machinery, tools, and containers. Iron ores are widely distributed in Australia and several deposits are known in the Northern Territory. Large tonnages of ore material are necessary for economic viability and the scope for this in the ferruginous laterite deposits in Tipperary is remote.

Reserves of ferruginous material near Mount Pleasant, on Tipperary, were first thought to exceed 120 million tons at an average grade of 23.5 percent iron but subsequent drilling proved the deposit to contain less than a million tons of low grade material.
LEAD AND ZINC

Lead and zinc commonly occur together in nature, but whereas zinc may be only a minor constituent of some lead deposits, zinc deposits are almost invariably sources of lead also.

The large lead-zinc deposits are also a source of many other metals, eg silver, gold, cadmium, antimony, bismuth, arsenic, tellurium, germanium, gallium, and indium.

Australia is one of the world's principal producers of both lead and zinc. Small deposits have been worked - for lead especially at many places in Australia, but most output has come from the large lead-zinc deposits at Broken Hill, Mount Isa, the west coast of Tasmania and Captains Flat.

Total lead production in the Northern Territory has been small (about 2600 tons) and has come almost entirely from the Pine Creek area, where the lodes were small irregular silver-lead-zinc bodies in limestone, and the Iron Blow mine, in which a copper-gold-silver-lead-zinc ore of the quartz-pyrite type occurred in slate and sandstone.

Zinc minerals are present in many of the lead deposits in the Territory, but no production of zinc or zinc concentrates is recorded. Lead mineralisation has been noted in the Cambrian sediments in Tipperary and that occurrence warrants consideration as an indicator of more extensive deposits especially considering that much of the world's production comes from deposits in carbonate sediments.

LIMESTONE

Limestone is a sedimentary rock of chemical or organic origin composed largely of calcium carbonate as the mineral calcite. Most limestones also contain magnesium, the amount ranging from a trace upwards; rock containing a large proportion of magnesium carbonate is called dolomitic limestone or dolomite.

More than two-thirds of the limestone produced in Australia (excluding that quarried as crushed rock for engineering purposes) is used in the manufacture of Portland cement, and nearly half the remainder is used as flux in the iron and steel industry.
Extensive beds of limestone are known in several parts of the Northern Territory, but the use of limestone has been very limited. A small quantity of burnt lime has been produced from Lower Palaeozoic limestone near Katherine where total reserves are very large, but the grade is extremely variable, both laterally and vertically. Cambrian limestones on Tipperary are mostly dolomitic but lenses of relatively pure limestone have been found to occur. A mineable lens of large tonnage could represent a major resource for cement manufacture.

LITHIUM

The principal commercial sources of lithium minerals are pegmatite deposits and veins closely related to pegmatites. The minerals are spodumene, petalite, lepidolite and amblygonite.

Well-defined dykes containing white crystalline amblygonite crop out 4 miles north-north-east of Mount Bennett near the Finnis River, north of Tipperary. A smaller deposit occurs 1 mile east of the principal deposit and similar occurrences have been reported in other parts of the area. The amblygonite occurs as veins and large segregations associated with pegmatite dykes containing both columbite and tantalite.

Amblygonite has also been reported from Mount Litchfield on Tipperary but no details of the occurrence have been located.

MAGNESITE AND DOLOMITE

Magnesite (magnesium carbonate) deposits are almost invariably formed by the decomposition of basic or ultrabasic igneous rocks, of which serpentinite is the most important in this respect.

Dolomite is a double carbonate of calcium and magnesium commonly associated with limestone.

The bulk of both the magnesite and dolomite produced in Australia is used in the iron and steel industry. In addition magnesite is used as a refractory in base-metal smelting and in cement kilns, and in the production of oxychloride cement, and chemical manufacture; and dolomite is used in the agricultural and glass-making industries.
Magnesite is reported from Darwin and from Stapleton Siding, and scattered occurrences are associated with the Antrim Plateau Volcanics throughout the Victoria River district. Dolomitic limestone is widespread in the Rum Jungle area. The Antrim Plateau Volcanics crop out along the western margin of the Daly River Basin on Tipperary and deposits of magnesite may be associated with them. Dolomite and dolomitic limestones form extensive deposits at Tipperary but opportunity for commercial exploitation is limited.

MANGANESE

The most important source of manganese is the oxide which occurs in the various mineralogical forms pyrolusite, cryptomelane, and gamma-MnO₂. These forms cannot be readily distinguished in the field, and the usual field terms are psilomelane for a hard massive mixture of oxides which may include several different minerals, pyrolusite for a soft black earthy mixture, and wad for an impure, soft, brownish earthy mixture of oxides. Most commercial deposits of manganese are of secondary origin, representing local concentration derived from various sources.

Several hundred tons of manganese ore were obtained from large boulders embedded in soil at the foot of a steep slope near Mount Shoobridge, east of Tipperary. The source of the boulders, which consist of Cretaceous siltstone partly replaced by manganese oxides, is not known. A grade of 60 percent manganese dioxide was produced by breaking up the boulders and hand-picking the ore. It is possible that similar bodies of manganese associated with the Cretaceous sediments occur on Tipperary but they would almost certainly be too small to be of any economic importance.

Secondary deposits of manganese may be associated with or derived from the extensive deposits of Antrim Plateau Volcanics.

MERCURY

Cinnabar, or natural vermilion, is the most important ore of mercury and appears to have been the primary mineral in all commercial deposits.

Ores of mercury usually occur in narrow veins, or as disseminations or impregnations in rocks of many types. In all occurrences the
cinnabar appears to have been deposited from epithermal solutions associated with volcanic activity. No occurrence of mercury mineral is known in the Tipperary region.

**MICA**

The mica minerals, although very complex in composition, are essentially silicates of aluminium and are characterized by a well developed basal cleavage which permits the mineral to be split into thin, flexible, more or less transparent plates and films with important electrical insulating properties.

Muscovite mica is very common as an accessory mineral in acid igneous rocks and metamorphic rocks and in sediments, but the only economic deposits are in pegmatites.

The Northern Territory has supplied almost all the Australian production of sheet mica and a large proportion of the Australian output of crude and scrap mica. Most of the muscovite came from the Harts Range, where mining has been conducted intermittently since 1892. Extensive pegmatization is not known on Tipperary and hence the area has a negligible potential for deposits of mica.

**MINOR METALS**

The minor metals strontium, tellurium, vanadium, selenium, indium, germanium and caesium are those used only to a small extent in science and industry and although Australian sources are known the likelihood of any significant occurrence of them on Tipperary is remote.

**MOLYBDENUM**

The principal ore mineral for molybdenum is molybdenite which is used as an alloying agent in ferrous metallurgy. Like tungsten, molybdenum increases the hardness and toughness of steel, its resistance to shock and corrosion, and its strength at high temperatures.

Small amounts of molybdenite occur in several of the tungsten deposits of the Northern Territory, but the only production was at intervals from 1914 to 1922 when a few hundredweight were obtained from Yenberrie 23 miles south-east of Pine Creek.
NICKEL

The physical and chemical properties of nickel are in many ways similar to those of cobalt, and the two metals are usually associated in nature, and to some extent closely allied in industry.

Nickel orebodies occur in three principal forms - segregations associated with intrusive ultrabasic rocks, hydrothermal and pneumatolytic vein deposits, and lateritic deposits. The lateritic deposits on Tipperary have formed over siliceous rocks which are not a significant source for nickel for concentration in the laterite.

OIL SHALE

Any rock from which oil can be produced by heating might be referred to as an oil-shale and the term has also been applied to carbonaceous material that has a low carbon/hydrogen ratio compared with other carbonaceous sediments, and a yield of mainly paraffinic oil which can be processed to conventional petroleum products by the normal petroleum techniques.

Cambrian and Ordovician sediments in the Georgina and Amadeus Basins in the Northern Territory have generated hydrocarbons and in the Amadeus Basin extensive gas and oil deposits have formed. The Daly River Basin is an extension of the Georgina Basin and similar time rocks occur in Tipperary to those containing hydrocarbons elsewhere. Although insufficient metamorphism and/or depth of burial probably preclude development of oil or gas accumulations the basement structure of the Basin may have some deep sediment filled wedges which would warrant examination and consideration.

PERLITE

The term perlite as used in geology refers to volcanic glass in which a concentric (perlitic) fracture pattern has been produced by cooling. The commercial use of the term is broader, and covers any naturally occurring glassy acid igneous rock which, when heated, expands rapidly owing to the volatilization of the chemically bound gases and liquids in it. As volcanic glass devitrifies with age, few perlite deposits older than Cretaceous are known and because of this it is unlikely that any of the acid Berinka Volcanics south of the Daly River crossing would constitute deposits of perlite.
PETROLEUM

Petroleum is a complex mixture of hydrocarbons occurring naturally in a free state in solid, liquid, or gaseous form. The liquid form is known as crude oil, and the gas as natural gas. Asphalt, pitch, tar, and ozokerite are terms used for solid forms of petroleum occurring in nature.

Petroleum occurs in rocks of all ages from Precambrian to Recent, in amounts ranging from a few parts per million to accumulations of millions of tons. Surface occurrences, such as seepages, are of commercial value in places, but practically all the world's supply of petroleum comes from subsurface accumulations.

Factors affecting the origin and accumulation of petroleum are not completely understood as yet. Current knowledge suggests that it was formed from organic material in organic muds and ooze, predominantly those deposited in a marine environment. The organic material is thought to be converted to petroleum by the catalytic action of active-surface minerals, bacterial activity, and probably other agents in an environment devoid of oxygen. The physical effect of heat and pressure may modify the composition of the petroleum. From the source rock, the petroleum migrates to a permeable reservoir rock. Through this rock it may travel considerable distances until it accumulates in a trap created by sub-surface structural and/or lithological conditions which prevent or restrict further movement of the petroleum.

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NATURAL PHOSPHATES

Naturally occurring phosphates of economic importance include phosphate rock, apatite, guano, and cave earth. Phosphate rock in its broadest sense includes any rock which is composed principally of phosphate minerals, and apatite, guano, and cave earth are distinct
generic varieties of phosphate rock. Natural phosphates are used chiefly as the raw material for the manufacture of phosphate fertilizers, principally superphosphate. A small amount is ground and applied directly to the soil.

Deposits of phosphate rock have been recognized at several places north and south of Rum Jungle. The deposits occur in and near bodies of Upper Proterozoic hematitic rock which overlie metamorphosed Lower Proterozoic siltstone and dolomite. The hematitic rocks are interpreted as remnants of an old weathering profile, and the phosphate deposits are considered to have formed by supergene concentration of phosphate from the underlying metasediments.

Similar phosphate rock occurs at the base of the Upper Proterozoic succession at Coronation Hill and Saddle Ridge South in the South Alligator River Valley about 50 miles north-east of Pine Creek, and at Sleisbeck, 70 miles east of Pine Creek.

Although the same unconformity surface extends over parts of Tipperary there is no indication of a similar source of phosphate for enrichment.

Phosphate deposits have also been found in lower middle Cambrian sediments equivalent to the Tindall Limestone in the Georgina Basin from Brunette Downs to the Queensland border and in Ordovician sediments in the Amadeus Basin south-west of Alice Springs. These are sedimentary deposits and the same seas, in which deposition took place, extended into the Daly River Basin. Hence prospects for phosphate deposits may exist in the Cambrian and Ordovician sediments at Tipperary.

Reconnaissance examination and drilling of the Tindall Limestone has been carried out by a few companies without success but this work could not be considered exhaustive.

Small deposits such as that at Rum Jungle are of little economic significance but the same deposit on Tipperary could be useful for domestic application in pastoral development.
PLATINUM GROUP METALS

Platinum and its allied metals — palladium, rhodium, ruthenium, iridium, and osmium — are classed as precious metals because of their rarity and possession of a combination of special properties — hardness, high melting point, good conductivity, and resistance to chemical attack unusual among the elements.

Platinum group metals occur in association with ultrabasic rocks, mainly as disseminations and seams in olivine and chromite rich rocks, or in ores wherein the metals are associated with sulphide minerals. Weathering of primary deposits forms alluvial (placer) deposits which are worked by methods and facilities similar to those for gold; the bulk of production comes from alluvial deposits. Ultrabasic rocks are not known in Tipperary but the strong positive gravity anomaly centred near Mt Haywood conceivably could be indicative of their presence beneath cover in this area. If prospecting found this to be so then the possibility, though seemingly remote, of platinum group metals occurring in the area should be kept in mind.

PIGMENT MINERALS

The natural earth pigments and their calcined products include a wide variety of substances used to give colour, body, and opacity to paints, stucco, plaster, mortar, cement, linoleum, rubber and other materials. The principal natural pigment minerals or mixtures of minerals are those that contain iron oxide as the essential constituent. Small quantities of pigment minerals probably may be found associated with laterite deposits and Cretaceous sediments on Tipperary but they would not be of any significant commercial value.

POTASSIUM

Potassium is very widely distributed in the earth’s crust and ranks sixth in order of abundance of the elements. In commerce, potash is a general term for potassium compounds, the name being derived from the former method of preparation of potassium bearing material, mainly potassium carbonate, by evaporating the leachings of wood ashes in iron pots.

Potassium is a constituent of many minerals, but is present in only small quantities in most. Commercial production is nearly all from naturally occurring soluble potassium compounds, deposits of which have
accumulated in land locked seas, salt lakes, and coastal lakes as a result of evaporation.

There does not appear to be any possibility for such deposits to have developed at Tipperary.

QUARTZ CRYSTAL

Although quartz, in its various forms, is one of the most common minerals in the earth's crust, large flawless crystals of a quality suitable for special industrial purposes are rare. The most important single property of quartz crystal (rock crystal) is its piezo-electric effect and among crystalline substances quartz crystal has the highest known efficiency of transfer, back and forth, between strain and motion or from potential to kinetic energy.

Quartz crystals occur in rock cavities, quartz reefs, veins, and pipes, in association with other minerals in pegmatites, and as gangue mineral in other mineral deposits. The weathering of these deposits may produce residual deposits of rock crystal at or near the site of the weathered outcrop, or alluvial deposits laid down at some distance from the source by streams.

No usable quartz crystal has been produced in the Northern Territory and it is not known whether any clear crystals are associated with the pegmatites at Tipperary.

RARE EARTHS

The rare earths are the elements cerium, praseodymium, neodymium, prometheus (ilinium), samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium, with atomic numbers ranging respectively from 58 to 71. In addition, the three elements scandium, yttrium, and lanthanum, with atomic numbers respectively of 21, 39 and 57, are commonly classed with the rare earth elements because of their natural association with them. The term rare earths arose from their apparent scarcity at the time they were named and from the fact that their oxides resemble the alkaline earth oxides. To avoid this misnomer the modern tendency is to call them the lanthanides.
Rare earth mineral occurrences are widespread in epigenetic metalliferous deposits including vein, pegmatite, and carbonatite deposits. Some radiometric anomalies in the thorium channel over the Upper Proterozoic sandstones on Tipperary may be due to monazite, a phosphate of the rare earth elements and thorium, but such occurrences are unlikely to be important.

SALT

Salt occurs as extensive deposits of rock salt, as deposits on lake beds in arid areas, as salt solutions, as sublimation products near volcanoes, and as efflorescent earthy crusts in arid regions. Of these only the first three are of commercial importance. Saline solutions include oceans, salt seas and lakes, and water from saline springs and wells, and are the principal commercial sources of salt.

Australia possesses large resources of salt. Production is derived chiefly from solar evaporation of sea water and brine, but also from the harvesting of lake salt deposits. Small quantities of salt are harvested from tidal salt pans north of Darwin for local consumption and the same may be done at Tipperary should a demand arise.

SILICA

Silica, predominantly as the mineral quartz, occurs in nature in many forms and has a great variety of uses.

Because silica is a low cost commodity the deposits exploited are those close to the industrial centres. Thus the extensive deposits of sand, sandstone, quartzite as well as deposits of reef quartz on Tipperary would have no value at present.

SILLIMANITE GROUP MINERALS

The minerals sillimanite, kyanite, andalusite, dumortierite, and mullite, are aluminium silicates which have very high melting points, and which maintain a high degree of strength and stability under thermal stress. They constitute an important group of refractory raw materials.

Sillimanite, andalusite, kyanite, and dumortierite are mostly found in metamorphic rocks. They commonly occur as disseminated crystals but may form large, relatively pure masses.
Andalusite occurs in schists in parts of the Daly River area, but no concentrations of this mineral have been found.

SILVER

Silver is the most efficient conductor of all the metals, and, next to gold, the most malleable. It has a good resistance to corrosion but tarnishes on exposure to hydrogen sulphide fumes, which are present in the atmosphere of even minor industrial areas.

Almost the entire Australian production of silver is a by-product of base metal and gold mining.

Silver was a constituent of many of the lead, copper and gold ores produced in the past from the Northern Territory, including Fergusson River, Iron Blow mine, McCarthy's mine, Mount Gardiner and the Flora Belle mine, all in the Pine Creek district. Silver is also a constituent of many of the copper deposits and gold deposits of the Pine Creek district. The potential for silver at Tipperary will be similar to that for the base metals, copper, lead and zinc as well as gold.

STONE, SAND, AND GRAVEL

Stone is the industrial synonym for rock and refers to rock fragments or blocks as used in industry. Sand and gravel are unconsolidated granular materials resulting from the natural disintegration of rocks.

Dimension stone is stone sold in blocks or slabs of specified shape and usually of specified sizes. Hardness, colour, strength, porosity, and workability are the most important physical properties.

Crushed and broken stone is produced from all three classes of rocks on the earth's surface - igneous, sedimentary and metamorphic. The physical properties of stone that is to be crushed and broken are very important, not only in the methods and hence cost of its production, but also in its use.
The physical properties of sand and gravel are determined largely by their method of formation and deposition. Thus the source material, the means and distance of transportation, the degree of abrading, washing and sorting, and the environment of deposition, control the cleanness, grain size and shape, the soundness of the grains, and so on.

Contrary to popular belief workable deposits of sand and gravel are not found everywhere, and many deposits cannot be utilized. Because sand and gravel fragments have appreciable size and weight, strong currents or turbulence are necessary for their transportation. Thus the main sand and gravel deposits are found in the proximity of hilly or mountainous country where streams are swift-flowing or in places where there has been a large body of water affected by wave action.

Stone, sand, and gravel are produced by private organizations, and government or semi-government bodies, from quarries which, for economic reasons, are generally developed as close as possible to the market. Large quarries are opened from time to time for a particular purpose, such as dam or harbour construction. Operations cease at these quarries on completion of the project. The most important potential for stone, sand and gravel at Tipperary would be for dam construction on the Daly River. One would need to move well ahead of detailed planning for a dam to delineate and secure rights to suitable deposits.

SULPHUR

Sulphur is a non-metallic element occurring both in the free state and in combination with other elements. Native sulphur may occur in a number of allotropic forms ranging from amorphous and soft, to hard, yellow crystals.

Part of the sulphur used in industry, besides that obtained from native sulphur deposits and from petroleum refinery residues is extracted from sulphide minerals. By far the most important use for sulphur is in the manufacture of sulphuric acid which is an essential raw material for fertilizers and many industrial chemicals.
Many sulphide ore deposits have been worked in the Northern Territory but no production for acid making is recorded. Perhaps the only potential demand for sulphur at Tipperary would be in the event of discovery of commercial phosphate deposits.

**TALC, STEATITE, AND PYROPHYLLITE**

Talc and steatite are both hydrated magnesium silicates which occur mainly as monomineralic rocks; the term 'talc' is applied to the foliated type and 'steatite' to the massive type. In Australia, 'soapstone' refers to any talcose rock which can be readily worked and cut into sawn blocks.

Talc and steatite are secondary minerals, the product of metamorphism or metasomatism of rocks rich in magnesium, such as dolomite, peridotite, or pyroxenite. Pyrophyllite is a much less common mineral formed by similar processes from acid alluminous rocks.

These minerals are not known to occur in the Tipperary region.

**TANTALUM AND COLUMBIUM**

Tantalum and columbium are malleable, corrosion-resistant metals with high tensile strength. Columbium is a good conductor of heat and electricity, and tantalum is a good thermal conductor but has a high electrical resistivity.

Until recently the principal ore mineral of both tantalum and columbium was a variable columbate and tantalate of iron and manganese known as tantalite or columbite according to whether tantalum or columbium predominates.

\[ \text{Tantalite has been found at several places in the Northern Territory but production is recorded from only a few, mainly in the Darwin area where mineralized pegmatites occur in a belt extending from the West Arm of Port Darwin south for 34 miles to Bamboo Creek. It is not known whether similar mineralisation is associated with pegmatite at Tipperary.} \]
TIN

Tin has poor conductivity, high resistance to corrosion and fatigue, and alloys readily with many other metals.

The almost universal source of tin is cassiterite and much of the world production comes from alluvial deposits, primary and eluvial deposits supplying the remainder. The mine product is dispatched as cassiterite concentrates, which usually contain about 70 percent Sn in the case of alluvial material, and 65 to 70 percent Sn when derived from lode deposits.

Most of the tin production in the Northern Territory, amounting to more than 7000 tons of concentrates, has come from the Katherine-Darwin region, in which the principal centres were the Maranboy field and the Pine Creek district. Most of the deposits in these and other areas are small and many have been worked out. Tin deposits in the Buldiva-Collio area of Tipperary are relatively small and have little potential for discovery of new additional deposits.

TITANIUM AND ZIRCONIUM

Titanium and zirconium are described together because their ores commonly occur together, in Australia, in detrital deposits.

Titanium has a very high strength to weight ratio, is only a moderately good conductor, and is relatively inert chemically. Its wide utilization is inhibited by metallurgical difficulties.

Most of the world's production of rutile and zircon is obtained from coastal beach sand deposits; much of the ilmenite is obtained from the same source, the three minerals being mined together; but large dyke-like bodies of ilmenite with various impurities have been exploited.

The most important use of rutile and ilmenite is the manufacture of titanium white, which, because of its high opacity and chemical inertness, is valued as a pigment and filler in paints, plastics, rubber, paper, etc. Titanium metal is used in aircraft and space vehicles and in machinery and plumbing exposed to moderately corrosive liquids.
Zircon is commonly used in its original mineral form as moulding sand and as a refractory in the glass and aluminium industries.

Heavy mineral deposits are known at several places in the Northern Territory, but most are small and unimportant. Sampling at Point Blaze near the mouth of the Daly River, indicated sands containing 4000 tons of heavy minerals between the foredune and the sea. The deposit, which overlies laterite, has a maximum depth of 2½ feet.

TUNGSTEN

Tungsten has the highest melting point of all the metals. The principal use of tungsten is as an alloying agent in steel. Addition of tungsten in conjunction with other metals confers on steels the ability to withstand abrasion, shock, great stress, and oxidizing atmospheres at high temperatures.

The tungsten minerals of commercial importance are wolframite and scheelite. Although small tonnages of wolfram have been won from prospects near Pine Creek no occurrences have been recorded in the Tipperary area.

URANIUM

Uranium does not occur in the native state. More than 150 uranium-bearing minerals are known, but only a few of these are of economic value. The most important are the primary minerals uraninite (pitchblende, UO₂, which is almost always oxidized and grades towards U₃O₈), and brannerite, an oxide of titanium and calcium and other metals. The principal secondary uranium minerals are autunite, a hydrated calcium uranium phosphate; uranophane, a hydrated calcium uranium silicate; torbernite, a hydrated copper uranium phosphate; carnotite, a hydrated vanadate of uranium and potassium and gummite, a fine-grained mixture of various secondary uranium minerals.

The most important property of uranium is its inherent instability, which leads to the breakdown of the atomic structure in a series of chain reactions whose stable end product is lead. During this transformation, alpha, beta, and gamma rays are emitted. The splitting of the uranium nucleus (fission) releases an enormous amount of energy. The release of this energy can be controlled to provide the most powerful source of energy known to man.
The principal commercial use for uranium is as a fuel for the
generation of nuclear energy. It has been used also in high strength
steels as an alloying constituent. Uranium oxide is used in ceramics
and glass making, primarily as a colouring agent (uranium yellow).
Small amounts are used in the chemical industry for analytical work,
and in photography as a toner intensifier. Radio isotopes of various
elements, produced in atomic reactors, are widely used in many branches
of science, industry and medicine.

The Katherine-Darwin region contains approximately 20 percent
of the world's known high grade uranium reserves. The Tipperary area
has geologic features comparable to those of known deposits and the
numerous radiometric anomalies on Tipperary support the probability of
the occurrence of deposits of uranium minerals.

MINERAL EXPLORATION

Mineral Exploration Philosophy

The following discussion examines the mineral potential at
Tipperary specifically in terms of exploration for minerals and rocks.

Numerous books and a great miscellany of scientific papers have
been written on the genesis of ore minerals and the formation of ore
deposits. Almost all of this material has come after the event of
discovery when studies have been carried out to determine, among other
things, how to find the same again. Thus a boundary rider
accidentally finds a Broken Hill, the students study to find another.

While this material is variously relevant to the business of
exploration, however, the old axiom of 'gold is where you find it'
should not be ignored.

For the purpose of assessing the mineral potential at Tipperary
Station in relation to specific exploration a simple basic
philosophy has been applied. This can be described in terms of the
formula:

- SOURCE of mineral elements
+ SEPARATION MECHANISM
+ TRANSPORT
TRAP

TIME TO give ACCUMULATION AND CONCENTRATION

If any one or more of these items is missing an orebody is unlikely to be formed.

Gravity

Gravity data are fundamental to consideration of any problems concerning the earth's crust. Gravity data are measures of the earth's gravitation and expressed as Bouguer anomalies indicate dense and less dense blocks of the crust which may be correlated to rocks and groups of rocks in outcrop.

The gradient or zone of change between positive (dense) and negative (less dense) features reflects the degree of contrast between two differing blocks; a narrow (or steep) gradient suggests a vertical contact between two contrasting blocks such as granite (negative) intruding sedimentary rocks (positive). The stronger the gradient the stronger the contrast in density and the narrower the gradient the steeper the slope of contact.

In the Katherine-Darwin region there is a general correlation between the distribution of mineralisation and the gradients between gravity features. This is consistent with intruding granites introducing minerals into the surrounding rocks; with the heat of an intrusion mobilising minor amounts of minerals in country rock and reconcentrating them into ore bodies; with structural situations being developed between crustal blocks of contrasting density and becoming favourable loci for deposition of mineralising solutions from whatever source; and with basement topographic control on sedimentation and facies development conducive to concentration of minerals.

Whichever hypothesis may apply is certainly relevant to the general theory of the genesis of orebodies, but for the purpose of finding orebodies one needs only to recognise the gravity feature and its geometry to identify a place for mineralisation.
Gravity data is sparse (in Australia) but none the less is significant. The measure or assessment of the quality and relevance of that significance is up to the skill and artistry of the explorer. For example the gravity high north of the Daly River Police Station may be readily dismissed as due to basic igneous rock as mapped on the B.M.R. geological maps using the B.M.R. gravity map with 5 milligal contour intervals. But when plotted at photoscale 1:88,000 and contoured at 1 milligal intervals it is clear that the gravity high is due to more than the basic rock as mapped.

**Magnetism**

The character and variation of the earth's magnetic field in the Tipperary region is relatively simple. Most of the Cambrian and Precambrian sediments have only broad regional feature type changes. Strong anomalies occur over basic intrusions (dolerites etc) and over portions of the lower Proterozoic sediments which compare with the magnetically active Golden Dyke Formation and equivalents found elsewhere in the Katherine-Darwin region though not mapped on Tipperary.

Numerous small anomalies are characteristic of the Antrim Plateau Volcanics and this enables their presence to be detected under cover of younger Cambrian sediments. Numerous small anomalies are also characteristic of a large portion of the Hermit Hill Complex. The Litchfield complex has negligible magnetic character.

**Radioactivity**

The nuclei of certain kinds of atoms can disintegrate spontaneously with the emission of various special types of radiation. The name radioactivity has been given to this phenomenon. Of the many elements that are naturally radioactive three occur commonly in the earth's crust; these are uranium 238, thorium 232 and potassium 40. The decay products of each element emit gamma rays which can penetrate two or three feet of rock or as much as several hundred feet of air. Instruments such as scintillometers can readily detect gamma rays.

Almost any material about us emits gamma rays to some degree and the systematic detection, recording and study of radiometric data can be very useful in learning the nature of this material. During an airborne
geophysical survey a detector in the plane flying overhead records variations of the gamma radiation from the top few feet of the earth's surface. The radiometric equipment used by Aero Exploration included a spectrometer which records those parts or 'windows' of the radiometric spectrum due principally to thorium, uranium, and potassium, as well as the bulk or 'total count' of the spectrum. Plotting and comparative study of this data enables identification and delineation of the distribution of soils and rocks that differ in their rate of radiation and also can give some lead to the origin of their formation.

An important feature of uranium is that it tends to remain with other residual elements in the weathering profile so that the gamma signature of eluvium is commonly similar or identical to that of the underlying bedrock. Although much of Tipperary is soil covered it has been possible to determine the probable bedrock type through study of the gamma signatures.

Economics of Mineral Exploration Targets

In very general terms mineral exploration targets fall into three categories according to incentive economics.

Large mining companies, especially the multinationals, need large production and long tenure of operations to be worth their while and so they concentrate exploration effort on the major commodities such as base metals, iron ore, bauxite, phosphate, and beach sands. They can deal with low grade deposits if the size is big enough. The style of exploration effort required to find these bodies is quite beyond small companies and syndicates or individual prospectors.

The second category is small but very rich deposits which can be worked by low capital plants readily assembled for short term operation and amortised or removed on completion to be reassembled elsewhere. These deposits typically are desired by smaller companies usually with some special flair or expertise but lacking the access to funds for the grander exploration techniques of the multinationals.

The third is for those minerals which any man with little more than a 'grubstake' can go and find for himself. These minerals are those found in alluvial deposits - gold, tin, gemstones - and special deposits such as opal, and pegmatite minerals.
Major Exploration Targets

When undertaking exploration in a given area it is desirable to design and budget activity on those minerals which are most prospective and rewarding. At Tipperary the major exploration targets fall into two categories - those whose origin relates to deep sources and those that relate to sedimentary basins. In both cases there is a potential for the occurrence of large mineral deposits.

1. Deep Sources

The place to look for mineral deposits whose origin relates to deep sources is delineated by gravity gradients. The strong positive anomaly between Litchfield and the Daly River Police Station may represent a large basic intrusive body or a thick pile of lower Proterozoic sediment. The elongate north-south negative feature on the western side may be due to a continuity or extension of the Litchfield Complex but the magnetic character of this area suggests complexity and the possibility of an as yet unrecognised rock mass.

The minerals likely to be found in this area are copper because copper mineralisation is known along the Daly River - Wheal Danks line of workings, and uranium because of the correlation with gravity gradients and mineralisation apparent elsewhere in the Pine Creek Geosyncline. The source for copper and uranium may be acid or basic intrusions, or lower Proterozoic sediments comparable to favourable uranium lithologies known elsewhere but as yet not recognised or delineated in the Daly River area.

This exploration target is especially interesting for uranium search because of its location in the general area of contact between Archean basement (the Litchfield and Hermit Hill Complexes) and lower Proterozoic sediments and low grade metamorphic rocks. Similar prospects may exist south of the Reynolds River Granite about 15 miles north west of Tipperary and in the Chilling Creek and Allia Creek areas but data is insufficient to ascertain this at present.

2. Sedimentary Basins

Some of the world's largest and most productive base metal ore deposits occur in sedimentary basins. Those deposits that are essentially restricted to one or a few well-defined tabular stratigraphic units, chiefly limestone or dolomite, are termed strata-bound deposits.
In general the most common host rocks for strata-bound deposits are shallow water marine carbonate rocks. In many areas they are most heavily mineralised near the margins of the sedimentary basins, adjacent to domelike positive areas, at facies contacts within the basins, or near unconformities within the basin strata.

The deposits are typically flat lying, large, and commonly localised by stratigraphic pinch out zones, by masses of breccia of diverse origin, by zones of minor faults and fractures, or by biohermes and associated sedimentary and organic features.

In many deposits the ore consists mainly of either galena or sphalerite, and barite and fluorite can be major gangue minerals in addition to calcite, dolomite and jasperoid.

The Daly River Basin, which covers the central south eastern part of Tipperary has characteristics comparable to basins containing stratabound deposits. These are:

1. carbonate stratigraphy
2. shallow water
3. probable ideal paleoenvironmental conditions for brines
4. a record of special chemistry in time rock equivalents in the adjoining Georgina Basin where phosphate deposits and minor base metal mineralisation is associated with the lower Cambrian formations.

A prospect 10 miles south west of Tipperary homestead and near the margin of the Daly River Basin has lead and zinc mineralisation in association with barite and fluorite at localities on the southern flank of a circular (dome-like) structure approximately three miles in diameter.

It is considered that this constitutes a strong prospect for lead-zinc deposits.

The basement of the Daly River Basin appears to be fairly even because of the overlap of younger Cambrian and Ordovician sediments as the basin filled. The margins of the Basin parallel regional north east and north west trending photo lineations which have varying topographic expression in the high ground (= Cambrian landform) surrounding the Basin. Therefore it can be expected that the basement topography to the Basin will be significantly irregular and have
appreciable scope for facies variation and disconformity in the basal units of the Cambrian sequence.

Thus numerous situations probably exist in the Basin for the containment of mineral deposits. In addition to base metal prospects, uranium derived from the surrounding mineralised Proterozoic highland may have deposited from ground waters at or near the base of the Cambrian sequence. This could be of considerable importance but as yet too little is known of the Basin structure and basal stratigraphy to delineate specific areas for investigation.

**Minor Exploration Targets**

Deposits of phosphate rock are widespread in the lower middle Cambrian equivalents in the Georgina Basin to the south east. It is known that the same phosphogenic seas extended into the Daly River Basin but exploration work carried out by a few companies has been unsuccessful.

The work was all of a reconnaissance nature and does not eliminate the possibility of the presence of phosphate deposits. The deposits in the Georgina Basin are located at the facies contact between clastic sediments (shale and sandstone and chert) and carbonate rocks (limestone and dolomite). Typically the zone of contact is long, narrow, and intermittent and therefore difficult to locate. Prospects for phosphate deposits in the Daly River Basin should be continually reviewed as more is learnt about the basement topography and the basal Cambrian lithologies.

Sand covers several square miles of country immediately to the north of the Collah Tinfield. It is unlikely that this ground has been tested for tin deposits by other than surficial testing. Both eluvial and alluvial tin deposits may be concealed under the sand cover.

Exploration for deposits of limestone for use in cement manufacture has been carried out during recent years. Although the carbonate sediments in the Cambrian sequence are dolomitic a few thin bands of limestone of suitable quality have been found. Larger tonnages would be required to provide a mineable economic deposit. The deposits have been located in the Tindall Limestone and the distribution of this unit is characterised by numerous sink holes and a characteristic gamma signature.
CONCLUSIONS AND RECOMMENDATIONS

1. It is recommended that the circular feature centred approximately 10 miles south-west of Tipperary homestead be investigated by a reconnaissance open-hole drilling programme to determine the subsurface stratigraphy structure and extent of lead-zinc and/or other mineralisation. Drill site procedures should include radiometric logging. Advantage of the presence of a drill rig in the area should be taken to drill a few stratigraphic holes in order to develop structure contour maps of the basal cambrian units and basement topography.

2. A separate study of radiometric anomalies should be carried out. The work should include detailed location of anomalies using 35mm film strip of the flight path, determination of ratios between the uranium, thorium, and potassium channels, and provisional listing in order of apparent interest by area and by related rock formation.

Where a group of anomalies is associated with a rock formation measurement of the background gamma count for the formation should be determined over several widespread areas to compare any drift in background with the area of anomalism. For example the background of the Stray Creek Sandstone increases from north to south and this may add to the inference drawn from anomalies.

Because a few feet of soil can mask a radiometric anomaly examination of the analogs calls for keen attention to subtle, low amplitude anomalies. Some areas may be considered to call for particular attention such as thin Cambrian over Burrell Creek Formation, this Cretaceous cover on lower Proterozoic rocks in the south of the area, and valleys such as that south of the Daly River mapped as undifferentiated lower Proterozoic.

No anomaly should be neglected. A ready illustration of the value of this contention is the fact that Pancontinental Mining Limited's Jabiluka I was not detected from the air by the conventional techniques of examination of data applying at that time (1970). Ground survey showed an anomaly of up to twice background readings over half an acre; Aero Exploration's equipment has the capacity to find such an anomaly.
3. All radiometric anomalies should be identified and examined in the field. This exercise will directly add to the understanding of the geology and any one or more of the anomalies could lead to new mineral discovery. Other mineral deposits as well as uranium deposits may have radiometric anomalies.

4. Additional definition of the principal crustal features should be obtained by carrying out a gravity survey of the property by taking readings at half mile or one kilometre intervals along suitable roads and tracks.

5. The gravity features between Litchfield and the Daly River need to be investigated where the Litchfield and Elizabeth Downs Exploration Licences (ELs) cover them.

The significance of the magnetic character of the Litchfield and Hermit Hill Complexes needs to be investigated in correlation with geology and gravity of the area.

It is recommended that application for an EL between Elizabeth Downs and Litchfield to cover the gravity gradient between the positive and negative features in that area should be made.

6. The relatively weak gravity gradient south west of the Reynolds River Granite should be investigated. The gravity data is sparse so the gradient may be stronger than indicated; the area has several radiometric anomalies, high background counts over the Burrell Creek Formation, thin cover of upper Proterozoic to mask deposits and/or protect them; as well as possible valleys in the Cambrian sediments for the passage of minerals and possible entrapment.

7. The area in the north east of Tipperary along Green Ant Creek has gravity gradient and magnetic character similar to that for Golden Dyke Formation as well as lying on a gravity gradient. The area borders the known mineralisation of the Mount Shoobridge area and may represent an extension under thin cover.

The relevant EL numbers are 1724 and 1384.
8. The Chilling Creek and Allia Creek areas may have interesting gravity features but paucity of data precludes further speculation. It is recommended that additional gravity be obtained as a prelude to further assessment.

The Fish River area has little definition of character for assessment of its mineral potential. It recommended that further data be obtained and studied through additional gravity work and field reconnaissance. One question for consideration is the thickness of upper Proterozoic cover in the area.

9. The large area of undifferentiated Cainozoic (C2) north of the Collah tinfield warrants review as a possible large low grade alluvial or eluvial tin prospect.

10. A stream sediment geochemical survey should be carried out over the whole of Tipperary. The results can be expected to further delineate areas for exploration. The technique has proven effective on comparable terrain and geology in the Mount Shoobridge-Fenton area immediately east of Tipperary.

11. All known mineral occurrences on Tipperary should be examined and re-appraised in the light of this study.

12. All bores on Tipperary should be radiometrically logged and water samples taken for analysis of uranium and other elements to be determined after consultation with an analytical laboratory chosen to carry out the analyses.
COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

1:250,000 GEOLOGICAL SERIES
EXPLANATORY NOTES.

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1962.

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APPENDIX II

PHOTOGEOLOGICAL STUDY
TIPPERARY STATION, NORTHERN TERRITORY

by J.B. Jeppe
R.F. Loxton, Hunting and Associates

March 1978
Mr. J. Barrie  
Consulting Geologist  
24, Jindivik Place  
SCULLIN, A.C.T. 2614

Dear John,

PHOTO GEOLOGICAL STUDY: TIPPERARY STATION

Further to our discussions of Friday, 3rd March 1978, the following is a summary report of the photogeological study of the Tipperary Station Area.

Introduction

The study covers about 5,600 sq km of Tipperary Station, Northern Territory. Initially 92 black and white RC9 aerial photographs at a scale of approximately 1:80 000 were used. Later, parts of the area that were not stereoscopically covered by the photographs supplied, were examined and annotated at the Division of National Mapping in Queanbeyan.

Method

A Zeiss mirror stereoscope was used, with x1 and x6 eyepieces, and the photogeology was annotated on to clear film on which a drainage base had been traced at photo-scale from enlargements of the published topographical map (original scale 1:100 000).
Purpose and Scope

The purpose of this study is to provide a map that, when field checked and integrated with geophysical data, will form a basis for mineral exploration in the area, and will also assist in the area's agricultural and pastoral development. The present investigation is restricted to the Cambrian and Ordovician rocks, and the formation boundaries marked are largely interpretative. The only subdivisions shown in the Proterozoic rocks are "Upper" and "Lower".

Previous Work

Stratigraphic interpretation has necessarily been based on the published information as follows:

1. Bureau of Mineral Resources Maps: Pine Creek (1962); Fergusson River (1961); Cape Scott (1969); all at the scale of 1:250 000.


3. Parts of Pine Creek Sheet: Mt. Hayward (1963); Reynolds River (1962); published by the B. M. R., at the scale of 1:63 360.


Presentation

The results are presented in the form of three coloured work-sheets at photo-scale (approx. 1:80 000).

General

It is anticipated that the continuation of this investigation will take the following form:

1. Re-assessment of the work-sheet maps by application of the geophysical results.

2. Field checking of photogeological and geophysical features.

3. Re-annotation of map, and presentation of detailed report.

Yours sincerely,

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