SOUTH ALLIGATOR VALLEY URANIUM FIELD

A. GEOLOGICAL SETTING

B. GEOLOGICAL APPRAISAL OF THE ROCKHOLE MINE AREA

C. SUGGESTED APPROACH TO EXPLORATION

by

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GEomin EXPLORATION PTY. LTD. AND UNITED URANIUM N.L.

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ABSTRACT

A geological reappraisal of the field has shown that cross-folding played a major role in localising uranium mineralisation.

Mineralisation at the Rockhole Mine is shown to be structurally controlled. Limits of the mine's potential are predicted and recommendations are made accordingly.

The other known deposits and radiometric anomalies are also shown to be associated with cross-folding. Proposals are put forward for the reassessment of several known areas and for initial exploration in others.
INTRODUCTION

1. Request

The request for a detailed geological appraisal of the South Alligator Valley Uranium Field was made to Geomin Exploration Pty. Ltd. by Mr. S. J. Griffiths, Managing Director of United Uranium N.L. and Chairman of the Joint Venture Committee.

Mr. J. B. McManus of Geomin Exploration Pty. Ltd. was commissioned to carry out the work. He arrived in the Northern Territory on October 5, 1968, and was based at United Uranium's El Sherana camp in the South Alligator Valley, where the bulk of the work, including report writing, was done in the ensuing seven weeks. Within a week of starting, however, it was realised that the project was far too large to be adequately completed, in a reasonable length of time, by Mr. McManus with only limited assistance. Consequently, Mr. McManus suggested that the interests of all concerned might be best served if the two geologists resident at El Sherana were to participate full-time in the project. Mr. J. Taylor, Chief Geologist, United Uranium, approved the suggestion. Accordingly, on the 16th of October, Dr. I. G. P. Wilding and Mr. N. G. Murphy commenced full-time work in conjunction with Mr. McManus.
2. Ain

The terms of reference for the project were:

a. To make a geological appraisal of the Rockhole Mine area;

b. To examine the overall setting of the uranium deposits in the South Alligator Valley Uranium Field, with a view to determining the factors controlling ore deposition and suggesting an approach to further exploration and

c. To present cross sections illustrating the information gained from the recent drilling of two diamond drill holes at El Sherana West.

Aiming to comply with the above mentioned objectives, it was decided to sub-divide the project, and the report, into three sections. In the first section the writers set out to examine the structural setting of the uranium deposits and to study structural features likely to have played a part in the control of ore deposition, with a view to invoking a theory of ore control.

The second section was devoted to a detailed examination of the structural geology of the Rockhole Mine area against the background of the regional setting, and in the final section an approach to exploration was planned.
It is felt that an appraisal of the El Sherana area, albeit important, would take longer than did the appraisal of the Rockhole area. Recommendations for further work on the El Sherana area are made in the report. In the interim, cross-sections showing the recent diamond drilling at El Sherana West are being prepared by the geological staff of United Uranium and will be submitted through the normal channels.

Aspects such as access, topography, climate, leases, services, etc. are not discussed in this report. As information on these aspects can be obtained from many of the papers listed in the bibliography, it was decided that duplication here would unnecessarily lengthen the report.

3. Previous information

Much of the information forming the basis of this report has been taken from Bureau of Mineral Resources maps and reports; South Alligator Uranium N.L. and United Uranium N.L. company records, and from both the published and unpublished papers and reports listed in the attached bibliography.

4. Current work

Information obtained during the current Joint Venture programme has been of considerable assistance. In particular,
the information gained from the Rockhole Mine 820 ft Level exploratory development and drilling, and from the detailed regional mapping of the valley, has proved most valuable.

5. Plans to accompany report

The following tabulation indexes the plans accompanying this report.

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<tr>
<th>Drawing No.</th>
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<th>Scale</th>
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<td>Structural Overlay to B.M.R. 1-mile Geological Map</td>
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<td>Inset Geological Plan Showing axes of inferred cross-folds Airstrip Anomaly area</td>
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<td>26/9</td>
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<td>Faulting Diagram Showing development of structure Rockhole Mine</td>
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<td>/26/25</td>
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</table>
6. Acknowledgements

The reader’s attention is again drawn to the fact that much pre-existing information has been used. Due acknowledgement is given throughout the report.

Mr. J. Taylor, Chief Geologist of United Uranium, has helped the writers by providing pertinent plans and reports whenever necessary.

In addition to this, Mr. Taylor has offered constructive criticism during discussion periods. The writers wish to record their appreciation of his assistance and interest.

Mr. B.W. Harding, United Uranium’s geological draughtsman, is responsible for the drafting of many of the drawings; his ready cooperation has greatly facilitated preparation of the report.

Mr. J.B. McManus wishes to thank the Management of United Uranium for the accommodation and messing facilities afforded to him.
A. GEOLOGICAL SETTING

1. Regional geology

a. Stratigraphy

In the South Alligator Valley area there are two major stratigraphic units. The older is the succession of Lower Proterozoic geosynclinal sediments (The Agicondian System); the younger is the Upper Proterozoic Katherine River Group of sediments and volcanics (Table I).

According to Walpole (1962), the Goodparla Group of the Agicondian System was deposited in the main basin of the Pine Creek Geosyncline. The succeeding sedimentation (Finniss River Group) did not extend to the South Alligator sector, as it was terminated by the formation of a subsidiary Eastern Trough. The South Alligator Group of sediments was subsequently laid down in this Eastern Trough. The western margin of this subsidiary trough is delineated by the small scattered outcrops of Stag Creek Volcanics strung out along the north west regional strike trend (Bureau of Mineral Resources, South Alligator River Area, 1 - mile Geological map (Dwg. No. 26/1)). These outcrops are the only exposures of Archaean basement in the area.

The Koolpin Formation, the oldest formation within the South Alligator Group,
comprises pyritic, ferruginous, cherty, and carbonaceous argillites. This formation is host to many of the deposits in the South Alligator Valley Uranium Field.

The Katherine River Group was deposited unconformably on the Lower Proterozoic strata. Considerable relief on the Agiconian surface gave rise to "valley fill" deposition in the Coronation Member. This member, which is host to some of the uranium mineralisation, includes rhyolite, ignimbrite and some pyroclastics in addition to sandstone and conglomerate.

No Mesozoic beds are known close to the area of the uranium deposits, but Quaternary and Recent alluvium and soil cover much of the valley floor.

Intrusive rocks are not common but the Malone Creek Granite (microgranite) crops out south east of the field, and intermediate -to- basic dykes and sills of the Zanu Complex intrude the Lower Proterozoic rocks.

Age determinations have been made on the Edith River Volcanics; these indicated a Middle rather than Upper Proterozoic age (Dunn, Plumb and Roberts, 1966). However, in this report the Katherine River Group is referred to as Upper Proterozoic in accordance with published maps.
<table>
<thead>
<tr>
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<td><strong>Mesozoic</strong></td>
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<td>Nullamam beds</td>
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<td>Arenites and rudites</td>
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<tr>
<td>Muck Tree Volcanic Member</td>
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<td>Kurundie Member</td>
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<tr>
<td>Edith River Volcanics</td>
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</tr>
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<td>Tul Pa Rhyolite Member</td>
<td>Siliceous quartz breccia</td>
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<tr>
<td>Sainto Breccia Member</td>
<td>Arenites, rudites, acid volcanics</td>
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<td>Coronation Member</td>
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<td>Microgranite</td>
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<td>Jim Jim Granite</td>
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<td>Wolme Creek Granite</td>
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<td>Kalorite</td>
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<td><strong>Lower Proterozoic</strong></td>
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<td>(Agcondam System)</td>
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<td>Pyongyang Volcanics</td>
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</table>
b. Metamorphism

In accordance with the mild orogenic history of the South Alligator Valley area, metamorphism is minimal in Lower Proterozoic rocks and virtually absent from Upper Proterozoic rocks.

Regional metamorphism in the Lower Proterozoic is generally exhibited by nicaceous and chloritic phyllites amongst the argillites and by quartzites amongst the arenites. Graphite is known to occur in carbonaceous shale as a result of tectonism, but it may occur also as a metamorphic effect. Cherty siltstone beds of the Koolpin Formation have a peculiar character due to the occurrence of chert nodules and attenuated chert stringers. It is considered that these characteristics were produced by colloidal processes associated with diagenesis rather than metamorphism. The cherty zones are commonly interbedded with ferruginous zones at approximately half-inch intervals; hence the term "banded iron formation" in this instance.

Within the Upper Proterozoic there is little evidence of regional metamorphism. Arenites are scarcely indurated, and kaolinisation of matrix components may be attributed in part to weathering processes.

Lower Proterozoic intrusives and Upper Proterozoic volcanics display retrograde metamorphism such as kaolinisation and chloritisation.
Thermal metamorphism is represented by hornfelsing of Lower Proterozoic siltstone in proximity to intrusive granite.

c. Structure

(i) Folding of Lower Proterozoic rocks

Within the area depicted on the 1-mile geological map (Dwg. No. 26/1) rocks of Lower Proterozoic age have been longitudinally folded about north westerly-trending axes. Walpole (1962) stated that the geometry of folding is variable within the region encompassing the South Alligator Valley.

In the South Alligator Valley the folding of Lower Proterozoic rocks would appear to be relatively tight when compared with the folding of the Upper Proterozoic rocks, although a study of the South Alligator River 1-mile map indicates that isoclinal folding is not a feature of the area. Folds are of a similar type.

Dips of the Lower Proterozoic beds are generally steep, and it is possible that local overturning has occurred (Wilding and Murphy, pers. comm.). This overturning is at present based on limited cross-bedding information and acceptance of regional stratigraphy.

In the north west of the subject area, the mapped folds plunge gently (20°) northwesterly; while in the south east there are folds which plunge both to the north west and south east.
Within the siltstones and shales of the Koolpin Formation, movement along cleavage planes, coincidental with bedding planes, has contorted the bedding on a minor scale. Such contortions are certainly due to tectonism in some cases; in others they may be due to slumping.

In following sections of this report it is shown that plunge reversals and associated cross-folding of the Upper Proterozoic rocks is of economic importance. However, with respect to plunges in the Lower Proterozoic no known semi-regional structural analysis has been undertaken to determine what effect folding of the Upper Proterozoic had on the previously folded Lower Proterozoic.

As the metamorphic grade in the Lower Proterozoic is of a low greenschist or high induration type, one would not expect transposition of bedding. Thus, the geometry of the folds now exposed in the Lower Proterozoic rocks would probably not differ markedly from the configuration of the folds prior to the folding of the Upper Proterozoic rocks.

Although the folding exhibited by Upper Proterozoic rocks would have only a slight imprint on pre-existing folds in Lower Proterozoic rocks, this imprint is nonetheless important from an economic viewpoint. Any appraisal of this aspect of structure in the field as a whole is beyond the scope of this project. A suggested approach to such work in a specific area is discussed in Section C of the report.
(ii) Longitudinal folding of Upper Proterozoic rocks

The Mount Evelyn 4-mile and the South Alligator 1-mile geological maps show that longitudinal folds, of northwesterly trend, are open and would be of a concentric type produced at shallow depths. In the Sleisbeck area, and possibly at El Sherana, folding is tighter than elsewhere in the Upper Proterozoic, and may be of similar, rather than concentric, type.

Unlike the Lower Proterozoic, the Upper Proterozoic displays no definite cleavage. Closely spaced and sometimes curved fractures are a localised feature of volcanic rocks of Upper Proterozoic age. Jointing is common in Upper Proterozoic rocks; vertical jointing is conspicuous in cliff exposures of sandstone and volcanics.

(iii) Cross-folding of Upper Proterozoic rocks

Changes in plunge of longitudinal folds in the study area indicate the presence of cross-folds. There is much direct evidence for both synclinal and anticlinal cross-folds. In some cases the anticlinal cross-fold is inferred between synclinal cross-folds. Domelike structures are not common: it would appear that erosion has removed Upper Proterozoic rocks in the domal localities.
The trend of the cross-fold axes, as plotted on the 1-mile overlay (Dwg. No. 26/2) is, in many cases, approximately normal to the trend of the longitudinal fold axes. Detailed description of cross-folding is made, with reference to specific localities, in a later section.

(iv) Faulting

In the South Alligator Valley, strike faulting is common and can be traced, in places, for up to 20 miles. These strike faults are high-angle reverse faults and, in many localities, within rocks of Lower Proterozoic age, they are also dip faults. These major faults also intersect rocks of Upper Proterozoic age. No extensive mineralogical alteration associated with faulting has been observed.

Hare (1963) gave the following description of an aspect of faulting. "The dominant geological feature of the field is an upthrust block of basement which, due to differential erosion of the softer shale group, now marks the position of the present South Alligator River Valley. Marginal reverse fault zones flanking this upthrust block are seated in the basement essentially parallel with the bedding. Along these fault zones the flatlying Upper Proterozoic cover rocks have been sliced through and tilted away from the upthrown block. The truncated edges of the more resistant cover rocks are now parallel erosional escarpments forming the sides of the river valley." Hare (op. cit.) recorded that the upthrust was of the order of 600 feet.
Carbonaceous shale beds within the fault zone appear to have localised some of the faults with which uranium mineralisation is associated.

Apart from strike faults, some relatively short, steep, transcurrent faults have been mapped in the Upper Proterozoic rocks. These faults are oblique to the axes of longitudinal and cross-folds. According to Hare, this oblique faulting also affects the Lower Proterozoic rocks. No conclusions regarding the tectonic setting of these faults are drawn, but observations are made relating them to folding in certain localities. In the Coronation Hill and Saddle Ridge areas there are steeply dipping, easterly-striking faults, and in the Palette and Scinto 5 South areas short, northerly-striking faults are present. In the case of the Palette, Saddle Ridge and Scinto 5 South areas, it is noted that the described faults are marginal to a basin. At Coronation Hill an easterly striking fault and explosive volcanism have complicated most of the structural features: little evidence of cross-folding was obtained.

Along with previous workers, the authors recognise the importance of faulting in the channelling of uranium mineralisation. Many references to faults will be made in following sections of this report.
(v) Valley fill

Walpole (op. cit.) reported: "In the South Alligator area, the basal member is a locally derived 'valley fill' deposit consisting of quartz and polymictic conglomerate and pyroclastics admixed with acid volcanics and commonly confined to depressions in the old Agicondian surface. These basal rocks are interfingered with lenses of silicified calcarenite breccia and both are overlain by rhyolite."

In view of the fact that Upper Proterozoic sedimentation commenced on an unconformity surface, allowance must be made for the possibility that some attitudes in the Upper Proterozoic may reflect relief on that surface.

d. Mineralisation and Control

(i) General localities and characteristics of deposits

Uranium deposits and prospects from Dinner Creek to Teague's are located separately on the inset maps and, in some cases collectively, on the 1-mile overlay which accompany this report.

The geological setting of all localities is summarized in the table of characteristics (Table 2). Information has been compiled from several sources,
including early reports and current field work. Production figures for the deposits are presented in a following section.
<table>
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<th>Location</th>
<th>Deposit</th>
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<th>Failure</th>
<th>Depth</th>
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<th>Y</th>
<th>Z</th>
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<th>Resource Status</th>
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</tbody>
</table>

**Symbols:**
- Present
- Absent
- Probable
- Possible
- Sporadic
- Primary Mineralisation
- Secondary Mineralisation
- Locality on Overlay
(ii) Type and Origin of mineralisation

The primary mineralisation is massive and disseminated pitchblende, characteristically of colloform habit, and accessory fine grained arsenides, sulphides, and native gold. Oxidation of the pitchblende has produced complex mixtures of secondary oxides, carbonates, sulphates, phosphates, vanadates and silicates, collectively referred to as uranium ochres. A number of hypotheses have been advanced to explain the origin of the mineralisation.

It has been suggested that leaching of a large, low grade source (such as the Upper Proterozoic volcanics) by downward migrating waters, with subsequent deposition in structural and/or lithological traps, could have produced the deposits.

Syngenetic precipitation of uranium minerals near Lower Proterozoic biothermal limestone reefs, with later migration under stress to a suitable structural environment, has been postulated by Condon and Walpole (1955).

Taylor (1968) favours a hydrothermal origin on the evidence of the paragenetic association (as determined by Threadgold (1960)), wall rock alteration and the constant association of fault structures with mineralisation.

The epigenetic nature of the mineralisation in its present position is not queried by the writers, although the question of source is debatable. In the
light of the current study, the writers favour deposition from ascending mineralisers. However, irrespective of the mineral source, the modus operandi of structural control is of paramount importance. Knowledge of this would facilitate further exploration in the South Alligator Valley Uranium Field.

(iii) Tonnages removed

Ten deposits of uranium minerals have been mined in the South Alligator Valley and some ore was taken from Sleisbeck (20 miles south east of Coronation Hill). A summary of the tonnages removed is given in Table 3.
TABLE 3
SUMMARY OF PRODUCTION STATISTICS FROM
THE SOUTH ALLIGATOR VALLEY MINES
(after Fisher (1968))

<table>
<thead>
<tr>
<th>MINE</th>
<th>TONNAGE MINED (long tons)</th>
<th>GRADE (lb/ton U₃O₈)</th>
<th>CONTENT (lb U₃O₈)</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORONATION HILL</td>
<td>25,711</td>
<td>5.93</td>
<td>152,600</td>
<td></td>
</tr>
<tr>
<td>SADDLE RIDGE</td>
<td>29,862</td>
<td>5.51</td>
<td>164,533</td>
<td></td>
</tr>
<tr>
<td>SKULL</td>
<td>523</td>
<td>11.10</td>
<td>5,805</td>
<td></td>
</tr>
<tr>
<td>PALETTE</td>
<td>4,773</td>
<td>55.00</td>
<td>262,522</td>
<td></td>
</tr>
<tr>
<td>SCINTO 5</td>
<td>5,713</td>
<td>8.22</td>
<td>46,979</td>
<td></td>
</tr>
<tr>
<td>SCINTO 6</td>
<td>1,723</td>
<td>3.47</td>
<td>6,015</td>
<td></td>
</tr>
<tr>
<td>KOOLPIN CREEK</td>
<td>2,290</td>
<td>3.02</td>
<td>6,926</td>
<td></td>
</tr>
<tr>
<td>EL SHERANA</td>
<td>38,437</td>
<td>12.42</td>
<td>477,419</td>
<td></td>
</tr>
<tr>
<td>EL SHERANA W</td>
<td>21,316</td>
<td>18.35</td>
<td>391,263</td>
<td></td>
</tr>
<tr>
<td>ROCKHOLE</td>
<td>13,207</td>
<td>25.17</td>
<td>332,445</td>
<td>(includes Teague's)</td>
</tr>
<tr>
<td>SLEISBECK</td>
<td>627</td>
<td>7.62</td>
<td>4,775</td>
<td></td>
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<tr>
<td>TOTAL</td>
<td>144,193</td>
<td>12.87 (Av.)</td>
<td>1851,279</td>
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</table>

(iv) Control

Set out below are brief summaries of structural and lithological controls which have been suggested by some previous workers in the area to explain the localisation of uranium mineralisation. They maintained that a combination of three or more structural and lithological factors was necessary...
for mineral deposition.

Matheson (1960)  
  a. Strike fault or shear  
  b. Cross fault or shear  
  c. Carbonaceous shale in association with "banded ironstone"  
  d. Unconformity between Lower Proterozoic and Upper Proterozoic  
  e. Sandstone better host than volcanic

Shepherd (1962)  
  a. Strike fault  
  b. Cross fault  
  c. Carbonaceous shales with nearby competent Lower Proterozoic rock  
  d. Upper Proterozoic sandstone or volcanics  
  e. Tension cracks and folds (particularly anticlinal)

Hare (1963)  
  a. Reverse strike fault  
  b. Carbonaceous shales in contact with siliceous shales  
  c. Small folds  
  d. Upper Proterozoic "cover"

Taylor (1968)  
  a. Faulting and shearing  
  b. Joints and fractures within competent rocks adjacent to fault  
  c. Carbonaceous shale  
  d. Faulted Upper Proterozoic sandstone
Although the writers acknowledge that all the factors discussed by previous workers could play a part in the control of ore deposition, they maintain that distribution of the deposits is not adequately explained on the basis of those factors alone. As a result of the current study, an over-riding structural control, namely cross-folding, has been invoked to account for the apparently random localisation of mineralisation, including ore deposits.

The reader is referred to the transparency (Dwg. No. 26/2) which sets out mineral localities together with structural data, including cross-folds. Cross-folding has been interpreted mainly from Upper Proterozoic data; for it may require detailed and time consuming structural analysis to validate data from Lower Proterozoic rocks. Study of the Lower Proterozoic rocks may reveal cross-folding which occurred prior to Upper Proterozoic time, but which may be nonetheless favourable for ore control; it may also reveal later cross-folding in areas from which Upper Proterozoic rocks have since been eroded.

The theory of cross-fold ore control is based on the premise that cross-folding modifies pre-existing fold or warp structures in Lower Proterozoic rocks. Resulting domes and anticlines are more favourable loci than basins and synclines, from which upward migration of mineral solutions would be likely.

Structural data on which the cross-folds are based are shown on the 1-mile overlay, which has been compiled from B.M.R. and U.U.N.L. mapping. Plans, which are hereafter designated "inset" plans, but which in reality are separate plans of small areas, show mineral localities and structure in more detail.
2. Local geology

a. Coronation Hill

The Coronation Hill deposit is a special case in that it occurs within volcanics. On the inset (Dwg. No. 26/3) the mine and two prospects are marked.

There is inconclusive evidence of cross-folding at this locality. However, the possibility of a synclinal cross-fold is supported to some extent by arcuate strike trends on the hill, and by isolated outcrops of Coronation Member volcanics and arenites 2½ to 3 miles northeast. The latter outcrops are possibly remnants preserved in synclinal cross-fold keel positions. An unpublished B.M.R. map (scale 1 inch rep. 1000 ft) shows that a basin-like structure is present on the hill, but subsequent reconnaissance mapping by U.U.N.L. has not confirmed this. The area is closely faulted and detailed mapping is required to establish the structure.

The large "S" bend in the South Alligator River is taken as evidence in support of cross-folding, since in other areas of established cross-folding variations in the river's course are noted. The mine and Coronation Hill SW Prospect lie near the axis of the inferred synclinal cross-fold, whereas Coronation Hill S anomaly is approximately 800 feet from the inferred axis.
In the Coronation Hill area a northwest plunging longitudinal synclinal fold is present in rocks of the Koolpin Formation. The existence of such a folded structure in the vicinity of the postulated cross-fold indicates that the Coronation Hill area should be subjected to further geological studies. The occurrence of strike faulting and carbonaceous shale in an area where there are overlying younger rocks further emphasises this need.

b. Saddle Ridge

Between Coronation Hill and Saddle Ridge, two cross-folds have been defined on the basis of existing regional mapping. None of these is, however, as clearly delineated as the Saddle Ridge anticlinal cross-fold. Within Upper Proterozoic rocks in the vicinity of Saddle Ridge NE Prospect (Dwg. No. 26/4), opposed synclinal plunges define the position of the anticlinal cross-fold within close limits. Immediately to the north west is a synclinal cross-fold of comparable definition. The axis of this fold passes through the main basinal structure within the Kombolgie sandstone on the Scinto Plateau, and between opposed plunges in a north north west aligned basin within Coronation Member sandstone and Edith River Volcanics north east of the plateau. Evidence for some of these cross-folds may also be construed from the sharp breaks in the competent Lower Proterozoic Coirwong Greywacke Member and changes in the course of the South Alligator River.
Saddle Ridge E, E Extended and Saddle Ridge S Prospects lie between the axis of the Saddle Ridge anticlinal cross-fold and a synclinal cross-fold to the south east. The Saddle Ridge Mine and the Painted Rock Prospect occur on the axis of the anticlinal cross-fold; the Saddle Ridge NE and Clear Springs Prospects are on the northwestern flank.

Carbonaceous shale has not been observed in the mineral localities cited. Previous workers have suggested that bleached shale may be derived from carbonaceous shale, which is possibly the case at Saddle Ridge. The occurrence of predominantly secondary mineralisation in the mine suggests that oxidising conditions, sufficient to bleach carbonaceous shale, could have prevailed.

c. Palette and Skull

Approximately one mile to the north west of Saddle Ridge is the Palette Mine, which was the third largest producer of uranium in the valley. Nearby are several other localities, including the Skull Mine.

Along with the 1-mile overlay, reference is made to the inset, Drawing No. 26/5, which shows three cross-fold axes based on plunge information obtained from arenites of Upper Proterozoic age.

The Palette Deposit is set near the edge of a small basin consisting of Coronation Member sandstone, Edith River Volcanics,
and Kombolgie sandstone. 2,000 feet to the north east of Palette is another small basin in sandstone. A synclinal cross-fold axis is plotted through these basins. Along, or near, the cross-fold axis under discussion, lie the Palette Deposit and Scinto 1, Palm and Scinto Camp Prospects. On the southwesterly projection of the axis, at its intersection with the inferred extension of the South Alligator Fault, lies a weak radiometric anomaly.

The Skull Mine is situated about 1,000 feet south south east of Palette Deposit. It lies in an anticlinal cross-fold which is marked by a domal structure in Kombolgie sandstone on the Scinto Plateau and by opposed plunges in older sandstone to the north east.

As previously noted, warps in the Coir-wong Greywacke Member are again found to coincide with the cross-fold axes. Depending on the local attitude of the greywacke, the warps can be interpreted either synclinally or anticlinally. For instance, the configuration of the warp south west of Scinto Camp is in accordance with that expected of a north easterly dipping bed which has been synclinally cross-folded. Similarly, the warp coinciding with the Skull anticlinal cross-fold is as expected.

Further, attention is again drawn to the slight changes in the course of the South Alligator River in the environment of the folds under discussion. Such changes occur too frequently in the known cross-fold areas to be dismissed as merely coincidental. The
writers believe that warps in the greywacke and changes in the river's course can be used in plotting the trends of cross-folding in areas where more definite structural determinants are lacking. For example, an inferred anticlinal cross-fold axis can be drawn south east of the Skull cross-fold on the basis of the altered course of the river, the arcuate trend in the greywacke and a necking in the outcrop of sandstone north east of the Scinto Plateau. The Christmas Creek Anomaly falls on this inferred axis.

The remaining cross-fold shown on the inset has been referred to in the discussion on the adjoining Saddle Ridge area. Apart from the synclinal nature of this fold there appears to be no obvious reason why mineralisation, such as that occurring at Palette Mine, should not be associated with it. In view of the fact that no workable deposit has been found in this area, it may be that mineralisation has favoured the adjacent cross-fold zones. Nevertheless, a full reappraisal of this particular synclinal cross-fold environment is warranted.

It is noted that the best mineralisation has been found where cross-folding occurs in conjunction with other accepted controls. The writers feel that mineralisation would be likely to occur in a favourable cross-fold environment; but in the absence of an important control, such as carbonaceous shale, only meagre mineralisation would be expected. Examples of chance mineralisation of this type are the Christmas Creek Anomaly and the radiometric anomaly shown on the inset. These localities have not been fully investigated, but they are away from the only known carbonaceous shale-bearing formation.
d. Scinto 5, Scinto 6 and Koolpin Creek

There has been a small amount of production from each of the Scinto 5, Scinto 6 and Koolpin Creek open cuts (Dwg. No. 26/6) which are located between Palette and El Sherana. A broad anticlinal cross-fold in the general area is inferred from south easterly plunges near Palette opposed to north westerly plunges beyond Koolpin Creek. Further evidence for this suspected broad anticlinal cross-fold is the arcuate trend of the greywacke member; the 1½ mile long open curve of the South Alligator River, centred near its confluence with Koolpin Creek; wedging of the exposure of the Kurrundie Sandstone Member; and the exposure of Lower Proterozoic rocks and the basal member of the Upper Proterozoic sequence over a strike length of a mile. The inferred position of this broad anticlinal cross-fold is plotted on the inset.

The Scinto 5 and Scinto 6 Mines and the Scinto 5 S and Koolpin E Prospects are situated in this anticlinal cross-fold. Between these deposits and the El Sherana area a synclinal axis has been plotted. This is based on a gentle warping and breaks in the greywacke horizon in the vicinity of the South Alligator River - Koolpin Creek confluence. It is recognised that there is no direct evidence to substantiate cross-folding in this area, but detailed mapping, possibly including an analysis, could clarify the structural setting. The Koolpin Creek Mine and Monolith Prospect lie close to the plotted position of the inferred syncline. In addition to these,
there is a radiometric anomaly in the greywacke opposite the South Alligator River - Koolpin Creek confluence. The radioactivity is in a pebble conglomerate lens within the greywacke succession. Since a synclinal cross-fold is postulated almost along Koolpin Creek, by necessity an anticlinal cross-fold must be inferred between Koolpin Creek and El Sherana. From mapping information currently available there is inadequate data to plot the position of any such likely axis. If such a cross-fold did exist, the Stockpile and Flying Fox Prospects would occur in an anticlinal environment.

As the writers have advocated that a control of mineralisation in the South Alligator Valley is cross-folding superimposed on pre-existing folds or warps, then the areas containing the above mentioned mines and prospects in the Lower Proterozoic rocks should be subjected to a detailed geological study. There is little documentation of detailed structural studies having been undertaken in these areas.

e. El Sherana and El Sherana West

It will be seen from the overlay (Dwg. No. 26/2) that two cross-fold axes have been plotted in the El Sherana locality. At El Sherana West a synclinal cross-fold is manifested by a longitudinally elongated basin-like structure in
sandstone and volcanics (Dwg. No. 26/7). El Sherana is in an environment of anticlinal cross-folding.

Because of inadequate mapping and complexities now believed to be caused by faulting, the writers cannot describe the structure categorically. However, field observations made during preparation of this report suggest that the El Sherana deposit is within a tight longitudinal anticline between two longitudinal synclines. The inset on a scale of 400 feet to an inch shows the authors' observations, the axis of the anticlinal cross-fold and inferred axes of longitudinal folds.

On purely theoretical grounds an anticline which has been cross-folded anticlinally, in conjunction with other parameters, would be an ideal ore control. Thus it may not be fortuitous that El Sherana, where carbonaceous shale, faulting and cover rocks are all present, is the largest deposit yet found in the valley.

Along the south westerly projection of the El Sherana anticlinal cross-fold axis there lies the South Alligator Fault Radiometric Anomaly. This type of anomaly in a faulted area away from the known carbonaceous shale-bearing zone has been described in a foregoing section.

On the El Sherana inset four other areas of anomalous radioactivity have been plotted. These are Charvat's Prospect, the High Road Prospect and the El Sherana N and Stag Creek Anomalies. As recommendation
is made in a later section for detailed geological reappraisal of the El Sherana area in general, any attempt to explain the geological setting of these prospects and anomalies would be best left until more information were to become available if the recommendation were approved.

Reference to the 1-mile geological map shows that north east of El Sherana there are longitudinal fold structures complicated by faulting. This area is one in which further study could be undertaken.

f. Airstrip Anomaly

In the environs of the Airstrip Anomaly (Dwg. No. 26/8), where a small amount of underground exploration was carried out by South Alligator Uranium N.L., the axes of two cross-folds have been inferred. Positions of the axes as shown on the inset are based dominantly on a marked warp in the Coirwong Greywacke Member, which has a configuration comparable with the warp south west of Palette and Skull. In this case, however, the dips are in the opposite sense and so the relative positions of the corresponding folds are reversed. The only other evidence at present available to support cross-folding in this area are inferred inflections in strike of bedding in the Kombolgie sandstone.

Known radioactivity within Lower Proterozoic rocks in the cross-fold environment is currently being investigated.
g. Rockhole

The Rockhole Mine is described in detail in "Part E" of the report. The inset plan (Dwg. No. 26/9) records three axes of cross-folding. These axes are based on warping in sandstone beds in the Plum Tree Creek Volcanic Member and also on a comprehensive study of underground information relating to the Rockhole Mine. Cross-folding has played an important part in localising mineralisation in the Rockhole area. This control has not previously been recognized and it would be fair to say that the writers could not have hypothesised this control with any degree of certainty were it not for recent information obtained as a result of development on the 820 ft Level.

Having based their cross-fold ore control theory on regional information, in the first instance, the writers then applied the theory to the Rockhole Mine.

3. Conclusions

Appraisal of the field has led the writers to conclude that cross-folding has played a major role in localising uranium mineralisation. Where cross-folds are imposed on faulted carbonaceous shale horizons, mineralisation is most likely to be concentrated, especially if such horizons were folded or warped previously.

Based on the conclusions of this study, recommendations are made for further exploration.
B. GEOLOGICAL APPRAISAL OF THE ROCKHOLE MINE AREA

1. Rock types

In the Rockhole Mine area, Lower Proterozoic argillites occur in faulted and unconformable relationships with Upper Proterozoic arenite and volcanics. Surface mapping (Dwg. No. 26/25) shows the strike fault contact between Lower Proterozoic to the south west and Upper Proterozoic to the north east.

The argillites consist of inter-bedded cherty and ferruginous siltstone, grey-green siltstone and carbonaceous shale (Koolpin Formation) with micaceous siltstone (Fisher Creek Siltstone) in addition in the Sterrit's area. Because of weathering effects it is often difficult to differentiate between units of the Koolpin Formation on the surface, as the argillites crop out as cherty and ferruginous beds with minor bleached shale occurrences. However, distinctions are apparent in the mine workings.

The arenite (Coronation Member), the oldest Upper Proterozoic unit at Rockhole, is strongly unconformable with the Lower Proterozoic. It consists mainly of medium- or coarse-grained quartz sandstone, variably kaolinitic and ferruginous with conglomerate and fine-grained micaceous sandstone. The basal conglomerate includes angular siltstone detritus. Ignimbrite and amygdaloidal volcanic
(Pul Pul Rhyolite Member) overlie the arenite, being in turn overlain by conglomerate and sandstone of the Kombolgie Formation. The youngest rocks encountered in the workings are volcanics.

Surface mapping of the Rockhole Mine area does not adequately convey the present spatial relationships between rock types. Discussion of the complex structure deduced in conjunction with underground observations follows in the next section.

2. Structure
   a. Faulting

Underground mapping and borehole data indicate that the structures encountered in the Rockhole Mine are not attributable solely to high angle reverse faulting. A structural development incorporating at least three stages of imbricate faulting, associated with overturning of the Lower Proterozoic, tilting of the unconformity and warping due to differential competence is now postulated. Evidence for such a complex structure is displayed on the mine sections.

Diagrammatic sections (Dwg. No. 26/10) illustrate the proposed structural development embodied in the mine sections. Complications to the recognised high-angle faulting are justified by observations of two kinds of low-angle faults;
some of these are intersected by high-angle faults; others intersect high-angle faults.

The earlier stage of low-angle faulting may have disrupted the unconformity considerably; for it is considered to have been associated with tilting of the unconformity and overturning of the Lower Proterozoic. In the mine, fine-grained nicaceous sandstone has been observed wedged into volcanic, apparently with movement along the upper as well as the lower contact, and coarse conglomerate has been observed faulted against sandstone. Displacement associated with the later stage of low-angle faulting is not considered to be great. Cross-section 160E (Dwg. No. 26/13) includes two such faults on the 820 ft Level, one with an apparent slip of 2 feet, the other with an inferred slip of 10 feet. The apparent displacement along a similar fault shown on section 750E (Dwg. No. 26/19) is less than 10 feet.

Conceivably the third stage of faulting was associated with warping of the incompetent argillite sequence across the high-angle fault zone between the upthrown and downthrown blocks of relatively competent arenite and volcanics (Fig. 4, Dwg. No. 26/10). Displacement of the competent unit produced a couple with anticlockwise torque relative to the mine sections. Stress was released by a combination of warping in the argillites opposed to the downthrown block and
incremental faulting. Figure 4 of Drawing No. 26/10 illustrates the possible style of incremental faulting associated with the development of warping. During the development of the warp it is possible that faulting also occurred along flow bedding planes in the volcanics: this would account for numerous talcose fractures observed dipping to the north east.

b. Warping and "Knick" folds

Following the preparation of 13 cross-sections through the Rockhole Mine, it was realised that a warp existed in the vicinity of the reverse fault zone discussed in the preceding section. These sections are based on information recently obtained from underground openings and relatively short boreholes, and from plans and literature prepared by United Uranium N.L., South Alligator Uranium N.L., Bureau of Mineral Resources and R. Hare and Associates.

Previous workers were not aware of the warp structure, but recent exploratory openings and short boreholes have enabled the writers to detect its presence and to appreciate its function as an ore control.

By studying cross-sections numbered 26/12 to 26/24, the shape and size of the warp can be gauged. The warp occurs over a general vertical distance of 200 feet and is generally confined to a width of not more than 150 feet.
The warp is of an incipient open syncline-anticline type with designations $S_1$ and $A_1$, respectively, on the sections. Known mineralisation is associated with the warp environment; details of its setting within this environment follow.

There are numerous small, gently plunging, sharp folds in the argillites, which are described herein as "knick" folds. These knick folds are thought to have developed by movements along southwesterly and northeasterly dipping fractures in the sandstone and volcanics. Those associated with the southwesterly dipping fractures are the larger, and occur up to 20 feet in width. An example of this type of fold is shown in the winze on cross-section 250E (Dwg. No. 26/14). The smaller knick folds, about one foot or so in width, have been observed in carbonaceous shale in No. 3 Adit Level.

c. Cross-folding

The criteria for determining the positions of the cross-fold axes in plan on a regional scale have been described and illustrated by examples in foregoing sections. In the Rockhole Mine area it will be seen, from the regional overlay (Dwg. No. 26/2), that two anticlinal cross-folds and one synclinal cross-fold have been plotted. These lie within a broad synclinal cross-fold which has its axis approximately 2½ miles north west of Rockhole Mine. This is illustrated on the schematic longitudinal section above the regional overlay. As mentioned
earlier in the report, the cross-fold axes in the Rockhole area have been positioned on the basis of inflections in gently northerly dipping sedimentary bands within the Plum Tree Creek Volcanic Member and on the basis of underground information from Rockhole Mine.

Inflections such as those mentioned in the previous paragraph are typical of the subtle characteristics that must be sought if additional cross-folds are to be detected and tentative ones verified. The writers are aware that structures of this type could be interpreted as drag-folds, but it is believed that the weight of evidence elsewhere throughout the area (discussed in detail in Part A) is suggestive of cross-folding rather than drag-folding. Regional mapping by the Bureau of Mineral Resources has indicated strike variations within the Kombolgie Formation north east of the inflections under discussion (Dwg. No. 26/9). The writers believe these variations to be related to cross-folding but consider that there is insufficient detail to make a specific correlation between them and cross-folds.

Still considering surface plan manifestations of structure, it is pointed out that the surface traces of the Lower / Upper Proterozoic unconformity and the sandstone / volcanics contact, both of which dip northeasterly in the mine area, are seen to mimic the warps in the arenite bands within the Plum Tree Creek Volcanics. This is somewhat obscure in
that the pattern is complicated by faulting, but by careful examination of the Rockhole inset (Dwg. No. 26/9) and the Rockhole surface geological plan (Dwg. No. 26/25) this feature can be seen, especially in the area between O'Dwyer's and Sterrit's.

Reference is now made to underground information in relation to cross-folding. All the mine cross-sections show the contact zone between the argillites and the sandstone / volcanics sequence to be warped. The characteristics and theory of origin of this warp have already been described. The anticlinal nose ($A_1$) and the synclinal keel ($S_1$) of the warp on each cross-section have been transposed to the longitudinal section and plan (Dwg. No. 26/11). The projected traces of the nose and keel in longitudinal section clearly show that the warp has been cross-folded.

The southeasterly anticlinal cross-fold axis is located approximately midway between Sterrit's and O'Dwyer's at about 18,100 mine west. The synclinal axis passes through the mine workings in the vicinity of 19,700 mine west, that is 240 feet east of No. 2 Adit portal. On the longitudinal section it can be seen that the warp is plunging from the west beneath the No. 2 Adit portal. The second anticlinal cross-fold, then, passes through the area to the west of Rockhole, in the Teague's sector. The writers realise that preparation of additional cross-sections would be required in an attempt to locate this fold precisely. There was insufficient time in which to undertake detailed studies relevant to Teague's. Moreover, the information
available for such studies is very limited in comparison with that pertaining to the Rockhole - Sterrit's area. Further references will be made to Teague's.

The trace of the warp elements is projected to plan as shown on Drawing No. 26/11. Just as O'Dwyer's and Sterrit's workings are offset to the north from No. 2 Adit Level, by virtue of their being in the anticlinal cross-fold position, so a similar offset of Teague's workings would be expected. The common reduced level of Teague's No. 1 Workings and Rockhole No. 2 Adit portal supports the above deduction.

The ensuing part of this report deals with the association of the discussed structure and mineralisation.

3. Mineralisation

Fisher (1968) recorded that 13,207 long tons of ore, having an average grade of 25.17 lbs U₂O₃ per ton, were mined from Rockhole, including Teague's area.

The longitudinal section (Dwg. No. 26/11) shows that Rockhole ore was won from small stopes (generally less than 10 feet in width) distributed intermittently in a zone of the order of 2,100 feet in length, and reaching a depth of up to 250 feet below surface. In the zone of oxidation, which extends down to 80 feet below the surface, virtually all uranium minerals have been leached out apart
from scattered flakes and patches of torbernite (Hare, 1963).

1,732 short tons (Hare, op. cit.) of uranium-bearing ore were mined from Teague's Workings which adjoin the Rockhole area. Teague's No. 1 Working (a small open cut) is approximately 1,000 feet to the north west of the Rockhole Mine area, Teague's No. 2 Working (a shaft) being a further 1,900 feet to the north west.

Most of the ore has come from within carbonaceous shale and interbedded cherty siltstone. The remainder has come from sandstone; none has come from volcanics. On the longitudinal section, stopes in shale and siltstone are depicted as red; stopes in sandstone and conglomerate are depicted as orange. Hare (op. cit.) wrote: "Mineralisation in the primary zone consists of stringers and veins of massive or sooty pitchblende. In places, galena and gold are found in association with the ore. Minor amounts of chalcopyrite, nickel and cobalt minerals have been detected in the ore. Pyrite is plentiful in places in the lode and in the wall rock."

The sections show that mineralisation is associated with a faulted narrow carbonaceous shale horizon on the footwall side of a sequence of interbedded carbonaceous shale and cherty siltstone, which is of the order of 200 feet in width. This particular fault horizon is possibly the one of greatest displacement within the reverse fault zone.

It will be noted that mineralisation is localised within or near a fault horizon, and is not distributed along it. Localised deposition is explained by the tendency for
mineralisers to migrate to positions of minimal stress, such as folds and fractures.

Examples of folds in Rockhole are the warp, knick folds and cross-folds. On reaching the anticlinal cross-fold position the mineralisation would be in a virtual dome-like trap; on reaching the synclinal cross-fold it would be in a basin-like structure from which further upward migration would be likely. Therefore, mineralisation occurring in the warp would be expected to be weaker in the synclinal cross-fold position than in the anticlinal position.

In the Rockhole Mine both warping and knick folds have been instrumental in controlling the deposition of uranium minerals. Sections 160E to 560E inclusive show mineralisation in small knick folds which are up-limb from the warp structure in the synclinal cross-fold environment. Sections 750E to 1935E inclusive, which relate to the anticlinal cross-fold environment, show mineralisation in similar knick folds, here encompassed by the warp, in contrast to those just mentioned.

Although mineralisation is associated with a faulted carbonaceous shale horizon, deposition often occurs within adjacent fractured, relatively competent, cherty siltstone. Uranium mineralisation can also be localised in Upper Proterozoic arenite, within a fractured unconformity zone, which is intersected by the faulted carbonaceous shale horizon. Sections numbered 26/12 and 26/22 show this type of localisation.
4. Ore reserves

Mineralised material undoubtedly remains in the mine. Underground openings and recent exploratory drilling have shown the material to be discontinuous. On the basis of sampling carried out by U.U.N.L. in the old workings, proved ore reserves were calculated to be of the order of 1,500 long tons, having a grade of approximately 11 lbs/ton. Small, scattered blocks around the old openings constitute these proved reserves. From observations made by the writers in the accessible stopes, it is apparent that the proved reserves would be classed as additional ore if the mine were operating.

Development of, and drilling from, the 820 ft Level have shown that mineralisation below No. 2 Adit Level workings is weak and intermittent. The longitudinal section portrays the results of lode zone intersections by elevated and depressed boreholes. On the 820 ft Level plan (Dwg. No. 26/32) the widths and grades of intersections in horizontal holes are shown. The mineralisation is patchy; some occurs in arenite, the remainder in argillites. Visual inspection of borehole data indicates that the overall grade of the mineralised zone between 19,900 W and 19,300 W is less than 1 lb U₂₀₈/long ton. The area between O'Dwyer's and Sterrit's has been shown, as a result of structural studies, to be one most favourable for mineral deposition. However, stoping has already been carried out in this area.

In view of the postulated origin of the warp, no repetition of it at depth can be
expected. Therefore it is considered that there are no grounds on which to predict potential ore below the zone already worked, which is embraced by the controlling structure. Thus, the potential of the Rockhole Mine lies only within the zone of stoping, and it is unlikely that potential tonnage exceeds the prize already won.

5. Conclusions

a. Mineralisation has been localised in the environment of a warped, reverse-faulted carbonaceous shale horizon, which has been anticlinally and synclinally cross-folded. The anticlinal cross-fold produced a dome-like trap favourable to deposition, whereas the synclinal cross-fold produced a basin-like structure from which mineralisation tended to migrate upwards. Within the overall environment favourable to deposition, concentrations of mineralisation occur in "knick" folds and fractures.

b. Because of the origin of the warp at the faulted contact of Upper and Lower Proterozoic rocks, the writers conclude that there is no repetition of the warp at depth.

c. Exploratory development and drilling on the 820 ft Level have not revealed mineralisation of economic tonnage and grade.
d. On the basis of structural interpretation and underground development, the potential tonnage would not exceed that already mined.
G. SUGGESTED APPROACH TO EXPLORATION

1. Rockhole Mine

   a. Exploratory development

      Advancement of the 820 ft Level Adit
      and the 750E Rise therefrom should be
      stopped.

   b. Drilling and radiometric probing

      Previously it was pointed out that
      the potential ore in the Rockhole Mine
      is most unlikely to exceed the tonnage
      already extracted. Whatever ore re-
      mains is to be found between existing
      stopes. It is difficult to imagine
      that drilling between stopes was not
      undertaken by previous operators, al-
      though the writers can find no record
      of such drilling.

      Should it be desired to assess
      the remaining tonnage and grade, rela-
      tively short, delineatory drilling
      could be carried out underground.
      Drilling from surface is impracticable.
      Preparation for this drilling by way
      of obtaining access (picking up drives
      and timbering in places), providing
      services and in some cases cross-cut-
      ting to strategic sites (to overcome
down or up-dip drilling) would be
      costly and time consuming.
With the foregoing factors in mind, the drilling specified on Table 4 could be implemented. This would involve a maximum drilling footage of 820 feet in 7 holes, from 3 or 4 levels, and would possibly require up to 75 feet of cross-cutting.

If the drilling is undertaken and no worthwhile tonnage and grade are outlined, exploration at Rockhole Mine should be terminated.

2. Regional approach

Since the writers have concluded that the major control in localising mineralisation in the South Alligator Valley Uranium Field is cross-folding, consideration should be given to the following recommendations.

These recommendations are made not necessarily in order of importance or priority. Recommendations for immediate studies ("a" below) are put forward because of a very marked contrast between field conditions in the wet and dry seasons.

a. Immediate geochemical and radiometric studies

By projection of the cross-fold axes several areas have been outlined for immediate exploration studies (Dwg. No. 26/2). Most of the areas suggested are in the vicinity of intersections of faults and cross-folds. These areas should be examined in the following manner:
<table>
<thead>
<tr>
<th>LOCATION</th>
<th>TARGET</th>
<th>ATTITUDE</th>
<th>DEPTH (ft)</th>
<th>ACCESS</th>
<th>SERVICES</th>
<th>CROSS-CUTTING (ft)</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>270 E</td>
<td>820 ft</td>
<td>Anticline</td>
<td>Syncline</td>
<td>Depressed</td>
<td>120</td>
<td>Accessible</td>
<td>Present</td>
</tr>
<tr>
<td>(refer to 250E Cross-Section)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>360 E</td>
<td>820 ft</td>
<td>Anticline</td>
<td>Syncline</td>
<td>Depressed</td>
<td>100*</td>
<td>Accessible</td>
<td>Present</td>
</tr>
<tr>
<td>460 E</td>
<td>820 ft</td>
<td>Anticline</td>
<td>Syncline</td>
<td>Elevated</td>
<td>110</td>
<td>Accessible</td>
<td>Present</td>
</tr>
<tr>
<td>560 E</td>
<td>820 ft</td>
<td>Anticline</td>
<td>Syncline</td>
<td>Elevated</td>
<td>110</td>
<td>Accessible</td>
<td>Present</td>
</tr>
<tr>
<td>650 E</td>
<td>820 ft</td>
<td>Anticline</td>
<td>Transitional</td>
<td>Elevated</td>
<td>110</td>
<td>Accessible</td>
<td>Present</td>
</tr>
<tr>
<td>960 E</td>
<td>No. 2 Adit or No.1 Level</td>
<td>Anticline</td>
<td>Transitional</td>
<td>Depressed</td>
<td>50</td>
<td>Inaccessible</td>
<td>Required</td>
</tr>
<tr>
<td>1115 E</td>
<td>No. 1 Level</td>
<td>Anticline</td>
<td>Transitional</td>
<td>Depressed</td>
<td>110</td>
<td>Accessible*</td>
<td>Required</td>
</tr>
<tr>
<td>1460 E</td>
<td>No. 3 Adit</td>
<td>Anticline</td>
<td>Anticline</td>
<td>Depressed</td>
<td>130</td>
<td>Accessible</td>
<td>Required</td>
</tr>
</tbody>
</table>
(i) Where applicable, stream sediment and water sampling programmes should be planned for implementation at the onset of the wet season. First rains could flush-out radioactive material which may not be detectable by a hand-held scintillator survey.

(ii) Notwithstanding the above, radiometric surveys using handheld scintillometers should be undertaken.

(iii) Geological studies of the areas should be made with priority given to the more encouraging areas. These priorities would be considered in conjunction with other geological recommendations made hereunder.

b. Geological studies

The following areas are considered in order of priority.

(i) El Sherana

In the light of the findings of this report, a detailed office and field structural study of the El Sherana area should be carried out. Little written attention has been given to longitudinal folding of Lower and Upper Proterozoic rocks, such as occurs at El Sherana. This longitudinal folding, in conjunction with cross folding...
could assist greatly in outlining areas of potential economic uranium mineralisation.

As much plan and section data are available, it is envisaged that a full-time office study by two geologists would take at least four weeks, in addition to the time required for a detailed field mapping programme of the El Sherana area.

(ii) Teague's

The association of the better mineralisation with anticlinal cross-folding singles out Teague's area as one which merits close study. Although information relating to Teague's area is lacking, an attempt should be made to verify its structural setting. This task will involve both office studies and field work.

(iii) Scinto-Koolpin Creek-Monolith area

Structural studies are recommended in the area to the north east of the South Alligator River where the Koolpin Formation crops out between Palette and El Sherana. In the first instance particular attention should be paid to zones of inferred cross-folding where mineralisation is known to occur, as shown on the relevant inset plan (Dwg. No. 26/6). Should the area prove to be structurally complex, it would lend itself to a structural analysis.
(iv) Airstrip - 9200NW - 9600 NW Anomalies area

It is recommended that geological studies be continued, particularly with a view to drawing sections, which may assist in defining the structure of the area. Following the structural appraisal, and in conjunction with the results of earlier work, consideration could be given to testing the localities by drilling.

(v) Other areas

Dependent upon the outcome of studies recommended above, similar consideration could be given to other localities of known interest, such as Coronation Hill, and to those which may prove encouraging as a result of the recommended geochemical and radiometric surveys.

c. "Outside " areas

1-mile and 4-mile geological plans should be scrutinised for areas of possible interest outside the uranium field. By application of rock-type and cross-fold theories, areas may be selected for reconnaissance.

d. Collation and Assessment of data

Substantiation or modification of the writers' theory, on which the above recommendations are based, can follow only
from a full appraisal of data as each stage of the recommended programme is completed. To gain maximum benefit from the exploration, it is essential that time be allotted for the collation and assessment of data, and for the writing and presentation of formal reports.

J.B. McMANNUS, I.G.P. WILTING, N.G. MURPHY

November 26, 1968
BIBLIOGRAPHY


Fig 1: Unconformity between Lower and Upper Proterozoic, dipping gently NE.

Fig 2: Tilting of the unconformity and development of low-angle reverse faulting.

Fig 3: High-angle reverse faulting producing major disruption of the unconformity.

Fig 4: Warping of the angulations and fault zones with incremental low-angle reverse faulting.

**LEGEND**
- Volcanics
- Conglomerate and sandstone
- Unconformity
- Cherty and argillaceous silicate
- Carbonaceous shale

**Faulting Diagram Showing Development of Structure**

**Rockhole Mine**

**Diagrammatic Sections Looking Mine East**

**Geomin Exploration Pty. Ltd. & United Uranium N.L.**

*Not to Scale*
LEGEND

Volcanics
Conglomerate & sandstone
Cheely-pororogous siltstone
Carbonaceous shale
Interbedded siltstone & carbonaceous shale
Uranium lode
Fault

2"39 An average of 38.3% per long ton equivalent UO₂ over 21t by probing method
S1 Keel of syncline
A1 Nive of antipole
Lx Long drill hole
sxh Sledge drill hole
LEGEND

Volcanics
Conglomerate & sandstone
Cherty ferruginous siltstone
Carbonaceous shale
Interbedded siltstone & carbonaceous shale
Uranium lode
Fault

S1 Keel of syncline
Ai Nose of anticline
s.d.h. Sludge drill hole

GEOMIN EXPLORATION PTY.LTD., UNITED URANIUM N.L.

Cross Section 750E
(1980 Mine West)
Looking Mine East
Rockhole Mine
P6 No. 1037
Sth Alligator Valley Uranium Field
Northern Territory

Drawn
B. Harding
Date 18-11-68
Scale in feet

0 10 20 30 40

DWB No. 26/69
**LEGEND**

- **Volcanics**
- **Conglomerate & sandstone**
- **Cherty fayalite-sillstone**
- **Carbonaceous shale**
- **Interbedded siltstone & carbonaceous shale**
- **Uranium lode**
- **Fault**

- 5' 110” = An average of 10-01 lbs./long ton equivalent 0.4% over 5’ using radiometric method
- **Si** = Keel of syncline
- **Ai** = Nose of anticline
- **was.** = Wagon drill hole

**GEMIN EXPLORATION PTY LTD & UNITED URANIUM N.L.**

**CROSS SECTION 2335E**

(17600 Mine West)

LOOKING MINE EAST

ROCKHOLE MINE

SOUTH ALLIGATOR VALLEY URANIUM FIELD

NORTHERN TERRITORY

**File No.** 1037

**Date** 01/01/68

**Scale in feet** 1:20000
(AFTER SOUTH ALLIGATOR URANIUM N.L. & UNITED URANIUM N.L.)

LEGEND

- UPPER PROTEROZOIC
- CONGLOMERATE & SANDSTONE
- UNCONFORMITY
- CHERRY & FERRUGINOUS SILTSTONE
- LOWER PROTEROZOIC
- CARBONACEOUS SHALE
- URANIUM LODE
- FAULT

GEOMIN EXPLORATION PTY. LTD. & UNITED URANIUM N.L.

GEOLOGICAL PLAN
ODWYER'S NO. 3 ADIT LEVEL
ROCKHOLE MINE
SOUTH ALLIGATOR VALLEY URANIUM FIELD
NORTHERN TERRITORY

Drawn:
B. Harding
Date:
5/11/68
File No.:
1037
DWG. No.:
26/27
Scale in feet:
100 200 300 400 500 600 700 800 900 1000
(AFTER SOUTH ALLIGATOR URANIUM N.L.)

LEGEND

- Upper Proterozoic
- Conglomerate & sandstone
- Volcanics
- Cherty & feruginous siltstone
- Carbonaceous shale
- Lower Proterozoic
- Uranium lode
- Fault
- Unconformity

GEOMIN EXPLORATION PTY LTD & UNITED URANIUM N.L.

GEological Plan
O'DWYERS (No.1) Level
ROCKHOLE Mine
SOUTH ALLIGATOR VALLEY URANIUM FIELD
NORTHERN TERRITORY

Drawn: B. Harding
Date: 8 Nov 68
File No.: 1037

Scale in feet: 160 80 0 80 160

DRAW NO.: 26/29
LEGEND

Volcanics
Conglomerate & sandstone
Cheeky & feruginous siltstone
Carbonaceous shale
Uranium ore
Fault

YEAR 1928

AFTER SOUTH ALLIGATOR URANIUM N.L., UNITED URANIUM N.L. & BUREAU OF MINERAL RESOURCES

GEOLOGICAL PLAN
No.2 ADIT LEVEL
ROCKHOLE MINE
SOUTH ALLIGATOR VALLEY URANIUM FIELD
NORTHERN TERRITORY

GEO MIN EXPLORATION PTY LTD & UNITED URANIUM N.L.

Drawn: D.Harding
Date: 5/11/68
File No.: 1037

Scale 1 in feet
Legend

- **Upper Proterozoic**
  - Volcanics
  - Conglomerate y sandstone

- **Lower Proterozoic**
  - Cherty feruginous siltstone
  - Carbonaceous shale
  - Interbedded siltstone y carbonaceous shale
  - Uranium lode

**Footh**

- An average of 13 long tons/long ton equivalent
- U3O8 over 0.1% by probing method
- Unless otherwise stated

**Note**
- Boreholes S.D.H. 18,19,20 were not probed — cuttings were radionuclidically analysed.