COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS.

RECORDS.

PRELIMINARY GEOLOGICAL REPORT ON MADIGAN'S URANIUM PROSPECT. N.T.

by

P.B. Rosenhain.

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PRELIMINARY GEOPHYSICAL REPORT ON MADIGAN'S URANIUM PROSPECT, N.T.

by

I.A. Mumme.

DARWIN, N.T.

GEOLOGICAL REPORT ON MADIGAN'S URANIUM PROSPECT

NORTHERN TERRITORY.

by

P.B. Rosenhain.

RECORDS

C O N T E N T S.

PLANS AND SECTIONS.

Plate No.	Plans.	Scale.
1	Geological Plan - Madigan's Uranium Prospect.	1 inch - 100 feet.

SUMMARY.

Madigan's uranium prospect is situated in a Lower Proterozoic sequence of interbedded sandy shales, sandstone and grits. It is located near the headwaters of the Charlotte River, near the crest and on the eastern side of a northerly trending ridge. Detailed geological and radiometric surveys were carried out and significant radioactivity was outlined over an area of approximately 300 feet by 400 feet. Some channel sampling was done over 50 feet in the zone of highest radioactivity. The greatest radioactivity appears to be associated with hematitic material occurring sporadically in a system of flat joints in a grit bed. Some fluorescent minerals were observed in this material.

INTRODUCTION.

Madigan's uranium prospect was discovered by Prospector Madigan early in July 1953. It occurs within the reservation taken out by the Bureau surrounding the area covered by the Airborne Scintillometer Survey in 1952, but it was not flown over by the plane. It is situated a half mile south west of the Bynoe Road, seventeen miles north easterly by road from the point where the road crosses the Darwin-Birdum railway line. The military co-ordinates are Southport Sheet 787761. Aerial Photograph coverage is obtained in Southport survey 1941, Run 15, Photographs 36966, 36967.

Access to the Prospect is provided by the Bynoe Road, and then east half mile by a track branching south west from it. The road is suitable for heavy transport in the dry season but would be impassable during the wet season. A number of bridges have been washed away and causeways damaged, necessitating detours over the river beds.

Preliminary inspection of the area was carried out by R.S.Matheson and R.B. Allen on 23rd. July 1953. Detailed geological and radiometric work was recommended and this was carried out in August 1953. Mapping was done by the author on a scale of one hundred feet to the inch.

TOPOGRAPHY.

The prospect is situated on a ridge two hundred yards wide and trending northerly. To the west the ridge gives way to alluvial flats and on the eastern side there is a small alluvial plain four hundred yards wide. East of this plain there is a sub parallel ridge line, and further east hilly country formed by a series of northerly trending ridges. At the anomalous area the relief is sixty feet and the average slope is ten degrees.

GEOLOGY.

REGIONAL GEOLOGY.

The prospect is located in interbedded sandy shales, sandstones and grits of the Brock's Creek Group eight mile east of the Litchfield Granite (Noakes 1949).

Mapping has been done two miles east of the prospect where very similar beds have been followed. These beds are folded in a series of steeply north plunging folds, and tentatively have been called the Lagoon Hill formation. Madigan's prospect occurs on the western limb of a steeply north plunging syncline of this formation. The beds strike north 10 degrees east and dip 75 degrees east. Four hundred yards to the east, the east limb of the syncline forms a sub parallel ridge and the beds dip 75 degrees west. The lagoon hill formation is thought to be folded into a syclinorium.

DETAILED GEOLOGY.

Lithology. The sediments of the ridge strike uniformly north 10 degrees east, and the dip varies from 65 degrees east to vertical. The dip steepens going east from the west of the ridge. The sediments consist of alternating beds of grits and sandstones, relatively resistant to erosion, and more easily weathered sandstones and sandy shales. The latter types are covered by soil and were exposed only by pit sinking. Some pits exposed sandy shales, and others poorly cemented sandstones all of which have been included together as sandy shales. The boundaries of these beds were easily determined against the more resistant grits.

At the foot of the ridge on the eastern side, and extending into the saddle at 200 feet south on the base line, laterisation of the rocks has occurred. The laterite is typically blocky and ferruginous and outcrops most prominently along the edge of the alluvial plain.

Structures. The strike of the beds is very uniform and no drag folding nor faulting can be observed in the area immediately surrounding the prospect. The more resistant beds form blocky outcrops due to two systems of joint planes. One of these systems may be termed the cross joints, and the other, the flat joints. The cross joints strike approximately 75 degrees east of the bedding and dip steeply north (70 degrees to vertical). A small number have been injected with quartz. The flat joints very in dip from 20 degrees to horizontal. The strike of this system is variable owing to the horizontal nature of the feature. Some joints of this system have also been injected with quartz.

Current bedding is evident in some of the finer grained sandstones, and grain size gradation may be seen in some of the grit beds. Both these features indicate that the facing of the beds is on top and that the beds are not overturned.

THE ANOMALY.

Mineralization is observable in the deposit associated mainly with the joint pattern. Both systems of joints appear to be equally susceptible to the quartz mineralization. The quartz veins are small, up to two inches wide. Some smaller quartz veins also can be seen through the sandstones and grits, unrelated to the joint pattern, but these are few.

Some joints of the flat system have earthy hematitic material upon their surfaces. This is associated with the hydrated iron oxide, goethite. Very high Geiger readings (some greater than 10,000 counts per minute on PRM 200) were obtained upon these hematised joint planes, and when samples were examined under the ultra-violet light, some fluorescent minerals were detected. One sample was submitted for mineralogical examination and the report is shown in Appendix I. The association of iron and uranium in a secondary phase is a common one in this region. samples of the grit beneath the hematitic joint surface failed to reveal any fluorescent minerals.

As seen on Plate I the anomalous zone extends 400 feet to the east of the most radioactive area. It appears that this could be derived from the main anomaly. Several pits were sunk to test this explanation, but the results are not conclusive.

Pit No.I: 26 feet east and 50 feet north of the 00base line peg. This was sunk to 2½ feet and entered poorly cemented sandstone. The count on the surface was 150 counts per minute on a PRM 200 type counter, this rose slightly to 175 counts per minute in the pit.

Pit No. 2: 200 feet east and 50 feet north of the 00 base line peg.
Surface count 620 counts per minute, remaining unchanged to 2½' where the hole was stopped in sandstone.

Pit No. 3: 100 feet north and 300 feet east of 00 peg.

Surface count 600 per minute rising to 800 at 1½ feet depth. The pit entered partly lateritised sandy shales at 2½ feet and at 3 feet the count had dropped to 450 per minute.

Pit No. 4: 150 feet north and 190 feet east of the 00 peg.

Surface count 650 per minute. The hole was sunk to 3½ feet, in sandstone and sandy shale and the count rose to 1050 per minute.

It is difficult to assess these results and it would appear that the ground has not been opened sufficiently. The holes have not been sunk to a great enough depth, nor have there been enough to derive accurate conclusions. The author recommends that the area should be gridded with a post hole digger, the resulting holes probed, and a subsurface radiometric contour plan drafted. It is felt that this would be the most satisfactory way of obtaining sufficient data. Bulldozing would be very costly owing to the distance of the prospect from the main highway.

GENESIS OF RADIOACTIVE MINERALIZATION.

There are two alternative views regarding the radioactive mineralization of the prospect. The first is that these beds are at the base of an old laterite profile and that enrichment has taken place by downward percolation of uranium and iron which solutions derived from the laterite. These have been reprecipitated in the joint planes of the grits. The alternative view is that hypogene solutions were introduced and these entered source of the joint planes precipitating uranium bearing minerals. There is no apparent structural reason why any particular area should have concentrated uranium more than another. There does seem to be some significance so the fact that the highest counts are obtained in a grit bed as shown on plate I. However, this bed outcrops along the strike and is well jointed. Thus it has more opportunity to show high counts at the surface where in other beds they may be concealed.

SAMPLING.

A sampling trench was dug 50 feet north and 86 to 105 feet east of the 00 base line peg. Channel samples were cut and the results are shown on Table I. The quantity of rock sampled was approximately one pound per foot of channel. Samples were also taken from pits No. 4. These results are also shown in Table I.

TABLE I.

86 - 93' E and 50' N of 00 peg	0.014 %
93 - 100' E and 50' N of 00 peg	0.143 %
100 - 105' E and 50' N of 00 peg	0.11 %

Grit and hematised joint.

Hematised joint	0.493%
0 - 1" below Hematised joint	0.292%
1 - 2 " " "	0.043%
Pit No. 4.	0.009%

Sampling of the grit and its associated hematised vein was carrie out. The procedure was as follows - A channel of the vein was cut having the approximate dimensions of 3½ inches along the strike of the bed, 3½ feet across the strike and 1 inch deep. This removed all the hematitic surface. The channel was then cut 1 inch deeper for the second sample and another inch deeper for the third. This was an endeavour to prove that the uranium was associated with the ferruginous material. Decreasing assays of ≡ U_3O_8 with depth indicate that this is very likely to be the case. This theory is supported by the microscopic examination shown in Appendix I.

GEOPHYSICAL RESULTS.

RADIOMETRIC SURVEYS.

It appears certain that the radioactive mineralization is associated with ferruginous material. Numerous specimens were taken from the surface in the anomalous area and assayed. Some assays gave quite high results. However, these results are unlikely to be of great value as none of the boulders was "insitu". They do show however, the high radioactivity of their grits which have been hematised.

The smaller anomaly on the western side of the base line in the alluvial cone, is thought by the writer to be superficial. Readings were taken from boulders "floating" in the alluvium. The anomaly thus represents radioactivity from transported material.

MAGNETIC SURVEY.

The magnetic survey aims to have an important bearing in assessing the value of the prospect. In appendix I it is stated "From the examination it would appear that the uranium occurs intimately related to one or more of the iron minerals present". It also states that magnetite is one of the three oxides of iron present. Here the uranium, and hence the iron minerals, occur throughout the grit beds then a high magnetic anomaly could be expected over these beds. This is not the case: thus the minerals must occur in very minor amounts.

GEOCHEMICAL RESULTS.

A geochemical survey was carried out and negative copper and lead results were obtained. This indicates a general absence of mineralizing solutions.

CONCLUSIONS.

Madigan's Prospect is a large area containing high radioactivity. Further work in the form of post holing or costeaning would be required to give an accurate assessment of the Prospect. Investigations to date appear to show that the enrichment of iron and uranium bearing minerals along joint planes is not sufficient nor abundant enough to warrant large scale development. Furthermore, the absence of a structural trap in the beds does not give encouragement for any significant deposit.

REFERENCE.

Noakes L. 1949: A Geological Reconnaissance of the Katherine-Darwin Region, Northern Territory. Bur. Min. Res. Bulletin 16

APPENDIX I.

MICROSCOPIC EXAMINATION OF RADIOACTIVE MATERIAL BYNOE HARBOUR NORTHERN TERRITORY.

PRELIMINARY REPORT.

The hand specimen is a sandstone with a highly ferruginous matrix. It showed a high radioactivity when tested with the geiger counter.

Four polished sections were made, these showed the specimen to consist of subangular quartz grains evenly distributed throughout, ranging in size from 0.1 to 1.0 m.m.

The matrix is a mixture of iron oxides consisting of an anisotropic oxide which differed from hematite in that it showed less anisotropism and etched with $Sn\ Cl_2$ plus HCl, this conforms to the hydrated oxide Goethite. It occurred as fine-grain aggregates and as areas up to 0.3 m.m. showing a colloform texture. Hematite and magnetite are the other two oxides present in lesser amounts. No evidence of a separate of uranium mineral was found in any of the sections.

The oxides are all closely intergrown and much altered to a limonitic material. It was not possible to separate them for microchemical tests, so these were done on a mixed powder. Of three tests made, one showed a definite uranium reaction with sodium and zinc acetates, the ramining two were nagative.

From the examination it would appear that the uranium occurs intimately related to one or more of the iron minerals present. It is suggested that further work be carried out on these sections when autoradiograph plates are available.

PRELIMINARY GEOPHYSICAL REPORT ON MADIGAN'S URANIUM PROSPECT, NORTHERN TERRITORY.

by

I.A. Mumme.

C O N T E N T S.

PLANS.

Plate No.	Description.	Scale.
2	Magnetic and self potential test traverses.	
3	Scintillometer traverses.	
4	Radiometric contour plan and Geophysical survey grid.	

INTRODUCTION.

A preliminary inspection of the radioactive deposit was made by R.S.Matheson and B. Allen.

A radiometric survey was commenced by the Brodribb geophysical section comprising I.A. Mumme, D. Fritchard and T.E. Hadley on July 24th 1953. On completion of the radiometric gridding self-potential and magnetic test traversing was done.

SURFACE RADIOMETRIC INVESTIGATIONS.

A base line of 1050 feet length bearing N 4 degrees east was surveyed and fifteen parallel traverses, 50 feet apart, pegged at right angles to it with peg intervals of 50 feet.

The radiometric gridding was carried out with a ratemeter unit type 1011C manufactured by the coveina Television Company of England.

Eight of the traverses were gridded with a Halross portable Scintillometer but owing to a drift which developed in the instrument readings, during the survey, the scintillometer gridding was discontinued.

A background reading of 5 microamperes on the ratemeter unit 1011C was adopted. This was the value obtained at the radiometric base station at Brodribb Camp in an area of low radioactivity.

A radiometric contour plan with contour intervals forming multiples of the background reading was prepared (See plate 4.)

Generally radiometric intensity values of up to 20 times background were recorded. At one place however, at a point 100 feet east of the baseline on Traverse (50N) a reading corresponding to 50 times background was recorded on a flat joint plane.

The surface radioactivity was found to occur in two areas separated at the twice background contour line by a distance of 80 feet.

The western anomaly occupies the smallest radioactive area and appears to owe its origin to the migration or transportati of radioactive minerals probably in ferruginous material but not laterite (see later) from the western radioactive area as the western anomaly occurs in an alluvial cone. Radioactive grit boulders occur in this alluvial cone and one boulder assayed 0.3 % equivalent U_3O_8.

The larger radioactive anomaly occupies a surface area of 490,000 square feet. This is the area enclosed by the twice background contour line.

Identical ferruginous grit boulders were located on the eastern radioactive area on the slopes of the ridge. One specimen assayed 1.89% equivalent U_3O_8.

On inspection these boulders were found to consist of grains of quartz enclosed in a matrix of hematite, limonite and some magnetite. Black magnetic grains were separated from a crushed speciment with a small magnet. On testing the radioactive grit boulders with a magnetometer all except one showed very low magnetic properties. One however was strongly magnetic.

Inspection of the grits under ultra-violet light showed fluorescent spots.

A number of radiometric assays were carried out at Brodribb and these gave interesting results.

RADIOMETRIC ASSAYS AND ABSORPTION TESTS.

RADIOMETRIC INVESTIGATIONS OF THE RADIOACTIVE GRITS.

Radiometric assays of grit boulders gave the following equivalent U_3O_8 percentages:-

TABLE I.

Specimen I	0.80 %	Equivalent U_3O_8
Specimen II	0.34 %	" "
Specimen III	1.89 %	" "

Radiometric absorption tests were conducted to attempt to ascertain which radioactive element or elements were present.

Initially the VRM2 battery operated ratometer was employed with a B12E tube and a lead castle type LCS/I. The results are shown in the following table:-

TABLE II.

Specimen.	Tin foil shield.	Lead foil shield.
0.1% U_3O_8	83% transmitted	25% transmitted.
1.0% U_3O_8	83% "	25.3% "
Thorium oxide specimen 1.	85.6% "	43% "
Thorium oxide specimen II	85.6% "	42.5% "
SPECIMENS OF RADIOACTIVE GRITS FROM MADIGAN'S PROSPECT.		
Specimen 1	82.5% Transmitted	33.8% Transmitted.
Specimen II	83% "	35.4% "
Specimen III	83% "	34.6% "

The B12E tube became faulty and these tests were checked with a replacement identical tube and further tests carried out. These are entered on table III.

TABLE III.

Specimen.	Lead foil shield.	Contents of Rock.
1.0% U_3O_8	33% transmission	Uranium oxide.
0.81% ThO_2	48% "	Thorium oxide.
Specimens from Madigan's Prospect.		
Specimen 1	40%)	Hematite, limonite, magnetite and an unknown radioactive mineral.
" 11	41%)	
" 111	43%)	
Specimens from Coronation Hill Prospect.		
Specimen A	25%	Contains calcium and copper uranates.
" B	27%	
" C	29%	

Table III Cont.

Specimens from Ella Creek.

Specimen.	Lead foil shield.	Contents of Rock.
X	43% transmission	Contains hematite and unknown radioactive mineral.
Y	39% "	

In table III it will be noticed that two radioactive specimens from Ella Creek Prospect have been included and further, radioactive absorption tests show that they have similar coefficients of absorption as the Madigan Prospect radioactive grits. The equivalent U_3O_8% concentrations of the Ella Creek specimens are 1.0% and 0.04% respectively.

RADIOMETRIC INVESTIGATIONS OF RADIOACTIVE JOINT LOCATED AT (50 NORTH AND 100EAST.)

TABLE IV.

Specimen No.	%U_3O_8 Equivalent.
4	0.31
5	0.40
8	0.60
9	0.71
11	0.12
12	0.60

Absorptions tests with lead foil shield gave the following results:-

TABLE V.

Specimen No.	% transmitted.
4	36%
5	35%
8	32%
9	34%
11	36%
12	32%

RADIOMETRIC INVESTIGATIONS OF LATERITE IN THE AREA.

The laterites occur in masses generally several feet thick bordering the soil covered plains. Once time they may have completely covered them and since have been dissected. A large laterite body occurs on the western edge of the quartz ridge marginal to the soil covered plains to the south of the gridded area.

Assays of portions of this body of laterite have been completed and the results are as follows:-

TABLE VI.

Specimens of laterite.	% U_3O_8 Equivalent.
No. 6	.004%
No. 7	.004%
No. 10.	.005%

RADIOMETRIC INVESTIGATIONS OF THE ROCK TYPES WHICH OUTCROP IN THE VICINITY OF MADIGAN'S PROSPECT.

TABLE VII.

Specimen No.	% U_3O_8 Equiv.
4	.02%
13	.01%

Specimen No. 4 was obtained from a costean adjacent to the radioactive joint plane (50N 100E) and is a fine grained argillaceous sericitic sandstone.

Specimen No. 13 was obtained in a shallow pit several feet from the intensely radioactive joint plane. This rock type is identical to specimen No. 4.

The assays results in tables Vl and Vll show only low activity in the laterites and argillaceous sericitic sandstone. It does not seem likely that the activity of the joint plane (50N 100E) has resulted from enrichment of radioactive minerals in laterites. It is possible however the activity has resulted from weathering of the friable argillaceous sericitic sandstones although a reverse process is also possible- namely migration of radioactive material from the joint plane into the sericitic argillaceous sandstones. Also ther is intense radioactivity associated with some hematitic grits which contain well rounded grains of quartz which occur on the slopes away from the highest radiometric contour areas.

The activity seems to be associated with ferruginous material on joint planes on the sandstone and gritty phases of the arrenaceous rocks and also in the matrix of "floaters" of ferruginous grits found on both flanks of the ridge in soil. However not all ferruginous rocks in the vicinity show activity. There are boulders of laterite, some botryoidal, in outline and others subhedral in which there is no activity at all as well as ferruginous grit material. The radioactive grits all show evidence of atmospheric weathering and no specimens so far obtained are unweathered.

The shape of the radioactive contour pattern, the type of radioactive boulders and the topographic features of the prospect suggest that the radioactive source was a linear one running parallel to the base line and about 100 feet to the east of it.

MAGNETIC PROSPECTING.

A magnetometer test traverse was completed across the most active area but no significant variation in the vertical force component of the earth's magnetic field was observed, this suggests the absence of magnetic ore bodies or structural changes producing large changes in polarization of the rocks in the vicinity of this traverse. For results see plate No. 2.

ELECTRICAL PROSPECTING.

Six self potential traverses were completed. The self potential profiles are rather variable and no obvious conclusions can be drawn from them. These traverses are parallel to the dip of the geological units and also cross the radiometric contour lines in a perpendicular direction. From geological mapping carried out there is no evidence of any subsurface bodies of sulphides or graphite which are capable of producing large anomalies of potential on the surface: for results see Plate 2.

SCINTILLOMETER PROSPECTING.

Eight scintillometer traverses have been completed but owing to a drift in the readings, which developed during this gridding, this work had to be discontinued and the area was completely gridded with the ratemeter 1011. The traverses that were completed with the scintillometer show the attitude of the most intensive radioactive zone. For results see plate 3.

RADIOMETRIC RECONNAISSANCE WORK.

Reconnaissance work was carried out with a PRM 200 and a ratemeter type 1011C but no other radiometric anomalies were recorded.

Away from Madigan's prospect the sandstone, grits and argillaceous sandstones give a normal background count. The ridge, in which Madigan's prospect is located was radiometrically prospected for a distance of approximately a mile to the north and south. The plains on both sides of this ridge gave normal background count as well as the ridges bordering the plains.

Laterite capping occur in these plains but gave no radioactive indications. Traverses were run along the roads to the nearest mineralized areas namely the tin mines occurring in the greisen belts to the west of Madigan's prospect but no activity was recorded in the schists or the pegmatites.

SUMMARY.

Madigan's prospect occurs on a ridge comprising sandstones, grits and argillaceous sandstones. The radioactive contour pattern suggests that the source was at one time a linear one running parallel to the base line and at a distance of 100 feet to the east. During the radiometric gridding of the area a number of boulders of a quartz hematite grit were found on the slopes and at the base of the ridge which gave high radiometric assays. Apart from these "floaters", the highest radiometric court was confined to a horizontal joint plane located at (50N 100E). The activity of the joint plane appeared to be confined mainly to the surface which appears hematised.

Other joint planes north and south of it also gave high radiometric intensity values.

Only one radioactive grit boulder was magnetic and this exhibited strong magnetic polarization. Black grains could be seen in the specimen and were separated by grinding and a magnet brought into close proximity. From this it would appear that the hematite resulted from magnetite and the grit was once a magnetite quartz grit.

No uranium minerals can be seen with the naked eye although fluorescent spots can be seen when viewing the radioactive specimens under ultra-violet light.

A magnetic test traverse showed very little variations in the vertical component of the terrestrial magnetic field along the traverse 50N.

Self potential test traverses gave no results which would suggest the presence of sulphides or graphitic bodies

There are large out crops of laterite on the western edge of the ridge to the north of Madigan's prospect and they give normal background counts with a PRM 200 suggesting the activity did not originate from these by enrichment.

Radiometric prospecting in the neighbourhood and at the nearest mineralized areas namely the tin mines in the greisen belts to the west did not indicate the presence of radioactive minerals.

Absorption tests were conducted and compared with uranium compounds, thorium compound and radioactive quartz hematite rocks from the Ella Creek area. These results appear to confirm the presence of uranium minerals.

CONCLUSIONS.

The intense radioactivity occurring at Madigan's Prospect is rather remarkable and no explanation as yet, can be offered to its origin, however if uranium can be identified chemically then this area would warrant test drilling. It is possible that it is present in an oxide form intimately associated with iron oxides.

Geological Plan
MADIGAN URANIUM PROSPECT

RUM JUNGLE AREA

NORTHERN TERRITORY AUSTRALIA

100 50 0 100 200 300

SCALE

Reference

QUATERNARY

- Alluvium.

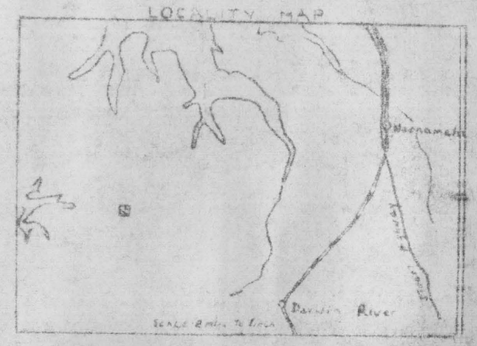
TERTIARY

- Ferruginous Laterite

PRE-CAMBRIAN

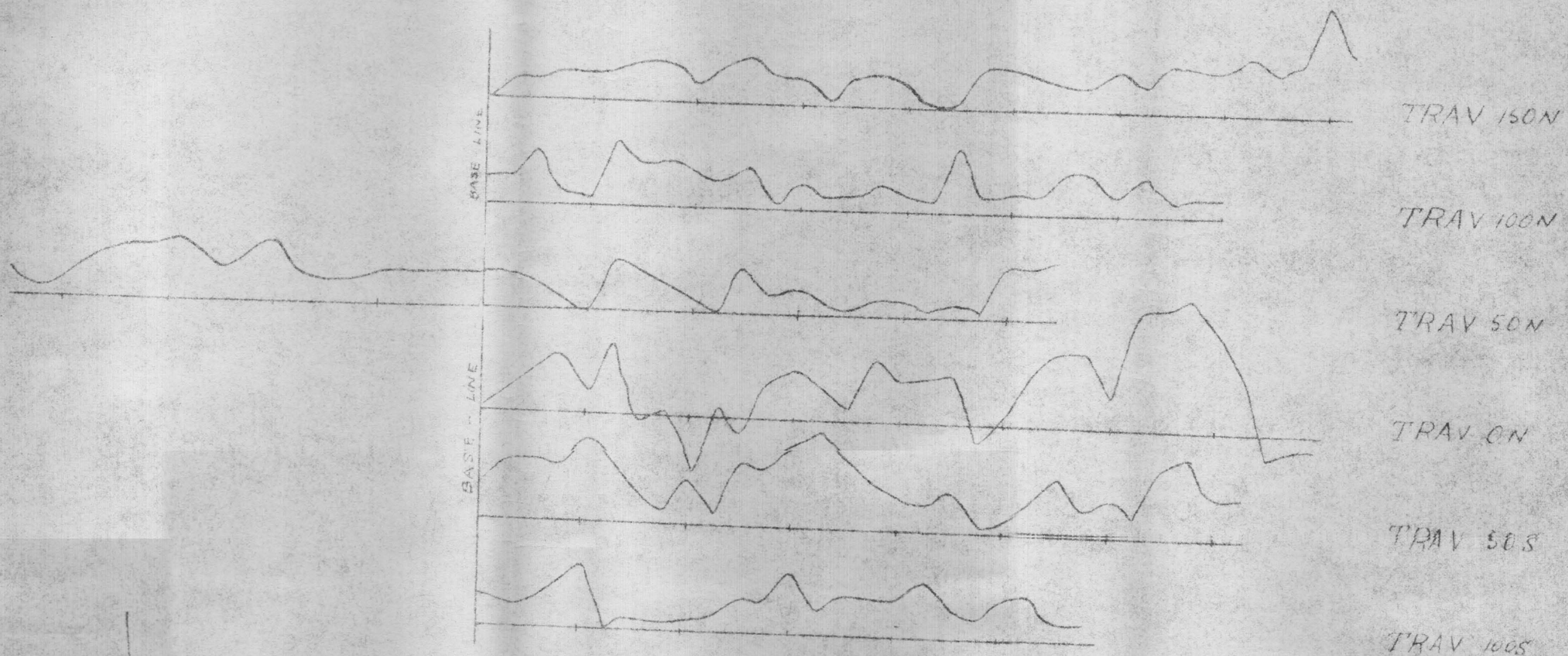
- Sandstone
- Sandy shale & sandstone
- Grits & sandstones
- Geol. boundaries definite
- Geol. boundaries approx.
- bedding / jointing / shearing } Strike & dip
- 350 Contours at 5' intervals
- x5 Radiometric Contours giving multiple of background

LOCALITY MAP

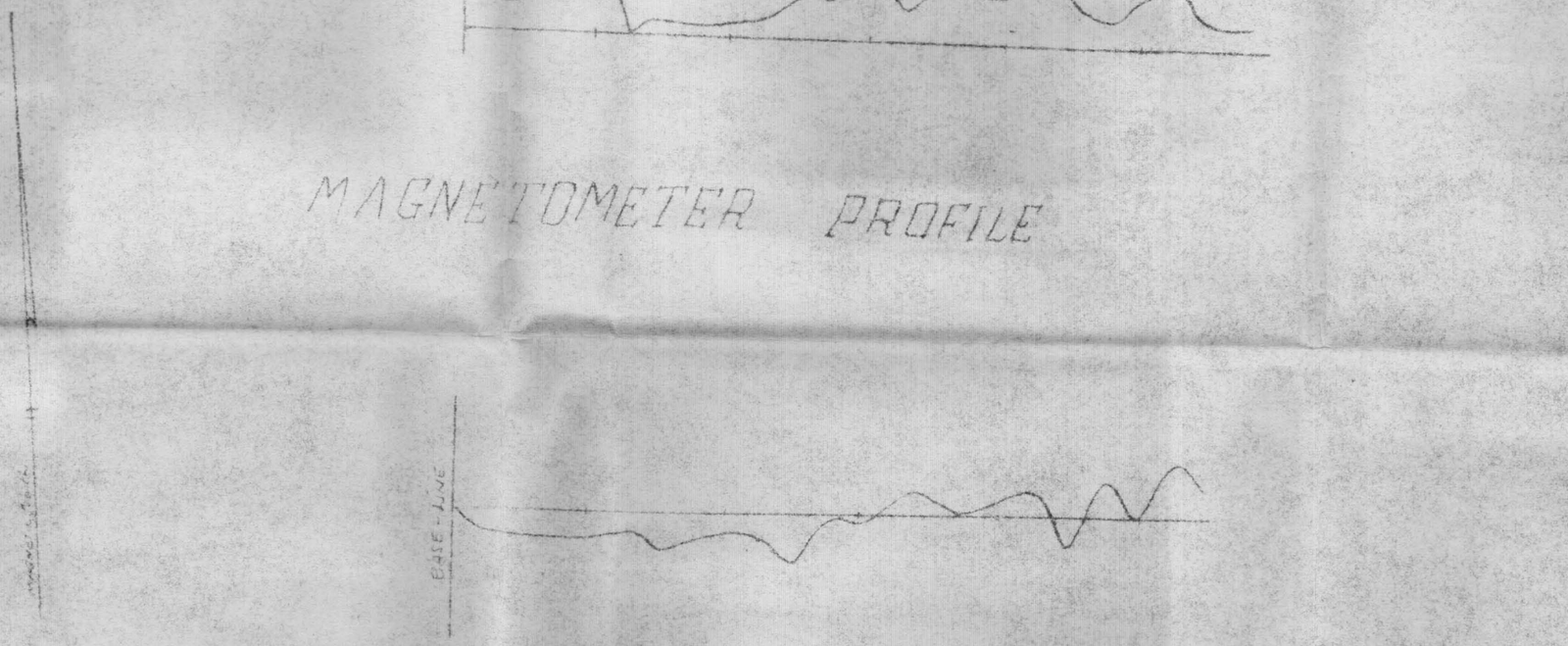


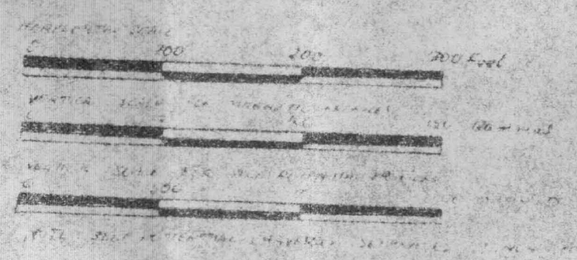
Plane Table & Telescopic Alidade Survey & Geology
by P.B. Rosenhain

SELF POTENTIAL PROFILES
MADIGAN'S PROSPECT



MAGNETOMETER PROFILE

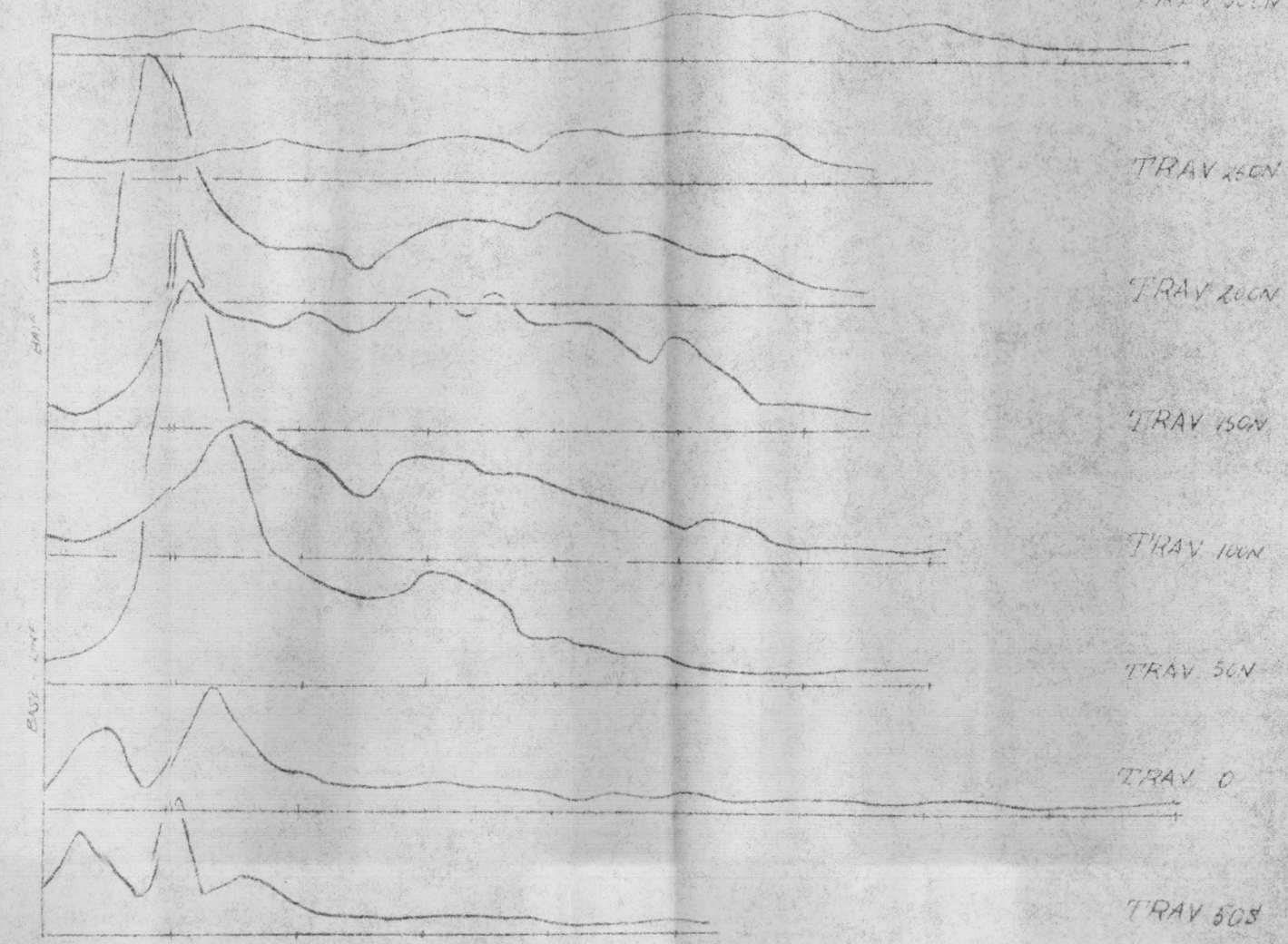


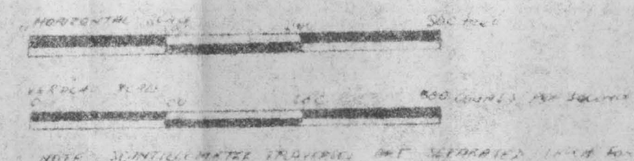


MAGNETOMETER MADE BY L.A. MADIGAN

PLATE 2

SCINTILLOMETER PROFILES





NOTE: SCINTILLOMETER TRAVERSES NOT SEPARATED LATERALLY FOR CLARITY

SCINTILLOMETER WORK BY I.P. MILLIMAN

PLATE 3

MADIGAN'S PROSPECT

PLAN SHOWING LAYOUT of
GEOPHYSICAL SURVEY GRID AND
RADIOMETRIC CONTOURS

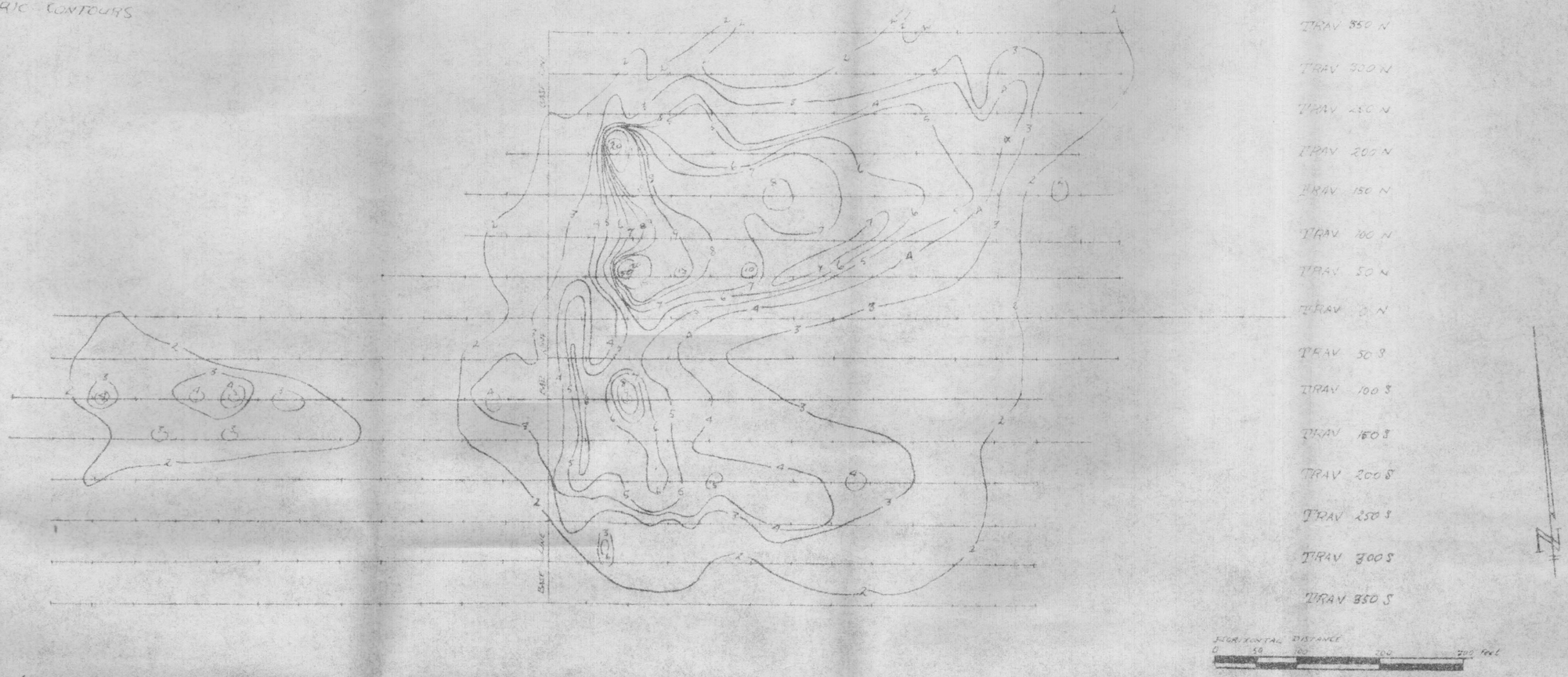


PLATE 4

SURVEYING AND RADIOMETRIC CONTOURING by I.A.MUMME