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UNITED NATIONS DEVELOPMENT PROGRAMME

PROJECT: MINERAL AND GROUNDWATER SURVEY

REPORT ON

Uranium, thorium and rare earths at Alio Ghelle

Somalia

Prepared for

The Government of the Somali Republic
by the United Nations acting as
Participating and Executing Agency for
the United Nations Development Programme

Mogadiscio
May 1968

INTRODUCTION

The principal objective of the United Nations Special Fund 1/ project, Mineral and Groundwater Survey, Somali Republic, is the search for mineral deposits of potential economic value. As a result of geological and geophysical surveys carried out from 1964 to 1967 in the Bur region of southern Somalia, a deposit of minerals containing thorium, uranium, and the rare earths yttrium, ytterbium and scandium was discovered at Alio Ghelle.

Exploratory drilling, surveying and sample testing is being continued by the project team and in specialised laboratories in order to establish the extent of reserves, determine the best mining and extraction methods, and in other ways to define its economic potential. The present report summarises the geological, mineralogical, assay, and economic information about the deposit through March 1968. The assistance of Mr. James Cameron of the International Atomic Energy Agency in Vienna in preparing the report is gratefully acknowledged.

1/ The United Nations Special Fund and the Expanded Programme of Technical Assistance were merged into the United Nations Development Programme on 1 January 1966.

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SUMMARY AND PRINCIPAL RECOMMENDATIONS

The Alio Ghelle radioactive mineral occurrence is situated about 200 kilometers west-north-west of Mogadiscio, Somali Republic. The country rock is Precambrian biotite gneiss intruded by syenitic and granitic bands. Radioactive mineralisation is mainly due to a thorite replacement but the nature of the ore controls have not yet been determined. Thorium, uranium, yttrium and small amounts of ytterbium and scandium are the potentially exploitable metals.

Project work consisted of mapping, trenching and drilling. Drilling totalled 320 metres in six vertical holes, one of which, drill hole No.2 reached a depth of 121.4 metres. Mineralisation is mainly confined to this hole and to the 36 metre deep drill hole No. 1.

Check assay work indicates that the average values, in per cent, over a length of 96.4 metres of drill hole No. 2 are:

ThO_2	U_3O_8	Y_2O_3	Yb	Sc
3.22	0.116	0.082	0.02	0.004

The heavy concentrate, obtained by gravity methods, contains:

ThO_2 - 30%; U_3O_8 - 0.83

Ore tonnage is presently estimated at 250,000 metric tons, on the basis of drill holes Nos. 1 and 2 only. The limits of mineralisation, however, are not defined either in depth or laterally, and geologically and spatially there is a good possibility of greater tonnages eventually being proved.

Marketing possibilities for thorium are very limited at the present time and doubtful in the distant future. The possibilities of finding a market for a thorite concentrate very rich in ThO_2 (30%) and comparatively rich in U_3O_8 (0.83%) must however be investigated. There is a clearly increasing interest in new uranium deposits and this metal is likely to command a market from the early or mid 1970's at about US $ 17.50 per

. . . 2

kilogram U_3O_8. Substantial and secure long-term supplies are believed to be an essential feature of any future purchase contract. Yttrium, ytterbium and scandium are subject to very complex marketing economics and are not in immediate demand but the possibilities for sale in the distant future may be generally improving.

Amenability testing of the ore by Warren Spring Laboratory, England, indicates that a direct chemical leaching of the ore is economically impossible. Physical pre-concentration tests are, however, encouraging and, in the opinion of Mr. J. Cameron, U.N. Consultant, suggest that a suitable pre-concentration process followed by acid leaching of concentrate and selective recovery of the uranium may prove to be a viable economic process.

If a viable process can be devised then the average uranium grade of 0.116 per cent U_3O_8 would normally be economically acceptable in a large tonnage orebody.

As exploration is at a very early stage, and as there are sound geological reasons for greater tonnages being eventually found, it would be correct and justifiable policy to continue to explore and evaluate the occurrence.

There is insufficient information at present concerning the grade of ore and the mineral composition at the levels of the deposit deeper than 120 metres. Taking into account the fact that most of the study up to the present time was limited to the altered upper zone of the deposit, the exploration of the deeper levels must be considered as a major task for the further prospecting programme. The data obtained on the grade and the mineralogical composition of the ore at the deeper levels must complement the data already obtained, to arrive at an economic evaluation of the deposit. Laboratory and pilot plant tests must be carried out simultaneously to determine the economics of treating this new type of U-bearing thorite ore.

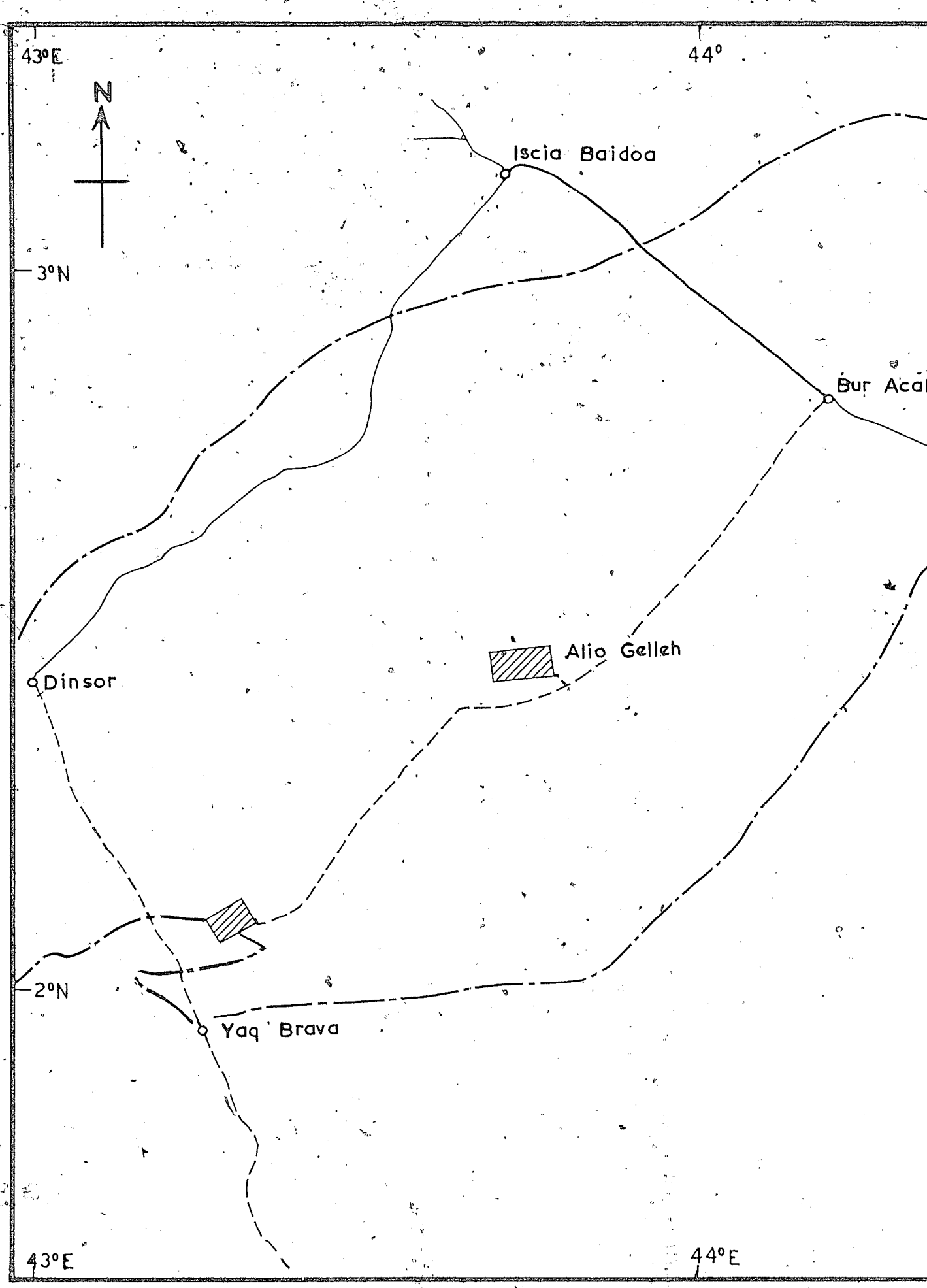
If commercially workable tonnage of ore of about the present grade cannot be found then the orebody is unlikely to be of any further interest and should be written off. If commercial tonnage is proved then further evaluation steps should be made, the next of which, in terms of priority, would be larger-scale extractive metallurgical tests. Other economic studies related to the nature and location of the orebody would also have to be initiated.

Other anomalies. Alio Ghelle was only one of a number of radioactive anomalies found by aerial scintillometer survey in 1965 in the Bur region, but as of March 1968 is the only one positively located on the ground. There appears to be a good geological possibility that at least some of the other anomalies are of the same or other promising mineralogical type as Alio Ghelle and could have similar tonnage possibilities. It is therefore recommended that every effort be made to locate and evaluate the other anomalies in the area either by improved ground techniques or by re-flying the immediate areas with a light aircraft or helicopter carrying a scintillometer.

LOCATION AND ACCESS

The radioactive anomalies and occurrences are situated in the Bur region of the Somali Republic approximately 150 to 250 kilometres north-west and west of the capital, Mogadiscio. The principal population centres of Bur Acaba, Iscia Baidoa, Dinsor and Yaq Brava approximately define the rectangular Bur area. The region is serviced by a poor road, which may be impassable in bad weather, running north-westwards from Mogadiscio through Bur Acaba to Iscia Baidoa. The re-building and asphalting of this road is expected to commence shortly. There are tracks into the region from Bur Acaba and Iscia Baidoa and from Dinsor through Yaq Brava south-eastwards to the coast but these are not reliable. There are two landing strips for aircraft at and near Iscia Baidoa.

The location of the area is shown in Map 1.


43°E
44°
N
Iscia Baidoa
3°N
Bur Acal
Alio Gelleh
Dinsor
2°N
Yaq Brava
43°E
44°E

MAP–1

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LOCATION MAP of the BUR AREA

SCALE 1 : 1000000

Km 10 0 10 20 30 40 50 Km

LEGEND:

Outline of the Bur Area

Roads – Tracks

Bur Acaba

Duddumai

MOGADISCIO

Scebeli River

Merca

Coast line

Indian Ocean

45° E

Topography

In general, the Bur region is a flat monotonous plain above which some widely separated, isolated, rounded granitic hills or "burs" rise sharply. The plain is covered by a residual soil of varying thickness which supports a dense featureless vegetation of thorn bush, three to four metres high.

General Geology

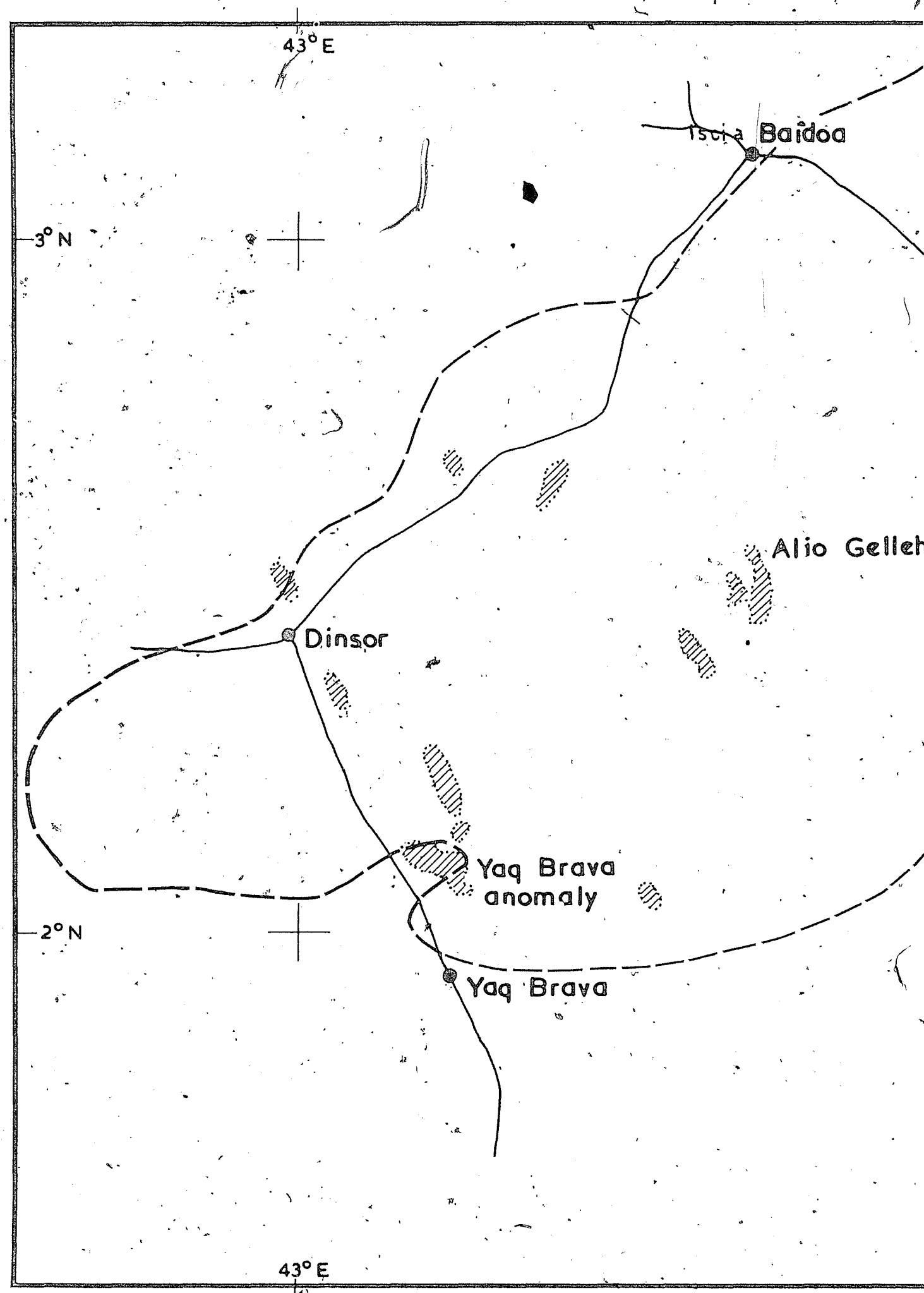
Precambrian basement rocks forming an oval to rectangular shaped area, 220 kilometres long and 100 kilometres wide are bounded on the north-west and south-west by Jurassic limestones. Recent deposits cover the south-east. The basement complex comprises a wide variety of metamorphic rocks including schists, quartzites, marbles, mica schists, amphibolites para-gneisses and granitic bodies of different ages. Two periods of folding are suggested, the earlier one producing a north-westward trend. Most of the granitic material was probably emplaced during this period of folding but some later granitic intrusions are also recognised. Some younger igneous activity is also known. Faulting, both pre-and post-Jurassic in age is recognised. The latter movements may be related to the radioactive mineralisation.

SUMMARY OF EARLIER WORK ON RADIOACTIVE ANOMALIES AND OCCURRENCES

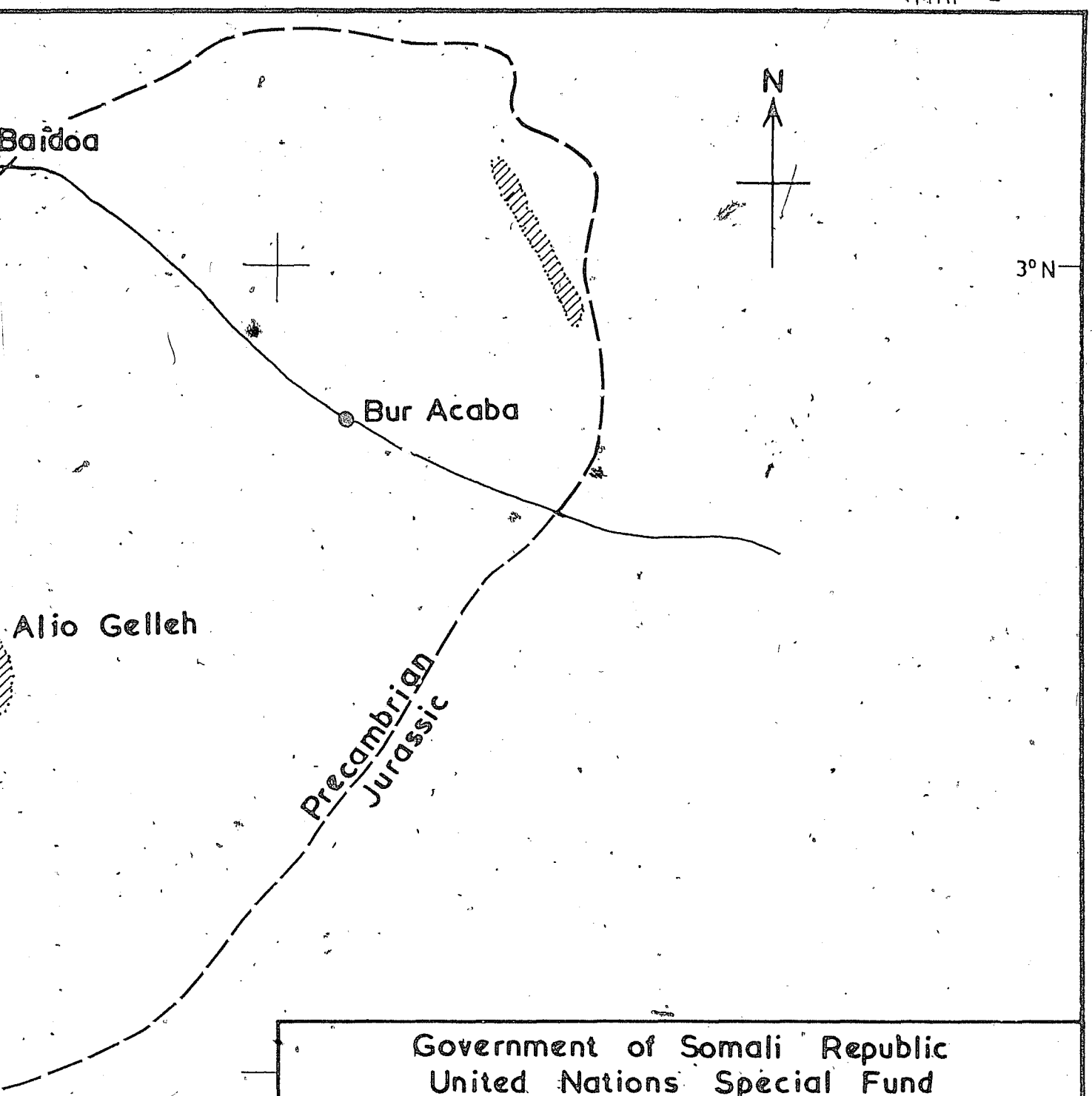
The discovery of radioactive anomalies in the Bur region of Somalia was made in late 1965 by the airborne geophysical survey conducted under contract for the Mineral and Groundwater Survey, a project of the United Nations Special Fund. There were no previous indications of radioactive occurrences in the region.

Airborne Geophysical Survey

The airborne magnetometer and scintillation survey was made by Canadian Aero Service Limited and covered 22,100 square kilometres of mainly Precambrian basement rocks. The boundaries are indicated on Map 2.


43° E
3° N
Isola Baidoa
Alio Gelleh
Dinsor
Yaq Brava
anomaly
2° N
Yaq Brava
43° E

MAP-2



Government of Somali Republic
United Nations Special Fund
Mineral & Groundwater Survey

MAIN AERO - RADIOACTIVE ANOMALIES IN THE BUR REGION

SCALE 1:1000000

Km10 0 10 20 30 40 50Km

LEGEND: *Radioactive anomaly*

Outline of the Bur – Region

The flight-line interval was normally one kilometre but two small areas were re-flown on cross lines at 500-metre intervals; terrain clearance was 120 metres. A twin crystal scintillometer was used with automatic recording of altitude and radiometric readings. Dopper navigation system was used for location and a continuous-exposure camera recorded the flight path. Only uncorrected photographic mosaics were available for ground coverage and great difficulty was experienced in locating the flight-path photographs of generally featureless bush on the mosaics.

Anomalous radioactivity was defined to be any recording of at least 1.5 times the local background radioactivity. In the final maps presented by the company 38 such anomalous areas were indicated. Of these, 26 were registered on a single flight line only and maximum readings were between 1.5 and 2.2 times background.

The other 12 anomalies, which are indicated on Map 2, were registered on more than one flight line and maximum readings ranged from 1.8 to 6.6 times background. These were assumed to be of greater potential importance, and two of them appeared to be of particular significance. The Alio Ghelle area which is situated about 60 kilometres south-west of Bur Acaba was registered on nine flight lines and had a maximum value of 4.8 times background and the Yaq Brava area which is situated between Dinsor and Yaq Brava village was registered on twenty flight lines, including cross lines, and had a maximum value of 6.6 times background.

Ground Proving of Anomalies

Extensive traversing on foot with a geiger counter was done in the Alio Ghelle area and in January 1966 the radioactive occurrence was located on the ground.

Two attempts were made to locate the Yaq Brava anomaly, but only minor ground radioactivity was found. Only a few unsystematic attempts usually incidental to journeys through the area for other purposes, have been made to locate any of the other anomalies.

The flat featureless nature of the bush and the difficulty of locating the flight-path photographs on the photomosaics made ground proving work very difficult.

Alio Ghelle

(a) Surface Prospecting. In 1966 two surface radiometric grid-traverse maps were made of the area. A 1:25,000 scale map covered a five-square-kilometre area centered on the main anomaly and a more detailed 1:1,000 scale map covered the immediate anomaly area. The anomaly was found to consist of two principal radioactive surface areas with centres about 170 metres apart and designated the north-east and south-west anomaly areas of which the latter is the more radioactive and more extensive. A minor radioactive area was also found about 500 metres south of the south-west anomaly. Twenty-six pits and trenches were put in to explore the immediate sub-surface ground of the two main anomaly areas. A few traverse lines, employing several geophysical methods, were run, but with inconclusive results.

(b) Drilling. Drilling, totalling 320 metres in six vertical drill holes but almost confined to the north-east anomaly area, was done during 1966-67. Good core recovery was effected. One hole, drill hole No. 2 is 121.4 metres in depth and most of the important subsurface indications of mineralisation are from this hole. A provisional interpretation of the geological structure was also made from the drilling.

(c) Laboratory Work. In addition to early testing and identification work, the Project chemical and mineralogical laboratories made a considerable number of systematic analyses.

A chemical laboratory assayed over sixty samples from drill holes No. 1 and 2 for thorium, uranium and yttrium. More than seventy thin sections were examined by the Project mineralogist and many heavy mineral separations were made.

Work done outside consisted of 55 spectrographic analyses and ten thin section examinations by the All Union Geological Institute (VSEGEI) Leningrad and five samples analysed and mineralogically examined by the Institute of Geological Science, Atomic Energy Division, London.

ALIO GHELLE

1. REVIEW OF GEOLOGY AND ORE MINERALOGY

Geology. The country rock is Precambrian hornblendebiotite, schist-gneiss interfoliated with syenitic and granitic material which ranges in thickness from a few millimetres up to several metres and has been intruded mainly along the foliation planes of the schist-gneiss.

A structural interpretation made by the Project geologists, and based only on the trenching and drilling, suggests that the principal structure is an anticline with a form as outlined on Map 3. It is suggested that the crest of the anticline strikes approximately north and that while mineralisation is absent from the crest it is symetrically disposed on the two limbs, dipping outwards at approximately 45° and forming the north-east and south-west anomaly areas.

This interpretation is admittedly tentative and as of March 1968 should be left open until more evidence is accumulated from further drilling. Examination of the core of drill hole No. 2 confirms that the schist-gneiss foliation does make an angle of 35° to 45° with the horizontal down to a depth of about 70 metres from the surface. Below this depth to the end of the hole at 121.4 metres the foliation is much flatter, being generally closer to 10° to 15° from the horizontal.

Below the first twenty-five metres, which has been subject to weathering alteration, most of the ore rock shows red-pink haematitic colouration but is hard and otherwise relatively unaltered. The only

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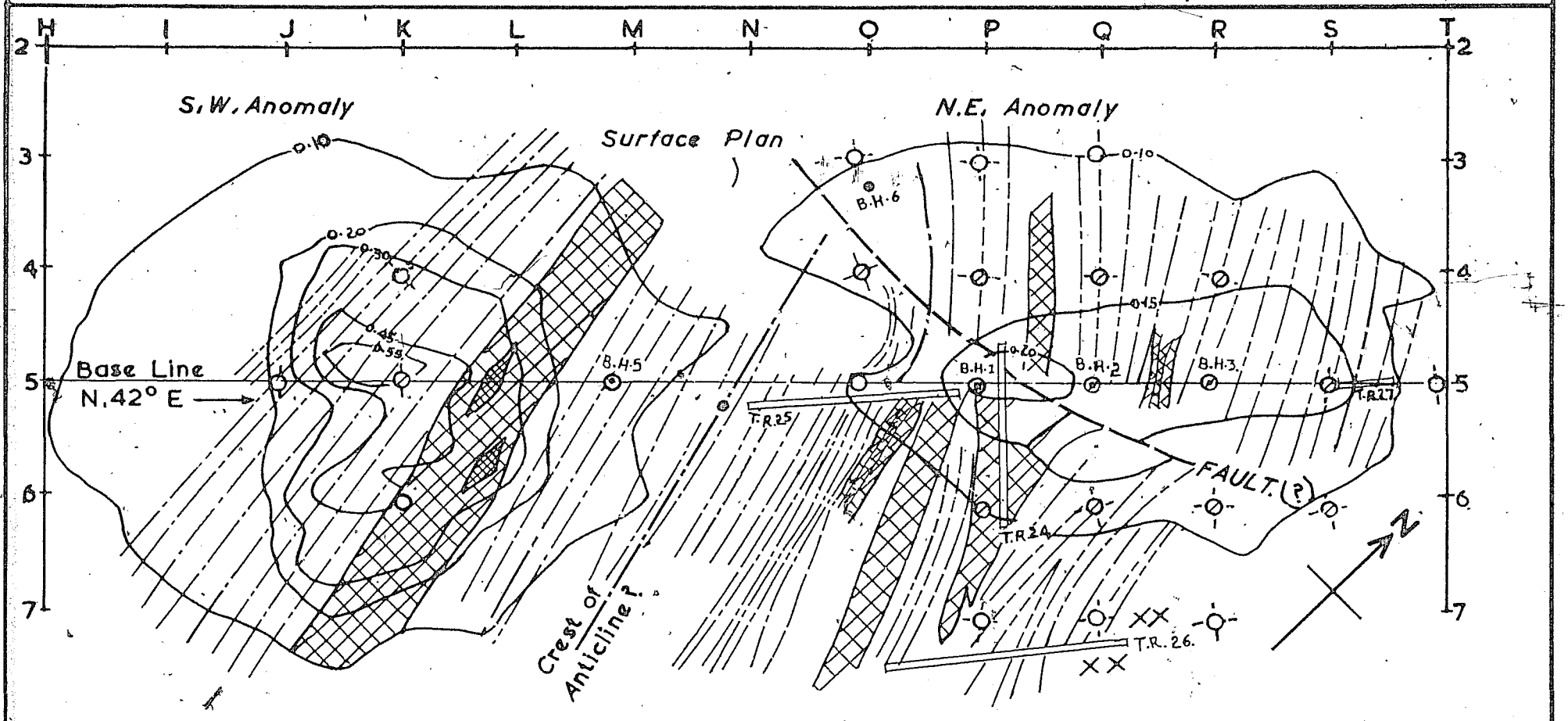
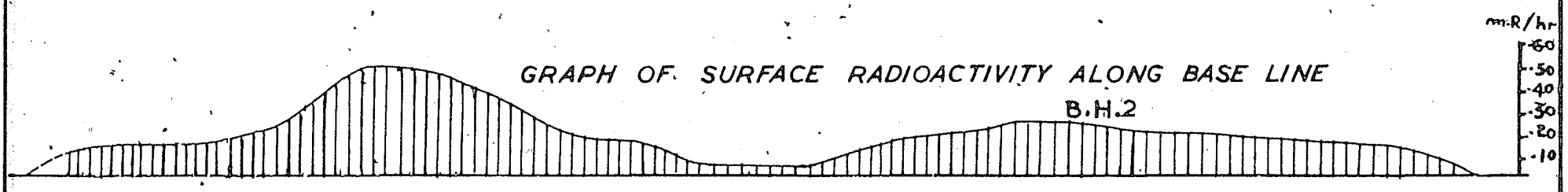
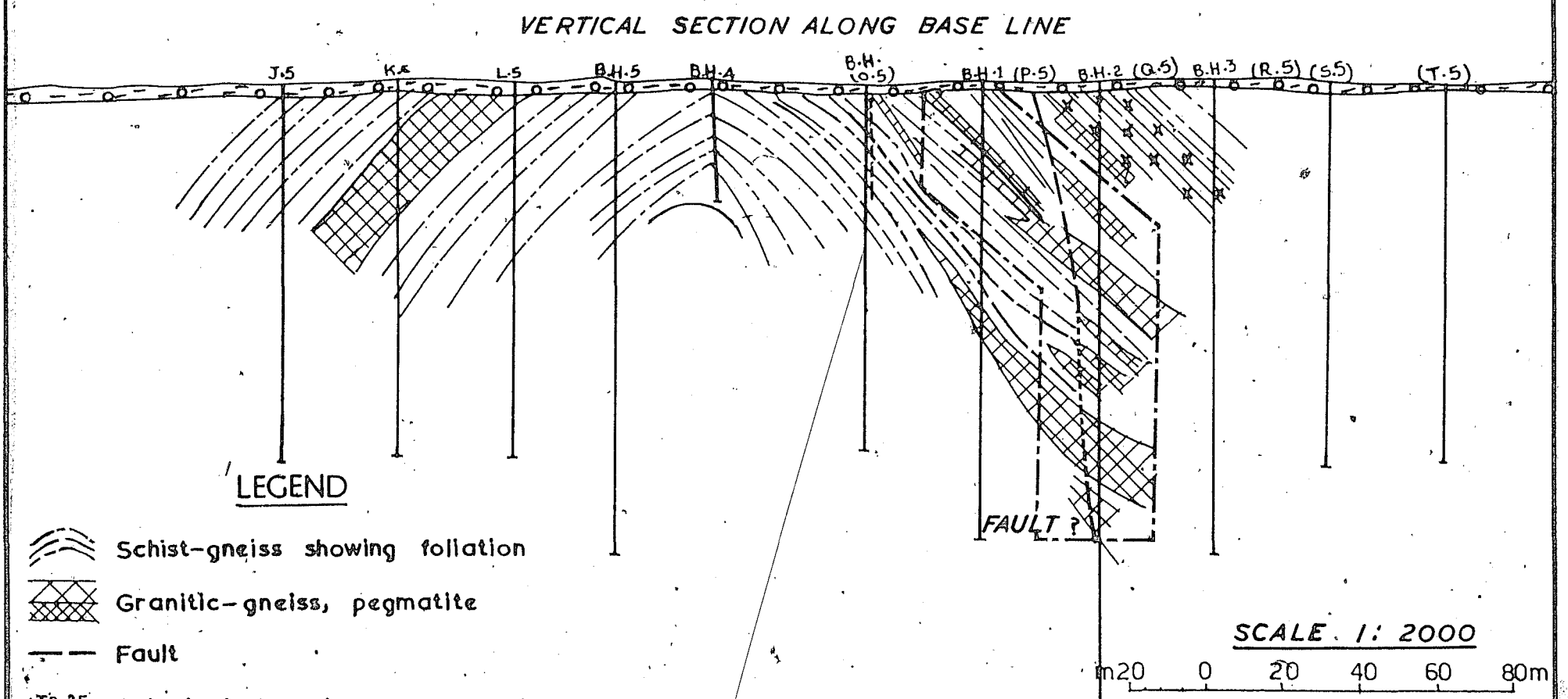
ALIO GELLEH

Radioactive Occurrence

MAP-3







LEGEND

- Schist-gneiss showing foliation
- Granitic-gneiss, pegmatite
- Fault
- TR.25 Principal trenches
- 0·15 Contours of surface radioactivity in m.R/hr.
- B.H.5 Existing drill holes
- Section of drill core with average radioactivity above 1·00 m.R/hr.
- Section of drill core check sampled
- Outline of probable ore tonnage estimate

SCALE 1: 2000

m 20 0 20 40 60 80m

RECOMMEDATIONS

- H 2 + Recommended drill hole reference system
- Recommended drill holes
- 1st Phase (1,040 metres)
- J.S O 2nd Phase (1,460 metres)

section which shows altered kaolinised and disintegrating rock, possibly associated with faulting is at approximately 115 metres depth. Other suggestions of faults were noted by the Project geologists in the surface trenches but they are also tentative and impossible to relate to any mineralisation controls at this stage.

Ore Mineralogy. While the general structural geology must remain tentative until further drilling is done, the petrology and mineralogy of the host rock and ore as revealed in the cores of drill holes Nos. 1 and 2, is well documented.

The Project mineralogist has done a very considerable amount of excellent petrological and mineralogical identification work despite the lack of polished section and other facilities. The following Table 1 is a summary of his findings.

TABLE 1: SUMMARY OF PARAGENETIC SEQUENCE AND MINERALOGICAL IDENTIFICATION DETERMINED BY MR. E. NEFEDOV, PROJECT MINERALOGIST

Paragenetic Sequence		Mineral Content
1. Biotitic schist-gneiss 2. Impregnation of granitic materials, including late pegmatites	Precambrian basement complex	Oliogoclase, Microcline, Quartz, Biotite, Amphiboles, Apatite, Zircon, Sphene, Magnetite, Ilemenite, Orthite.
	Interval	
3. Albitisation, causing alteration of the ferromagnesium minerals, releasing iron and producing red colouration of the feldspar.		Albite, Calcite, + Sericite, Riebeckite
	Interval	
4. Fracturing, producing channels into which hydrothermal solutions were introduced	Post Jurassic (?)	Calcite, Thorite, Quartz, Zircon, Apatite, Haematite, Geothite, Pyrite, Marcasits
5. Minor fracturing and introduction of siliceous solutions with sulphides		Chalcopyrite, Galena, Sphalerite, Uraninits, Pitchblende(?) Baryte, Sphene
6. Carbonate replacement		
7. Oxidation and Secondary Alteration		Montmorillinite, Chlorite, Stilpnomelane + Calcite, Leucoxene, Geothite, Limonite, Marcasite, + A Secondary uranium mineral (?)

\+ may be hydrothermal

The replacement nature of the thorite and sulphide mineralisation is obvious and clearly shows that this is not a syngenetic radioactive mineralisation but is due to hydrothormeral activity and replacement at a geologically later stage.

The examination of the first five specimens sent to the I.G.S. London, produced the following comments from the I.G.S. mineralogist, ... "thorium is present as thorite which also accounts for the uranium and the yttrium. The thorite is present for the most part as spherulites; a most unusual mode of occurrence". A further comment was that "The samples cannot be considered to contain sufficient uranium relative to thorium to justify description of the ore mineral present as uranothorite rather than thorite. The ratio of U to Th is not nearly high enough to raise hopes that the very rare mineral thorogummite is present".

The I.G.S. mineralogist, reporting on the series of seven samples sent by the writer to London, made the following comments on the radioactive mineral identification:-

"Thorite was identified in (samples) 44, 46, 47 and 48. Separated thorite from these specimens was scanned by X-ray fluorescence, and the U/Th and Y/Th ratios were in each case sufficiently high to account for all the U and Y determined. Specimen 45 differed from the others in two ways. Thorium was present as uranothorite rather than thorite (U/Th ratio approximately 1:5) and some of the uranothorite was intergrown with coffinite $USi(O,OH)_4$, forming black grains that might be mistaken for uraninite. So far as is known, coffinite has not been reported from other localities in intimate accociation with uranothorite".

The mineralogical reports from I.G.S. London and from Columbia University, New York, are reproduced in full as Appendices Nos. 1 and 2 in this report.

The Columbia University mineralogist noted the presence of uranium oxide, a pitchblende variety, in colloform masses and coating rock interstices but this was not confirmed by the I.G.S. mineralogist who identified the black radioactive mineral as coffinite. Small amounts of monazite are mentioned in both reports.

The presence of small patches of carbonate material is important as this has an adverse influence on the acid leaching properties of the ore.

In the spectrographic analyses done in Leningrad on normal ore samples, thorium, uranium and yttrium were reported in the proportions expected but in addition, ytterbium was noted in significant quantities and also minor amounts of scandium. The occurrence of these two elements was confirmed on two composite samples sent to I.G.S. London. The results being as follows:

Sample 39	= 0.02 % Yb	0.004 % Sc
" 40	= 0.02 % Yb	0.003 % Sc

It is assumed that both these elements are also present in the thorite. Samples have also been tested by the Eldorado Laboratory for the presence of europium, but these results are not as of March 1968 available.

Specially prepared heavy mineral extracts prepared by Mr. Nefedov and spectrographically analysed at VSEGEI in Leningrad indicated the expected Th, U, Y, Yb and Sc but no significant quantities of any other metallic elements which might be of economic interest; e.g. Pb, Zn, Cu, Bi, Ce, Ag, Cd, Sb, Co, G, Sn, Me, V, W, Ga, Hf, Be were all very low or absent.

In conclusion, it is clear that the radioactivity is mainly due to the mineral thorite containing small quantities of U, Y, Yb and Sc, but in some high-grade sections, uranothorite is present and also small quantities of coffinite.

The origin of mineralisation is hydrothermal replacement and not syngenetic. It may thus be related to, and controlled by, geological fracture structures which are not yet known and may be revealed only by considerable further drilling.

From the economic extractive viewpoint, the principal points are that the high specific gravity and spherulitic nature of the thorite ore makes it fairly easy to separate from the gangue by specific gravity methods. The mineral itself and the calcite in the ore would, however, be adverse factors in any direct acid leaching process.

SAMPLING AND ASSAY RESULTS

Apart from radiometric readings and samples taken from the early trenching, which are not discussed in this report, the present evidence of mineral values is based on samples from two drill holes, Nos. 1 and 2, respectively to 35.80 and 121.40 metres deep and located as indicated on Map 3.

Drill hole No. 1

Project sampling and assaying. Sampling of the core of this hole was done selectively and not continuously. In all, 21 samples about half a metre of core length each were cut from more radioactive sections between 13.70 and 33.00 metres. At that early stage in the Project only ThO_2 could be determined chemically and values for these 21 samples lay within the range 0.45 to 1.14 per cent ThO_2.

Radiometric readings on the core samples [illegible] average values of about 1.0 milliroentgens per hour (mR/hr) over a length of 33.00 metres. No rechecking of samples from this hole has been attempted on the present investigation, but on the radiometric evidence it seems probable that the average values are of the same order of magnitude as those confirmed in drill hole No. 2.

Drill hole No. 2

Project sampling and assaying. Project sampling of this hole was more continuous and systematic than in No. 1. Between 25.0 metres depth and the end of the hole at 121.4 metres but omitting the section from 28.5 to 33.4 metres, 75 samples were cut. These were mainly in one metre lengths; the principal exceptions being two samples covering 11.0 and 6.0 metres. The total core length sampled was therefore 91.5 metres but 40 samples, from 81 to 121.4 were not assayed.

Project chemical analyses was therefore done on 34 samples between 25 and 81 metres depth and covering 51.1 metres of core. The weighted average results, in per cent, are as follows:

ThO_2	U_3O_8	Y_2O_3
2.37	0.13	0.32

Check sampling and assaying. With the double purpose of checking the above chemical assays and sampling and assaying the remaining radioactive sections of the hole below 25 metres depth, i.e. from 28.5 to 33.4 metres and from 81.0 to 121.4 metres, a further series of samples, termed the "C" series, was re-selected or re-cut.

Existing duplicate reserve samples were used where possible to give new weighted samples and new core cutting was done for sections where this was not possible. A series of 38 samples of two-or three-metre lengths and covering 96.4 metres of core between 25 and 121.4 metres was prepared. Sample 39 was a weighted composite of the whole series 1-38 and sample 40 was a weighted composite of samples 16-21 covering 65 to 80 metres, believed to have a higher U_3O_8 content. The samples were numbered C1-C40 and prepared in quadruplicate sub-series (a), (b), (c) and (d).

The sample series were sent for analysis as indicated on a previous page. The detailed individual results are presented in Appendix No. 3 Section (a) and (b). The principal results may be summarised as follows:

	ThO_2	U_3O_8	Y_2O_3
	(in per cent)		
Series (a)			
Analysed by I.G.S. London by X-ray fluorescence (XRF) and radiometric methods			
(1) Weighted average of samples C1-C38	3.29	0.111	0.085
(2) Comparative composite samples C39	3.30	0.120	0.080
Series (b)			
Analysed by Eldorado Mining & Refining Ltd. Ottawa			
(In this series the results were reported as per cent thorium which has been adjusted here to per cent ThO_2 for comparison)			
(1) Weighted average of samples C1-C38	3.10	0.117	n.d.
(2) Comparative composite sample C39	3.49	0.133	n.d.
Series (c)			
Analysed by I.A.E.A. Laboratories Vienna			
Comparative composite sample C39	2.94	0.098	n.d.
Average of all determinations	3.22	0.116	0.082

n.d. - not detected

The comparative figures for the selected and presumed higher uranium grade section from 65.0 to 80.0 metres is as follows:

	ThO_2	U_3O_8	Y_2O_3
	(in per cent)		
Series (a)			
(1) Samples C16-C21	3.84	0.149	0.097
(2) Composite sample C40	3.50	0.130	0.090
Series (b)			
(1) Samples C16-C21	3.49	0.143	n.d.
(2) Composite sample C40	3.43	0.122	n.d.
Series (c)			
Composite sample C40	3.52	0.107	n.d.
Average of all determination	3.56	0.130	0.093

The difference between the results for the presumed higher-grade section of 15.0 metres and those for the whole 96.4 metres are not as significant as had been expected and it seems probable that this section will have no selective economic significance.

Comparison with the Project chemical analysis can be made from the calculated weighted average of samples C16-C34 plus C37 and C38 in the (a) and (b) series, representing 50.10 metres of core. The comparison is as follows:

	ThO_2	U_3O_8	Y_2O_3
	(in per cent)		
Series (a) samples C16-C34, C37-C38	3.46	0.121	0.092
Series (b) " " "	3.31	0.144	n.d.
Average of (a) and (b)	3.38	0.132	(0.092)
Equivalent Project chemical Weighted average	2.37	0.13	0.32

These results show that there is excellent agreement between the Project U_3O_8 analyses and the two outside laboratories. The Project ThO_2 results are however considerably lower than the outside laboratories while the Y_2O_3 Project results are much higher than the I.G.S. figures.

General Comments. A full statistical and analytical study of the results has not been done but it is recommended that this should be made by the Project geologists and analysts.

Relationship to Radiometric Readings

More than eight hundred separate radiometric readings were taken by the Project geologists on small sections of core normally about 0.15 metres in length and about 1 kilogramme in weight from drill hole No. 2. The non constant ThO_2: U_3O_8 ratios found in the sample analyses make any direct correlation between radiometric readings and ThO_2 or U_3O_8 values impossible and no discrimination equipment was available. Variations in weight of the core sections measured is also an irregular factor although this may be less important considering the number of measurements made.

Despite these qualifications the radiometric readings may be the only guide to values in drill holes before analytical results are received and may be useful until bore hole logging equipment and discrimination equipment can be obtained. Approximate comparisons are as follows:

Section sampled	Radiometric Readings		Comparative aver. analyses		
(Depth in metres)	No taken/Av.value mR/hr		ThO_2%	U_3O_8%	Y_2O_3%
102-113.0	143	0.29	0.89	0.05	0.03
102-121.4	89	0.77	2.55	0.07	0.07
25-121.4	754	1.30	3.30	0.12	0.08
65-80	115	1.50	3.87	0.15	0.10

Very approximately, 1.30 mR/hr measured on small core sections appears to be equivalent to 3.30% ThO_2, 0.12% U_3O_8, and 0.08% Y_2O_3. It may be that a radiometric value of about 0.50 mR/hr could be used as a "cutoff" guide to ore until better equipment for preliminary evaluation is obtained.

Conclusions. The check sampling has shown that the average values in 96.4 metres of core of drill hole No. 2 is 3.22% ThO_2, 0.116% U_3O_8 and 0.082% Y_2O_3. Ytterbium and scandium determined on one composite sample by one laboratory gave values of 0.02% Yb and 0.004% Sc.

By comparison with the radiometric readings it is probable that only marginally lower values can also be assigned to a 33 metre length of drill hole No. 1. For other drill holes, Nos. 3-6, records show that only in holes Nos. 3-5 were lengths of very limited radioactivity found.

ORE TONNAGE AND METAL CONTENT

As of March 1968 it is somewhat difficult to put ore tonnage and metal content into figures because of many factors as yet unknown.

Present relevant facts are that:

(a) Two of the six vertical drill holes, 30 metres apart, have gone through radioactive mineralisation from near surface to 35.80 metres and from 25 to 121.40 metres depth;

(b) Both holes stopped in mineralisation and the lateral extent of the mineralisation is not defined despite the other four drill holes;

(c) The south-west anomaly area with higher surface radioactivity is virtually unexplored at depth;

(d) The mineralisation is of a hydrothermal replacement type and is not syngenetic;

(e) Assay values of 3.22% ThO_2, 0.116% U_3O_8 and 0.082% Y_2O_3 have been proved for the 96.4 metres of drill hole No. 2.

More controversial and requiring further proof are that:

(f) The above assay values can be applied to the ore body generally;

(g) A vertical cross fault postulated by the Project geologists, exists in the north-east anomaly and controls mineralisation.

Controlling structures such as faults could be of importance in this type of mineralisation. Some evidence of a fault was seen in trenches 13 and 24 and in the core of drill-hole No. 2 at about 115 metres depth. This evidence is admitted by the geologists to be

tenuous but if correct, may infer a relatively narrow zone of mineralisation extending along the fault walls. After examination of the evidence it is believed that it is not sufficiently strong to be accepted at this stage and therefore a conventional and conservative estimate of tonnage based on the two drill-holes and a limited horizontal projection around them is deemed preferable.

A cylindrical body of 15 metres radius surrounding and related to the mineralised sections of drill holes Nos. 1 and 2 is assumed. The suggested outline is shown in Map 3. In effect, this is equivalent to a column of ore 135 metres in length and with a 15-metre radius containing 95,000 cubic metres of ore.

Small and fairly crude tests made by Mr. Cameron on five small sections of mineralised core gave an average specific gravity value of 2.73. Allowing for the crudity of the tests and for air space in the rock in place it may nevertheless be possible to assume a specific gravity of 2.65 for this ore.

It is therefore estimated that the cylindrical block of ore, as described and illustrated, contains 250,000 tons of ore. It is realised that the final proven shape of the ore body is highly unlikely to be precisely this but it is the best conservative estimate which can be made on the present evidence.

Assuming that the average assays of the sampled length of drill hole No. 2 are applicable to the whole ore body then the metallic contents, per 250,000 metric tons, dry core, may be as follows:

	Av. Grade (in per cent)	Content (in metric tons)
ThO_2	3.22	8,050
U_3O_8	0.116	290
Y_2O_3	0.082	205
Yb	0.02	50
Sc	0.004	10

It is highly probable that this is not the final limits of ore and that extensions will be found. There are good possibilities of extensions in the north-east ore body both laterally and in depth and also of finding ore in the south-west anomaly area. Spatially and geologically it is not difficult to visualise the possibility of at least a further three quarters of a million tons being found at Alio Ghelle.

Four ore reserve categories based on degree of certainty are used here. These are proven, probable, possible or inferred and potential ore. The definitions of the latter two categories are:

Possible or inferred: Ore exposed and sampled on only one side or cut by a very small number of widely spaced drill holes. Its extensions and other dimensions being a matter of reasonable projection.

Potential: Ore for which quantitative estimates are based largely on a general knowledge of the geological character of a deposit in circumstances where no systematic sampling has been done and measurements may be approximate. Estimates in this category are regarded as no more than an informed guess indicating the degree to which the deposit merits exploration.

In conformity with these definitions, the situation at Alio Ghelle should be presently summarised tentatively as:

Possible or inferred Ore - 250,000 metric tons containing approximately 8,050 tons ThO_2, 290 tons U_3O_8 and 205 tons Y_2O_3.

Potential Ore - 750,000 metric tons which should be regarded as primarily a target for further exploratory drilling.

AMENABILITY TESTING OF THE ORE

Preliminary amenability testing of the ore has been done by the Metals Extraction Division of the Warren Spring Laboratory, Stevenage, England. Three samples were selected and dispatched in early November. The principal sample, No. C39 was representative of the core from 25 to 121.40 metrres of drill hole No. 2 weighed about 6 kilogramme and was ground to -22 mesh. A small sample, No. C40, representative of the higher-grade material from 65 to 80 metres and a sample of the uncrushed core (C41) for grinding and crushing tests were also sent. Instructions given to the Division were to regard the material as primarily a potential uranium ore and only secondarily as a possible rare earth and thorium ore.

From the outset, the nature of the radioactive minerals suggested considerable problems in extractive metallurgy. Even prior to actual testing, Warren Spring Laboratory noted that although it might be technically possible to extract the three principal metals from the ore by direct chemical methods, the possibilities of recovery for only uranium might well be very slight insofar as the economic viability of any process was concerned. If a market could be found for thorium and yttrium the economic possibilities would be more favourable. It was noted that it would not be possible to extract uranium selectively direct from the ore but that it could have been extracted selectively from leach liquors and thorium hydroxide could have been precipitated separately as a fairly high grade concentrate. The problem in regard to thorium was, however, that if it were not immediately marketable (as is the case), then aged thorium precipitates become very difficult to reprocess. It was suggested that pre-concentration of the ore followed by chemical treatment of the concentrates might be the only possible route to the economic recovery of uranium.

Tests carried out by Warren Spring Laboratory proved that direct chemical methods were, in fact, quite impractical. The details of the direct chemical testing is given in the first part of the Warren Spring report in Appendix No. 4. Briefly, it was found that in addition to the expected high acid requirements in breaking down the thorite - uranothorite the ore also contained alkali equivalent to 8 per cent of limestone causing very high total acid consumption. The best leaching test obtained was an extraction efficiency of 81 per cent on -200 mesh ore using the equivalent of 0.4 tons of sulphuric acid per ton of ore which would be completely uneconomic. (About 9.00 US dollars per kilogramme U_3O_8 for acid alone).

Direct chemical treatment of the ore for the recovery of uranium was therefore found to be economically impossible and the possibility of employing physical methods of pre-concentration were then examined. Preliminary results of the pre-concentration tests are given in the second part of the Warren Spring Laboratory statement in Appendix No. 4. The results show that 63.3 per cent of the ThO_2 and 53.2 per cent of the U_3O_8 were recovered in grades of 30.0 per cent and 0.83 per cent respectively. Mr. North of the Warren Spring Laboratory emphasises that the tests were on the ground ore as received and were on a very small scale. He was confident that with controlled grinding of the original ore and larger scale testing, very much better figures could be obtained. The laboratory staff were enthusiastic about the fact that a very good clean separation of the thorite could be made with relative ease. In fact a concentration ratio of 1:8 was achieved and it is confidently expected that this can be improved.

The subsequent stage of acid leaching of the concentrate and selective precipitation of the uranium had not been done at the time of reporting but no problems were foreseen in this. Because of the pre-concentration and elimination of the alkali, acid requirements would come down enormously and selective precipitation would be fairly straightforward.

Comparison with the Radium Hill and Mary Kathleen deposits of Australia, both of which had difficult refractory uranium mineral problems, suggests that an economic process for Alio Ghelle could most probably be worked out on the basis of a suitable pre-concentration stage. Considerable further bulk testing work will, however, have to be done.

MARKETING POSSIBILITIES

The occurrence at Alio Ghelle contains five metals of possible interest, thorium, uranium, yttrium, ytterbium and scandium. Present information on their marketing possibilities may be summarised as follows:

(a) Thorium: In the non-nuclear field the commercial possibilities of marketing thorium appear to be very limited at the present time. World wide, about 300,000 pounds ThO_2 per annum goes into gas mantles and less that 100,000 pounds into magnesium alloys. Other uses for refractories, dispersion hardened nickel and thoriated tungsten are quite small and total non-nuclear consumption is less than 500,000 pounds per annum with growth rate not more than 5 per cent per annum and no new developments in sight. No realistic price quotation can be made.

In the nuclear field, thorium is a potential fuel for the generation of nuclear energy. Considerable research is being conducted in various countries to this end but no actual outlet for this purpose exists and the economics of its use in preference to uranium are still doubtful. Thorium may be more strongly promoted for nuclear purposes only if there is indeed a shortage of cheap uranium in the post-1975-80 period, which some authorities predict. The International Atomic Energy Agency in Vienna organises a bi-annual meeting of a "Working Group on Thorium Utilisation" at which this subject is reviewed.

With such a small market there is no problem of raw material supply, most of which comes as a by-product of the Elliot Lake, Canada, uranium production but there is also a substantial surplus available elsewhere from the processing of monazite for rare earths. In both cases, much thorium is presently allowed to go to waste or dumped because of lack of market. It is estimated that reserves of over 500,000 short tons of ThO_2 exist in the world most of which could be produced in the low-cost range.

An economic assessment of the possible uses of very high grade thorium ores must, however, be carried out before the commercial evaluation of our deposit can be considered as complete.

For the present, it would therefore be safer to regard the thorium content of the Somalia occurrence as being of no economic significance. This could however be reviewed at intervals in the light of nuclear power developments.

(b) Uranium: The period of high price, strong demand for uranium from about 1945 to 1957 was followed by a period of considerable over supply which is still in effect and may be expected to last until about 1970.

Starting from about 1970 a rising demand for uranium for nuclear power requirements is anticipated. The estimates of uranium requirements have been almost continuously up graded over the last few years. A recent estimate published by the U.S. Atomic Energy Commission (A.E.C.) is as follows:

	Estimated Annual Demand	Cumulative Demand
	Short Tons U_3O_8	Short Tons U_3O_8
1970	12,000	38,000
1975	32,000	156,000
1980	65,000	409,000

Progressively greater demands are anticipated in the decades 1980-1990 and 1990-2000.

The ore reserve situation, also estimated by the U.S.A.E.C. in September 1966 (as a total "western world" reserve) was 690,000 short tons U_3O_8, but the apparent surplus on these two sets of figures may not exist when maximum production rate, which is the controlling factor, is taken to account. This and the continuously revised upward estimate in demand indicate the possibility of a short fall in uranium supply around 1975-1980. After 1975 production will be increasingly dependent upon new districts.

These estimates are made on an estimated price range of US $ 5 - 10 per pound U_3O_8. In trying to estimate a closer figure, most authorities are of the opinion that the U_3O_8 purchase price will rise to about US $ 8.00 per pound U_3O_8 (or US $ 17.50 per kilogramme U_3O_8) by the mid 1970s and might be held there if successful new low-cost discoveries are made in the meantime.

Unlike the early 1950s, small deposits and supplies are unlikely to be attractive to buyers and power producers. An essential feature of future demand will be that substantial contracted supplies be assured on a long-term basis.

In summary, there appears to be a good prospect of commercial sale of uranium concentrates from about the early 1970s onwards at a probable price of about 17.50 US dollars per kilogramme U_3O_8 provided that the deposits are substantial and that secure long-term contracts are arranged with purchasers.

As exploration, development and the bringing of a deposit to the production stage may take about five years on the average, the present early stage exploration of the Somali occurrence appears to be correct timing for possible future production stage.

(c) Yttrium, ytterbium and scandium

In recent years there has been an increasing demand for yttrium and some other of the heavier rare earth elements for use in the television and other industries. A review of the situation written by Dr. D. Slater of the Institute of Geological Science, London, is reproduced with his permission as Appendix No. 5 to this report. The prices quoted are for the metals and oxide prices which might be more relevant to plant production are of the order of US $ 1 - 5 per kilogramme Y_2O_3 at the present time.

As far as outlet and markets are concerned, the matter is very complex and there are no very clear indications of what might be possible. Another industrial authority in a private communication to Mr. Cameron, U.N. Consultant, states "In regard to the rare earths, there is some current interest in raw materials with rare earth distribution different from monazite and bastnaesite. There is no known deposit which contains substantial thorium with a particularly interesting distribution of rare earths but we are only just starting to get a useful picutre on rare earth occurrences. While rare earth markets are developing rapidly in some directions, the economics are complicated by interdependance of a number of elements from a particular source. The only possible general comment is that rare earths at the heavy end could be interesting but if they are mostly cerium down to samarium there is unlikely to be much commercial outlet".

The position is somewhat similar for scandium. In general, supplies of rare earths are not difficult and very large resources exist in the bastnaesite deposits, in placer-monazite, in the Canadian uranium deposits and sources in various by-product effluents etc. The economics are, however, very dependant on the nature of the deposit and the Alio Ghelle occurrence could prove to have some commercially attractive factors in the medium term and more distant future.

The economics of the rare earths are very complex and could probably only be judged by the highly specialised commerical companies dealing in the metals.

General: In Mr. Cameron's opinion, for the immediate and medium term future, the Alio Ghelle occurrence should be judged on its uranium potential only. Economic exploitation of the other metals may be possible in the more distant future. The mineralisation is of a highly complex specialised type which would have no hope of successful exploration on a small scale by an inexperienced organisation, but instead, would require highly sophisticated technical engineering and development.

Regarded as purely a uranium deposit, some foreign Government organisations and quite a number of commercial enterprises might be interested if the ore tonnage were proved to be big enough, that is, in the multi-million ton class. Ideally every attempt should be made to exploit all the metals if and when possible and this could only be done by an integrated organisation controlling production, refining and outlet facilities for all possible marketable products.

PRELIMINARY ECONOMIC CONCLUSIONS

On the present evidence, no clear-cut economic conclusion about the Alio Ghelle ore deposit can be reached. Normally, a uranium ore deposit of about one million tons with an average grade similar to that of Alio Ghelle of about 0.12 per cent U_3O_8, with uncomplicated recovery possibilities and no other adverse factors would be regarded as most probably a viable economic proposition.

The overall cost of recovering uranium from thorite ores of the Alio Ghelle type has not yet been determined and it is therefore difficult to compare this deposit with other uranium deposits when recovery is simple.

A special technical study to determine the economics of uranium recovery from the Alio Ghelle ores must therefore be one of the principal tasks of any further exploration programme.

The inferred ore tonnage at Alio Ghelle is not at present high enough but there are reasonably good geological prospects that at least one million tons of ore could eventually be proved and this is the level at which, in Mr. Cameron's opinion, real commercial interest would start.

Another problem to be investigated is the mineralogical constitution of the deeper levels of the deposit. If the assumed increase of the uranium content and/or, the existence of independent uranium minerals were confirmed, the economics of mining the deposit would be improved.

It is evident that increasing interest is being expressed in this type of mineralisation for the mid and long term future, not only for uranium but to a lesser extent, also for the rare earths and possibly even for thorium.

Exploration as of March 1968 is at a very early stage and as there are sound geological possibilities for greater tonnages being eventually found both at Alio Ghelle and at some of the other radioactive anomalies in the area, it would be correct and justifiable to continue to explore, define and evaluate Alio Ghelle and any other deposits in the area.

It is therefore recommended that exploration be continued to define ore tonnage. If this exploration can prove at least one million tons of ore with the present ore grade or better then more detailed large scale extractive metallurgical testing should be initiated together with studies of all the other relevant economic factors particularly related to location such as power, transport water supply, mining methods.

If further exploration, however, defines the ore bodies and fails to prove one million tons of ore, then the occurrence is unlikely to be of further interest.

APPENDIX No. 1

MINERALOGICAL REPORT FROM INSTITUTE OF GEOLOGICAL SCIENCES

GEOLOGICAL DIVISION, LONDON

Source of samples: United Nations Mineral and Groundwater Survey, Somali Republic. Samples Nos. 42 to 48.

Sample No. 42

Field description: Half core from 2½-inch borehole. The Project mineralogist describes rock as "schistose gneissic granitoid country rock apparently unaltered".

Petrographical description: Heavily albitized oligoclase-amphibole granofels. The amphibole is pleochroic in greens and yellows and is probably common hornblende. It is partially altered to magnesian chlorite with some rare stilpnomelane. Very small crystals of monazite are present, but rare, along with minor patches of carbonate.

Spectrographic analysis: X-ray fluorescence spectrometric analysis gave the following results:

ThO_2	=	< 0.001%
U_2O_3	=	< 0.001%
Y_2O_3	=	< 0.003%

Sample No. 43

Field description: Half core from 2½-inch borehole. Project mineralogist described rock as, "granite textured country rock normally occurring as conformable bands of up to a few metres width within country rock of the type in Sample No. 42."

Petrographical description: The rock is fairly coarsely banded gneiss. The light band is a plagioclase-quartz granofels with subordinate biotite with a little ilmenite surrounded by leucoxene.

The dark band is a plagioclase-biotite-amphibolite with ilmenite and pyrite. Rare pleochroic haloes in biotite surrounded small unidentifiable inclusions. Some apatite is present but without pleochroic haloes against biotite.

Spectrographic analysis: X-ray fluorescence spectrometric analysis gave the following results:

ThO_2	=	< 0.001%
U_2O_8	=	< 0.001%
Y_2O_3	=	< 0.002%

Sample No. 44

Field description: Half core from 2½-inch borehole. Project mineralogist describes rock as, "altered mineralized schistose-gneissic type ore".

Petrographical description:

A biotite-oligoclase granofels with marked schistosity indicated by parallel alignment of biotite and dimensional orientation of plagioclase. The oligoclase is heavily albitised and some relict hornblende is seen mantled by biotite and chlorite.

Spherulitic thorite associated with haematite is very frequently associated with areas of carbonate and chlorite apparently formed from degradation of amphibole. The thorite is often confined to the boundaries between the carbonate and the host rock giving a pseudevesicular appearance to the schist. Otherwise the thorite is located along tension cracks within and grains boundaries between plagioclase grains. The spherulites are apparently nucleated on centres upon one wall of the crack giving incomplete spherules.

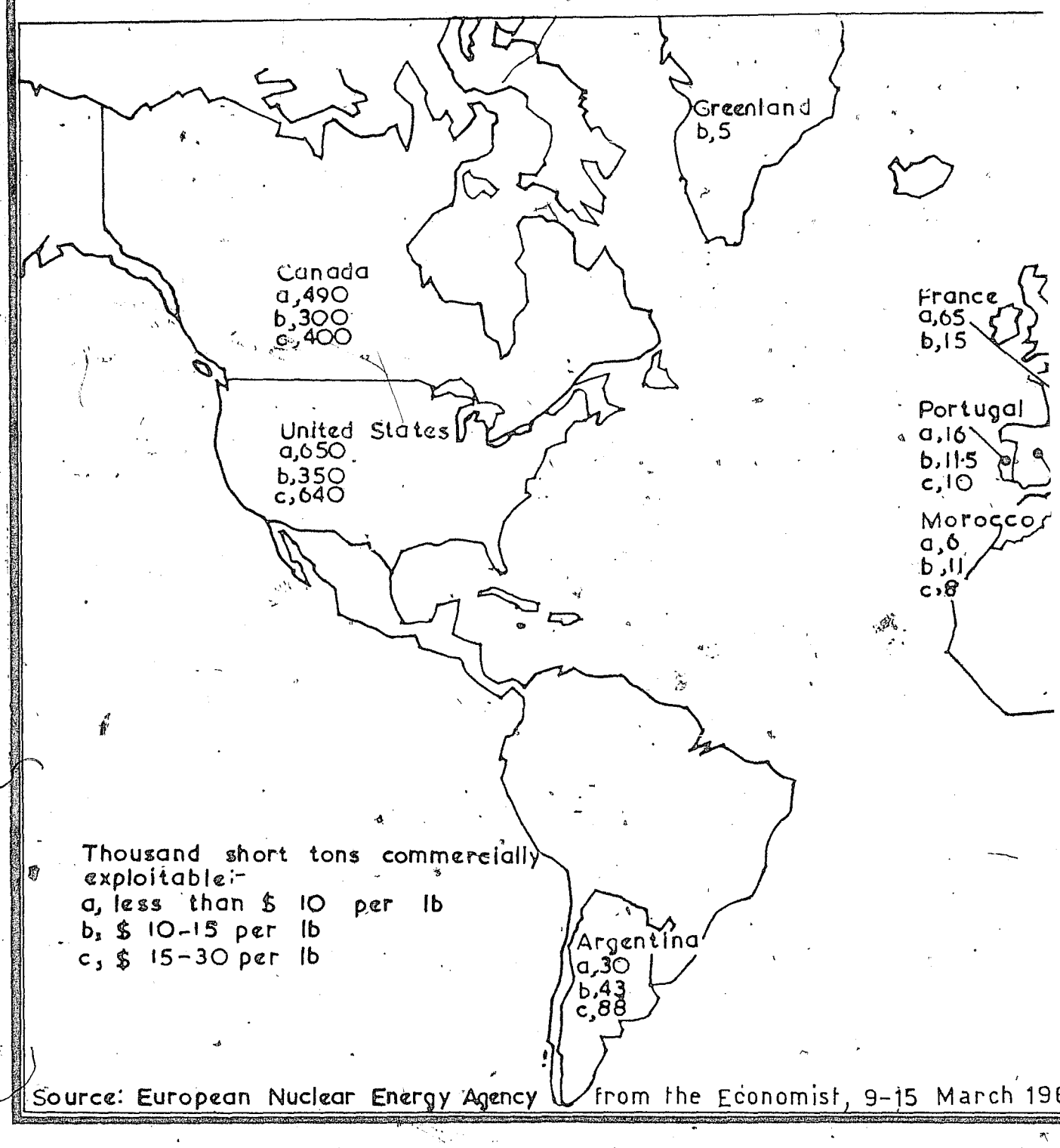
Spectrographic analysis:

X-ray fluorescence spectrometry gave the following results:

ThO_2	=	5.2%
U_3O_8	=	0.24%
Y_2O_3	=	0.13%

The thorite accounted for all the uranium and yttrium in the rock.

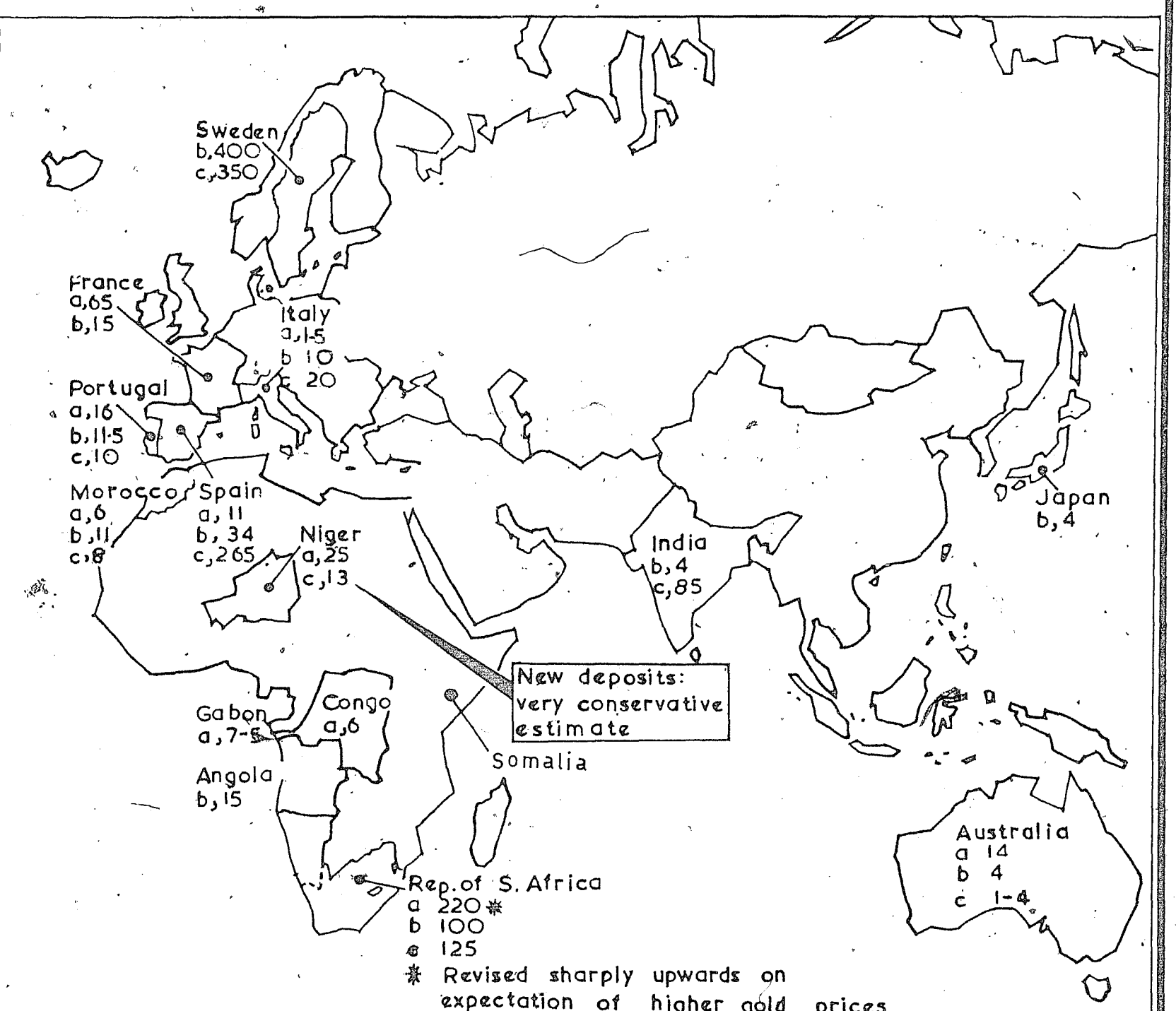
URANIUM F



Source: European Nuclear Energy Agency from the Economist, 9-15 March 19

MAP-4

ANIUM RESOURCES OF THE WORLD



9-15 March 1968

Sample No. 45

Field description: Half core from 2½-inch borehole. Project mineralogist describes rock as, "altered schistose-gneissic type of ore with less marked banding".

Petrographical description: A plagioclase biotite gneiss with abundant patches of uranothorite.

The uranothorite is spherulitic and in most cases is nucleated on coffinite U Si $(O, OH)_4$. The uranothorite is mainly confined to large areas where it appears to be a pseudomorph after amphibole. Where these patches are entirely composed of uranothorite and coffinite considerable quantities of haematite are also present, sometime imparting a deepred body colour to the uranothorite. Elsewhere, but rarely the uranothorite is accompanied by chlorite but without haematite.

Spectrographic analysis: X-ray fluorescence spectrometry gave the following results:

ThO_2	=	6.6%
U_3O_8	=	1.4%
Y_2O_3	=	0.17%

Analysis of uranothorite separated from the sample gave $ThO_2/U_3O_8 = 5$. The remaining U_3O_8 is accounted for by the coffinite.

Sample No. 46

Field description: Half core from 2½-inch borehole. Project mineralogist describes rock as "altered mineralized schistose-gneissic type of ore, similar to Sample No. 44 but at boundary with granitic type of ore".

Petrographical description: In hand specimen the rock can be divided into two parts; a light part which is a plagioclase biotite schist with small amounts of interstitial carbonate and thorite, the biotite being occasionally replaced with chlorite, and a dark part consisting of the above constituents in roughly the same relative proportions but with thorite making up about 20% of the total. In this part of the rock the biotite has been almost entirely replaced by chlorite. The thorite is virtually confined to the grain boundaries between the very much larger plagioclase crystals and localised along tension cracks within the plagioclase. Rather large quantities of haematite are associated with the thorite.

Spectrographic analysis: X-ray fluorescence spectrometry gave the following results:

ThO_2	=	5.8%
U_3O_8	=	0.12%
Y_2O_3	=	0.15%

Analysis of separated thorite from this rock gave results for the three oxides listed above which were in the same relative proportions so that the thorite accounted for all the uranium and yttrium in the rock.

Sample No. 47

Field description: Half core from 2½-inch borehole. Project Mineralogist describes rock as, "altered mineralized granitic type of ore".

Petrographical description: Originally a plagioclase rich rock with biotite. The rock is albitised and skeletal biotite remains in places. The most interesting feature of this thin section is that there appear to be large geodes which are zoned with thorite rims and passing inwards into quartz which has overgrown relict rims of calcite, apparently replacing the carbonate.

Spectrographic analysis: X-ray fluorescence spectrometry gave the following results:

ThO_2	=	5.8%
U_3O_8	=	0.04%
Y_2O_3	=	0.15%

The thorite accounts for all the uranium and yttrium in the rock.

Sample No. 48

Field description: Half core from 2½-inch borehole. Project mineralogist describes rock as, "altered granitic type of ore with some ferruginous staining".

Petrographical description: A very coarse gneiss originally with large altered plagioclase and microcline crystals cracked and broken; the veinlets formed being filled with aggregates of thorite associated with well-formed clinochlore and biotite. Some vesicular structures are also present with a similar nature to those described in Sample No. 47, i.e. margins covered with thorite grading inwards through carbonate to quartz. Although the cracks in the feldspar crystals usually contain thorite, cracks filled entirely with carbonate are also found.

Spectrographic analysis: X-ray fluorescence spectrometry gave the following results:

ThO_2	=	10.5%
U_3O_8	=	0.07%
Y_2O_3	=	0.26%

The thorite contained sufficient U and Y to account for these elements in the rock.

Origin:

A complex of banded gneisses including granitic and plagioclase amphibolitic bands has undergone later possible hydrothermal retrograde alteration along certain bands with extensive albitisation of feldspars, the production of chlorite from biotite and the alteration of amphibole to carbonate magnesian chlorite and haematite. Possible concomitant with this hydrothermal action was the introduction of thorium, uranium and small amounts of rare earths, along with silica. The fact that uranothorite, identical in appearance to the spherulitic thorite commonly found in these rocks, is apparently nucleated upon coffinite suggests that the uranium bearing solutions may have proceeded the thorium in certain cases.

- Submitted: T.K. Ball
- Approved: J.E.T. Horne

Young Street, W.8
8 January 1968

APPENDIX No. 2

MINERALOGICAL REPORT FROM COLUMBIA UNIVERSITY, N.Y., USA

Preliminary Report of the results obtained from the study of Core samples from Somalia Th/U occurrence

Optical observations in thin sections:

Sample 42 — Feldspars-amphibole-biotite schist. Medium grained banded rock. Mineral present in order of decreasing abundance are: Feldspars altered to various degrees, hornblende and biotite (interstitial), apatite, zircon and monazite.

Sample 43 — Feldspars-amphibole-biotite rock with little quartz. Generally similar to Sample 42, but mafic minerals (hornblende and biotite) are less abundant. Bent lamellae in feldspars and strain shadows suggest metamorphic origin for the named rock.

Sample 44 — Banded rock fundamentally similar to Samples 42 and 43 but extremely altered. Replacement of primary minerals and deposition of secondary minerals is widespread. Spherulites and botryoidal masses are filling spaces between feldspars and appear to be replacing amphiboles and biotite to various degrees. Usually these masses have a core of a cubic mineral completely altered and replaced. Occasionally zircon is found at the center of the spherulites.

Sample 45 — Medium-grained rock very similar to sample 44. Botryoidal and globular masses are abundant and commonly stained by possibly iron oxides. Interstitial calcite is common. Occasional colloform masses, black-greenish, appear to be pitchblende.

Sample 46 — Similar to Sample 45. The grain is a little finer, but the mineral assemblage is very similar to the preceding one. Iron stains appear however to be less.

Sample 47 — Similar to 45 and 46 but not banded and coarse grained Replacement and alteration is extreme. The same type of botryoidal and globular masses are present occasionally with very fine needles of an opaque mineral which could not be identified. Occasionally colloform-masses appear to be pitchblende.

Sample 48 — Similar to the preceding sample but hornblende is not present and the biotite shows leaching effects.

Opitcal observation in polished sections:

Sample 42 — Pyrite and some galena, both in very small amounts.

Sample 43 — Pyrite, small amounts of galena and some ilmono-magnetite.

Sample 44 — Thorite (?) in thorogummite masses, possible some pitchblende.

Sample 45 — Very little pyrite, some metamict minerals probably zircon or thorite.

Sample 46 — Similar to sample 44.

Sample 47 — Only very few grains of chalcopyrite.

Sample 48 — Similar to 42.

X-ray identification:

All the samples have been crushed and sieved and individual fragments have been separated. Mineral selected from the ⟨80 fraction were analysed using X-ray diffractometer methods.

Results follow:

Sample 43 - the dark mica is hydrobiotite

Sample 44 - a) whole sample; hornblende -albite
b) reddish black pellets: thorogummite

Sample 45 - Reddish fragments: thorite or thorogummite

Sample 46 - Whole sample: feldspars, chlorite (chamosite) thorogummite.

Sample 47 - a) whole sample: feldspars, thorogummite (thorite?)
b) red globular masses: thorogummite (thorite?), some hematite
c) dark brown masses: quartz and thorogummite (thorite?)

Sample 48 - Green masses: chamosite.

Comments:

The separation of the botryoidal masses was carried out because identification with optical methods, due to the very small size of the crystals in the aggregates, was impossible.

The description of thorogummite as given in Frondel, does not quite correspond to the mineral that produces constantly the pattern of thorogummite, in X-ray analysis.

Most of the spherulites or botryoidal masses contain a relict crystal in their core. Could have been thorite or ferrothorite but it is at present altered and replaced.

Distinction between thorite and thorogummite cannot be obtained by X-ray methods because both minerals produce, fundamentally, the same pattern.

Other minerals (samiresite, clarkeite, curite) could be present in the aggregates in amount below the limit of sensitivity of X-ray methods. More information could be obtained through separation with heavy liquids and analysis of separate fractions, but more time and work will be required.

Occasionally the spherulites contain relicts of zircon and/or monazite. Both minerals may contain uranium, thorium and yttrium.

Uranium oxide, pitchblende variety, appears to be present in colloform masses and as coating in the rock interstices and is probably of secondary origin.

Some of the monazite and zircon crystals are very fresh and relatively abundant in many of the samples.

Thorite and the secondary mineral thorogummite could very well account for the uranium content of the submitted samples.

APPENDIX No. 3 (a)

CHECK ASSAYS BY INSTITUTE OF GEOLOGICAL SCIENCES, LONDON

RADIOACTIVE SAMPLES FROM SOMALI REPUBLIC

1. ANALYTICAL RESULTS

Sample	Length metres	% ThO_2 XRF	% ThO_2 RA	% U_3O_8 XRF	% U_3O_8 NA	% Y_2O_3 XRF	% Yb OE	% Sc OE
1	3.40	6.5		0.09		0.18		
2	3.00	4.6		0.08		0.18		
3	2.00	2.1		0.12		0.06		
4	3.00	0.3		0.05		0.01		
5	3.00	1.3		0.04		0.04		
6	2.00	1.1		0.05		0.02		
7	3.00	0.9		0.05		0.03		
8	3.00	4.0		0.14		0.11		
9	3.00	4.8		0.14		0.05		
10	3.00	4.0		0.12		0.11		
11	3.00	3.8		0.21		0.10		
12	3.00	3.1		0.16		0.08		
13	2.00	3.2		0.04		0.08		
14	2.00	4.0		0.14		0.11		
15	3.00	3.5		0.12	0.11	0.09		
16	3.00	3.1		0.16		0.08		
17	2.00	3.5		0.21		0.09		
18	3.00	7.0		0.25		0.17		
19	2.00	4.2		0.19		0.10		
20	3.00	2.6		0.04		0.07		
21	2.00	2.3		0.04		0.08		
22	3.00	1.8		0.04		0.04		
23	3.00	2.3		0.07	0.09	0.05		
24	2.00	5.1		0.04		0.13		
25	2.00	3.1		0.11		0.09		
26	2.00	4.2		0.13		0.11		
27	3.00	2.2		0.02		0.05		
28	2.00	5.0		0.11		0.13		
29	2.00	3.6		0.24		0.10		
30	2.80	4.8		0.12		0.12		

APPENDIX No. 3 (a) Continued

Sample	Length metres	% ThO_2 XRF	% ThO_2 RA	% U_3O_8 XRF	% U_3O_8 NA	% Y_2O_3 XRF	% Yb OE	% So OE
31	3.00	3.6		0.21		0.10		
32	3.00	3.5		0.16		0.15		
33	1.80	3.6		0.12		0.09		
34	2.00	4.0		0.14		0.10		
35	2.40	2.2		0.07		0.05		
36	2.50	3.1		0.12		0.05		
37	1.50	1.3		0.11		0.05		
38	2.00	1.3		0.04		0.05		
39	96.40	3.3	3.6	0.12	0.13	0.08	0.02	0.004
40	15.00	3.5	4.0	0.12	0.14	0.09	0.02	0.003
42	Min. Samp.	n.d.		n.d.		0.003		
43	" "	n.d.		n.d.		0.002		
44	" "	5.2		0.24		0.13		
45	" "	6.6		1.4		0.17		
46	" "	5.8		0.12		0.15		
47	" "	5.8		0.04		0.15		
48	" "	10.5		0.07		0.28		

n.d. = not detected.

XRF X-ray fluorescence, analyst Mr. E.J. Raynor

RA Radiometric assay, analyst Mr. E.J. Raynor

NA Neutron activation, analyst Mr. M.J. Brown

OE Optical emission spectrography (semi-quantitative determinations), analyst Miss D.E.M. Hosking (Chemistry and Ceramics Unit, Gray's Inn Road Office).

Comment. The X-ray fluorescence, radiometric and neutron activation results for the representative samples 39 and 40 are in good agreement. With the radiometric detectors used, 0.12% U_3O_8 is equivalent to 0.3% ThO_2, so the ThO_2 contents calculated from the XRF results are 3.8% and 4.0% for samples 39 and 40 respectively, as compared with 3.6% and 4.0 % by radiometric assay.

APPENDIX No. 3 (b)

Check Assays by Eldorado Mining and Refining Ltd., Ottawa, Canada

Sample R&D No.	UN	Lon. Met.	Analyst 1 Uranium $\%U_3O_8$	Analyst 2 Uranium $\%U_3O_8$	Analyst 1 Thorium % Th	Analyst 2 Thorium % Th
605-222-1	C1(b)	3.40	0.100	0.100	5.05	5.11
-2	C2(b)	3.00	0.111	0.114	3.71	3.97
-3	C3(b)	2.00	0.121	0.122	1.73	1.92
-4	C4(b)	3.00	0.037	0.037	0.23	0.31
-5	C5(b)	3.00	0.060	0.067	0.95	1.08
-6	C6(b)	2.00	0.038	0.043	0.68	0.80
-7	C7(b)	3.00	0.054	0.053	0.55	0.74
-8	C8(b)	3.00	0.142	0.149	3.25	3.19
-9	C9(b)	3.00	0.142	0.147	3.51	3.88
-10	C10(b)	3.00	0.122	0.129	3.55	3.88
-11	C11(b)	3.00	0.201	0.210	3.16	3.09
-12	C12(b)	3.00	0.167	0.163	2.78	2.60
-13	C13(b)	2.00	0.091	0.083	2.76	2.63
-14	C14(b)	2.00	0.164	0.167	4.10	
-15	C15(b)	3.00	0.112	0.107	2.52	2.37
-16	C16(b)	3.00	0.170	0.166	2.76	2.63
-17	C17(b)	2.00	0.170	0.175	2.67	2.50
-18	C18(b)	3.00	0.234	0.239	5.67	
-19	C19(b)	2.00	0.140	0.149	2.39	2.90
-20	C20(b)	3.00	0.056	0.056	1.76	2.23
-21	C21(b)	2.00	0.051	0.049	1.88	1.92
-22	C22(b)	3.00	0.049	0.050	1.27	1.19
-23	C23(b)	3.00	0.080	0.082	2.01	1.75
-24	C24(b)	2.00	0.050	0.048	5.07	4.95
-25	C25(b)	2.00	0.111	0.112	3.13	3.46
-26	C26(b)	2.00	0.168	0.185	4.43	4.81
-27	C27(b)	3.00	0.053	0.051	2.26	
-28	C28(b)	2.00	0.179	0.173	4.90	
-29	C29(b)	2.00	0.234	0.222	2.82	2.93
-30	C30(b)	2.80	0.111	0.100	3.68	
-31	C31(b)	3.00	0.176	0.183	2.78	2.63
-32	C32(b)	3.00	0.157	0.172	2.73	2.93
-33	C33(b)	1.80	0.139	-	2.93	2.84
-34	C34(b)	2.00	0.119	0.113	2.93	
-35	C35(b)	2.40	0.115	0.108	1.64	
-36	C36(b)	2.50	0.117	0.109	1.54	
-37	C37(b)	1.50	0.100	0.095	1.38	
-38	C38(b)	2.00	0.042	0.047	1.43	
-39	C39(b)	96.40	0.133	0.132	3.00	3.13
-40	C40(b)	15.00	0.123	0.121	2.91	

APPENDIX No. 4

PRELIMINARY REPORT ON AMENABILITY TESTING OF SOMALIA ORE BY WARREN SPRING LABORATORY, STEVENAGE, ENGLAND

The representative composite sample, C39, contained U_3O_8, 0.105%; ThO_2, 3% and Y_2O_3, less than 0.1%. The same result was obtained for yttriumin in the sample of higher grade section, C40; this was found to contain only 0.115% U_3O_8, and 4% ThO_2.

Note on Direct Leaching Tests

Preliminary leaching tests on the composite sample indicated that the ore contains alkali equivalent to 8% of limestone. Treatment of the material as received, i.e. 28% minus 200 mesh, was not satisfactory as boiling 50 g of ore for 6 hours with 50 ml of 4N H_2SO_4 extracted only 24% of the uranium. Grinding the ore to all minus 200 mesh increased the leaching efficiency to 42%, and to 81% when the solution to ore ratio was doubled. When 50 g portions of finely ground ore were boiled for 6 hours with 50 ml aliquots of nitric acid solution of normality 1.6, 3.2 and 4.8 the percentage extraction of uranium was, respectively, 1.4, 29 and 41. Doubling the volume of 4N HNO_3, increased the extraction to 72%. For the latter test the usage of 70% nitric acid corresponded to 0.6 tons per ton of ore; whilst the best result, an extraction efficiency of 81%, was obtained using 0.4 tons of sulphuric acid per ton of ore.

As reagent requirements for the direct chemical treatment of the ore are excessive, we propose to examine the possibility of employing physical methods for the production of a concentrate from the ore. If such a concentrate can be obtained it will be used in stringent-leaching testwork.

APPENDIX No. 4 (Continued)

Note on Pre-concentration Tests. Sample C39 as received, contained 43% + 72 mesh material, this coarse fraction was ground in a small mill to complete the liberation of the thorite and re-combined with the original - 72 mesh fraction. A sample of 1.61 kilograms of this material was treated on a small laboratory size shaking table. The concentrate and tails fractions obtained amounted, respectively, to 7% and 71% of the feed and there was a slimes loss of 22%. The distribution results are as follows:

	Assay %		Distribution	
	ThO_2	U_3O_8	ThO_2	U_3O_8
Table feed	3.3	0.11	100	100
Concentrate	30.0	0.83	63.3	53.2
Tailings	1.5	0.06	32.2	39.0
Slimes (calculated)	(0.7)	(0.04)	4.5	7.8

As the original sample had been ground to 44% - 200 mesh careful grinding of the ore would reduce the loss of values in the table tails and slimes. A concentration ratio of about 8:1 is indicated.

- signed: A.A. North

APPENDIX No. 5

The demand for rare earths with particular reference to that for yttrium, gadolinium, thulium, europium and erbium. Prepared by Dr. D. Slater, Institute of Geological Science, London, 1966.

Since the early part of this century and until the last decade the demand for the rare earth (RE) metals has been virtually synoymous with that for Mischmetal, a crude mixture of the RE metals, utilised as a grinding agent in the glass industry, for alloying with iron to produce lighter flints, for the cores of arc light carbons and miscellaneous other applications. However more stringent requirements, particularly in the television, metallurgical and nuclear power industries, have recently created a demand for the purer forms of individual rare earths, notably for europium and yttrium. Several large concerns have therefore undertaken the separation of these elements on a commercial scale.

The recent interest in the marketing of purer rare earths may be measured by the degree of company activity in this field. A new concern, the Yttrium Corp. of America, has been formed to produce pure yttrium compounds in response to demand from the television industry. The shares are held by Pyrites Ltd., which is owned by the Rio Tinto Zinc Corp. and the Molybdenum Corporation of America. A plant to be built in the U.S.A. will have an initial capacity of 180,000 pounds of yttrium oxide per annum, and the raw materials will be derived from the Rio Algom Mines, Limited, in Canada. Molycorp is also in the act of spending 2.7 million dollars to expand its capacity for production of a new concentrator at the Mountain Pass mine, a doubling of the present production rate of europium oxide to 20,000 pounds per year and a new facility for the output of praesodymium and neodymium oxides. The new capacity will total 30 million pounds of rare-earth oxides. The purchase of the Vitro Chemical Co. of Chattanooga by W.R. Grace and Co. is also notable and gives the latter a wide operating base in the RE field.

Much of this recent activity has resulted from the new europium-activated yttrium vanadate phosphor which is employed in colour television to give a truer red and a better colour balance. The most favoured combination for this purpose is europium added to yttrium orthovanadate in the ration of 1 europium atom of 19 yttrium atoms, but other combinations are possible. Europium is reported to be effective with gadolinium orthovanadate and rare-earth borates and phosphates have received attention.

Of recent interest too, is the use of yttrium iron garnet or yttrium aluminium garnet in microwave devices. The latter material, doped with neodymium, is said to operate at room temperature, cooled by tap water, and to support continuous laser action using a tungsten filament lamp source.

In 1962 the Crane Company announced the development of a process for producing nodular cast iron using yttrium metal or yttrium alloys as the "nodulariser". Yttrium has the desirable properties of the conventional nodularisers magnesium and cerium, but not their undesirable properties. This application represents the first potential large scale commercial use of a heavy rare earth in "pure" form. Mischmetal has, of course, been used to improve low-alloy and stainless steels for some years, and as foundry experience is gained with yttrium, increasing interest in its applicability is to be expected. Yttrium additions to iron chromium alloys improve high temperature oxidation resistence and in chromimit retards nitrogen absorption. It can also be used as a container for molten lithium, dodium, potassium and cerium and its non-resistivity with fluorides has led to suggestions that it might be used as plumbing for processing fluorides. In these last functions it would compete directly with certain refactory metals and with plastics.

RESERVES

No figures are available for reserves of individual RE elements. The world's largest reserve, 5 million tons REO is in California bastnaesite at Mountain Pass. India, Australia, Brazil, Malagasy and Malaysia all have large reserves of monazite, but bastnaesite is now preferred by RE producers who have difficulty in finding markets for the thorium contained in monazite. Altschuler (1966)[1/] has pointed to the possibility of doubling present production of the rare earths as a byproduct of wet process phosphoric acid. Moreover, he estimates that 3,000-4,000 tons are annually made available for recovery from the treatment of about 18 million tons of marketable Florida phosphate rock alone. Such marine phosphorites are relatively rich in lanthanum and yttrium at the expense of cerium and the lighter rare earths, in contrast to monazite in which the relationship is reversed. However, it is presumed that the technical difficulties encountered in economic extraction of the rare earths from these waste liquors would be considerable.

Prices

Prices of the pure forms of metals and oxides vary greatly according to purity and lot size. The following are example priced at the end of 1964.

Yttrium

Metal -	Commercial Grade	$ 75 per lb.
	Nuclear Grade	$ 300 per lb.
	[illegible]uble distilled	$ 500 per lb.
	[illegible]lloy Grade	$ 24-50 per lb.

1/ References are not listed in this report

Europium

Metal	$ 1,200 to	$ 3,500 per lb.
Oxide	$ 350 -	$ 1,000 per lb.

No recent quotations for the prices of gadolinium, erbium or thulium have been found.

OUTLOOK

The trend for increased usage of yttrium and europium should continue, mainly due to demand for colour television. Demand for these materials is being, and almost certainly will be, met from expansion of existing facilities. Due to the limited size of the industry, end-use research is on a mode[illegible]s and new applications remain largely dependent on the consumer. [illegible] seems doubtful if any concern would be successful which was not vertically integrated to the extent of carrying out all the process involved in mining, concentrating and refining rare earths.