

**INTERNATIONAL
URANIUM RESOURCES
EVALUATION PROJECT**

**IUREP ORIENTATION
PHASE MISSION**

Report

SOMALIA



**A report prepared on behalf of the
Executive Group for the IUREP Orientation Phase
by the
INTERNATIONAL ATOMIC ENERGY AGENCY**

INTERNATIONAL ATOMIC ENERGY AGENCY

INTERNATIONAL URANIUM RESOURCES EVALUATION PROJECT

- I U R E P -

IUREP ORIENTATION PHASE MISSION REPORT

SOMALIA

A REPORT PREPARED ON BEHALF OF THE EXECUTIVE GROUP

FOR THE IUREP ORIENTATION PHASE

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PREFACE

The Mission was undertaken by two consultants, Mr. Robert A. Levich and Mr. Eberhard Muller-Kahle. Both consultants commenced the work in Somalia on 17th February 1983. Mr. Levich terminated his mission on 17th April and Mr. Muller-Kahle completed his investigation on 20th April 1983. No field trips could be undertaken due to the lack of transport and the impossibility of obtaining permission to visit SOARMICO's calcrete deposits.

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I. SUMMARY

The IUREP Orientation Phase Mission to Somalia suggests that in addition to the reasonably assured resources (RAR) of 5 000 t uranium and estimated additional resources (EAR) of 11 000 t uranium in calcrete deposits, the speculative resources (SR) could be within the wide range of 0 - 150 000 t uranium. The majority of these speculative resources are related to sandstone and calcrete deposits. The potential for magmatic hydrothermal deposits is relatively small.

The Mission recommends an exploration programme of about US \$ 22 000 000 to test the uranium potential of the country which is thought to be excellent. The Mission also suggests a reorganization of the Somalia Geological Survey in order to improve its efficiency.

Recommended methods include geological mapping, Landsat imagery interpretation, airborne and ground scintillometer surveys, and geochemistry. Follow-up radiometric surveys, exploration geophysics, mineralogical studies, trenching and drilling are proposed in favourable areas.

II. INTRODUCTION

II.1. Terms of Reference

The basic objective of the International Uranium Resources Evaluation Project (IUREP) is "to review the present body of knowledge pertinent to the existence of uranium resources, to review and evaluate the potential for discovery of additional uranium resources, and to suggest new exploration efforts which might be carried out in promising areas in collaboration with the countries concerned".

Following the initial bibliographic study, which formed Phase I of IUREP, it was envisaged that a further assessment in co-operation with, and within, the country concerned would provide a better delineation of areas of high potential and a more reliable estimate of favorability for the discovery of additional uranium resources. It was planned that this work would be accomplished through field missions to the country concerned and that these field missions and the resulting report would be known as the Orientation Phase of IUREP.

The purpose of the Orientation Phase Mission to the Somali Democratic Republic was:

- a) to develop a better understanding of the uranium potential of the country;
- b) to delineate areas favorable for the discovery of speculative uranium resources;
- c) to make appropriate recommendations of the best methods for evaluating the favorable areas, operating procedures and estimated costs;
- d) to develop the logistical data base required to carry out possible further work; and
- e) to compile a report which would be available immediately to the Somali authorities.

II.2. General Geography of the Somali Democratic Republic

The Somali Democratic Republic (SDR) or in short, Somalia, occupies the largest part of the Somalia Peninsula in East Africa. The country is located between the Gulf of Aden and the Indian Ocean between

latitudes $1^{\circ}30'$ S and 12° N and longitudes 41° and 51° E, and has an area of $637,657 \text{ km}^2$. It is surrounded by the Gulf of Aden to the north, the Indian Ocean to the east (coastline approx 3200 km), Djibouti to the northwest, Ethiopia to the west, and Kenya to the southwest (fig. II-1). The borders with Djibouti, Ethiopia and Kenya are poorly defined and disputed in many places.

The country has the shape of an arrowhead pointed to the northeast. Its southeastern side, the Indian Ocean coast, has a total length of ca. 1650 km, while its northern side, flanked by the Gulf of Aden, measures ca. 800 km. The country's width ranges from a maximum of ca. 400 km in the southern part to a minimum of 120 km in the extreme northwest, adjoining the border with Djibouti. Fig. II-2 is a topographic map of Somalia at 1:2,000,000 scale, compiled probably in 1965. It is therefore not up to date in respect to new roads.

The morphological features of Somalia (fig. II-3) are most pronounced in the northern part of the country. Along its Gulf of Aden coast extends a coastal plain varying in width from 110 km in the west to two to three km in the east. This plain, referred to as "Guban", is scrub-covered, semiarid, extremely hot and crossed by intermittent drainages. When the rains arrive, normally in April-May and October-November, the vegetation is quickly renewed, providing grazing for livestock.

South of this coastal plain and limiting it lies the east-northeast trending escarpment ("Golis") considered to be the southern border of the Gulf of Aden rift zone. South of the Golis follow a number of east-west striking mountain ranges with an average elevation of ca. 2000 m. The highest point of these mountains and of Somalia is the Shimber Berris with an elevation of 2408 m (fig. II-3).

Further south the mountains develop into the interior plateau of about 1000 m elevation, which gradually slopes to the east into the Indian Ocean. A dominant feature in this region, approximately at latitude $9^{\circ}30'$ N, is the Nogal Valley with its extensive network of intermittent rivers. To the south, this valley is bordered by the Central Somali Plateau with

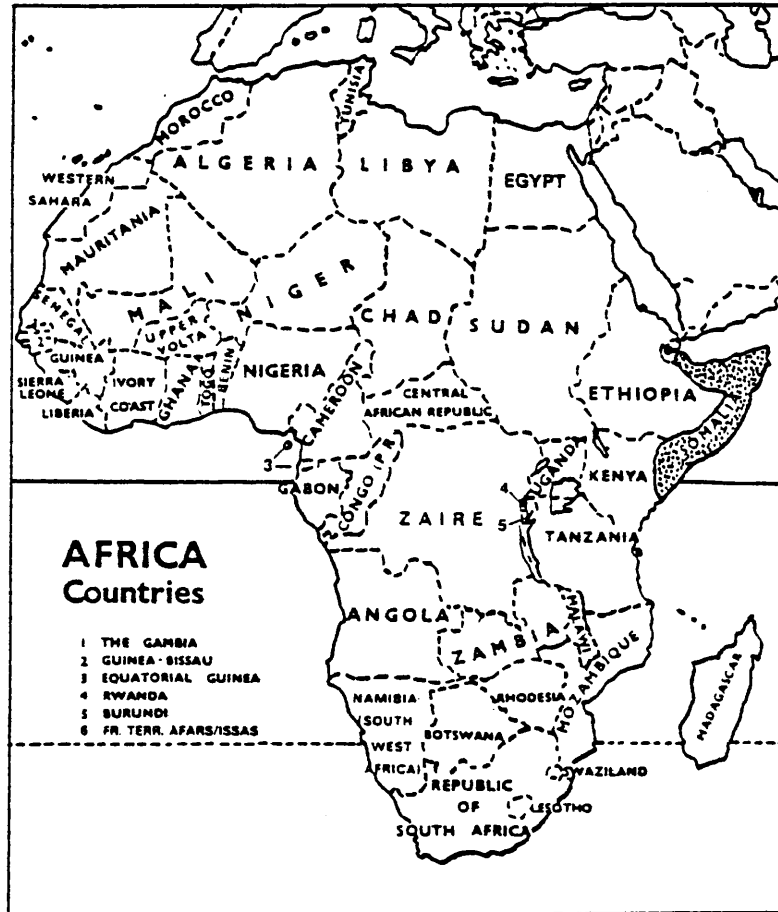


Fig. II-1. Location map.

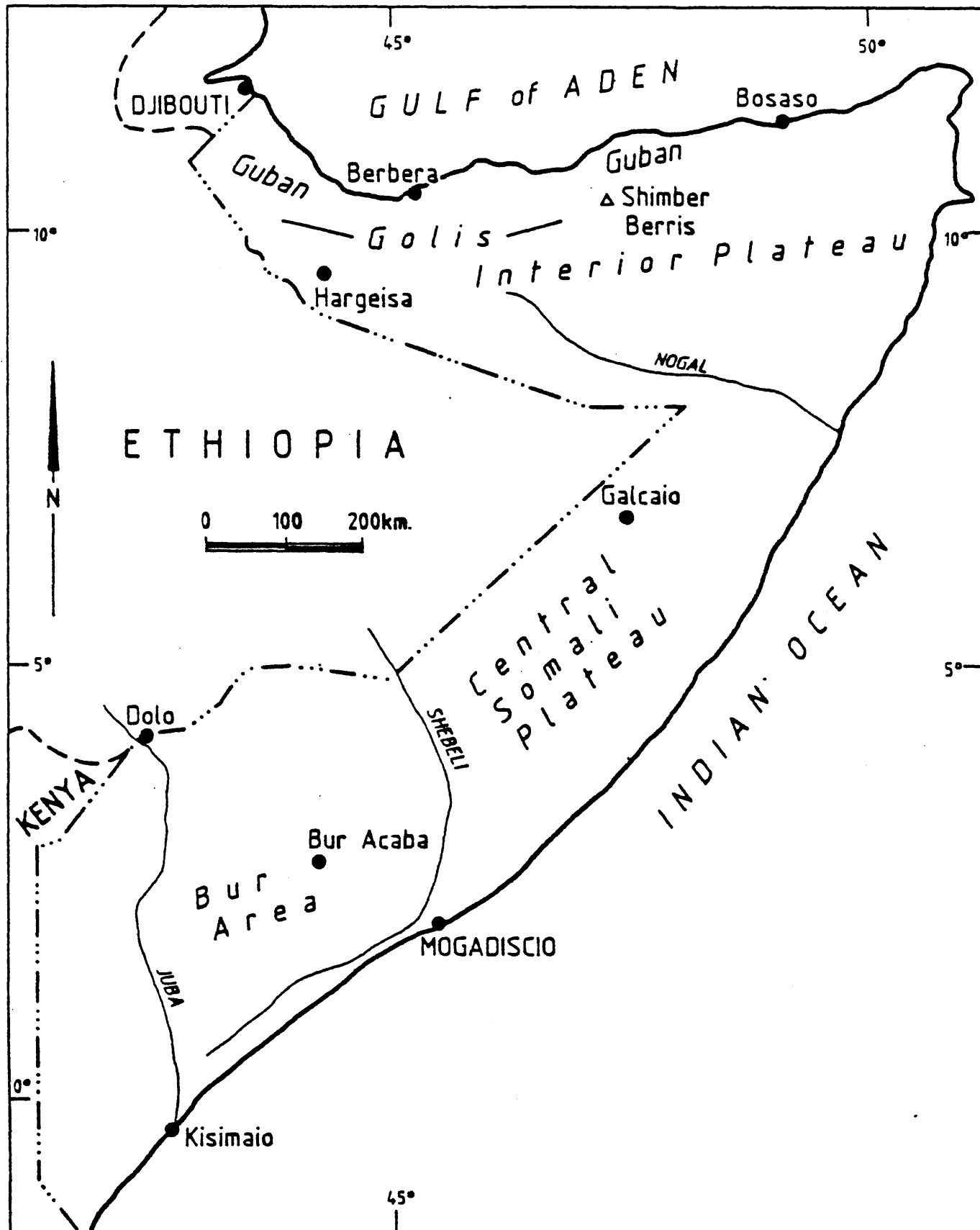


Fig. II-3. Main morphological features

elevations of up to 400 m. It represents part of the easterly slopes of the Ethiopian Highlands and decreases gently to sea level at the shore of the Indian Ocean.

Outstanding morphological features in the southern part of the plateau are the "inselbergs" or "Burs", located in the area between Bur Acaba and Dinsor. These isolated, loaf-shaped mountains reach elevations of 450 m, or some 150 m above the southern part of the plateau.

Somalia is drained by three hydrographic basins, which because of the low precipitation and high evaporation are poorly developed: the Nogal, mentioned above, the Shebeli and the Juba. While the Nogal River carries water only after heavy rains, the Shebeli and Juba are perennial rivers having their origin in the Ethiopian Highlands. The Shebeli does not reach the Indian Ocean but loses itself in marshes north of Gelib, while the course of the Juba meanders into the sea near Kisimayo (fig. II-2, II-3). The area between the Shebeli and Juba is a very fertile region, which provides bananas, peanuts, sugar cane, fruit, maize, cotton, etc., and which is the center for the country's largest sedentary rural population.

The climate in the northern part of the SDR is arid. Annual precipitation is around 100 mm and temperatures of up to 45° C are common during May through September. The southern part of Somalia is more humid and has more moderate temperatures of between 25 and 34° C.

In general, there are four climatic seasons:

- Gilal, a northeast monsoon, without precipitation from mid-December through mid-March;
- Gu, strong rains and high temperatures from mid-March through mid-May;
- Hagai, a southwest monsoon with weak precipitation in the southern coastal region from mid-May through mid-September;
- Der, the second rainy season, less pronounced than the Gu, from mid-September through mid-December.

Table II-1 summarizes the meteorological data from five stations located at Berbera, Bosaso, Djoher, Mogadiscio and Bardera.

Station, location elevation	Berbera 10° N, 45° E 14 m	Bosasa 11° N, 49° E 7 m	Djoher 3° N, 45° E 110 m	Mogadiscio 2° N, 45° E 22 m	Bardera 2° N, 42° E 118 m
Month					
	Temperature (°C), medium daily high				
January	28.9	29.4	36.3	32.2	40.0
July	41.7	40.0	30.2	28.6	33.3
Ø Year	34.4	34.2	33.2	30.2	36.4
	Precipitation (mm)/No. of days with precip. (> 1 mm)				
February	3/1	0/0	1/0	0/0	5/2
April - May	21/2	3/0	184/14	116/12	124/16
Oct. - Nov.	8/0	3/3	192/14	65/8	104/15
Ø Year	53/6	5/8	502/49	402/63	333/61

Table II-1. Meteorological data (Statistisches Bundesamt, 1982)

Ethnically, the majority of the Somali population consist of various Hamitic tribes such as the Dir, Galla, Danakil, Isaq and Digli, which share common cultural, linguistic and religious backgrounds. Especially in the coastal areas, there is a large inter-mixture of Arab and Bantu influences. In addition, a small part of the population is of Asian (mostly Indian) and European (mainly Italian) heritage. The state religion is Islam, and most Somalis belong to the Sunni sect.

The official language since 1972 is Somali, which replaced Italian and English. In 1973, a nationally accepted Latin script was adopted for the Somali language. The second official language of the SDR is Arabic.

Because of the different languages involved, topographic names may be in Italian, English or Somali. An attempt is made throughout this report to spell in a consistent manner.

The population of Somalia was estimated in 1975 at 3.8 millions and is divided into three major groups: urban (35%), settled rural (10-15%) and nomadic or semi-nomadic (50-55%).

The urban population lives in towns, located mainly along the coast including Mogadiscio, the country's capital with an estimated 450,000 inhabitants, Kisimayo (ca. 60,000), Merca (ca. 30,000) and Brava (12,000). Inland centers include Hargeisa (ca. 60,000), Baidoa (ca. 30,000) and Afgoi (ca. 22,000). The average population density (fig. II-4) amounts to 5.7 inhabitants/km², with the highest densities of 11-48 inhabitants in the Shebeli and Juba Valleys, as well as in urban areas including Mogadiscio, Obbia, Burao, Hargeisa and Berbera.

Somalia, independent since 1960, is a socialist republic headed by a president, elected for a period of 6 years, who is also Chairman of the Somali Revolutionary Socialist Party. In 1980 the country constituted its first parliament, with 177 members drawn from the Party. The Government, headed by the President, consists of 25 ministers and 27 vice-ministers.

Administratively, the SDR is divided into 11 regions and 83 districts (fig. II-5). The 16 regions and their respective capitals and areas are listed in Table II-2.

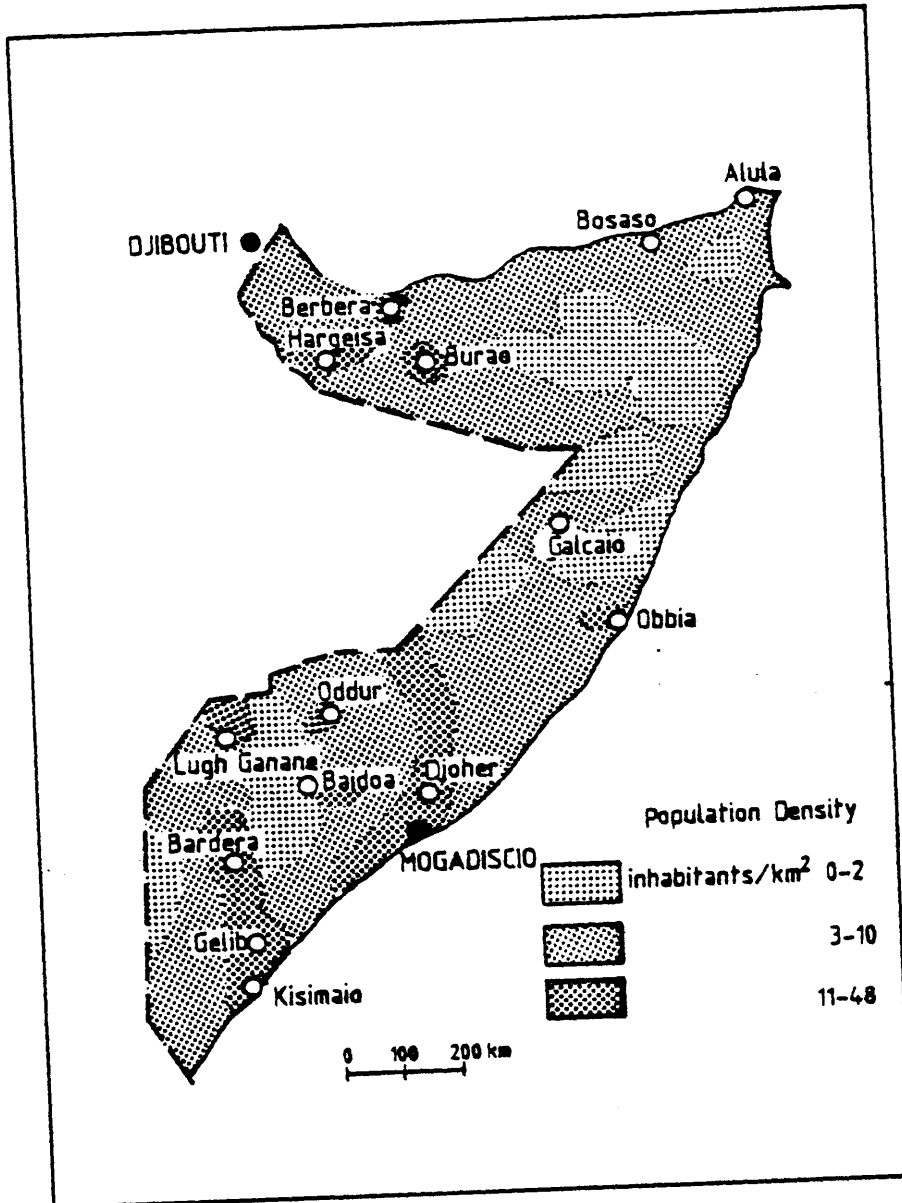


Fig. II-4. Population density (Statistisches Bundesamt, 1982)

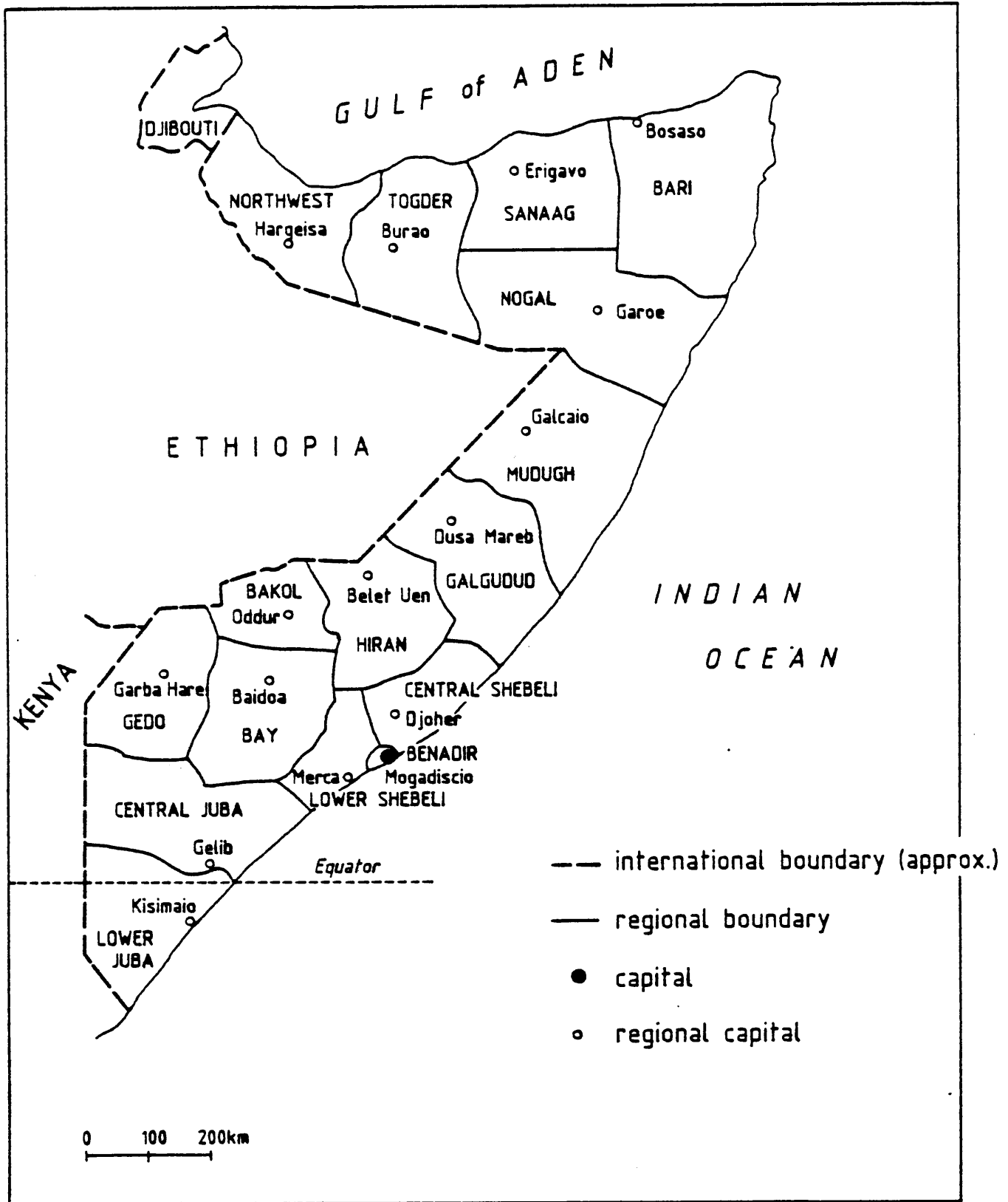


Fig. II-5. Administrative divisions (Statistisches Bundesamt, 1982)

Table II-2. Administrative Divisions

Region	Capital	Approx surface (km ²)
Northwest	Hargeisa	45,000
Togder	Burao	41,000
Sanaag	Erigavo	54,000
Bari	Bosaso	70,000
Nogal	Garoe	50,000
Mudugh	Gallacaio	70,000
Galgudud	Dusa Mareb	43,000
Hiran	Belet Uen	34,000
Central Shebeli	Djoher	22,000
Lower Shebeli	Merca	25,000
Benadir	Mogadiscio	1,000
Gedo	Garba Hare	32,000
Central Juba	Gelib	23,000
Lower Juba	Kisimayo	61,000
Bakol	Oddur	27,000
Bay	Baidoa	39,000

The country has no railways. All domestic traffic is either by road or by air. The road network (fig. II-6) consists of a total of some 19,380 km, in the following categories:

paved roads: 2153 km
 unpaved roads: 17,257 km.

Somali Airlines and several international airlines maintain flights from Mogadiscio to Kenya and various Arab countries, as well as to Italy and Germany. In addition, Somali Airlines serves the local airports of Hargeisa, Berbera, Kisimayo, Burao, Gardo, Bosaso, Alula, Candala and Gallacaio from its main base in Mogadiscio (fig. II-6). Domestic shipping along the Somali coast is insignificant as the near-coast coral reefs impede traffic. The important international seaports are Mogadiscio, Kisimayo, Merca, Bosaso and Berbera. The total ingoing and outgoing shipments are ca. 2,000,000 t per annum (1978).

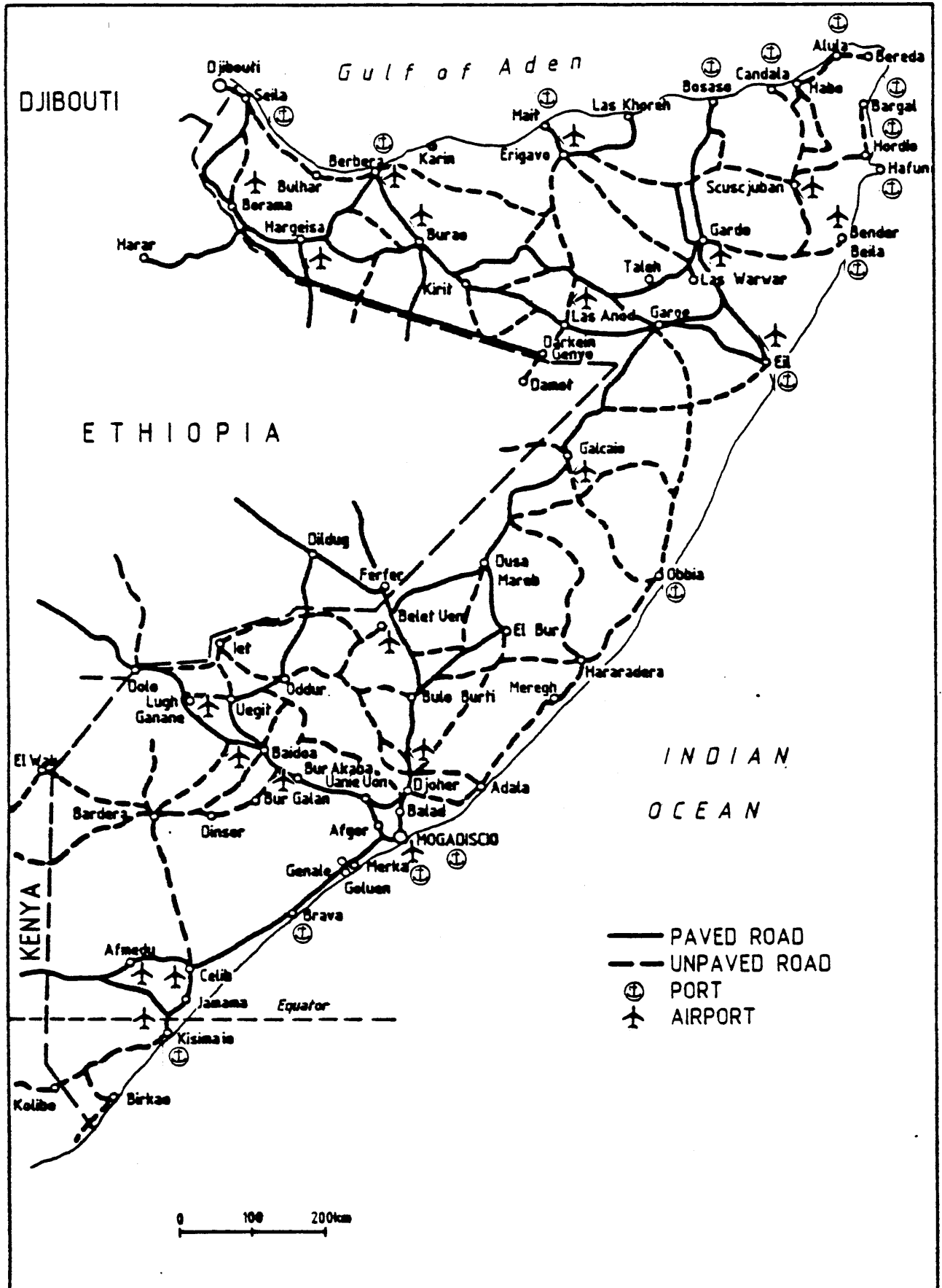


Fig. II-6. Infrastructure (Statistisches Bundesamt, 1982)

The Somali economy is largely based on agriculture and consists of both livestock production and cultivation.

Livestock include 4 million cattle, 10 million sheep, 16.5 million goats and 5.5 million camels. The products (meat, hides) are very important both for the domestic market and export. 70% of the value of total exports is contributed by meats and hides.

The cultivation of agricultural products is geographically limited to the area between the Juba and Shebelle Rivers. Principal crops are maize, sorghum, bananas and sugar cane.

The main trading partners for the SDR in 1979 were:

Imports:	Italy	US\$ 84.2 million	53%
	UK	US\$ 32.9 million	21%
	FRG	US\$ 17.7 million	11%
	Kenya	US\$ 16.1 million	10%
	P.R. China	US\$ 5.1 million	3%
	USA	US\$ 3.0 million	2%
	TOTAL	US\$ 159.0 million	

Exports:	Saudi Arabia	US\$ 81.2 million	85%
	Italy	US\$ 13.5 million	14%
	P.R. China	US\$ 1.0 million	1%
	TOTAL	US\$ 95.8 million	

Mineral production plays only a very minor part in the Somali economy. In 1978 only 597 persons or 0.5% of the working population were engaged in the mineral industry (Statistisches Bundesamt, 1982) at some 30 production sites. The value of the mineral production of Somalia is estimated at 0.03% of the GNP of US\$ 470 million (1978), i.e. about US\$ 140,000.

Information on the energy economy is very scarce and limited to Mogadiscio. Approximately 90% of the energy in the Mogadiscio area is generated by diesel-powered generators, which in 1980 provided some 59.8 million kWh

or about 150 kWh per capita. Somalia plans to construct a hydroelectric plant with a capacity of 25 MW in the Juba Valley at Bardera. Construction of the dam and associated hydroelectric plant is scheduled to begin in 1984.

All petroleum and oil derivatives required in the SDR are imported from oil-producing Arab countries. The total value of these imports amounted to US\$ 13.5 million in 1980 (Statistisches Bundesamt, 1982) and are estimated to have reached approximately US\$ 20 million in 1982.

The utilization of nuclear energy in Somalia is not planned within the foreseeable future.

II.3. Available Maps and Aerial Photographs

Topographic and geological maps of Somalia as well as aerial photographs, even when available, are very difficult to obtain. The best source for consultations concerning maps, is the Somali Geological Survey's cartographic section.

Below is an attempt to describe the coverage of the various series of maps and aerial photographs.

Topographic maps of Somalia exist at the following scales:

1. 1:1,000,000. Published originally in 1942 by the British Government, reproductions were made in 1946 by the War Office. This map series covers all of Somalia. At the same scale is the Operational Navigation Chart of 1977 which has complete coverage of Somalia, on five sheets: ONC/K-5, K-6, L-5, L-6 and M-5.
2. 1:500,000. Published in black and white by the British Government in 1942, and reproduced by the War Office in 1946; these maps cover the whole of Somalia (fig. II-7).
3. 1:250,000. Published by the British Directorate of Overseas Surveys through 1959, coverage of this series is limited to the former British Somaliland Protectorate.

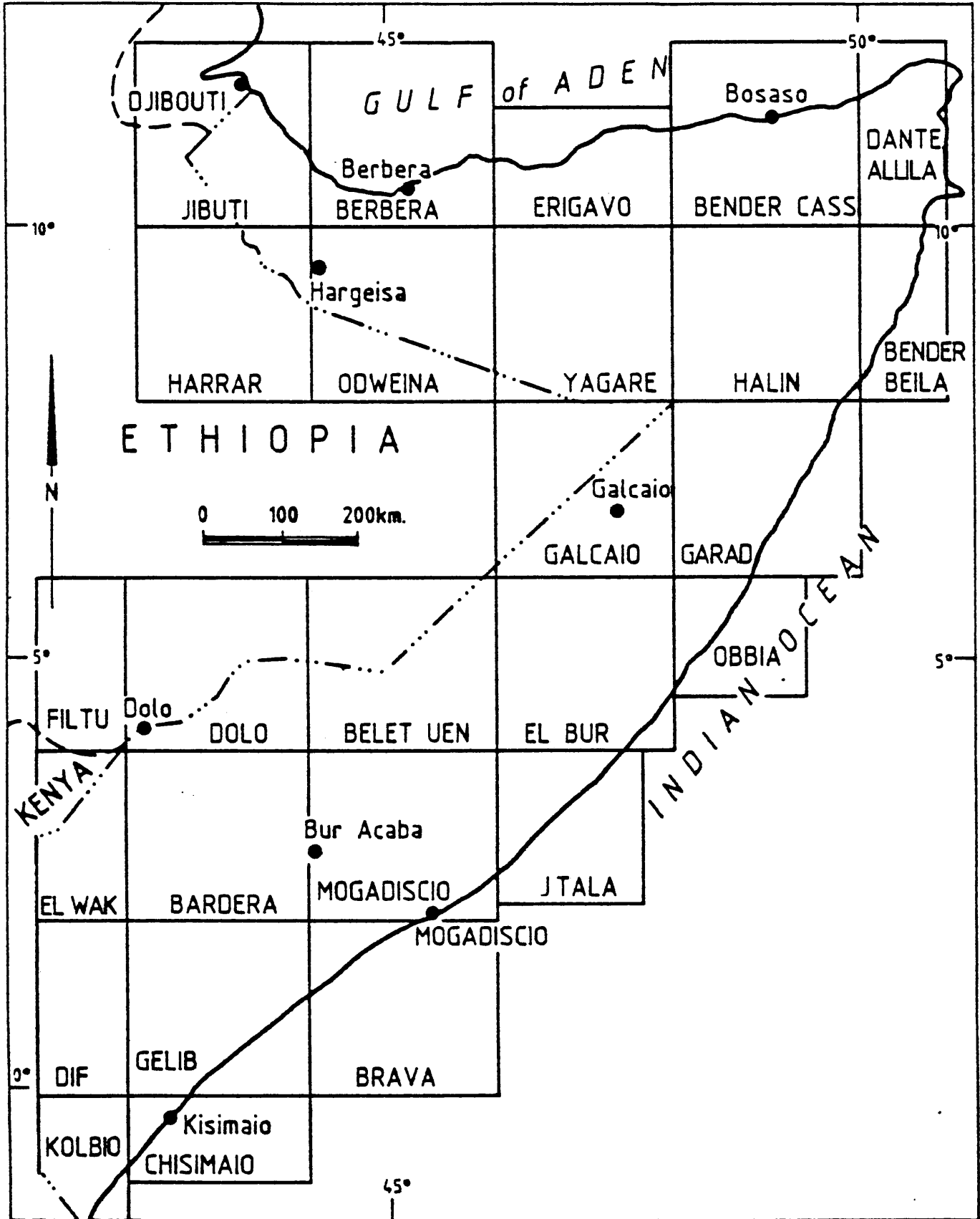


Fig. II-7. 1:500 000 scale topographical map coverage.

4. 1:125,000. Published by the British Directorate of Overseas Surveys through 1959, these maps exclusively cover the area of the former British Somaliland Protectorate.
5. 1:100,000. Published by Russian Technical Aid, in Moscow, USSR, in 1976, this series covers the entire SDR. The map legends are only in the Somali language. A limited stock of maps exists in the cartographic section of the Somali Ministry of Defense, but are not available for purchase, as reprints of these maps cannot be obtained from Moscow following the deterioration of political relations between Somalia and the Soviet Union in 1978.

The Geological Survey has acquired the necessary equipment to make black and white reproductions of these topographic maps. It consists of a DS Photoace C-260-D medium low-bed process camera manufactured by the Dannippon Screen Mfg. Co., Ltd. of Kyoto, Japan. It can provide copies ranging from 20% (1/5) through 800% (8 X) of the original. Thus, using a set of the 1:100,000 topographic sheets as originals, it can provide maps at scales ranging from 1:500,000 to 1:12,500. The equipment was not yet in operation in March 1983.

The available geological maps of Somalia include a series of 14 sheets at a scale of 1:250,000 published in 1950 (McKay and others, 1950) by the British Petroleum Company, as well as $\frac{1}{2}$ -degree sheets at a scale of 1:125,000 published in Britain between 1956 and 1970 for the Somali Geological Survey.

The 1:250,000 scale series consists of 14 sheets covering an area between coordinates (Fig. II-8):

A : 11°46' N / 42°23' E
 B : 9°00' N / 42°23' E
 C : 9°00' N / 45°22' E
 D : 8°00' N / 45°22' E
 E : 8°00' N / 49°31' E
 F : 11°22' N / 49°31' E
 G : 11°22' N / 48°11' E
 H : 11°04' N / 48°11' E

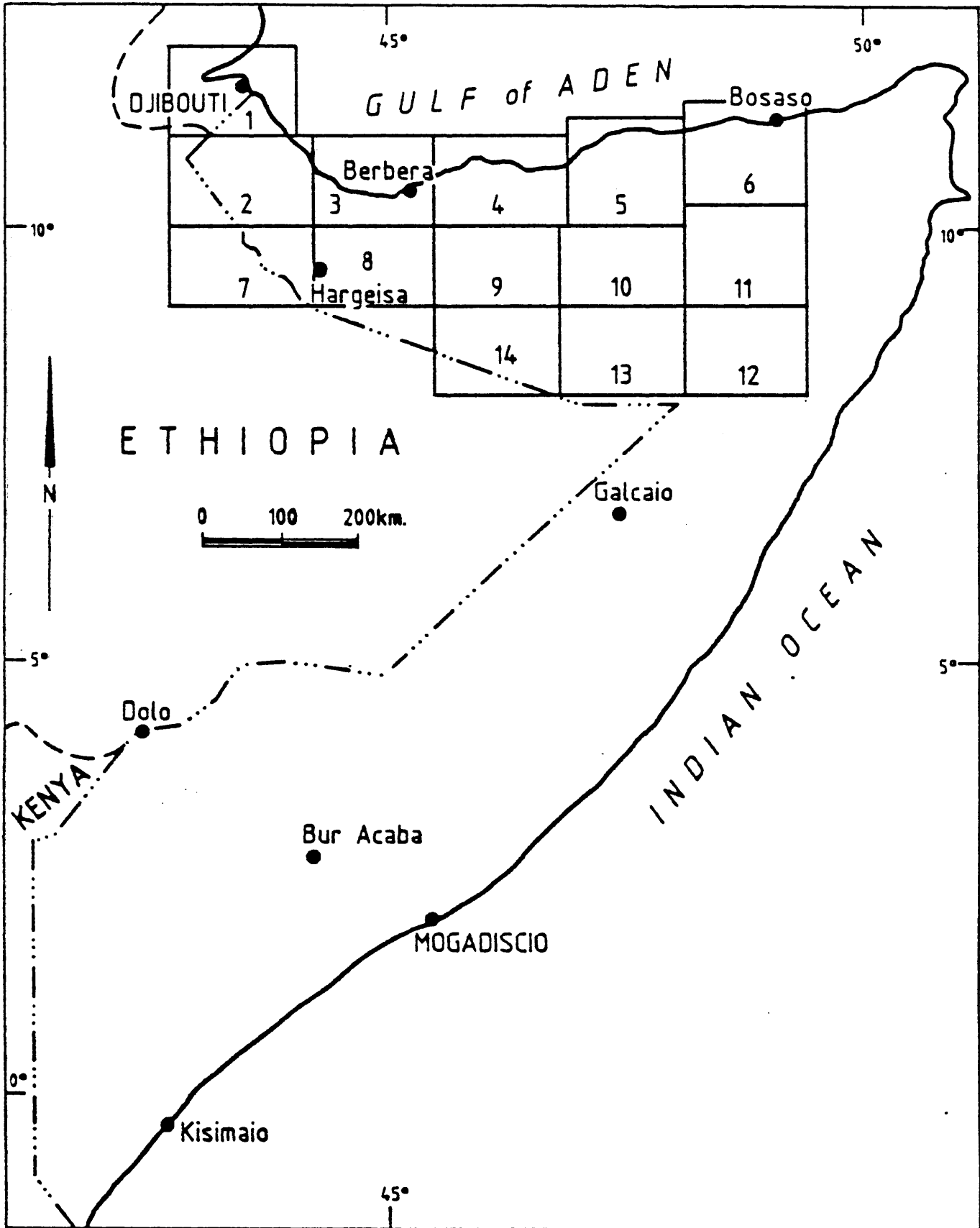


Fig. II-8. 1:250 000 scale geological map coverage

I : 11°04' N / 46°49' E
 J : 10°55' N / 46°49' E
 K : 10°55' N / 43°46' E
 L : 11°46' N / 43°46' E

This area, slightly larger than the former Somaliland Protectorate is shown in fig. II-9.

The 1:125,000 scale geological maps also cover parts of the former Somaliland Protectorate and include 24 sheets, namely Abdul Qadr, Gocti, Silil, Bawn, Borama, Hargeisa, Qabri Bahar, Gebile, Bulhar, Adadleh, Laferug, Berbera, Sheikh, Las Dureh, Burao, El Dur Elan, Habaji, Harshaw, Heis, Erigavo, Waqderic, Medishe, Las Khoreh and Elayu (fig. II-9). The total area covered by these maps amounts to 43,505 km² or about 6.8% of Somalia. In addition, large parts of Somalia are covered by geological maps at various scales produced by several oil companies. All geological information available before 1971 was compiled by UNDP (1972a) into the unpublished Geological Map of Somalia at a scale of 1:1,000,000. Copies of this map are difficult to obtain and must be handcolored. The original is a sepia print which is kept in the Geological Survey's cartographic section. Copies are of very poor quality.

Conventional aerial photographs made by the British Royal Air Force and private survey companies including Hunting Geology and Geophysics cover some 96% of the country at scales of about 1:30,000 (northern Somalia) and 1:60,000 (southern Somalia). Single copies of these photographs are stored at the Geological Survey and can be consulted on the premises.

The area not covered by aerial photographs is located around Kisimayo (fig. II-10) and comprises ca. 27,000 km² equal to ca. 4% of the country. This area is limited by the following coordinates:

A : 1°32' N / 42°43' E
 B : 0°38' N / coast
 C : 0°34' S / coast
 D : 0°28' N / 41°23' E

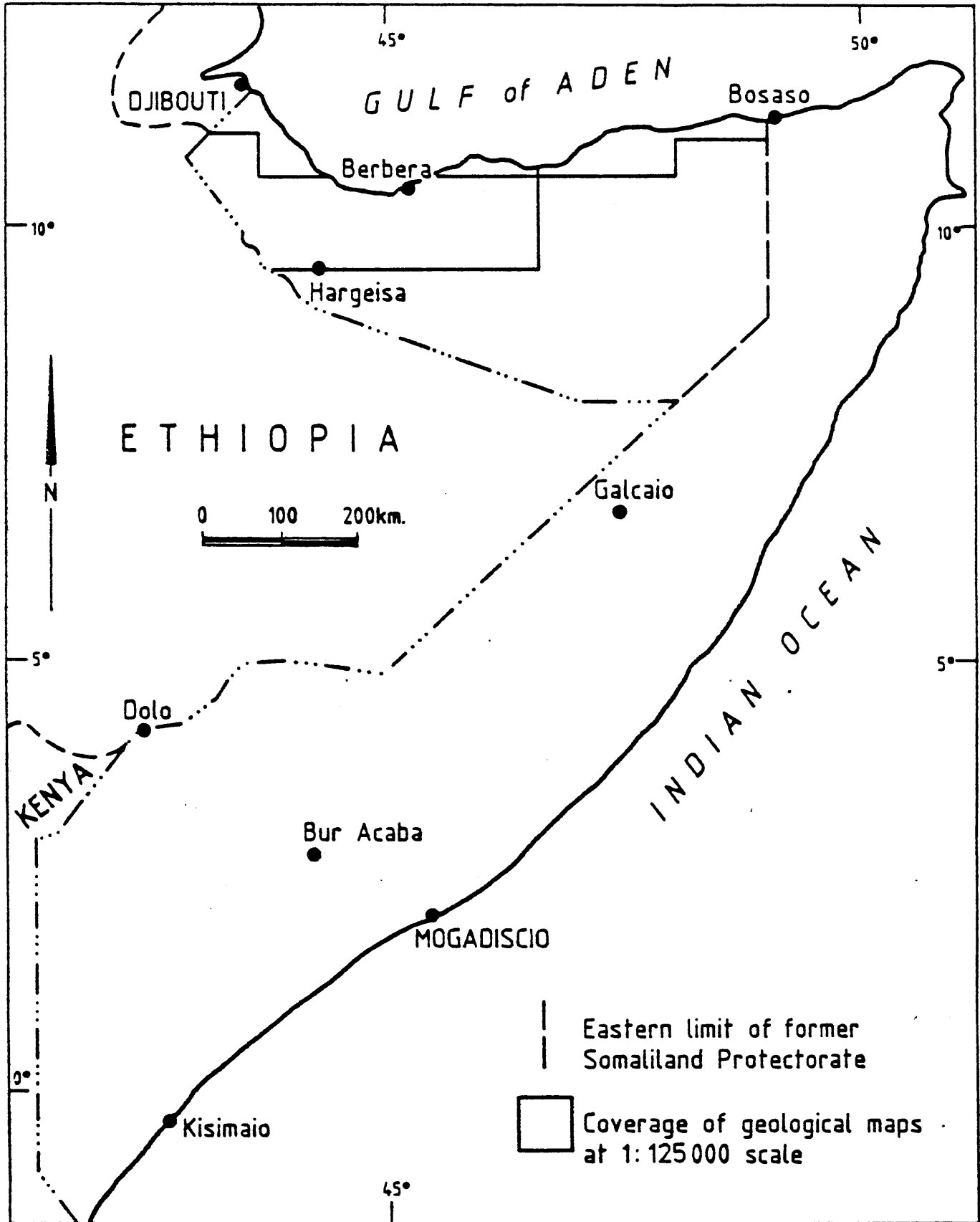


Fig. II-9. 1:125 000 scale geological map coverage

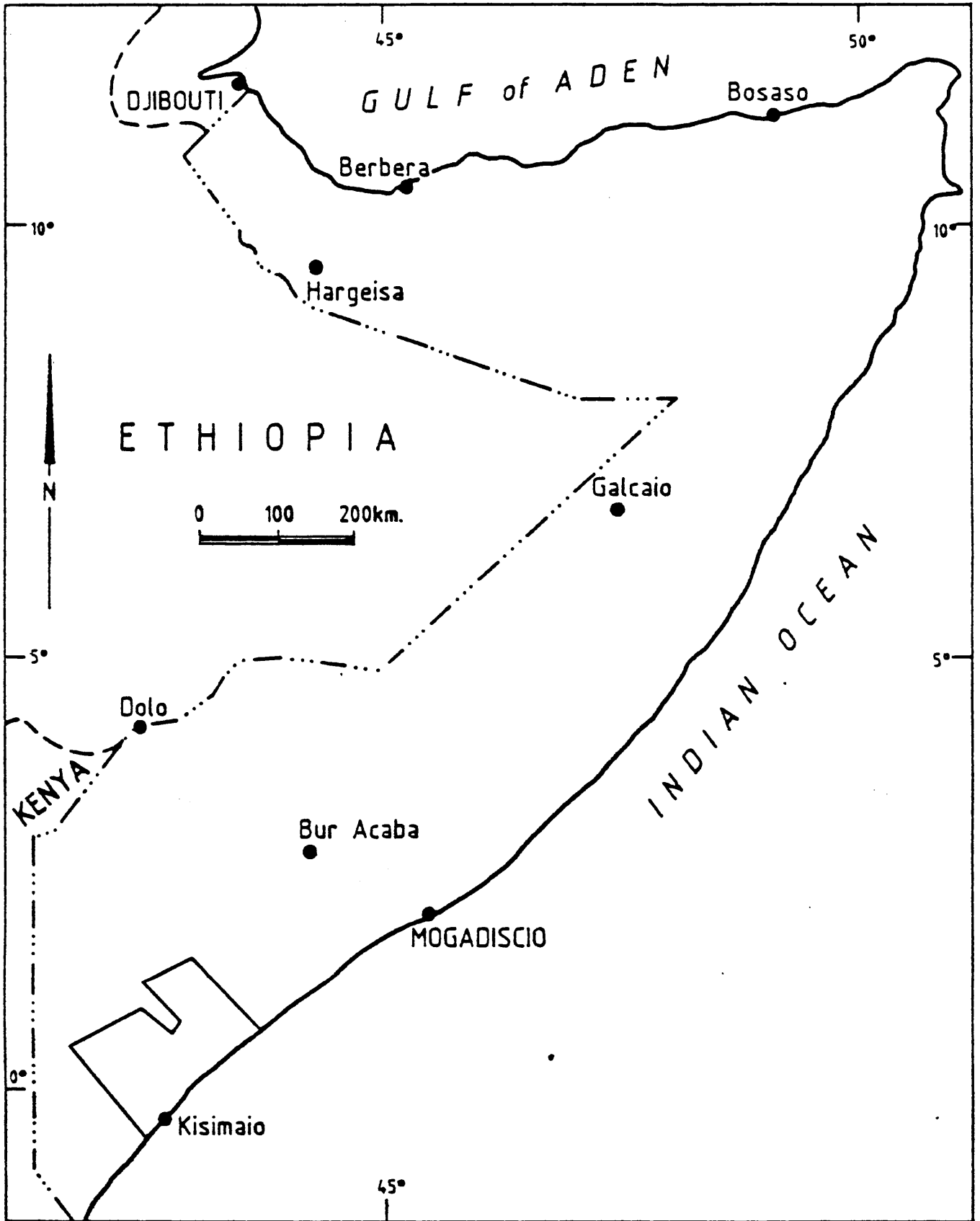


Fig. II-10. Area not covered by conventional aerial photographs.

E : 0°58' N / 42°13' E
F : 0°37' N / 42°32' E
G : 0°45' N / 42°38' E
H : 1°15' N / 42°13' E

It is reported that Russian Technical Aid produced complete aerial photographic coverage of Somalia about 1975. These photos were used to produce the 1:100,000 scale topographic maps. Unfortunately the negatives and copies of these air photos are in the USSR and cannot be obtained by the Somali government.

Satellite imagery covers Somalia in 43 frames on seven north-northeast trending lines. The quality of this imagery is unknown (fig. II-11).

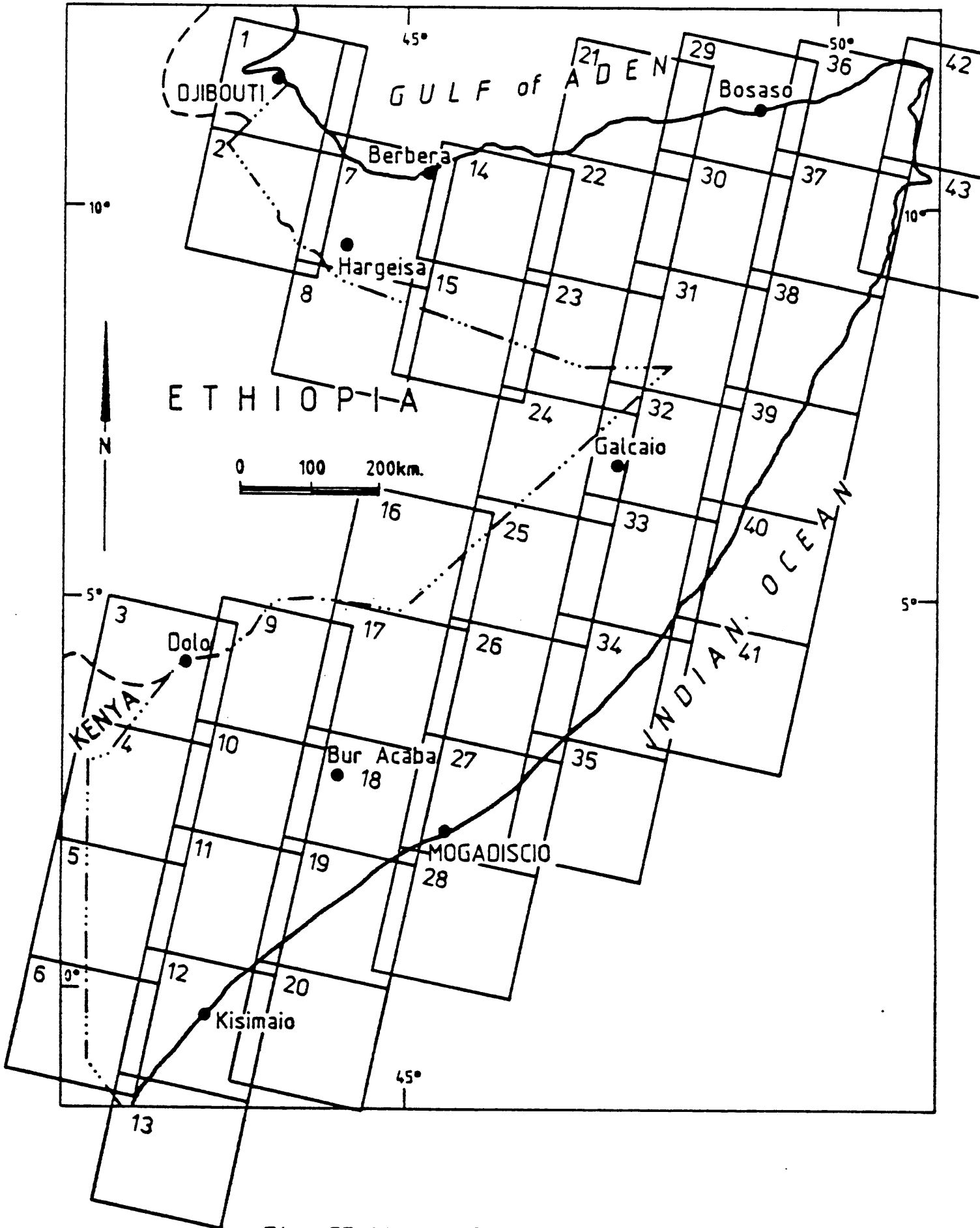


Fig. II-11. Satellite imagery coverage.

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III. GOVERNMENTAL ORGANIZATIONS OF GEOLOGICAL AND MINING ACTIVITIES

III.1. General Organization

The entire natural resources field is under the authority of the Ministry of Mineral and Water Resources, located at km 7 of the Afgoi Road in Mogadiscio. The postal address is P.O. Box 744, Mogadiscio.

Fig. III-1 is an Organization Chart of the Ministry and illustrates the relation of the Directorate General to the four departments:

- the Geological Survey department;
- the Mining and Hydrocarbons department;
- the Hydrology department; and
- the Administrative department.

Both the Geological Survey and the Mining and Hydrocarbons departments are concerned with different stages in the development of a uranium industry.

The Geological Survey department, located on the same premises as the Ministry, is headed by its Director (1983), Mr. Mohamed Said Abdi, a professional geologist. Besides the main office in Mogadiscio, the Geological Survey maintains a branch office for northern Somalia in Hargeisa. The main office consists of five sections:

- geology;
- laboratories with units for sample preparation, analytical chemistry and mineralogy/petrography;
- cartography with units for photogeology and drafting;
- geophysics; and
- drilling.

The total staff of the Geological Survey consists of 128 persons including:
 29 professionals (geologists, geochemists, etc.)
 4 technicians;
 82 on-the-job trained skilled workers (drivers, mechanics, etc.);
 and
 13 unskilled workers.

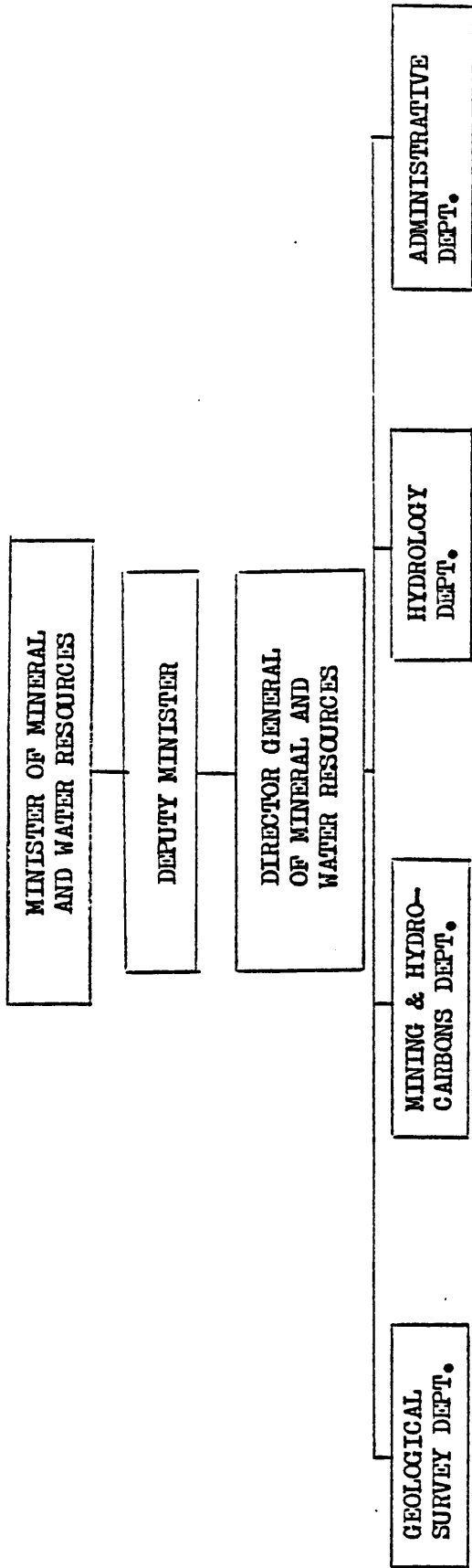


Fig. III-1: ORGANIZATION CHART: MINISTRY OF MINERAL AND WATER RESOURCES

The 1981 budget, according to the Three Year Development Plan 1979 - 1981, was to amount to SoSh 28,551,000, or US\$ 4,605,000 (6.20 SoSh = 1 US\$). The actual Geological Survey budget for 1981, however, reached only SoSh 6,296,074 or US\$ 1,015,495, (22% of the budget projected in the Three Year Development Plan). This actual budget includes all Survey projects including the counterpart contributions for the UN- TCD Project "Strengthening of the Geological Survey" SOM/82/003.

The projected budget for the Geological Survey for the Five Year Development Plan 1982 - 1986 is as follows:

1982:	SoSh 31,150,000	= US\$ 2,076,666	(at 15 So.Sh = 1 US\$)
1983:	SoSh 33,189,000	= US\$ 2,212,600,	+ 6.5%
1984:	SoSh 34,353,000	= US\$ 2,290,200,	+ 3.5%
1985: ⁺	SoSh 27,657,000	= US\$ 1,843,800,	- 24%
1986:	SoSh 29,113,000	= US\$ 1,940,867,	+ 5.3%

In addition to the projected budgets of the Geological Survey are the contributions of the UN- TCD Project for equipment, personnel, fellowships and other cash expenditures approximately amounting to:

US\$ 400,000	for 1982
US\$ 450,000	for 1983
US\$ 204,000	for 1984.

The Mining and Hydrocarbons department, also housed at the Ministry of Mineral and Water Resources, consists of three sections:

- mining;
- joint ventures between the Government and mining companies (e.g. with the Arab Mining Company); and
- hydrocarbons.

The actual 1981 budget for the Mining and Hydrocarbons department amounted to SoSh 3,510,000 or at an exchange rate of 6.20 SoSh = 1 US\$ to US\$ 566,129.

The Five Year Development Plan 1982 - 1986 provides the following budgets:

⁺drastic decrease due to termination of UN- TCD Project

1982:	SoSh	50,947,000	= US\$ 3,396,467
1983:	SoSh	55,504,000	= US\$ 3,700,266, + 11%
1984:	SoSh	81,734,000	= US\$ 5,448,933, + 47%
1985:	SoSh	101,896,000	= US\$ 6,793,066, + 25%
1986:	SoSh	101,896,000	= US\$ 6,793,066, -

The projected budget increased, especially for 1984 and 1985, are mainly for the Mudugh Uranium Project located near Dusa Mareb, which shall be operated by the Somali Arab Mining Company.

III.2. Uranium Exploration Capabilities of the Geological Survey

The overall technical capabilities of the Geological Survey to carry out uranium exploration appears to be very limited. Following the successful completion of UNDP Phase I and Phase II Projects (1964 - 1974), in which many Somali geoscientists participated in uranium exploration as counterparts to UNDP personnel, only one uranium exploration program has been carried out by the Somali Geological Survey. Naleye (1981) described a radiometric carborne survey in the Nogal area.

The Geological Survey's radiometric instruments were examined by a UNDP consultant in November - December 1980 (Bosschart, 1980), who inventoried the following equipment and evaluated its condition:

- 8 Scintrex scintillometers BGS-1, five are operational and three unserviceable;
- 1 SRAT scintillometer SPP-2, unserviceable;
- 1 Geometrics scintillometer, unserviceable;
- 5 Scintrex spectrometers GIS-2, three are operational and two unserviceable;
- 1 Geometrics spectrometer DISA-400A, unserviceable;
- 2 Scintrex drillhole probes BHP, one operational and one unserviceable;
- 1 Scintrex sensor, crystal volume unknown, serviceable with GIS-2 spectrometer.

The present (1983) condition of these instruments could not be ascertained by the Mission. It may, however, be assumed that the

equipment's condition has further deteriorated, since the consultant's recommendations for maintenance and reconditioning do not appear to have been followed.

The Geological Survey's geochemical laboratory is equipped with a Jarrel Ash fluorimeter which was acquired in 1971, but has not been used since 1974. At present, the analytical laboratory is headed by a UNDP chemist who is able to analyze for uranium, when his work is not interrupted by frequent water cuts, power outages and equipment failures.

It may be concluded that for all practical purposes, the Geological Survey has no technical personnel experienced in uranium exploration. Should the Survey decide to carry out uranium exploration projects, it will have to request professional support from the IAEA or bilateral agencies in addition to a supply of modern field radiometric equipment (scintillometers, spectrometers, etc.).

The library at the Geological Survey is very small and contains few references on uranium geology. Furthermore, it is almost totally disorganized, and it is practically impossible to find references on local geology, even when they are known to exist. Many reports are kept in the personal collections of the Director of the Geological Survey and other officers of the Ministry of Mineral and Water Resources. Periodicals are in poor supply and few have been received during the last decade. A number of reports are merely third or fourth carbon copies which are difficult to read and next to impossible to photocopy. Other reports are unavailable and their whereabouts unknown. If the condition of the library is permitted to deteriorate further (as seems likely), it soon shall be most difficult to locate and use any basic data concerning the geology of Somalia and previous studies, especially those concerning uranium exploration.

IV. MINING LEGISLATION AND CONTRACTUAL MODELS FOR URANIUM
EXPLORATION AND MINING

IV.1. Mining Legislation

Although it is known that a new mining code is being prepared (1983), the Mining Code, published as Law No. 77 of 22nd November 1970, and the Mining Regulations, the Decree of the President of the Supreme Revolutionary Council No. 173 of 3rd April 1971 are still in force and do not exclude the prospecting, exploration and mining of radioactive minerals (Art. 1 of the Mining Code).

The Mining Code consists of ten parts which treat the following topics:

Part I	General Provisions;
Part II	Rights and Obligations of Holders of Prospecting and Mining Rights;
Part III	Prospecting and Mining for Minerals Other Than Mineral Oil;
Part IV	Mineral Oil;
Part V	Royalty on Export and Local Sale of Minerals;
Part VI	Restricted Minerals;
Part VII	Safety, Inspection and Accidents;
Part VIII	Registration;
Part IX	Disputes;
Part X	Miscellaneous, Penal and Final Provisions.

Part I decrees that the entire property and the control of all minerals on and off-shore is vested in the Somali State. The State is empowered to grant permits, licences and leases, except in areas closed for prospecting, exploration and mining activities (burial grounds, mosques, land required for public purpose, in settlements, around pipelines, canals, dams, roads, highways, game and forest reservations, water wells, airports, etc.). The State, however, has the right to remove minerals required for any public purpose from any land, also subject to permits, licences and leases.

Part III states the legal basis for prospecting and production activities. The prospecting permit has a duration of one year, and is renewable for further periods of one year. This permit, which is not exclusive, can upon application proving the necessary financial means, be transferred

into an exclusive prospecting licence for 8 mi² or greater, under conditions the Secretary of Mines may think fit. The duration of the exclusive prospecting licence is initially one year with extensions of one year each up to a maximum of five years duration. For larger areas licences of longer duration are possible. Both the prospecting permit and the exclusive prospecting licence can, upon application, lead to the granting of a mining permit, which is necessary for the production of mineral resources other than oil. The initial duration of the mining permit is one year, renewable for an undefined period. If the mining operation being conducted under the mining permit reaches a scale warranting a mining lease, the holder of the permit may be required to obtain one. The duration of the mining lease is between 5 years and a maximum of 21 years.

Part V states that royalties must be paid for all minerals removed from the land, subject to prospecting permits, exclusive prospecting licences, mining permits or mining leases, and that permits must be obtained for the export of mining products.

The Mining Regulations contain ten parts dealing in detail with the following matters:

- Part I: General Provisions;
- Part II: Prospecting Permit;
- Part III: Exclusive Prospecting Licence;
- Part IV: Mining Permit;
- Part V: Mining Lease;
- Part VI: Miscellaneous Applications;
- Part VII: Permits and Lease for Mineral Oil;
- Part VIII: Returns, Reports, Annual Plans, etc;
- Part IX: Registration, etc;
- Part X: Use of Explosives for Prospecting or Mining;
- Part XI: Miscellaneous and Final Provisions.

Part III provides for a rectangular shape for the exclusive prospecting licence area, the form of application and an annual work obligation of So.Sh. 2000 (US\$133)⁺ per mi². The annual rent for an exclusive prospecting licence area of eight mi² amounts to SoSh 1600 or approximately US\$ 107, according to the First Schedule of the Mining Regulations.

⁺SoSh = Somali Shillings, actual exchange rate is approx. 15 SoSh = 1 US\$.

Part IV contains the provisions for a mining permit. Its size is 300 x 300 ft for building material and alluvial minerals, and 1500 x 600 ft for all other minerals except mineral oil. The annual rents for quarrying stone or burning lime are:

- . for an area of less than 5000 yd²: SoSh 300 (ca. US\$ 20)
- . for areas between 5000 and 10,000 yd²: SoSh 600 (ca. US\$ 40)
- for all other minerals except mineral oil: SoSh 100 (ca. US\$ 6.70).

The mining lease is discussed in Part V and the First Schedule states an annual rent of SoSh 7000 (US\$ 470) per mi², while the annual surface rent payable under Article 47 of the Mining Code is fixed at SoSh 14,000 (US\$ 935) per mi².

The Second Schedule of the Mining Regulations provides a 5% net royalty for all minerals removed from the land subject to permits, licences or leases. The net value is defined in Part I of the Mining Regulations as "the gross value of the mineral or mineral product less such deductions as the Secretary (of Mines) may allow in respect of expenditure on transport, insurance, assaying, smelting or refining charges, where these are borne by the producer of the mineral or mineral product".

IV.2. Contractual Models for Uranium Exploration and Mining

IV.2.1. Introduction

In the past, the Government of Somalia concluded a number of agreements with international mining companies on uranium exploration and mining activities within certain areas of the SDR. The first three agreements were concluded in 1968 and 1969 with SOMIREN S.p.A.⁺ of Italy, Western Nuclear, Inc. of the USA and a German consortium including Uranerzbergbau GmbH & Co. KG and Urangesellschaft mbH and Co. KG. The Government had invited bids from the international mining industry for areas in the Precambrian Bur area, where a UNDP-financed aerial magnetometer scintillometer survey had encountered radiometric anomalies.

⁺ a company of the ENI-Group

Later, in September 1977 the Somali Government entered into an agreement with the Government of Iraq and the Arab Mining Company of Jordan for the exploitation of the calcrete deposits of the Mudugh Area.

In the following sections the agreements with SOMIREN and Western Nuclear, Inc., published in the Official Bulletin (Somali Republic, 1969a, 1969b) will be reviewed. Copies of the contracts with the German consortium and with the Government of Iraq and the Arab Mining Company were not available to the Mission.

IV.2.2. SOMIREN Agreement

In December 1968 Somalia granted SOMIREN an exclusive licence for prospecting, exploration and development of mineral deposits with special reference to uranium and allied minerals. The area covered by this licence consisted of eight blocks of approximately 1031 km each totalling ca. 8249 km² with the following coordinates:

Block 1-E	A	3°20' N / 43°45' E
	B	3°20' N / 44°00' E
	C	3°00' N / 43°45' E
	D	3°00' N / 44°00' E
Block 4-W	A	3°00' N / 43°30' E
	B	3°00' N / 43°45' E
	C	2°40' N / 43°30' E
	D	2°40' N / 43°45' E
Block 4-E	A	3°00' N / 43°45' E
	B	3°00' N / 44°00' E
	C	2°40' N / 43°45' E
	D	2°40' N / 44°00' E
Block 8-E	A	2°40' N / 43°15' E
	B	2°40' N / 43°30' E
	C	2°20' N / 43°15' E
	D	2°20' N / 43°30' E
Block S-W	A	2°40' N / 43°30' E
	B	2°40' N / 43°45' E
	C	2°20' N / 43°30' E
	D	2°20' N / 43°45' E

Block S-E	A 2°40' N / 43°45' E
	B 2°40' N / 44°00' E
	C 2°20' N / 43°45' E
	D 2°20' N / 44°00' E
Block 13-E	A 2°20' N / 43°15' E
	B 2°20' N / 43°30' E
	C 2°00' N / 43°15' E
	D 2°00' N / 43°30' E
Block 14-W	A 2°20' N / 43°30' E
	B 2°20' N / 43°45' E
	C 2°00' N / 43°30' E
	D 2°00' N / 43°45' E

This exclusive licence was granted initially for a period of five years, but could have been extended by three consecutive periods of one year each.

For the purpose of conducting activities SOMIREN would incorporate a Somali subsidiary, and the Somali Government was entitled to a participation in the share capital of the company. The agreement provided for the issue of three classes of shares:

- Class A : shares belonging to the Government of Somalia,
- Class B : shares belonging to SOMIREN,
- Class C : shares belonging to a possible third partner.

These classes of shares would have been freely transferable among the partners, who also had a right of first refusal should one of the partners desire to sell shares.

The annual rental for the exclusive prospecting licence amounted to So.Sh. 200 per mi², equal to ca. SoSh 77.20 per km².

The annual work obligation for the area covered by the exclusive prospecting licence amounted to SoSh 2000 per mi², equal to SoSh 772 per km², which included a subsidy charge of some SoSh 54 per km² to the Somali Government for the aerial survey carried out over areas of the licence. The total amount of the annual work obligation (8048 x SoSh 772 = SoSh 6,213,056) had to be covered by a bank guarantee.

If an economically viable uranium and/or allied mineral deposit was

discovered, the exclusive prospecting licence would have been transferred into a mining lease.

If this discovery was made in areas other than Block 9-W which included the Alio Ghelle Prospect, the Government had the right to obtain without consideration the transfer of 10% of the total share capital. In the event, however, that the discovery was located in the Alio Ghelle Area, Block S-W, the number of free shares issued to the Government would have amounted to 20% of the company's share capital.

The mining lease would have had an initial duration of 21 years, extendable by two consecutive periods of 10 years each.

On the granting of the mining lease the company would have had to make the following payments to the Government:

- a filing fee of SoSh 1000 per mi² or SoSh 386 per km²;
- a mining lease rent of SoSh 7000 per mi² or SoSh 5405 per km² p.a.; and
- a royalty of 1% on the total FOB Somali port value of production sold, minus transport and loading costs from the harbor depot to the exporting vessel.

The fiscal provisions stipulated a tax holiday of one year and thereafter a total payment for the company including all taxes, rentals, fees, etc. of 50% of the profits. Should the total amount of all those payments be in excess of 50% of the profit, the excess would have been carried forward and credited against the fiscal obligations of the following years.

In addition to the fees and rentals to be paid to the Somali Government, SOMIREN had the following special obligations:

- a bonus payment of US\$ 100,000, payable in two equal installments upon receipt of the exclusive prospecting licence and after being granted the mining lease;
- a 2 year exploration program having an overall expenditure of US\$ 2,000,000 in the northern regions of Somalia, being defined as follows:

Western Area: size 38,215 km²

limits: Berbera

9°52' N / 46°45' E

Hargeisa

line running west from Hargeisa to the
international boundaries of Somalia with
Ethiopia and Djibouti;

Eastern Area: size: 11,564 km²

limits: 10°44' N / 46°43' E

11°15' N / 48°59' E

11°00' N / 49°11' E

Erigavo

10°28' N / 46°50' E

If SOMIREN desired to get title to all or portions of the two areas, bids from other international mining companies would be invited by the Somali Government and SOMIREN would have the first option to match the highest offer.

IV.2.3. Western Nuclear Agreement

In December 1968 Somalia granted to Western Nuclear, Inc.⁺ of Denver, Colo., USA, an exclusive licence for prospecting, exploration and development of uranium and allied deposits covering two adjoining blocks of 1031 km² each and lying inside the following corner points:

A : 2°40' N / 43°15' E

B : 2°40' N / 43°00' E

C : 2°00' N / 43°15' E

D : 2°00' N / 43°00' E

The rights and obligations of the two contracting partners were identical to those of the SOMIREN Agreement discussed in the previous section, with the exception of the tax provisions and the requirements for carrying out exploration in areas other than those covered by the exclusive licence.

⁺ the subsidiary of Western Nuclear in Somalia was named White Star Mining Co.

The following discussion is a brief review of the tax provisions:

- for the first year of production, a tax holiday would have been in effect;
- for the following four years a tax of only 10% of the net profits would have been levied by the Government;
- for the following years a tax of 50% of the net profits would have been paid to the Government (this included all fees, royalties, etc.);
- if in any year those total payments exceeded 50% of the company's net profit, the excess would have been credited against the fiscal obligations for the following years.

V. MANPOWER IN MINERAL EXPLORATION

The Geological Survey employs 29 earth scientists, many of whom have advanced degrees from foreign universities (USSR, Italy, USA, UK and others). On-the job training of geo-scientists is one of the objectives of the UN- TCD Project "Strengthening of the Geological Survey". As stated in the Five Year Development Plan 1982-1986, the Ministry of Mineral and Water Resources has a shortage of young field geologists, especially since many experienced geologists have left the country or did not return from scholarships abroad.

The academic training of geologists in Somalia is carried out at the Geological Faculty of the Somali National University. The University has an exchange program for lecturers with Italian universities. The Faculty offers a four year course in geology, from which some five geologists graduate annually following the submission of a thesis. The theses cover a wide range of topics, including an occasional one related to uranium geology. Eiyow (1982) studied the Dusa Maseb uranium deposit. The graduates appear to be well prepared academically, but lack motivation for geological field work and prospecting, possibly due to their extremely low salaries.

VI. GEOLOGY OF SOMALIAVI.1. Geology of Africa

The structure of the African continent was basically established by the dawn of Phanerozoic time. It resulted from brief episodes of tectonism separated by long periods of stability.

Seven major orogenies have been described in the various parts of Africa (fig. VI-1). They consist of the following: (a) ca. 3000 MY; (2) the Shamvaian Orogeny, 2500 - 2800 MY; (3) the Eburnian and Huabian Orogenies, 1850 ± 250 MY; (4) the Kibaran Orogeny, 1100 ± 200 MY; (5) the PanAfrican (Damaran - Katangan) Orogeny, 550 ± 100 MY; (6) the Caledonian Orogeny of middle Paleozoic time and the Hercynian Orogeny of late Paleozoic to early Mesozoic time; and (7) the Alpine Orogeny of Tertiary age. Almost 60% of Africa consists of Precambrian exposures.

Since the close of Precambrian time, Africa has, for the most part, remained emergent and stable, except in the north where it has been transgressed by epicontinental seas during the Phanerozoic. Several other coastal areas have also been the sites for limited marine transgressions. Phanerozoic strata, generally continental or marginal marine in origin, commonly rest unconformably on the Precambrian crystalline basement.

Africa was formerly part of the vast protocontinent of Gondwanaland, along with Madagascar, Australia, Antarctica, South America, India and Arabia. Various strata, including the Karoo of South Africa, were derived from sources beyond the boundaries of present-day Africa.

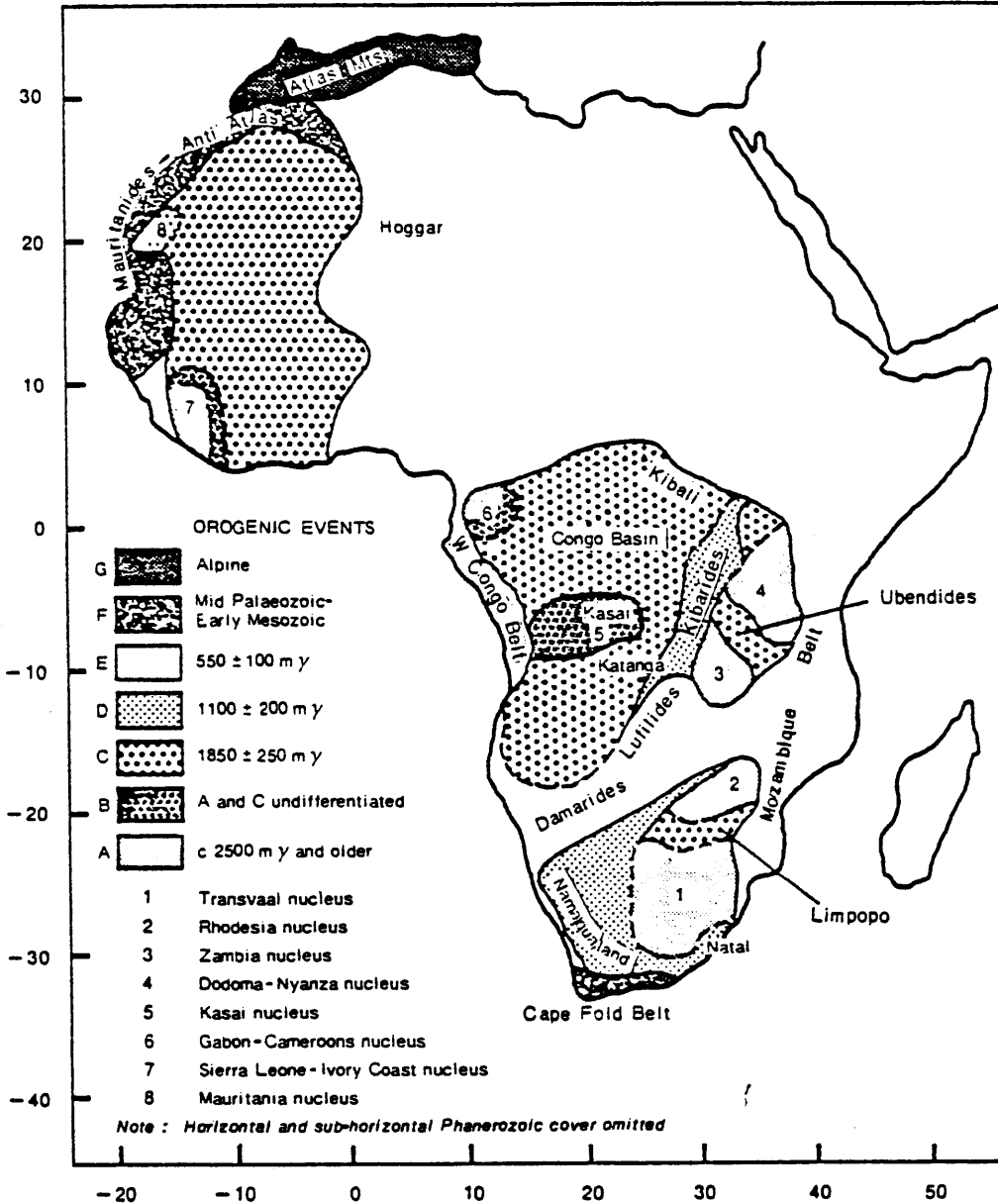
The present outline of the continent dates from early Cretaceous time. Seaward dipping marine rocks of Cretaceous age are located in several coastal basins. Several ages of Precambrian deformation have been dated to two main periods: (1) 900 - 1200 MY and (2) 450 - 600 MY.

These deformational episodes were concentrated in several mobile belts (fig. VI-2). Since the start of the Phanerozoic era, few strong orogenic movements have been recorded in Africa. Minor folding

Fig. VI-1.

GENERALISED MAP OF THE MAJOR STRUCTURAL UNITS OF AFRICA

(After Clifford, T.N., 1970, African magmatism and tectonics, chap. 1, p. 2)



occurred in the Sahara during Paleozoic time; during the Hercynian Orogeny (Triassic), the Cape ranges in South Africa were folded; and the Atlas Mountains of Morocco is the only recorded Tertiary orogenic episode. Outside the mobile belts, broad basins separated by upwarps have been formed by epeirogenic deformation during Precambrian through Recent times.

Perhaps the most spectacular structures of Africa are the rift valleys. These structures date from Tertiary, Cretaceous, Paleozoic and probably Precambrian times, however the present valleys are principally Plio-Pleistocene in age. The rift valleys extend from Mozambique to the Red Sea (fig. VI.3). They were formed as tensional features, similar to those that divided Gondwanaland, and have separated Arabia from Africa.

Volcanism has occurred in Africa throughout geologic time. Extensive areas of volcanism are found throughout Africa. Basalts and rhyolites, extruded at the close of Karoo deposition are about 8800 m thick, while in South Africa several dolerite sheets cover 9100 and 13,000 km² respectively. During mid-Tertiary time large plateau-forming phonolites were extruded in Kenya.

Recent volcanism in eastern Africa is generally related to the rift valleys. Along the eastern Rift, sodic volcanism is most common, while along the western Rift in Zaire and Uganda, volcanism is dominantly potassic. Recent volcanism has also occurred in the Cameroons and at several localities in North Africa.

VI.2. Introduction to the Geology of Somalia

Information available concerning the geology of Somalia is neither complete nor well-organized. A few areas, notably parts of the former British Protectorate in the northwest, were mapped and studied, however much of the country's geology is poorly understood. Correlations between stratigraphic units in the various parts of Somalia are remote and commonly poorly documented. The most recent geological map of the entire country is a compilation at a scale of 1:1,000,000 completed in 1972 by UNDP and included as fig. VI.4a of this report. However, no explanatory text is available for this map, nor is any documentation

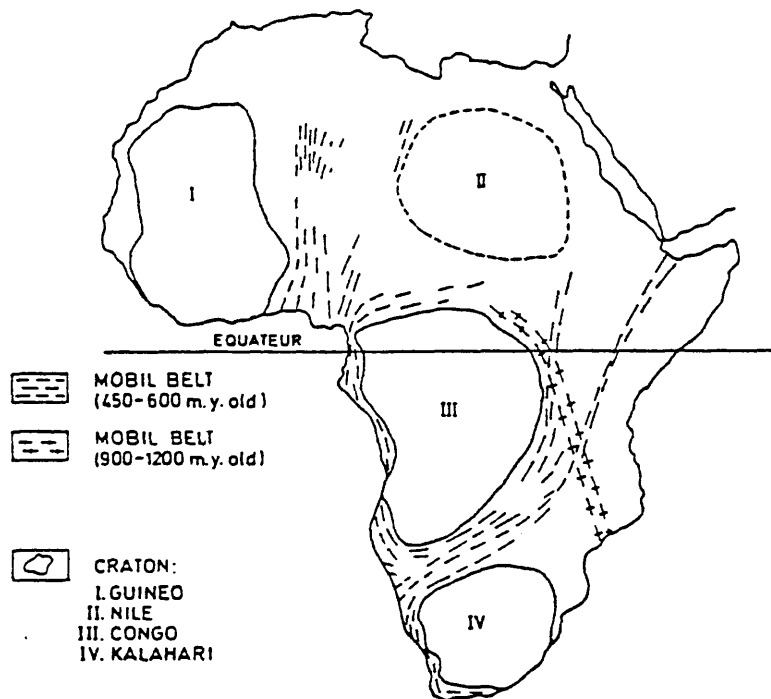


Fig. VI-2. Mobile belts and major cratons of Africa.

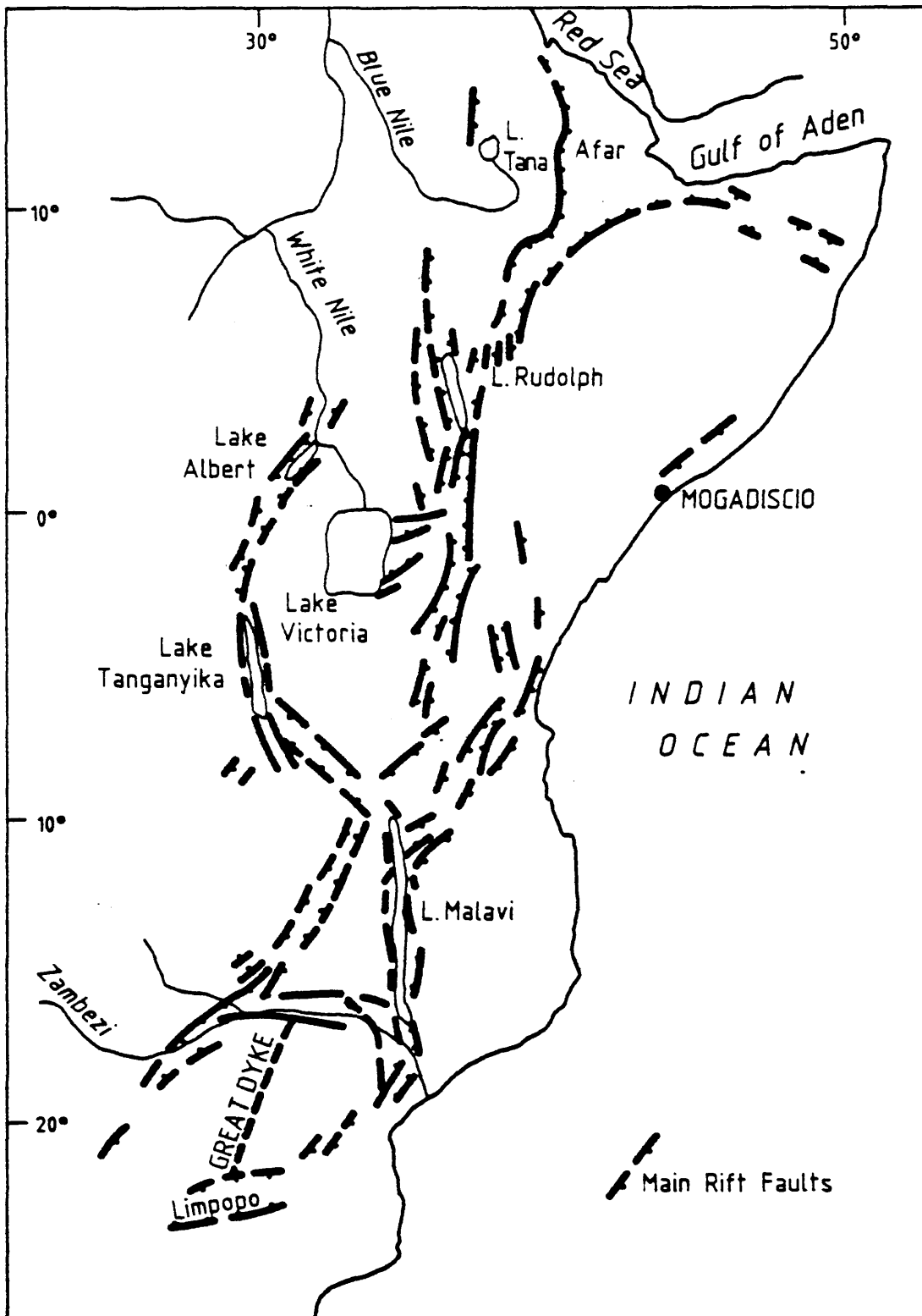


Fig. VI-3. Rift faults of East Africa (after Mitchel, A.H.G. and Garson, M.S., 1976, Minerals Sci. Engng., v. 8, p. 128).

for either the rock units, or the original sources of the compilation. A small-scale geological map of Somalia appears as figure VI-4 b.

The information contained in this section of the present report was compiled by the authors from several references which are listed in the Bibliography (Sect. XV) plus discussions held with various geologists. This information is the best we could obtain at the time this report was written (March 1983), but is certainly not the final word on Somali geology.

Few absolute age dates are available for Somali rocks. These few dates were obtained mainly from the published and unpublished reports of Osman and others (1976), BRGM (1976b) UNDP (1972b) and D'Amico and others (1981).

Rocks, especially in central and southern Somalia, are commonly poorly exposed, deeply weathered, lateritized, and/or covered by Quaternary deposits.

VI.3. Stratigraphic Succession

The following stratigraphic succession is taken largely from the Geological Map of Somalia (UNDP, 1972a). Alterations, explanations and changes are from several other sources, notably UNDP (1972b and 1973a), Osman and others (1976), Hilal and others (1977) and Greenwood (1982). We use this succession mainly because it is used on the latest available geological map of the entire country, and not because it is necessarily the best or most complete. Several alternate systems have been compiled which are probably equally valid. In general, the stratigraphy of Somalia is poorly understood, and based on minimal field research.

VI.3.1. Precambrian

VI.3.1.1. General

Precambrian rocks crop out in two parts of Somalia. In the north 30,000 km² are exposed in three inliers along an east-west trend between the southern escarpment of the plateau and the coastal range. In the 22,000 km² Bur Area, west of Mogadiscio, the Precambrian

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basement is exposed in rounded hills (or Burs) which stand out above the surrounding peneplain. Figure VI-5 is a map of Precambrian exposures in Somalia.

According to Osman and others (1976, p.5-6), the Precambrian of Somalia can be correlated with both African and Arabian complexes. "The oldest gneissic complex is correlated with the Lower Proterozoic gneisses of southern Ethiopia. The amphibolite complex has the same age limit (900 MY) with the metasedimentary and volcanic rocks of the series Hali Baish of Saudi Arabia, Naferelabi of Sudan and Abu Fannany of Egypt. The greenstone-volcanic complex (series Abdul Kadir) can be correlated with the metavolcanic series of Halaban of Saudi Arabia, which formed 750-900 MY...the youngest metamorphic complex of the northern region...the Inda Ad Series is similar to the Murdawa of Saudi Arabia which is intruded by granites with radiometric age of 600 MY".

BRGM (1979, p.9) stated that the work of British geologists indicates "...the basal series and the Arapsio Dobo-Gebile Series would be older than 2000 MY; the Boroma and Abdul Qadr series more than 1000 MY; the Inda Ad Series, would range about 600 to 650 MY. Alkaline granites intruding the Inda Ad Series are dated about 500 MY."

The Geological Map of Somalia (UNDP, 1972a) places the Daabrurruk and Olontole series as Archean in age; the Arapsio Dobo, Dinsor and Borama-Baraksan series as early Proterozoic; and the Abdul Qadr, Heis and Inda Ad series at late Proterozoic.

Near Gorei in the Shilemadu Range, on the north side of the Nogal Valley, a small window of crystalline rocks crop out over a total area of ca. 5 km². Mason (1954) mapped these exposures, which consist of various granites, syenites and felsic porphyries, unconformably overlain by a basal conglomerate of the Nubian Sandstone of Cretaceous - Paleocene age, and concluded they were similar to Precambrian rocks in northern and central Somalia.

VI.3.1.2. Archean

The Archean rocks of Somalia consist of gneisses, migmatites and amphibolites. In the northern part of the country they are placed

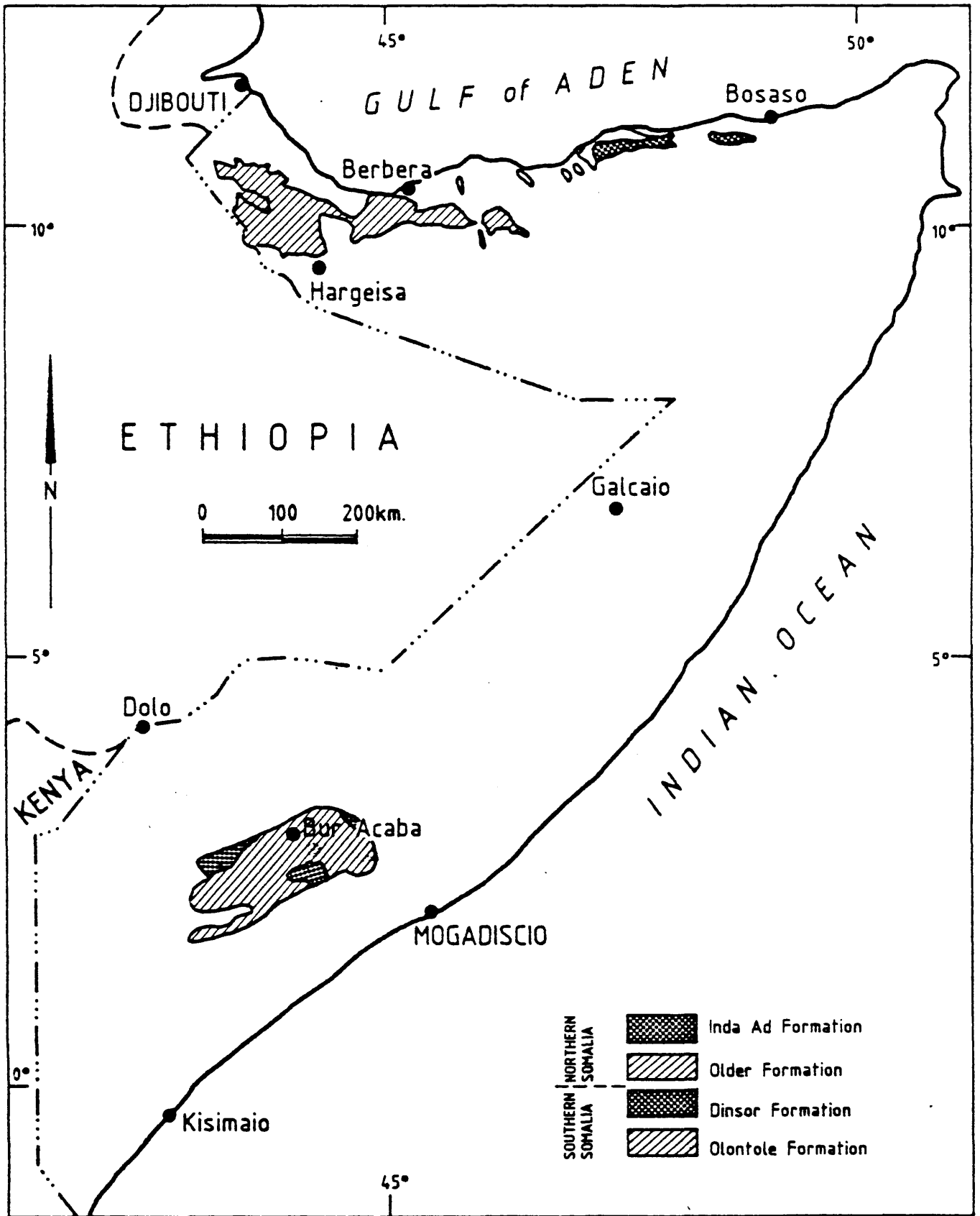


Fig. VI-5. Precambrian exposures (D'Amico and others, 1981).

in the Daabrurruk Series, while in the Bur area they comprise the Olontole Series. These rocks originally consisted of pelitic, psammitic, and calcareous rocks, as well as volcanics, which have undergone high grade metamorphism and migmatization. They are now mainly biotite gneisses and range from melanocratic to leucocratic and aplitic. They contain variable amounts of biotite, K-feldspar and quartz, with garnet and sphene as the most common accessories. Biotite quartz gneisses, biotite amphibolite schists and gneisses and amphibolites are also common in the Archean complexes. It appears that the absolute ages of all older rocks in Somalia have been reset by thermal events during the Kibaran and PanAfrican orogenies at 1100 ± 200 MY and $550 \pm$ MY respectively.

VI.3.1.3. Lower Proterozoic

VI.3.1.3.1. Arapsio Dobo/Dinsor Series

The oldest Lower Proterozoic rocks in the northern part of Somalia are named the Arapsio Dobo Series. They consist of quartzites, silicic metavolcanics, silicic meta-tuffs, mica schists, leucocratic gneisses, marbles, and amphibolites.

In the Bur area, equivalent rocks comprise the Dinsor Series, which is dominantly composed of quartzites, marbles and calc-silicates, but also contains amphibolite-gneisses and bedded spilites. Some marbles in the Modu-Mode area, 25 km west of Bur Acaba contain 24% P_2O_5 . Total thickness is about 2500 m.

In the western part of the Bur area, the Dinsor Series consists entirely of quartzites with minor intercalations of gneisses and granite gneisses. Arkosic quartzites and ferruginous quartzites are interlayered with the white banded quartzites which comprise the bulk of the series. It has been estimated that the quartzite section is between 2000 and 3000 m thick.

VI.3.1.3.2. Borama - Baraksan Series

The youngest Lower Proterozoic rocks crop out only in the northern part of Somalia, and consist of the Borama-Baraksan Series. This unit contains amphibolites, metadolerites, hornblende schists and quartzitic

gneisses, as well as gabbros, anorthosites, peridotites, marble lenses and serpentinites. The Borama Series is thought to be the equivalent of an ophiolite complex in Saudi Arabia (BRGM, 1979b). The Borama Series is reported to be over 1000 m thick (Osman and others, 1976).

VI.3.1.4. Upper Proterozoic

VI.3.1.4.1. Abdul Qadr Series

Rocks of the Abdul Qadr Series are exposed only in the northern part of Somalia. The upper part of the series consists of greenstones, meta-andesites, meta-basalts, meta-rhyolites, meta-dacites, and meta-tuffs, while the lower part is comprised of hornblende schists, quartzites, phyllites and marbles. These rocks are generally metamorphosed to the greenschist facies. BRGM (1979b) suggested that the Abdul Qadr Series is equivalent to the Hulayfah Group in Saudi Arabia. The thickness of this Series is estimated to be more than 1000 m.

VI.3.1.4.2. Heis Series

The Heis Series consists of greenstones, meta-andesites, meta-tuffs, and hornblende schists, intercalated with limestones, quartz sericite schists and in the upper part, quartzites. It overlies the Abdul Qadr Series and was formerly considered part of the same unit. Exposures of the Heis Series have only been found in northern Somalia, and are reported to be over 1000 m thick (UNDP, 1973a).

VI.3.1.4.3. Inda Ad Series

The Inda Ad Series is exposed only in northern Somalia, where it is reported by some authors, to lie unconformably upon the older rocks of the Precambrian basement (Mason and Warden, 1956; UNDP, 1972b). Other authors disagree (Greenwood, 1960; Osman and others, 1976), suggest the unconformity does not exist, and note the Inda Ad Series shows increasing grade of metamorphism to the west, and thus may merely be a less metamorphosed equivalent of other rocks.

The rocks of the Inda Ad Series are cataclastically metamorphosed clastic sediments ranging from claystones and mudstones to coarse-grained sandstones and less commonly to conglomerates, intercalated with layers of siliceous shales, tuffs, limestones, dolomites and andesites. Close

to contacts with intrusive granites these sedimentary rocks have been thermally metamorphosed to hornfelses, phyllites, quartzites, marbles, and schists. The Inda Ad Series has been estimated to have a total thickness of about 8500 m.

UNDP (1973a) divided the Inda Ad Series into five formations. From oldest to youngest these are the Arar Formation, consisting of 3000 m of sandstones, conglomerates, siltstones, mudstones and interbedded carbonate rocks; the Magno Formation, 2000 m of sandstones and siltstones; the Haddit Formation, 2500 m of poorly sorted sandstones, siltstones and conglomerates; the Seinat Formation, 800 m of tuffaceous sandstones and siltstones interbedded with conglomerates, mudstones and schists; the Helveto Formation, 200-300 m of claystones, siltstones, and sandstones, interbedded with limestones. These strata are generally compressed into tight, north-trending folds, which are locally isoclinal.

Grits (coarse sandstones) of the Inda Ad Series were reported (Greenwood, 1960) as arkosic, while mudstones are commonly variegated, ranging from red to purple, blue or black. Greenwood (1960) also reported altered silicified volcanics, interbedded with the sedimentary rocks, in layers up to 10 m thick. Some spilitic pillow lavas and associated hornfelses were found as float, but never seen in situ.

"From east to west the Inda Ad Series shows an increased degree of folding from moderately broad folds to tight isoclinal fold belts. In the east interbedded volcanic rocks occur but sparsely whereas westward quartz porphyry and rhyolite dykes appear more frequently and with them diorite dykes and sills" (Greenwood, 1960, p.15).

Metamorphism tends to show an increased grade to the west, but is generally in the low grade greenschist or possible zeolite facies.

The Inda Ad Series may have covered a much larger area than its present outcrops indicate. Similar rocks have been described in southern Arabia (Greenwood, 1960) and others have been found in a borehole drilled in the Ogaden region of Ethiopia and as xenoliths in basaltic dikes in the Afar depression (D'Amico and others, 1981).

VI.3.1.5. Precambrian Sequence of Events

A sequence of events, based on currently available data, was suggested by D'Amico and others (1981) for both southern and northern Somalia. The following proposed sequences are generally taken from this source, however with notable changes based on several other reports.

Bur Area (southern Somalia)

1. Deposition of sediments during Archean time to form the Olontole Series. This deposition may have been multi-cyclic and may represent a long time span possible including early Proterozoic time.
2. The arenaceous, argillaceous and calcareous rocks of the Dinsor Series with their interbedded spilite flows were deposited during early Proterozoic time.
3. Approximately 600 million years ago the Olontole and Dinsor series were folded and metamorphosed to amphibolite grade rocks. This orogenic event was accompanied by large-scale anatexis and migmatization.
4. About 500 million years before present, large granitic masses were intruded into Dinsor and Olontole rocks. It is possible the magmas originated during the anatectic event mentioned above (No.3.).
5. Mafic bodies intruded the rocks of southern Somalia between 420 and 600 million years ago, and consist of small plutons and dikes of gabbro, syenite and diorite.

Northern Somalia

1. During the Archean time, argillaceous, arenaceous and calcareous sediments were deposited and formed the Daabrurruk Series. This deposition may have been poly-cyclic in character, and possibly continued into early Proterozoic time.
2. Arenites, argillites, silicic and mafic volcanic flows, silicic tuffs, and calcareous sediments were deposited during early Proterozoic time and now constitute the metasedimentary and metavolcanic rocks of the Arapsio Dobo Series.
3. Later, during the latter part of early Proterozoic time, the ophiolitic complex was deposited and intruded. This formed the Borana-Baraksan Series.

4. About 740 million years ago, the Archean and Lower Proterozoic rocks were folded and metamorphosed to amphibolite-grade metamorphic rocks. This orogenic event was also accompanied by anatexis and metamorphism.
5. In late Proterozoic time was deposited a sequence of argillaceous, arenaceous and calcareous rocks, and above these a volcanic sequence consisting of andesites, basalts, rhyolites, dacites and tuffs. These rocks comprise the Abdul Qadr Series.
6. Following the close of Abdul Qadr deposition, the Heis Series, a sequence of volcano-sedimentary rocks were laid down, and consists of andesites, tuffs, limestones, argillites and arenites.
7. A series of large and small granitic bodies were intruded into the older Precambrian rocks. These intrusives formed contact metamorphic aureoles in the country rocks. The absolute age of these intrusives is unknown. The magmas may have originated from the anatexis reported above (No. 4).
8. Single or multiple episodes of mafic magmatism intruded the Precambrian rocks of northern Somalia forming discordant layered plutons and dikes of gabbroic, dioritic and syenitic composition.
9. During late Proterozoic to possibly early Phanerozoic time, a series of clastic sediments interbedded with carbonate rocks were deposited over a large area. These sediments comprise the Inda Ad Series, which also contains rare spilitic lavas.
10. The Inda Ad Series was folded and cataclastically metamorphosed in late Proterozoic or possibly early Phanerozoic time. The Abdul Qadr and Heis series were metamorphosed to greenschists, and older metamorphic rocks were also "overprinted".
11. Post-Inda Ad granitic rocks were intruded into Inda Ad and older Precambrian rocks about 500 million years ago in the form of shallow discordant plutons, dikes, sills and pegmatite bodies. This event probably took place following the close of post-Inda Ad orogenesis. The plutons formed thermal metamorphic haloes in the surrounding country rocks.
12. Small bodies of diorite and dikes of varying intermediate to mafic composition intruded the Precambrian rocks. The age of these rocks is not known, and may possibly be Karoo (Permo-Triassic).

VI.3.2. Mesozoic

VI.3.2.1. General

Pre-Jurassic sedimentary rocks are rare in East Africa. The Adigrat

Sandstone in northern Somalia has been assigned to the Triassic by some authors (Osman and others, 1976) however no paleontological evidence has been found which supports this classification (Pallister, 1971). Mesozoic strata are generally sub-horizontal or dip gently to the south-east. More steeply dipping strata have locally been displaced by faults. Figure VI-6 is a correlation chart of the Phanerozoic rocks of Somalia.

VI.3.2.2. Jurassic

VI.3.2.2.1. Introduction

Jurassic strata overlie Precambrian rocks with distinct unconformity in both northern and southern Somalia. In the north, they crop out as narrow bands on the northern escarpment of the Somali highlands, and within grabens amidst Precambrian rocks. In the south, Jurassic rocks are exposed from the Kenyan-Somalian border, eastward to the Juba River, and between the Juba and Shebelle rivers.

VI.3.2.2.2. Lower Jurassic - Adigrat Formation

The Lower Jurassic sequence is described (UNDP, 1972a) as conglomerates, limestones and marls interlayered with sandstones, however this fails to take into account the major Lower Jurassic unit in northern Somalia: The Adigrat Formation, which consists of sandstones, conglomerates and rare basaltic lavas and has a reported thickness of between 100 and 140 m (Osman and others, 1976). UNDP (1973a) stated that the Adigrat consists of 40-1000 m of coarse-grained quartz sandstones, interbedded in the lower part with siltstones and in the upper part with limey sandstones and limestones.

In an earlier report, the Adigrat was said to "...overlie unconformably the basement complex. Interlayers and lenses of conglomerates containing quartz pebbles are common at the base of the Adigrat Sandstone and crossbedding is common. Thin basalt sheets occur in some areas. Limestone interlayers occur in the middle and upper portion of the Series. Lower Jurassic ammonites have been identified. The thickness of the series is up to 200 m" (UNDP, 1972b, p.14).

In southern Somalia, Lower Jurassic rocks crop out in a semi-circle around the northern edge of the Bur Precambrian metamorphic complex.

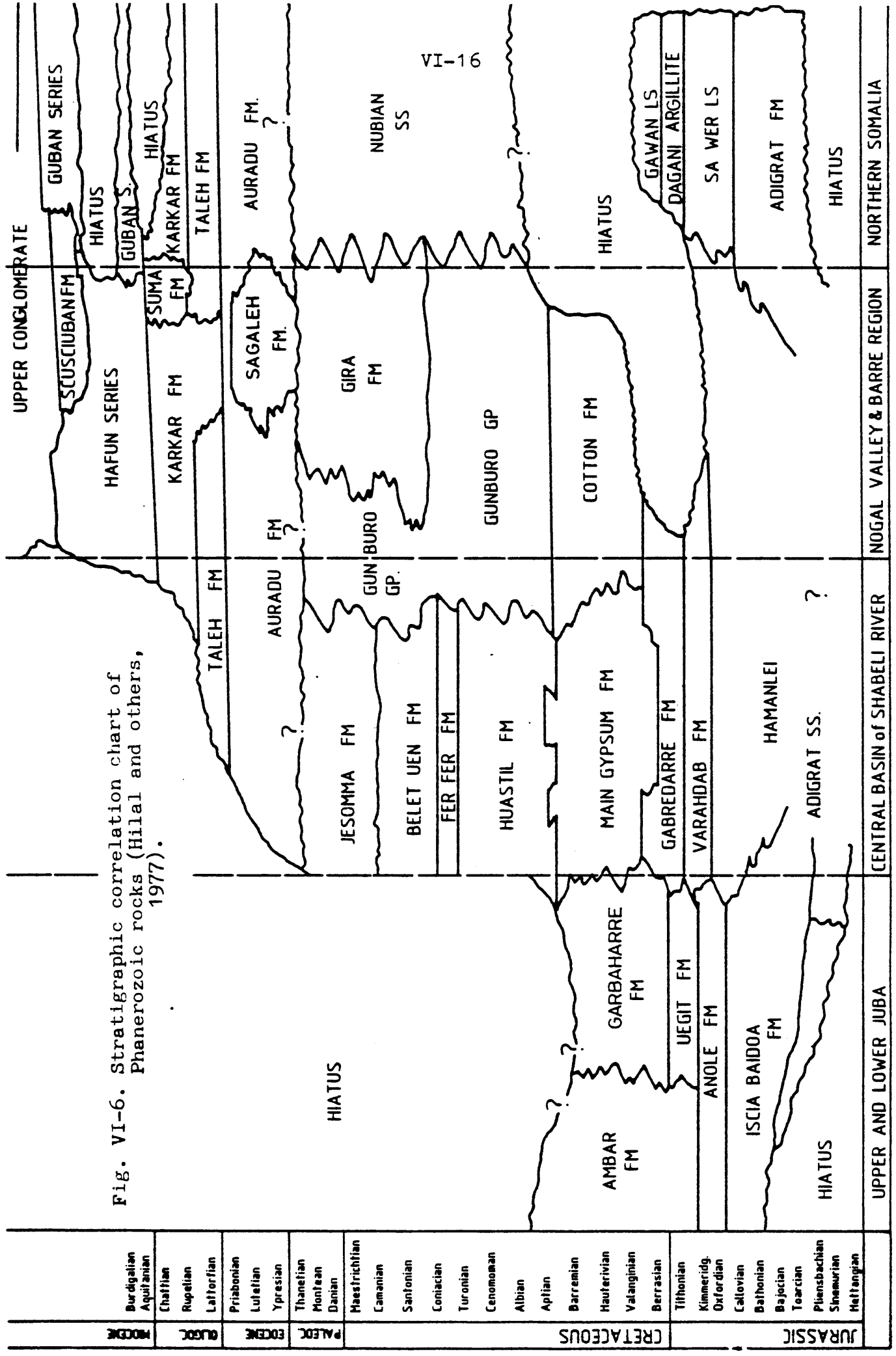


Fig. VI-6. Stratigraphic correlation chart of Phanerozoic rocks (Hilal and others, 1977).

MIOCENE	Burdigalian Aquitaniian
OLIGOCENE	Chaffin Rupelian Lafforian
Eocene	Priabonian Lufelian Ypresian
PALEOCENE	Thanetian Ponfean Danian
CRETACEOUS	Maestrichtian
	Campanian
	Santonian
	Coniacian
	Turonian
	Cenomanian
	Albian
	Aptian
	Barremian
	Hauterivian
Valanginian	
Berriasian	
JURASSIC	Tithonian
	Kimmeridg.
	Oxfordian
	Callovian
	Bathonian
	Bajocian
	Toarcian
Pliensbachian	
Sinemurian	
Mettangian	

VI-16

Basal layers of quartz conglomerate and sandstone are overlain by an alternating sequence of clayey marls and variegated limestones (UNDP, 1972b).

VI.3.2.2.3. Iscia Baidoa Formation

Overlying the Lower Jurassic rocks and surrounding the northern and western edges of the Bur Precambrian complex, are rocks of the Iscia Baidoa Formation of late Jurassic age. The thickness of this unit is between 250 and 870 m and it is comprised of four members. From oldest to youngest these consist of the 40 m thick basal Deleb quartz sandstone and conglomerate; the 120 m thick Uanei thin-bedded limestone; the Baidoa clastic and lithographic limestone (90 meters thick); and the capping Goloda detrital limestone which is up to 620 m thick (UNDP 1973 a). Near the Shebeli River, and in the Nogal Valley and Barre Region, the Iscia Baidoa Formation is the time-stratigraphic equivalent of the Hamanlei Formation, while in northern Somalia it is equivalent to the upper part of the Adigrat Sandstone and the lower part of the Sa Wer Limestone.

VI.3.2.2.4. Anole Formation

Surrounding the northern and western sides of the Bur area and overlying the Iscia Baidoa Formation is the Anole Formation, also of late Jurassic age. It consists of shales, marls, and marly and clastic limestones. The equivalent time stratigraphic units in the Central Basin of the Shebeli River are the upper part of the Hamanlei Formation and the lower part of the Varahdab Formation, while in northern Somalia, the equivalent strata is the upper part of the Sa Wer Limestone. The thickness of the Anole Formation is between 300 and 450 m.

VI.3.2.2.5. Uegit Formation

Overlying the Anole Formation in the Juba River area are beds of the late Jurassic Uegit Formation. This unit consists of 350 m of reef limestones and calcarenite containing a marker band of pisolitic algal limestone. In the Central Basin of the Shebeli River, the Uegit Formation is equivalent to the upper part of the Varahdab Formation and the lower part of the Gabredarre Formation, while in northern Somalia, it is equivalent to the Dagani Argillite and the lowermost Gawan Limestone.

VI.3.2.2.6. Jurassic-Cretaceous Garbaharre Formation

In the northern part of the Juba area and between the valleys of the Juba and Shebeli rivers are exposures of the Garbaharre Formation, of late Jurassic to early Cretaceous age. It consists of 400 m of bioclastic and oolitic limestones in its lower part, and dolomites, marls, and quartz sandstones in its upper part. In the southern part of the Juba area, the Ambar Formation is its equivalent. In the Central Shebeli River Basin, the uppermost Gabredarre Formation and the Main Gypsum Formation are equivalents to the Garbaharre Formation; and in the Nogal Valley and Barre Region, the Cotton Formation is its equivalent. In northern Somalia the upper Gawan Limestone is its time-stratigraphic equivalent. The Garbaharre Formation has also been called the Marehan Formation.

VI.3.2.3. Cretaceous

VI.3.2.3.1. Introduction

Extensive exposures of Cretaceous rocks are located in both the Juba River and Shebeli River basins. In southern and central Somalia, Cretaceous strata overlies Jurassic-age rocks, but in northern Somalia, the Cretaceous rocks commonly unconformably overlie the rocks of Precambrian age. Cretaceous age rocks were mainly formed by chemical precipitation during early and middle Cretaceous times, but were preponderantly deposited as clastic sediments during the late Cretaceous period.

VI.3.2.3.2. Main Gypsum Formation

In the Central Basin of the Shebeli River, the Gabredarre Formation is overlain by the Main Gypsum Formation of early Cretaceous age. UNDP (1972a; 1973a) and Osman and others (1976) considered this unit to be younger than the Garbaharre formation and its time-stratigraphic equivalents, the Ambar and Cotton formations. The accompanying stratigraphic correlation chart (fig. VI.6) however, revised from Hilal and others (1977) indicates that the Main Gypsum Formation has the same age as the Garbaharre and its equivalent formations, but was formed in a different depositional environment. The limited information available does not permit us to make a definitive judgement between these conflicting correlations. The unit is 350-450 m thick and is predominantly comprised of crystalline and massive gypsum and anhydrite interbedded with marly shales and claystones. The formation includes irregular bodies of gray argillaceous material and intraformational dolomite which is gray and very finely crystalline to sugary in texture, and contains fossil molds.

VI.3.2.3.3. Mustahil Formation

Conformably overlying the main Gypsum Formation in the Central Shebeli River Basin is the Mustahil (Huastil) Formation, composed of 300-400 m of gypsiferous siltstones and mudstones interbedded with clastic and fossiliferous limestones. The Mustahil Formation appears to gradually change upwards from massive gypsum to green gypsiferous shales. The strata contains a multitude of shallow water fossils including ammonites. In the Nogal Valley and the Barre Region, the time-stratigraphic equivalent of the Mustahil Formation is the lower part of the Gunburo Group, and in northern Somalia, its equivalent is the lowermost Nubian Sandstone.

VI.3.2.3.4. Fer Fer Formation

The Fer Fer Formation conformably overlies the Mustahil Formation in the Central Shebeli River Basin. It consists of 55-90 m of unfossiliferous white crystalline anhydrite and gypsum, gray to tan clastic dolomites and soft clayey limestones. In the Nogal Valley and Barre Region, the Fer Fer Formation is equivalent to the uppermost part of the Lower Gunburo Group, while in northern Somalia it is equivalent to part of the middle Nubian Sandstone.

VI.3.2.3.5. Belet Uen Formation

Overlying the Fer Fer Formation in the Central Shebeli River Basin are 200 m of shallow water marine limestones, marls and gypsiferous shales. The limestones are fossiliferous and chalky or argillaceous, and commonly contain pyrite and bioclastic debris. The upper part of the unit contains evidence of a shallowing marine sequence which Osman and others (1976) called the Transition Beds Formation and which consists of shallow water marine limestone contaminated with clay, silt, sand, carbonaceous material and abundant fossils. The limestones are interbedded with thin-bedded light to dark gray to green shales which contain abundant pyrite, fine carbonaceous material and rare coalified plant remains. Between the Shebeli River and Nogal Valley, the Belet Uen Formation is equivalent to the lower part of the Upper Gunburo Group, and in the Barre Region it is equivalent to the Gira Formation. In northern Somalia the time-stratigraphic equivalent of the Belet Uen Formation is the middle part of the Nubian Sandstone.

VI.3.2.3.6. Cretaceous-Paleocene Nubian Sandstone - Jesomma Formation

Overlying the Belet Uen Formation unconformably in the Central Basin of the Shebéli River is the Jesomma Formation. This is directly correlatable to the Nubian Sandstone in northern Somalia, Ethiopia and the Sudan, which was deposited under mainly non-marine conditions in late Cretaceous and Paleocene times. The Jesomma Formation consists of cross-laminated coarse-grained red and brown sandstones, interbedded with variegated claystones. Estimates of thickness for the Nubian Sandstone range between 1000 and 1500 m, while the thickness of the Jesomma Formation in southern Somalia has been estimated at between 100 and 200 m. The quartz sandstones are essentially unfossiliferous and probably of eolian origin. In the Galladi area of Ethiopia, close to the Somalia border, the Jesomma consists of a sequence of dark gray to black shales and silty shales, interbedded with fine sandstones. The shales are pyritic, lignitic and fossiliferous. Boreholes in the Dusa Mareb area indicate the formation consists of 400 m of poorly-sorted reddish multi-colored coarse-grained sandstones interbedded with rare dark gray to black basalts. In the northeast, the Jesomma Formation has been divided into the lower Sagaleh strata, consisting of dark gray deep water marine limestones, marly limestones and marls; and the overlying marine Marai-Ascia strata, which is transitional between the Sagaleh and the overlying Auradu Formation. Between the Shebéli River and the Nogal Valley, the equivalent of the Jesomma Formation-Nubian Sandstone is the upper part of the Gunburo Formation. In the Barre Region, the equivalent is the Gira Formation.

VI.3.3. Cenozoic

VI.3.3.2. General

In Somalia, Tertiary and Recent sediments are found mainly near the coastal areas bordering the Indian Ocean and the Red Sea. Clastic and calcareous rocks of Tertiary age cover vast areas of Somalia and are representative of a variety of depositional environments, as well as several episodes of volcanism. Figure VI-7 correlates the exposures of Cenozoic rocks in Central Somalia with the strata revealed in coastal boreholes.

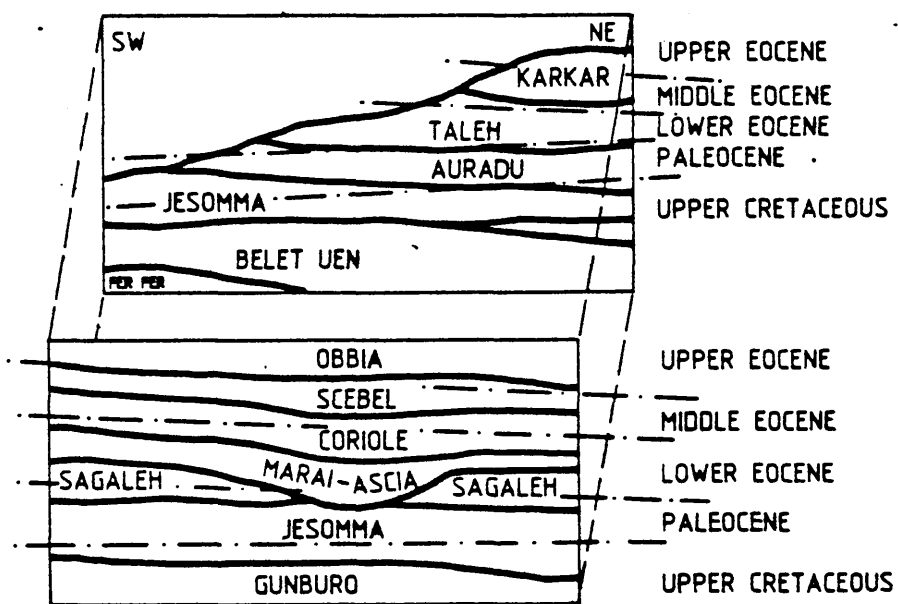
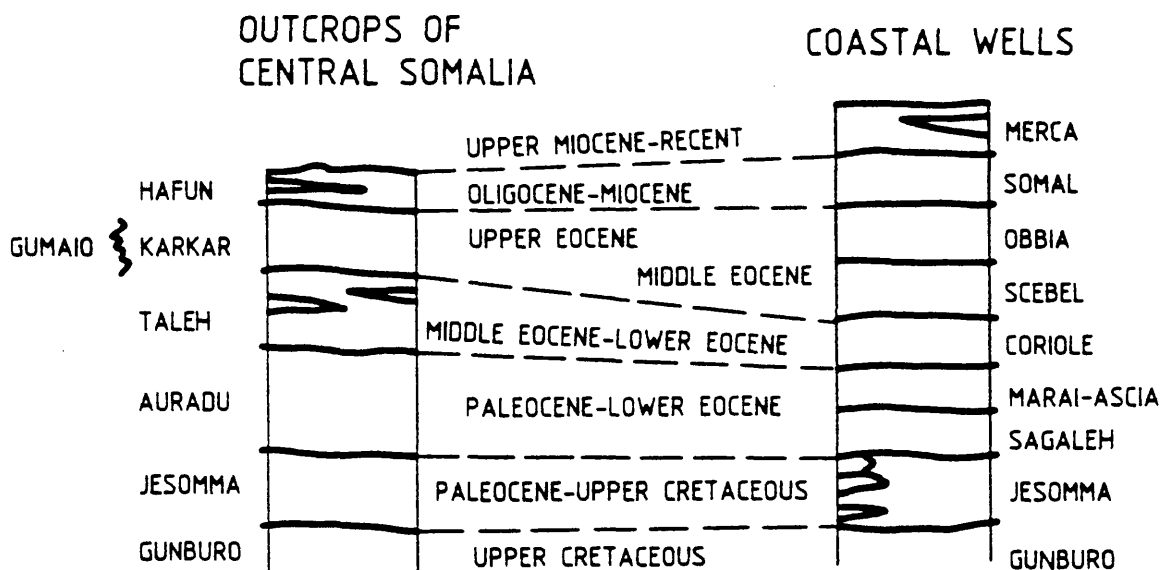


Fig. VI-7. Stratigraphic correlation between exposures in central Somalia and coastal boreholes (Altichieri and others, 1981).

VI.3.3.2. Paleogene (Paleocene-Oligocene)VI.3.3.2.1. Introduction

Several lithostratigraphic units, Paleocene to Oligocene in age, comprise the Paleogene succession in Somalia. The lowermost strata are the Cretaceous-Paleocene Nubian sandstone and Jesomma Formation described above. Paleogene rocks crop out only in the northern part of Somalia.

VI.3.3.2.2. Aurudu Formation

Overlying the Cretaceous-Paleocene Jesomma Formation and its time-stratigraphic equivalents with questionable conformity is the Aurudu Formation. The base of the Aurudu consists of 200-400 m of massive gray limestones containing numerous calcareous concretions, overlain by 200-300 m of thick-bedded limestones, limey dolomites, marls, greenish-yellow siltstones and some interbedded gypsum. Boreholes in the Dusa Mareb area revealed fossiliferous and dolomitic limestones interbedded with siltstones and poorly sorted quartz sandstones and capped by highly altered basalt. In the northeast, the Aurudu Formation consists of open marine shallow water dolomites and limey dolomites. The Aurudu Formation is probably of Paleocene to Eocene age and crops out in the Central Shebelle River Basin, the Nogal Valley and northern Somalia. In the Barre Region, its time-stratigraphic equivalent are the limey shales of the Sagleh Formation. In the Hargeisa area, the equivalent of the Aurudu Formation is the Allakajed Formation.

VI.3.3.2.3. Tahleh Formation

Conformable above the Aurudu Formation is the Tahleh Formation, which is up to 400 m thick, and consists of banded gypsum and anhydrite interbedded with dolomites, siltstones and claystones. It was formed as reef and shallow marine deposits. The Tahleh Formation crops out over a large area in northern Somalia as well as in the Central Shebelle River Basin and the Nogal Valley. In the Barre Region its equivalent is the lower part of the Karkar Formation. The Tahleh Formation is of Eocene age.

VI.3.3.2.4. Karkar Formation

The Karkar Formation overlies the Tahleh Formation in the central basin of the Shebeli River, the Nogal Valley and especially in north-eastern Somalia. It consists of 80 to 400 m of alternating white and gray limestones interbedded with light brown marl and greenish-yellow siltstone. Beds of gypsiferous siltstone occur at the base, and clayey dolomites and dolomitic limestones also occur in the unit. The Karkar Formation is middle to late Eocene in age. In the Barre Region the Gumaio Formation is considered to be equivalent to the Karkar strata.

VI.3.3.2.5. Lower and Middle Daban Formations

The Lower and Middle Daban Formations crop out near Berbera in northern Somalia. The lower unit is about 250 m thick consists of sandstones, siltstones, marls, lenses of gypsum and conglomerate and rare silicified wood. The middle unit, between 800 and 2000 m thick is comprised of sandstones, siltstones and limestones, and contains lenses of boulder conglomerate. The Lower Daban Formation is thought to be of late Eocene to Oligocene age, and the Middle Daban Formation is considered Oligocene in age. The series represent an estuarine depositional environment. Hilal and others (1977) and Greenwood (1982) refer to these strata as the Guban Series, and include the Middle Daban Formation in this unit. Along the Gulf of Aden south of Bosaso and Elaya the Guban Series consists of coarse reddish sandstones and conglomerates containing lenses of fossiliferous limestone. In the Nogal Valley and Barre Region the Hafun Series is equivalent to the Daban-Guban and consists of about 200 m of marine biogenic limestones, limey sandstones and claystones.

VI.3.3.3. Neogene (Miocene-Pliocene)

VI.3.3.3.1. Introduction

The Neogene strata consist of various lithostratigraphic units which are commonly difficult to distinguish from sediments of early Quaternary age. Along the Indian Ocean and Gulf of Aden are found marine sedimentary rocks of Miocene age. In the Darror Valley, Miocene lagoonal-continental and marine rocks crop out, and these have also been logged in deep boreholes drilled for oil in central and south-eastern Somalia.

VI.3.3.3.2. Trap Basalts

In the area between the Juba and Shebeli Rivers are found 60 to 80 m of alkali-olivine basalts and mafic tuffs. These rocks are reported to be of Paleocene to Miocene age.

VI.3.3.3.3. Upper Daban-Scusciuban Formations

The Upper Daban Formation crops out in northern Somalia south of Bosaso where it consists of 100-300 m of sandstones and conglomerates. These strata are reported to be of Oligocene to Miocene and possibly Pliocene age. In the Barre Region between 100 and 200 m of lagoonal marls, marly sandstones and subordinate limestones, limestone conglomerates and gypsum lenses crop out. These strata are known as the Scusciuban Formation. This unit underlies much of the Darror depression and several places near the Gulf of Aden. Some authors (e.g. Hilal and others, 1977) consider the Daban rocks as part of the Guban Series, and its stratigraphic equivalent in the Nogal Valley are the marls, sandy marls, sandstones and fossiliferous limestone of the Upper Hafun Series.

VI.3.3.3.4. Dubar Series

The Dubar Series is mapped along the Gulf of Aden coast as a separate lithostratigraphic unit by UNDP (1972a). However both UNDP (1973a) and Greenwood (1982) consider this unit as the time-stratigraphic equivalent of the Daban-Guban-Hafun-Scusciuban strata described above. Greenwood (1982) reports that the Dubar sequence is of early to middle Miocene age and was generally deposited in a rapidly aggrading littoral marine and reef environment along the actively tectonic edge of a proto-Gulf of Aden. The unit consists of widespread fossiliferous marine marls and coralline limestones containing lenses of boulder conglomerate derived from rocks exposed in nearby mountains. UNDP (1973a) reports the thickness of Durbar-Hafun strata is between 50 and 560 m.

VI.3.3.3.5. Merca-Mudugh Series

Overlying the Dubar Series and its equivalents are strata of the Merca and Mudugh Series of Miocene age. They represent continental-lagoonal and offshore depositional environments and unconformably overlie older

rocks. The Merca and Mudugh series crop out in central Somalia and southeastward along the Indian Ocean coast, and were penetrated by deep boreholes in a large area from Obbia south towards Kenya. The exposed lower part of the Series commonly consists of clayey sandstones and marls containing rare beds and lenses of limestone and gypsum. Fluvial, alluvial flood plain and lagoonal facies have been recognized. This lower series ranges from 25 to 30 m thick and commonly overlies weathered basalt. The outcropping upper Merca Series generally consists of a light gray cryptocrystalline limestone, not exceeding 20 m in thickness, and containing lenses of breccia and sandstone. The Sinclair Oil Company reported that in the subsurface the Merca strata differed in composition in various localities, and contained sandstones sandy claystones, marls or limestones. It ranges in thickness between 40 and 700 m but averages 300 m and overlies the Somal Series of Miocene age, which is only known in the subsurface (UNDP, 1972b). Some authors (e.g. Greenwood, 1982) believe that the calcrete uranium deposits in the Mudugh area are contained in the upper part of the Merca Series.

VI.3.3.3.6. Aden Volcanic Series

Unconformably overlying various older rock units in northern Somalia are the Aden Volcanic rocks of Pliocene to Quaternary age. For the most part, this Series consists of basalts, with some layers and lenses of tuffs and other pyroclastic rocks. In some areas, rhyolitic extrusives have been found. The Aden basalts are up to 70 m thick and in places are interbedded with Pliocene to Quaternary sediments.

VI.3.3.3.7. Undifferentiated Pliocene-Quaternary Sediments

Several varieties of Pliocene to Quaternary sediments overlie all other rocks in Somalia. Some of the older sediments are interbedded with the basalts of the Aden Volcanic Series. From the Kenyan border to approximately 8° North latitude, fixed sand dunes extend continuously along the Indian Ocean coast. The dune sand is commonly cemented into hard sandstone, and the dune belt is up to 25 km in width. In many localities along the coast, Recent coral limestones crop out between 10 and 15 m above sea level.

On the coastal plain along the Gulf of Aden, are sediments consisting of

conglomerates, gritstones, coarse gravels and sands. Amidst these clastic sediments on the marine terraces are outcrops of marine limestones containing mollusks and corals. The thickness of these rocks is unknown.

In northern Somalia are large closed depressions filled with gravelly, sandy and clayey sediments, which have been reworked by eolian activity. In the Burao area these sediments are at least 130 m thick.

Alluvial sediments are widely developed on the extensive plains in the south near the Kenyan border. These consist of clays, coarse-grained pebbly sandstones and rare beds of limestone, and range in thickness between 100 and 150 m.

It has been suggested by at least one exploration geologist that the calcrete deposits at Mudugh are at least partly hosted by the Pliocene-Quaternary sediments, as they overlie basaltic volcanics probably belonging to the Aden Volcanic Series.

VI.4. Magmatic and Anatectic Rocks

The discussion which follows is mainly derived from the following sources: UNDP (1972b), UNDP (1973a), D'Amico and others (1981) and Greenwood (1982).

Several episodes of intrusion and migmatization are indicated by studies of the rocks of Somalia. Most of these events took place during the Precambrian or early Phanerozoic time.

In both northern Somalia and the Bur region of southern Somalia, the earliest events relating to magmatic or migmatitic rocks, are episodes of anatexis and migmatization. In the Bur area this event has been approximately dated at 600 MY, while in the north it took place at ca. 740 MY (D'Amico and others, 1981). The leucocratic migmatites are generally granitic and include both small concordant and discordant bodies and major discordant plutons.

Granitic rocks were emplaced in southern Somalia about 500 MY (D'Amico

and others, 1981). In the western part of the Bur region, a large triangular mass crops out, while several large masses are exposed in the eastern part of the area. The granitic rocks are melanocratic and gneissose and contain biotite, hornblende and commonly large microcline porphyroblasts (UNDP, 1972b). Greenwood (1982) states that they consist of medium to coarse-grained pink to yellow "monzogranites", which commonly contain large phenocrysts of microcline and biotite. The rocks are locally alaskitic and subordinate rock-types include aplites syenogranites, and syenites. The syenogranites and syenites commonly contain considerable coarse-grained magnetite.

The rocks in the Bur Region have also been intruded by a number of mafic bodies. These consist of five moderately-sized plutons of gabbroic composition, but also include dikes and other bodies of diorite and syenite. The time of the mafic intrusive event is uncertain, however UNDP (1972b) suggested a possible range of 420-600 MY.

The anatectic event in northern Somalia was also followed by the intrusion of granitic bodies. UNDP (1972b) stated that the timing of this event was 600 MY. The granite bodies have either sharp or diffuse contacts and exhibit magmatic textures as well as cataclastic to low grade metamorphic overprints. They include gneissic granites, biotite granites, amphibole-biotite granites and leucogranites, and form large massifs as well as small bodies. They are considered as late to post-orogenic intrusives (D'Amico and others, 1981). The granitic bodies are commonly surrounded by a halo of contact metamorphic rocks.

Some time after the intrusion of the silicic intrusive rocks and before the deposition of the Inda Ad Series, an extensive episode of mafic magmatism took place. No absolute age dates are available for this event.

Greenwood (1982) reported that the mafic rocks consist of gabbros, metagabbros and minor diorites. The gabbroic rocks are coarse-grained and dark gray. Some plutons are layered and rhythmically banded, and interlayered pyroxenites and anorthosites are not uncommon. The gabbroic bodies are generally discordant and many are found in synformal structures in metamorphic country rocks.

D'Amico and others (1981) state that the diorites are mainly confined to the area east of Berbera, and are generally elongated NNE to SSW. Field evidence may indicate that the diorites are older than the gabbros.

West of Berbera, gabbros predominate and range in composition from hornblende gabbros to hornblende norites and troctolites. Many bodies have a layered structure and consist of successions of pyroxenites, gabbros, troctolites, anorthosites and less commonly peridotites and websterites. To the east, norites and hypersthene gabbros are found intruding the Precambrian basement. Following emplacement, some mafic rocks were locally foliated and partially metamorphosed to amphibolites or amphibole schists. Syenites and nepheline syenites also intrude the western part of the Precambrian basement.

Currently, it is not possible to state whether the mafic intrusive activity represents a single or multiple intrusive episodes, or whether the magmatism was calc-alkaline, tholeiitic (doubtful), or perhaps calc-alkaline to shonkonitic (D'Amico and others, 1981).

Following the deposition of the late Proterozoic to possibly early Phanerozoic Inda Ad Series, a final episode of felsic magmatism took place in northern Somalia, probably about 480-500 million years ago (and therefore possibly contemporaneous with the intrusion of granites in the Bur area) according to UNDP (1972b).

The granites are massive to foliated, mainly medium to coarse-grained granodiorites and "monzogranites". The mafic constituents generally consist of biotite or biotite with lesser amounts of hornblende. The bodies intrude rocks of the Inda Ad Series, as well as older rocks, and are probably late to post-orogenic (Greenwood, 1982). These post-Inda Ad granites are unmetamorphosed, form shallow discordant plutons, and are generally surrounded by contact metamorphic aureoles consisting of hornfelses commonly containing biotite and cordierite. A structural discordance exists between these intrusives and the regional folding of the Inda Ad Series. D'Amico and others (1981) believe that this indicates the intrusive episode is entirely post-orogenic.

Also included in this intrusive group are unmetamorphosed and undeformed sharply-bounded granites intruding the pre-Inda Ad basement rocks. These include porphyritic granites, alkali feldspar granites, granitic dikes and sills, beryl and columbite-bearing pegmatites, and microcline-bearing granites. Several masses are themselves intruded by pink microgranites, suggesting that the intrusive event was multi-episodic.

The last known intrusive event in Somalia is evidenced by dikes and other small bodies of mafic material which intrude Inda Ad rocks. These include diorite dikes, titanium augite-bearing dolerite dikes, quartz microdiorites, and analcime-bearing basalts (Gellatly, 1960). These intrusions may represent several episodes, and D'Amico and others (1981) suggested that they may be of Karoo (Permo-Triassic) age.

VI.5. Structure and Tectonics

VI.5.1. Introduction

The following discussion is based mainly upon the reports of: Dixey (1956), UNDP (1972b) and Greenwood (1982), and to a lesser extent upon Wiltpolt and Simov (1979) and D'Amico and others (1981).

VI.5.2. Precambrian Structure

Several tectonic episodes during Archean and Proterozoic times are evidenced by the clastic metasedimentary rocks, metavolcanics, intrusives, migmatites and regionally and cataclastically metamorphosed rocks. However the problem of deciphering the complex basement rocks is compounded by the sparsity of exposures, several orogenic overprintings, and the lack of detailed definitive studies. Absolute age dates presently available for Somalia, indicate the re-setting of isotopic ages during the Kibaran (900 - 1300 MY) and PanAfrican (450 - 650 MY) orogenic episodes. All evidence indicates that the entire country is underlain by a Precambrian basement which crops out in northern Somalia and the Bur Region of southern Somalia.

The complex tectonic history of the Bur Region is described in Section VI.3.1.5. of this report. Complex patterns of deformation indicate either polyorogenic development or polyphase deformational activity during a single metamorphic-anatectic event (D'Amico and others, 1981).

The sequence of events in northern Somalia during Precambrian time is also detailed in Section VI.3.1.5. of this report. The Inda Ad Series is exposed in a narrow east-northeast trending anticline. Along with the older layered rocks of northern Somalia, this series exhibits north to north-northeast trending foliation east of longitude $45^{\circ}30'$ E. To the west, the foliation changes abruptly to east-northeast, east and west-northwest to the Ethiopian border, where it turns to the southwest. The rocks are tightly folded, commonly isoclinally and exhibit slaty cleavage to schistose foliation. Pre-Inda Ad rocks exhibit polyphase deformation. Locally, strike-slip and thrust faults have cataclastically deformed the various Precambrian rocks sub-parallel to the local structural trend. There is a progressive increase in the intensity of folding and metamorphic cleavage from east to west (Greenwood, 1982).

VI.5.3. Mesozoic Structures

During the Jurassic period, the Indian Ocean expanded and India and Madagascar rifted away from the Horn of Africa, accompanied by horst and grabentectonics and local drape folding along a hinge line or intraplate boundary in Southern Arabia. A marine transgression covered much of Somalia, and there was contemporaneous folding on east-northeast axes (Greenwood, 1982).

This Jurassic folding in northern Somalia is evidenced by the distribution of Jurassic and Cretaceous rocks. In fig. VI.8 the Jurassic zero isopach appears as a solid line which delineates the Northern Somalia High. A similar paleo-high was probably located to the east of Candala. The basal sandstone of Triassic-early Jurassic age is thickest along the axis of the downwarp, and thins away from it, indicating these structures began developing at that time. The structures remained active throughout Cretaceous time, as is evidenced by the greater thickness of Cretaceous sediments in these same downwarps. These Mesozoic structures were steep-sided and strongly asymmetrical, and sedimentary deposits rapidly pinch-out.

These are indicative of down-to-basin and drape faulting, which may have been shallow responses to deeper extensional faulting. Pillow basalts found in the basal sandstone is additional evidence for local Mesozoic extensional tectonics.

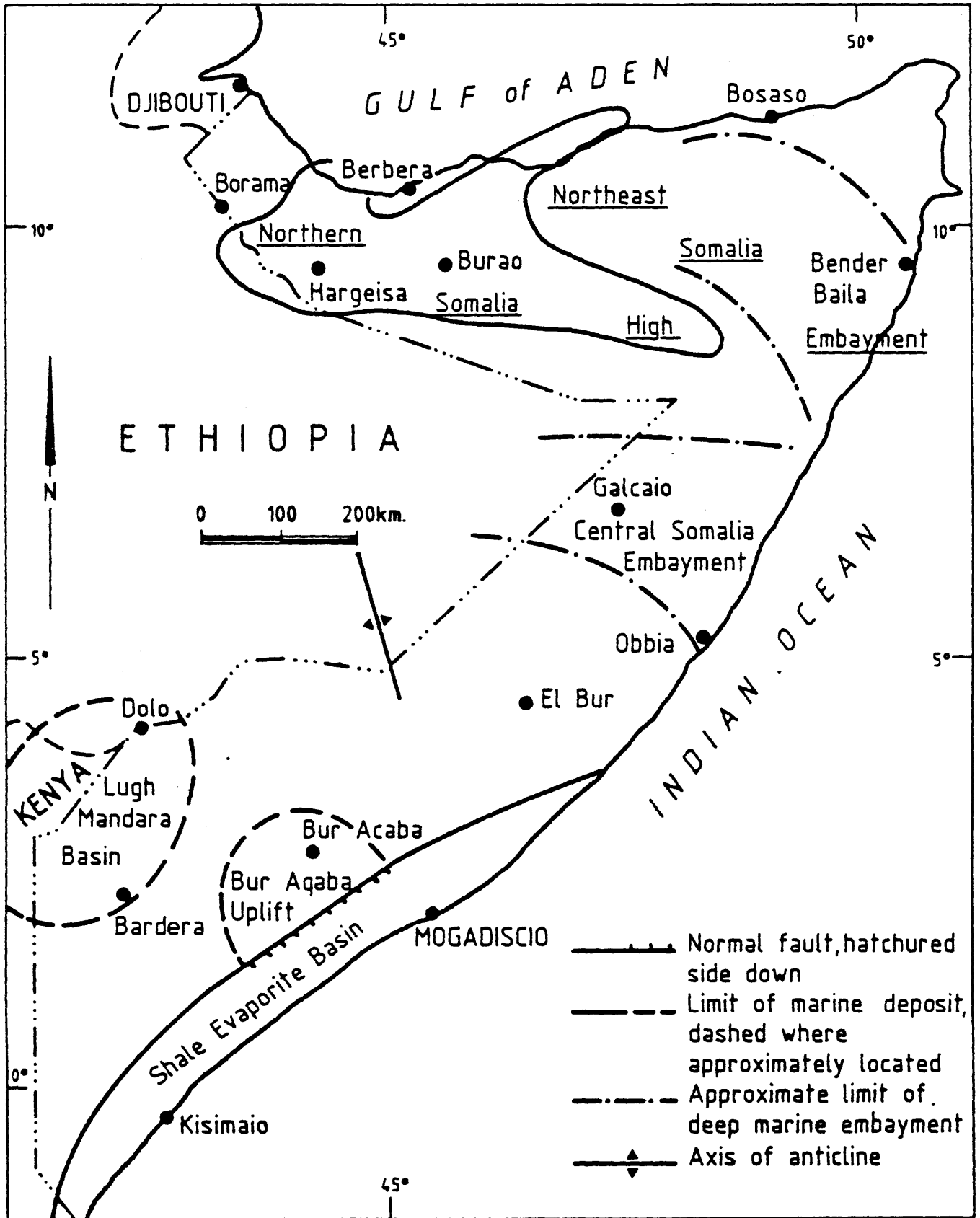


Fig. VI-8. Mesozoic structures (Greenwood, 1982).

During Mesozoic time, the emergent North Somalia High separated several small marine basins in northwestern Somalia from the main depositional areas to the south and east. The Jurassic strata of the Bihendula and Borama-Zeila areas resemble each other, but are quite distinct from the Jurassic deposits to the east. Jurassic sedimentary deposits indicate paleo-highs in the El Afweina area and upper Nogal Valley.

Several deep embayments were formed adjacent to the North Somalia High during Jurassic time. The Bur Aqaba Uplift was emergent throughout most of the Mesozoic era. The Uplift is related to the formation of the Lugh Mendera Basin in western Somalia, as well as a shale-evaporite basin (Somali Coastal Basin) to the east which probably formed during the rifting and southward movement of Madagascar from its original position on the southeast edge of Somalia (Greenwood, 1982).

VI.5.4. Tertiary Structures

Early Tertiary deposition in northern Somalia was unaffected by the earlier Mesozoic structures, which had eroded by the close of the Cretaceous period. The early Eocene marine transgression extended into northwestern Somalia, and is represented in southern Somalia in the subsurface along the Indian Ocean coast (fig. VI-9). Sequences of regressive marine evaporites and carbonates deposited in late Eocene time, indicate a probable period of uplift for the Nogal Valley area. The area continued to emerge in Oligocene time, as is indicated by the distribution of marginal marine rocks of that age, which roughly tend to follow the present coastline.

Major tectonic activity began again during the Miocene epoch. In northwestern Somalia late Oligocene to Miocene sedimentary breccias and limestone conglomerates formed upward coarsening strata near Miocene faults south of Berbera and conglomeratic lenses are found in contemporaneously deposited rocks to the east. A major graben in the Darror Valley area was the site of lagoonal deposition, which grades into marginal marine deposits to the east and fluvial deposits to the north and south near other Miocene faults. West of Bender Beila other Miocene lagoonal deposits indicate another downfaulted or downwarped area (Greenwood, 1982).

These early Miocene faults were apparently syndepositional and formed

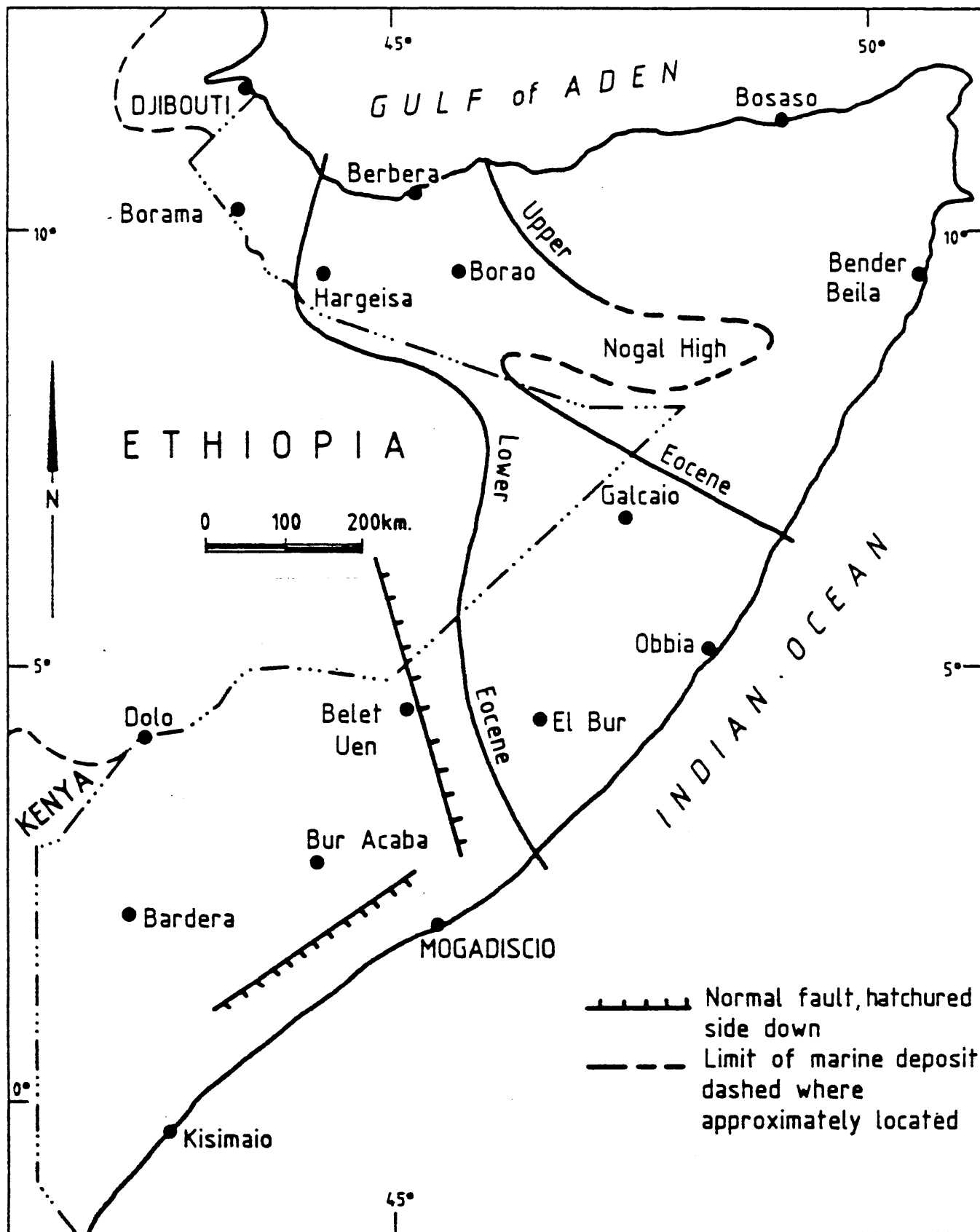


Fig. VI-9. Early Tertiary structures (Greenwood, 1982).

as growth structures contemporaneous with marginal marine deposition. The formation of the Gulf of Aden by sea-floor spreading caused the simultaneous uplift of mountains in northern Somalia. Complex synthetic and antithetic faults were formed and sedimentary blocks were rotated respectively away and toward the Gulf of Aden (fig. VI-10).

In middle to late Tertiary time, a major northeast trending downwarp formed along the Indian Ocean coast, probably in response to the uplift of the Bur Region. The north side of this uplift is bounded by a north-northwest trending structure extending through Belet Uen (fig. VI-8), which probably marks a major tectonic boundary. This structure extends into the Ogaden region and the Afar depression where it forms a major arch (Greenwood, 1982).

VI.5.5. Rift Structures

Somalia lies on the Ethiopian-Arabian shield which has been relatively stable for most of geologic history. As indicated above however, since Mesozoic time it has been affected by epirogenic movements related to the development of the Gulf of Aden rift zone. This fault-zone is probably developed on an old zone of weakness which possibly was established during Precambrian time, and was rejuvenated repeatedly in Mesozoic and Tertiary times, until it became the site for the sea-floor spreading event beginning in early Miocene time.

Faulting follows three main directions: 1) the Gulf of Aden trend (E-W to ENE-WSW); 2) the Red Sea trend (NW-SE to WNW-ESE) and 3) the East African trend (N-S). The latter trend is less important than the first two, which are probably interrelated contemporaneous responses to crustal extension near a rift triple point.

The faults are steeply dipping normal faults, and seem clean-cut and unrelated to any mylonitized zones. Vertical displacement along the Red Sea trend is commonly between 500 and 1000 m, and in one locality apparently 3000 m. Along the Gulf of Aden trend individual displacements can be as great as 800 to 900 m, and the cumulative vertical displacement between the edge of the northern plateau and the coast is more than 2000 m in several localities. A vertical

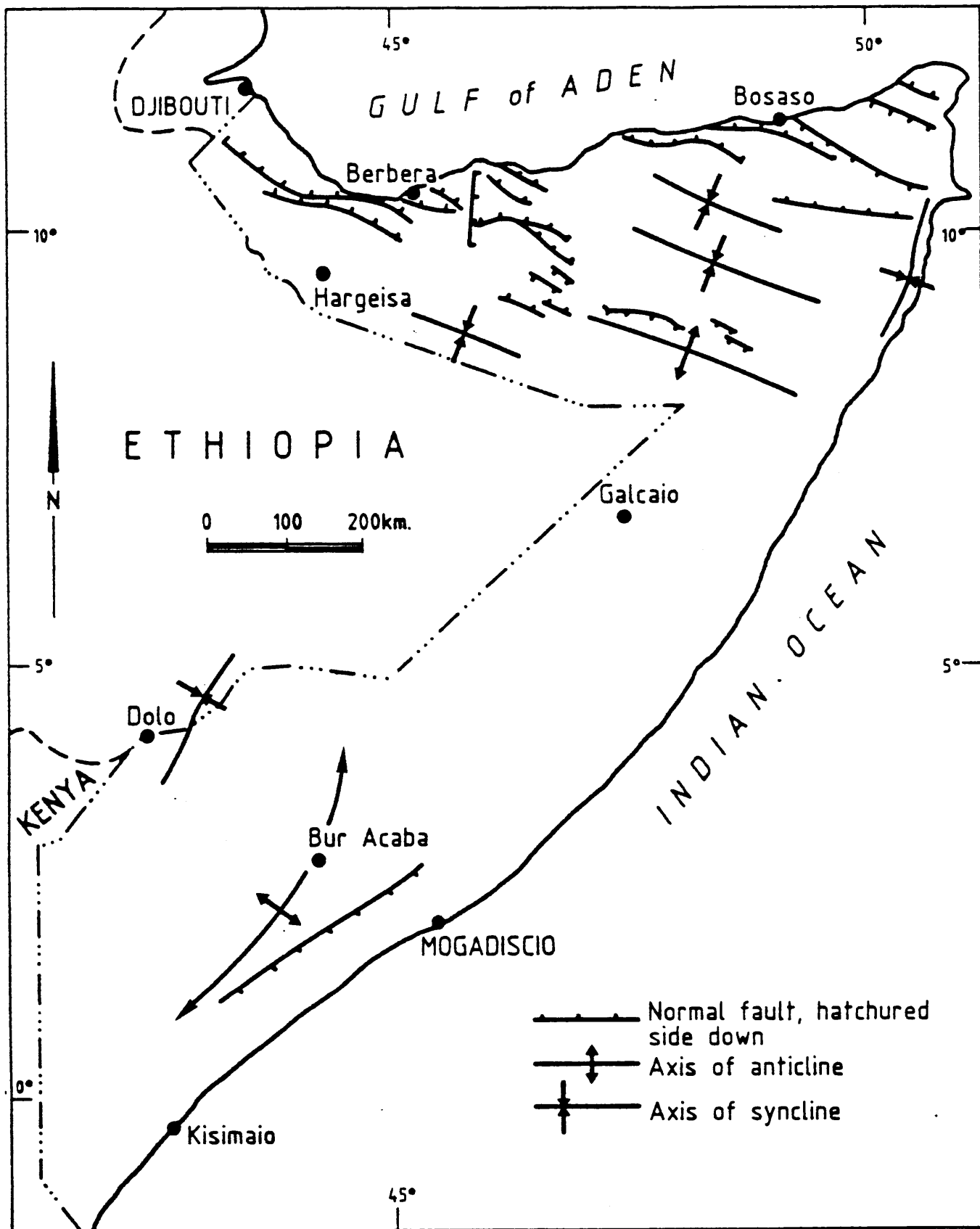


Fig. VI-10. Late Tertiary structures (Greenwood, 1982).

displacement of at least 1500 m has been measured along a nearly vertical fault of the East African trend.

The rift-related faulting which began in early Miocene time, continued into the Pliocene epoch and probably into Recent time. Although sea-floor spreading results in mainly a horizontal displacement, the North Somalia Plateau has been uplifted to over 2000 m in elevation, while the floor of the Gulf of Aden is more than 2400 m below sea level (Dixey, 1956).

The Red Sea trend is the most extensive of the fault systems, crossing the whole of Somalia from southeast to northwest. This system divides the country into a southwestern block and a northeastern block along the Shebeli River near Belet Uen. Smaller faults in this trend are commonly en echelon and the large Darror Valley and Nogal Valley grabens are bordered by these faults.

The Gulf of Aden trend is most important in northern Somalia and forms the main escarpment of the North Somalia Highlands, separating it from the coastal plain along the Gulf of Aden. Parallel faults form the step like structures underlying the Gulf of Aden.

Although the East African trend is not significant in northern Somalia, it is quite extensive along the Indian Ocean coast in the central and southern part of the country. These faults may extend for hundreds or even several thousand km (UNDP, 1972b).

VII. OCCURRENCES OF NON-RADIOACTIVE MINERALS

VII.1. Introduction, State of Knowledge

The information about non-radioactive mineral occurrences in the SDR consists mainly of numerous reports on single indications of iron, copper, lead-zinc, molybdenum, tin, sulphur, gypsum, sepiolite, ornamental facing stone, salt, clays, quartz, etc. The authors of the best available publications are Pallister (1957), UNDP (1970a,b,c, 1971, 1972) Osman and others (1974), Trashliev and Kamenov (1976a,b,c), Kamenov (1976a,b) and BRGM (1979). A summary description of the mineral occurrences of Somalia and their regional geological-metallogenic relationships is lacking, as is a pure inventory with appropriate maps. Exploration to date has not led to the discovery of a single economic mineral deposit. At present there is minor production of sepiolite and solar evaporation pads for sea water which yield some 250 tpd of low purity salt, used mainly for the curing of skins and hides. Information concerning the value of mineral production is not available, but it is estimated that it does not exceed 0.03% of Somalia's GNP of ca. US\$ 470 million (1978).

VII.2. Mineral Occurrences

The following section is a brief review of known and described occurrences of copper, lead-zinc, tin-tantalum, molybdenum, iron, pegmatite minerals, kaolin, coal and sepiolite. These commodities are briefly described in their respective regional geological settings, based upon information obtained from a number of references mentioned in Sect. VII.1. Fig. VII-1 shows the approximate locations of Somalia's known non-radioactive mineral occurrences (excepting pegmatite minerals) which were discussed in this section.

VII.2.1. Copper

The most promising copper prospects are located in the Seinat area, lying between East longitudes $47^{\circ}28'30''$ and $47^{\circ}31'40''$ and North latitudes $10^{\circ}56'45''$ and $10^{\circ}03'30''$ (Kamenov, 1976). The occurrences consist of copper oxides and secondary and primary sulfides in nine repetitive rhythmic sedimentary sequences of sericite-chlorite siltstones and sericite slates within the upper part of the Upper Proterozoic Inda Ad Series.

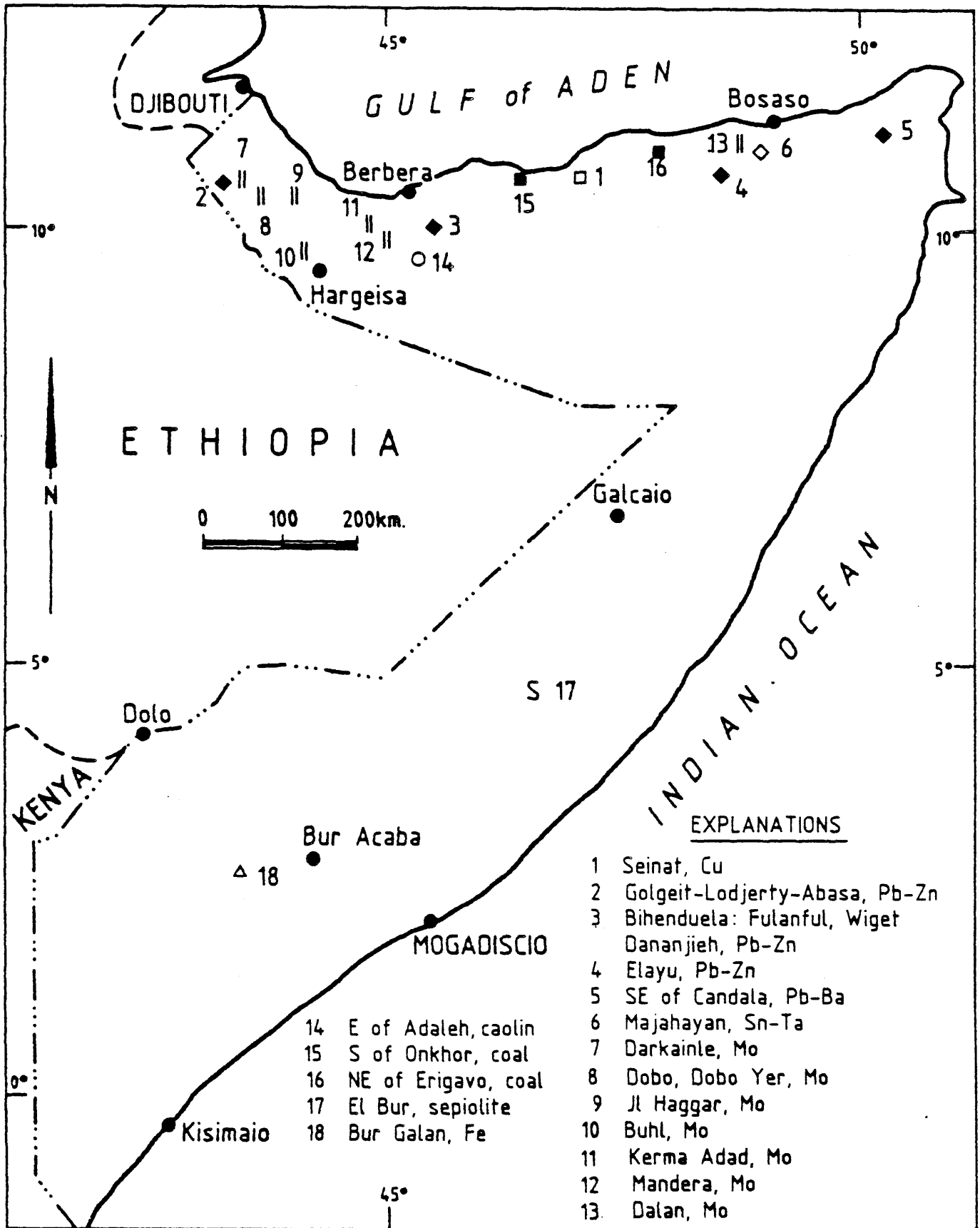


Fig. VII-1. Location of non radioactive mineral occurrences

From the descriptions (Kamenov, 1976; BRGM, 1979), the Seinat prospects appear to be stratiform. However, further work is required for a better understanding of the genetic model and its economic potential. This work is justified considering the economic importance of stratiform copper deposits including the Kupferschiefer in Europe and Spar Lake in North America.

VII.2.2. Lead-Zinc

Three areas of lead-zinc occurrences are known in northern Somalia, all of which are associated with Jurassic limestones. Their exact location within the stratigraphic sequence is not clear. Some authors (BRGM, 1979) believe the host limestones are at the base of the Jurassic section, above the Precambrian basement, while others (Julin, 1983) place it in the Upper Jurassic sequence.

In the Bawn area, occurrences are known at Golgeit ($43^{\circ}03'$ E / $10^{\circ}06'$ N), Lobjerty ($43^{\circ}03'$ E / $10^{\circ}12'$ N) and Abasa ($43^{\circ}05'$ E / $10^{\circ}06'$ N). None have been properly investigated. Some work was recently completed in Golgeit by Julin (1983), who suggested a stratigraphic control for the occurrences. This concept justifies further investigations in areas hosting similar occurrences.

In the Bihendulah area, however, the lead occurrences are located in both the Precambrian basement and the Jurassic cover in crosscutting structures which strike $30-50^{\circ}$ and $100-120^{\circ}$. According to BRGM (1979) this type of occurrence was observed in Fulanful, Wiget, Dananjieh and Bihendulah, but does not have any economic potential.

Another structurally-controlled group of lead-zinc occurrences were reported in the Elayu area where the prospects at Selid, Karin Kul, Unkah, Gedad, Gedaalan, Idig, Dalan North, etc. are located in 30° and 100° striking structures that cut the basement and the base of the transgressive Jurassic cover formations. No information is available concerning the economic potential of these prospects.

Another apparently stratiform lead-barite prospect which is located in the Lower Cretaceous sediments near Candala is also mentioned by BRGM (1979). Although no further information is available, this

deposit-type appears to warrant further investigations aimed at understanding the genetic model and its possible economic significance.

VII.2.3. Tin-Tantalum

Tin-tantalum minerals were reported mainly from the Majahayan area (40°00' E / 11°04' N) in northern Somalia. They are associated with an intrusive phase (alkaline granites and pegmatites) at the close of Precambrian time approximately 470-550 MY. The prospect had been discovered in 1938 and mined until 1942 by the Italian mining company, COMINAR. After 1972 it was re-examined by UNDP and later assessed by Technoexport of Bulgaria. This organization carried out 4105 m of drilling, 1233 m of drifting including restoration of old workings, sampling (6200 samples) and the construction of a one ton/hr pilot concentration plant.

The tin minerals consist mainly of cassiterite and occur in pegmatites and associated quartz veins belonging to three structural systems which strike 35°-50°, 80°-110° and 160°-170° respectively. The thickness of the structures ranges from about 10 cm to 1 m, and they extend along strike for up to 600 m. Technoexport calculated reserves of 200,000 tons of ore containing 0.075% Sn, 0.011% Cs, 0.104% Rb and 0.08% Ta, with no mention of Nb (BRGM, 1979).

VII.2.4. Molybdenum

Kamenov (1976) stated that the molybdenum occurrences are associated with both Upper Precambrian pegmatitic-granite and nepheline syenite intrusions. He lists eight molybdenite shows in northwestern Somalia within an area 120 km E-W by 80 km N-S. These prospects and their locations are listed as follows:

Darkainle	43°16' E / 10°23' N	nepheline syenite
Dobo	43°17' E / 10°16' N	pegmatite dikes
Dobo Yer	43°18' E / 10°18' N	pegmatite dikes
Il Haggar	43°43' E / 10°13' N	pegmatite dike
Buhl	43°56' E / 9°49' N	syenite
Kerma Adad	44°31' E / 10°03' N	leucocratic granite

Mandera	44°46' E / 10°01' N	granite gneiss
Dalan	48°50' E / 11°02' N	granite with anomalous Mo content

The prospects do not appear to be fully assessed, and therefore no information can be ascertained about their potential. Their geological settings, however, mainly associated with pegmatites and nepheline syenite intrusions, do not appear to justify high expectations.

VII.2.5. Iron

The most significant iron prospect currently known in Somalia is the iron occurrence at Bur Galan. It lies within the Precambrian Bur uplift, some 200 km west of Mogadiscio, in the Lower Proterozoic Dinsor Formation. About ten ore bodies are known following roughly an 80 km long northwest trend between Cul Cul in the southeast and Daimir in the northwest. The ore belongs to a Precambrian "banded iron formation", and consists of magnetite and martite. The estimated reserves (UNDP, 1970) amount to ca. 170 million tons of ore with an average grade of 30-35% Fe and 42-45% SiO₂. A feasibility study (Kamenov and Trashliev, 1976) concluded that the iron ore of Bur Galan and satellite bodies was not competitive on the world market.

VII.2.6. Pegmatite Minerals

Numerous pegmatites, already mentioned as hosts for tin-tantalum (Sect. VII.2.3.) and molybdenum (Sect. VII.2.4.) mineral occurrences, contain feldspar, mica, beryl and piezo-electric quartz. The latter mineral may eventually be of economic interest. Several uranium minerals have been found in pegmatites including samarskite and euxinite which were described by Pallister (1957) (Sects. VIII and IX).

VII.2.7. Kaolin

A kaolin occurrence was described by BRGM (1979) from an area ca. 50 km east of Adaleh along the road between Berbera and Hargeisa. Here, the Cretaceous Nubian Sandstone covers an old weathering surface above Precambrian granites and granitic gneisses. This environment may offer some uranium possibilities, and therefore will be discussed in the appropriate section.

VII.2.8. Coal

Occurrences of Cretaceous-age coal were reported in the central part of northern Somalia along the Gulf of Aden coast, particularly from areas south of Onkhor and northeast of Erigavo. The coal is sub-bituminous and has a calorific value of 3500 kcal/kg (BGR, 1981). It occurs in approximately one m thick seams in shallow water deltaic sediments. These coal prospects in northern Somalia are presently being assessed by a FRG technical cooperation project, which will submit its final report in 1983.

VII.2.9. Sepiolite

The sepiolite or meerschaum ($2 \text{MgO} \cdot 3\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) deposits, which have some limited significance for the Somali economy, are located close to the town of El Bur, about 370 km north of Mogadiscio, in Mudugh Province. The deposits occur as sub-horizontal beds containing various grades of sepiolite and have a total thickness of approximately two m within Eocene or younger limestones over an area of nine km^2 (UNDP, 1970; BRGM, 1979). The contacts between the sepiolite and the limestones are gradational, indicating a metasomatic replacement of the limestones or a pedogenic origin as proposed by BRGM (1979). The material from the El Bur deposit contains 79% sepiolite, and the impurities consist of evaporites. The low grade of the deposit (high grade sepiolite from Tanzania grades 88% sepiolite) makes the product unfit for pipe manufacture, but suitable for industrial purposes including special drilling muds, cat litters, soil absorbents, etc.

VII. HISTORY OF EXPLORATION FOR RADIOACTIVE DEPOSITSVIII.1 Introduction

This history of the radioactive mineral exploration began after World War II in what was then the British Somaliland Protectorate. After Independence exploration for radioactive minerals was carried out by UNDP (1964-1974), foreign private mining companies (1968-1972, 1975-1976) and finally after 1977 by a Somali Government - Arab Mining Company - Government of Iraq consortium in the Mudugh area. The activities of those programs will be reviewed below.

VII.2. Previous Exploration ProgramsVIII.2.1. Geological Survey of the Somaliland Protectorate

Following the end of World War II the Geological Survey of the British Somaliland Protectorate carried out some prospecting for radioactive minerals in Precambrian pegmatites. References to this work and its results were made by Daniels (1957), Pallister (1957) and Daniels (1960).

Pallister (1958) briefly mentioned two occurrences of samarskite associated with pegmatites in the Hunbeleh Range and along the Berbera-Hargeisa road at localities close to Lafarug and Daabuduk.

VIII.2.2. United Nations Development Programme

During Phase I (1964-1968) of the UNDP-financed Mineral and Groundwater Survey, a combined magnetometer-scintillometer airborne survey was conducted in 1965 by the contractor, Canadian Aero Service Ltd. over an area of 22,110 km². This area included Precambrian rocks of the Bur area, with a slight overlap onto the overlying Jurassic Adigrat Formation. The known characteristics of the aerial survey are as follows (UNDP, 1970):

Equipment: airborne magnetometer and scintillometer, Doppler navigational control, continuous strip photography of the flight path over a width of 150 m.

ground clearance	150 m
line interval (general)	1.0 km
line interval (detail)	0.5 km
interval between readings	1.0 km
line direction (general)	N 30° W

line direction (detail) N 25° E
N 60° E

The area covered by this survey has a rectangular shape, measuring 230 km in a N 60° E direction and 95 km in a N 30° W direction (fig. VIII-1). The results, which were submitted to UNDP in mid-1966, indicated a number of magnetic anomalies caused by the banded iron ore at Bur Galan (Sect. VI.2.5.) and 38 radiometric anomalies, occurring mainly in the southwestern part of the survey area of Yac Brava, Bur Galan and Alio Ghelle. Between 1966 and 1969 further work by UNDP was concentrated at Alio Ghelle. The results of this survey led Somalia to issue an invitation for bids from international mining companies for further exploration for radioactive deposits in the Bur area (see further below).

In 1968, during the concluding stage of Phase I of the UNDP Mineral and Groundwater Survey, a reconnaissance flight was conducted using a gamma-ray spectrometer along the route between Mogadiscio, El Bur, Dusa Mareb and Galcaio. The results of this survey indicated radioactive anomalies in the El Bur, Dusa Mareb, Adado and Ghelinsor areas (UNDP 1973). These results led to a systematic radiometric survey over an L-shaped area of 33,000 km² in the Mudugh area between the towns of El Bur in the southeast and Galcaio in the northeast during Phase II of the UNDP-Project (1969-1970) (fig. VIII-1). Details of this survey, which was carried out between August and October 1970 with UNDP-owned scintillation equipment and an airplane of the Somali Air Force, are not known. UNDP (1973) did not provide data on the instrumentation and flights, but mentioned only that the line-spacing was 5 km. The area covered by this 1970 aerial survey is defined by the following approximate coordinates:

A: 7°38'53" N / 47°26'16" E
 B: 6°51'07" N / 48°06'40" E
 C: 5°42'13" N / 46°57'46" E
 D: 5°11'07" N / 47°33'20" E
 E: 4°44'26" N / 47°44'26" E
 F: 4°17'49" N / 46°40'00" E
 G: 5°28'53" N / 45°28'53" E

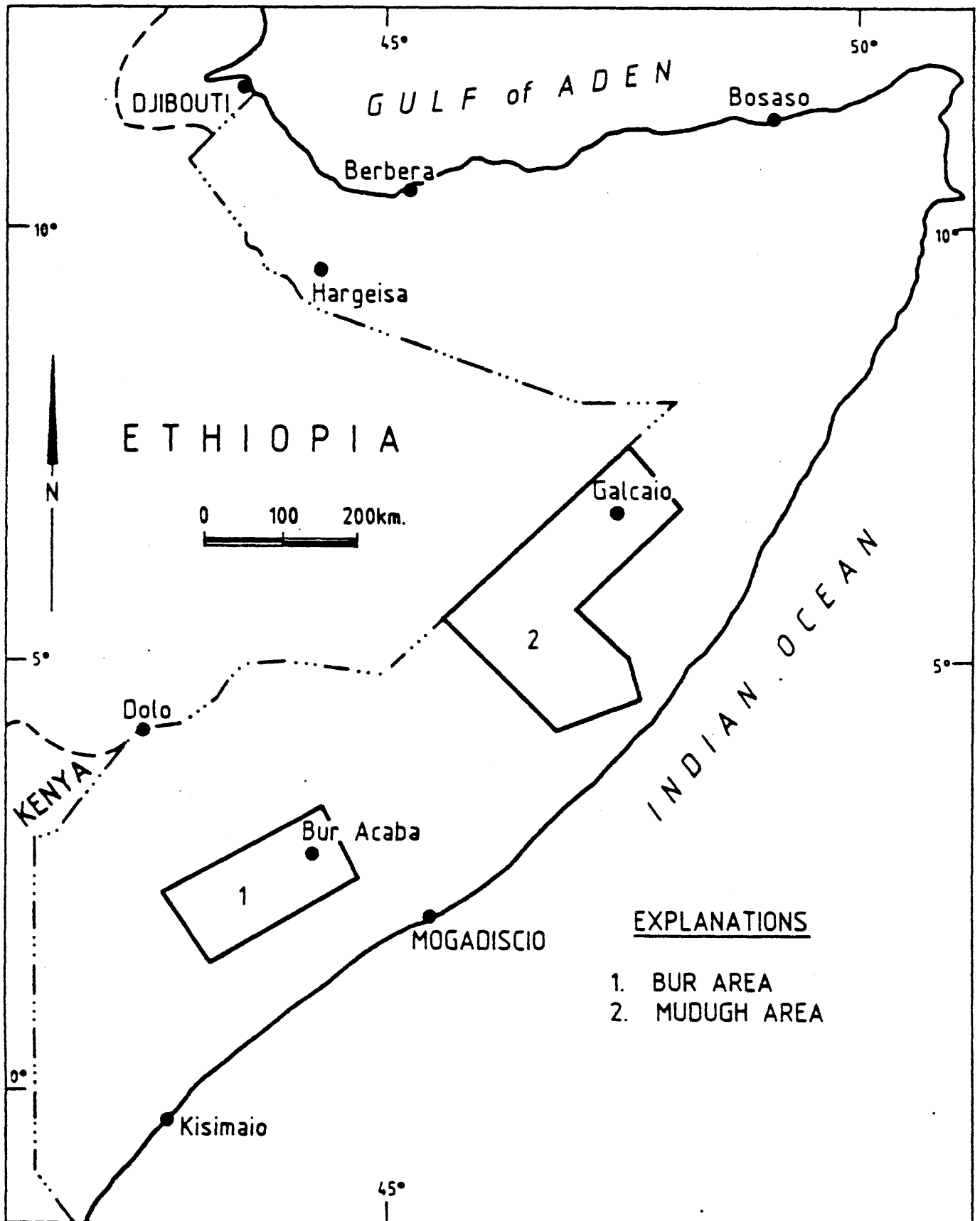


Fig. VIII-1. Location of areas covered by UNDP airborne radiometric surveys.

This survey resulted in the discovery of 18 radiometric anomalies located between El Bur and Ghelinsor. Among these is a north-south trending anomaly containing several peaks, which lies between the towns of El Bur and Dusa Mareb, a distance of 93 km. Further investigations during Phase III of the UNDP-Project (1972-1974) concentrated on the evaluation of the best anomalies at Wabo, Mirig, and Dusa Mareb and resulted in the recognition of calcrete-type uranium deposits of possible economic significance.

The total work by UNDP in the Wabo, Mirig and Dusa Mareb areas during the 1972-1974 Phase III survey is summarized in the following table (McKee Overseas Corporation, 1979):

<u>Type of work</u>	<u>Unit</u>	<u>Wabo</u>	<u>Mirig</u>	<u>Dusa M</u>	<u>Total</u>
airb rad.	km ²	-	-	-	33,000
ground rad.					
recon	line-km	-	-	-	500
detailed	km ²	18.0	15.8	39.0	72.8
pitting	No/m	1530/3050	206/1655	125/400	1861/5105
pit rad.	m	6000	3000	800	9800
drilling					
auger	No/m	677/5877	225/2635	138/1307	1040/9819
core	No/m	13/882	1/74	19/859	33/1815
logging	m	3000	3500	1700	8200
sampling					
channel	No	1293	270	278	1841
bulk	No	1	1	1	3

The expenditures for the uranium projects in the Bur and Mudugh areas carried out by UNDP during Phases I, II and III are not indicated. Estimates, however, can be made based on the total amounts spent for the entire Phases I, II and III:

Phase I:	US\$ 981,268	:	US\$ 649,000	= 66% UNDP
			US\$ 332,668	= 34% Somalia

Phase II: US\$ 1,662,501 : US\$ 909,800 = 55% UNDP
 US\$ 752,701 = 45% Somalia

Phase III: US\$ 2,286,960 : US\$ 1,270,000 = 55% UNDP
 US\$ 1,016,960 = 45% Somalia

totalling US\$ 4,930,729. The uranium-related work during Phase I included mainly ca. 24,000 line-km of an airborne magnetometer-scintillometer survey of the Bur area at an estimated cost of US\$ 20 per linear km amounted to US\$ 480,000 plus US\$ 120,000 for drilling, mapping, etc. while the uranium-related investigation of Phase II and III concentrated on the Mudugh area. The cost to the Somali Government was estimated at US\$ 575,760 (Joubin, 1974). As the UNDP contribution of US\$ 703,706 was for 55% of the amount, the total cost was US\$ 1,279,466. Thus, the total expenditures incurred for UNDP uranium investigation in the Bur and Mudugh areas amount to about:

US\$ 600,000 : Phase I (Bur area)
 US\$ 1,279,466 : Phases II and III (Mudugh area)
 totalling US\$ 1,859,466.

After lengthy deliberations and preparations for an international tender, in 1977 the Government of Somalia decided to conclude an agreement with the Arab Mining Company of Amman, Jordan and the Government of Iraq for the further development and eventual production of the calcrete deposits in the Mudugh area (see Sect. VII.2.6.).

VIII.2.3. SOMIREN / Nucleare Somala S.p.A.

After having accepted SOMIREN's tender offer for uranium exploration and production in the Bur area, the Government of Somalia concluded an agreement with the company in December 1968. These rights were transferred in March 1969 to Nucleare Somala S.p.A, another subsidiary of the Italian ENI Group, who carried out exploration programs in the following areas (fig. VIII-2):

Southern Somalia: Bur area, covering 8249 km²,
 within the coordinates listed in
 Sect. IV.2.2;

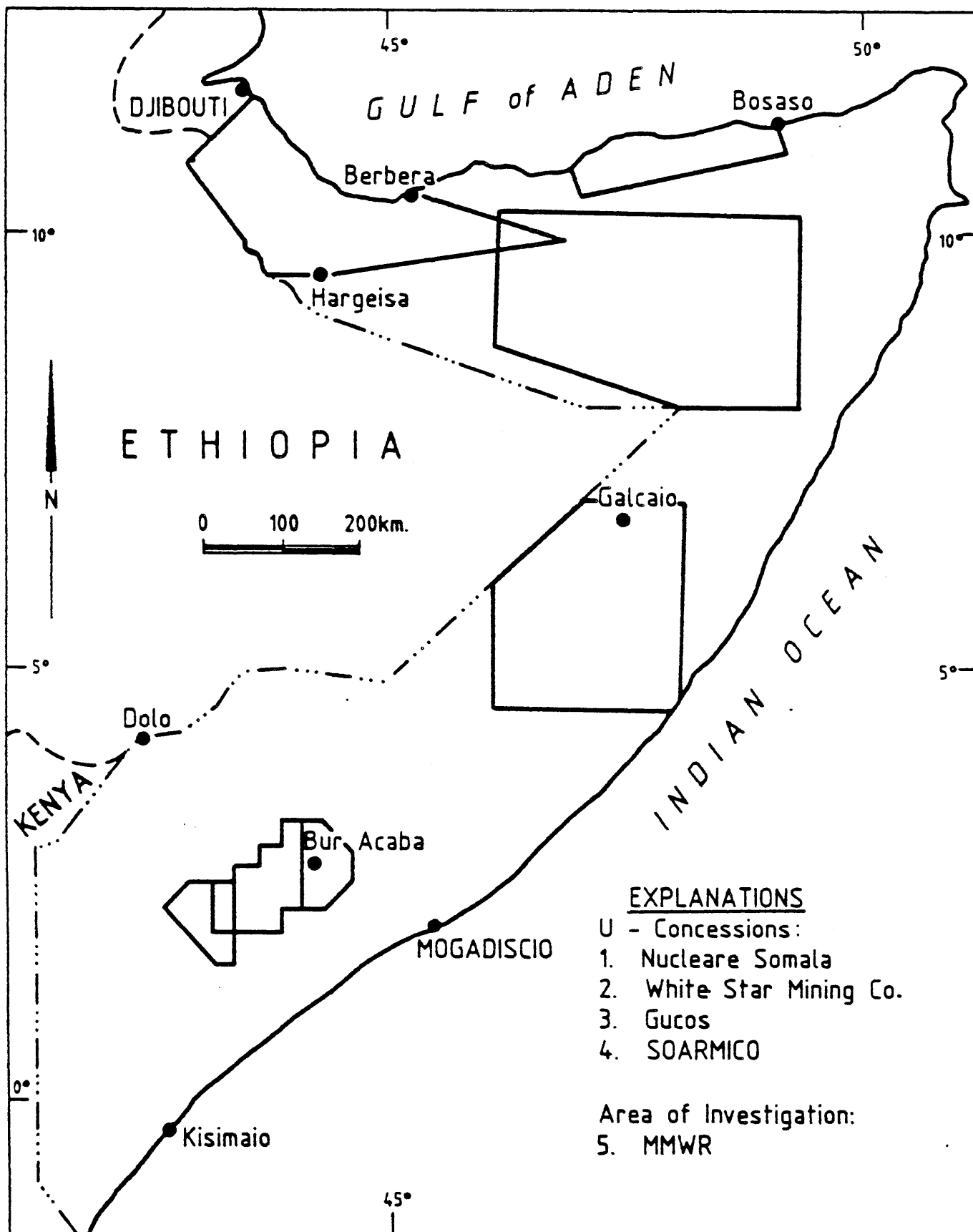


Fig. VIII-2. Location of concession areas and of area of investigation covered by the Ministry of Mineral and Water Resources (MMWR).

Northern Somalia: Western area, covering 38,215 km²
 within the coordinates listed in
 Sect. IV.2.2; and
 Eastern area, covering 11,564 km²
 within the coordinates listed in
 Sect. IV.2.2.

Exploration of the southern area was carried out in two phases:

1) from 1969 to 1972; and 2) from 1975 to 1976, when Nucleare Somala terminated its agreement with the Somali Government.

The work done during the 1969/1972 period included the following:

- | | |
|---------------------------|------------------------|
| 1. airborne spectrometry: | 8256 km ² |
| 2. ground radiometrics: | |
| a. reconnaissance: | 4109 km ² |
| b. detail: | 61.09 km ² |
| 3. photogeology: | 21 km ² |
| 4. trenching: | 17,837 km ³ |
| 5. drilling: | 94 holes with 11,279 m |
| 6. analyses: | |
| a. chemical | 1025 |
| b. radiometric | 3914 |
| c. petrographic | 122 |
| d. mineralogic | 39 |

In addition, mineral dressing tests and a feasibility study were also carried out.

Details of the activities listed above were not available. It is known, however, that the airborne work had been carried out under contract by Hunting Geology and Geophysics Ltd., who submitted a report to Nucleare Somala in 1970 (Nucleare Somala, 1977). The area covered by this survey overlaps with the central part of the area flown by Canadian Aero Service Ltd. for UNDP in 1965 and is defined by the following coordinates:

A: 3°20' N / 43°45' E
 B: 3°20' N / 44°00' E
 C: 2°20' N / 44°00' E
 D: 2°20' N / 43°45' E
 E: 2°00' N / 43°45' E
 F: 2°00' N / 43°15' E
 G: 2°45' N / 43°15' E
 H: 2°45' N / 43°30' E
 I: 3°00' N / 43°30' E
 J: 3°00' N / 43°45' E

This survey discovered 409 radiometric anomalies, of which 47 were assigned a high priority. Follow-up work, including trenching and drilling concentrated mainly on the anomalies at Alio Ghelle (A, B, C, D, E, F), Bur Gheluai and Tingurru. Of the total of 94 holes drilled on these anomalies, 80 tested the Alio Ghelle anomalies. The results of this work confirmed the presence of Th-U minerals within the albitized episyenite of Precambrian age which had been discovered and recognized as an albitite-type U-Th radioactive occurrence by UNDP (1970).

Encouraged by the results of the Alio-Ghelle investigation, Nucleare Somala carried out further work between 1975 and 1976 during the second phase of the program. This phase included the following activities:

1. photogeology;
2. geostatistics for determination of the optimal drill-hole pattern;
3. track-etch survey;
4. drilling of 27 core holes for a total of 6105 m;
5. chemical analyses;
6. ore reserve calculations which resulted in an estimate of 1700 t U_3O_8 at a grade of 0.07% ("drill indicated").

As a result of Phase 2 it was concluded that mineralized bodies with relatively low U_3O_8 content but high Th-grades (\pm 3% ThO_2) were of small size and erratically distributed (Nucleare Somala, 1977). In

VIII-9

March 1976 the company therefore decided to rescind the agreement concluded in December 1968, after expending a total of SoSh. 44,395,292, equalling US\$ 7,103,247 in the southern area.

As stipulated in the agreement between the Somali Government and SOMIREN (Sect. IV.2.2.) the company had to evaluate two areas in northern Somalia (fig. VIII-2): a western area comprising 38,215 km²; and an eastern area containing 11,564 km². This work was accomplished between July 1970 and July 1971, although the contract provided for a two year evaluation with a total expenditure of US\$ 2,000,000.

As no documentation from this work was available to the IUREP Mission, some information from other sources was used.

The evaluation of these two areas included an airborne gamma-ray spectrometer survey and a three month ground follow-up check of the encountered anomalies. The contractor for the aerial survey was Hunting Geology and Geophysics Ltd., who used a fixed-wing DC-3 aircraft. Further information on the instrumentation used as well as flight data are not available. Because of military and geological reasons, only approximately 16,050 km² or 42% of the western area were flown.

The main target in the western area was the Precambrian basement and its Phanerozoic sedimentary mantle. The target in the eastern area was the Upper Protorozoic Inda Ad Series and patches of Neogene sediments along the Gulf of Aden coast.

The results of the airborne survey are as follows: in the western area, ten radiometric anomalies were encountered, of which eight were interpreted as contrast anomalies and two as expressions of radioactive pegmatites (Sect. VII.2.1.); in the eastern area, six radiometric anomalies were located in the coastal plain, but assessed as contrast anomalies.

The ground follow-up was of three months duration and covered the Nubian Sandstone between Hargeisa and Adadle, a strip along the Ethiopian border, the coastal plain between Berbera and Zeila and the

pegmatite area of Daabuduk. As the results were negative, Nucleare Somala returned the area in 1971.

It is assumed that the expenditures incurred by Nucleare Somala in the two areas in Northern Somalia amounted to ca. US\$ 2,000,000 as had been stipulated in the agreement.

VIII.2.4. White Star Mining Company S.p.A.

The Somali Government invited bids for radioactive minerals exploration in the Bur area, covered by the 1965 UNDP aerial survey. Western Nuclear's offer was accepted and the Government assigned the Yaq Brava anomaly to Western Nuclear's Somali subsidiary: White Star Mining Company (fig. VIII-2). The agreement between the two parties was concluded in December 1968 (Sect. IV.2.3.), covering an area of ca. 2060 km², which was subsequently explored by White Star Mining Company during the period which ended in May 1970. The information reviewed below was abstracted from the final report on the company's operations (Duff, 1970).

Ground follow-up work on the UNDP anomaly at Yaq Brava outlined five anomalous areas which were named: East Airport, Northeast Airstrip, Bur Edan, Graveyard and Yaq Brava (strict sense) anomalies, and subsequently were tested by core drilling.

1. East Airport Anomaly strikes NW-SE for a length of 800 m and peaks at 6X background. It covers a flat plain with no outcrops or geomorphological indications of structure at the surface. The anomaly was tested by three core holes: YB-1* (TD = 213 m), YB-2 (TD = 186 m) and YB-3 (TD = 171 m).
2. Northeast Airstrip Anomaly is a possible northeast extension to the East Airport Anomaly and strikes E-W. The radioactivity is lower than the East Airport Anomaly, but covers a larger area. Two core holes were drilled: YB-4 (TD 192 m), YB-6 (TD 286 m).

* It is not known whether the drill holes were vertical or angled.

3. Bur Edan Anomaly is a point anomaly located at the foot of Bur Edan, a quartz-capped biotite gneiss outcrop. A single core hole was drilled: YB-5 (TD 220 m).
4. Graveyard Anomaly lies approximately 1.5 km north of Bur Dibidividen and is a narrow N-S striking anomaly with peaks of 6-8X background, along the eastern edge of a small unnamed "Bur". Seven core holes were drilled and all encountered technical drilling problems: YB-7 (TD 222 m), YB-8 (TD 259 m), YB-9 (TD 203 m), YB-10 (TD 144 m), YB-11 (TD 168 m), YB-12 (TD 155 m), and YB-13 (TD 127 m).
5. Yaq Brava Anomaly encloses a 2 X background contour and measures 5.5 km E-W by 2.4 km N-S. Six core holes were drilled into this anomaly: YB-14 (TD 128 m), YB-15 (TD 160 m), YB-16 (TD 161 m), YB-17 (TD 161 m), and YB-18 (TD 90 m), the sixth hole is undocumented.

As Duff (1970) states "... nothing of commercial interest has been discovered through the exploration program to the present time. However, less than one-fourth of the large Yaq Brava Anomaly has been studied, and approximately only 15% to 20% of the total concession area has been examined".

The main activities of the White Star Mining Company consisted of drilling: a total of 3246 m in 19 core holes (one undocumented). The total expenditures made by the company are estimated at about US\$ 800,000 using Duff's statement that monthly operating costs amounted to US\$ 50,000-55,000.

VIII.2.5. German Uranium Company of Somalia

When the international tender for the Bur area was formulated by Somalia in 1968, Uranerzbergbau GmbH & Co. KG made an offer on behalf of a German consortium (which in addition to Uranerz also included Urangesellschaft GmbH & Co. KG) for their Somali subsidiary: German Uranium Company of Somalia (GUCOS). In November 1968, the Somali Government assigned to this consortium two areas located in the eastern and western parts of the Bur area (fig. VIII-2). The agreement between

GUCOS and Somalia was signed in February 1969. Subject to this contract were two areas called the Eastern area around Dinsor and the Western area, surrounding Bur Acaba. The coordinates of these areas were as follows:

Eastern area: 5167 km²;

coordinates: A: 2°40' N / 42°45' E
 B: 2°40' N / 43°00' E
 C: 2°00' N / 43°00' E
 D: 2°00' N / 43°15' E
 E: 1°40' N / 43°15' E
 F: 1°40' N / 43°00' E
 G: 2°20' N / 42°30' E

Western area: 4654 km²;

coordinates: A: 3°20' N / 44°00' E
 B: 3°20' N / 44°15' E
 C: 3°00' N / 44°30' E
 D: 2°40' N / 44°30' E
 E: 2°40' N / 44°15' E
 F: 2°20' N / 44°00' E

The only available information on GUCOS' work, which was terminated in June 1970, consists of Hunting's report on the airborne gamma-ray spectrometer survey of the Bur region, carried out under a contract from GUCOS (Hunting Geology and Geophysics Ltd., 1970).

The main features of this aerial survey, flown with a fixed-wing DC-3 aircraft were:

1. 4 channel gamma-ray spectrometer;
2. 2 sodium iodide crystals of 1846 cm³ each;
3. 35 mm positioning camera;
4. radar altimeter; and a
5. 2000 Doppler navigation system.

A total of 29,070 line km were flown at a 400 m line spacing. The flight direction was north-south and flying height 150 m. East-west tie lines were flown at 10 km spacing.

The results of Hunting's survey were the definition of 780 spectrometric anomalies, of which 78 were considered to be of relatively high interest. Most high-interest anomalies were detected over areas mapped as underlain by Mesozoic limestones, with relatively few over Precambrian rocks.

As the ground follow-up, consisting of geological and radiometric investigations did not yield any positive results, the project was terminated in June 1970. The total expenditures incurred by GUCOS in the two concession areas are estimated at US\$ 750,000. The bulk of this amount was the cost for the airborne spectrometer survey.

VIII.2.6. Somali Arab Mining Company

In 1977, the Somali Government concluded an agreement with the Arab Mining Company and the Government of Iraq, for the further exploration of an area comprising 53,513 km² in the Mudugh area (fig. VIII-2) and the evaluation, development and mining of the calcrete deposits of Wabo, Mirig and Dusa Mareb. Subsequently, the three parties founded the Somali Arab Mining Company (SOARMICO).

Information concerning the work completed following the granting of this concession is extremely scarce, and the main source is the technical and economic pre-feasibility study submitted to SOARMICO by McKee Overseas Corporation of San Mateo, California, USA in January 1979.

The concession area is located in the Mudugh area and delineated by corner points with the following coordinates (fig. VIII-2):

- A: 7° N / 47° E
- B: 7° N / 48° E
- C: 4°30' N / 48° E
- D: 4°30' N / 46° E
- E: 5°50' N / 46° E

The main activities carried out in this concession area consist of the pre-feasibility study by McKee; metallurgical tests conducted by AMDEL of Australia in 1981; and an airborne radiometric survey carried out in 1982 by a Brazilian company. As mentioned above, the only

reference available to the Mission is by McKee Overseas Corporation (1979), which included:

1. review and assessment of one reserve calculations prepared by UNDP;
2. development of mining plans;
3. selection of a metallurgical process;
4. preliminary estimates on capital and operating costs for the complete mining and milling complex; and
5. cash flow and rate of return on investment calculations.

Details of SOARMICO's expenditures for the period 1977 through 1982 are not available. It is estimated that for the above-mentioned activities, mainly done by foreign contractors, ca. US\$ 2 million was expended.

VIII.2.7. Ministry of Mineral and Water Resources

The Geological Survey Department of the Ministry of Mineral and Water Resources of Somalia, carried out some uranium exploration in 1980, which is described by Naley (1981). This work included a carborne radiometric survey using a hand-held scintillometer, as well as a gamma-ray spectrometer, and was aimed at prospecting for calcrete uranium deposits in the region of Nogal. Between March and December 1980, an area of 116,800 km² was covered by ca. 9000 km of carborne traverses in northern Somalia (fig. VIII-2). The coordinates of the area are approximately:

- A: 10°10' N / 46°00' E
- B: 10°10' N / 49°30' E
- C: 8°00' N / 49°30' E
- D: 8°00' N / 48°00' E
- E: 8°45' N / 46°00' E

Settlements in this area are Gardo, Grawoe, Las Anod, Hudun, Ainabo, as well as Hagigarad. The geology of the area of investigation includes Tertiary sedimentary rocks ranging in age from Eocene to Miocene and consisting of marls, sandstones, gypsum and anhydrite (Naley, 1981).

Resulting from this survey was the discovery of a radiometric anomaly of 4-8 X background (bg = 10-15 cps) in a N-S trending depression overlain by a gypsum crust. Some follow-up work was done over an area 5 km N-S X 4 km E-W. This anomaly is located in Hagigarad (10°13' N / 46°15' E) on the road leading from Burao to Erigavo, close to the village of War-idad. Eight pits, 3 m deep exhibited increased radioactivity with depth (max. 200 cps) in the gypsum, sand-gypsum or clayey gypsum surface crust 0.5 to 1 m thick. No uranium minerals were observed by Naleye.

VIII.3 Conclusions

As has been indicated in this section, significant efforts have been made to explore for and develop uranium deposits in Somalia, by government departments (Somaliland Geological Survey, Ministry of Mineral and Water Resources), international agencies (UNDP), and private companies (SOMIREN/Nucleare Somala, White Star Mining Company, German Uranium Company of Somalia), as well as by a state-owned international company (Somali Arab Mining Company). In addition, several international companies, including Westinghouse's subsidiary, Wyoming Mineral Corp., were interested in concluding co-operative agreements with the Somali Government prior to 1979. This record seems to indicate a willingness by the Somali Government to allow foreign investments in the uranium mining industry. It shows also that the Government recognized the high risk of uranium exploration, and that it opted for attracting foreign risk capital rather than using its own funds which were urgently needed for other development projects.

In summarizing the operations described in detail in this section, the following can be said:

1. A total of 103,227 km² of Somalia, equal to 16.18% of the country, have been covered by airborne radiometric surveys (fig. VIII-3): 22,110 km² were flown by UNDP over the Precambrian uplift in the Bur area, and for the most part re-flown by Nucleare Somala and GUCOS. 53,513 km² were flown in the Mudugh area by Somali Arab Mining Company, partly resurveying the UNDP survey area of 1970, the records of which may no longer be available. 27,614 km² were also flown in northern Somalia by Nucleare Somala.

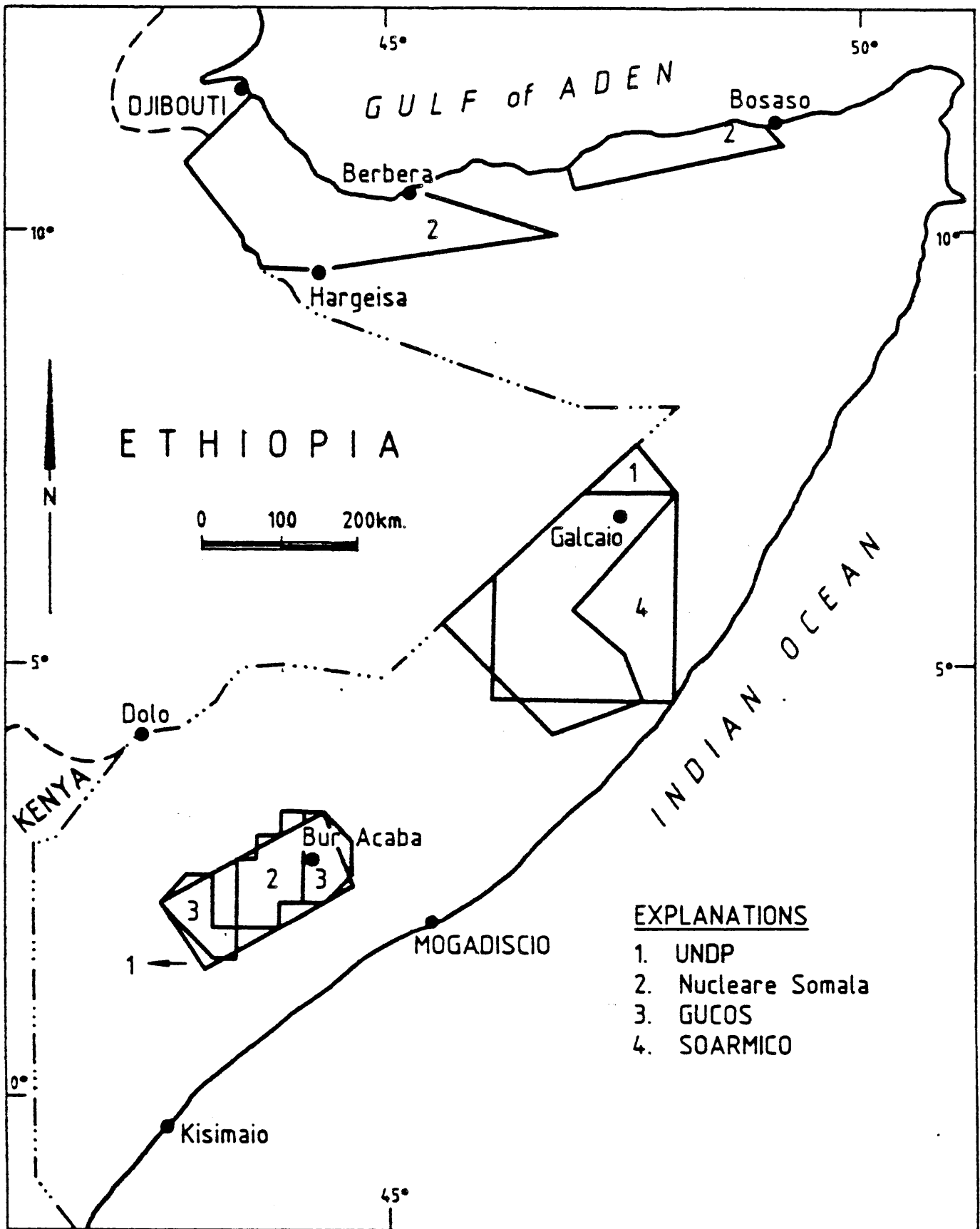


Fig. VIII-3. Location of areas covered by airborne radiometric surveys.

2. A total of 186,779 km², equal to 29.3% of the country, have been covered by various ground survey methods in the search for uranium deposits. 20,127 km² were surveyed in the Precambrian Bur uplift by Nucleare Somala, White Star Mining Company and GUCOS. 73 km² were examined in the Mudugh area by UNDP and Somali Arab Mining Company. 49,779 km² in northern Somalia were covered by Nucleare Somala and 116,800 km² in the Nogal area was covered by a carborne survey conducted by the Geological Survey of Somalia.
5. The total expenditures disbursed for uranium-related activities (exploration through feasibility studies) over the period 1965 to 1982 amounted to over US\$ 14,500,000, as summarized below:

Geol. Survey of the Somil. Protectorate:		?
UNDP:	Bur area: estim.	US\$ 600,000
	Mudugh area:	US\$ 1,279,466
Nucleare Somala:	Bur incl. Alio Ghelle	US\$ 7,103,247
	northern Somalia	US\$ 2,000,000
White Star Mining Co:	estim.	US\$ 800,000
GUCOS:	estim.	US\$ 750,000
SOARMICO:	estim.	US\$ 2,000,000
Geol. Survey of Somali D.R.		US\$?
	Total +	<u>US\$14,532,713</u>

IX. RADIOACTIVE OCCURRENCES OF SOMALIAIX.1 Introduction

This section deals with the radioactive occurrences which have been examined and described in detail. Some overlap exists with the contents of Sect. VIII. The occurrences discussed are those related to Precambrian pegmatites, as well as Alio Ghelle and those discovered in the Mudugh area.

IX.2 Description of the Radioactive OccurrencesIX.2.1. Pegmatites of Northern Somalia

As mentioned in Section VIII, the Geological Survey of the British Somaliland Protectorate discovered radioactive occurrences in northern Somalia, which were described in some detail by Pallister (1957) and Daniels (1960). The occurrences were found to contain the radioactive minerals samarskite, orthite and betafite and are associated with Precambrian pegmatites.

Pallister (1957) briefly mentions two occurrences of samarskite in pegmatites, which crop out at two different localities in the Hunbeleh Range along the road leading from Berbera to Hargeisa. The northernmost of the two localities lies ca. 10 km north of Lafarug, at approximately coordinates $10^{\circ}04'49''$ N / $44^{\circ}46'07''$ E. The second locality, further to the southwest along the same road, is located 5 km south of Daabuduk at approximately $9^{\circ}47'09''$ N / $44^{\circ}27'47''$ E (fig. IX-1).

Daniels (1960) referred to a radioactive occurrence which contained the minerals betafite and orthite (allanite) in a pegmatite cutting a gabbro at a locality near Hamar, Hargeisa District at coordinates $9^{\circ}58'$ N / $43^{\circ}53'$ E (fig. IX-1). The betafite and orthite were found together with biotite in a small pegmatite body consisting of potash and soda feldspars, quartz, abundant tourmaline and rare beryl. Analyses of the two radioactive minerals are given below (Daniels, 1960):

	<u>Orthite</u>	<u>Betafite</u>
SiO ₂	30.74	4.52
Al ₂ O ₃	11.98	1.50
TiO ₂	1.52	16.65
Fe ₂ O ₃	18.60	4.70
MnO	-	0.18

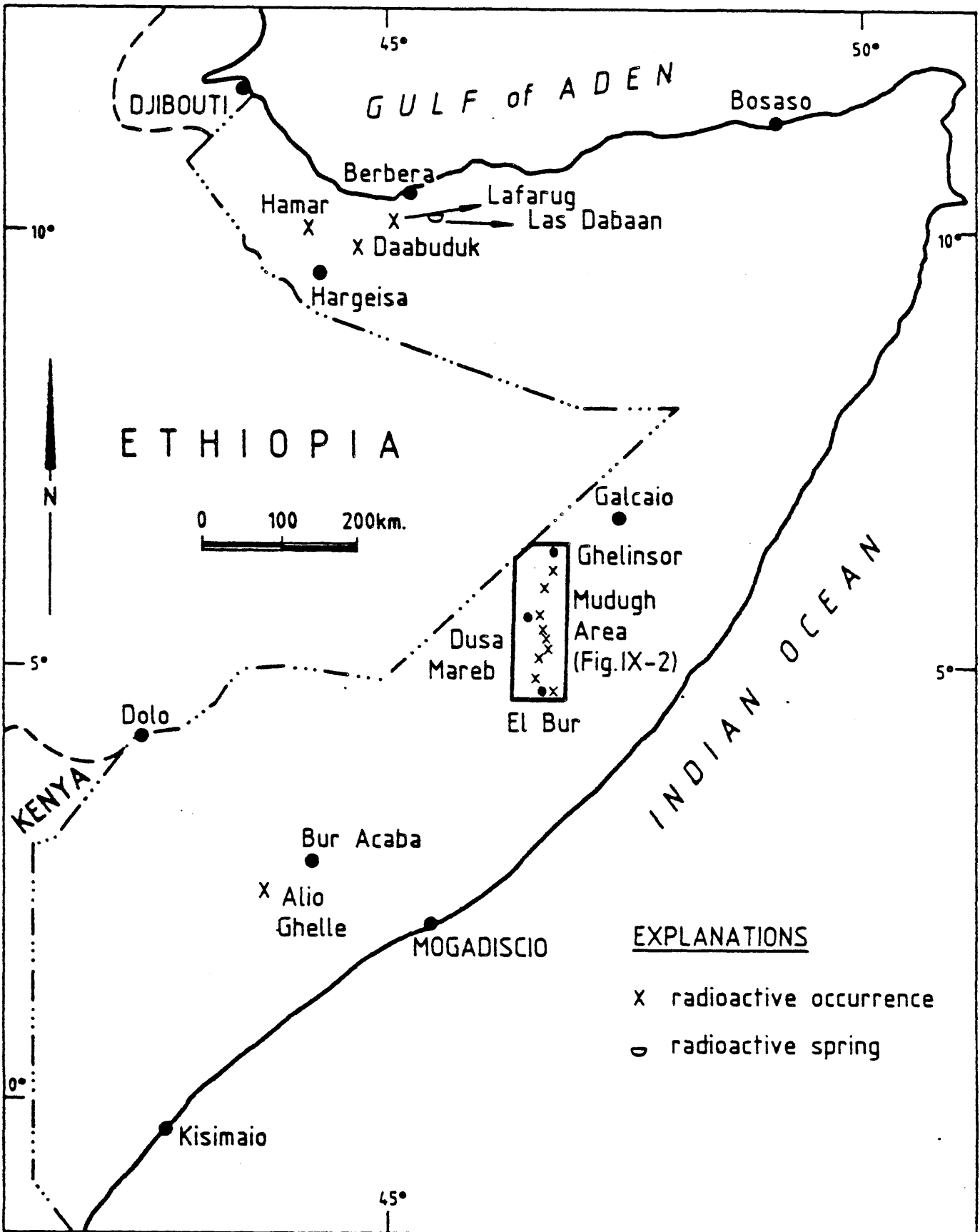


Fig. IX-1. Location of radioactive occurrences

	<u>Orthite</u>	<u>Betafite</u>
CaO	10.40	3.58
MgO	1.52	0.44
Na ₂ O	-	0.21
K ₂ O	-	0.33
H ₂ O +	-	8.49
H ₂ O -	-	2.66
RE	21.74	4.54
U ₃ O ₈	0.47	17.69
ThO ₂	0.81	2.80
Nb ₂ O ₅	-	24.00
Ta ₂ O ₅	-	6.62
PbO	-	0.93
F	-	1.05
LOI	2.07	-
	<hr/>	<hr/>
	99.85%	100.94%

The authors believe that the occurrences of samarskite, betafite and orthite do not have any economic significance. They may, however, have some metallogenetic bearing for future work on Precambrian granitic intrusives in northern Somalia.

IX.2.2. Alio Ghelle

This occurrence, located at 2°39' N / 43°40' E (fig. IX-1), within the Precambrian uplift in the Bur area was discovered by UNDP's aerial radiometric survey in 1965. Ground follow-up work, which included a limited drilling program as well as mineralogical and metallurgical studies (UNDP, 1970), demonstrated the presence of a Th-deposit associated with albitites located at the contact between syenitic intrusives and gneissose country rocks. A first summary of this discovery was published by Cameron (1970). Subsequently, the area of Alio Ghelle was part of the concession granted by the Somali Government to SOMIREN in 1968, and assigned to Nucleare Somala (Sect. XIII.2.3.).

In this context, credit is due to the UNDP Project personnel, who in 1968 were able to recognize Alio Ghelle as an albitite-type U-Th deposit, when this deposit was virtually unknown in the Western world.

The area is underlain by the Archean and Lower Proterozoic Olontole and Dinsor formations which consist of crystalline schists, biotite gneisses, amphibolites, amphibole gneisses, quartzites, iron quartzites, and marbles intruded by migmatites, equigranular and porphyritic granites, aplites and pegmatites. This sequence is overlain by Jurassic-Cretaceous sediments of the Lugh Mandara (NW) and Somali Coastal basins (SE). The Bur area has been uplifted as a northwest-trending horst, probably in Tertiary time. While in some areas the Precambrian metamorphics crop out, the largest part is covered by a "caliche mantle," 2-3m thick and overlain by alluvial gravel about 30 m thick.

The geologic events affecting the area of Alio Ghelle were summarized by Nucleare Somala (1977) as follows:

1. Deposition of sandy and clayey sediments with interbedded tuffs of basaltic composition, probably in a Precambrian geosynclinal basin;
2. compressional folding of the Precambrian formations into a NE-striking anticline, during the PanAfrican orogenic event (600-650 MY according to whole rock age determinations);
3. regional metamorphism, still within the PanAfrican tectonic-metamorphic event, synmetamorphic refolding, granitization (490 MY according to K/Ar age determinations of biotites);
4. uplift;
5. Jurassic - Cretaceous marine transgression which deposited both clastic and chemical sediments;
6. faulting and fracturing trending mainly N-S and NW-SE and development of step-fault structures;
7. Jurassic-Cretaceous basaltic magmatism;
8. Middle Cretaceous faulting and fracturing striking N-S and E-W;
9. uplift in Tertiary time;
10. subsidence and marine transgression in Tertiary time, deposition of clastic and calcareous sediments in marginal marine basins;
11. Tertiary magmatism; rhyolites and basalts of Bur Galo and Alio Ghelle.

As a result of the geologic events described above, at present there is a NE-striking anticlinal structure, the eastern and western limbs of which dip 15° SE and 45° NW respectively. Both limbs contain radioactive

horizons which form a number of NE trending anomalies, while the crest of the anticline shows only background radiation. Subsequent drilling has indicated that the anomalous radioactivity was caused mainly by Th-U mineralization, hosted in lit-par-lit injections of concordant tabular altered granitic bodies or discordant dikes. The alteration associated with the Th-U minerals includes a strong albitization (Na-metasomatism) and desilicification (formation of "episyenite") of the host rock. In addition, horizons and crosscutting veins of calcite up to 2 m thick were commonly found to be radioactive.

The Th-U mineral occurrences which were described by Nucleare Somala (1977) as "erratic", were found to contain mainly thorite and some coffinite, uranophane, allanite and monazite as radioactive minerals. Other ore minerals present included stilpnomelane, barite, pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, chalcocite, covellite, magnetite, martite, hematite and limonite.

Thorite occurs as grains 0.1 mm in diameter in the form of round colloform spheres with concentric layers, which are partly radially textured and are cemented with hematite. In general the Th/U ratio is 20:1 and the Yttrium and Rare Earth (Sc, Yb) content is 3%. Coffinite was observed replacing thorite. The Th/U ratio was found to be 1:3 in coffinite-rich samples.

The following paragenetic sequence and mineral association table was authored by E. Nefedov, UNDP-mineralogist and was published by Cameron (1970).

<u>Paragenetic Sequence</u>		<u>Minerals</u>
1. biotite schists		oligoclase, microcline,
gneisses	Precambrian	quartz, biotite, amphiboles,
2. injection of granitic		apatite, zircon, sphene,
late pegmatites		magnetite, ilmenite,
		orthite
interval		

3. albitization & alteration of the ferromag. minerals, releasing iron and producing red coloration of feldspars		albite, calcite, sericite, riebeckite
<hr/> interval <hr/>		
4. fracturing, introduction of hydrothermal solutions	Post-Jurassic?	calcite, thorite, quartz zircon, apatite, hematite, goethite, pyrite, chalcoppyrite, galena, sphalerite,
5. minor fracturing and introduction of siliceous solutions with sulfides		uraninite(?), pitchblende(?), barite
6. carbonate replacement		
<hr/> interval <hr/>		
7. oxidation and secondary alteration		chlorite, clay minerals, psilomelane, calcite, leucocene, limonite, marcasite

While UNDP (Cameron, 1970) classified Alio Ghelle as a hydrothermal deposit associated with albitization of the host rock, Nucleare Somala (1977) favored a genesis by selective endogenous leaching of the Th/U contents in the basement rocks and redeposition in favorable traps.

Some age determinations from Alio Ghelle samples were summarized by Nucleare Somala (1977). Material from DH 2 of Anomaly A (46 - 47 m in depth) yielded a $Pb_{208}Th_{232}$ date of 88 ± 6 MY for the age of radioactive mineralization. The age of the ultrametamorphism (granitization) was measured at 600 MY, while the sodium metasomatism (albitization) was purported to have taken place ca. 490 MY. If this is true, it means that between the albitization of the host rocks and the Th-U mineralization was a time break of about 400 MY. There is no statement or explanation noting the method which was used to derive the purported date of the sodic metasomatism.

The possible economic viability of the Alio Ghelle ore depends, apart from the final ore reserve calculation, on the recovery of the U_3O_8

content. Early tests by the Warren Springs Laboratories, UK, for UNDP indicate a high acid consumption due to the 8% CaCO_3 content in the samples submitted. In laboratory tests, the samples were ground to minus 200 mesh and then boiled for six hours with HNO_3 or H_2SO_4 . The best recovery was 81% and was achieved by using either 600 kg of 70% HNO_3 or 400 kg of H_2SO_4 for each ton of treated ore.

Other tests were conducted using gravity separation methods. At a grain size of 44% minus 200 mesh a concentrate of 30% ThO_2 and 0.83% U_3O_8 was obtained. No further tests to recover the uranium were carried out.

It is not known to the Mission personnel whether Nucleare Somala conducted metallurgical tests on the Alio Ghelle ore. Very limited work was performed elsewhere on two samples from Alio Ghelle, and the results indicated that only 19% of the total U_3O_8 content of 0.197% was leachable in 4N HNO_3 at 25°C, while the remaining 81% was leachable only in HF, which is not considered a viable industrial method.

The final ore reserves calculated for Alio Ghelle outlined 1700 t U_3O_8 at a grade of approximately 0.07% in the "drill-indicated" reserve category. As pointed out above, it is questionable whether the uranium can be recovered by standard leaching methods. Nucleare Somala (1977) dropped the Alio Ghelle prospect because "...the mineralized bodies as they were defined, are of modest extension, erratically distributed and of low grade."

IX.2.3. Mudugh Area

This area was found to contain calcrete occurrences and deposits, which lie in a N-S elongated area, 210 x 85 km included within the following corner points (fig. IX-1):

- A : 6°14' N / 46°17' E
- B : 6°14' N / 46°57' E
- C : 4°39' N / 46°57' E
- D : 4°39' N / 46°17' E.

Geomorphologically this area is a vast undulating plain of approximately 300 m elevation, partially covered by lateritic sands and soils and

dissected by a NNW-oriented depression. It covers a 0.5 to 15 km wide strip 200 km long between El Bur on the south and Ghelinsor on the north. This morphological low appears to represent an old structural lineament, presently occupied by a drainage and bordered by a very low "escarpment" between 3 and 5 m high (UNDP, 1974).

Geologically, the area is part of a Mesozoic-Cenozoic sedimentary platform which unconformably overlies the Precambrian basement. This unconformity was encountered at a depth of ca. 3900 m in the drill hole Dusa Mareb I located about 18 km west of Dusa Mareb (Eiyow, 1982). UNDP (1974) stated that the Tertiary and post-Tertiary strata are represented by the sequence listed below:

1. Black shales, modular limestones, plastic clays and sandstones.
2. These rocks are overlain by basalt flows, probably belonging to the Aden Volcanic Series.
3. Above the basalts lie sandy clays, sandstones, grits, marls, clays etc. of continental-lagoonal origin, the upper members of which are replaced or overlain by a gypsum crust up to 12 m thick, and which is in turn overlain (except in the morphologically depressed areas) by a siliceous fresh water algal limestone. The exact age of the different parts of this sequence is not clear. UNDP (1973 b) proposed that the gypsum crust and the algal limestone, as well as limestone breccias are in fact plateau-type gypcretes, calcretes, and silcrettes of possible Plio-Pleistocene to Recent age.

The uranium minerals include carnotite, which is concentrated throughout the area in a horizon between 2 and 15 m below the ground surface. Favorable lithologies are Ca-rich layers, as well as unsorted sandstones and gravels, partly cemented by carbonate-rich material. The carnotite principally occurs as fracture fillings, coatings and poorly defined segregations within the calcrete-gypcrete-silcrete duricrust and the poorly sorted clastic sediments in paleochannel fillings. Other minerals found in samples from Mirig, Dusa Mareb and Wabo are shown in the following table.

Table IX-1: Three ore samples from Mirig (Sample 1), Dusa Mareb (Sample 2) and Wabo (Sample 3) were mineralogically examined by McKee Overseas Corporation (1979). This table includes the estimated weight percentages for the minerals in each sample:

Mineral	Sample	1	2	3
quartz		12	1	16
polygorskite		14	7	22
sepiolite		3	12	16
dolomite		30	35	-
calcite		25	30	36
gypsum		12	12	3
halite		2	1	5
unidentified		2	2	2
Total weight %		100	100	100

The radioactive anomalies are always related to areas covered by gypsiferous duricrusts. Within the 210 km long area, a number of anomalies were detected by UNDP, using various radiometric methods. From north to south anomalies were detected at the following localities (fig. IX-2):

1. Ghelinsor size: 1.5 km², low priority;
2. Adado size: 3.0 km², medium priority;
3. Adado Er size: 4.0 km², low priority;
4. Kar Addei size: 1.8 km², low priority;
5. Dusa Mareb size: 45 km², high priority;
6. Mirig size: 14 km², high priority;
7. Wabo size: 16 km², high priority;
8. Bulhale size: 8 km², no information;
9. Hamur size: 25 km², high priority;
10. Wamoley I/II size: 8 km², high to medium priority;
11. El Bur I-III size: 55 km², medium to low priority;.

The anomalies at Dusa Mareb, Wabo and Mirig were selected for further work aimed at a thorough evaluation of the ore reserves.

The carnotite does not appear confined to a single favorable lithologic unit, however, according to UNDP (1973b; 1975c) and Eiyow (1982), no

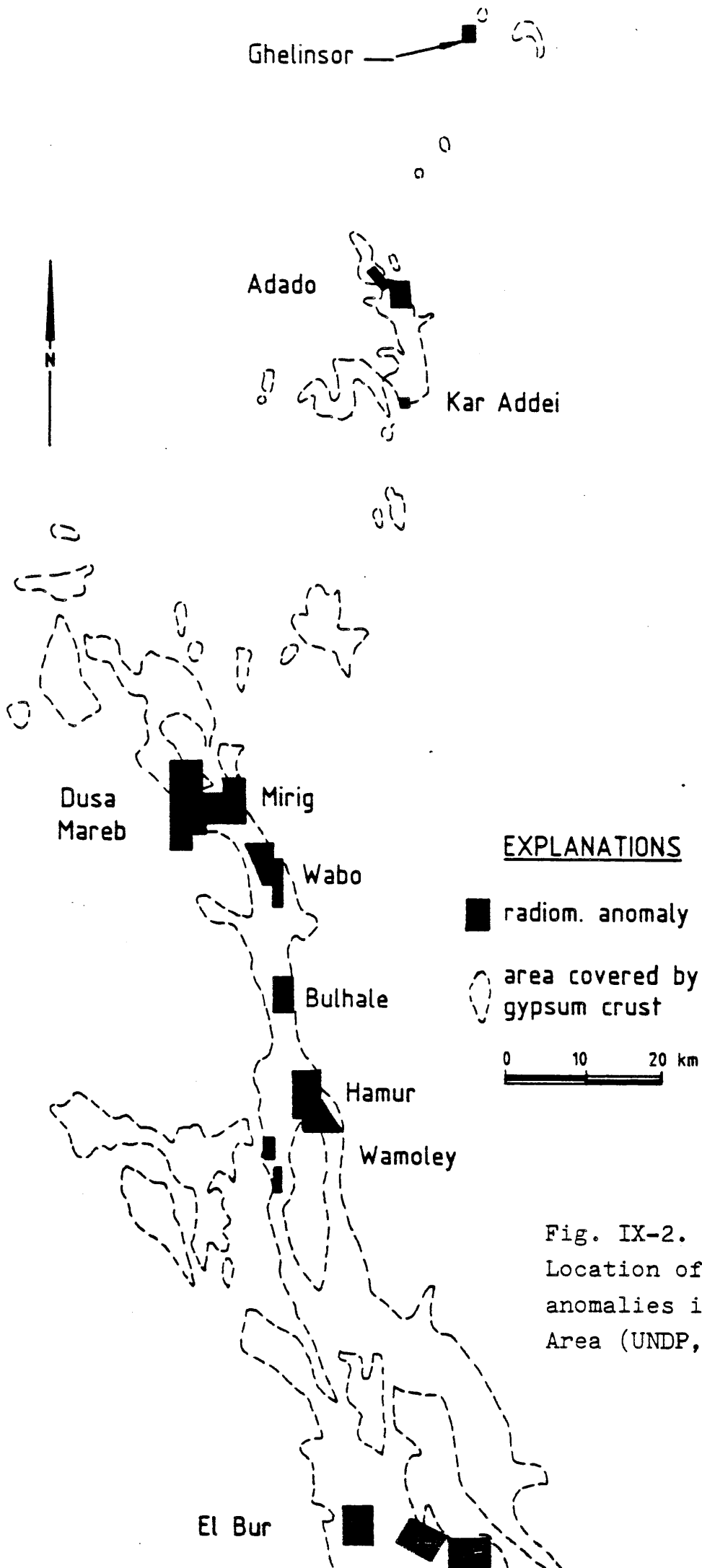


Fig. IX-2.
Location of radiometric anomalies in the Mudugh Area (UNDP, 1973 b).

significant quantity of mineralized material was found in the gypsum crust. At Dusa Mareb (fig. IX-3), the bulk of the uranium minerals are associated with a gray clay which generally underlies the gypcrete. At Wabo (fig. IX-4), the gray clay, marls and limestones, as well as the poorly sorted unconsolidated sands in paleochannels are mineralized; and at Mirig (fig. IX-5), the potential ore bodies are also found in clays, marls and poorly consolidated channel fill.

Whole rock analyses of samples from Wabo, Mirig and Dusa Mareb reported by Mc Kee Overseas Corporation (1979) and BRGM (1979) are shown in tables IX-2 and IX-3.

Table IX-2: Whole Rock Analyses of Mineralized Samples from the Wabo, Mirig and Dusa Mareb Deposits (McKee Overseas Corporation, 1979). Samples were analyzed by the Colorado School of Mines Research Institute, Golden, Colorado, USA.

Component %	Sample 1 Wabo	2 Mirig	3 Dusa Mareb
U ₃ O ₈	0.146	0.083	0.066
V ₂ O ₅	0.02	0.02	0.01
Cl	1.81	0.73	0.39
CO ₃	13.4	23.2	35.2
Ca	10.2	16.0	21.0
Mg	4.54	3.77	5.92
Mo	-0.001	-0.001	-0.001
S (total)	0.66	2.77	3.21
Fe	1.16	0.87	0.23
Cu	-0.005	-0.005	-0.005
Zn	-0.01	0.025	-0.01
Al	1.88	1.41	0.38
SO ₄	0.76	6.16	0.43
PO ₄	0.08	0.08	0.07

The work completed for SOARMICO was described in Section VIII.2.2. As previously mentioned, the only information available about these investigations, is the pre-feasibility study by McKee Overseas Corporation (1979). The main parts of McKee's study concern: a review of UNDP's reserve calculations; consideration of mining and metallurgical methods; and an economic calculation of cash flow and rate of return.

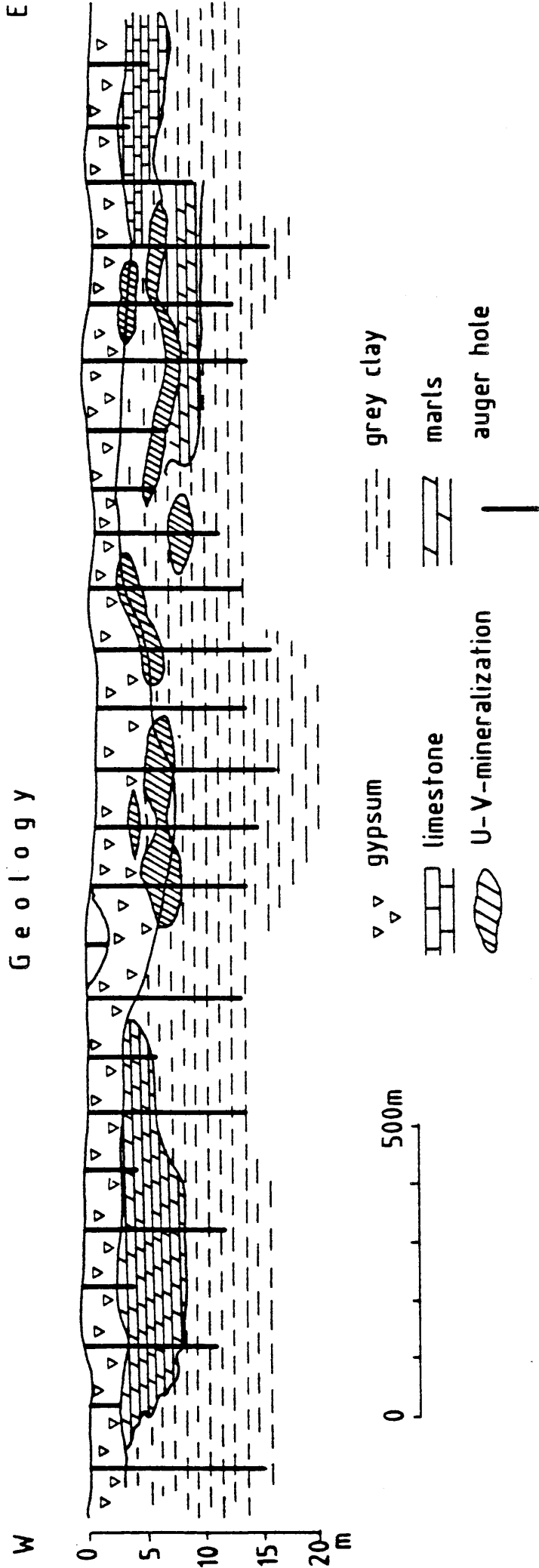


Fig. IX-3. Geological profile of Dusa Mareb Area (UNDP, 1975 c).

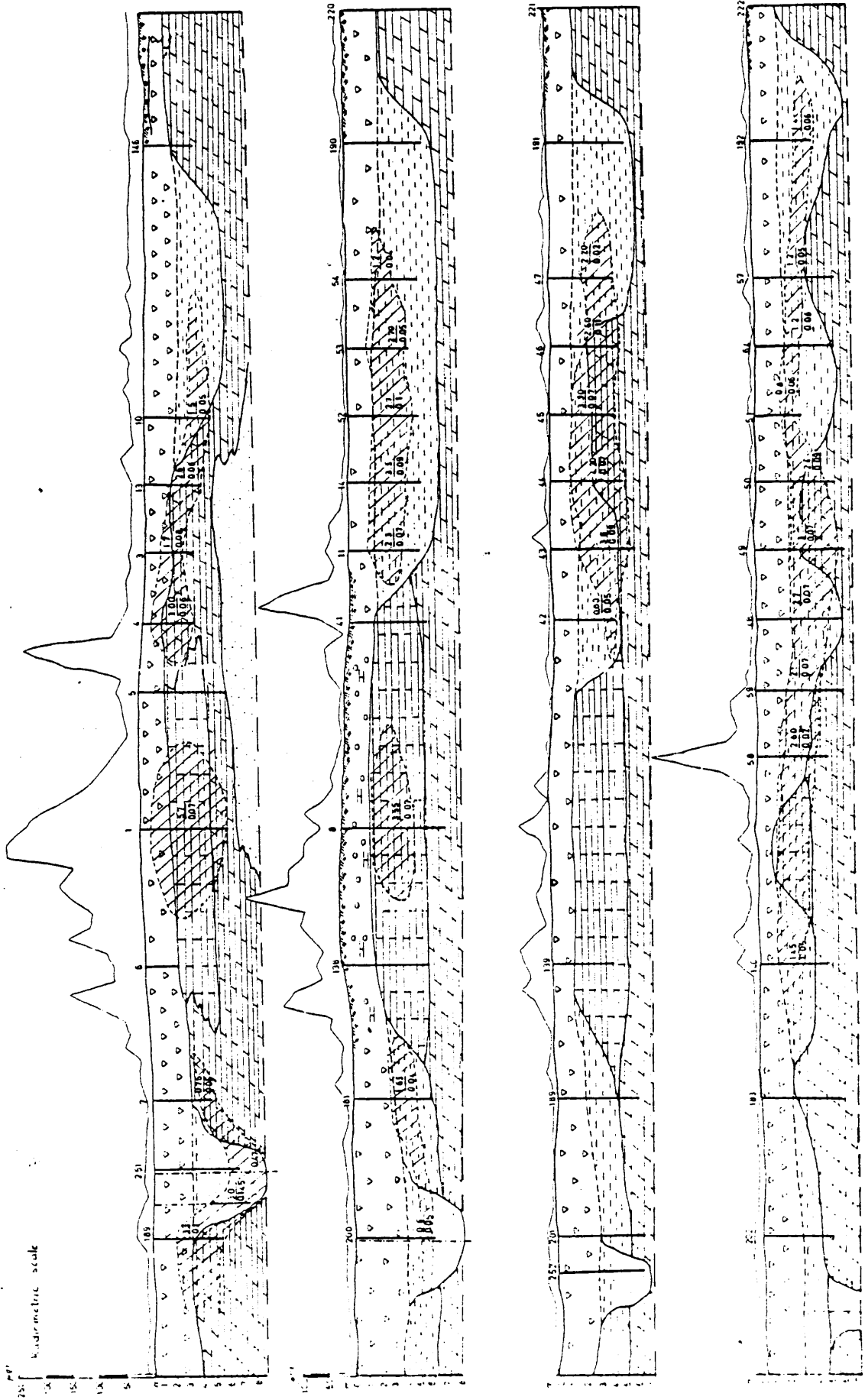
SOMALIA

MINERAL AND GROUNDWATER SURVEY (PHASE II)

GEOLOGICAL CROSS SECTIONS THROUGH PITS, WABO DEPOSIT

VERTICAL EXAGGERATION TENTH TIMES HORIZONTAL

1/4 KM



SOMALIA MINERAL AND GROUNDWATER SURVEY (PHASE II)
 GEOLOGICAL CROSS-SECTION THROUGH LINE OF PITS, MIRIG

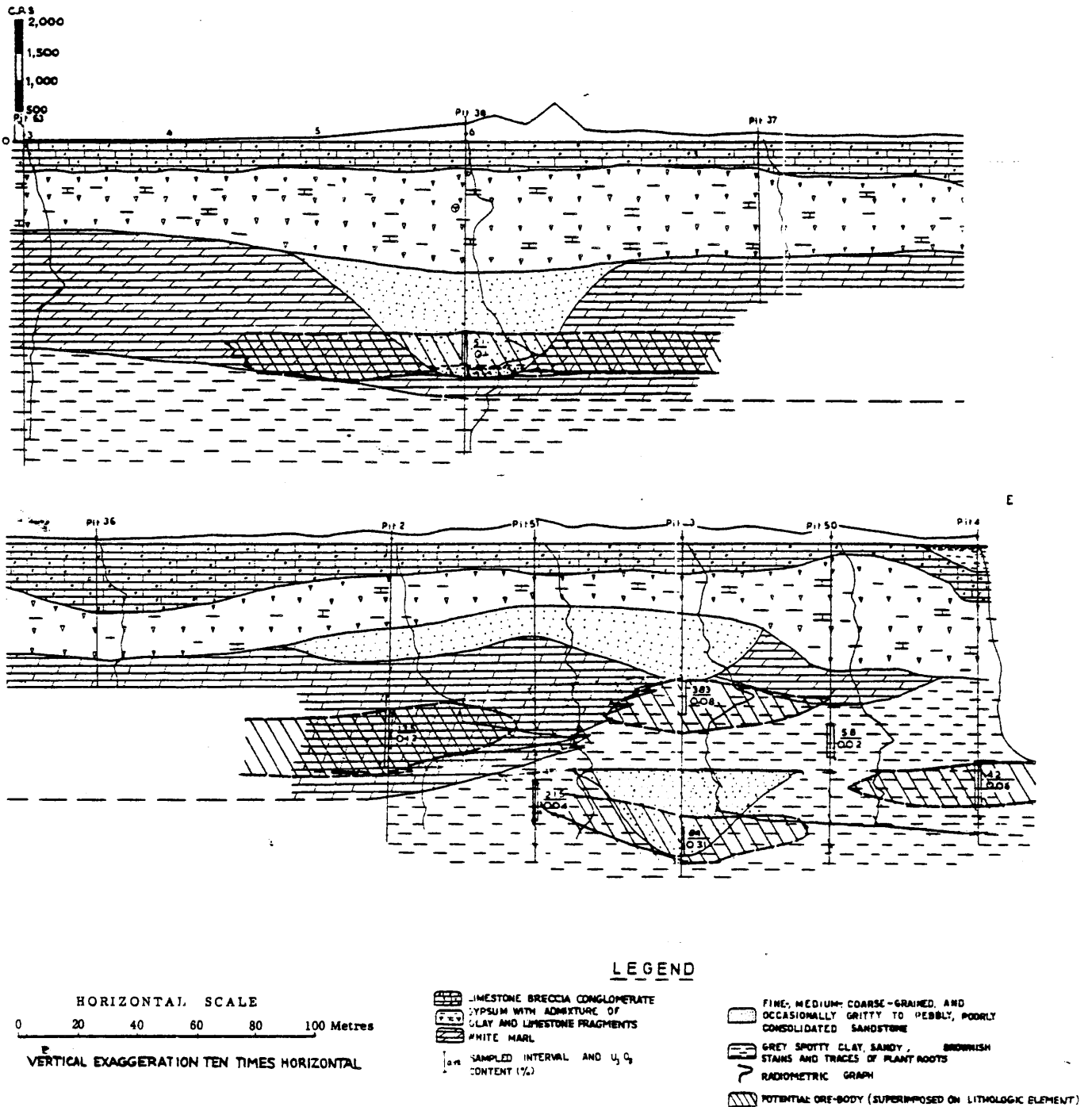


Fig. IX-5. Geological cross-section through line of pits, Mirig.

Name of deposit	Prominent lithology	Locality	Sample N°	U content kg/t	Equilibrium U/e Ra	Macroscopical petrography	Rock composition %												
							CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Na ₂ O	K ₂ O	TiO ₂	MnO	P ₂ O ₅	H ₂ O	Fine loss
HARO	Marls and bentonic clays Sandstones	pit n° 1	2 W 1	3.6	1.2	conglomeratic calcareous sandstone	17.91	1.66	59.91	0.93	0.61	0.07	0.25	0.11	0.07	0.01	0.02	0.86	16.69
							35.85	5.70	19.49	2.02	0.89	0.06	0.10	0.27	0.13	0.01	0.02	3.00	11.79
							1.03	7.09	68.91	4.98	2.12	0.09	0.15	0.52	0.27	0.02	0.07	5.51	8.50
MIRIG	Calcareous sandstones, calcrites	pit n° 73	1 M 73	0.42	1.2	conglomeratic calcrite	36.47	7.55	17.11	0.52	0.45	0.15	0.15	0.10	0.06	0.01	0.02	2.82	15.78
							51.75	1.40	2.92	0.20	0.12	0.07	0.10	0.03	0.01	0	0.02	0.19	12.30
DUSA MAREB	Silicified marls ; Limestone ;	pit n° 35	DM 3	0.62	1.0	fine-grained, siliceous solid limestone													

Table IX-3. Whole rock analyses of mineralized samples from the Wabo, Mirig and Dusa Mareb deposits (BRGM, 1979).

For the ore reserve calculation, a cut-off grade of 0.05% U_3O_8 and a specific gravity of 0.16 t/m³ were used. The results of both the UNDP and the McKee calculations are as follows:

Dusa Mareb: possible reserves:

UNDP: 2351 t U_3O_8 at an average grade of 0.083%

McKee: 3040 t U_3O_8 at an average grade of 0.085

Wabo: indicated reserves:

UNDP: 4000 t U_3O_8 at an average grade of 0.10%

McKee: 4486 t U_3O_8 at an average grade of 0.095%

Mirig: indicated reserves:

UNDP 1197 t U_3O_8 at an average grade of 0.085%

McKee: 1070 t U_3O_8 at an average grade of 0.075%.

Plans have been made for three open pit mining operations at Wabo, Mirig and Dusa Mareb respectively. The respective averages for overburden thickness, ore thickness and stripping ratio are given in table IX-4.

Table IX-4: Average Overburden, Ore Thickness and Stripping Ratios for Proposed Mines at Wabo, Mirig and Dusa Mareb.

Proposed Mine	Overburden m	Ore Thickness m	Stripping ratio
Wabo	2.82	1.62	1.74
Mirig	5.07	1.74	2.91
Dusa Mareb	4.64	1.82	2.55

The mining methods proposed by McKee Overseas Corporation

include the following steps:

1. Overburden stripping by tractors with rippers and bowl-type scrapers; after mining for ore has progressed sufficiently, the removed overburden will be used for the back-fill of mined-out areas.
2. Depth control for the removal of overburden will be accomplished by drilling holes on 10 m grids and radiometric probing of the drill holes.

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3. Selection of ore and waste as follows: Ore = + 0.04% U_3O_8 ,
lean ore = 0.02 - 0.04% U_3O_8 ; waste = - 0.02% U_3O_8 .
4. Mining and hauling will be done by front-end loaders and trucks.

The annual production for the operation will amount to 660,000 t ore; 1,004,850 t waste and 143,550 t lean ore, for a total of 1,808,400 t /year.

The ore milling process includes the following stages:

1. Ore receiving: 2000 tpd;
2. crushing to minus 19 mm;
3. leaching: sodium carbonate-bicarbonate leach solution and a 48 hr leach duration at 82°C;
4. liquid-solids separation: still problematical due to the slow filtration rate of the ore;
5. yellowcake precipitation as sodium diuranate with sodium hydroxide added, retention time 16 hrs at a temperature of 71°C (about 98% of the uranium and 65% of the vanadium contained in the pregnant solution will be precipitated under these conditions);
6. yellowcake roasting and washing to remove the co-precipitated vanadium;
7. yellowcake drying and packing;
8. vanadium recovery: since a sulfuric acid leach is not possible due to the carbonatic nature of the ore, lime is added to recover a marketable low-grade calcium vanadate product containing 20% V_2O_5 .

The preliminary capital and operating cost were estimated as follows:

- capital costs:	mining :	US\$ 3,787,000
	milling :	US\$42,400,800
	admin. and infrastruct. :	US\$19,686,200
	Total:	US\$65,874,000

- operating costs :

	mining :	US\$ 5.612/kg U_3O_8
	milling.:	US\$23.560/kg U_3O_8
	admin. and infrastruct. :	US\$11.385/kg U_3O_8
	Total:	US\$40.557/kg U_3O_8
	=	US\$18.413/lb U_3O_8

For modeling the cash flow and rate of return on investment, three total operating periods: 10, 15 and 20 years, were taken into account using the basic data for a 2000 tpd plant operating at a recovery rate of 84% for 330 days per year. Further assumptions on economic and fiscal parameters were:

1. A price for U_3O_8 of US\$ 40/lb, escalating at 5% p.a. compounded;
2. operating costs, excluding royalties and interest also escalating at 5% p.a. compounded;
3. depreciation to be totalled over the life of the mine but not exceeding 15 years;
4. capital investment consisting of 60% equity and 40% loan financing at 8% p.a. interest;
5. tax payments to begin 5 years after start-up of operation and to be calculated at 30% of net income (revenue minus operating costs and depreciation);
6. royalty payments to begin after 5 years of operation at the rate of 2% of gross income.

Based on the above assumptions, the following total cash flow over 10, 15 and 20 years of operation and the rate of return on investment (IRR) were determined:

	10 years	15 years	20 years
Total cash flow (US\$ 1,000)	295,728	524,905	524,505
IRR (%)	19.73	20.40	19.22

To further develop the Wabo, Mirig and Dusa Mareb deposits, in September 1981, the Somali Arab Mining Company published the tender for the construction of the mine/mill complex and the necessary infrastructure including water and power supply as well as housing facilities. The total project value is estimated at US\$ 150 million. US\$ 70 million is for the mine/mill complex and US\$ 80 million for the infrastructure. Bids from interested companies were to be submitted to SOARMICO before January 1983. SOARMICO is now evaluating four (?) bids. Details of these offers were not available to the Mission.

IX.2.4. Las Dabaans Radioactive Spring

It was reported (BRG, 1981) that a radioactive thermal spring was discovered close to a fault near thin coal seams of Tertiary age at Las Dabaans in northern Somalia (fig. IX-1). No other information is known about this occurrence.

IX.3. Conclusions

The occurrences at Alio Ghelle and the Mudugh area, both discovered by UNDP, represent two entirely different metallogenetic types. Alio Ghelle is a magmatic-hydrothermal albititic uranium deposit and the Mudugh deposits represent the calcrete deposit type. Unfortunately, Alio Ghelle is mainly a Th-deposit with only very small amounts of easily leacheable uranium. The exploration history of this deposit showed that the initial discovery of the radiometric anomaly was relatively easy and of low cost, while the evaluation of the anomaly and the assessment of the deposit's quality, quantity and shape turned out to be very costly. In contrast, both the discovery of the Mudugh area calcrete deposits and the delineation of the ore bodies were relatively easy and associated with only modest expenditures. Even the projected operating costs as calculated by McKee Overseas Corporation (1979), do not appear to exclude the deposits economic viability under improved market conditions. Difficulties will arise, however, in finding an economically viable milling and recovery process and in establishing the necessary infrastructure including water and power supply.

In general it has to be concluded, that even assuming that an Alio Ghelle-type deposit can be found which contains a higher grade of leachable U_3O_8 ($\pm 0.2\%$), a larger reserve (+ 15,000 t U_3O_8), and ore bodies which are larger and more evenly distributed, it would be mineable only by costly underground methods, due to the depth of the unweathered ore and its general association with steeply dipping deep seated structures. Also, it is likely that the uranium shall prove difficult to recover from the refractory minerals which comprise the ore. Therefore, its economic prospects are not as favorable as those of the Mudugh calcrete deposits, which are close to the surface, and thus easy to mine by open cast methods, and once a suitable process is found, easy to concentrate.

X. FAVORABLE AREAS FOR URANIUM EXPLORATION IN SOMALIA

X.1. Introduction

The selection and delineation of areas to be recommended for further uranium exploration in the SDR is a very difficult task. As was discussed in the review of the regional geology of Somalia (Sect. VI), the general geological framework, stratigraphy, depositional environments of sedimentary sequences and their lithofacies and the ages and chemical compositions of intrusive rocks, etc. are not well known. Therefore the delineation of areas (fig. X-1) which can be considered geologically favorable to contain various types of uranium deposits is only preliminary, and subject to change with increasing geological knowledge.

On the other hand, there are two types of uranium deposits found in Somalia which may prove economically viable: the calcrete type and the magmatic-hydrothermal albititic type. The radioactive occurrences in pegmatites are not considered economic targets for future exploration and are therefore excluded from consideration. As was shown in Sect. IX, not one uranium occurrence has been found in sedimentary rocks, although sandstone uranium deposits may occur in some areas.

X.2. Description of Favorable Areas for Uranium Exploration

X.2.1. Areas with Potential for Calcrete Deposits

Although the exact stratigraphic age of the calcrete-gypcrete-silcrete crusts in central Somalia is not known, they are assumed to be of Plio-Pleistocene to Recent age and are located in a narrow but long northwest-trending depression in the upper part of the Mudugh series.

According to the Geological Map of Somalia (UNDP, 1972a), similar geological conditions occur throughout the area bounded by 46° East longitude, 4° North latitude, the Indian Ocean coast, the Ethiopian border and 8° North latitude, a total area of ca. 105,000 km² (fig. X-1). This area includes ca. 13,000 km² in the Ghelinsor-El Bur depression, which was investigated in detail by UNDP.

UNDP (1972a) also mapped two similar depressions east of the Ghelinsor paleodrainage. The Mission considers these areas favorable for the discovery of calcrete deposits.

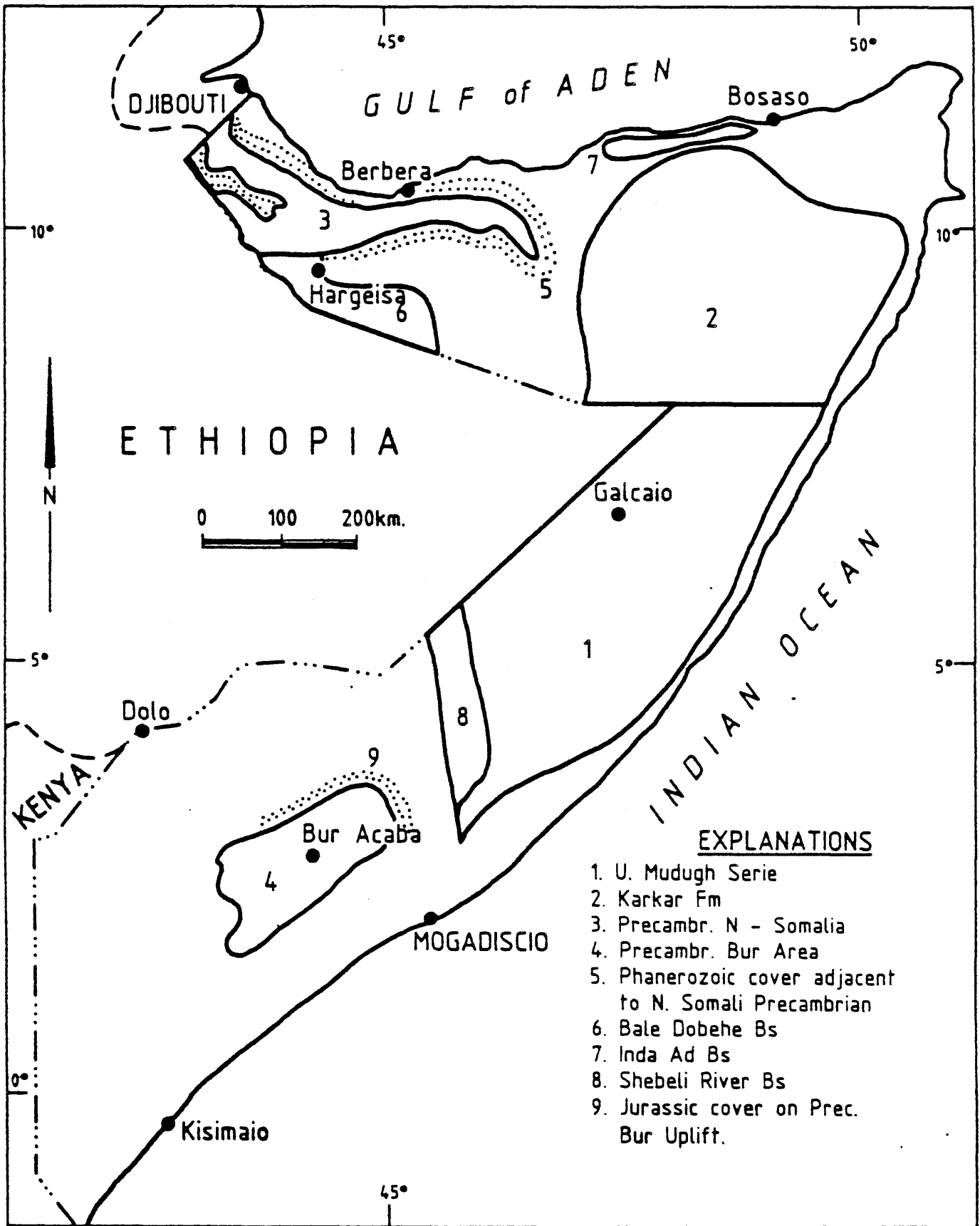


Fig. X-1. Location of favourable areas for uranium exploration (geology after UNDP, 1972 a).

105,000 km² underlain by the Upper Mudugh Series are considered to have calcrete potential (fig. X-1) and ca. 53,000 km² of this area is covered by the SOARMICO concession. Should it be confirmed that the Paleogene Karkar Formation, explored partially by a airborne radiometric survey (Naleye, 1981) also hosts mineralized depression fillings, then the potential favorable area for calcrete deposits shall be increased by ca. 95,000 km². Given a uranium-vanadium source, the area bounded by 47° East longitude, 8° and 10°10' North latitude, the Ethiopian border and the Indian Ocean coast, has good potential to host uranium deposits in duricrusts.

Therefore, the area with calcrete potential amounts to 105,000 km² underlain by the Upper Mudugh Series, and an additional 95,000 km² underlain by the Karkar Suite, a total of 200,000 km². The potential resources of this area are discussed in the following section.

X.2.2. Areas with Potential for Magmatic-Hydrothermal Uranium Deposits

The two areas of Somalia with potential for magmatic-hydrothermal uranium deposits are the Bur uplift in the southern part of the country, which is underlain by crystalline metamorphic and intrusive rocks of Archean and Lower Proterozoic age and a 280 km east-west striking belt in northern Somalia, underlain by similar rocks (fig. X-1).

Aside from the pegmatitic occurrences in northern Somalia described in Section IX.2.1. of this report, the only radioactive occurrence known in rocks of Precambrian age is the albititic, thorium-uranium occurrence at Alio Ghelle (Section IX.2.2.) in the Bur area. No hydrothermal occurrences unrelated to albitites are known.

If it is assumed that exploration in the Bur area by Nucleare Somalia and other companies fully tested the known radioactive anomalies in the uplift for albititic deposits, then the main potential areas remaining for deposits related to Precambrian rocks are in northern Somalia, where exploration has been of a much more limited nature. Several episodes of migmatization, tectonism and intrusion may have concentrated uranium in veins, shear zones or other potential hosts, either as authigenic deposits in the intrusive granitic rocks or as allogenic deposits in the metamorphic country rocks. The episyenites

related to the albititic occurrence at Alio Ghelle, may be an indication of potential for vein-type deposits in granitic rocks. Descriptions of the metamorphic and intrusive rocks in both southern and northern Somalia are reminiscent of similar rocks which host uranium deposits and occurrences in the western American states of Washington and Colorado.

There is no information available concerning the uranium content or uranium-thorium ratios in any of the granitic rocks of Somalia, other than the immediate area of Alio Ghelle. Thus, much basic work remains in the areas which are underlain by rocks of Precambrian age.

In northern Somalia, rocks of Precambrian age underlie some 10,000 km² between longitude 45°30' and the Ethiopian border. In the Bur area of southern Somalia, approximately 20,000 km² are underlain by Precambrian rocks (fig. X-1).

It may be noted that the Bur area has been covered by several airborne radiometric surveys, and there has been intensive drilling in several anomalous areas. Limited exploration and some airborne radiometric surveying has taken place in northern Somalia. It is questionable how thoroughly these areas have been explored and the Mission does not believe either area can be excluded from further work.

X.2.3. Areas with Potential for Uranium Deposits in Sandstones

The following areas were selected using both the lithological-depositional characteristics of sediments and their relationship to possible source rocks of Precambrian age.

X.2.3.1. Northern Somalia

Northern Somalia appears to have the best potential, based on the variety of both possible source rocks and possible host rocks. The areas selected for their favorability to host sandstone uranium deposits are (fig. X-1): 1) the Phanerozoic sedimentary cover adjacent to the northern Somali Precambrian basement; 2) the Bale Dobehe Basin underlain by the Nubian Sandstone and the Jesomma Formation, as well as the Inda Ad Basin which follows the coast of the Gulf of Aden from Longitudes 46° to 49° E. Although the sedimentary

cover adjacent to the Precambrian basement, as well as the Inda Ad Basin were explored by Nucleare Somala (Sect. VIII.2.3.), it is believed that this work was neither comprehensive nor thorough and does not rule out a uranium potential.

X.2.3.1.1. The Phanerozoic Sedimentary Cover Adjacent to the Northern Somali Precambrian

The mantling cover of the east-west trending Precambrian basement overlies rocks of Archean and Proterozoic age and both metamorphic and igneous origin. It includes sedimentary rocks of Jurassic, Cretaceous (Nubian Sandstone) and Paleogene age, in many places apparently covered by Neogene-Quaternary sediments. The Jurassic strata of northern Somalia have not been subdivided on the Geological Map of Somalia (UNDP, 1972a). They include clastic sediments in addition to limestones and gypsum and may even contain the Adigrat Formation, which is a clastic sedimentary sequence several hundred meters thick, consisting of sandstones, conglomerates and siltstones and which becomes more limey towards the upper part.

The Nubian Sandstone of late Cretaceous age is of non-marine origin and contains cross-laminated coarse-grained red and brown sandstones interbedded with variegated claystones. The thickness of the Nubian Sandstone is estimated at between 1000 and 1500 m.

The Paleogene sequence includes the middle unit of the Daban Formation, which comprises between 800 and 2000 m of sandstones and siltstones, with lenses of conglomerate and limestone.

The surface covered by the sedimentary mantle adjacent to the Precambrian basement is assumed to form a 10 km wide band that surrounds the +300 km long Precambrian exposures and thus covers an area of 6000 km².

X.2.3.1.2. Bale Dobehe Basin

The Bale Dobehe Basin is located between East longitudes 43°20' and 45°15', south of Bale Dobehe, and is cut by the Ethiopian border. In the northwestern part of the basin lies the Nubian Sandstone, while the greater part of the basin is underlain by the Jesomma Formation of

Paleocene age, consisting of an oxidized sandstone-claystone sequence several hundred meters thick. BRGM (1979) reported the presence of carbonaceous material in the Jesomma Formation. The surface of the Somali part of the Bale Dobehe Basin is approximately 7200 km² and is considered to have potential for sandstone uranium deposits.

X.2.3.1.3. Inda Ad Basin

The Inda Ad Basin occupies a heavily tectonized strip extending 200 km east-west along the coast of the Gulf of Aden, and is underlain by the Upper Proterozoic Inda Ad Series (fig. X-1). This series consists of cataclastically metamorphosed clastic sediments ranging from claystones to coarse-grained sandstones and less commonly to conglomerates which are interbedded with siliceous shales, tuffs, limestones, dolomites and andesites. The total thickness of the Inda Ad Series has been estimated at about 8500 m. The basin covers an elongated area 10 km wide and 200 km in length, equalling 2000 km².

X.2.3.2. Southern Somalia

Within southern Somalia, the following two areas are recognized to have a potential for sandstone uranium deposits: The Shebeli River Basin and the Jurassic cover of the Bur uplift (fig. X-1). The latter area has been partly explored by GUCOS between 1969 and 1970, but the authors believe that this environment still offers good possibilities for uranium deposits.

X.2.3.2.1. Shebeli River Basin

The Shebeli River Basin is located to the east of the Shebeli River and is underlain by the 400 m thick Jesomma Formation of Cretaceous-Paleocene age. The Jesomma Formation consists of unfossiliferous quartz sandstones of probable eolian origin, interbedded with dark grey to black pyritic shales, lignitic shales and fine-grained sandstones. No information is available concerning the structural geology of the Jesomma Formation.

The area underlain by this formation covers 8000 km² in a north-south elongated block measuring 200 km long by 40 km wide.

X.2.3.2.2. Jurassic Cover of the Bur Uplift

The Jurassic age cover forms a semi-circle around the northern edge of the Bur uplift and includes the Adigrat Formation of early Jurassic age which contains a basal quartz conglomerate and sandstones that unconformably overlie the Precambrian complex.

As no information is known as regards the attitude of dip of the Adigrat Formation into the basin, a 10 km width surrounding a 170 km Precambrian margin is assumed. Thus the entire favorable area covers about 1700 km².

X.2.4. Other Potential Types of Uranium Deposits

Several other environments favorable for uranium deposits may occur in Somalia. The geological framework of the country suggests the existence of these potential hosts cannot be excluded. However, at present, so little is understood of the detailed geology of Somalia, it is simply unknown whether or not any favorable localities may be found.

Possible favorable environments include: Proterozoic unconformities, quartz pebble conglomerates, marine phosphates, carbonatites, uraniferous lignites and clastic rocks of Tertiary age.

The clastic rocks of the Inda Ad Series of late Proterozoic age may unconformably overlie Lower Proterozoic and/or Archean rocks in northern Somalia (fig. X-1). Mason and Warden (1956) stated that this unconformity exists, and their map of the 1:125,000 Erigavo Sheet (No. 15) indicates conglomerates, grits, sandstones and siltstones of the Inda Ad Series unconformably overlying chlorite schists of the older Precambrian basement. In other localities, the Inda Ad strata is shown only in contact with Phanerozoic rocks by both Mason and Warden (1956) and Greenwood (1960). Therefore the possibility exists for a favorable locality for Proterozoic vein unconformity-type deposits. The areas adjacent to Inda Ad rocks should be examined carefully with this model in mind, as should Inda Ad strata near basement rocks. It is also suggested that in localities where clastic rocks of Phanerozoic age unconformably overlie the Precambrian basement, a favorable environment may exist. One example is the occurrence of kaolin 50 km east of Adaleh along the road between Berbera and Hargeisa where the Nubian Sandstone of

Cretaceous age overlies an old weathering surface on Precambrian granites and granite gneisses.

The absolute ages for deposition of the metasedimentary basement rocks are unknown. These rocks have not been carefully studied, especially in southern Somalia. It is possible that quartz pebble conglomerates were deposited in early Proterozoic times, when this planet still had an anoxic atmosphere, and might host detrital uraninite deposits. Later orogenies may have metamorphosed these rocks and made them difficult to recognize, however anyone who studies the Precambrian basement should keep this model in mind, particularly if any early Proterozoic isotopic ages are discovered, especially in the range of 2000-2500 MY.

BRGM (1979) suggested the possibility of marine phosphorites occurring in the Mesozoic section of Somalia. If these are discovered, they should be examined radiometrically to determine their uranium content. The possibility of Tertiary age phosphorites should also not be ignored.

In many parts of East Africa, carbonatites occur, generally related to the Rift Valley Faults (fig. X-2). No carbonatites have been reported in Somalia, however the many known carbonate rocks and the poor level of geologic knowledge certainly indicates a possibility that they have been overlooked, especially adjacent to rift faults. Thus the possibility of carbonatite-related uranium deposits must not be overlooked.

It has been reported (BGR, 1981) that a radioactive spring was discovered adjacent to lignites in the Tertiary section at Las Dabaans (Sect. IX.2.4), northern Somalia. Therefore any studies of Tertiary rocks and coals should examine lignites and related clastic units for radioactivity.

In northern Somalia lie four basins filled with continental and marginal marine clastic rocks of Tertiary age described in Sect. VI.3.3. Many of these strata contain favorable host rocks for sandstone-type uranium deposits. The Mission has not estimated potential uranium

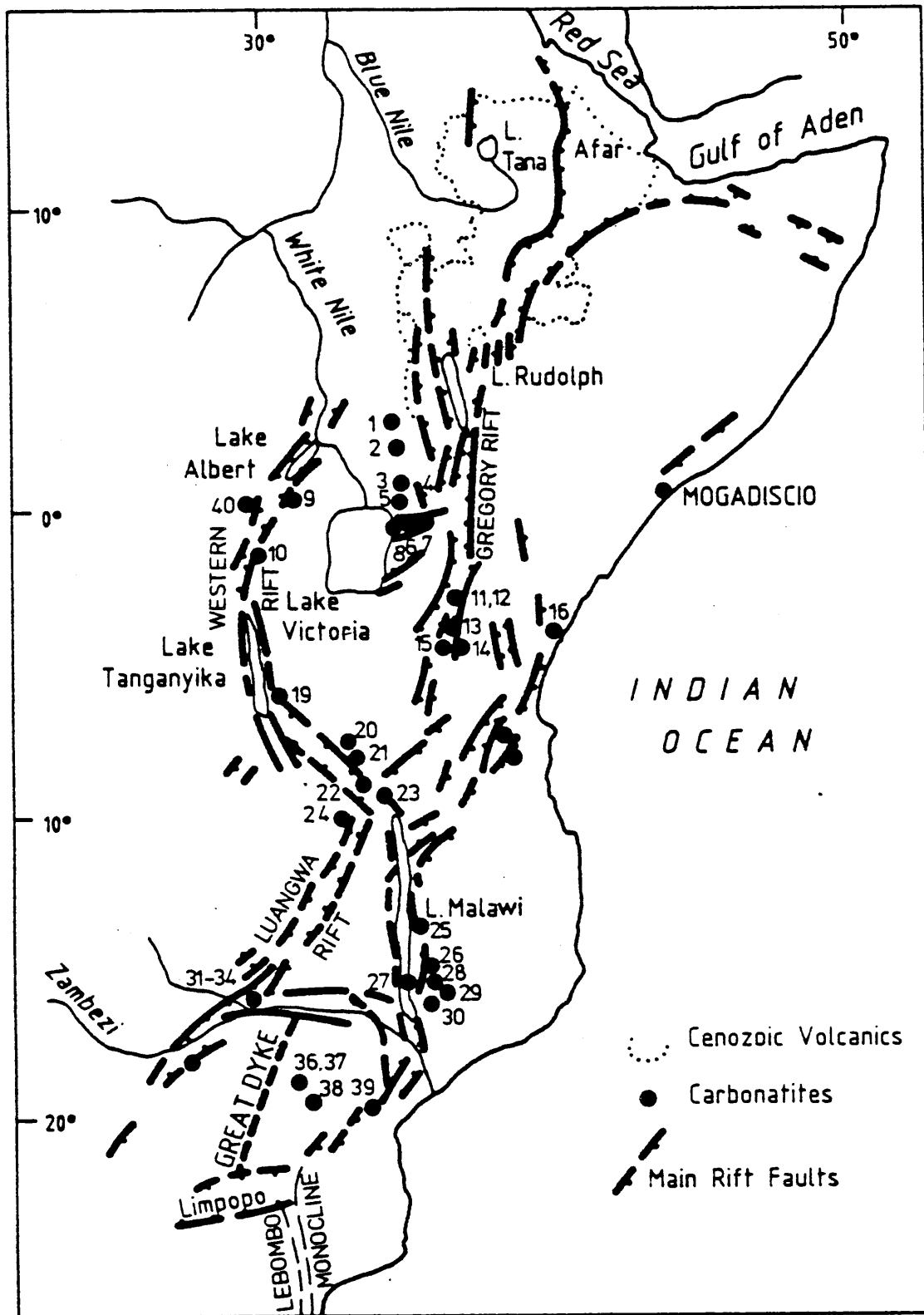


Fig. X-2. Distribution of carbonatites in relation to Rift faults in Eastern Africa (after Mitchell, A.H.G. and Garson, M.S., 1976, Minerals Sci. Engng., v.8, p. 128).

deposits for these areas because it was not possible to locate favorable source rocks to provide uranium to the basins. However, the Mission believes the basins should be examined geologically and radiometrically. The four Tertiary Basins are:

1. Las Dawa - Meleden Basin: 10,000 km² (200 km E-W x 50 km N-S); bounded approximately by longitudes 49° and 50°50' E and latitudes 10°10' and 10°55' N; potential host rocks are Lower Daban Fm. and overlying Middle Daban Fm.
2. Adado-Bosaso Basin: 1800 km² (90 km E-W x 20 km N-S); bounded approximately by longitudes 48°20' and 49°15' E, latitude 11°05' N and the Gulf of Aden; potential host rocks are Upper Daban Fm., underlain by basalts and covered by Neogene-Quaternary eolian sediments.
3. Alula Basin: 400 km² (20 km E-W x 20 km N-S); bounded approximately by longitudes 50°40' and 50°55' E, latitude 11°40' N. and Gulf of Aden; potential host rocks are Upper Daban and Karkar fms.
4. Candala East Basin: 700 km² (70 km E-W x 10 km N-S); bounded approximately by longitudes 49°55' and 50°40' E and latitudes 11°20' and 11°30' N; potential host rocks are Upper Daban and Karkar fms. which are cut by NNE lineament and E-W faults.

X.3 Summary

The following table contains a summary of the various potential uranium deposits described in Sections X.2.1. through X.2.3. above. They are listed in the same sequence as they appear in the text.

Area km ²	% of Total	Geology	Potential U-deposit
105,000	41.2	Mudugh Series with duricrust in filled depressions	calcrete
95,000	37.3	Karkar Fm. with duricrust in filled depressions	calcrete
30,000	11.8	Precambrian metamorphic intru- sive rocks of northern Somalia and the Bur area	magnetic- hydrothermal
6,000	2.3	Phanerozoic sedimentary cover adjacent to the northern Somali Precambrian basement	sandstone

Area km ²	% of Total	Geology	Potential U-deposit
7,200	2.8	Bale Dobehe Bs.	sandstone
2,000	0.8	Precambrian Inda Ad Bs.	sandstone
8,000	3.1	Shebeli River Bs.	sandstone
1,700	0.7	Jurassic cover on the Pre-cambrian Bur uplift	sandstone
254,900 km ²	100%		

The total area of 254,900 km², which has been designated as favorable for potential uranium deposits comprises about 40% of Somalia. 78.5% of the total favorable area has calcrete potential; 11.8% has magmatic-hydrothermal potential and 9.7% may host sandstone deposit sequences of various ages. In addition, a number of localities may have "longshot" potential for other types of uranium deposits discussed in Section X.2.4.

XI. URANIUM RESOURCES OF SOMALIA

XI.1. Introduction

In the following section an attempt has been made to estimate the uranium resources of Somalia on the basis of known resources which have been discovered in Somalia and geological settings analogous to those of uranium deposits elsewhere in the world.

XI.2. Definitions

For the purpose of this report, the uranium resource estimates are divided into three separate categories reflecting different levels of confidence:

1. Reasonably Assured Resources;
2. Estimated Additional Resources;
3. Speculative Resources.

The definitions according to the Nuclear Energy Agency/International Atomic Energy Agency (NEA/IAEA) are as follows:

Reasonably Assured Resources (RAR) refers to uranium that occurs in known mineral deposits of such size, grade and configuration that it could be recovered within the given production cost ranges (- US\$ 30/lb U₃O₈, US\$ 30 - 50/lb U₃O₈) with currently proven mining and processing technology. Estimates of tonnage and grades are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. RAR have a high assurance of existence and in the cost category below US\$ 30/lb U₃O₈ are considered as reserves for the purpose of this report.

Estimated Additional Resources (EAR) refers to uranium in addition to RAR that is expected to occur, mostly on the basis of direct geological evidence, in:

- extensions of well-explored deposits;
- little explored deposits; and

- undiscovered deposits believed to exist along a well-defined geological trend with known deposits.

Such deposits can be identified, delineated and the uranium subsequently recovered, all within the given cost ranges (- US\$ 30/lb U_3O_8 , US\$ 30-50/lb U_3O_8). Estimates of tonnage and grade are based primarily on knowledge of the deposit characteristics as determined in its best-known parts or in similar deposits. Less reliance can be placed on the estimates in this category than for RAR. The resource level of EAR should be considered as having a potential for later conversion to RAR as the possible result of further exploration effort.

Speculative Resources refers to uranium in addition to RAR and EAR that is thought to exist mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing exploration techniques and exploitable at costs less than US\$ 50/lb U_3O_8 with present mining and processing techniques. The location of deposits envisaged in this category could generally be specified only as being somewhere within a given region or geological trend.

In addition, concerning the Speculative Resources outlined below, a number of facts must be emphasized. The Speculative Resources, although expressed in tons U_3O_8 , are not meant to indicate ultimate resources, as this amount is bound to change with increasing geological knowledge of Somalia. Even if these Speculative Resources exist, there is no guarantee that they will be discovered or if they are discovered, that they will be mined. Constraints may arise on many fronts such as access to favorable areas, use of inadequate exploration techniques, rates of discovery, financial difficulties, and the availability of requisite manpower. Even if serious efforts are undertaken to discover the Speculative Resources of Somalia, the lead times from early exploration to production are such that these resources may not be mined until the first decade of the 21st century.

XI.3. Uranium Resources

XI.3.1. Reasonably Assured Resources

The Reasonably Assured Resources (RAR) of Somalia are located in the deposits at Wabo and Mirig which were investigated by UNDP and reassessed by McKee Overseas Corporation. The two ore reserve calculations agree quite well and result in the following "indicated" reserves:

Wabo:	UNDP:	4000 t U ₃ O ₈ ,
	McKee:	4486 t U ₃ O ₈ ;
Mirig:	UNDP:	1197 t U ₃ O ₈ ;
	McKee:	1070 t U ₃ O ₈ .

The total indicated reserves for the two deposits is 5197 t U₃O₈ (UNDP) or 5556 t U₃O₈ (McKee). As McKee Overseas Corporation (1979) believes that both ore reserve estimates are low, the Mission is confident that a total RAR of 5500 t U₃O₈ exists in the Wabo and Mirig deposits, which can be produced between US\$ 30 and 50/lb U₃O₈.

The resources outlined at Alio Ghelle by Nucleare Somala are not included as RAR. The Mission believes that the estimated 1700 t U₃O₈ occur largely in refractory minerals whose uranium content cannot be recovered within a cost range below US\$ 50/lb U₃O₈.

XI.3.2. Estimated Additional Resources

By definition, this category includes "little explored deposits" and "undiscovered deposits believed to exist along a well-defined geological trend with known deposits." These criteria apply to the Dusa Mareb deposit, as well as to the remainder of the El Bur-Ghelinsor paleodrainage, where radiometric anomalies were found but not fully evaluated.

The estimated resources at Dusa Mareb were placed into the category of "possible reserves" by McKee Overseas Corporation (1979). The Mission feels that this term can be correlated best with the EAR category of the NEA/IAEA, as "possible reserves" reflect a lesser degree of reliance usually associated with "little explored deposits".

The resources at Dusa Mareb, as estimated by UNDP and McKee, amount to 2357 and 3040 t U_3O_8 respectively. McKee believes that these estimates are conservative and the Mission is confident that the EAR at Dusa Mareb amounts to 3000 t U_3O_8 .

The part of the Ghelinsor-El Bur paleodrainage that is not fully explored includes, in addition to Mirig, Wabo and Dusa Mareb, seven radiometric anomalies or groups of anomalies at Ghelinsor, Adado, Kar Addei, Bulhale, Hamur, Wamoley and El Bur. Based on the cumulative surface area of these anomalies and the spatial extension of the gypsum crust, the Mission estimates the EAR for this part of the paleo-drainage at 8000 t U_3O_8 .

Thus the total EAR for Somalia amounts to 11,000 t U_3O_8 at US\$ 30-50/lb.

XI.3.3. Speculative Resources

XI.3.3.1. Introduction

With the exception of uranium minerals in calcretes and in albitized metamorphic/intrusive rocks no radioactive occurrences are known in Somalia that are indicative of the presence of additional economically viable types of uranium deposits. Nevertheless, the Mission decided to include magmatic-hydrothermal deposits as well as sandstone deposits in addition to the calcrete deposits. The favorable areas for these potential deposits was indicated in Sect. X.

XI.3.3.2. Calcretes

Speculative Resources in calcrete deposits may exist in depressions mapped in the Galcaio⁺ area (UNDP, 1972a) and also further north in areas underlain by the Upper Mudugh and Karkar series.

The depressions in the Galcaio area, also considered to be paleo-drainages, are sickle-shaped. The longer depression is 170 km in length, and extends to the southeast from Beira and turns eastward to Dabaro. The shorter depression extends north-south for ca. 130 km. from a point 30 km northeast of Galcaio to a point at coordinates 6°N / 47°25' E.

+ On the geological map of Somalia at a scale of 1:1,000,000 it is erroneously named "Gallacio".

In addition, the area underlain by rocks of the Mudugh Series amounts to a total area of ca. 87,000 km² (Sect. X.2.1.). However, 12,300 km² of this area must be subtracted from this total as they include the favorable areas for RAR (Wabo and Mirig) and EAR (Dusa Mareb and the Ghelinsor El Bur paleodrainage). Therefore the area considered to be favorable for Speculative Potential in the Mudugh area is ca. 74,700 km².

The total Speculative Resources estimated for the Mudugh Series range between 0 and 15,000 t U₃O₈.

In addition, Speculative Resources for the 152,000 km² underlain by the Karkar Series are thought to range between 0 and 20,000 t. This number is relatively low compared to the resources of the Mudugh Series, however, the Karkar Series lacks strong radiometric indications or known mineral occurrences. The Speculative Resources believed to exist in calcrete deposits amounts to a total of between 0 and 35,000 t U₃O₈.

XI.3.3.3. Magmatic-Hydrothermal Deposits

The potential areas for magmatic-hydrothermal deposits are located in the Archean-Proterozoic terrains of northern Somalia and the Bur area of southern Somalia. Both areas have received some attention by exploration companies, but are still believed to have a potential for magmatic-hydrothermal deposits.

The Precambrian rocks of northern Somalia, although mapped at several scales, are still poorly understood, and this is reflected in a high degree of uncertainty for the estimates of Speculative Resources. Based on the discussions in Sect. X.2.2., the Speculative Resources may be in the range between 0 and 10,000 t U₃O₈.

The Bur area hosts the Alio Ghelle Th-U occurrence associated with albitized metamorphic-intrusive rocks. Although Alio Ghelle cannot be considered a uranium resource, it is conceivable that additional deposits may be found with more favorable mineralogical compositions.

This assumption justifies an estimate of Speculative Resources ranging from 0 to 10,000 t U_3O_8 at US\$ 30-50/lb.

In summary, the Mission believes that Speculative Resources to be found in the Precambrian areas amount to:

- 0 - 10,000 t U_3O_8 for northern Somalia, and
- 0 - 10,000 t U_3O_8 for southern Somalia

X.3.3.4. Uranium Deposits in Sandstones

The areas with potential for uranium deposits in sandstones as outlined in Sect. X.2.3. are located both in northern and southern Somalia. In northern Somalia they include:

1. the Phanerozoic sedimentary cover adjacent to the Precambrian basement;
2. the Nubian Sandstone and the Jesomma Formation of the Bale Dobehe Basin; and
3. the Inda Ad Basin which unconformably covers Proterozoic and possibly Archean basement.

In southern Somalia favorable areas include:

1. the Cretaceous-Paleocene Jesomma Formation in the Shebeli River Basin; and
2. the Jurassic Adigrat cover on the Precambrian Bur uplift.

The mission has made the following Speculative Resource estimates for uranium deposits in sandstones:

Northern Somalia:

1. Phanerozoic cover on the Precambrian basement: based on the favorable source rocks, the Speculative Resources are thought to range between 0 and 20,000 t U_3O_8 .
2. The Nubian Sandstone and Jesomma Formation of the Bale Dobehe Basin could contain Speculative Resources ranging between 0 and 15,000 t U_3O_8 .
3. The Speculative Resources of the Inda Ad Basin are estimated to range between 0 and 25,000 t U_3O_8 ; this reflects the favorable geological position of this Series.

Southern Somalia:

1. The Jesomma Formation of the Shebeli River Basin with its spatial relationship to the Bur Precambrian uplift could host Speculative Resources between 0 and 10,000 t U₃O₈.
2. The Jurassic Adigrat Formation which unconformably overlies the Precambrian rocks of the Bur area is estimated to contain between 0 and 10,000 t U₃O₈.

A summary of the total Speculative Resources of uranium believed to exist in sandstone-type deposits is contained in Table XI-1.

Area	Speculative Resources (t U ₃ O ₈)
Phanerozoic cover on northern Somalia Precambrian	0 - 20,000
Nubian Ss and Jesomma Fm in Bale Dobehe Basin	0 - 15,000
Inda Ad Basin	0 - 25,000
Jesomma Fm in Shebeli River Basin	0 - 10,000
Adigrat cover on Bur Precambrian	0 - 10,000
Total for Sandstone deposits:	0 - 80,000 t U ₃ O ₈

Table XI-1 Speculative Uranium Resources in sandstone-type deposits.

XI.4. Summary of the Total Uranium Resources

Table XI-2 summarizes the uranium resources of Somalia in all three categories, together with the favorable localities, the expected deposit-types, and availability of land.

Resource Category	Resources t U ₃ O ₈	Area Deposit-Type	Land Status
RAR	5500	Wabo, Mirig; calcrete	Controlled by SOARMICO
EAR	3000	Dusa Mareb; calcrete	Controlled by SOARMICO
	8000	Ghelinsor-El Bur; calcrete	
	----- 11,000		
Speculative Resources	0 - 15,000	Galcaio & remainder of area covered by Mudugh Series, calcrete	Partly controlled by SOARMICO
	0 - 35,000	Area covered by Karkar suite; calcrete	Open ground
	0 - 20,000	Precambrian areas in N- and S- Somalia; magmatic-hydrothermal deposits	Open ground
	0 - 80,000	Sedimentary basins in N- and S- Somalia; sandstone deposits	Open ground
	----- 0 - 150,000		

Table XI-2 Summary of Uranium Resources of Somalia

Table XI-2 shows the preponderance of calcrete-type uranium deposits in the overall resource position of Somalia. 100% of the RAR and EAR, and 34.5% of the Speculative Resources are contained in calcretes; while the magmatic-hydrothermal deposits and sandstone uranium deposits are estimated to contain 10.3 and 55.2% respectively of the Speculative Resources.

In addition, there are several other favorable environments in Somalia, which were outlined in Sect. X.2.4. They may contain some "highly" speculative uranium resources not included in the above estimate.

XII. RECOMMENDATIONS FOR FUTURE EXPLORATION AND ESTIMATES OF COSTS

XII.1. Introduction

The objective of this section is twofold: to set forth recommendations for future exploration programs in those areas considered favorable for the presence of uranium deposits (Sect. X); and to present preliminary cost estimates for the recommended work. As these recommendations are made without considering who may conduct and fund these projects, the SOARMICO concession is included in the recommendations.

The aim of the recommended exploration program is to evaluate the favorable areas, to discover the Speculative Uranium Resources and to transfer them into the category of Estimated Additional Resources (EAR).

XII.2. Recommendations for Future Exploration of Favorable Areas and Outline of Costs

The recommendations are for the favorable areas selected in Sect. X:

1. the areas underlain by the Upper Mudugh and Karkar series which are favorable for calcrete deposits;
2. the areas in northern and southern Somalia underlain by Precambrian metamorphic and intrusive rocks;
3. the sedimentary basins which range in age from Precambrian to Cretaceous/Tertiary.

XII.2.1. Areas underlain by the Upper Mudugh and Karkar Series

Of the total favorable area of 200,000 km², ca. 12,000 km² which lie between Ghelinsor and El Bur have been investigated in detail. The results obtained justified the inclusion of the discovered resources into the RAR and EAR categories. In addition, the entire SOARMICO concession of 53,000 km², which includes these 12,000 km², was covered by a detailed airborne gamma-ray spectrometer survey in 1982. To assess the remaining area of ca. 150,000 km², the Mission suggests the area first to be screened by use of Landsat imagery to locate the paleodrainages or depressions and to attempt to recognize the mineralized valley-calcretes. Some research may be needed to establish

the most suitable techniques, using the known calcrete deposits as standards. This method might then be applied to the favorable areas, to delineate specific localities which have characteristics similar to the known mineralized calcretes. The cost for this study for an area of 150,000 km² would probably amount to US\$ 75,000 based on a similar project in Australia.

It is assumed that the study of Landsat imagery will delineate ca. 15% of the original favorable area or ca. 23,000 km², which should then be covered by an airborne radiometric survey using fixed-wing aircraft and a line spacing of 2 km. Thus, the radiometric survey would require 11,500 line-km, which at US\$ 50/line-km would cost US\$ 575,000.

For the ground follow-up program on the encountered radiometric anomalies, the Mission uses the following assumptions:

- anomalous area: 2300 km²
(10% of the area flown)
- ground methods used: radiometrics, pitting, trenching, auger drilling, sampling, assaying etc.
- costs per km²: US\$ 150

The total allocation for this phase would thus amount to US\$ 345,000.

The results of this work should lead to a further reduction of the area of investigation to ca. 300 km², which would subsequently have to be evaluated using closer-spaced ground radiometrics, auger drilling, pitting, trenching, sampling, assaying and metallurgical testing. The cost for this work could amount to US\$ 1,500,000 or more.

The total cost for the proposed investigation of the calcrete potential of the Upper Mudugh Series and Karkar Series would amount to ca. US\$ 2,500,000.

XII.2.2. Areas underlain by Precambrian Metamorphic and Intrusive Rocks of Northern Somalia and the Bur Area

Areas underlain by Precambrian rocks are located both in northern and southern Somalia and recommendations for further exploration in the two areas will be made separately.

XII.2.2.1. The Precambrian of Northern Somalia

Nucleare Somala investigated part of this area by means of an aerial radiometric survey using fixed-wing aircraft. Nevertheless the Mission recommends re-examining the entire part of northern Somalia underlain by Precambrian rocks with a magnetometer and gamma-ray spectrometer survey using rotary-wing aircraft, as the previous survey covered only 42% of Nucleare Somala's area, and fixed-wing aircraft are unsuitable for surveying mountainous terrain.

The Mission makes the following recommendations:

- equipment: rotary-wing aircraft with gamma-ray spectrometer and magnetometer;
- survey area: 10,000 km²;
- line-spacing: 2 km;
- total line-km: 5000;
- cost per line-km: ca. US\$ 150;
- total cost: US\$ 750,000.

The first phase of ground studies should be mainly, but not exclusively concentrated on locating and evaluating the airborne survey anomalies on the ground. Geological, geochemical and radiometric methods should be used. Particular attention should be paid to granitic rocks related to anomalies, however other granitic bodies should not be ignored. The granites should be examined at regular intervals, and their radioactivity and uranium and thorium contents determined. An effective method might be the use of a field gamma-ray spectrometer, possibly the Scintrex GAD-6, as this instrument can rapidly and accurately determine uranium and thorium contents and Th/U ratios, especially when used with a lead shield (to eliminate the effects of geometry) and the appropriate programmable calculator (e.g. TI-59). High uranium contents would indicate favorability as a source and/or host rock, while the Th/U ratios could help determine whether the uranium has been enriched or possibly leached away. Samples should be collected and the uranium minerals identified to determine whether the granites are "fertile". Mineralogical and metallurgical tests at an early stage on any discovered ore would establish its amenability to conventional leaching. It is assumed

that the area for ground investigation would amount to roughly 10% of the original survey area, i.e. ca. 1000 km², and that the recommended work would average US\$ 75/km² or US\$ 75,000. Additional work on the granites would cost another US\$ 50,000 for a total of US\$ 125,000.

The second phase of ground work will center on an area which has been further reduced to ca. 250 km². It will consist of a variety of geological, geochemical and geophysical (radiometrics, magnetics, VLF, etc.) methods, mineralogical and metallurgical laboratory investigations and limited pitting, trenching and core drilling. The total price for this work excluding drilling will amount to ca. US\$ 75,000 at a cost of ca. US\$ 300/km²; the drilling which should include about 20 coreholes to an average depth of 100 m, should cost US\$ 300/m including probing, sampling and assaying, for a total of US\$ 600,000. Therefore, the total funds to be allocated for the second phase should be US\$ 675,000.

The grand total for the entire suggested exploration program would reach US\$ 1,550,000.

XII.2.2.2. The Bur Area of Southern Somalia

The Bur area of southern Somalia has been covered by two airborne gamma-ray spectrometer surveys which were conducted for UNDP and Nucleare Somala. Therefore, it is suggested that the basic data collected during these surveys should be obtained from the respective contractors and re-evaluated. During this reinterpretation, special attention should be given to those anomalies which were assessed, selected and later studied and drilled by Nucleare Somala and White Star Mining Company. Current knowledge should allow the comparison of these anomalies with others in the area which were not selected for further study at that time. An amount of US\$ 20,000 is allocated for the re-examination of the old airborne studies.

The first phase of ground studies should be similar to that recommended for the Precambrian of northern Somalia in Sect.

XII.2.2.1 and should include the location and preliminary assessment of the selected radiometric anomalies by geological, geochemical and geophysical techniques. The granites of the Bur area should be examined, even outside anomalous areas to determine their uranium and thorium contents, Th/U ratios, alteration zones, etc. as discussed in the previous section. Furthermore, it has been suggested that the Bur area may be a metamorphic core complex (i.e. gneiss dome) similar to the Kettle Dome in northeastern Washington State, USA (R.T. Cannon, 1983, oral communication). This possibility should be kept in mind and the importance of cataclastic rocks, anatexites and other significant features should not be ignored. The Kettle Dome hosts numerous uranium occurrences, is considered a highly favorable area for a variety of uranium deposits by the U.S. Dept. of Energy, and has many structural and petrographic features similar to both the Rossing (Namibia) and the Jabiluka (Australia) areas. Mineralogical and metallurgical examinations should be made of any ore minerals and drilling, probing, etc. should also be part of the program. The cost for the field program, excluding drilling should total about US\$ 112,500 (based on US\$ 75/km² for 1500 km²) plus an additional \$ 50,000 for the study of granites, for a grand total of \$ 162,500. Drilling is expected to consist of 50 coreholes to an average depth of 150 m at US\$ 350/m for a cost of US\$ 2,625,000. A second phase drilling program, if warranted would consist of 100 coreholes to a depth of 150 m at US\$ 350/m for a cost of \$ 5,250,000. The total cost of the recommended exploration program for the Bur area would amount to US\$ 8,057,500.

XII.2.2. Sedimentary Basins

As indicated in Sect. X.2.3. and X.3., five areas were selected as favorable for the occurrence of uranium deposits in sandstones:

1. the Phanerozoic sedimentary cover above the Precambrian basement in northern Somalia (6000 km²);
2. the Bale Dobehe Basin (7200 km²);
3. the Precambrian Inda Ad Basin (2000 km²);
4. the Shebeli River Basin (8000 km²); and

5. the Jurassic cover overlapping the Precambrian Bur Uplift (1700 km²).

Recommendations for exploration and an outline of costs are made separately for each of these areas.

XII.2.3.1. Phanerozoic Sedimentary Cover Adjacent to the Northern Somalia Precambrian Basement

For the initial assessment of this area, which includes about 6000 km² surrounding the Precambrian basement of northern Somalia, it is suggested that an airborne rotary-wing gamma-ray spectrometer-magnetometer survey should be conducted, if possible as part of the same survey recommended for the adjacent Precambrian area (Sect. XII.2.2.1.).

The following logistics are assumed for this integrated survey:

- line spacing: 2 km;
- line-km: 3000;
- cost per line-km: US\$ 150;
- total cost for survey: US\$ 450,000

A first phase ground follow-up is recommended to examine anomalous areas, estimated for the purpose of the costing at 10% (600 km²) of the original favorable area. The methods to be applied in this phase include geological, geochemical and radiometric investigations. The objective is the identification of the anomalies on the ground and their preliminary assessment. It is assumed that the total price for this phase will amount to US\$ 45,000, at a cost of US\$ 75/km².

A second field phase will be required to assess the smaller anomalous areas estimated to cover ca. 100 km² which were delineated during the first phase. The main Phase II activities should include geological, geochemical and radiometric studies in addition to pitting, trenching and drilling. The assumed cost excluding drilling would amount to US\$ 30,000, based on a cost of US\$ 300/km². The drilling program, including probing, sampling, assaying, geological evaluation, etc.

would include 90 rotary holes to an average depth of 150 m at US\$ 100/m and 10 coreholes to an average depth of 150 m at US\$ 300/m. The total cost for the drilling program would be ca. US\$ 1,800,000.

The total program to assess the Phanerozoic cover above the northern Somali Precambrian amounts to US\$ 2,325,000.

XII.2.3.2. The Bale Dobehe Basin

The investigation of the uranium potential of the Nubian Sandstone/Jesomma Formation in the Bale Dobehe Basin is recommended using methods similar to those described in Sect. XII.2.3.1.

A fixed-wing airborne gamma-ray spectrometer-magnetometer survey over the total 7200 km² area at a line spacing of 2 km, would comprise 3600 line-km at US\$ 50/line-km and would cost US\$ 180,000.

A subsequent ground follow-up program would include the evaluation of the radiometric anomalies and use standard geological, geochemical and radiometric methods over roughly 10% of the surveyed area or ca. 720 km² at a cost of US\$ 75/km². The total cost for this work would amount to US\$ 54,000.

If justified, a second phase would be carried out which would include a more detailed investigation of a number of selected areas covering ca. 100 km². Detailed geological, radiometric and geochemical work including some pitting and trenching would cost about US\$ 300/km² which would total US\$ 30,000. Envisaged are approximately 90 rotary holes to an average depth of 150 m at US\$ 100/m and 10 coreholes also to an average depth of 150 m at US\$ 300/m, for a total cost of US\$ 1,800,000. Thus, the grand total for this phase would amount to US\$ 1,830,000.

The total cost for the recommended exploration program for the Bale Dobehe Basin amounts to US\$ 2,064,000.

XII.2.3.3. Inda Ad Basin

The Inda Ad Basin appears quite complex structurally, due to the influence of the Gulf of Aden rifting as well as earlier tectonic episodes. This may be unfavorable for the formation and preservation of uranium deposits, but nevertheless the Mission recommends the evaluation of this basin and its contact areas.

The first phase of the investigation should be to re-evaluate the fixed-wing gamma-ray spectrometer survey conducted by Hunting for Nucleare Somala, which should cost ca. US\$ 20,000.

Should this reinterpretation indicate the area should be re-surveyed, a rotary-wing integrated gamma-ray spectrometer-magnetometer survey should be flown over the entire area of 2000 km². This survey would be predicated on the following data:

- line spacing: 2 km;
- line-km: 1000;
- cost per line-km: US\$ 150;
- total cost: US\$ 150,000

A follow-up first phase of ground studies using geological, geochemical, and radiometric methods should then be undertaken. Both stratiform and structurally controlled mineral deposits may occur and the latter might be indicative of uranium deposits in the underlying basement (model: Midwest Lake, Saskatchewan, Canada). The cost for this first phase, which should cover approximately 200 km² at ca. US\$ 75/km², should amount to US\$ 15,000.

If warranted, a more detailed ground investigation of several favorable localities may be required. It is estimated the area to be covered by these second phase studies will total 100 km²; shall cost ca. US\$ 30,000 and will include detailed geological, geochemical and geophysical studies, the latter including radiometrics and VLF. A follow-up drilling program of 90 rotary holes to a depth of 150 m at US\$ 100/m and ten coreholes to a depth of 150 m at US\$ 300/m would cost US\$ 1,800,000.

The total cost for each of the two alternatives (with or without a rotary-wing airborne survey) to evaluate the Inda Ad Basin would amount to either US\$ 2,015,000 or US\$ 1,865,000 respectively.

XII.2.3.4. Shebeli River Basin

The Shebeli River Basin is underlain by the Jesomma Formation and covers an area of ca. 8000 km². Compared with the same unit in northern Somalia, the geology is poorly understood. It is proposed therefore, to initiate the investigation with a geological reconnaissance to collect litho-stratigraphical, structural, radiometric and geochemical information. The presumed costs for this reconnaissance phase will amount to US\$ 10/km² or a total of US\$ 80,000.

If results indicate a uranium favorability, a rotary-wing airborne gamma-ray spectrometer survey should be flown covering selected stratigraphic units. Assuming that these horizons would cover roughly 30% of the total area or 2400 km², that the line spacing should be one km, and that a total of 2400 line-km will be flown at a cost of US\$ 150/line-km, then the total cost would reach US\$ 360,000.

A ground follow-up phase will probably cover roughly 10% of the area, or approximately 240 km². This should include detailed geological, geochemical and radiometric investigations, trenching, pitting, drilling, sampling, assaying, etc. The costs (excluding those for drilling) may amount to US\$ 72,000, at US\$ 300/km². The proposed drilling program includes 150 rotary holes to a depth of 150 m each at US\$ 100/m and 15 coreholes to a depth of 150 m each at US\$ 300/m and would cost US\$ 2,925,000.

The total cost for the recommended exploration program for the Jesomma Formation underlying the Shebeli River Basin amounts to US\$ 3,437,000.

XII.2.3.5. The Jurassic Cover above the Precambrian Bur Uplift

The Jurassic Adigrat Formation unconformably covers the Precambrian rocks of the Bur area, forming a narrow semicircular band around the

northern edge of the uplift. The mapped outcrop area (UNDP, 1972a) covers only 1700 km².

It is recommended that data from several airborne radiometric surveys which cover the area of Adigrat overlap on Precambrian rocks, should be examined, and the information evaluated. This study should cost ca. US\$ 15,000.

If the old survey data are not of usable quality, a new rotary-wing airborne gamma-ray spectrometer survey should be flown above the unconformity and the Adigrat outcrops. At 2 km line spacing, ca. 850 line-km would be flown at a cost of US\$ 150/line-km and a total cost of ca. US\$ 127,500.

A subsequent ground follow-up would evaluate selected radiometric anomalies which are assumed to cover about 200 km². The allocations for this phase, which consists of semi-detailed geological, geochemical and radiometric investigations, would amount to US\$ 20,000 at US\$ 100/km².

If the results justify further efforts, a more detailed work program would include detailed investigations at costs of US\$ 300/km² over a selected area of ca. 50 km² for a total cost of US\$ 15,000. In addition, a drilling program including 15 rotary holes to a depth of 150 m at US\$ 100/m would cost US\$ 225,000.

The total expenditure for the investigation of the unconformable Adigrat cover above the Bur Precambrian would amount to US\$ 275,000 without an aerial survey or US\$ 402,500 including an aerial survey.

XII.3. Summary

Below, is a summary of the suggested investigations and assumed costs for each of the areas discussed in this section. They are summarized and tentatively related to the Speculative Resources thought to exist in each area.

A) Upper Mudugh and Karkar Series calcretes:

recommended work	costs (x 1000 US\$)	%
Landsat imagery, interpretation and evaluation:	75	3.0
fixed-wing airborne survey:	575	23.0
ground studies (radiometrics, pitting, trenching, auger drilling, sampling):	345	13.8
detailed radiometrics, pitting, trenching, sampling, metallurgical testing:	1,500	60.2
Total A):	2,495	100

Speculative Resources: 0-50,000 t U_3O_8
 0-110,000,000 lbs U_3O_8
 minimum discovery costs: 2,500,000 divided by 110,000,000
 = US\$ 0.023/lb U_3O_8

B) Precambrian

B/1) Northern Somalia Precambrian:

recommended work	costs (x 1000 US\$)	%
rotary-wing mag & gamma-spec survey	750	48
ground studies (geology, geochemistry, radiometrics), mineralogical and metallurgical lab tests:	125	8
detailed ground studies (geology, geochemistry, geophysics, pitting, trenching):	75	5
drilling:	600	39
Total B/1):	1550	100

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Speculative Resources: 0-10,000 t U_3O_8
 0-22,000,000 lbs U_3O_8
 minimum discovery costs: US\$ 0.0705/lb U_3O_8

B/2) Southern Somalia - Bur Area:

recommended work	costs (x 1000 US\$)	%
re-evaluation of previous airborne survey data:	20	0.2
ground studies (geology, geo- chemistry, geophysics), mineral- ogical and metallurgical lab tests:	162.5	2.0
drilling:	2625	32.6
drilling:	5250	65.2
Total B/2)	8057.5	100

Speculative Resources: 0-10,000 t U_3O_8
 0-22,000,000 lbs U_3O_8
 minimum discovery costs: US\$ 0.3663/lb U_3O_8

Total Costs B) US\$ 9,607,500

Speculative Resources: 0-20,000 t U_3O_8
 0-44,000,000 lbs U_3O_8
 minimum discovery costs: US\$ 0.2184/lb U_3O_8

C) Sedimentary Basins

C/1) Phanerozoic Cover adjacent to the northern Somalia Precambrian:

recommended work	costs (x 1000 US\$)	%
rotary wing gamma-spec & mag survey:	450	19.4
ground studies (geology, geochemistry, radiometrics):	45	1.9
detailed ground studies (geology, geochemistry, radiometrics, pitting, trenching):	30	1.3
drilling:	1800	77.4
Total C/1)	2325	100

Speculative Resources: 0-20,000 t U_3O_8
 0-44,000,000 lbs U_3O_8
 minimum discovery costs: US\$ 0.0528/lb U_3O_8

C/2) Bale Dobehe Basin:

recommended work	costs (x 1000 US\$)	%
fixed-wing airborne survey:	180	8.7
ground studies (geology, geochemistry, radiometrics):	54	2.6
detailed ground studies (geology, geochemistry, radiometrics, pitting, trenching, etc):	30	1.4
drilling:	1800	87.3
Total C/2)	2064	100

Speculative Resources: 0-15,000 t U_3O_8
 0-33,000,000 lbs U_3O_8
 minimum discovery costs: US\$ 0.0625/lb U_3O_8

C/3) Inda Ad Basin:

recommended work	costs (x 1000 US\$)	%
re-evaluation of previous airborne survey data:	20	1 ⁺ / 0.9 ⁺⁺
eventual rotary-wing gamma-spec & mag survey:	(150)	- / 7.4
ground studies (geology, geochemistry, radiometrics):	15	0.8 / 0.7
detailed ground studies (geology, geochemistry, radiometrics, VLF):	30	1.6 / 1.5
drilling:	1800	96.6 / 89.5
Total C/3)	1865 ⁺ 2015 ⁺⁺	100

Speculative Resources: 0-25,000 t U₃O₈
 0-55,000,000 lbs U₃O₈
 minimum discovery costs: US\$ 0.0339/lb U₃O₈⁺
 US\$ 0.0366/lb U₃O₈⁺⁺

C/4) Shebeli River Basin:

recommended work	costs (x 1000 US\$)	%
ground reconnaissance:	80	2.3
rotary-wing airborne gamma-spec survey:	360	10.5
ground studies (geology, geochemistry, trenching, pitting, etc.):	72	2.1
drilling:	2925	85
Total C/4)	3437	100

Speculative Resources: 0-10,000 t U₃O₈
 0-22,000,000 lbs U₃O₈
 minimum discovery costs: US\$ 0.1562/lb U₃O₈

+ = excluding }
 ++ = including } airborne survey

C/5) Jurassic Cover above Precambrian Bur Uplift

recommended work	costs (x 1000 US\$)	%
re-evaluation of previous airborne survey data:	15	5.5 ⁺ / 3.7 ⁺⁺
possible rotary-wing airborne gamma-spec survey:	(127.5)	- / 31.7
ground studies (geology, geochemistry, radiometrics):	20	7.3 / 5.0
detailed ground studies (geology, geochemistry, radiometrics):	15	5.5 / 3.7
drilling:	225	81.7 / 55.9
Total C/5)	275⁺ 402.5⁺⁺	100

Speculative Resources: 0-10,000 t U₃O₈
 0-22,000,000 lbs U₃O₈
 minimum discovery costs: US\$ 0.0125/lb U₃O₈⁺
 US\$ 0.0183/lb U₃O₈⁺⁺

Total Costs C): between US\$ 9,966,000⁺

and US\$ 10,243,500⁺⁺

Speculative Resources: 0-80,000 t U₃O₈
 0-176,000,000 lbs U₃O₈
 minimum discovery costs: between US\$ 0.0566/lb U₃O₈⁺
 and US\$ 0.0582/lb U₃O₈⁺⁺

Grand Total A - C):

A) US\$ 2,495,000
 B) 9,607,500
 C) 9,966,000
 (10,243,500)
US\$ 22,068,500⁺
 22,351,000⁺⁺

+ = excluding) airborne survey
 ++ = including)

Speculative Resources: 0-150,000 t U_3O_8
0-330,000,000 lbs U_3O_8
minimum discovery costs: between US\$ 0.067/lb $U_3O_8^+$
and US\$ 0.068/lb $U_3O_8^{++}$

+ = excluding)
++ = including) airborne survey

XIII. OPTIONS TO THE SOMALI GOVERNMENT FOR THE IMPLEMENTATION OF RECOMMENDATIONS

In previous sections of this report the Mission outlined 254,900 km² or about 40% of the SDR as areas favorable for uranium exploration; estimated the Reasonably Assured Resources (RAR) at 5500 t U₃O₈, the Estimated Additional Resources (EAR) at 11,000 t U₃O₈, and the Speculative Resources to range from 0 to 150,000 t U₃O₈; and made recommendations on exploration methods and expenditures (+ US\$ 22 millions) designed to discover the speculative resources. It is believed that the suggested investigation can be carried out over 5 - 8 years.

The suggested exploration program is very ambitious and was designed irrespective of who would conduct and fund it. Some of these ideas however, may assist the Government of Somalia in planning those steps required to implement at least part of the recommended program.

As the Mission indicated by giving the Speculative Resources a range with a lower limit of zero, there is no guarantee that these resources will be discovered even after committing sizeable expenditures. This is the nature of exploration for natural resources and therefore it cannot be recommended that the Ministry of Mineral and Water Resources carry out the suggested program entirely with its own resources.

Unfortunately the UNDP-TCO Project SOM/82/003 aimed at "strengthening the Geological Survey" also hasn't the means to conduct uranium-related investigations, even when working in areas with uranium potential.

Therefore it must be concluded that the implementation and funding of the recommended program must be sought from other sources.

The logical option would be to attract the interest of foreign uranium mining companies, as Somalia has in the past, to explore areas at their own risk, under various contractual models (production sharing, joint ventures, etc.). However, the international uranium market, has been very weak since 1979 and may remain so for years to come. It therefore seems unlikely that foreign mining companies will show a current interest in investing in uranium exploration in Somalia.

A second alternative is for the government to seek the assistance of either bilateral or multilateral organizations such as IAEA, UNDP, World Bank, etc., to carry out basic investigations including airborne surveys. The data obtained from these surveys are not only useful for uranium exploration, but also provide useful data for regional geological mapping. In other African countries, the results of airborne surveys have been instrumental in attracting foreign companies to conclude agreements with the governments concerned. If the Government of Somalia is interested, it is suggested that appropriate steps be undertaken without delay, since it usually requires several years to request and obtain the necessary bilateral or multilateral support.

It is further suggested that the Somali Authorities provide the legal base for foreign investment in the field of uranium exploration and mining. The Mission has been informed that a new mining code is about to be introduced. It is hoped that it will provide reasonable, fair and practical terms as regards the size of the original concession areas, their reduction schedule, annual exploration commitments, royalties, income tax regulations, tax and duty-free imports of capital goods, repatriation of earnings, export of uranium concentrates etc.

After implementing all or parts of the suggestions made in this section, Somalia would be in a very favorable position to attract foreign capital when the uranium market improves and mining companies are again active.

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XV.

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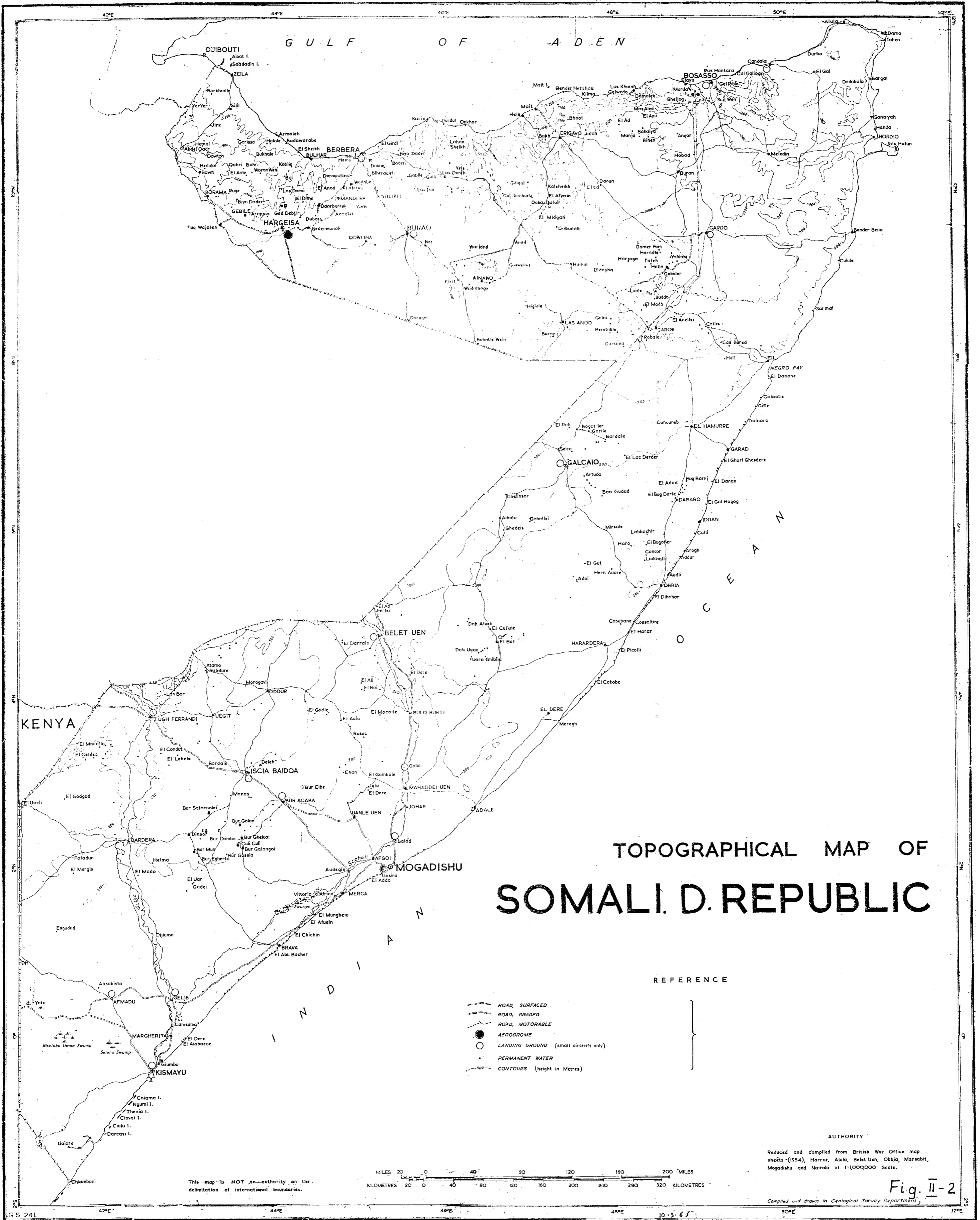
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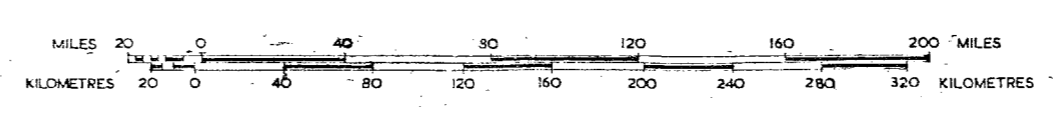


TOPOGRAPHICAL MAP OF SOMALI D. REPUBLIC

REFERENCE

- ROAD, SURFACED
- ROAD, GRADED
- ROAD, MOTORABLE
- AERODROME
- LANDING GROUND (small aircraft only)
- PERMANENT WATER
- CONTOURS (height in Metres)

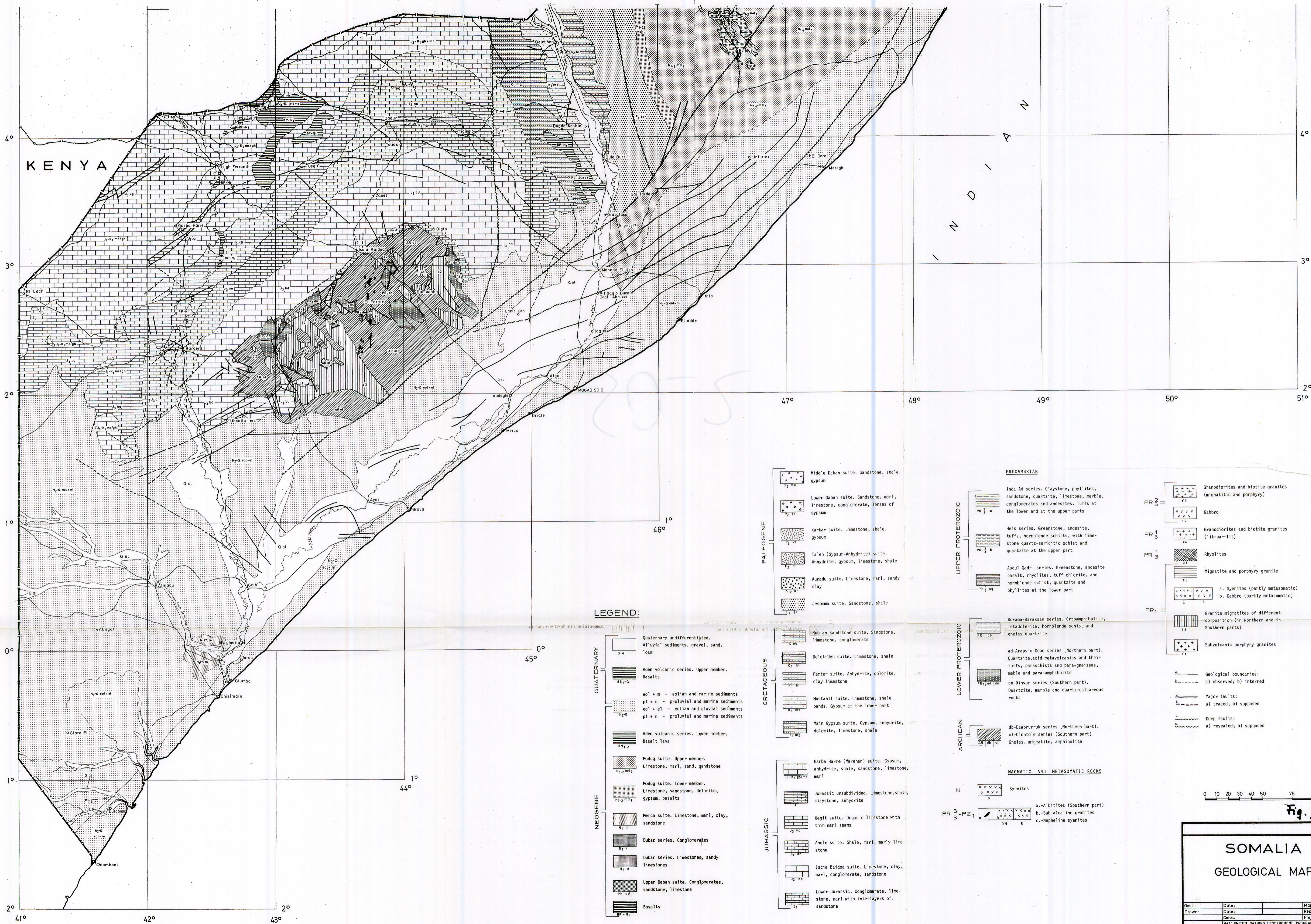
AUTHORITY
 Reduced and compiled from British War Office map sheets (1954), Harrar, Alula, Belet Uen, Obbia, Marsabit, Mogadishu and Nairobi of 1:1,000,000 Scale.



This map is NOT an authority on the delimitation of international boundaries.

Fig. II-2

Compiled and drawn in Geological Survey Department



KENYA

S O M A L I A

LEGEND:

- QUATERNARY**
- Quaternary undifferentiated. Alluvial sediments, gravel, sand, loam
 - Aden volcanic series. Upper member. Basalts
 - Aden volcanic series. Lower member. Basalt lava
 - Mudug suite. Upper member. Limestone, marl, sand, sandstone
 - Mudug suite. Lower member. Limestone, sandstone, dolomite, gypsum, basalts
 - Merca suite. Limestone, marl, clay, sandstone
 - Dubar series. Conglomerates
 - Dubar series. Limestones, sandy limestones
 - Upper Daban suite. Conglomerates, sandstone, limestone
 - Basalts
- NEOGENE**
- eo1 + m - eolian and marine sediments
 - pl + m - proluvial and marine sediments
 - eo1 + eo1 - eolian and eluvial sediments
 - pl + m - proluvial and marine sediments

- PALEOGENE**
- Middle Daban suite. Sandstone, shale, gypsum
 - Lower Daban suite. Sandstone, marl, limestone, conglomerate, lenses of gypsum
 - Karkar suite. Limestone, shale, gypsum
 - Taleh (Gypsum-Anhydrite) suite. Anhydrite, gypsum, limestone, shale
 - Auradu suite. Limestone, marl, sandy clay
 - Jesomma suite. Sandstone, shale

- CRETACEOUS**
- Nubian Sandstone suite. Sandstone, limestone, conglomerate
 - Belet-Uen suite. Limestone, shale
 - Ferter suite. Anhydrite, dolomite, clay limestone
 - Mustahil suite. Limestone, shale bands. Gypsum at the lower part
 - Main Gypsum suite. Gypsum, anhydrite, dolomite, limestone, shale

- JURASSIC**
- Garba Harre (Marehan) suite. Gypsum, anhydrite, shale, sandstone, limestone, marl
 - Jurassic undivided. Limestone, shale, claystone, anhydrite
 - Uegit suite. Organic limestone with thin marl seams
 - Anole suite. Shale, marl, marly limestone
 - Iscia Baldoa suite. Limestone, clay, marl, conglomerate, sandstone
 - Lower Jurassic. Conglomerate, limestone, marl with interlayers of sandstone

- UPPER PROTEROZOIC**
- Inda Ad series. Claystone, phyllites, sandstone, quartzite, limestone, marble, conglomerates and andesites. Tuffs at the lower and at the upper parts
 - Heis series. Greenstone, andesite, tuffs, hornblende schists, with limestone quartz-sericitic schist and quartzite at the upper part
 - Abdul Qadr series. Greenstone, andesite, basalt, rhyolites, tuff chlorite, and hornblende schist, quartzite and phyllites at the lower part

- LOWER PROTEROZOIC**
- Borana-Barakani series. Orthoamphibolite, metadolomite, hornblende schist and gneiss quartzite
 - ad-Arapsio Dobo series (Northern part). Quartzite, acid metavolcanics and their tuffs, parashists and para-gneisses, marble and para-amphibolite
 - dn-Dinsor series (Southern part). Quartzite, marble and quartz-calcareous rocks

- ARCHAIC**
- db-Daaburruruk series (Northern part). Gneiss, migmatite, amphibolite
 - ol-Olontole series (Southern part). Gneiss, migmatite, amphibolite

- MAGMATIC AND METASOMATIC ROCKS**
- Syenites
 - a-Albitites (Southern part)
 - b-Sub-alkaline granites
 - c-Nepheline syenites

- Grandiorites and biotite granites (migmatitic and porphyry)
- Gabbro
- Grandiorites and biotite granites (lit-par-lit)
- Rhyolites
- Migmatite and porphyry granite
- a. Syenites (partly metamorphic)
- b. Gabbro (partly metamorphic)
- Granite migmatites of different composition (in Northern and in Southern parts)
- Subvolcanic porphyry granites

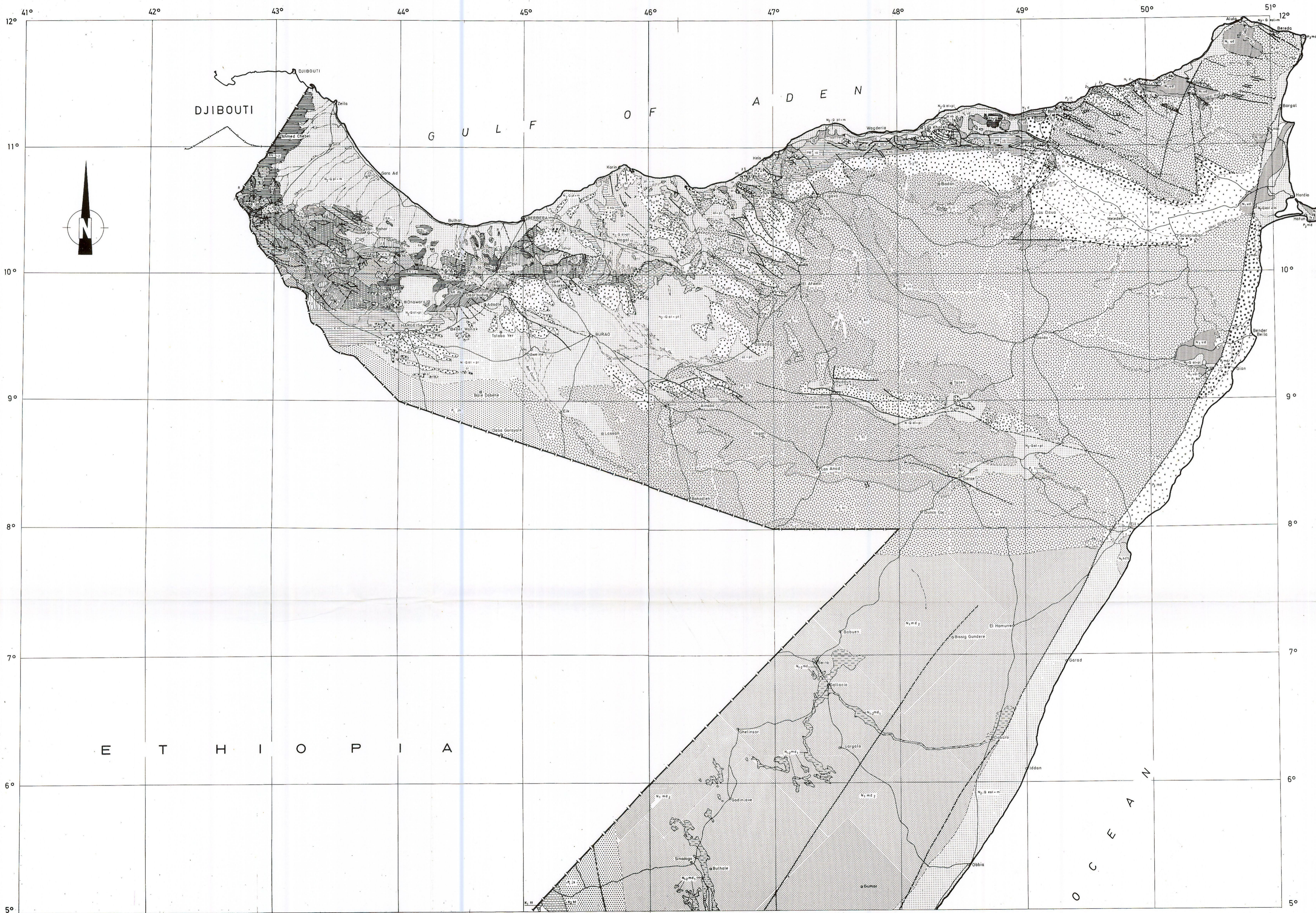
- Geological boundaries:**
- a) observed; b) inferred
- Major faults:**
- a) traced; b) supposed
- Deep faults:**
- a) revealed; b) supposed

0 10 20 30 40 50 75 100 km

Fig. 11-4a

SOMALIA GEOLOGICAL MAP

Geol.:	Date:	Map No.:
Drawn:	Date:	Report:
Conc.:	Date:	Project: 4303
Ref. UNITED NATIONS DEVELOPMENT PROGRAMME		

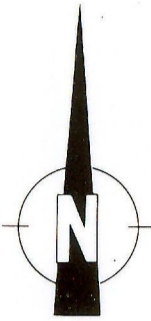


DJIBOUTI

G U L F O F A D E N

E T H I O P I A

O C E A N



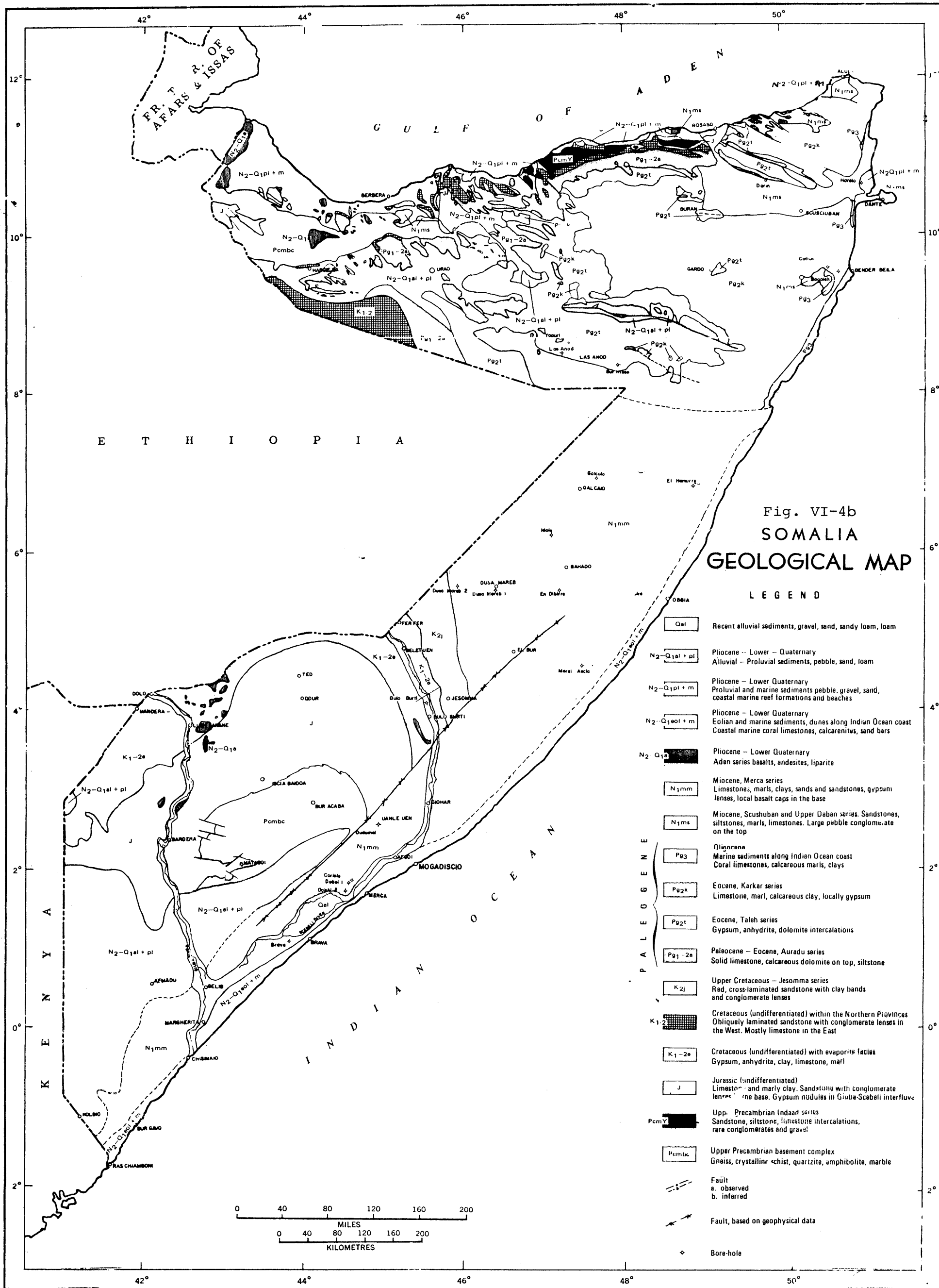


Fig. VI-4b
SOMALIA
GEOLOGICAL MAP

LEGEND

- Recent alluvial sediments, gravel, sand, sandy loam, loam
- Pliocene - Lower - Quaternary Alluvial - Proluvial sediments, pebble, sand, loam
- Pliocene - Lower Quaternary Proluvial and marine sediments pebble, gravel, sand, coastal marine reef formations and beaches
- Pliocene - Lower Quaternary Eolian and marine sediments, dunes along Indian Ocean coast Coastal marine coral limestones, calcarenites, sand bars
- Pliocene - Lower Quaternary Aden series basalts, andesites, liparite
- Miocene, Merca series Limestones, marls, clays, sands and sandstones, gypsum lenses, local basalt caps in the base
- Miocene, Scushuban and Upper Daban series. Sandstones, siltstones, marls, limestones. Large pebble conglomerate on the top
- Pliocene Marine sediments along Indian Ocean coast Coral limestones, calcareous marls, clays
- Eocene, Kerkar series Limestone, marl, calcareous clay, locally gypsum
- Eocene, Taleh series Gypsum, anhydrite, dolomite intercalations
- Paleocene - Eocene, Auradu series Solid limestone, calcareous dolomite on top, siltstone
- Upper Cretaceous - Jesomma series Red, cross-laminated sandstone with clay bands and conglomerate lenses
- Cretaceous (undifferentiated) within the Northern Provinces Obliquely laminated sandstone with conglomerate lenses in the West. Mostly limestone in the East
- Cretaceous (undifferentiated) with evaporite facies Gypsum, anhydrite, clay, limestone, marl
- Jurassic (undifferentiated) Limestone and marly clay. Sandstone with conglomerate lenses at the base. Gypsum nodules in Giuba-Scabeli interfluve
- Upp. Precambrian Inadaad series Sandstone, siltstone, limestone intercalations, rare conglomerates and gravels
- Upper Precambrian basement complex Gneiss, crystalline schist, quartzite, amphibolite, marble
- Fault a. observed
- Fault b. inferred
- Fault, based on geophysical data
- Bore-hole