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REVIEW OF THE MINERALS AND HYDROCARBONS POTENTIAL OF SOMALIA

A DESK STUDY
AUGUST 1996

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1. INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The Somali Salvation Alliance commissioned Mr Richard J. Bray to investigate the natural resources of Somalia. After discussion, Hunting Technical Services Limited were contracted, through the Gabriel Trust plc, London, to undertake a desk study on the geological literature of Somalia, with particular reference to the mineral and hydrocarbons resources. Opinions on the quality of previous work and exploration were to be addressed as appropraite.

During briefing for carrying out the work, it was suggested by Dr Barr to Dr Phillips that effort should be concentrated on the southern part of the country.

The name "Somalia" is used in this report for the area included within the borders of Somalia during the 1980s. "Southern Somalia" is used for the area south of approximately latitude 8° N, and "northern Somalia" is used for the area north of approximately latitude 8° N. This is a reflection of the political situation during the time of publication of most of the open literature. By coincidence, 8° N is also the approximate southern boundary of the Nogal Uplift.

The geographic area considered for the detailed sections of this report varies. For the Precambrian only the Bur Acaba block is discussed, as it is isolated from and different to the Precambrian of northern Somalia. Discussions of the Phanerozoic include all of Somalia but are biased towards southern Somalia.

1.2 FORMAT OF THE REPORT

Following this introductory section, there is a a section on the basic geological knowledge about Somalia. That section includes information on previous work and the geological history of the region.

The third section discusses the previous hydrocarbons exploration, the hydrocarbons context, and suggests the kinds of plays that might yield hydrocarbons. The fourth section provides information on the mineral resources, and areas which might be suitable for further exploration.

The last section summarises the opinions of the author, and suggests some further steps to increase the exploration knowledge database.

The cited reference list is not completely comprehensive, as there are many references within the cited references which would be useful for a reference library but which would add little to the information provided in this report.

Included at Annex A are the Contents Pages from three commercially available reports on the hydrocarbons potential of particular sedimentary basins of Somalia. Copies of printouts on the holdings of the Geological Society of London on the geology of Somalia are included at Annex B. During the course of this study, several other requests for information on literature held were initiated but without any returned results by the time this report was written. If and when such information is received it will be forwarded to Gabriel Trust plc.

2. GEOLOGICAL BACKGROUND

2.1 PREVIOUS WORK

Figure 2.1 provides an overview of the geology of Somalia by locating the basement outcrops and the sedimentary basins. The positions of the hydrocarbons exploration wells drilled up to 1987 are also shown. Table 2.1 lists the names of the wells.

One of the first geological reports was on the mapping undertaken by Thompson & Ball (1918) of the Daga Shabell Oilfield south of Berbera in northern Somalia. They recommended testing and further studies. Extensive geological reconnaissance of central and western parts of northern Somalia by geologists of the Anglo-Persian Oil Company was carried out in 1920-21, and further reconnaissance mapping by Somaliland Petroleum Company geologists in 1928-30. These last two surveys were disappointing and interest waned.

In 1933 the National Research Council of Italy published a geological map of the whole of Somalia and Ethiopia (Stefanini,1933).

In 1947-49 the Somaliland Oil Exploration Company Ltd undertook further mapping in northern Somalia, and continued with another exploration licence in 1949-51. Although further work was not considered justified, the 1954 (SOEC, 1954) report does indicate thin oil shales present in the Anhydrite Series (which can be correlated with the Taleh Formation) in the southern part of the Nogal and occurrences of oil impregnation in Jurassic strata adjacent to faults.

Regional 1:500,000 scale geological maps were produced by AGIP/Sinclair Oil (Azzaroli & Merla, 1959), but they are only of "reconnaissance" standard. 1:125,000 scale maps of the former British Somaliland Protectorate (northern Somalia) were also produced in the 1950s and 1960s to accompany survey reports.

In the 1970s and 1980s there was significant geological and geophysical work, including airborne geophysics, carried out by oil exploration companies, but very little was reported in the open literature. Regional exploration was carried out under the auspices of a United Nations Development Program (UNDP, 1970 and 1972). Merla et al. (1973 and 1979) produced an updated geological map of Somalia at 1:2,000,000 scale.

During the late 1980s and early 1990s there were several large campaigns investigating the geology of Somalia and/or surrounding areas. The three principal programs were the:

- German Special Research Project 69
- The "Mechanisms of ocean development: Red Sea - Gulf of Aden system and the Afro-Arabian shield" project (and other projects) of the Italian National Council for Research
- UNDP/World Bank Red Sea - Gulf of Aden Regional Hydrocarbons Study Project

Investigations into all parts of the stratigraphic column in Somalia were carried out under German Special Research Project 69, with the results published in 1990 in the Berliner geowissenschaft Abh., volume 120 part 2. However, most of the investigations concentrated on the northern parts of Somalia.

The UNDP/World Bank project, carried out between 1989 and 1992, concentrated on the Red Sea and Yemen Gulf of Aden coast but did consider the Somali north coast and on-shore region. Beydoun & Sikander (1992) provide a summary of the work carried out and the results obtained.

FIGURE 2.1 MAP OF SOMALIA SHOWING LOCATION OF PRINCIPAL BASEMENT OUTCROPS, EXPLORATION WELLS (SEE TABLE 2.1 FOR WELL NAMES), AND SEDIMENTARY BASINS (after Bosellini, 1992, fig.1, and others).

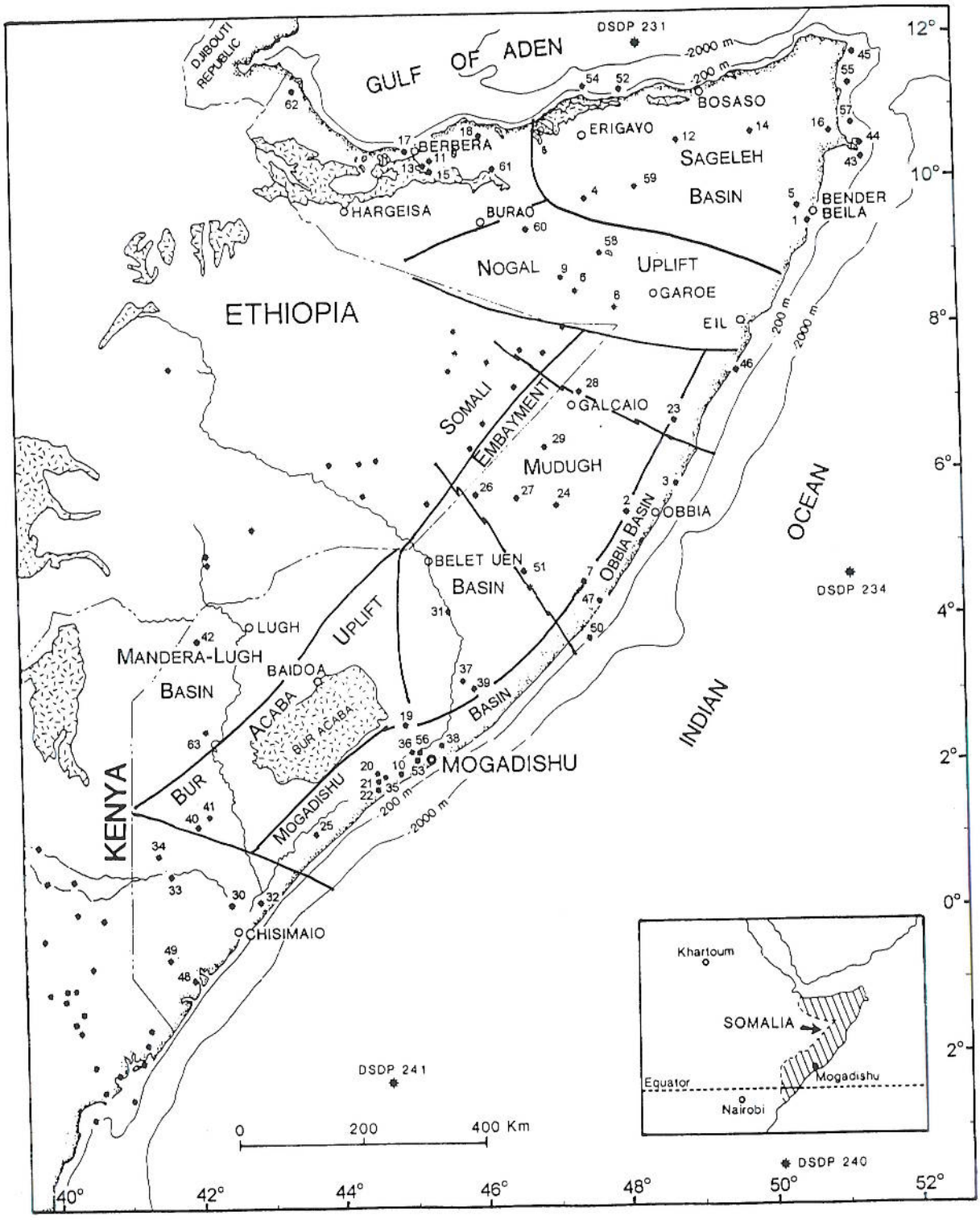


TABLE 2.1 DETAILS OF EXPLORATION WELLS SHOWN ON FIGURE 2.1

Well Name	Number on Fig. 2.1	Operator (if known)		Basin
Sageleh	1	AGIP	pre-1976	Sageleh
Gira	2	Sinclair	pre-1976	Mudugh
Obbia	3	Sinclair	pre-1976	Mudugh
Faro Hills	4	Amerada	pre-1976	Sageleh
Cotton	5	AGIP	pre-1976	
Las Anod	6	Amerada	pre-1976	Nogal uplift
Marai Ascia	7	Sinclair	1958	Mudugh
Burhisso	8	Amerada	pre-1976	Nogal uplift
Yaguri	9	Amerada	pre-1976	Nogal uplift
Merca	10	Sinclair	1959	Mogadishu
Dagah Shabell-1	11			
Buran	12	AGIP	pre-1976	Sageleh
Dagah Shabell-2	13			
Darin	14	AGIP	pre-1976	Sageleh
Dagah Shabell-3	15			
Hordio	16			Sageleh
Berbera	17			
Bio Dader	18			
Duddumai	19	Sinclair	1960	Mudugh / Mogadishu
Coriole-1	20	Sinclair	1961	Mogadishu
Dobei-1	21	Sinclair	1961	Mogadishu
Dobei-2	22	Sinclair	1961	Mogadishu
El Hamurre	23			Mudugh
En Dibirre	24			Mudugh
Brava	25	Sinclair	1963	Mogadishu
Dusa Mareb-1	26			Mudugh
Dusa Mareb-2	27			Mudugh
Calcaio-1-2	28			Mudugh
Idole	29			Mudugh
Oddo Alimo	30	Sinclair	pre-1976	Lamu Embayment
Bulo Burti	31			Mudugh
Giamama	32	Sinclair	1965	Lamu Embayment
Lach Dera	33	Gulf	1965	Lamu Embayment
Lach Bissigh	34	Gulf	1965	Lamu Embayment
Coriole-2	35	Sinclair	1965	Mogadishu
Afgoi-1	36	Sinclair	1966	Mogadishu
Gal Tardo	37	Sinclair	1967	Mudugh
Uarsciek	38	Sinclair	1968	Mudugh / Mogadishu
Bio Addo	39			Mudugh
Das Uen	40			
Gheferso	41			
Hol-1	42			Mandera-Lugh
Hafun	43			Sageleh
Hafun-T	44			Sageleh
Guardafui	45			Sageleh
Garad Mare	46	AGIP	1977	Mudugh
El Cabobe	47	ARCO	1980	Mudugh
Kudha	48	Deutsche Texaco	1982	Lamu Embayment
Obbe	49	Deutsche Texaco	1982	Lamu Embayment
Meregh	50	Esso	1982	Mudugh
El Bur	51			Mudugh
Dab Qua	52			Sageleh
Afgoi-2	53	Govt of Somalia	1985	Mogadishu
Bandar Harshau	54			Sageleh
Ras Binnah	55			Sagaleh
Afgoi-3	56	Govt of Somalia	1985	Mogadishu
Gumbah	57			Sageleh
Nugal	58			Nogal uplift
Hedad	59			Sageleh
Bur Dab	60			Nogal uplift
Las Dureh	61			
Zeila	62			
El God	63			Mandera-Lugh

The Italian supported research, usually in co-operation with the Somali National University, led to the "First International Meeting on the Geology of Somalia and Surrounding Regions" (GEOSOM '87), held in Mogadishu in 1987. Unfortunately, there was a delay in publishing the proceedings of the meeting (Abbate et al., 1993), including a new 1:1,500,000 scale geological map of Somalia, due to political and funding problems.

The plate tectonic evolution of the Somali oceanic margins, including the Indian Ocean margin, has recently been re-evaluated by Bosellini (1992) in work based in part on an examination of the confidential files of the Somali Ministry of Mineral and Water Resources.

Much of the previous work carried out falls into three broad categories: those based on proprietary geophysical or well log data, those based on surface geological exploration, and those which are purely review in nature (ie those which depend on the first two categories).

The quality of the work in the first category is hard to evaluate. Certainly the well cuttings and cores will conform to an industry basic standard, but the advances in drilling techniques in the last fifteen years means that it is possible that potential reservoir sections were not identified due to (for example) too much over-balance whilst drilling. It is not known if the well logs, both geological and geophysical, have been re-evaluated using contemporary understanding, but it is considered unlikely.

Advances in seismic survey have been rapid, and it is unlikely that much of the data acquired are of today's standard, either by not having any 3-D data acquired or in basic data processing for 2-D surveys.

Somewhat in contrast, the surface geological exploration has been revised to fit into current paradigms and recent stratigraphic work is at the forefront of depositional environment interpretations for the Phanerozoic or geochemical modelling for the Precambrian. However, most of the work appears to have been concentrated in the north, and there are "modern" techniques, such as vitrinite reflectance and Total Organic Carbon analyses that do not appear to have been carried out but which would provide useful information on hydrocarbons potential from selected sequences.

The standard of field mapping, based on the 1:125,000 scale maps of the Somali Geological Survey is quite good, but the AGIP maps for the southern part of the country were not evaluated. However, since the fieldwork to produce those maps was carried out there has been revision and refinement of the stratigraphic nomenclature to reflect the current understanding of the many lateral facies variations present. Even so, there is still no standardisation of the nomenclature, in boundary definitions or name spelling. Also, much of the sedimentary column and structure of interest to hydrocarbons exploration is buried under Eocene and Oligocene sequences and known only from subsurface information (e.g. the Jurassic Somali Embayment).

The map of Abbate et al. (1993) provides an up to date overview of the geology and would appear to incorporate subsurface data, but at a scale of 1:1,500,000 it cannot provide much detail. However, there is probably much useful information collected by the Italian academics, who may also have copies of theses of the Somali National University and reports of the Somali Ministry of Mineral and Water Resources produced in the 1980s.

2.2 STRATIGRAPHY

2.2.1 Precambrian

The Precambrian basement in Southern Somalia is part of the Pan-African mobile belt of East Africa and is exposed west of Mogadishu. The most recent description of the Pan-African granitoids in the Bur Acaba (usually referred to as simply "Bur") basement block is by Küster et al. (1990a), from whom much of this section is derived. Frizzo (1993) and Binda et al. (1993) also provide a summary of the Bur basement. It is located in a peneplained area, and 98% of the terrain is covered by thick residual soil and alluvial deposits with the Precambrian rocks exposed only in isolated inselbergs.

The outcropping basement consists of pre-Pan-African upper amphibolite to granulite facies meta-sedimentary and meta-igneous rocks, including Banded Iron Formations, into which late to post tectonic Pan-African granitoids were discordantly intruded. Two different granitoid suites have been differentiated.

The northeastern granitoids are post-kinematic (absence of a pervasive foliation) coarse to medium grained equigranular and K-feldspar porphyritic quartz-monzonites to monzo-granites emplaced during multiphase magmatic activity. The southwestern granitoids are predominately fine grained leucocratic weakly foliated monzo- and syeno-granites and subordinate trondhjemites.

Age determinations using U/Pb from zircons and Rb/Sr indicate an emplacement age of about 536 ma for the southwestern late syn-kinematic granitoids and an emplacement age of about 470 Ma for the northeastern post-kynematic granitoids. The granitoids were produced from the crust, compared to a mantle origin for the granitoids in northeastern Somalia.

Gamma-ray spectrometry, reported in Küster et al. (1990a), indicates that the northeastern granitoids have higher U and Th contents than the southwestern granitoids whereas K2O contents are comparable. However, high amounts of U (50 ppm) and Th (475 ppm) were measured in local pegmatoid phases of the southwestern granitoids, predominately monzonites

2.2.2 Mesozoic to Cenozoic

Recent syntheses (Bosellini, 1992; Dualeh et al., 1990) attempt to place the Phanerozoic of Somalia into a coherent tectonic framework. However, the stratigraphic nomenclature varies from author to author and correlations across Somalia are not always clear, due to the different exploration history (Italian and British), many facies variations and lack of detailed chronostratigraphic control. The most comprehensive source appears to be Bosellini (1992), who provides paleogeographic maps of key time periods.

The Phanerozoic sedimentary history can be related to five geodynamic events (Figure 2.2), although Bosellini (1992) subdivides the sedimentary succession into seven major depositional sequences:

1. Assumed late Carboniferous - Permo-Triassic to middle Jurassic continental rifting, resulting in the formation of depositional basins. It is assumed that the axial regions of these basins contain continental sediments (Adigrat Formation, the local "Karoo" name) and shallow marine, mainly evaporitic sediments although no sediments older than Jurassic have been recorded in Somalia.
2. The onset of sea-floor spreading in the middle Jurassic with the southeastwards movement of Madagascar away from present East Africa until the early, resulting in

FIGURE 2.1 GEOLOGICAL SKETCH MAP AND LOCATION OF KNOWN ORE DEPOSITS OF THE BUR REGION (after Frizzo, 1993, fig. 1)

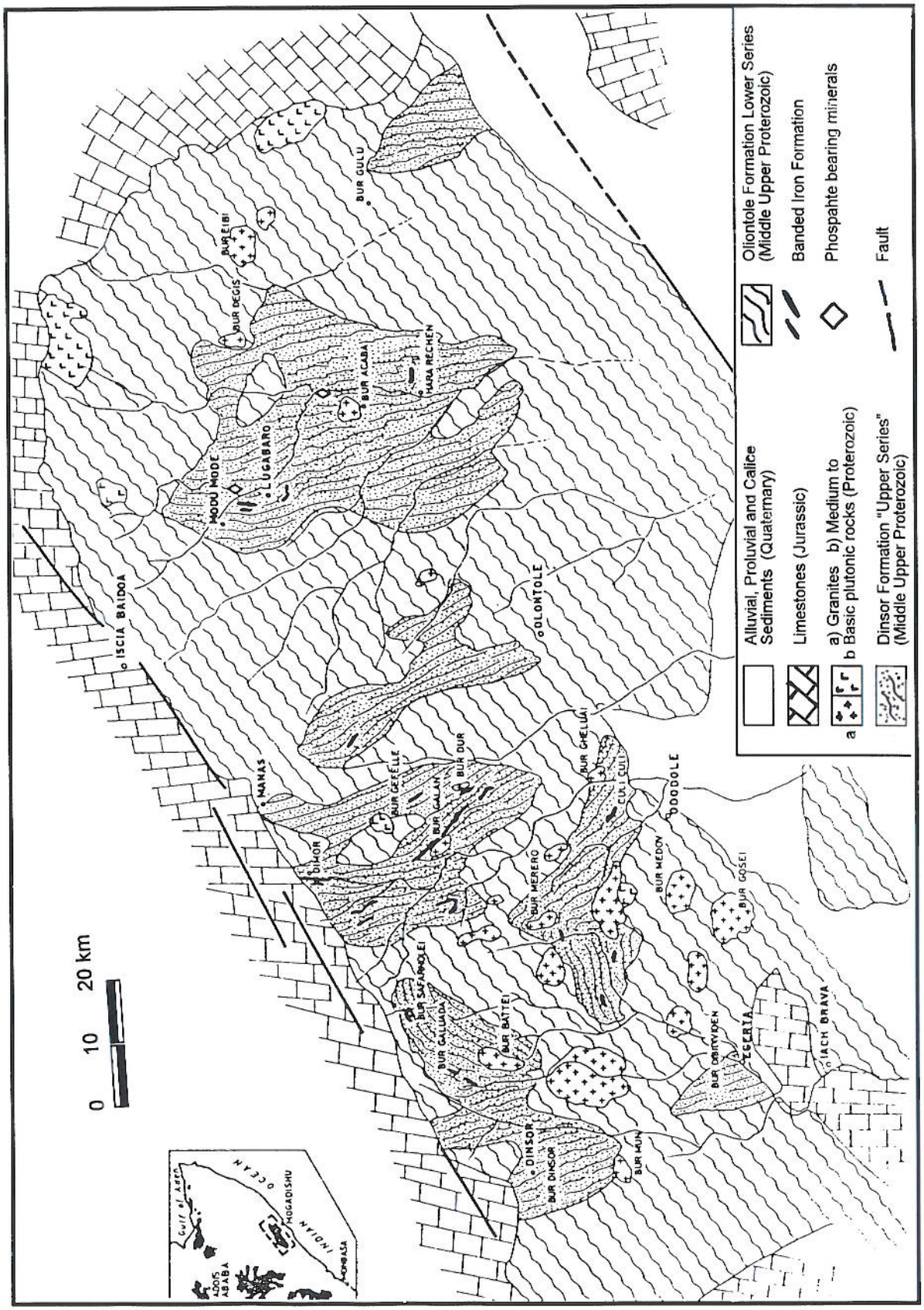
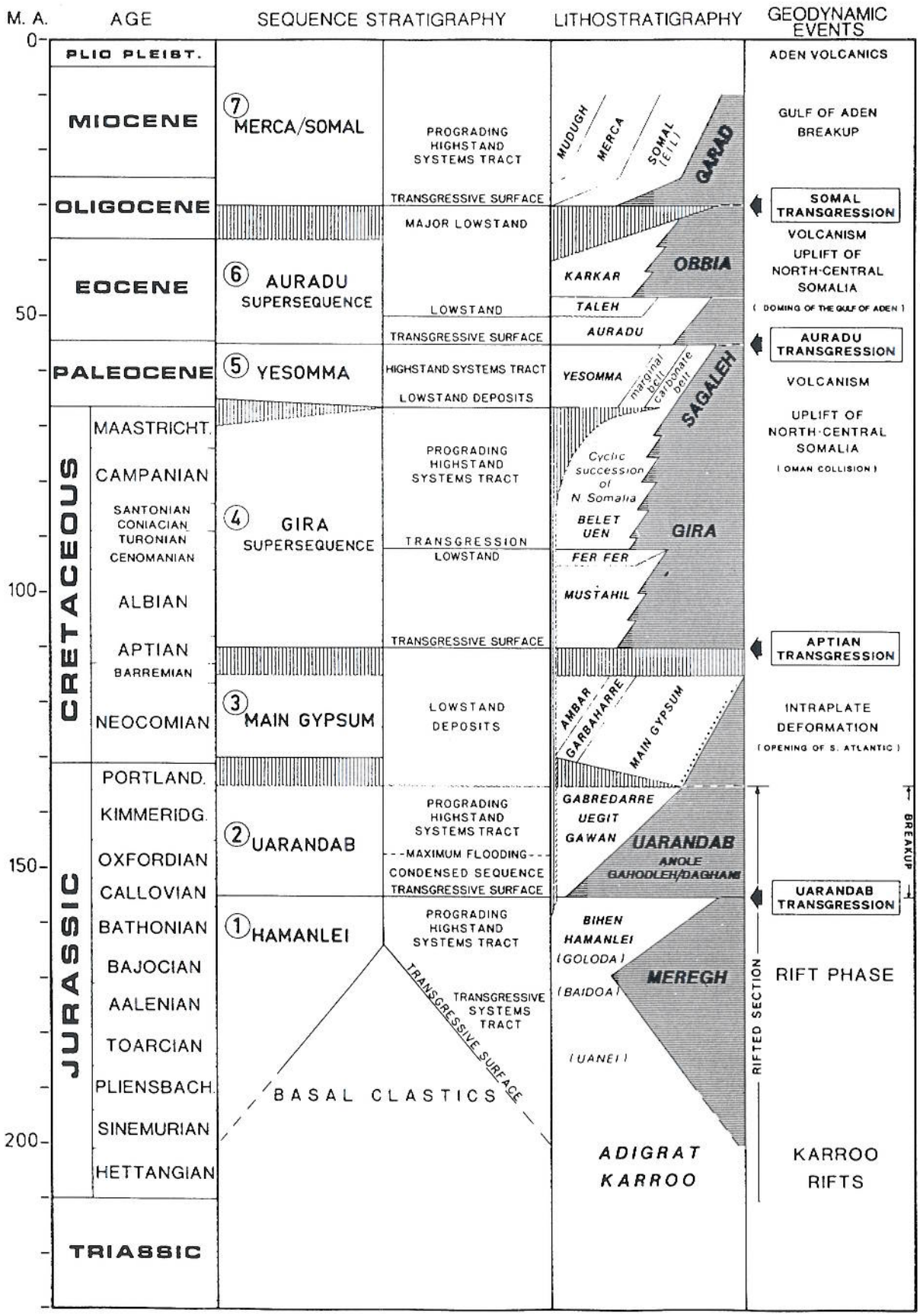


FIGURE 2.2 CHRONOSTRATIGRAPHIC CHART OF SOMALI RELATING SEQUENCE STRATIGRAPHY, LITHOSTRATIGRAPHY AND MAJOR GEODYNAMIC EVENTS (from Bosellini, 1992, figure 21)



dextral oblique extension of the Somali coastal margin south of about 6° N. The northern boundary corresponds to the "El Hamurre" trend.

3. A strong transgression starting in the Aptian that flooded most Somali Jurassic basins, and is related to the formation of the northeastern Somali - Indian Ocean margin.
4. Separation of India from the Seychelles microcontinent during the Paleocene, leading to closure of the Tethys during the Eocene.
5. The movement of Arabia away from Africa and the development of the East African rift system during the Oligocene to Miocene, leading to regression from northern Somalia.

The variation in sedimentary sequence across southern Somalia is schematically shown in Figure 2.3.

A concise summary of basin development, but perhaps a bit out of date, is provided by Barnes (1976, p406, 409), with a more up to date summary provided by Dualeh et al. (1990). Coffin & Rabinowitz (1988) give a recent summary of the development of the Mogadishu Basin (Somali Coastal Basin) and adjacent regions.

2.3 STRUCTURE

The broad crustal structure is not well described in the open literature. Dorre & Rapolla (1993) describe the results of work to unify the pre-existing gravity data, including preliminary Free Air and Bouguer Anomaly maps. The Free Air map shows a broad negative anomaly in central Somalia and a broad anomalous positive feature in the south. The Bouguer Anomaly map included oil company data, and again shows the negative anomaly in central Somalia and the positive anomaly in southern Somalia. A gravity low corresponds to the Mandera-Lugh Basin.

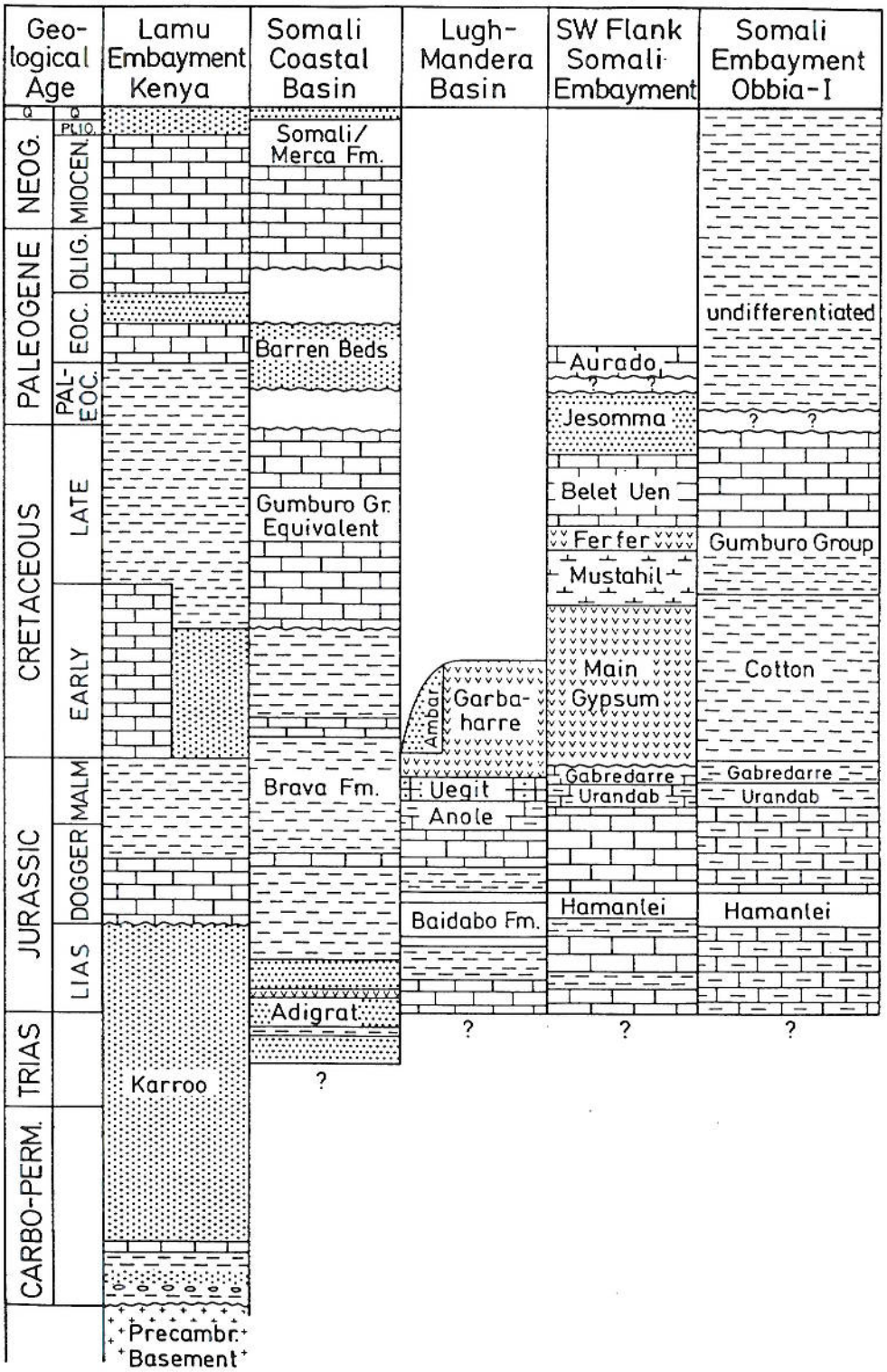
Rapolla et al. (1995) extend the gravity work to coincide with five International Lithosphere Program geotransects. One of the interesting results of their work is the identification of the NNE-SSW trending Shabelli Rift in central Somalia, which is an extension of the Somali Embayment trend. Their preferred interpretation is that the rift is related to the transform fault along which Madagascar separated from the Somali coast, although an interpreted basin depth of 7 km south of their subsurface Bio Adde High indicates that the alternative hypothesis of Karoo aulacogen may be more likely.

Folds and faults are not well described in the open literature. Most structures in eastern Somalia are related to the Indian Ocean margin development, and comprise extensional faults and roll-over anticlines affecting Jurassic and Cretaceous strata (for examples, see the map of Abbate et al., 1993). General trends are northeast-southwest with fault movements down to the southeast, although there are other trends.

The Somali Embayment was bounded by east-west and northwest-southeast trending faults. The sub-surface El Hamurre Escarpment trends east-west and forms the northern border to the Somali Embayment. The boundary between the deep marine facies in the Jurassic and the shelf edge of the Embayment to the west appears to correspond to a continuation of the north-northeast trending fault system that bounds the southern margin of the Bur Acaba Uplift (Dualeh et al., 1990).

Kassim Mohamed et al. (1993) describe two deformation belts in the Gedo Region of southwest Somalia (central Mandera-Lugh Basin) which they interpret as being formed during post Early Cretaceous dextral transpression. However, the data as presented are

FIGURE 2.3 SCHEMATIC STRATIGRAPHIC CHART OF SOUTHERN SOMALIA (from Dualeh et al., 1990, figure 3)



inconclusive and there appears to be a degree of constrained interpretation. North-northeast trending broad low-amplitude folds in the Mandera-Lugh Basin are also discussed by Dualeh et al. (1990).

Development of the Gulf of Aden and the Red Sea during the Tertiary led to reactivation of Mesozoic faults and the development of northwest trending faults in the Nogal Valley area and eastern Somalia.

Cross-section 9 on the face of the map of Abbate et al. (1993) shows intrusion of Jurassic evaporites into overlying Cretaceous and Tertiary strata, with either salt wall or diapir development, in-land from Kismaayo in southern Somalia. No wells appear to have penetrated the mobile evaporites and so it is assumed that the structures were identified on seismic data.

3. HYDROCARBONS POTENTIAL

3.1 PREVIOUS EXPLORATION AND ANALYSES

The early exploration activities were outlined in Section 2.1. The 1980s saw significant exploration interest in Somalia, with geophysical work and drilling being undertaken.

Part of the Sageleh Basin was covered by a 1981 24,900 line km aeromagnetic survey for Somalia Cities Service Inc. (Hunting, 1981). Hunting (1985) carried out in 1984 a 76,600 line km aeromagnetic survey with flight line spacing of 2 km over much of southern Somalia on behalf of Esso (Figure 3.1). In 1986-1987 a 22,100 line km aeromagnetic survey was flown by Hunting (1987) for Conoco Somalia Limited over northern Somalia (Figure 3.2). It is assumed that these reports are still confidential.

In a landmark paper, Barnes (1976) reviewed the geology and hydrocarbons prospects of Somalia, largely based on exploration by Sinclair-Somal Corporation in the late 1950s and material released by AGIP Mineralia in Somalia. Barnes concluded that Somalia has potential source and reservoir rocks but that plays are likely to be stratigraphic rather than structural. The most promising regions were considered to be the Mesozoic shelf and reef area around the Somali embayment and around the Nogal uplift, with secondary targets in the coastal and offshore marine Tertiary strata which have had gas shows.

In a general review of African hydrocarbons resources, Chatellier & Slevin (1988) indicate that the Somali Embayment has significant potential reserves, although they also point out that the Tanzania Coastal Basin has a high discovery success rate and significant reserves but is considered unattractive for exploration because it is gas prone and lacking nearby markets. Petersen (1985) provides USGS unconditional estimates of undiscovered petroleum resources for the "Somali Basin" as about 3.8 billion barrels of oil and 18.6 Tcf of gas, both figures being the means of cumulative probability curves. There are no measured reserves estimates.

The pre-rift (Gondwana) position of the Seychelles is located adjacent to mid-Somalia (e.g. Bosellini, 1992), and the subsequent pre-Jurassic history of the western Seychelles is similar to that of the eastern coast of Somalia. Plummer (1993) notes that shows of migrant hydrocarbons were recorded in three wells drilled by Amoco in 1980-81 which targeted rift fault-block plays of the Western Shelf of the Seychelles.

Naleye & Harms (1993) produced a brief summary of the petroleum exploration up to 1987.

Petroconsultants produced non-exclusive reports on the Somali Basin (1995a), Guban Basin (1995b), and Sagaleh-Socotra Basins (1995c) at a cost of Swiss Francs 3,000, 4,500, and 3,000 respectively. The source material on which the reports are based is not known. Copies of the Contents pages of these reports are included as Annex A.

In the list of country data inventory in their price list, Petroconsultants indicate that they have data for 70 wells spread over 9 concession areas, with a total of 95 geophysical surveys also having taken place. However, most papers (eg Bosellini, 1992; Naleye & Harms, 1993) record fewer exploration wells drilled up to 1987, with three further wells meant to have been drilled in 1988 (one in the Mandera-Lugh Basin and two in the western Guban Basin). Sixty-three wells are located on the geologic map of Abbate et al. (1993) (Figure 2.1). The approximate drilling density is given in Table 3.1.

FIGURE 3.1 LOCATION OF ESSO 1984 AEROMAGNETIC SURVEY (from Hunting, 1985, figure 1A)

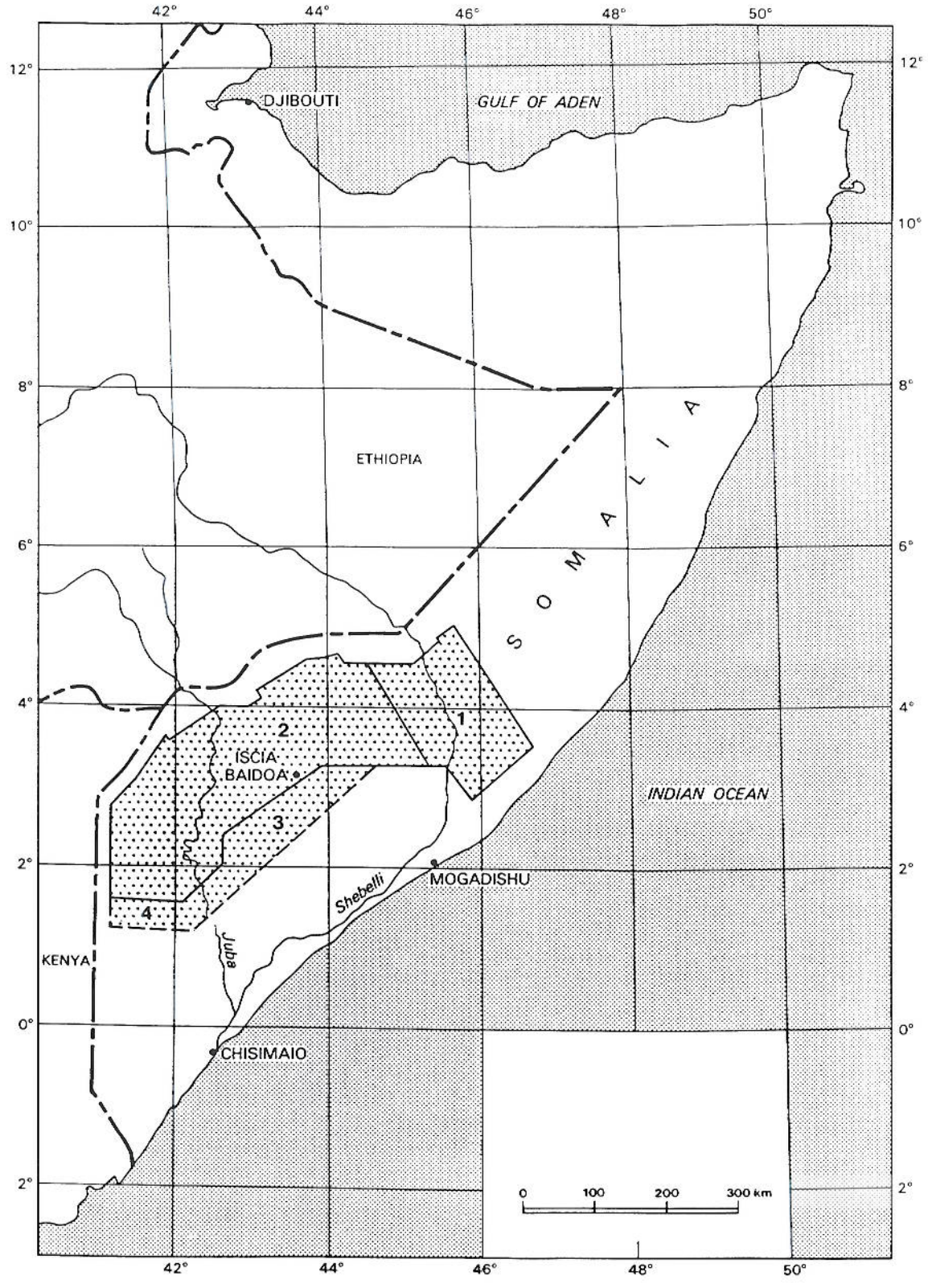


FIGURE 3.2 LOCATION OF CONOCO 1986-1987 AEROMAGNETIC SURVEY (from Hunting, 1987, figure 1)

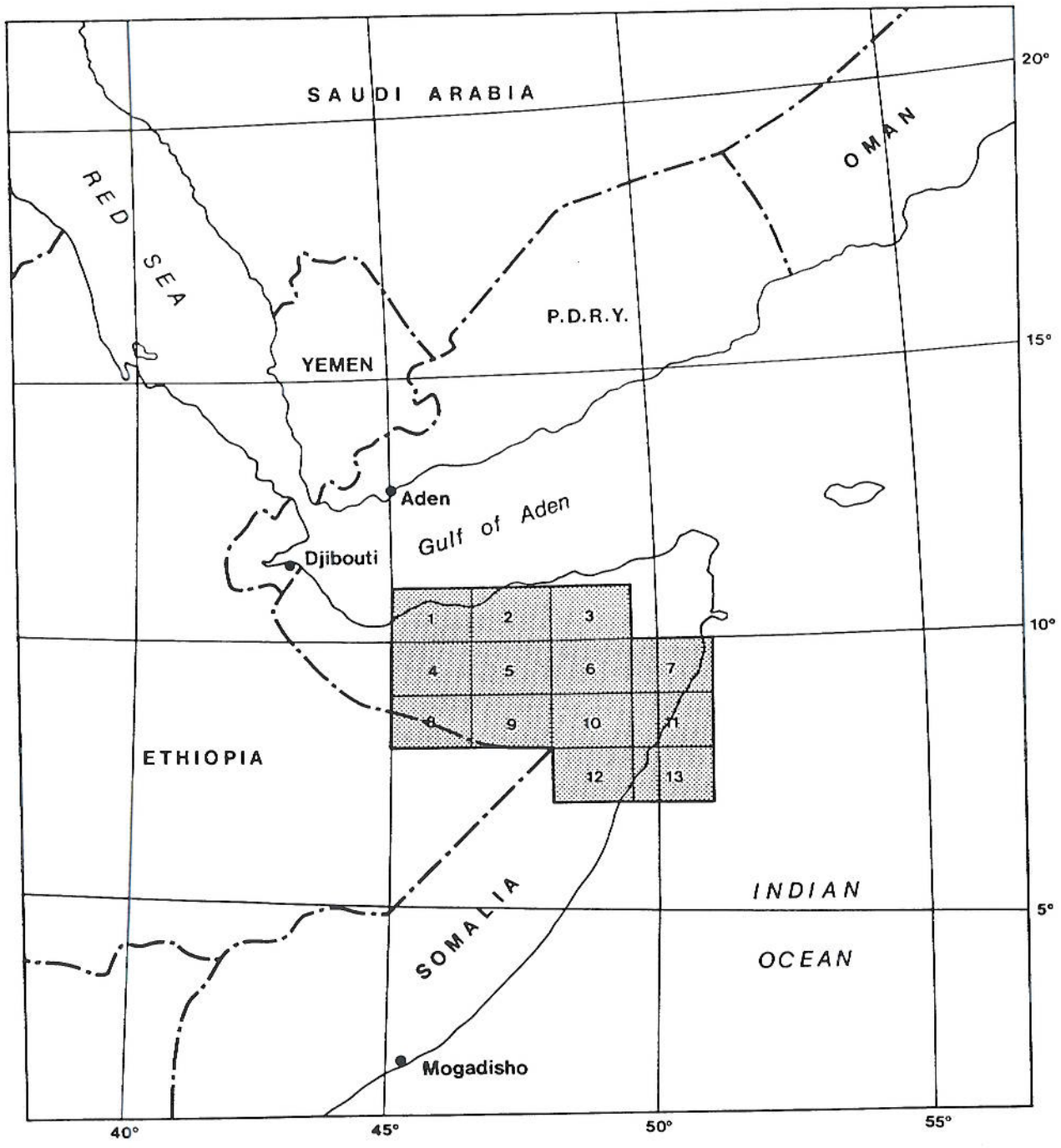


TABLE 3.1 EXPLORATION IN SOMALI BASINS (after Naleye & Harms, 1993)

Basin	Approx.Area (sq km)	Wells	Drilling Density (area/wells sq km)
Mandera-Lugh	70,000	3	23,000
Juba-Lamu	45,000	6	7,500
Mogadishu (Coriole)	25,000	11	2,300
Mudugh/Obbia	150,000	16	9,400
Sageleh (Darror-Nogal)	160,000	14	11,400
Guban	35,000	7	5,000

Abbate et al. (1993), on the face of the map, reference a 1991 unpublished report produced by Geomin Ltd on the petroleum evaluation of the Somali Region. No other information on this Geomin report was available.

As Naleye & Harms (1993) point out (Figure 3.3), most of the exploration wells were drilled with little or poor geophysical guidance. Undoubtedly, modern seismic acquisition would lead to refined play concepts and target identification.

At October 1987 there were six active concessions (Figure 3.4). Informal communication from some oil exploration companies indicate that at present there is no short to medium term interest in exploration in Somalia. No information was obtained from AGIP, who would appear to be the most likely to continue exploration based on their long history in the region.

3.2 POTENTIAL SOURCE ROCKS

Petersen (1985) discusses possible source rocks in Somalia. Marine grey shale and argillaceous limestones of Jurassic, Cretaceous and Tertiary age, particularly those associated with back-reef and evaporitic facies.

Based on the paleogeographic maps in Bosellini (1992), basinal facies were present in southeastern Somalia during most of the late Jurassic to mid Cretaceous and early to mid Eocene in which potential source rock material is likely to have been deposited. Beydoun & Sikander (1992) identify possible source rocks on the Somali margin of the Gulf of Aden from strata of the same age.

However, there are no TOC or organic maturity analyses reported in the open literature which makes a proper evaluation of source rock impossible.

3.3 POTENTIAL RESERVOIR ROCKS

Petersen (1985) identifies the porous limestone and dolomites of the oolitic-fossiliferous facies of the Middle Jurassic Hamanlei Formation and the fossiliferous-reefal facies of the Upper Cretaceous Gumburu Group as possible reservoir rocks. Barnes (1976) indicates areas of Upper Cretaceous limestone build-up adjacent to the Ethiopian border at about 7° N, and an even larger area of Lower to Middle Jurassic (Hamanlei Fm.) limestones which he considers to be potential carbonate reservoirs.

Petersen (1985) also identifies porous limestone and dolomites of the upper Tertiary in the coastal and offshore basins as suitable reservoir rocks. South of the Bur Acaba uplift the

FIGURE 3.3 AREAS WITH POST-1972 SEISMIC ACQUISITION (stippled; basement outcrop, dashed pattern) (from Naleye & Harms, 1993, figure 9)

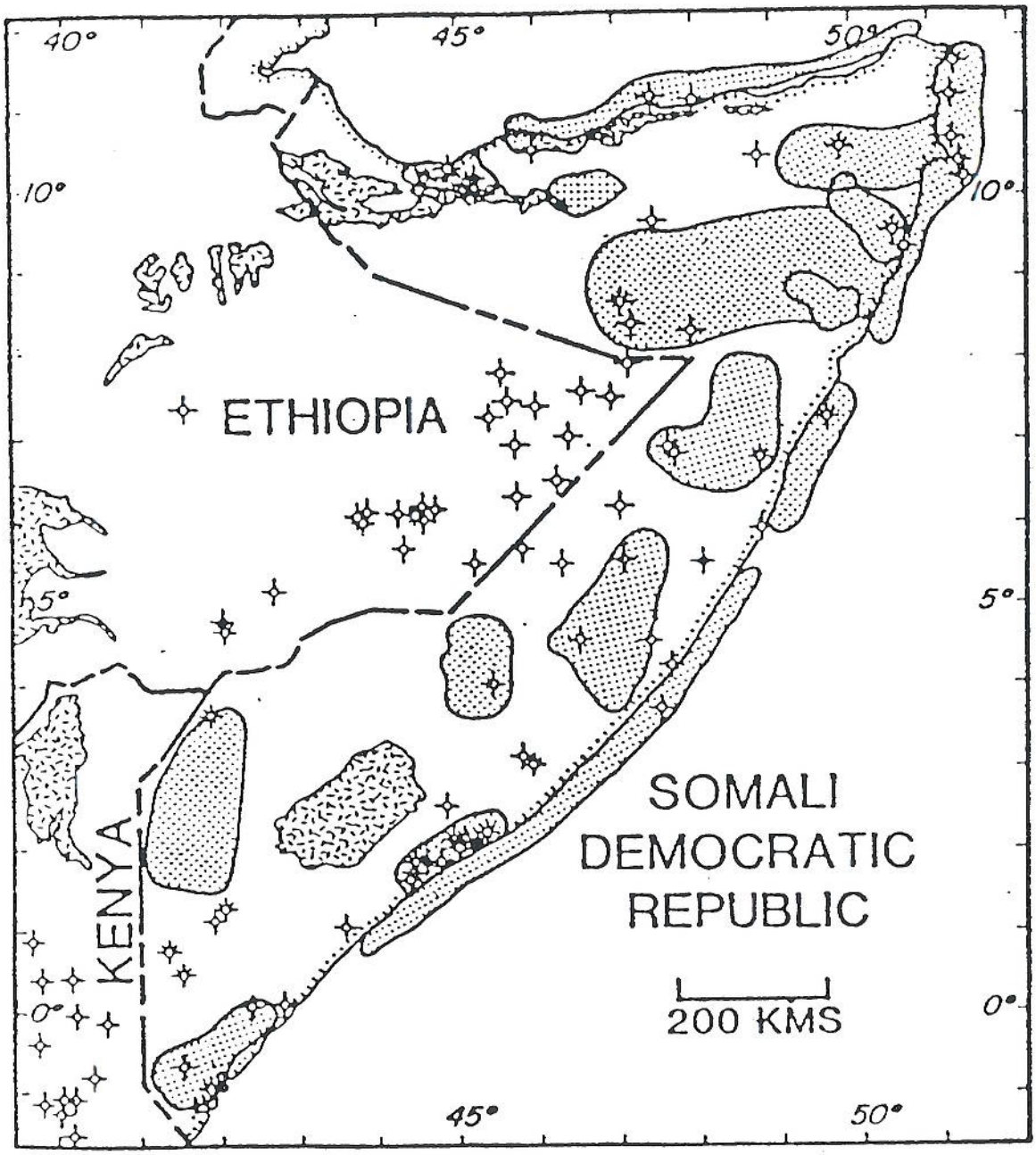
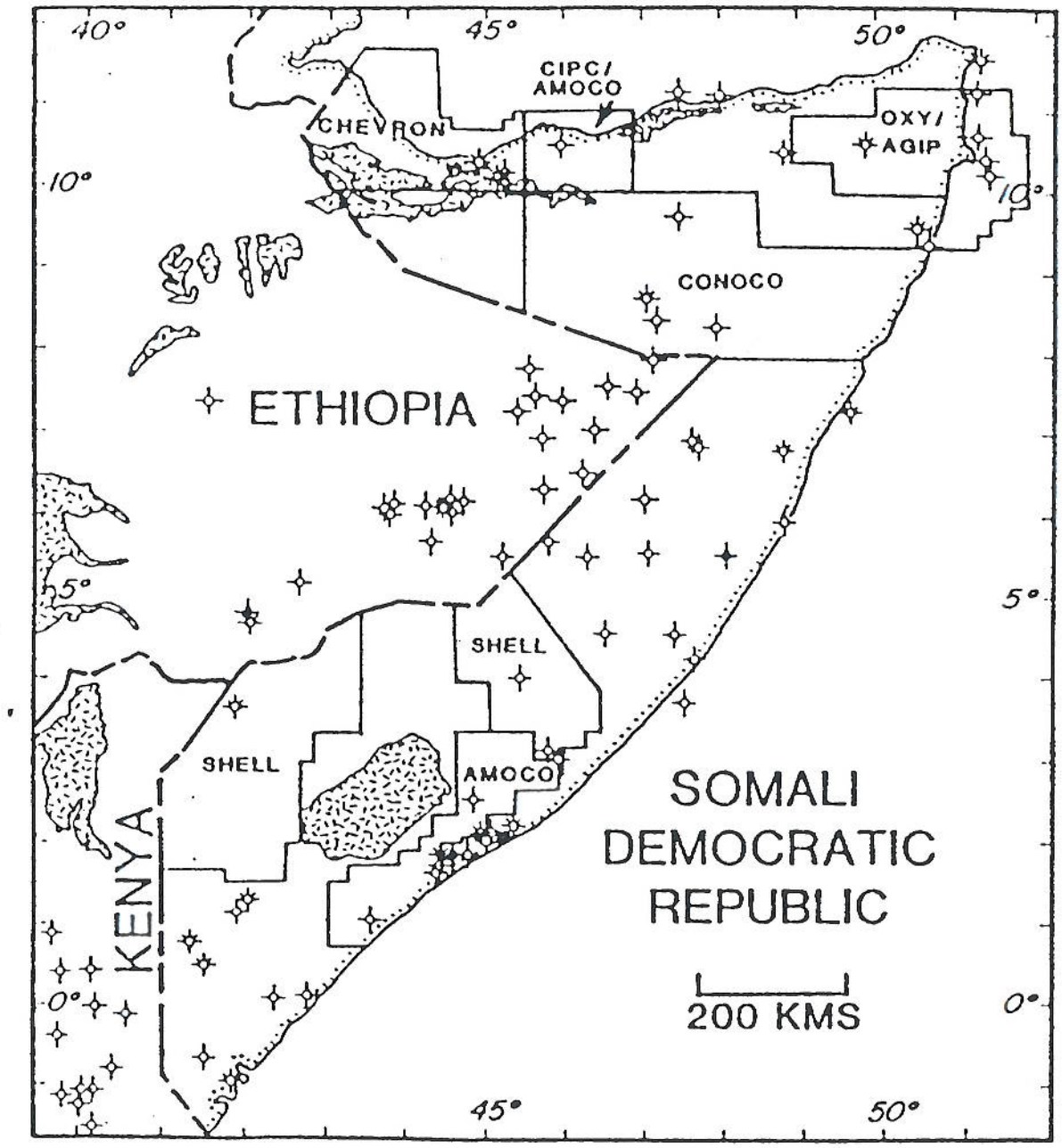


FIGURE 3.4 EXPLORATION CONCESSIONS HELD IN OCTOBER, 1987 (from Naleye & Harms, 1993, figure 10)



most promising reservoir rocks are the mainly sandstone beds of Cretaceous and Tertiary age and Miocene carbonate strata.

The Oligocene platform carbonates in the 1 Merca well showed no hydrocarbons traces but the Eocene sandstones had good oil staining and gas under pressure. A drill-stem test at 2,703 m to 2,705 m flowed salt water at 15 gallons per minute with about 25-30 Mcf gas, and there was another flow of salt water between 2,395 m and 2,397 m. The Sinclair Agfoi 1 well, north of the 1 Merca well and near Mogadishu, also had good gas shows.

3.4 PLAYS

3.4.1 Structural

There is limited compressive folding in the Phanerozoic of Somalia. Most folds appear to be associated with extensional faulting, and are "roll-over" anticlines or "drape" folds, although the folds in the Mandera-Lugh Basin were supposedly formed during dextral transpression. According to Barnes (1976), nearly all of the anticlinal features have been drilled with negative results.

On the Gulf of Aden margin Beydoun & Sikander (1992) consider that the pre-rift Jurassic - Eocene sequences are the most prospective, with exploration plays in extensional fault blocks and basins developed during Late Jurassic - Early Cretaceous rifting. They also suggest that syn-rift plays exist in Early Oligocene transtensional basins and roll-over anticlines but that, in contrast to Allen et al. (1991), source immaturity is a significant risk.

In southern Somalia, in the region of Kismaayo, the presumed Tertiary development of evaporite intrusions in the subsurface would appear to be prospective, with potential Jurassic source rocks and Cretaceous reservoir rocks present. However, the presence of a good seal is uncertain.

3.4.2 Stratigraphic

The areas of maximum limestone build-up in the Jurassic and Cretaceous are considered by Barnes (1976) to be possible areas of hydrocarbons accumulation. Within those areas it is likely that more prospective reefal or structural targets could be identified with more detailed geophysical surveys.

Lateral facies changes within the sedimentary column, particularly to evaporites, are potential targets, particularly associated with pinch-outs and overlaps. The western margin, and presumably the northern and southern margins, of the Somali Embayment show a facies change from basinal to shallow water facies. Further north, in the Nogal area, Eocene evaporites of the Taleh Formation pass laterally into limestones towards the Indian Ocean, and between the Obbia and Sageleh wells the change is from shales to dolomites.

Lateral facies variations adjacent to structural highs, such as the Nogal uplift, may also be possible targets. Reef facies in shelf carbonates are potential targets, and have probably already been identified in the subsurface.

The thick Tertiary sequence in the Coastal Basin of southeastern Somalia has had some exploration activity. The facies variations in the Jurassic and Tertiary, together with overlap, are potential plays. The combination of suitable stratigraphy and extensional faulting, with or without concomitant folding, may produce some suitable targets, although they are likely to be only small to medium in size and difficult to identify. As most writers comment, the

continental shelf is very narrow along the eastern coast of Somalia which will limit exploration opportunities.

4. NON-HYDROCARBONS MINERAL RESOURCES

4.1 PREVIOUS MINING AND EXPLORATION

4.1.1 Published Accounts

Apart from the Geological Survey of Somalia reports in the 1950s, the non-hydrocarbons resources and exploration activities of southern Somalia have only been briefly documented in the open literature, usually as an adjunct to petrologic descriptions of the Precambrian Bur Acaba block.

In the 1970s there were several exploration programs funded by overseas agencies, such as China (1972), UNDP (1972). The current availability of the reports of these activities is probably limited.

Binda et al. (1993) reviewed the mineral occurrences in the Precambrian of northeast Africa and Arabia. Frizzo (1993) produced a summary of the metallogenesis of the Precambrian of Somalia; much of the description below is based on his section on the southern Somalia basement.

Most mineral occurrences are found in the Dinsor Formation, including stratiform and strat-bound deposits of ferruginous quartzites (Banded Iron Formations - BIF), marble with apatite, calc-silicatic rocks with sphene, and marble with rhodonite.

4.1.2 Uranium Oxide

Reserves of 20,000 tonnes grading 0.08% U_3O_8 had been revealed in the Mudagh district (Mining Journal, 1996). However, Bakos & Sassi (reported in Binda et al., 1993, p. 498) give a figure of only 1,500-2,000 tonnes of ore at the Alio Ghelle deposit. Minor sulphides are present at the Alio Ghelle deposit. According to Cameron (1971) the Alio Ghelle area shows evidence for albitization by S and B bearing fluids enriched in Th, U, Fe, Ti, Zr, REE, Pb, Cu and Zn, although no significant resources are identified.

4.1.3 Iron Oxide

Iron ore reserves of 170 million tonnes grading 35-40% iron have been identified in the Bur Galan, Dinsor and surrounding regions (Mining Journal, 1996). A concise summary is provided by Frizzo (1993), who identifies the most important orebodies as Daimir, Bur Ghalan, Qadia and Culi-Culi, with others near Lugabarao, Bur Galuado, Dimor and Bur Dibidwiden. Important magnetic anomalies have also been identified at Bur Eibi.

The ferruginous quartzites occur mainly at the base of the Dinsor Formation (Frizzo, 1993), and, mineralogically, show martite after magnetite, with Fe-pyroxenes and amphiboles, biotite and chlorite as accessory minerals (Binda et al., 1993, p 498). The ores are free from Ti, Mn, S, and the P content is below the Bessemer limit.

The Dahimir orebody has a reserve estimated at 48 Mt, of which 31 Mt were considered economic in the 1970s. Iron oxide contents vary between 35% and 40% in a highly prospective area 3 km long with an average width of 50 m (UNDP, 1972).

The Bur Ghalan orebody is reported to have a reserve of 119 Mt, of which the UNDP (1972) report identified 41Mt as economic. However, China (1972) indicated a reserve of 394 Mt to a depth of 200 m, but that report is not widely available. Iron oxide content is similar to Dahimir.

4.1.4 Tin

Prior to the civil war, a tin mining pilot project was established in the Majaychan area (Mining Journal, 1994). Small reserves of cassiterite were exploited. No grade or resource values are definitely known although de Kun (1965, p. 73) states that "veins average 1% tin" and "reserves are moderate". Mineralisation extends west to Dagan Kuled-Asileh, and placer deposits are known south of Bender Ziada, downstream from Majaychan. However, there are no known tin occurrences in southern Somalia.

4.1.5 Mineral Sand Deposits

The mineral sand deposit of Kisimaayo at the mouth of the Juba River in southern Somalia has been known since 1915 (Artini). In the early 1970s, under the auspices of the United Nations development programs, more extensive exploration and evaluation of the resources, mainly to the northeast of the mouth of the Juba River, took place (Dimitriev, 1971 & 1973; Lartsev & Dahir, 1970; MacDonald, 1973; Savadsky & Chernishev, 1973). The main conclusion was that only the dune belt about 5 km southwest and 25 km northeast of the mouth of the river was of interest (Dimitriev, 1973).

To the northeast of the Juba River, Dimitriev (1973) calculated the presence of about 900 million tonnes of sand, with heavy mineral contents varying between 1.5% and 66%, and systematically decreasing away from the river. Working in the dunes immediately north of the mouth of the river, MacDonald (1973) identified two possible resources. One was of an area of 11.6 sq km with an average content 18.4% heavy minerals in 184 million tonnes of sand. The second area of 2.5 sq km contained an average of 23.5% heavy minerals in reserves of 30 million tonnes of sand.

Frizzo & Cortiana (1993) report on exploration carried out to the southwest of the Juba River. They identified average heavy mineral contents of 11.5% and 11% for the beach and dune sands respectively. In some small bays the heavy mineral content of the beach sand may reach 70% by weight. Mineralogical analyses of the heavy minerals (Tables 1 and 2 of Frizzo & Cortiana, 1993) give amphibole as the most abundant (4.44% in beach sands and 4.26% in dune sands), with garnet, titanite, zircon and pyroxene between 0.9% and 0.1%. A value about 0.05% was determined for rutile in the dune sands compared to 0.04% in the beach sands. Frizzo & Cortiana (1993) conclude that quantities of minerals such as zircon and rutile are substantially in agreement with those reported by MacDonald (1973), and that in the area investigated mobile dune sands are estimated at 50-60 million tonnes compared to only a few million tonnes for the beach sands.

4.1.5 Coal

Cretaceous bituminous coal is reported in the Hedhed Tug, 19 km from Onkhor (de Kun, 1965, p. 531). Calorific values average 5,660 and ash content is 12%. Other occurrences are at Biyo Gora and Subera. Although no deposits are reported from the south, it is possible that there are some in the Cretaceous sediments of the Mandera-Lugh Basin.

4.1.6 Other Minerals

Within the gneisses of the Dinsor Formation of the Bur Acaba Precambrian outcrop there are reported concentrations of apatite. In the Modu-Mode deposit 24% of P_2O_5 is reported (Frizzo, 1993, p. 523).

Near Modu-Mode and Lugabaro, along the bed of the Tug Bur Acaba and its tributaries, discontinuous metre-thick lenses of up to 10% sphene have been discovered.

4.2 POTENTIAL EXPLORATION AREAS

4.2.1 Uranium Oxide

It is unlikely that any new deposits of Uranium oxide remain to be discovered. Depending on the price of Uranium, further feasibility studies may be appropriate on the known deposits.

4.2.2 Iron Oxide

It is considered that the location and extent of the significant iron oxide ore bodies is already know. Further targeted exploration will help refine grades and the economic extent of these deposits.

4.2.3 Heavy Minerals

Apart from the concentrations of heavy minerals in the dune and beach sands to the northeast and southwest of the Juba River in Southern Somalia there could be similar deposits where along the present or paleo channels of the Shabeelle River. However, Pöhl (1983) considers mineral concentrations related to Pan-African acidic intrusives in East Africa to be specific to two areas: the transition between the Mozambique Belt and the Arabian-Nubian Shield in Northern Somalia; and the triple junction between the Zambesi Belt, the Mozambique Belt and its southern extension into the Antarctic. Therefore, the main areas of mineral potential are in northern Somalia not the southern part of the country.

4.2.4 Coal

Although no coal deposits are reported from the south, it is possible that there are some in the Cretaceous sediments of the Mandera-Lugh Basin.

4.2.5 Other Minerals

Rare metals and tin in northern Somalia are found in late kinematic pegmatites situated in Pan-African shear belts (Küster et al., 1990b). It is possible, despite that just said, that some small pegmatites do occur in the Bur Acaba outcrop, but they are probably not going to be economic.

5. CONCLUSIONS

5.1 GEOLOGICAL KNOWLEDGE

It is considered that the basic geological knowledge of Somalia is of a good standard. Airborne geophysical surveys in the 1980s, together with seismic surveys and multi-disciplinary academic programs, plus a re-evaluation of the geological data in view of current paradigms indicate that Somalia is not a true frontier province.

The current problem is that much of the detailed information either resides as proprietary information with exploration companies or was located at the Somali National University and/or the Ministry of Mineral and Water Resources. In the case of the latter instances it is assumed that much of the information has been lost, although there is a suspicion that Italian and visiting Somali academics, in particular, may at least have summaries.

Commercially available non-exclusive reports are likely to have been produced with some degree of initially proprietary information.

5.2 HYDROCARBONS

There have been oil and gas shows, and the basic stratigraphy for hydrocarbons generation and trapping is obviously present. The margins of the Somali Embayment and the faulted southeast margin of Somalia would appear to have most potential away from the Gulf of Aden coast, for primarily stratigraphic traps. Structural traps are not common and those that can be identified from surface data have been drilled with negative results.

It is considered that high resolution modern seismic surveys over key areas might identify suitable stratigraphic or subsurface structural targets. Further work on source rock maturity and porosity studies, together with basin modelling, will also help refine play concepts.

However, based on personal comments made to the author, there is little interest at present or in the short-term future in further exploration. The risks are too great and the possible rewards too small in the present exploration climate.

5.3 MINING

The main potential in non-hydrocarbons is in heavy mineral placer deposits, uranium oxide, and iron oxide.

The heavy mineral deposits would appear to be most attractive due to their nearness to a port but the current world-wide market is not favourable with widespread increased dredging activity.

The uranium market is expected to show slight yearly growth but with increasing demands met either from existing mines or from recycling and military inventories, leading to depressed prices. The prospect for developing a new mine is limited.

Development of the banded iron formations for high quality iron ore might be possible, particularly for export to the Asian countries. Diligent feasibility studies would be required to fully ascertain if this is economically justified.

5.4 SUGGESTED FURTHER WORK

Although the general conclusions for the economic potential of the mineral and hydrocarbons resources of (southern) Somalia are pessimistic, it would be beneficial to build-up a reference library of literature and reports upon which it may be possible to draw more soundly based opinions.

In the first instance the following should be carried out:

- set up an appropriate departmental section to a) liaise with companies that have carried out exploration in Somalia, b) negotiate the acquisition of copies of their proprietary data, and c) act as a depository for all information and data.
- contact foreign academics and ex-patriate Somalians to evaluate their holdings of unpublished reports, theses, and data;
- obtain copies of Somaliland Geological Survey reports and maps (through the Geological Society of London) and those produced by Consignio Nazionale delle Ricerche, Italy;
- obtain copies of UNDP reports, and those produced by other aid agencies;
- obtain copies of commercially available reports (eg Petroconsultants);
- locate and obtain copies of, as far as possible, the holdings of the (former) Somali National University.

Once all the above information and data has been collected, the Government should carry out a thorough analysis to identify the most promising areas for further work. Some Government funded exploration work may have to be carried out to attract future outside interest, such as:

- geochemical sampling
- potential source rock analyses
- detailed field mapping
- geophysical surveys (or possibly reprocessing existing data), including detailed/in-fill magnetic and seismic surveys.

Whether or not there exists any current interest in exploration or exploitation by non-Somali companies, the process of promulgating regulations to encourage and foster an exploration and development climate should take place. The regulations should be developed through consultations with exploration companies, other African governments, and possibly institutions such as the World Bank, African Development Bank, etc.

Before any major exploration activity resumes the exploration companies will have to have confidence a) in the long-term political stability of the country, b) that the legal framework provides security of tenure of the exploration/development concession, and c) that the fiscal framework assures the investor of sufficient financial returns. Since the indications are that resources are not "world class" it will be extremely important to provide a stable political and fiscal environment if any outside investment is to be attracted.

Once appropriate regulations are in force, consultants should be retained to aid the Government in developing and promoting licensing rounds for hydrocarbons and minerals explorations.

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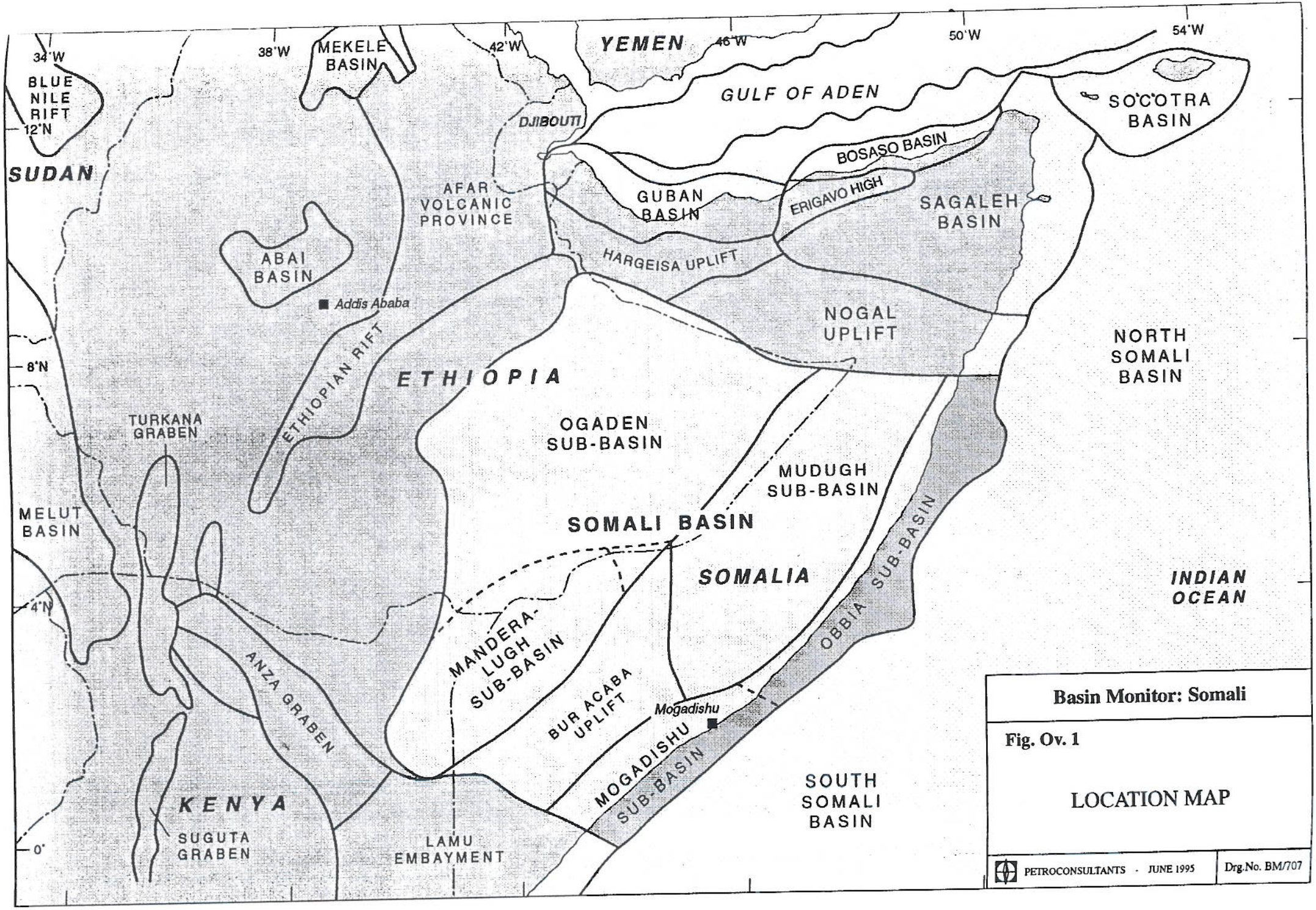
ANNEX A

COPIES OF CONTENTS PAGES OF

PETROCONSULTANTS' BASIN MONITOR REPORTS

FOR SOMALIA



Basin Monitor: Somali

Fig. Ov. 1

LOCATION MAP

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ANNEX B

HOLDINGS OF THE LIBRARY OF THE GEOLOGICAL SOCIETY OF LONDON ON SOMALI GEOLOGY

Title: Mineral resources pamphlet. Ministry of Natural Resources, Somaliland

Holdings: 3(1960)
Formerly: Mineral resources pamphlet. Geological Survey, Somaliland Protectorate

Location(s): MR (677)

Title: Report. Geological Survey, Somaliland Protectorate

Holdings: 1(1956) - 4(1960)

Location(s): MR (677)

Title: Report on the Somaliland Agricultural & Geological Department for the year ...

Holdings: 1927/28(1929)
Continued (in part) as: Annual geological report for ... Somaliland Agricultural and Geological Department

Location(s): S 47

Title: Report on general survey of British Somaliland

Holdings: 1944 - 1947(1948)
Continued as: Report on general survey of Somaliland Protectorate

Location(s): S 47

Title: Report on general survey of Somaliland Protectorate

Holdings: 1948 - 1949(1950)
Formerly: Report on general survey of British Somaliland

Location(s): S 47

Title: Report. Somali Republic Geological Survey

Holdings: RKP/1(1961); DCG/12(1961)

Location(s): S 47

Title: Annual report of the Geological Survey, Somaliland Protectorate

Holdings: 1952/53 - 1956/57(1957)
Formerly: Annual geological report for ... Somaliland Agricultural and Geological Department Continued as: Annual report of the Geological Survey Department for period ... Somaliland (Protectorate)

Location(s): S 47

Title: Annual geological report for ... Somaliland Agricultural and Geological Department

Holdings: 1929(1930)
Formerly: Report on the Somaliland Agricultural & Geological Department for the year ... Continued (in part) as: Annual report of the Geological Survey, Somaliland Protectorate

Location(s): S 47

Title: Annual report of the Geological Survey Department for period ... Somaliland (Protectorate)

Holdings: 1957/58(1958) - 1959/60(1960)
Formerly: Annual report of the Geological Survey, Somaliland Protectorate Continued as: Annual report of the Geological Survey Department of the Ministry of Commerce and Industry, Somali Republic

Location(s): S 47

Title: Annual report of the Geological Survey Department of the Ministry of Commerce and Industry, Somali Republic

Holdings: 1960/61 - 1961/62(1962)
Formerly: Annual report of the Geological Survey Department for period ... Somaliland (Protectorate)

Location(s): S 47

Title: Mineral resources pamphlet. Geological Survey, Somaliland Protectorate

Holdings: 2(1959)
Vol.2 reprinted from: Overseas geology and mineral resources; 7(2) pp.154-65 Continued as: Mineral resources pamphlet. Ministry of Natural Resources, Somaliland

Location(s): MR (677)

Authors: ABBATE,E. / SAGRI,M. / SASSI,F. P.
Corp./Conf.: /
Title: Geology and mineral resources of Somalia and surrounding areas (with a geological map of Somalia 1:1,500,000) / edited by E. Abbate, M. Sagri and F.P. Sassi.
Firenze: Istituto Agronomico per L'Oltremare, 1993.
2 v.(ix, 733p.): ill, maps; 24 cm.
(Relazioni e monografie agrarie subtropicali e tropicali. Nuova serie; 113 A)
Note: 2 folded col. maps in pocket of vol. B.
Contents: [Vol.] A. Regional geology - [v.] B. Mineral and water resources.

Descriptors: SOMALIA: REGIONAL GEOLOGY / SOMALIA: MINERAL RESOURCES / HYDROGEOLOGY; WATER RESOURCES / /
Series: Relazioni e monografie agrarie subtropicali e tropicali. Nuova serie; 113 A

Location: 55(677) ABB

Authors: THORWEIHE,Ulf / SCHANDELMEIER,Heinz /
Corp./Conf.: / INTERNATIONAL CONFERENCE ON GEOSCIENTIFIC RESEARCH IN NORTHEAST AFRICA (1993: Berlin)
Title:
Geoscientific research in northeast Africa: proceedings of the International Conference on Geoscientific Research in Northeast Africa, Berlin, Germany, 17-19 June 1993 / edited by Ulf Thorweihe & Heinz Schandelmeier.
Rotterdam: Balkema, 1993. ISBN 90 5410 329 9
xvii, 776p.: ill, maps; 25 cm.

93-305

Descriptors: AFRICA, NORTH EAST: REGIONAL GEOLOGY / PRECAMBRIAN STRATIGRAPHY; SEDIMENTOLOGY; MINERALOGY; METALLOGENY / CRUSTAL EVOLUTION; STRUCTURAL GEOLOGY; EGYPT; SUDAN; GONDWANA; / ETHIOPIA; RED SEA; TANZANIA; SOMALIA; MOZAMBIQUE /
Series:

Location: 55(61/65) THO

Authors: / /
Corp./Conf.: UNITED NATIONS DEVELOPMENT PROGRAMME /
Title:
Mineral and groundwater survey: Somalia: interim report/ prepared for the Government of the Somali Republic by the United Nations, participating and executing agency for the United Nations Development Programme.
New York: United Nations, 1970.
133p.: maps; 28 cm.
Note: 3 folded maps in pocket.

93-6R

Descriptors: SOMALIA: MINERAL RESOURCES / SOMALIA: GROUNDWATER / / /
Series:

Location: 553(677) UNI

Authors: PETERSON,James A. / /
Corp./Conf.: UNITED STATES GEOLOGICAL SURVEY /
Title: Assessment of undiscovered conventionally recoverable petroleum resources of northwestern, central and northeastern Africa (including Morocco, northern and western Algeria, northwestern Tunisia, Mauritania, Mali, Niger, eastern Nigeria, Chad, Central African Republic, Sudan, Ethiopia, Somalia, and southeastern Egypt)/ by James A. Peterson.
[s.l.]: U.S. Geological Survey, 1983.
i, 26 leaves: map; 28 cm.
(Open-file report. United States Geological Survey; 83-598)
94-170

Descriptors: NORTH WEST AFRICA: OIL & GAS RESOURCES / NORTH EAST AFRICA: OIL & GAS RESOURCES / CENTRAL AFRICA: OIL & GAS RESOURCES / MOROCCO; ALGERIA, TUNISIA; MAURITANIA; MALI; NIGER; NIGERIA; CHAD; / CENTRAL AFRICAN REPUBLIC; SUDAN; ETHIOPIA; SOMALIA; EGYPT

Series: Open-file report. United States Geological Survey; 83-598

Location: 553.98(6) PET

Authors: COFFIN,Millard F. / RABINOWITZ,Philip D. /
Corp./Conf.: GEOLOGICAL SOCIETY OF AMERICA /
Title:
Evolution of the conjugate East African - Madagascan margins and the western Somali Basin / Millard F. Coffin, Philip D. Rabinowitz.
Boulder, Colo.: Geological Society of America, c1988.
vii,78p.: ill.; 28 cm.
Special Paper; 226.

Descriptors: WESTERN SOMALI BASIN / EAST AFRICA & MADAGASCAR: CONTINENTAL MARGINS / SEDIMENTARY BASINS / SEISMIC & BOREHOLE DATA / TECTONIC EVOLUTION; RIFTING

Series: Special Paper. Geological Society of America; 226

Location: [SERIAL]

Authors: PETERSON,James A. / /
Corp./Conf.: UNITED STATES GEOLOGICAL SURVEY /
Title:
Geology and petroleum resources of central and east-central Africa/ by James A. Peterson.
[Reston, Va.?]: U.S. Geological Survey, 1985.
ii, 48 leaves [4] folded leaves of plates: ill., maps; 28 cm.
(Open-file report; 85-589)

90-291

Descriptors: CENTRAL AFRICA: REGIONAL GEOLOGY / CENTRAL AFRICA: OIL & GAS RESOURCES / CENTRAL AFRICA: SEDIMENTARY BASINS / SOMALI, CHAD, NIGER, ETHIOPIAN RIFT, RED SEA: BASINS /
Series: Open-file report. United States Geological Survey; 85-589

Location: 553.98(67) PET

Authors: MERLA,Giovanni / /
Corp./Conf.: / INTERNATIONAL MEETING IN MEMORY OF GIOVANNI MERLA (Florence: 1986)
Title:
Proceedings of the International Meeting in memory of Giovanni Merla geologist and paleontologist [held in] Florence, March 24-26, 1986.
Memorie della Societa Geologica Italiana; 31, (1986).
461p.,[3]folded leaves of plates: ill.,maps; 26 cm.
Notes: 3 folded col. maps in pocket.
Text in English.

Descriptors: NORTHERN APENNINES: REGIONAL GEOLOGY / APENNINES: MINERAL RESOURCES / HORN OF AFRICA: GEODYNAMICS / EAST AFRICA: RIFTS / ETHIOPIA; SOMALIA

Series: Memorie della Societa Geologica Italiana; 31

Location: [Serial]

Authors: KLITZSCH,Eberhard / SCHRANK,Eckart /
Corp./Conf.: /
Title: Research in Sudan, Somalia, Egypt and Kenya: results of the Special Research Project "Geoscientific Problems in Arid and Semiarid Areas" (Sonderforschungsbereich 69): period 1987-1990/ Edited by Eberhard Klitzsch and Eckart Schrank. - Berlin: Selbstverlag Fachbereich Geowissenschaften, 1990. - 2 v. (1072p.[70] plates): ill., maps; 30 cm. - (Berliner Geowissenschaftliche Abhandlungen. Reihe A; 120.1 & 120.2) - Note: 4 folded maps in pocket of each volume. - Contents: Bd. 120.1: Geoscientific research in Sudan - bd. 120.2: Geoscientific research in Somalia, Egypt and Kenya.
91-115 91-289

Descriptors: SUDAN: REGIONAL GEOLOGY / SOMALIA: REGIONAL GEOLOGY / EGYPT: REGIONAL GEOLOGY / KENYA: REGIONAL GEOLOGY / ARID REGIONS; GROUNDWATER

Series: Berliner Geowissenschaftliche Abhandlungen. Reihe A; 120.1 & 120.2

Somalia in Reihe A Band 120.2

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