Proceedings of the Second International Congress of Somali Studies

University of Hamburg
August 1–6, 1983

edited by
Thomas Labahn

VOLUME IV

STUDIES IN HUMANITIES AND NATURAL SCIENCES

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EXPLORATION FOR OIL IN SOMALIA

Introduction

Among the energy resources oil and gas belong to those that have to be extracted from the subsurface. They are not readily available everywhere because they constitute only a miniature fraction of the volume of the rocks of the earth's crust.

Thus the search for oil means to explore the geologic subsurface for favourable conditions

- for generating liquid and gaseous hydrocarbons;
- for reservoir rocks to store such hydrocarbons;
- and for sealing formations to hold the hydrocarbon accumulation in the reservoir rocks once it has been formed in the geologic history.

These and a number of other preconditions have to be investigated carefully to assess the potential for hydrocarbons of an area.

Morphology

Somalia is situated on a prominent block bordered by the Gulf of Aden, the East African Rift and the Somali Deep Sea Basin. This present configuration developed during the Cenozoic break-up of the African-Arabian shield. The break-up was associated with a tilting of the Somalia block towards the Indian Ocean. The topographic elevati n still today resembles this event.

The rather short time span elapsed since did not permit the weathering and denudation of the elevated mountains. The rivers and valleys show the Indian Ocean as the base level indicating the direction of the detrital mass transport in the more recent times.

Geologic map

The geologic map shows the formations as they outcrop at the surface. The oldest crystalline rocks reach the surface at various locations at the updip end of the Somalian Plate followed downdip by the younger sediments from Permotriassic through Jurassic, Cretaceous, Tertiary to Recent.
Besides large volcanic masses associated with the break-up of the African-Arabian shield occupy vast areas along the East African Rift.
As an exception from the generally SE dipping Somali block there appears the crystalline basement complex of the Bur Acaba modifying the outcrop pattern of the geologic formations. The Bur Acaba massif also forces the Shabelle and Juba rivers to flow at some distance around it and thereby pointing to its rather recent uplifting.

Stratigraphy and lithology

Permotriassic (Adigrat/Karroo)

On the metamorphosed and crystalline basement rocks rest as oldest sediments a series of conglomerates, sandstones, quartzites and shales deposited in a continental/littoral environment and indicating an extended period of erosion and denudation on the African continent. Locally evaporites and some limestones have been observed.
The age determination is somewhat vague because of the scarcety of paleontological evidence in Eastern Africa.

The Adigrat most likely represents the equivalent to the Karroo. Agewise it may reach up to upper Triassic/lower Jurassic, while in southern Somalia the lowermost interval might represent lower Permian. Because of greater thickness in the south the name of Karroo has been introduced for the lower interval.
The Adigrat is rather thin in the north, partly absent on the Nogal uplift, possibly pointing to an upwarping and an erosional period in early Jurassic.
At Shileh Madu Cretaceous directly rests on basement leaving two possible explanations. Either it was uplifted already in Permotriassic time with no Adigrat being deposited, this would then also apply to the Jurassic, or both were previously present and have been removed by early Cretaceous erosion.
In the south the thickness exceeds 700 m in the Brava well and may reach about 2000 m in the Juba and Lugh basins according to depth estimates for the top basement from aeromagnetic interpretations.
No Adigrat sediments are described in outcrop around the Bur Acaba. However, a coarse quartzitic sandstone at the base of the Jurassic limestone and resting on basement may either be the remnant of the clastic Adigrat formation or the transgressive layer of the Jurassic. Either explanation suggests that the Bur area at the end of Triassic time was uplifted and either no considerable thickness of Adigrat had been deposited or the deposits had been removed by erosion.

Jurassic

With a hiatus marine Jurassic carbonates and shales transgressively overstep the continental Permotriassic Adigrat. This is the first marine incursion on the Somalian Plate.
At Shileh Madu on the Nogal uplift Jurassic sediments

are absent.
The Jurassic sequence is represented by three formations: the Hamanlei, the Uarandab and the Gabredarre.
The Hamanlei formation consists mainly of carbonates, mostly dense, partly oolitic, argillaceous to porous, some dolomites, marls and occasionally anhydrite in the lower interval with a thickness exceeding 2200 m in the Obbia well.
In the Lugh basin, the formation may exceed 2500 m in thickness.
Isolated remnants of Jurassic deposits on top of the Bur Acaba basement indicate that the Bur area was subsided at mid Jurassic time below sea level.
The Uarandab formation overlies the Hamanlei and consists predominantly of dark-grey shale with marly limestone intercalation. It is not present in northern Somalia but further to the south reaching thicknesses of 700 m and may be considered as a potential source rock for hydrocarbon generation. The absence in northern Somalia of the Uarandab formation as well as the increasing thickness from there in southerly direction indicate that North Somalia was later, probably during early Cretaceous time, uplifted and exposed to erosion.
The Gabredarre formation consists of limestone, marls, some gypsum and with increasing thickness basinward predominantly of shale. In central Somalia the Gabredarre reaches a thickness exceeding 400 m, while in northern Somalia it is not present probably due to erosion in early Cretaceous time. In the south apparently the stratigraphic gap is diminishing and there seems to be no depositional discontinuity from Jurassic to Cretaceous.
The thickness of the three Jurassic units ranges from 700 m inland in the mid Somalian basin, exceeding 2700 m at the Obbia well at the coastline and exceeding 3000 m in the Lugh basin. This indicates that the depositional basin

axis was located near the coastline or offshore of the Obbia area. Further south comparing the thickness of I300 m at the Brava well with the thickness of over 3000 m in the Lugh basin leaves it open to discussion whether and if so to what extent the Bur Acaba block was uplifted in Jurassic time and modified the depositional basin configuration.

Cretaceous

Cretaceous sediments cover a wide area of the Somalian Plate with two exceptions: They are absent in northern Somalia probably due to uplifting and continued erosion, and absent also on the Bur Acaba high either because of non-deposition or erosion.

Lower Cretaceous

The lower Cretaceous sediments consist of an intercalation of calcareous, marly shale and sandy members containing varying amounts of gypsum or anhydrite with maximum thickness of about 300 m.
They are developed in a zone in some distance from the present coastline from the Ogaden to the Lugh basin and represent a restricted environment tending from marine to lagoonal to continental. In northern Somalia the lower Cretaceous is missing while in central Somalia the marine incursion begins in Albian time with limestone and subordinate dolomite and shale. Because of the deep subsidence in southern Somalia no informations are available there.
In Kenya sandstone and shales represent lower Cretaceous.
The thickness may reach up to I000 m.

Upper Cretaceous

The upper Cretaceous consists in northern and central Somalia of limestones with a reefoidal unit and gypsum and shale. At the top a sandstone member shows some regional

development. The total thickness of upper Cretaceous is up to 1000 m.
The Nogal uplift was submersed because it is known from outcrop that the upper Cretaceous rests unconformably on basement.
Further south the limestones are replaced by shales, mudstones and silts indicating a marine to near shore environment.
There is no control about the thickness in this area. It may be speculated that the thickness could be in a range of 2000 m.
At the same time the Bur Acaba may have been covered by the sea, however, it appears unlikely that more than a thin veneer of sediments were deposited because there are no remnants preserved.

Tertiary

Tertiary sediments in general are present east of a line Berbera - Mogadishu in the coastal basin in front of the Bur Acaba uplift and in the Lower Juba area. The thickness ranges from about 1500 m in the north to over 5000 m in the south. The upwarping of the Plate boundary at the Gulf of Aden is reflected by this considerable difference in thickness.
An area free of Tertiary has developed from the Bur Acaba northward to the Eastern Rift. This is indicative for the uplifting phase of the beginning East African rifting.
In upper Tertiary time the sea even further retreats from the Somalian Plate covering only the NE tip of Somalia, the coastal basin SE of the Bur Acaba and the Lower Juba area. The updip limit of upper Tertiary sediments is approximating the present coastline rather closely.
The Tertiary is also the time of extensive volcanism with lava flows associated with the break-up of East Africa.

The basaltic sills drilled in the Merca and Coriole wells are probably events of this time. The intrusion may have provided increased temperatures to generate the observed oil and gas indications.

Lower Tertiary

In northern Somalia and in the Nogal area the lower Tertiary is made up from limestone, gypsum and anhydrite and some shale intercalations. It has been deposited in shallow water environment changing intermittently to a restricted lagoonal environment. Towards the coast the lower Tertiary changes to dolomite and towards south into calcareous sandstone and further into shale of deep water facies.
In the Juba area the lower Tertiary is represented by a sequence of clastic sediments of deltaic environment.

Upper Tertiary

The upper Tertiary is made up of limestone and marl and sandstone with subordinate clay and shale. In the Lower Juba area the clastic sediments prevail over limestones.
It is absent in most of Somalia, but present on the NE tip of Somalia, and along the coast from Eil to Obbia and again in the coastal basin SE of the Bur Acaba and the Lower Juba area.

Geologic sections

The longitudinal section from the SW across the Bur Acaba towards Bosaso and the Gulf of Aden reveals considerable differences in subsidence or uplifting form NE to SW.
There is the very young basin at the northern coast located outside the Plate boundary in the Gulf of Aden separated by the coastal basement ridge from the Darror Basin. The

Nogal uplift (Las Anod Arch) with the basement outcrop at Shileh Madu forms the divide to the mid Somali basin (Mudugh Basin) which extends far inland towards the East African Rift. The Bur Acaba basement uplift borders a narrow coastal basin between Mogadishu and Brava followed by the deeply subsided Juba basin. The sedimentary thickness onshore Somalia in these four basins increases from 4000 m through 5000 m and 7000 m to 10.000 m.
Furthermore, there is the Lugh-Mandera Basin developed NW of the Bur Acaba.
The sequence of perpendicular cross sections shows that generally a deepening sedimentary basin toward SE is present in Somalia approaching the Indian Ocean. However, the sedimentary sequence shows no continuation across a wide shelf area as in many other parts of the world.
After crossing the coastline towards SE into the ocean the seabottom rather immediately drops off after a very narrow coastal shelf into the deep sea Somali basin with sea bottom depths below -5000 m.
At places where basement outcrops at surface evidently the sedimentary thickness is nil indicating the margin of the basin. The Somalian Plate is surrounded from north turning SW to south by basement outcrops delimiting the basin in these directions. From there the sedimentary thickness steadily increases towards the Indian Ocean with the exception of the interspersed Bur Acaba Basement massif.
The Basement contour map shows the general basin configuration as well as the thickness of the sediments.
Since the actual drilling depths never exceeded 5000 m, basement is controlled by drilling only in northern Somalia. All other figures are derived from aeromagnetic and seismic interpretations and geological extrapolations.

Exploration potential

To form a hydrocarbon accumulation of economic size several favorable conditions and parameters must exist.
Oil and gas generate in sizeable sedimentary basins mainly from bituminous shales deposited in a marine environment with a rich supply of organic material. Dark shales generally suggest the presence of organic material. Such shales have been found in the Jurassic Uarandab formation. Shales of upper Cretaceous age have been observed in central Somalia. Besides carbonates which are present in many stratigraphic intervals from Jurassic through Tertiary may act as generative source for hydrocarbons.
Thus qualitatively the source rock potential appears to be present.
Once such bituminous shales have been deposited and younger sediments are laid down as a cover on top during geologic time while the depositional area is subsiding, then pressure of the overburden as well as increasing temperatures lead to the formation of liquid and gaseous hydrocarbons from the organic material in the bituminous shales.
Below about 5000 m generally the temperature has increased to such a degree that at these conditions the oil generative potential has been fully exhausted.
Under the prevailing conditions at depths these hydrocarbons are forced out of the shales into rocks that have been able to preserve pores and vugs so that they can offer space for the expelled oil and gas (reservoir rocks).
Sandstones and limestones, preferable reefoidal, can provide this pre-requisite. Both sedimentary rock types are present in the geologic sequence: sandstones in Permotriassic, Cretaceous and Tertiary, limestones and dolomites respectively in Jurassic, Cretaceous and Tertiary.
A further condition is a sealing formation above the reservoir rock to hold the accumulation of oil or gas in its

place once it has been formed. Such impervious rocks are shales like they have been mentioned for the Jurassic and Cretaceous. Shales are also present in Tertiary.
Besides, structuring of the sediments is needed to allow migration and segregation of hydrocarbons from accompanying liquids. In addition the timing of the structure forming event has to be concurrent with the time of migration so that accumulations in a reservoir rock in commercial quantities can be trapped.
Block faulting partly associated with draping of overlying horizons seems to prevail over simple anticlines. Another possibility are stratigraphic traps like pinch-outs and wedge-edges. However, they are hard to determine by seismic, particular under the surface conditions in a semi-arid/ arid climate.
Qualitatively also this pre-requisite appears to be met.

Exploratory activities

Except for some early geologic field work exploration in Somalia began in the 1950s. Since then extended geologic and geophysical surveys have been conducted. The geologic field work comprises nearly 500 crew months.
In 1952 the first gravity and magnetometer crews began working followed by seismic in 1954. Gravity and magnetometer work in the field exceeds 100 crew months not accounting for aeromagnetic surveys that have been flown. Approximately 400 months of seismic surveys have been executed.
Wildcat drilling was commenced for the first time in 1956. Some 50 wildcats have been drilled since, representing 150.000 m of bore hole. The deepest well drilled reached a total depth of 4971 m in the Lower Juba area. Thirty oil companies were operating or held an interest in exploration

acreage at different times during the last three decades.

Hydrocarbons

Oil and gas shows have been encountered in Somalia several times but no economic quantities of hydrocarbons have been found so far.

Oil shows

Oil shows have been reported from two locations in northern Somalia notably from Dagah Shabel in Cretaceous and Jurassic. The earliest report on using oil from oil seeps near Dagah Shebel date back to 1912 yielding at times up to 40 gallons of oil.
Oil has also been tested in the central and coastal basins in the Coriole well (12 b/d - 44^{o} API from Eocene dolomite, 100 b/d - GOR 14000 from Upper Cretaceous sandstones only a few meters above a volcanic sill or intrusion), and in El Kuran well (tested unknown quantities of 32 - 39^{o} API oil from Jurassic at about 1550 m depth). Oil traces have been found in several other wells in

- Jurassic (Gira, Sagaleh)
- Cretaceous (Marai Ascia, Sagaleh)
- Tertiary/Paleocene (Cotton, Gira, Sagaleh)

Gas shows

Gas shows have been reported

- in the Central Basin for the Calub well (35 MMCFGD) from Permotriassic Adigrat/Karroo sandstones from an interval below 2750 m depth;
- and in the coastal basin for the Afgoy well (extensive testing has yielded so far only non-commercial quantities of gas);
- and for the Merca well (25 - 30 MCFGD from Eocene sand-

stones which is underlaid by a thick sequence of basaltic sills).

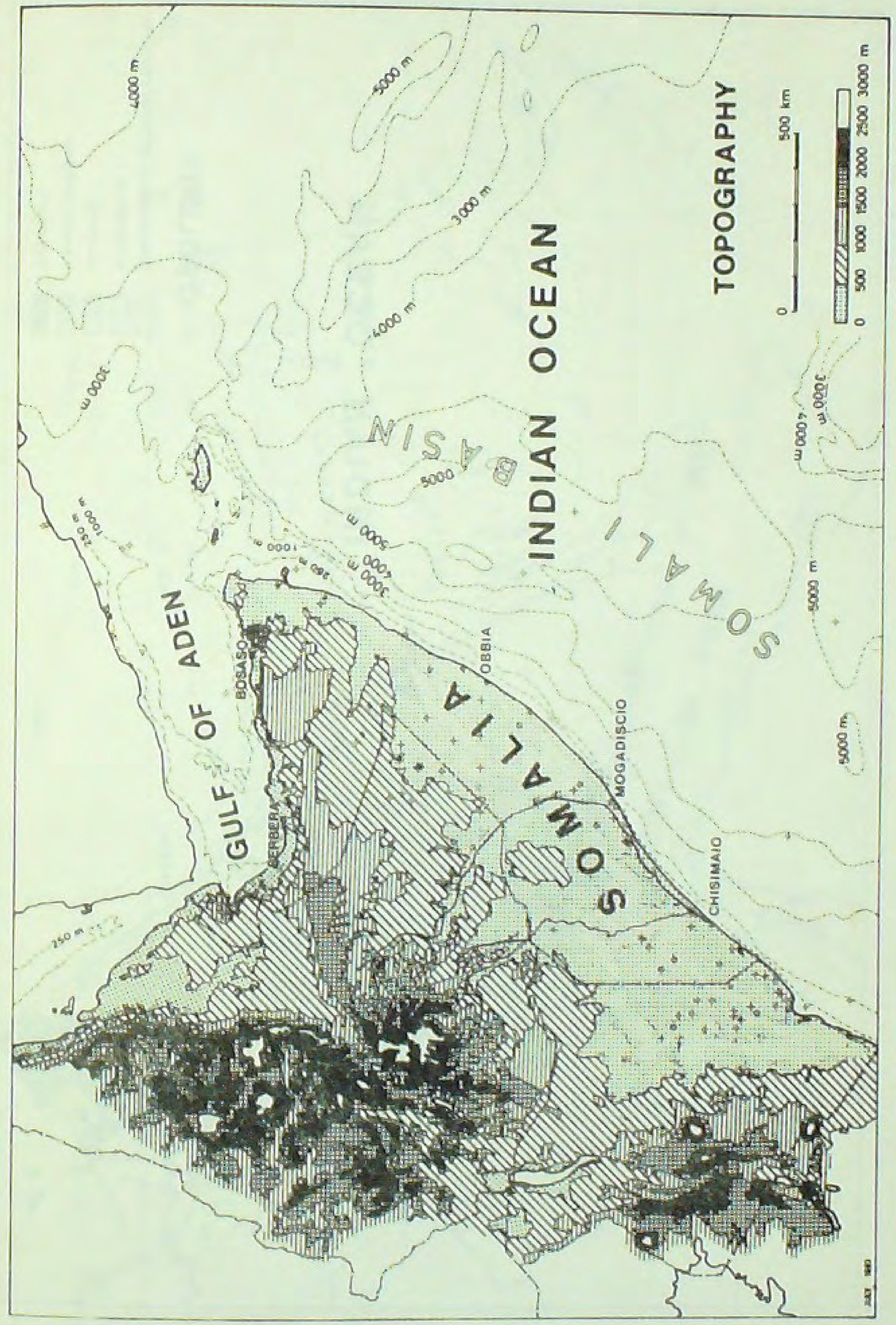
Besides, gas traces have been observed in northern Somalia:

- in Cretaceous (Cotton, Darin, Guardafui)
- in Tertiary (Berbera).

Conclusion

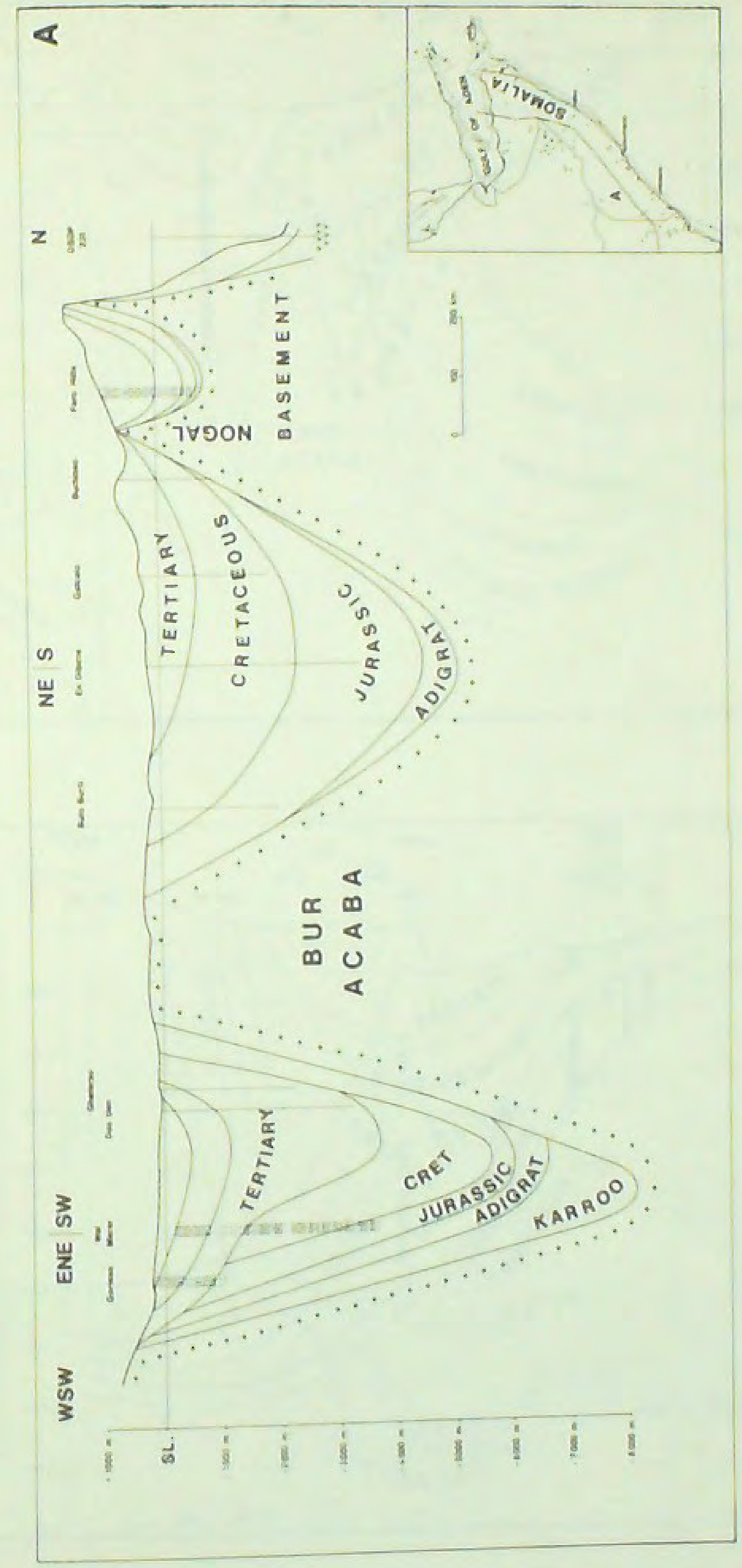
While the exploration for oil and gas in Somalia after the considerable efforts of the industry over the last 30 years has not yielded an economic discovery, it must be recognized that cautiously interpreted the exploratory parameters compared with the size of the country and the number of wildcats drilled seem to offer a fair exploration potential.

Map I. Topographic Map

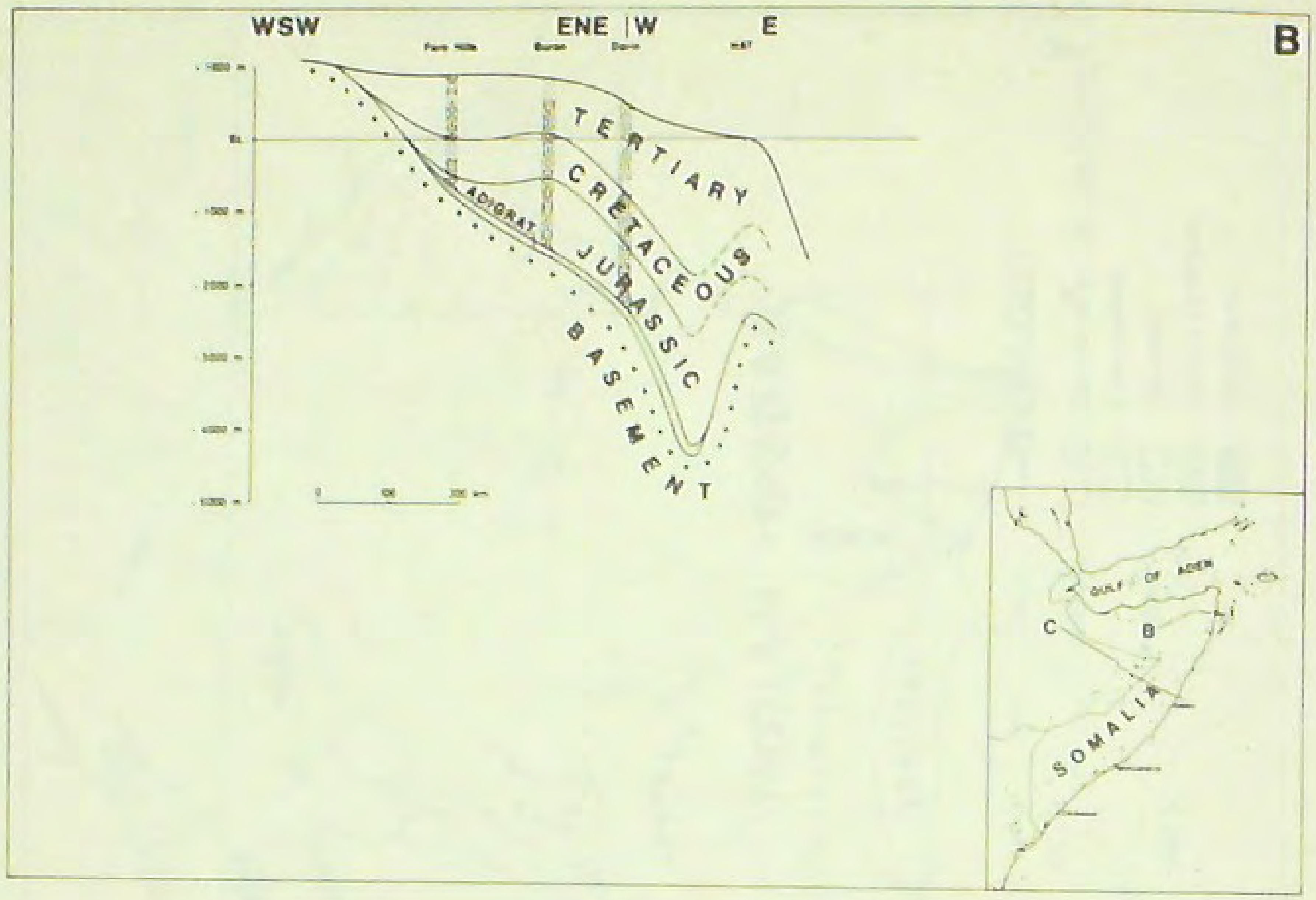


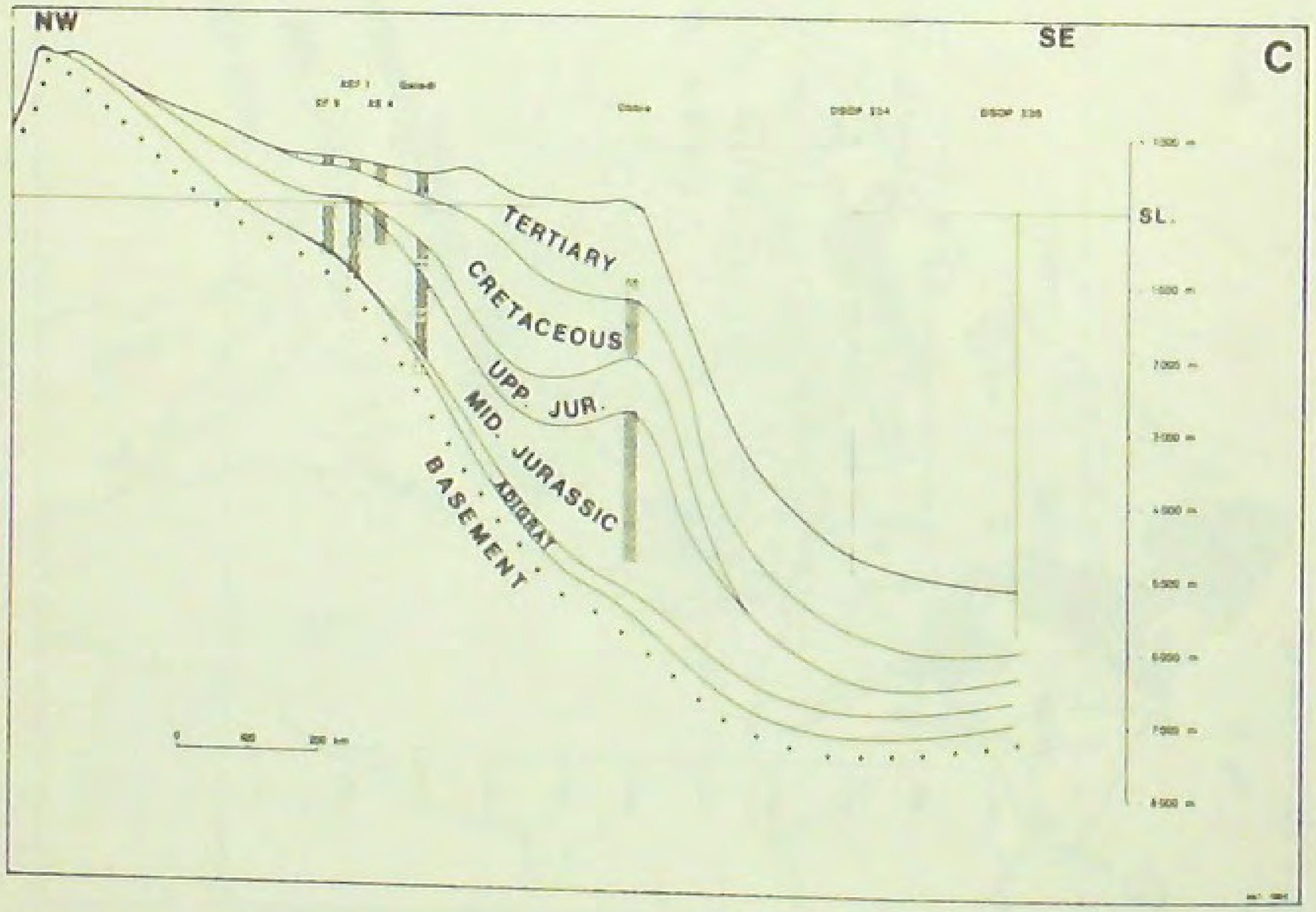
Map 2. Geologic Map

Map 3. Geological Section A

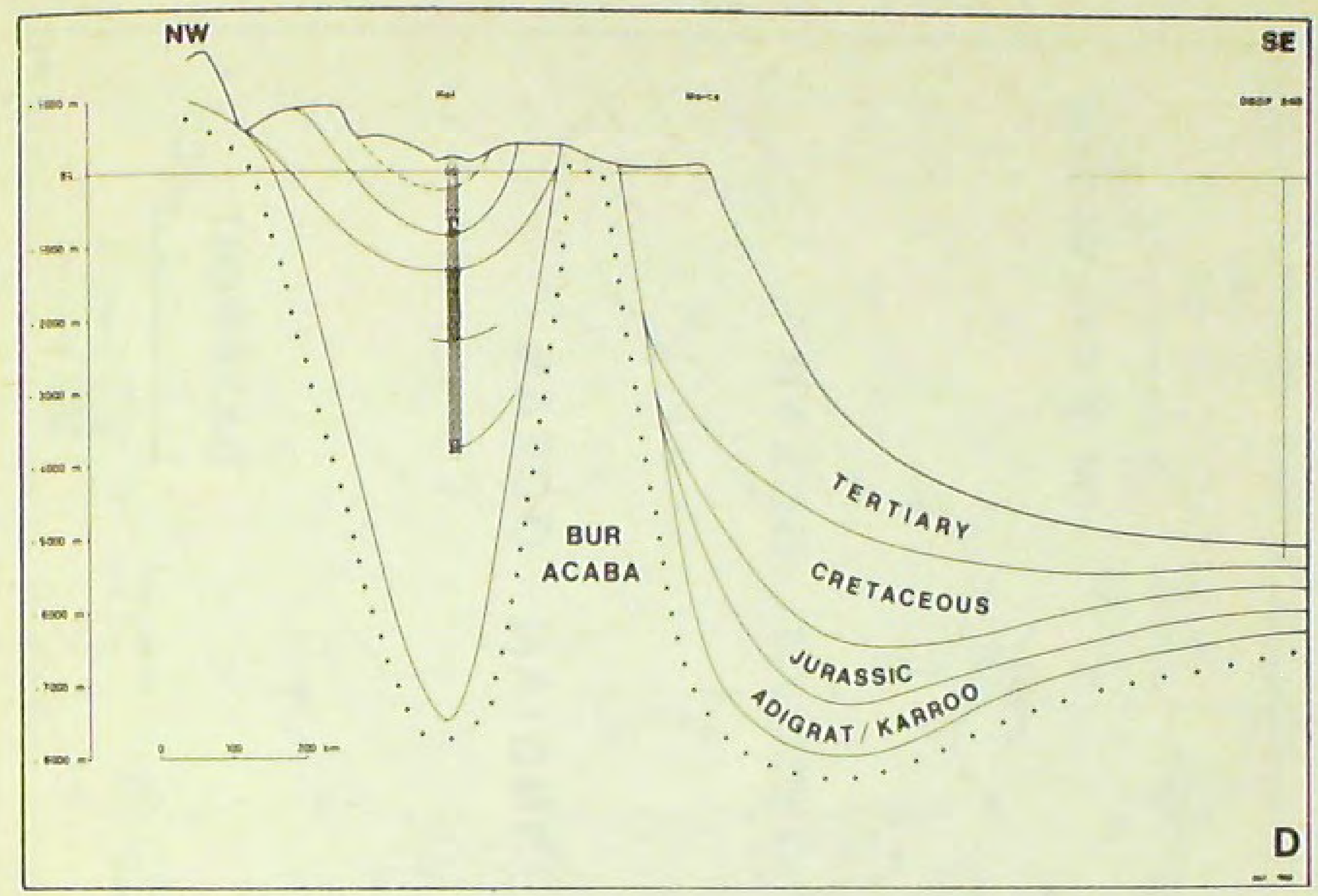


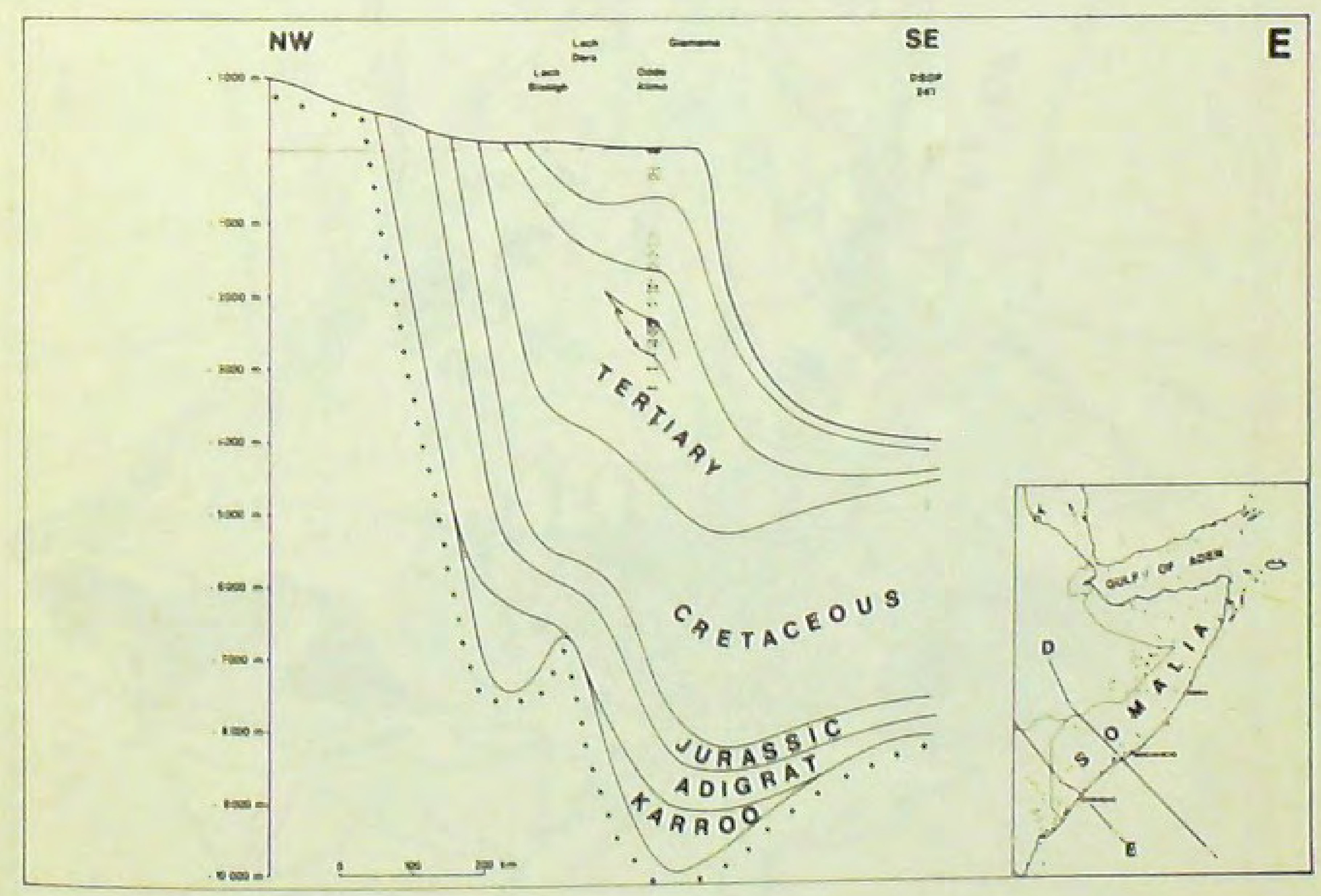
Map 4. Geological Sections B and C



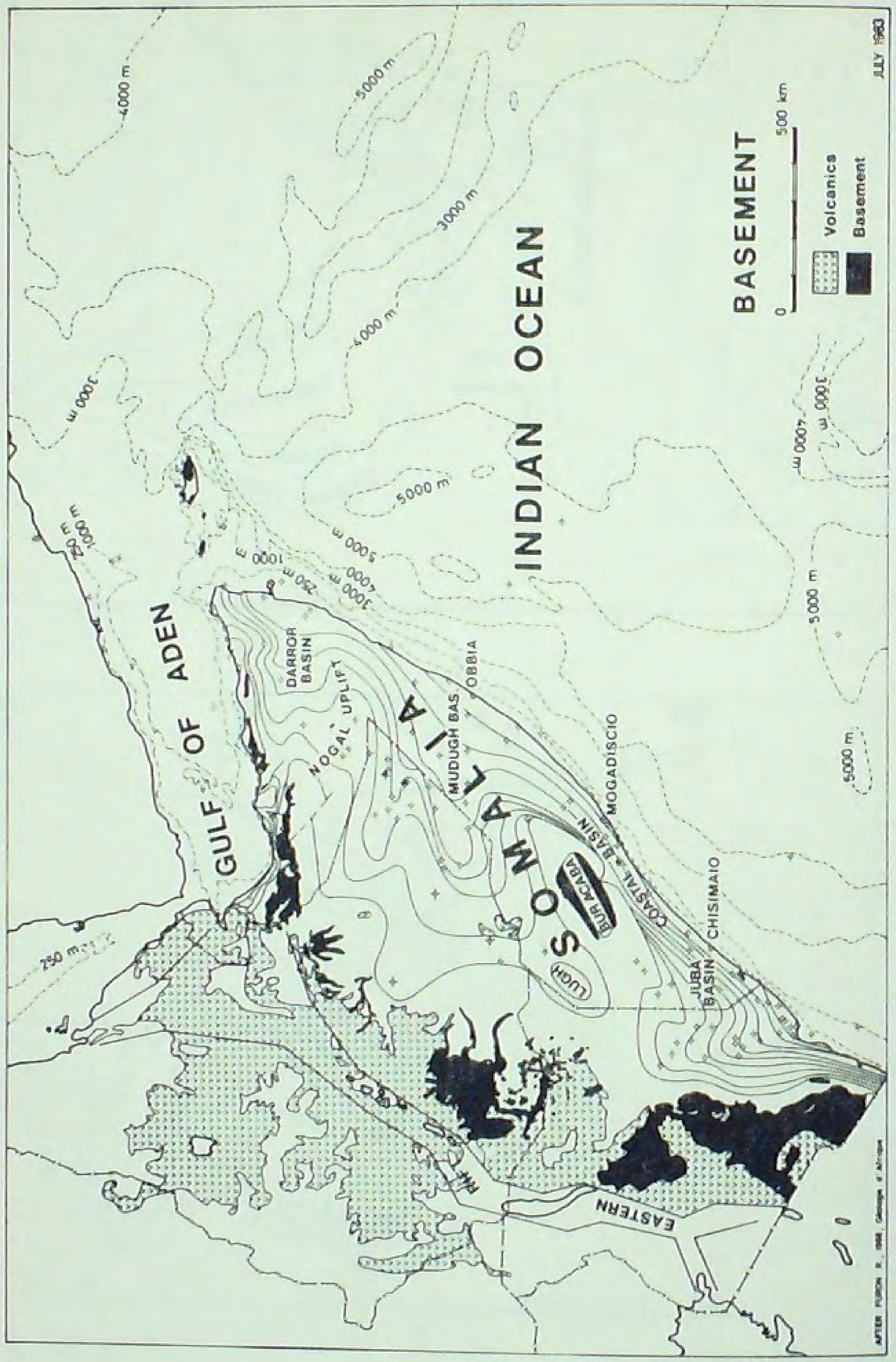


Map 5. Geological Sections D and E





Map 6. Basement Map



Map 7. Oil and Gas Shows