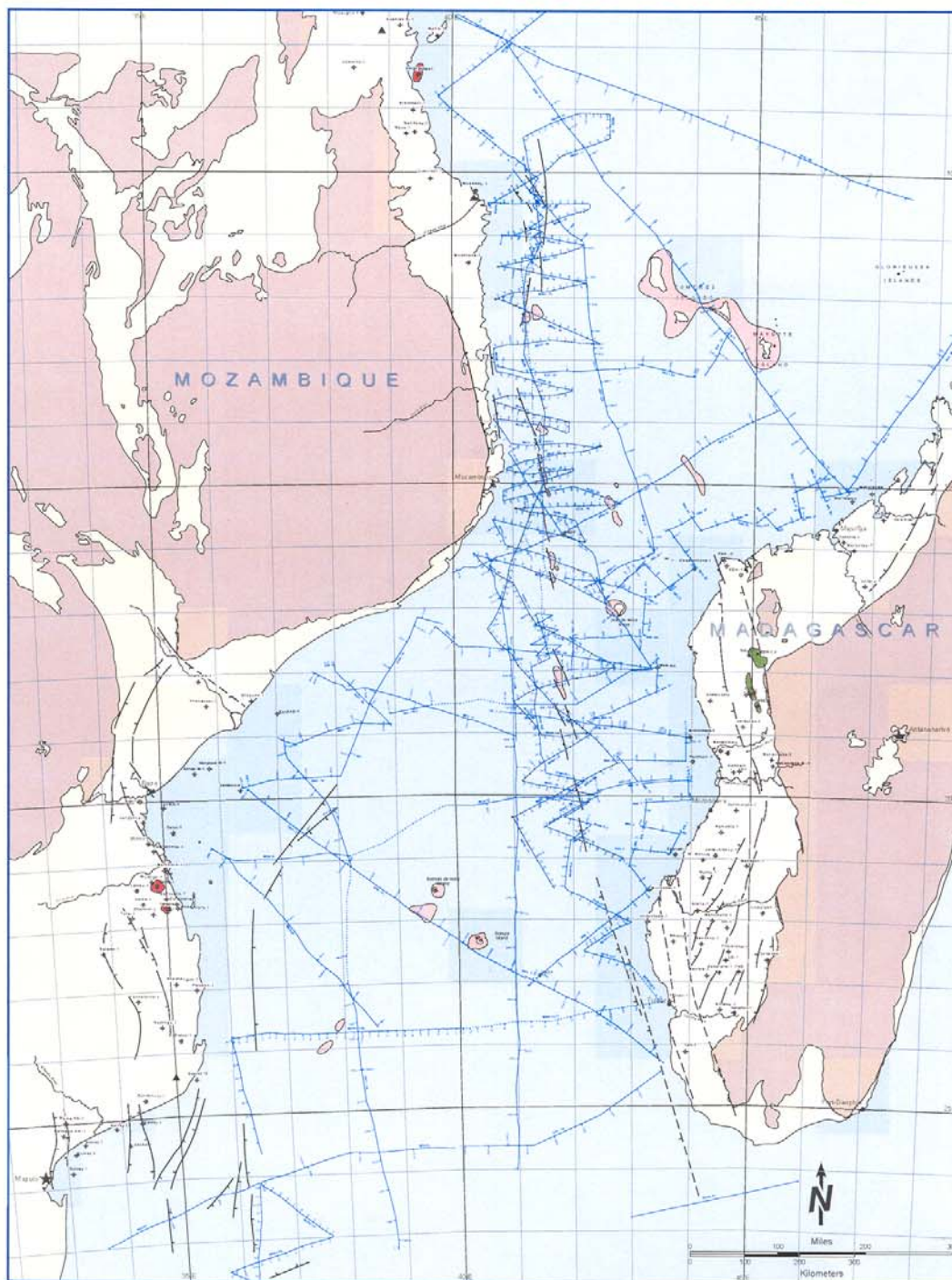


# PETROLEUM GEOLOGY AND GEOPHYSICS OF THE MOZAMBIQUE CHANNEL



*Rusk, Bertagne & Associates*

**TGS NOPEC**  
GEOPHYSICAL COMPANY

## **PETROLEUM GEOLOGY AND GEOPHYSICS OF THE MOZAMBIQUE CHANNEL**

### **ANNOUNCEMENT**

Rusk, Bertagne & Associates and TGS-NOPEC are pleased to announce the completion of a three year study and the publication of a report entitled “The Petroleum Geology and Geophysics of the Mozambique Channel”.

The study includes the coastal and offshore sectors of Mozambique, southern Tanzania, northern and western Madagascar and the Comoros Islands. It covers an area of approximately 1.3 million sq.km., representing one third of offshore East Africa and equivalent to 1 and 1/2 times the size of the North Sea.

This vast frontier incorporates nine basins, with sedimentary sections ranging from 6,000 meters to 11,000 meters in thickness. On the periphery, oil and gas have been discovered: two offshore gas fields in southern Tanzania have combined reserves exceeding 2Tcf; the Mozambique Pande-Temane complex, with gas now being delivered by pipeline to South Africa, has approximately 3,5 Tcf of reserves; and in Madagascar the Bemolanga tar sands have reserves estimated at 21 billion barrels while the Tsimiroro oilfield has an estimated 8 billion barrels of heavy oil-in-place.

In spite of the regional expanse, favorable geology and petroleum occurrences, to date only 23 offshore exploration wells have been drilled in the area of study. This lack of activity in the past was mostly due to water depth which averages roughly 2000 meters over the area.

The basis of the study has been our exclusive use of 31,000 km of deep-water seismic data. These data, which are the property of some of the Host governments and three French universities and associated research groups, have not been used previously for detailed petroleum exploration studies. This data set has been integrated with 2000 km of shallow-water seismic and data from all pertinent onshore and offshore wells throughout the region. Additionally, in 2001, TGS-NOPEC acquired 2000 km of 98 fold CDP data strategically positioned to verify new geological concepts revealed by the study.

In addition to establishing the stratigraphy and structure configuration of each of the nine basins we have identified an abundance of structural leads, some salt related, with dimensions analogous to giant fields. Also, based on well data analyses, effective oil and gas prone source beds of Permo-Triassic, Jurassic and Cretaceous ages are represented in seven of the nine subject basins.

Finally, of particular importance in regard to area or basin comparison and focus, offshore basin evaluation summaries have been prepared and include a concise compilation of petroleum related elements with risk analyses.

## EXECUTIVE SUMMARY

- 1) Large frontier area 1 and 1/2 times the size of the North Sea comprising 9 sedimentary basins with limited exploration on the shelf areas only. The basins display varied structural styles, a thick sedimentary section (over 10 km or 33,000 ft) the presence of evaporites, and appear to be mostly oil-prone.
- 2) Multi petroleum systems combined with mega-anticlinal structures. Several prospects with shallow drill depth (2000 mts) and in technologically manageable water depths (1300 to 1600 mts) have been conclusively established.
- 3) Sea bottom samples and core holes indicate that the Davie Fracture Zone is not of volcanic origin but a more recent wrench fault zone similar to the San Andreas fault oil province of California.
- 4) Period of expulsion and migration of hydrocarbons synchronous with the growth of the anticlinal structures.
- 5) Near-by presence of large fossil oilfields in Madagascar (Bemolanga 21 billion barrels of reserves; Tsimiroro 8 billion barrels of reserves) and gas in Mozambique (Pande-Temane gas field: 3 Tcf recoverable; now being developed commercially with gas being piped to South Africa).
- 6A) Comprehensive geological/geophysical report (text plus 70 enclosures in electronic format) based on 31,000 Km of single and multi-channel 2D seismic (including 2200 Km of strategically positioned 98 fold CDP coverage acquired in 2001) tied to existing well control. Until recently, most of these data were not available for petroleum exploration purposes.
- 6B) Additional report (available separately) providing data on sea bottom samples and shallow core information establishing the sedimentary nature of the Davie Fracture Zone, and including detailed maps and montages of all the major mega-prospects and leads which are considered as drillable with minor additional seismic work. 6 to 8 strategically positioned well locations should determine at an early stage whether the area will become a major oil province.
- 7) Welcoming governments with attractive PSC terms and the proximity to the traditional tanker routes to Europe and the Far East. Large amount of open acreage.
- 8) Excellent marine facilities at Diego Suarez, Madagascar, as supply base, manufacturing and repairs, and Narinda Bay for platform assembly and/or construction.

- 9) The Mozambique Channel is comparable to the North Sea in the mid-sixties when the discovery of a large gas field to the south (Groningen) attracted the attention to an area which is now established as a major petroleum producing province.
- 10) **In conclusion, the area provides an opportunity for a major acreage play offering the possible discovery of large reserves on a short term basis, which could have a strong impact on the growth of a mega-independent or a major.**



## **INTRODUCTION**

The study area, which includes the Mozambique Channel with water depths from 500 to 4000 meters, and the bordering coastal shelves of Madagascar, Mozambique, and southern Tanzania is approximately 1,300,000 sq. kms, an area greater than the North Sea (Figs. 1 & 2). This vast area of study comprises 9 basins or sub-basins, each with a unique set of hydrocarbon factors. Although major gas reserves (3.5 TCF) of the Pande-Temane complex in Mozambique, and the Bemolanga tar sands (20 billion barrels) and Tsimiroro oilfield (8 billion barrels) in Madagascar have been known for years, a total of only 23 exploration wells have been drilled offshore.

## **DATABASE**

Approximately 31,000 kms of seismic profiles have been interpreted and integrated with well, gravity, and magnetic data (Fig. 2). The seismic data, which were not available until now, are 1972 to 1989 vintage, multi-channel recordings with Flexotir source. These data can be integrated with the existing seismic control acquired by oil companies on the Mozambique shelf (50,000 kms) and on the Madagascar shelf (40,000 kms). Seismic refraction data, recorded in tandem with reflection data along several profiles provides additional control. Geologic data from approximately 80 onshore and 23 offshore wells in Mozambique, Madagascar and southern Tanzania has been utilized in the interpretation and evaluation process. Research and other archival geologic and geophysical studies provided by OMNIS, ENH, IPCP, EOST, CNRS and Geoscience Azur have been utilized for the project.

## **GEOLOGIC SETTING**

From late Carboniferous to late Triassic - early Jurassic, East Africa was deformed by recurrent rifting, which resulted in Karoo continental deposition. During a post-Karoo early Jurassic transgression, clastic, carbonates and evaporites were deposited along the pre-breakup plate margins. A subsequent marine transgression took place in mid Jurassic with widespread deposition of shelf carbonates and basinal sediments. At this stage, probably Bajocian, the onset of drift occurred. The Madagascar - India - Antarctica plate separated from Africa, moving incrementally southward along the Davie Fracture Zone until early Aptian (Fig. 3). During the drift phase, predominantly marine deposition took place throughout the region. The post-drift marginal sag phase, which followed an Aptian hiatus and persisted until the present, resulted in the deposition of thick marine siliciclastics.



# SIZE COMPARISON BETWEEN THE MOZAMBIQUE CHANNEL AND THE NORTH SEA

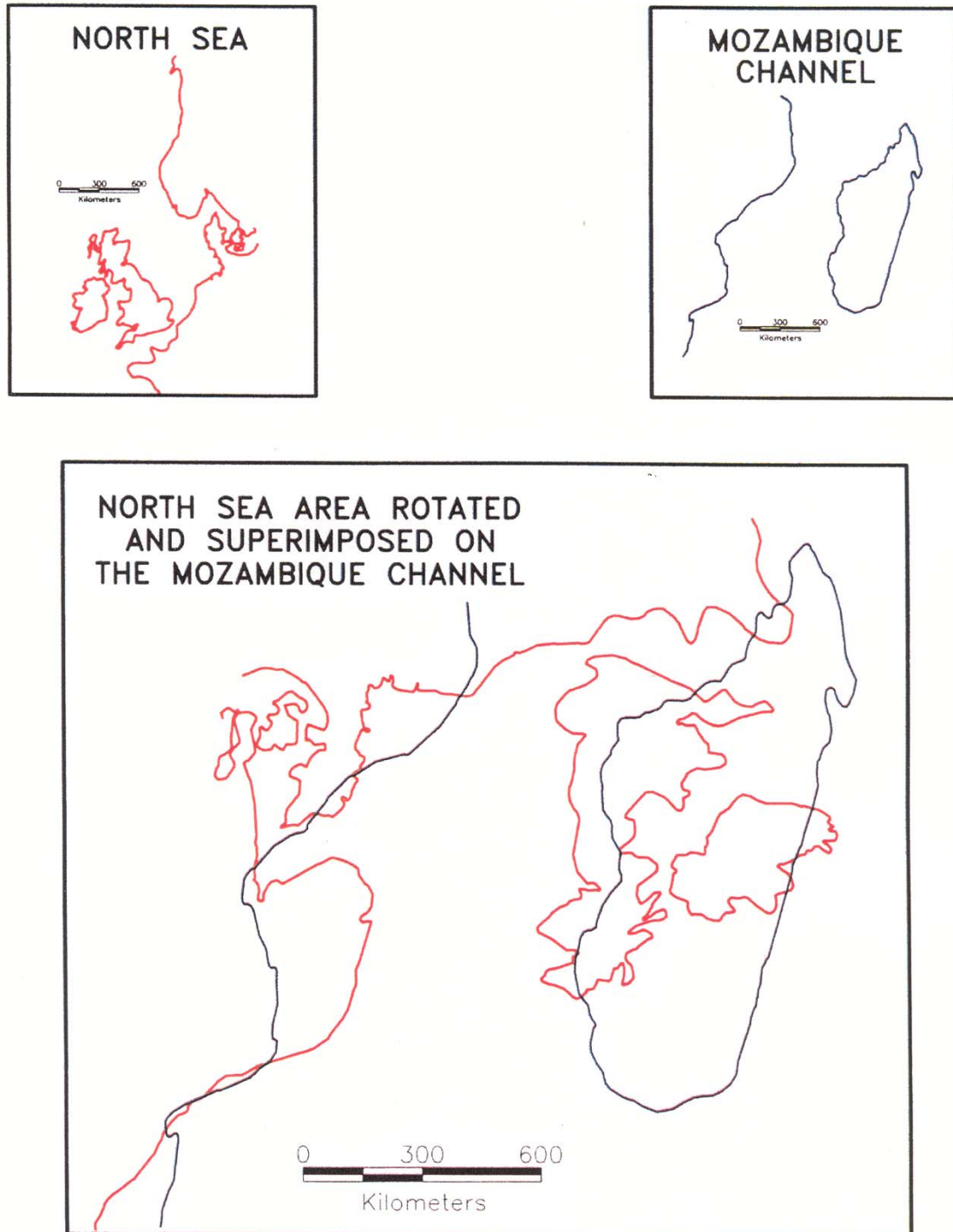
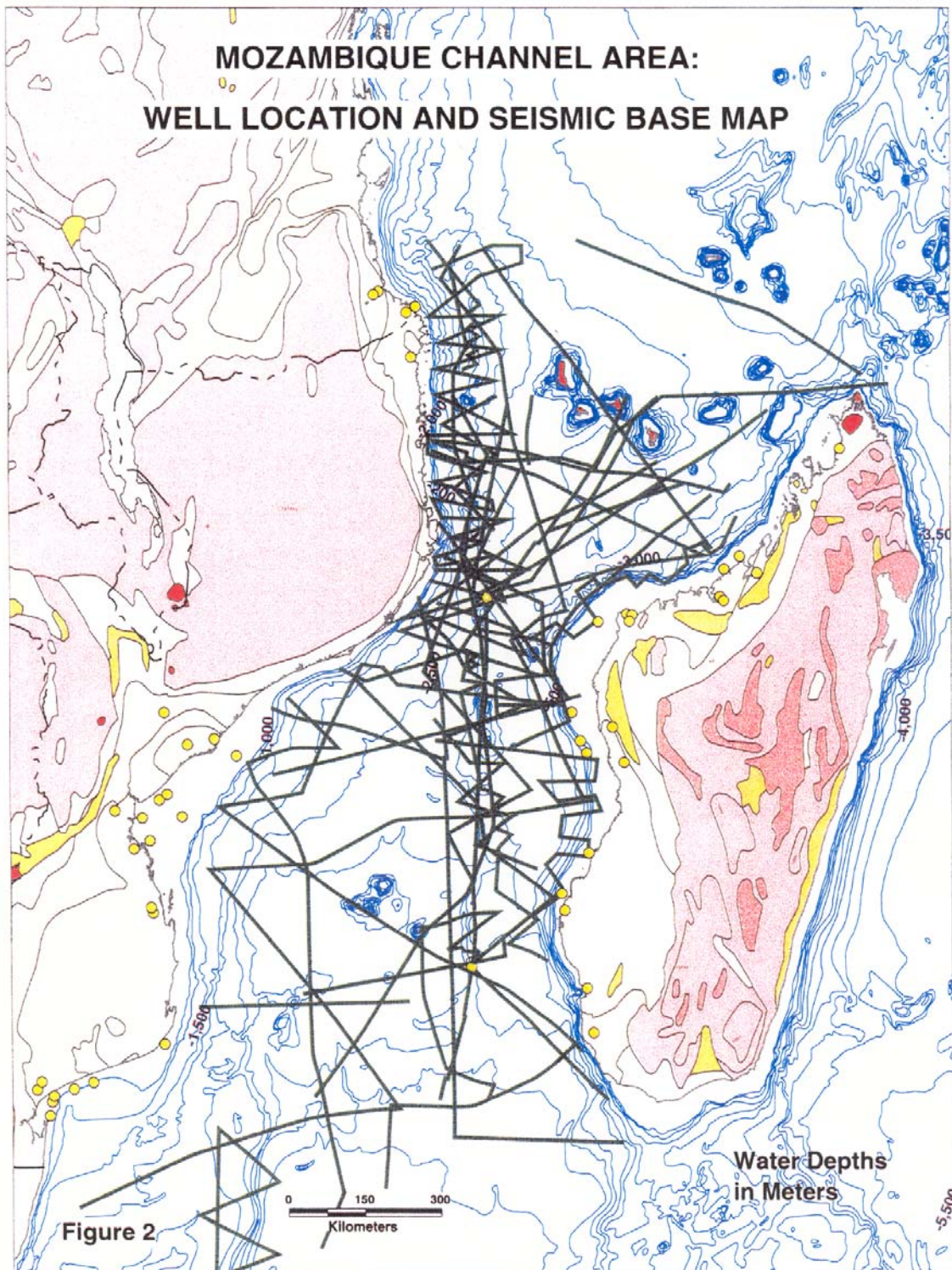
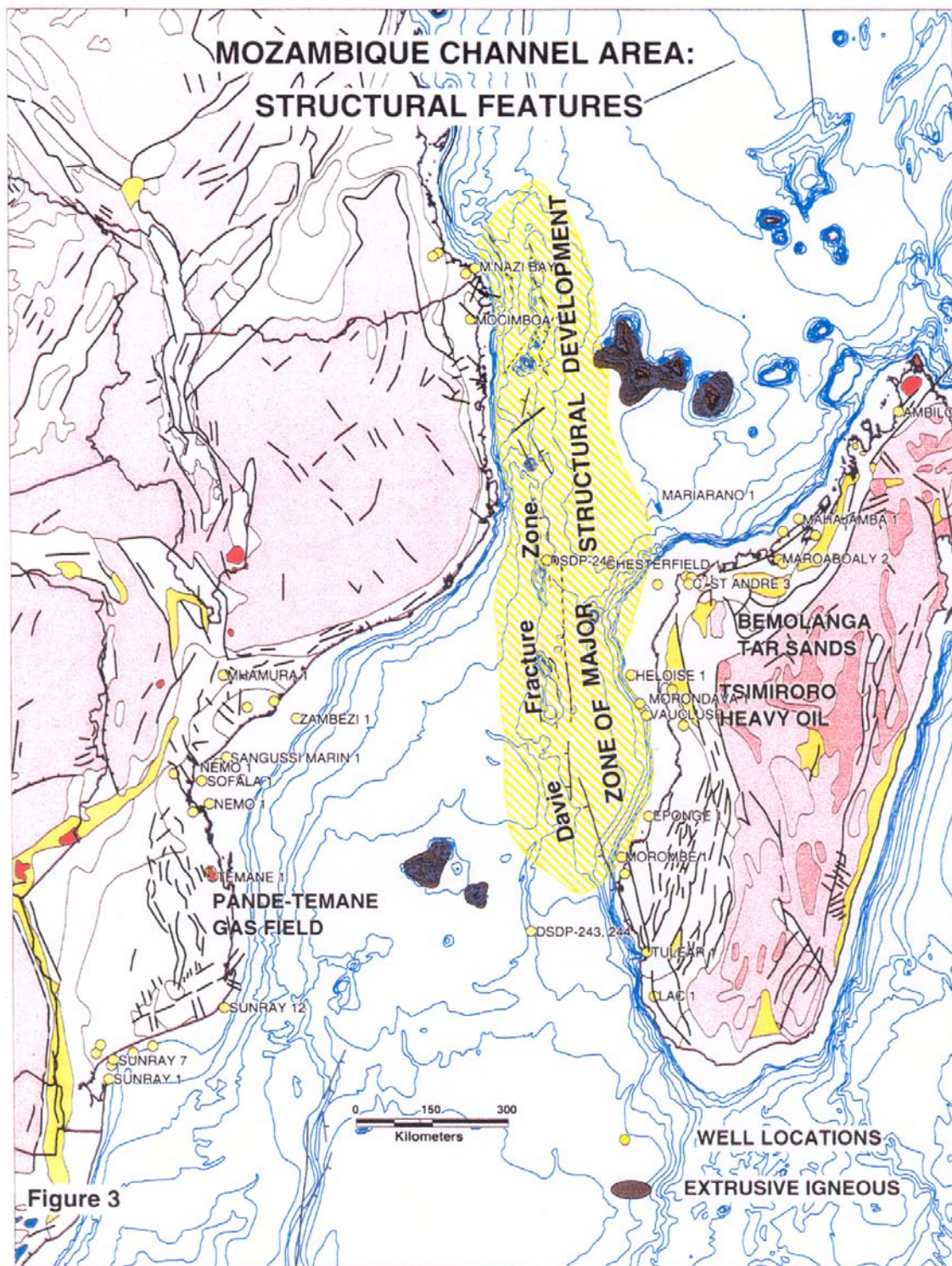


FIGURE 1

**MOZAMBIQUE CHANNEL AREA:  
WELL LOCATION AND SEISMIC BASE MAP**









## **HYDROCARBON SYSTEMS AND PLAYS**

### **Stratigraphy**

Numerous sandstone and, to a lesser degree, carbonate quality reservoir objectives have been penetrated in wells along the shelf and coastal areas. In consideration of the thick sedimentary section further offshore, equally potential reservoir sequences are expected (Fig. 4).

### **Source Rock**

Permo- Triassic lacustrine shale, the established source for the Bemolanga Tar Sand deposit, can be expected in any of the offshore sectors underlain by continental crust (Fig. 5).

Lower Jurassic rich, oil-prone shale has been identified in two basins and most likely is present in others. Also, geochemical results from well data indicate extensive occurrence of oil and gas-prone source beds of Middle Jurassic to Upper Cretaceous age. Throughout the study area, there is evidence for a consistent increase of argillaceous facies and organic matter basinward, as would be expected. This evidence coupled with the likelihood that faulting associated with the Davie Fracture Zone formed barriers to circulation, suggests that deposits with oil-prone kerogen may be prevalent within the Jurassic - Cretaceous section.

### **Trap Types**

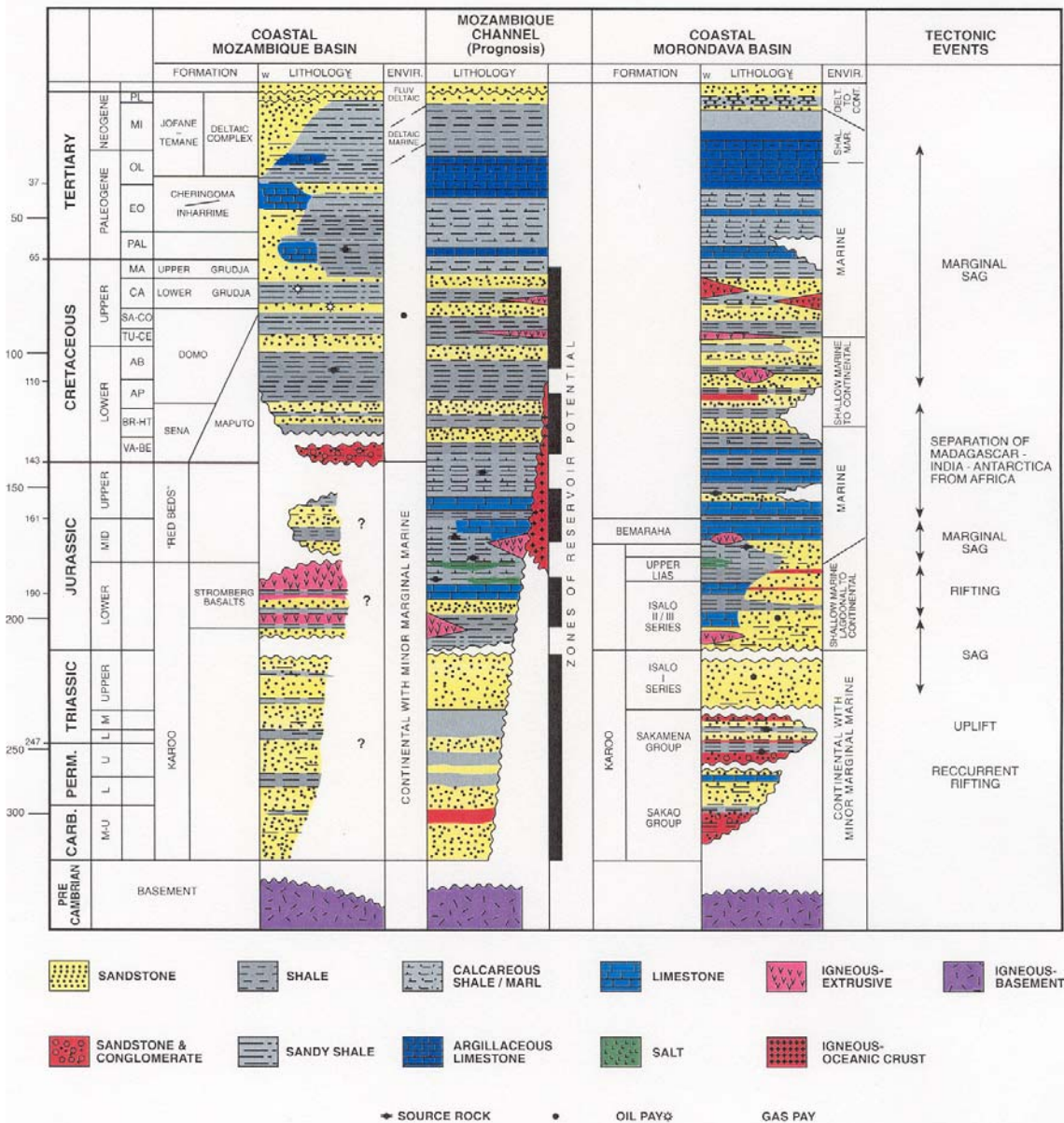
A wealth of trap types of potentially major dimensions have been identified, including salt structures, tilted fault blocks, horsts, drape anticlines and flower structures (Fig. 6 & 7).

The combination of multiple reservoirs and source rocks and the seismic evidence for numerous structural leads suggests the presence of a wide variety of plays with major resource potential.

## **PROSPECTS**

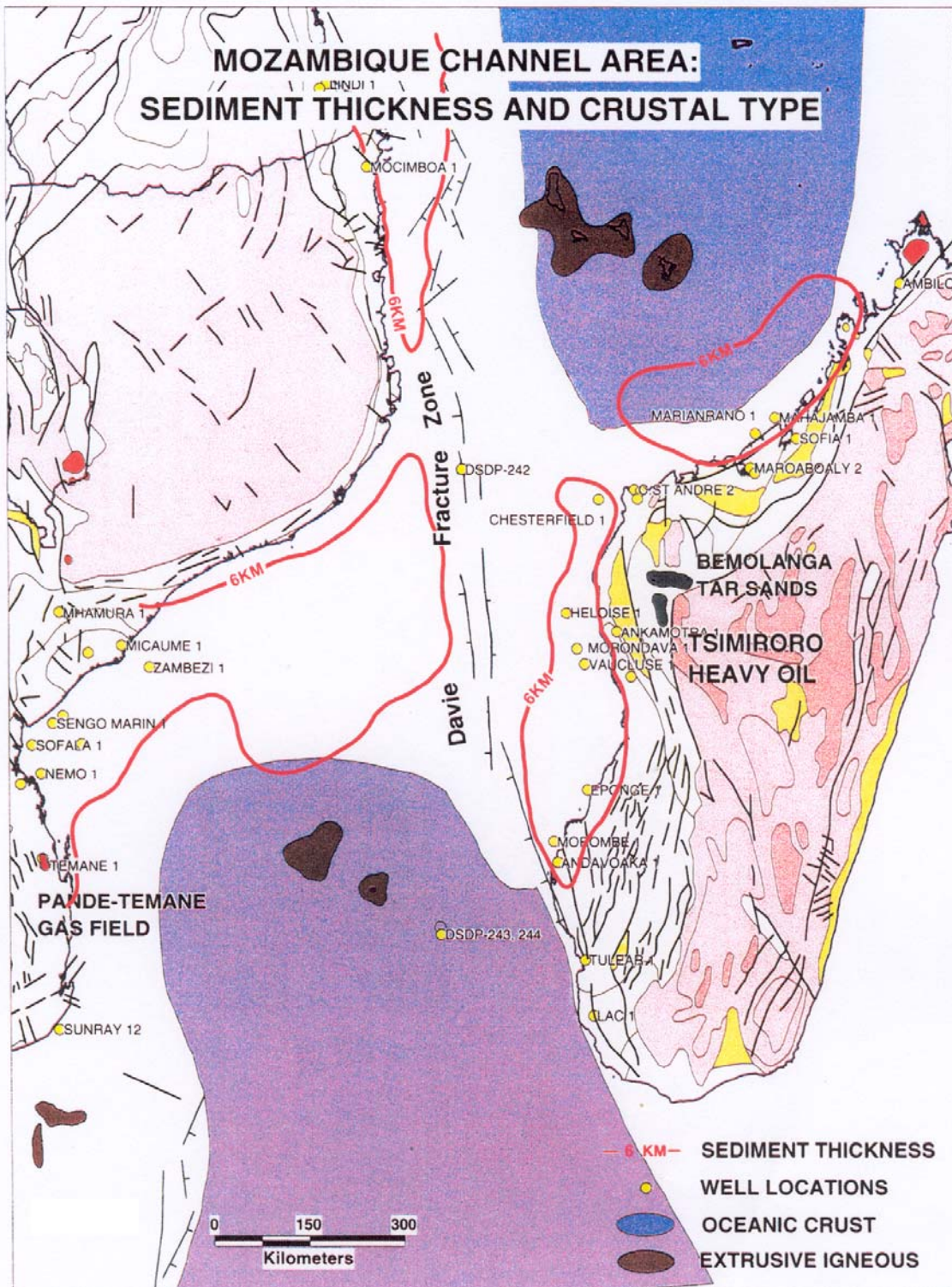
Several maps have been generated of the Mozambique Channel anticlinal prospects superimposed on major oil provinces around the world. As an example of our findings, the following figures (8, 9, and 10) illustrate these prospects superimposed on the North Sea and Middle-East oilfields for size comparison.

# STRATIGRAPHIC CORRELATION CHART





# **MOZAMBIQUE CHANNEL AREA: SEDIMENT THICKNESS AND CRUSTAL TYPE**





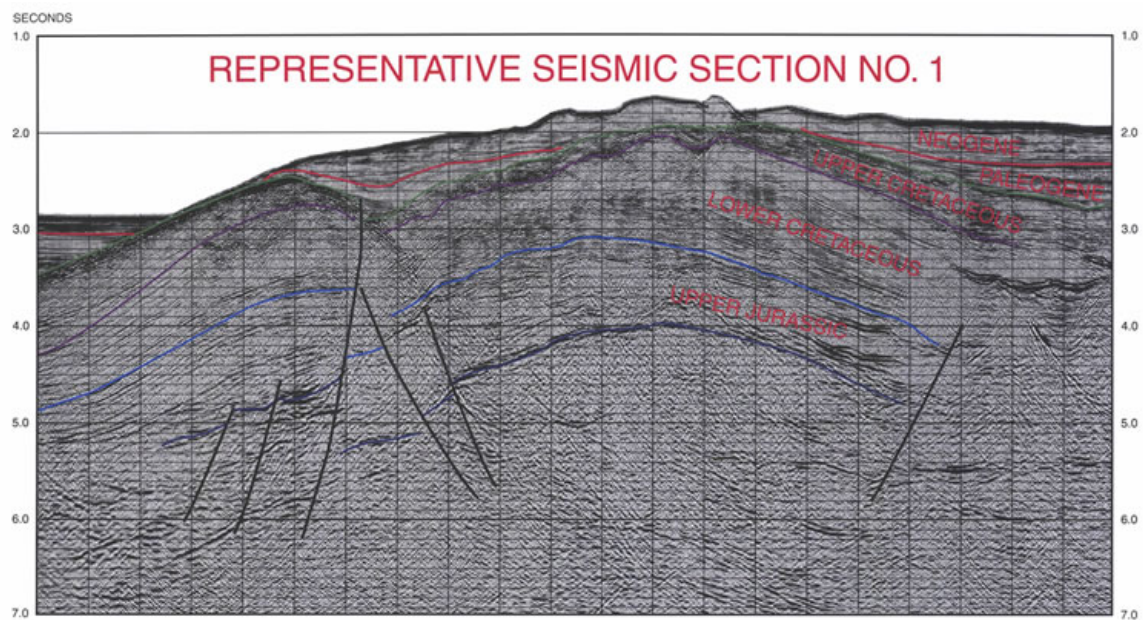


Figure 6

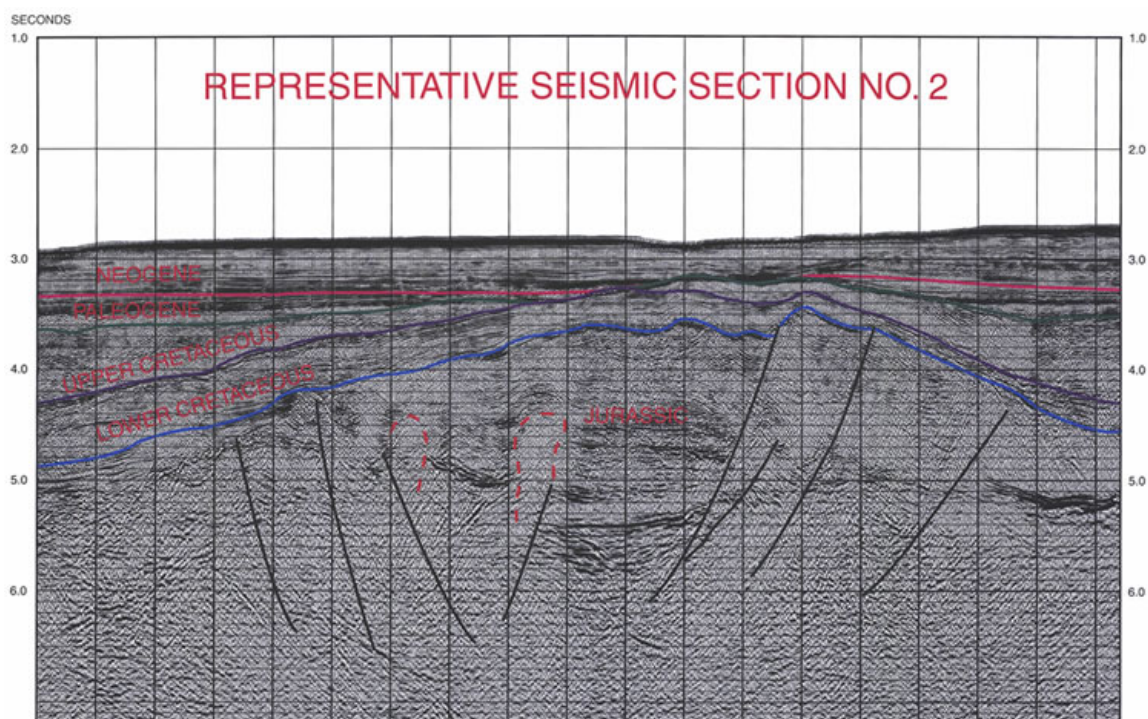
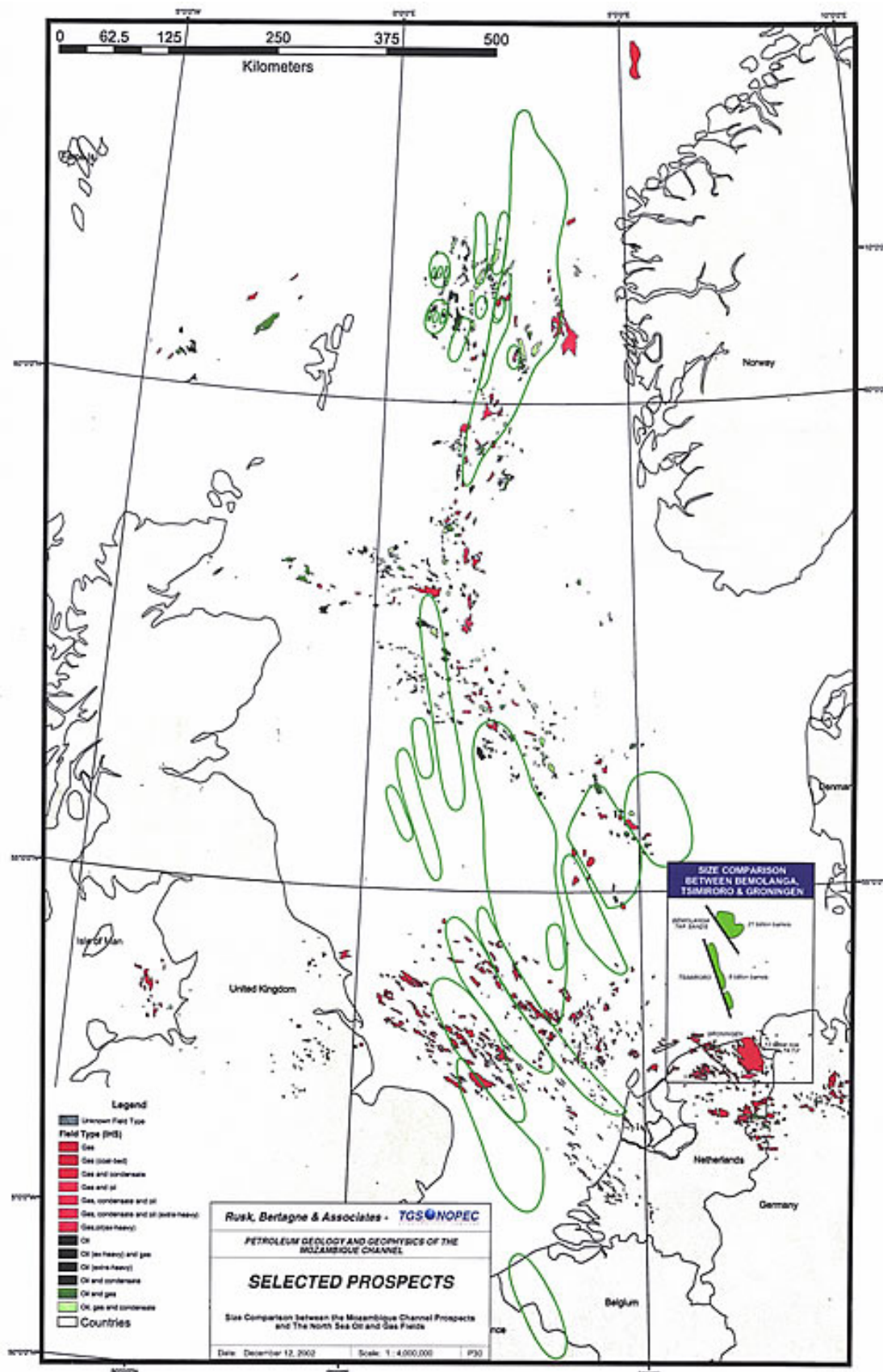
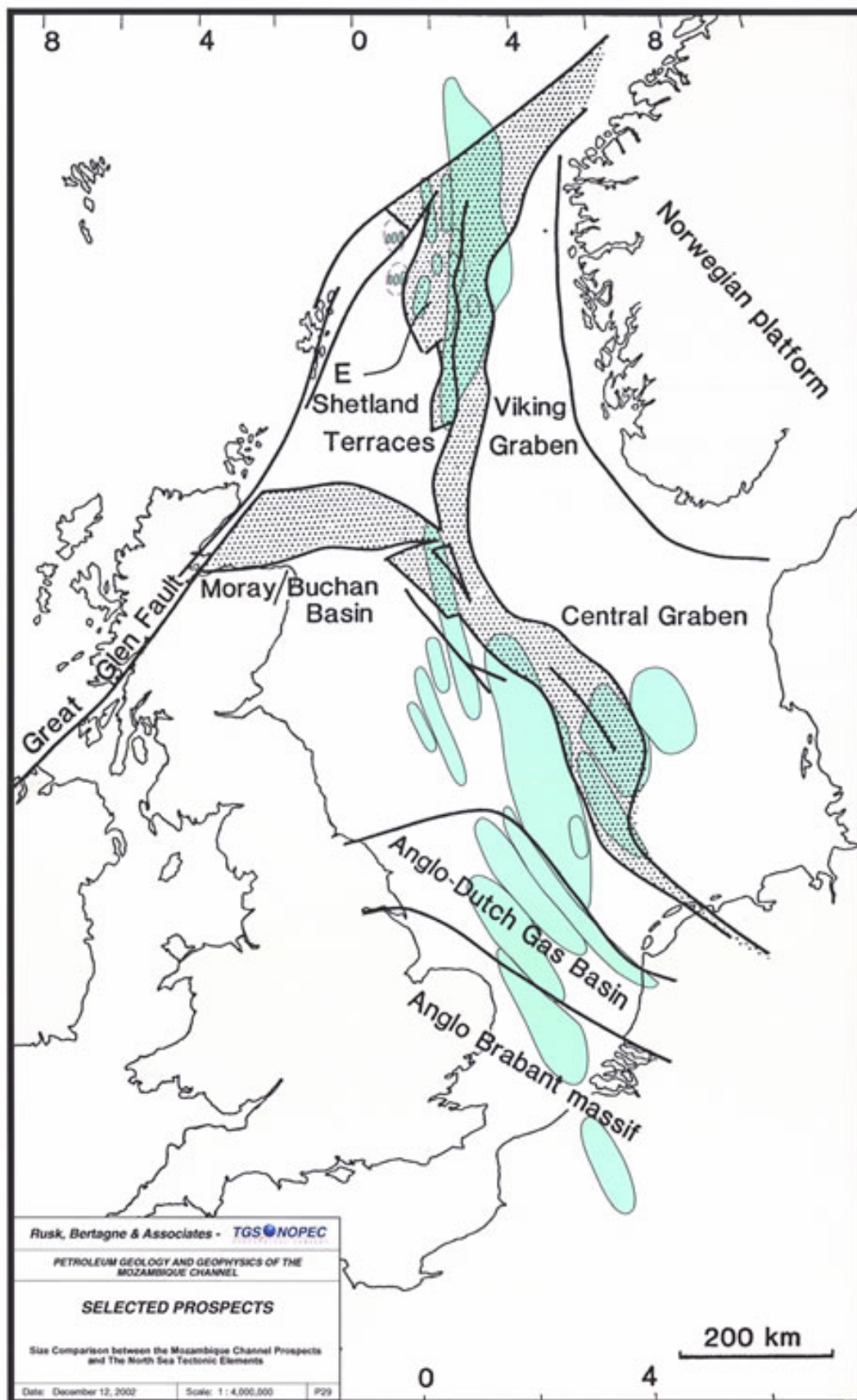


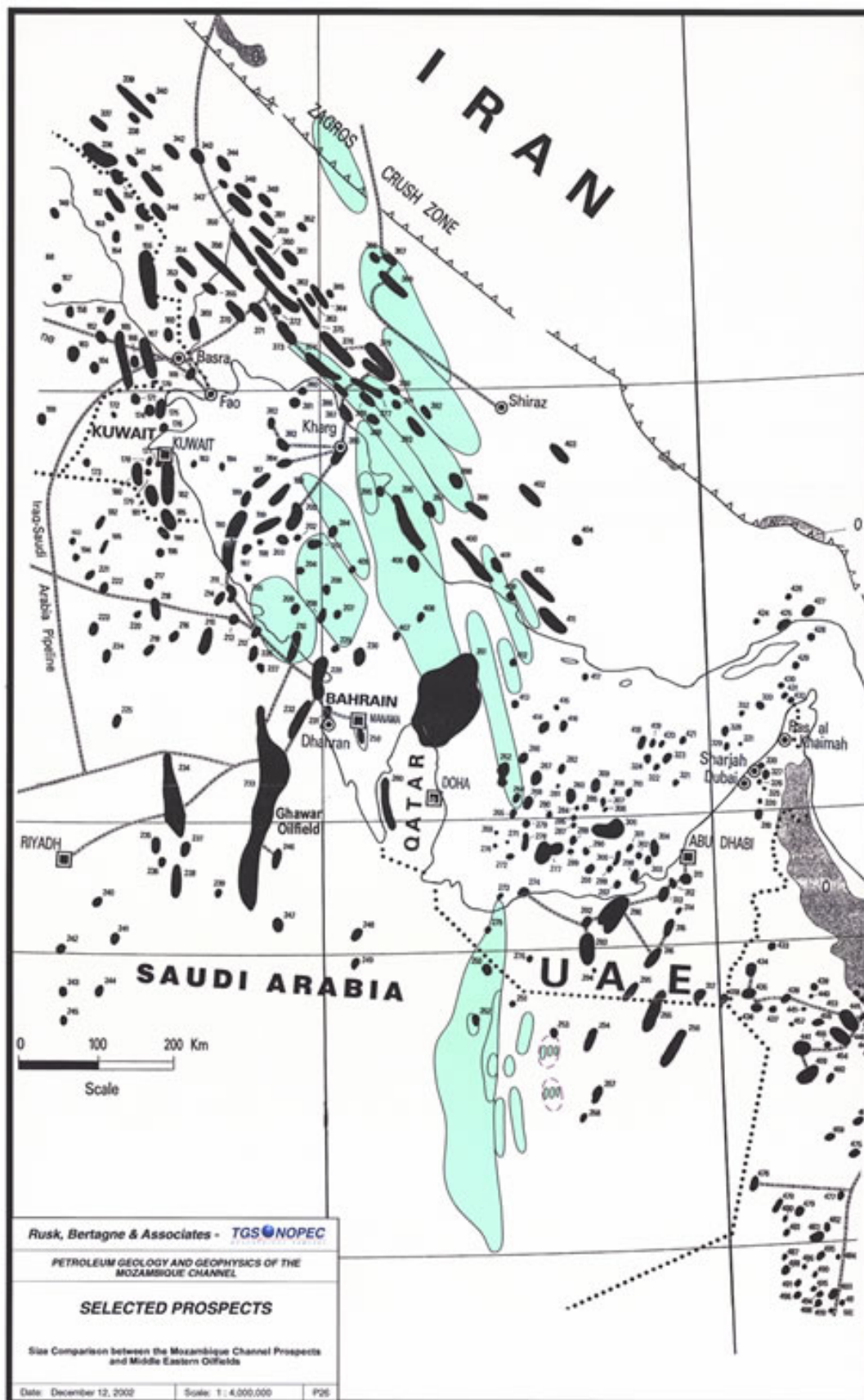
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## **REPORT - FORMATS**

The license fee will include a digital copy of all 70 maps and a .pdf of the text. All the maps will be in Illustrator format, except for the 8 listed below, which will be in ArcGIS 8.1.

Maps in ArcGIS 8.1 format:

1. Potential Oil-Prone Source Rock Distribution & Maturity, Karoo & Lower Jurassic- Panel I
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Paper copies and additional digital copies of the maps and the report are available at reproduction costs.

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