Presentation UC171

Presentation Title

Unraveling the hydrocarbon potential of deep water Mozambique Channel

(The role of GIS)

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Presentation Abstract

The deep water Mozambique Channel is a frontier exploration area of over 100,000 km^2, covering several national jurisdictions. Surveys ranging from Radar satellite to 3-D Seismic were used to determine the hydrocarbon potential of the area.

Advanced ArcGIS for Desktop was employed to integrate spatial datasets and imagery from these surveys for robust analysis.

This paper highlights the use of GIS as a platform for Exploration integration analysis as well as a geopolitical organizational tool.

1.0 Introduction

The deep water Mozambique Channel lies in the South-Western part of the Indian Ocean and it is bordered by East African countries Mozambique, Madagascar, and French Island Juan de nova. Exploration of oil and gas in this region would be discussed using studies from SAPETRO's Juan de nova and Belo profond acreages. The Juan de nova and Belo Profond acreages lie adjacent to each other and are operated by South Atlantic Petroleum Limited (SAPETRO) under permits from TAAF (Terres Australes et Antarctiques Françaises) and the Madagascan Government respectively.

SAPETRO's Geosciences team employed GIS using ArcGIS as a mapping tool to integrate spatial datasets and imagery from various geological surveys, to delineate and map out further areas of key interests. The use of this ArcGIS tool has enabled our exploration team to increase efficiency and reduce uncertainties in interpretation of surveys with respect to its spatial data. Incorporating these results have significantly reduced risks of accessing identified targets and clearly demarcating spatial data along boundaries of the Juan de Nova and Belo Profond blocks belonging to different national authorities from survey across these international boundaries.

2.0 Project History and details

The task of unraveling the hydrocarbon potential of the Juan de nova and Belo Profond blocks have been highly motivated by recent massive discoveries in East Africa. SAPETRO reached an agreement in 2011 with ROC Oil Australia and purchased a 90% operating interest in the Juan de Nova and Belo Profond Production Sharing Contract (PSC), which is situated in deep-water offshore Madagascar, in the Mozambique Channel. The other 10% interest is operated by MAREX. MAREX is led by Robert Bertagne, one of the first to recognize the potential of the area.

This study area is a total area of 66,760 km^2 with water depths across ranging from 500m to 3,200m. The Permit, off the Coast of Juan de Nova Island, covers an area of 52,990 km^2 while that of the Belo Profond block covers an area of 13,770 km^2. Exploration successes in this east African region has been proven by discoveries from the heavy oil at Tsimiroro and Bemolanga onshore Madagascar, to the commercial gas reserves in the Rovuma basin. USGS estimated East African potential hydrocarbon volumes at 27.6 billion barrels of oil, 441.1 cubic feet of natural gas and 13.77 billion barrels of natural gas liquid (USGS, 2012).

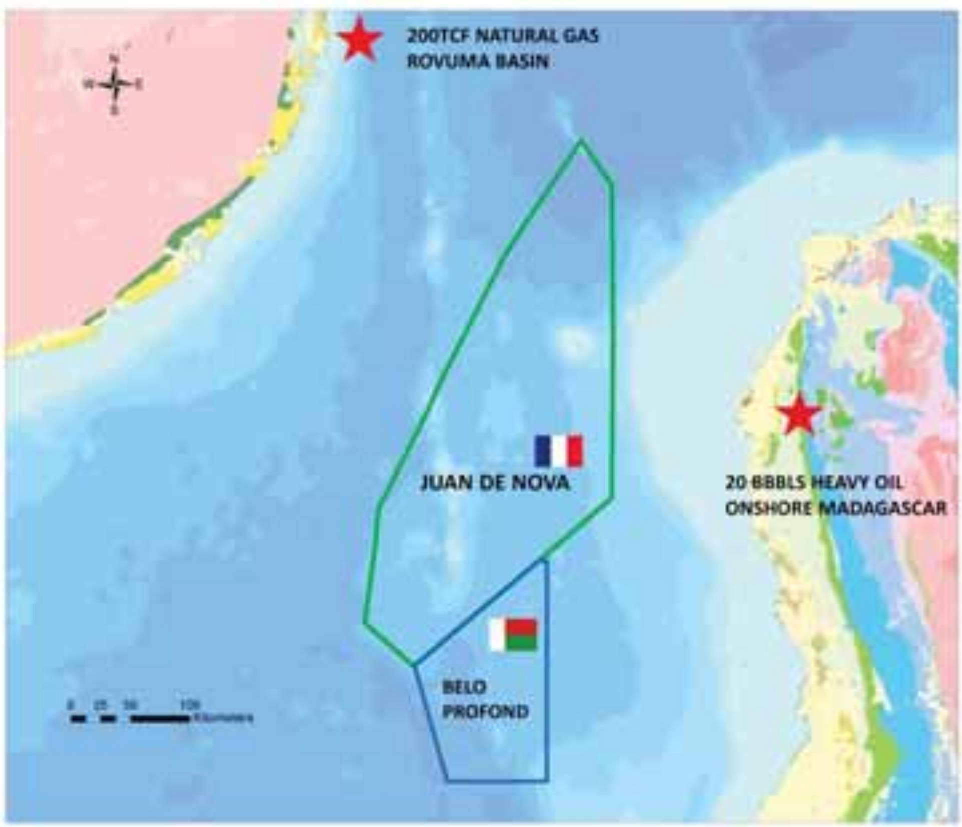

Fig 2.1 showing location and description of survey area

3.0 Geologic Background

3.1 Structural settings

The study area (Fig 3.1) lies across the Rovuma, Mozambique and Morondava basins, but sits primarily in the Morondava basin with the Davie Fracture Zone cutting across the blocks. The Davie Fracture Zone (DFZ) is a major feature of the East African Margins that was generated during Gondwanan break-up (GETETCH, 2009). Today the Davie Fracture Zone is An approximately 50m-200km wide N-S feature extending far more than 1500km with crustal fractures and diffuse deformation that extends from the SW corner of Madagascar to the intersection with the Kenyan coast.

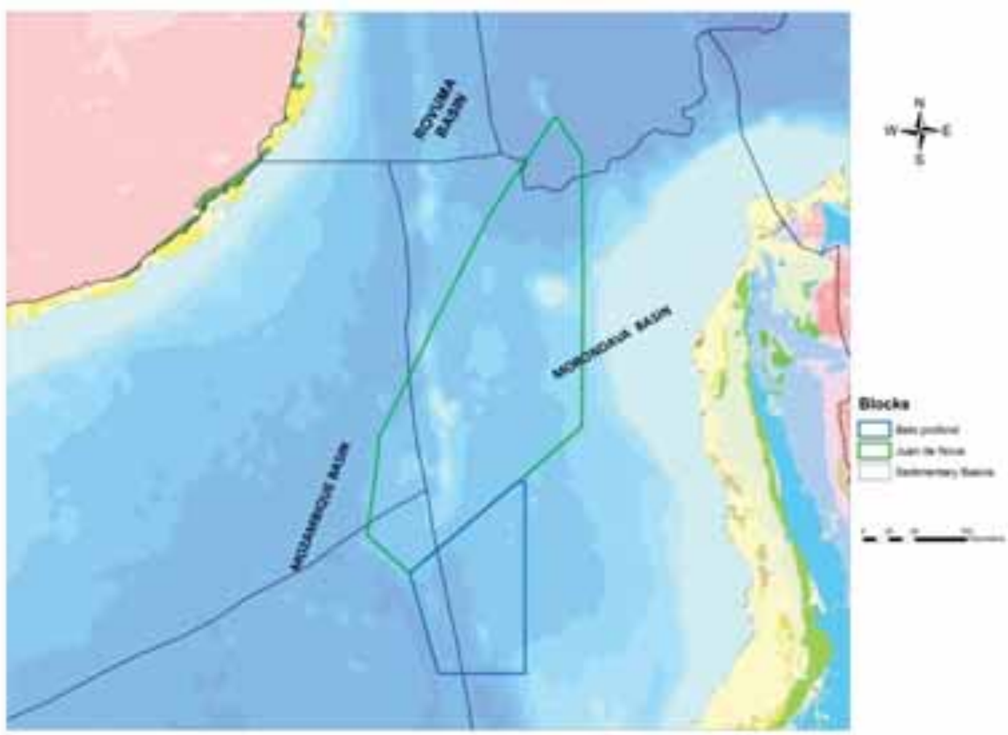

Fig 3.1 shows location of the study area overlying the corresponding basins. This helps in understanding the geology of the Area when interpreting survey results.

Before the Gondwana break-up in the Mid-Jurassic geologic period, Madagascar lay at the center of the Gondwana super continent with South America to the west, Antarctica to the southeast, and India and Australia to the east (GETECH, 2009). From the Late Cambrian – Late Triassic, intra-continental East African Karoo Rift Basins were created as a result of an earlier failed attempt at Gondwana break-up (Schandelmeier et al., 2004). The presence of Karoo sedimentary sequences in basins across continents including the intra-continental East African Karoo Rift Basins further provides evidence of this earlier failed attempt at Gondwana break-up.

The formation and development of the Morondava basin through different geological periods can be summarized in four major Periods;

- The Karoo Intra Continental Deformation
- The Early Jurassic Continental Break–Up and Early Drifting of Gondwana
- The Middle Jurassic – Late Jurassic Post Rift Phase 1 and The Aptian Post Rift Phase 2
- The East African Rift System

Although, the Rovuma and Mozambique basins have slightly different geologic structural settings from the Morondava basin, they also play significant roles in the development of these acreages.

3.2 Petroleum Geology

There have been no wells drilled in the study area yet. However, prospective exploration has proven significant discoveries in the region that shows existence of a working petroleum system comprising of Source, Reservoir, Seal, Trap, Maturation and Migration (GETETCH, 2009). This is well proven from nearby wells with minimal convincing gas shows from the Vacluse-1, Morondava-1 and Heliose-1 which were all incorporated into the study. Exploration wells and discovered accumulations on the continental shelf and upper slope (IHS Energy, 2009) provide evidence for the existence of an active petroleum system containing Mesozoic source rocks, the migration of the hydrocarbons most likely since the Late Cretaceous, and the migration of the hydrocarbons into Cretaceous and Cenozoic reservoirs, World Petroleum Resources Project (USGS, 2012).

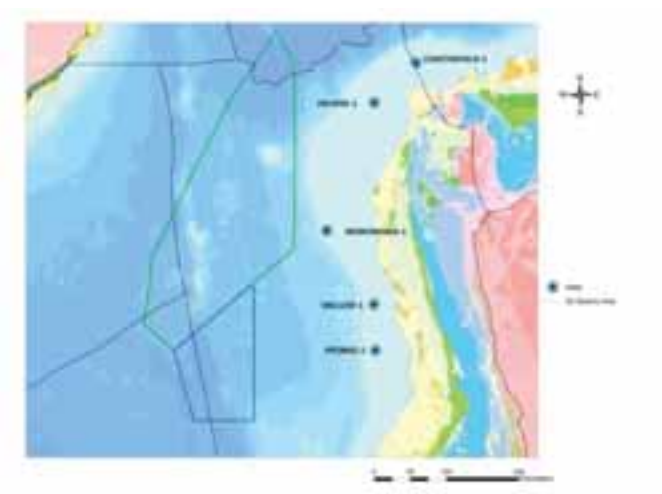

Fig 3.2 shows wells that have been drilled in the shallow-water region of the Mozambique Channel. Some of the wells have convincing gas shows and have been incorporated into the evaluation and study of the area. Others show wells used for detailed integration in interpretation of formation top on the seismic data.

4.0 Role of GIS

The study area is a frontier exploration venture in which different surveys were required to delineate the hydrocarbon prospect of the area. The surveys were done for reconnaissance and hydrocarbon detection which were integrated to give a qualitative interpretation and define petroleum system of the study area.

These surveys include:

- Satellite remote sensing data (Synthetic Aperture Radar (SAR) Imagery)
- Gravity
- Magnetic
- 2D Seismic survey and interpretation
- Geochemical slick sampling
- Seabed Coring

The surveys were analyzed spatially using the work flow below;

Data Acquisition → Geodatabase and Shapefile → Customization → GIS integration with other exploration tools → Maps and Analysis

The following objectives were achieved;

- Developing a working GIS database for the project.
- Integration of different spatial data set for proper analysis.
- Mapping and planning of new survey areas.
- Create accurate spatial information for use in other exploration software.
- To delineate spatial data along the boundary of the two acreages for proper positioning of seamless cross-border data sets.

4.1 *Developing a GIS database for the project;*

The creation of a GIS database in this project was driven by the need for a platform for mapping and visualizing spatial data sets. This database helped in presenting spatial data in different forms as required, such as maps, charts, data tables, and also culture files for integration with other software.

The different surveys were organized into GIS layers which consist of vector data and raster data to produce a GIS Database. From this database the first reconnaissance maps which would serve as a platform for further integration were produced. Using ArcGIS, shapefiles and feature classes were been built and designed for different spatial datasets. This was not aimed at replacing the modalities of all existing softwares or methods in analyzing spatial data but to enhance and provide a more central acceptable and integrative unit of analyzing spatial data. This has helped distinguish geologic trends in the acreages from different surveys and has greatly helped in achieving exploration objectives. The database would continually serve the working purpose of analyzing spatial data in further development of the acreage. Fig 4.1.1 shows the database as designed in Advanced ArcGIS for desktop.

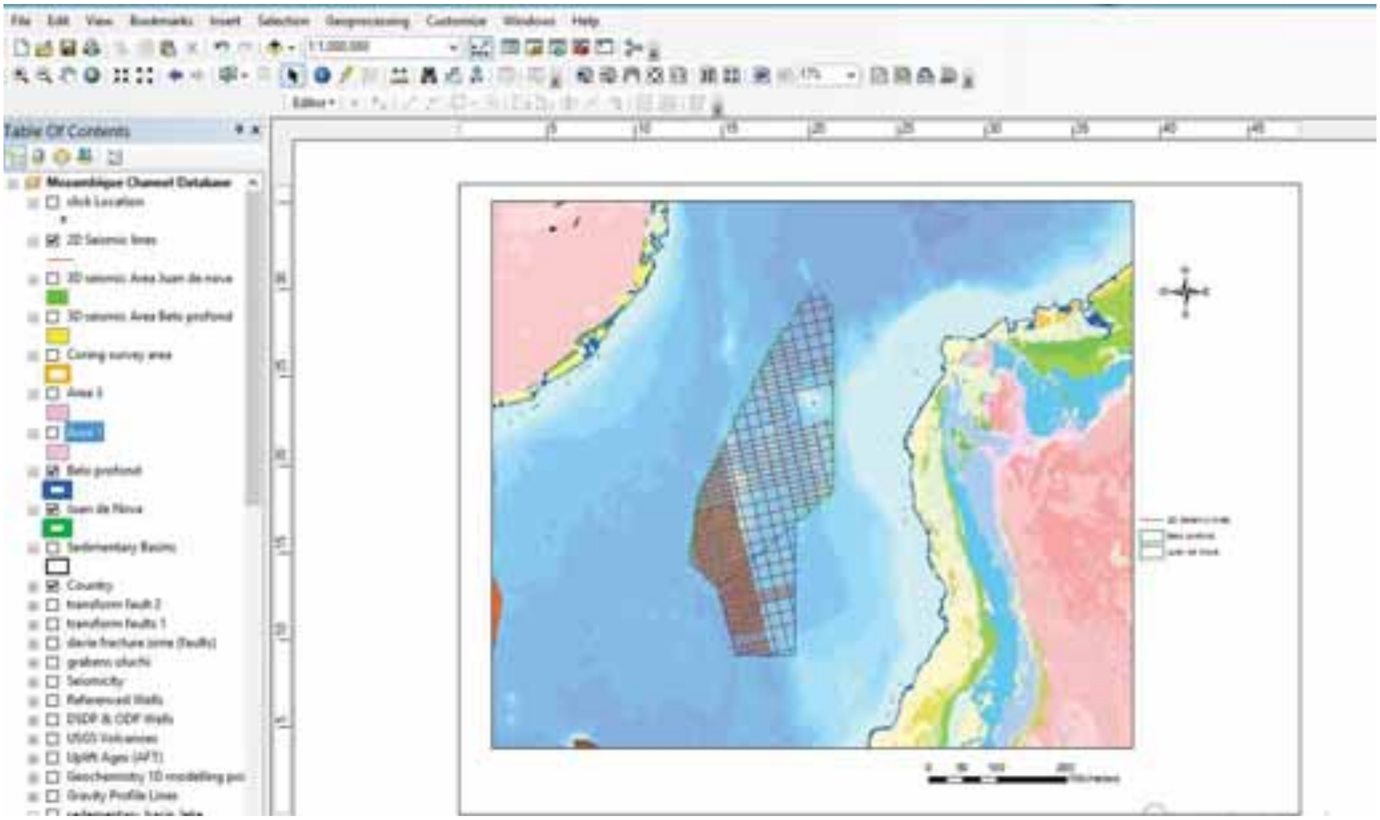

Fig 4.1.1 shows a screen capture of the developed database on Advanced ArcGIS for desktop software.

4.2 Integration of different spatial data set for proper analysis;

Different studies have been carried out by the team and results of these studies have shown prospective areas for further exploration. Prospective studies using 12,252 km 2D seismic lines (103 Pre-stack Time Migrated (PSTM) spanning 63,000 km^2), well data information, Geochemical slick samples, preliminary magnetic and gravity data and satellite remote sensing data was integrated to give a qualitative interpretation and in defining the petroleum system of the study area.

The ArcGIS built database enhanced the evaluation process to achieve its aims. Preliminary regional studies and spatial files from reports on the East African margin were used to understand the geology of the area. Spatial data from these reconnaissance surveys were integrated to give proper geologic meaning to the features seen in the acreage with respect to their locations. These studies helped in delineating hydrocarbon play, prospects and leads. The integration of spatial data from the different surveys helped in building confidence level of prospects seen on the surveys.

An example of such can be seen below, here integrating spatial data from imagery and other GIS data can increase confidence level of a prospect and lead to further exploration work.

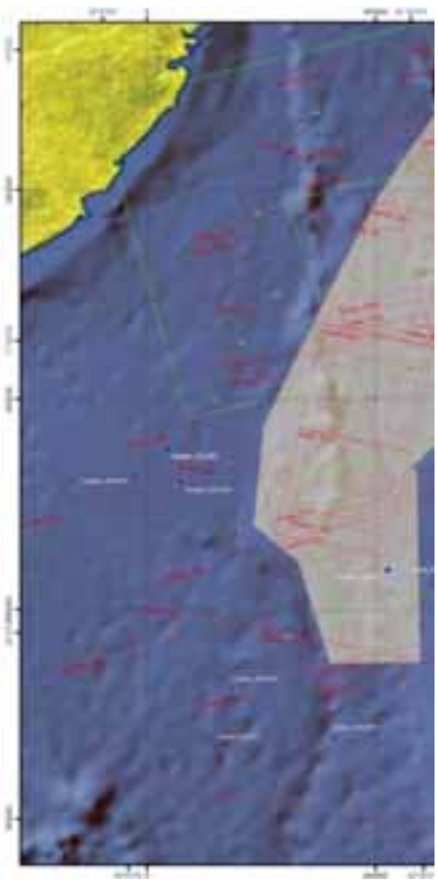

Fig4.2.1

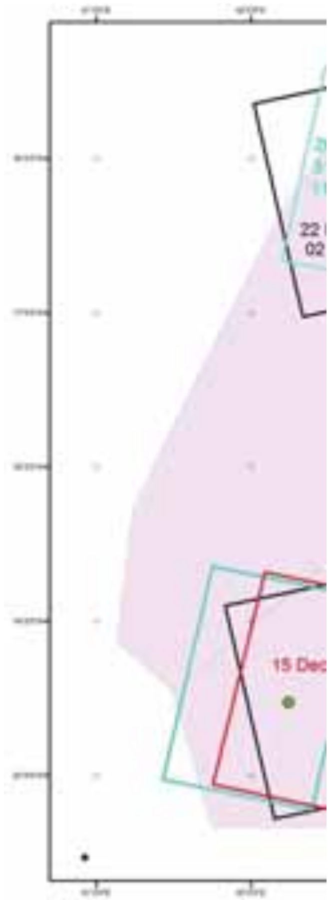

Fig4.2.2

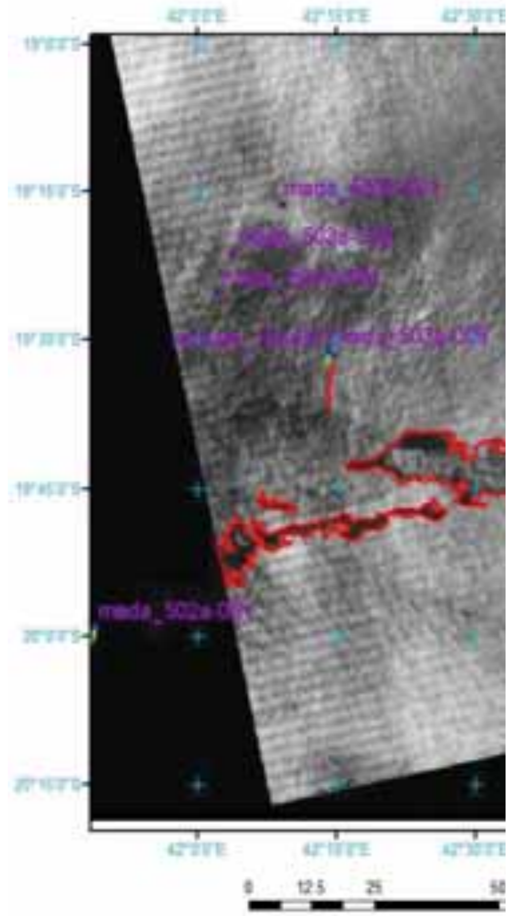

Fig4.2.3

Regional Multi-Year SAR Satellite Coverage Fig 4.2.1

New Custom Satellite Scenes Fig 4.2.2

Dec.2011 Image used to Locate Slicks 5 Days Prior to Sampling Voyage Fig 4.2.3

The fig 4.2.1 depicts the manner in which potentially important sea surface slicks were located for further study and sampling. An atlas of multiyear slicks visible on Satellite Synthetic Aperture Radar imagery was consulted to get these locations. New satellite coverage was commissioned from ASTRIUM Satellites by SAPETRO shortly before the voyage (fig 4.2.2). Fresh analysis using this imagery and locations confirmed a natural (non-anthropogenic) seep occurring in the area (fig 4.2.3). The area was sampled a week after the analysis in January 2012.

Fig4.2.4

Fig4.2.5

Fig4.2.6

Fig 4.2.4 shows the slick sampling locations on an operational scale mapped using GIS. A SAPETRO geologist is being sighted approaching from a downward direction near the front of the sampling vessel, which is moving slowly (less than 2 knots) through the slick Fig 4.2.5. The slick is sampled with an AGI module (Fig4.2.6) and the samples for Gas chromatograph-Mass spectrometer analysis.

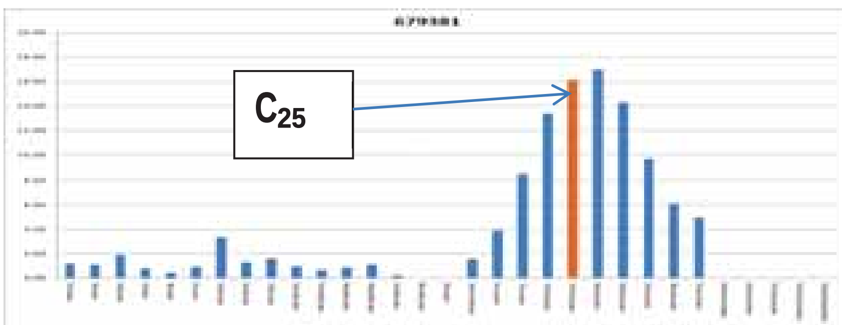

Fig4.2.7

Fig 4.2.7 shows MS molecular profile indicating heavy alkanes (Pentacosane C_{25}) currently associated with natural oil seeps.

GIS has made spatial data integration seamless and helped in achieving exploration goal. Further integration and analysis using seismic data was employed alongside the successful slick sampling studies and this created the need and confidence for further exploration work.

4.3 Mapping and planning of new survey areas;

Ongoing exploration work in this acreage has helped enhance exploration objectives, resulting in more concise cost effective and focused exploration. After the interpretation of the 2D seismic and other reconnaissance surveys, results seen have encouraged and developed more interest and confidence in further exploring the acreages. This in turn created the necessity of mapping out new areas for newer surveys to further understand and plan potential exploitation of the block. Using ArcGIS, areas for 3D seismic and shallow coring surveys were properly mapped. Mapping out of identified areas can be tricky when designing seismic acquisition area with respect to coordinates and economic objectives. GIS efficiently helps in achieving working maps that met these objectives, thereby reducing spatial assumptions during exploration interpretations and activities.

The illustration in fig 4.3.1 shows properly mapped area using GIS for seabed coring survey.

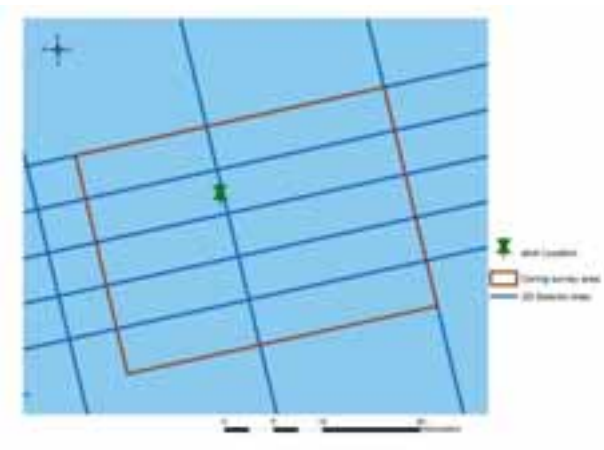

Fig 4.3.1

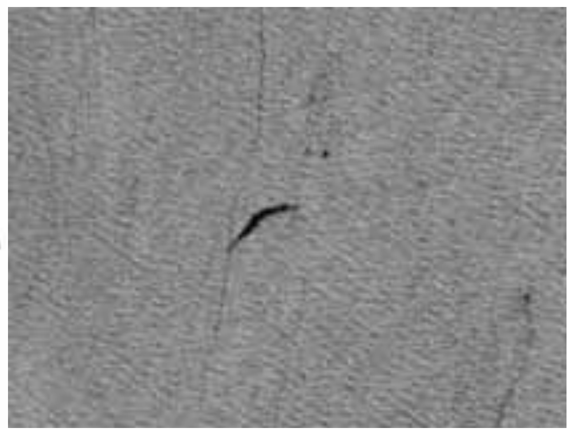

Fig 4.3.2

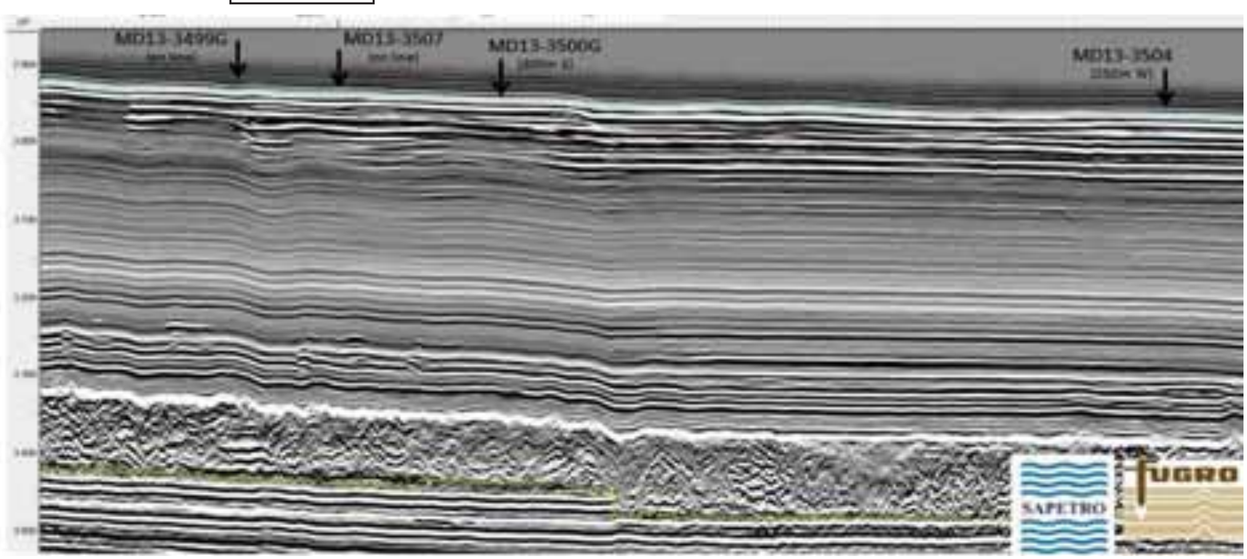

Fig 4.3.3

The Coring survey was done to collect possible larger oil samples in cores. Both 2-D seismic and the oil slick studies helped in effect to identify and sample the seabed features from which the surface slicks may have emanated. The seismic data in fig 4.3.3 shows faulting and possible seepage pathways. This locations on seismic were mapped to delineate coring area.

16 core totaling over 140 meters in length were collected in water depth of about 2200 – 2800 meters by the *R/V Marion Dufrense French Research Vessel*. Sample analysis is ongoing with some positive results emerging and all the core sample locations are already mapped in GIS for further analysis with results from ongoing 3D seismic program.

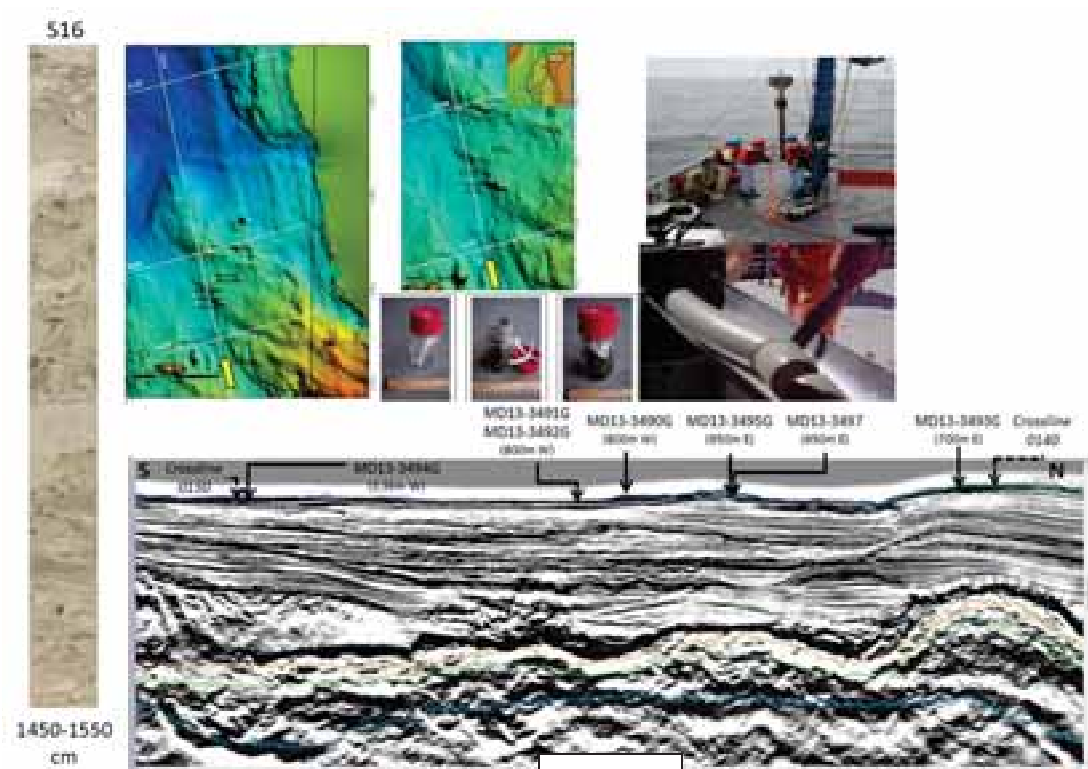

Fig 4.3.4

Fig 4.3.4 shows a Montage that depicts the entire coring/sampling process with locations seen on GIS close to 2D seismic lines on bathymetry maps. A cross section of the seismic is below the maps and operation pictures. A one-meter core from 15 cm below the seabed is shown at the left.

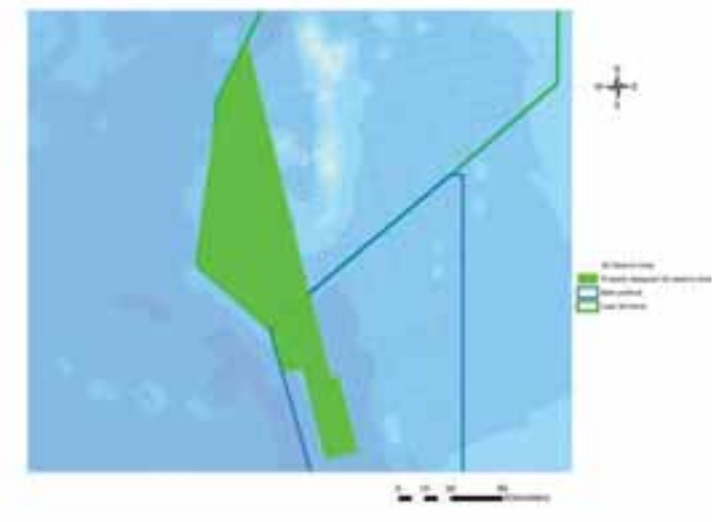

Fig 4.3.2 shows 3D seismic Area (Mapped area in green) properly mapped to meet exploration objectives using ArcGIS. Area extent and size can be tweaked easily to access targets seen during evaluation. This also helps in analyzing further cost and management when planning further exploration work.

4.4 Create accurate spatial information for use in other exploration software;

Spatial data files created using ArcGIS were imported into other exploration software as shapefile to serve as spatial control and also Quality check for spatial analysis. This helped in checkmating spatial errors that could be derived from data loading and interpretation during survey analysis. Another key factor this helped in achieving was that of creating limits and boundary focus for identified desired targets especially when analyzing potential hydrocarbon bearing structures and stratigraphic plays across 2D seismic survey lines.

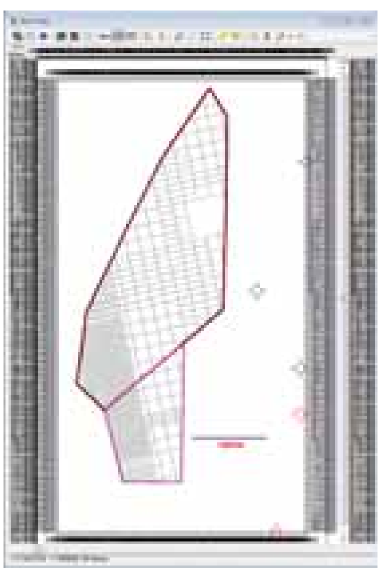

Fig 4.4.1 shows spatial file (Juan de Nova and Belo Profond blocks in brown and purple outlines respectively) from ArcGIS been imported into IHS Kingdom suite seismic interpretation software to serve as a control for coordinate discrepancy errors and also irregularities that may have occurred from data handling.

4.5 To delineate spatial data along the boundary of the two acreages for proper positioning of seamless cross-border data sets;

The two blocks within the acreage belongs to two National Authorities with a common boundary. GIS has served as an efficient platform for properly demarcating data limits and thereby producing accurate data delivery to different National Authorities. SAPETRO achieved excellent and seamless geophysical surveys (7202 Sq.km 3D survey Grid inclusive) data across borders which was properly divide using accurate spatial information from GIS.

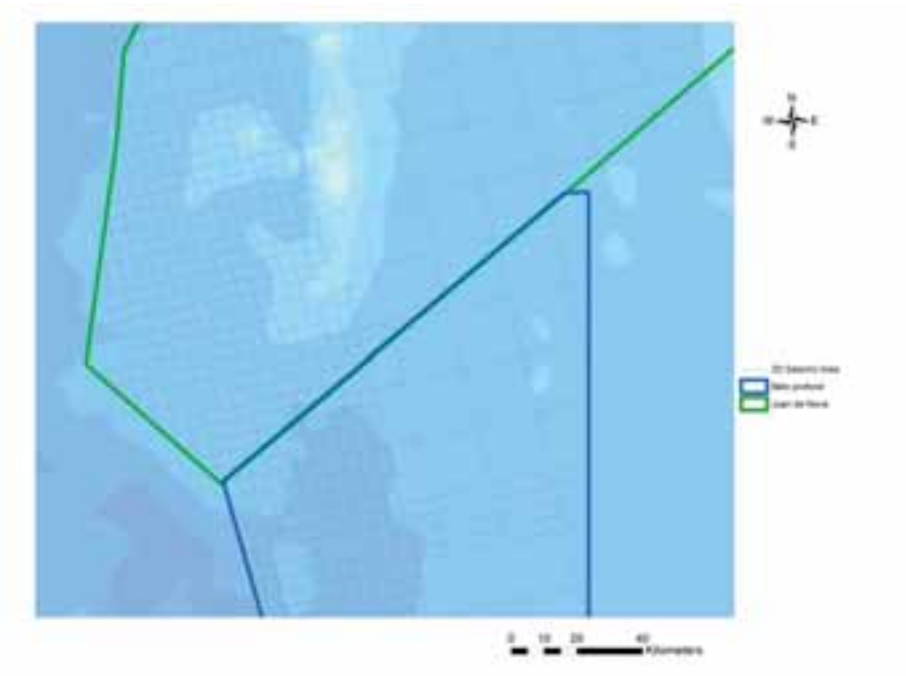

Fig 4.5.1 shows how both blocks in the acreage are delineated properly and demarcating spatial data from overlying 2D lines.

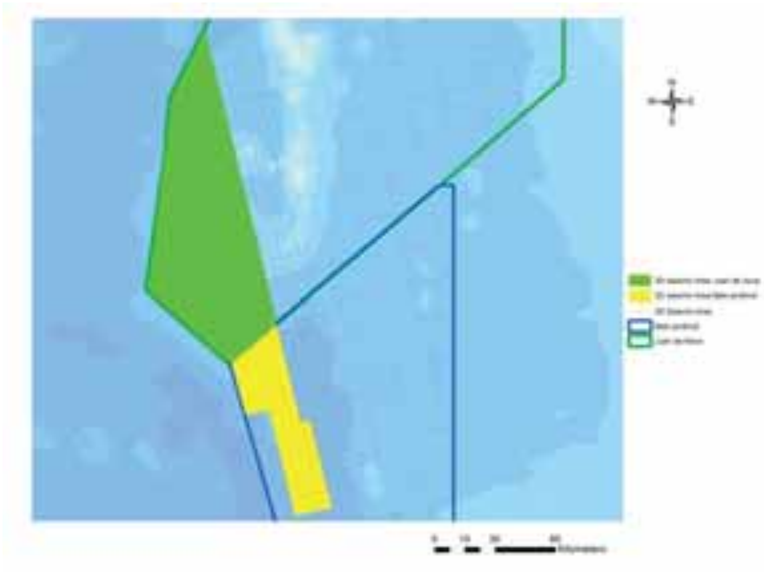

Fig 4.5.2 shows 3D seismic area of 7202 sq.km clearly and accurately demarcated spatially into the different dataset for the corresponding authorities.

Overall, developing and implementing GIS using ArcGIS for desktop into this project has helped in achieving set goals. Integrating spatial data from the Juan de Nova and Belo Profond blocks and regional studies through GIS has been successful in demystifying the hydrocarbon potential of the deep-water Mozambique Channel. This has been shown in the illustrations elaborated above and also continuous usage of GIS is expected to further enhance exploitation and development of the Acreage

5.0 Conclusions

Hydrocarbon exploration has gotten complex in recent years. More sophisticated methods and technology are employed to meet the teeming demands for success in the petroleum industry. GIS has proven to be one of the essential tools in holding the pieces together and has helped SAPETRO in unravelling the hydrocarbon potential of its frontier deep-water Mozambique Channel Acreage.

Utilizing GIS through the Advanced ArcGIS for desktop platform has aided in achieving exploration objectives. This can be seen in its application for visualizing spatial data in maps, data integration and evaluation processes. Another unique objective of the study area in which GIS has helped tremendously, is demarcating the international boundary in the acreage. GIS has been used in demarcating clearly the boundaries spatially during survey activities allowing for continuous ease of flow across international boundaries and meeting Government requirement for accurate requested data.

Acknowledgement

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