INTEGRATED APPROACH OF GIS AND GEOPHYSICS TO OIL-GAS EXPLORATION IN THE SOUTHEAST VIETNAM CONTINENTAL SHELF

Dr. Tran Tuan Dung, Trinh Hoai Thu

Institute of Marine Geology and Geophysics

Vietnamese Academy of Science and Technology

18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam

trantuandung@yahoo.com

ABSTRACT

Exploration for oil and gas always depended on many subsurface geological conditions. In this study, the authors have applied an integrated approach of GIS spatial analysis techniques with surface-subsurface geological and geophysical data for evaluating the oil-gas potential zones. GIS can be used to integrate information from the data layers, in which consists of well, gravity field, sediment, fault system, then combine them into a meaningful way to deal with the oil-gas exploration problem.

The oil-gas reservoirs have close correlations with gravity field, sedimentary thickness, and basement structure, faults system. These correlations were assessed and integrated for delineating oil-gas potential zones. The information layers above-mentioned are generated from the satellite-derived gravity in combination with seismic and other geological data.

The results presented in this paper prove the significance and importance of using a GIS integrated with surface-subsurface geological and geophysical data for inferring oil-gas reservoirs. The GIS environment can be used as an effective data management system throughout the oil-gas exploration. The results obtained have showed out the oil-gas potential zones detected are in agreement with the available seismic and well data in the middle Vietnam continental shelf.

1. INTRODUCTION

Application of GIS to the earth sciences facilitates data compilation and synthesis, permits explorative data analysis and modeling, and may reveal insights not readily obtained by more traditional means of data analysis and display. GIS is quickly becoming an integral part of many mineral resource management as well as oil-gas exploration. The common spatial analysis procedures in GIS are data interpolation, contour generation, buffer zone generation and thematic merging. Contour generation from grids of gravity anomaly, sedimentary thickness, basement structure, bathymetry etc. make for efficient comparison to point and line observations already loaded into the GIS environment. Merging functions allow two or more individual datasets to be combined for further analysis. The all important data analysis functions focus on developing and synthesizing spatial relationships of data in order to solve spatial problems in oil-gas exploration.

The study area is located in the southeast of the East Vietnam Sea bounded by longitudes 107^0.00'E, 110^0.00'E and latitudes 7°00'N, 11°00'N. The total geographical area of this area is about 128100 sq.km. The area covers a part of the Cuu Long, Nam Con Son basins and especially in the alternative part between two these basins. There have been a lot of oil-gas explorative wells that carried out in this area. The oil-gas discovered wells occupy a quite high ratio of the total of wells. In the region, according to the seismic, geochemistry and well data, numerous oil-gas reservoirs develop in the Eocene-Oligocene and the Early Miocene formation with the marine-river source, but lots of other reservoirs concentrate in the broken rock of the Pre-Cenozoic strata. The multiple oil-gas reservoirs are developing at different depths and connected together horizontally. The numerous studies pointed out that

the rocks fill up the garbens in the Eocene-Oligocene strata, which are contacting with the horst of carbonate basement rock, create the potential oil-gas reservoirs (Tran Khac Tan, Nguyen Quang Bo, 2002).

3. METHODOLOGY

Applying a methodology of interpretation of the geology-geophysical and well data in combination to produce a GIS database (thematic information maps) that is associated with oil and gas reservoirs. These maps can be listed: Well information, satellite-derived gravity anomaly, bathymetry, sedimentary thickness, basement structure, fault system, and normalized total gradient (NTG) of gravity.

Evaluate the spatial association of oil-gas reservoirs to these thematic maps. Integrate all the thematic maps in order to determine the optimum approach for detecting oil-gas potential zones and comparing with well data.

4. INTEGRATED GEOPHYSICAL AND GIS DATA

The thematic maps are prepared and integrated by some special geophysical software (NTG, GraMax, Gra3D…), Surfer and MapInfo. These thematic maps have the relationship with oil-gas reservoir at different levels. The maps can be listed as follows:

Well information; bathymetry; gravity anomalies; sedimentary thickness; faults system; NTG of gravity; basement structure.

a. Well information

In the southeast Vietnam continental shelf, there have been a lot of wells, which were drilled by Vietnam Petroleum Institute and the other companies, including both oil-gas discovered and undiscovered types. From these wells many oil-gas reservoirs have been found in the sedimentary basins and some of which also discovered in the upper part of Pre-Cenozoic basement. The information from the well data such as depth, location, and presence of hydrocarbon shows and tests, porosity distributions are used as a datum for creating and verifying the thematic maps and GIS database (fig. 1a).

b. Satellite-derived gravity anomaly

In this paper, the authors have used the satellite altimetry-derived gravity (Sandwell and Smith (1997, 1999) and available shipboard- gravity in the area. Gravity anomalies play an important role in discovering sedimentary basins and local structures with high oil-gas potentiality. Gravity anomalies caused by mass of density anomalies related to oil-gas reservoirs can be detected by means of gravity data analysis. Gravity highs typically occur over ranges where basement rocks are near the surface; gravity lows occur over basins filled with young, low-density volcanic and sedimentary deposits. Interpretation of gravity anomalies of possible oil-gas reservoirs is often carried out at the initial period of the exploration. Gravity anomaly map with grid interval 1'x1' is showed in fig. 1b.

c. Sedimentary thickness

In Vietnam continental shelf, many oil-gas reservoirs have been found in the sedimentary basins and in the upper part of Pre-Cenozoic basement. Previous researches also have shown out the correlation between the oil-gas reservoir and basement structure, the hydrocarbon migration is basement controlled. Therefore, the knowledge of composition, structure and depth of basement is crucial to any analysis of oil-gas resource.

In this study, the thickness of Pre-Cenozoic sediment is calculated by using seismic data and isostatic residual gravity anomalies (fig. 1c). Most of these data is collected from

seismic profiles of oil-gas surveys. For the areas that have no seismic data then inverse model of gravity anomalies is used.

d. Basement structure

On the regional scale, a structural high of Pre-Cenozoic basement must be in close proximity to a structural low. Structural highs of Pre-Cenozoic basement near structural lows are the preferred targets for oil and gas exploration. Structure of Cenozoic basement can be used to determine the preferred lateral hydrocarbon migration directions in a basin. Previous studies showed that the traps are mostly concentrated on steep flank of basement highs (IGC Foodnotes series, August 2000).

Here, basement surface is determined via inversion of a satellite-derived gravity and seismic data (fig. 1d). The basement structure is interpreted and classified, which is based on its slope, into three primary classes: a- on top of basement structural high; b- in steep and faulted flanks of basement structural highs; c- basement structural lows.

e. Faults system

The surface and subsurface faults system are interpreted from satellite-derived gravity anomalies and seismic data. Correlation between surface- subsurface faults system and subsurface oil and gas reservoirs were investigated. There is a strong association both in orientation and location between the linear features and the subsurface reservoirs. The faults analysis can be used for delineating oil and gas reservoirs in the area (Genliang Guo, Stephen A. George, 1999, Tran Tuan Dung et al, 2006).

The faults system map is established by interpreting the horizontal gradient and maximum horizontal gradient of satellite gravity anomalies and collecting information from seismic profiles of oil-gas surveys (fig. 1e). Faults system map have been analyzed using rose diagram. The main developed direction of the faults is northeast-southwest. The oil and gas potential zone in the area will be likely associated with the northeast- southwest surface-subsurface faults system.

f. Normalized total gradient of gravity anomalies

To detect the gravity anomalies caused by oil-gas reservoirs in the marine sedimentary basins, the normalized total gradient (NTG) of gravity anomalies method can be applied (Hualin zeng et al, 2002, Tran Tuan Dung, 2004). Previous studies have showed out that the closed minima of the NTG of gravity anomalies are associated and well coincided to known oil-gas reservoirs. The closed minima of the NTG of gravity anomalies allow indicating the existence as well as locations of the density deficient anomalies that closely related to the possible oil-gas reservoirs at different depths. In general, the NTG method can be used to choose the locations of oil-gas explorative wells to estimate the depth of the possible reservoirs and to detecting the oil-gas potential zones.

In this paper, the author has applied the NTG method for detecting the oil-gas potential areas in the southeast Vietnam continental shelf (fig. 1f). The achieved results are fully checked and confirmed by the seismic and well data.

g. Bathymetry

Bathymetric data is collected from various sources, from geology-geophysical surveys, oil-gas exploration that carried out by different organizations inside and outside Vietnam. All the data is merged into a unique form with high resolution and accuracy.

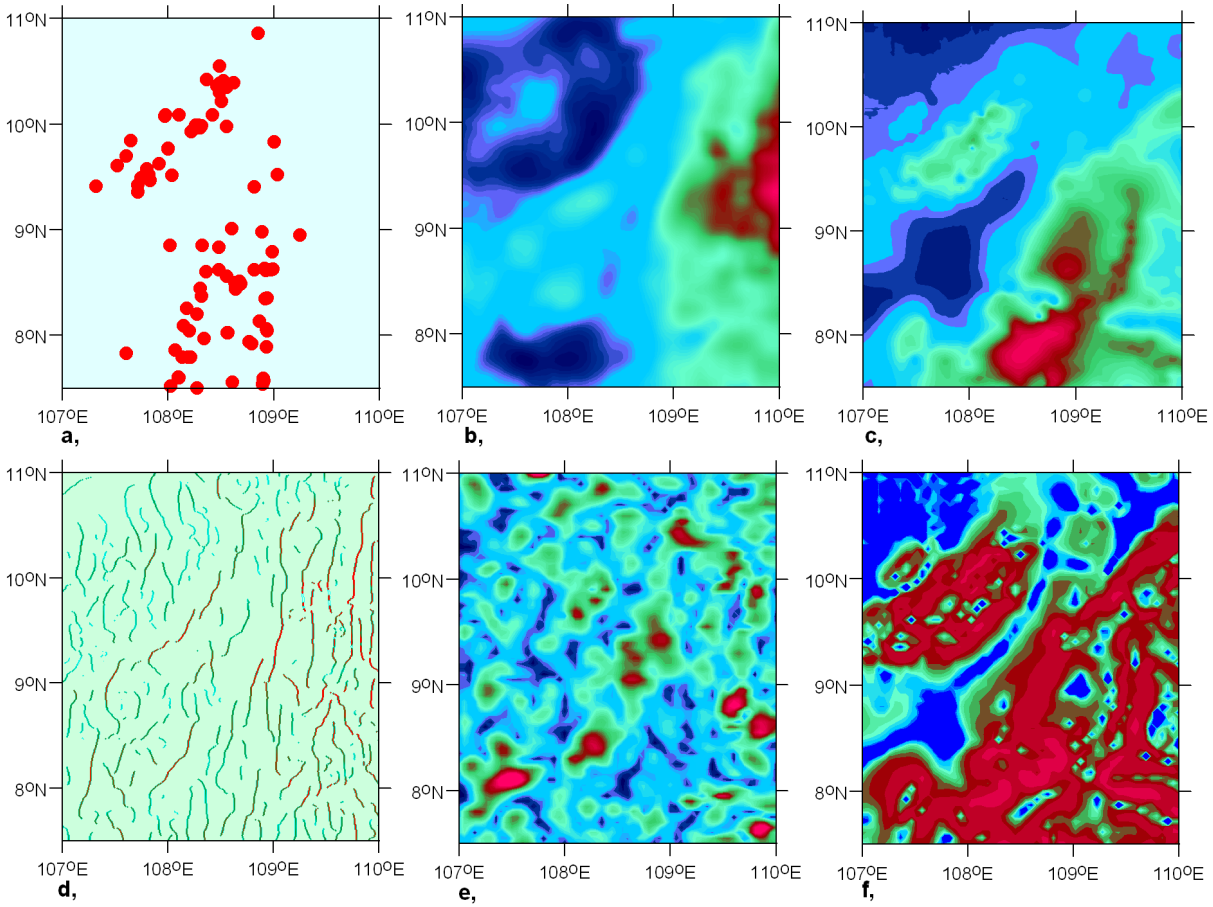

Figure 1. Thematic maps: a- Well information; b- Gravity anomaly; c- Sedimentary thickness; d- Faults system; e- NTG of gravity; f- Basement structure

5. DELINEATING OIL-GAS POTENTIAL ZONES

The delineation of oil-gas potential zones is based on above-mentioned multiple thematic maps (fig. 2), (Tran Tuan Dung 1996, 2005; P. K. Sikdar et al, 2004).

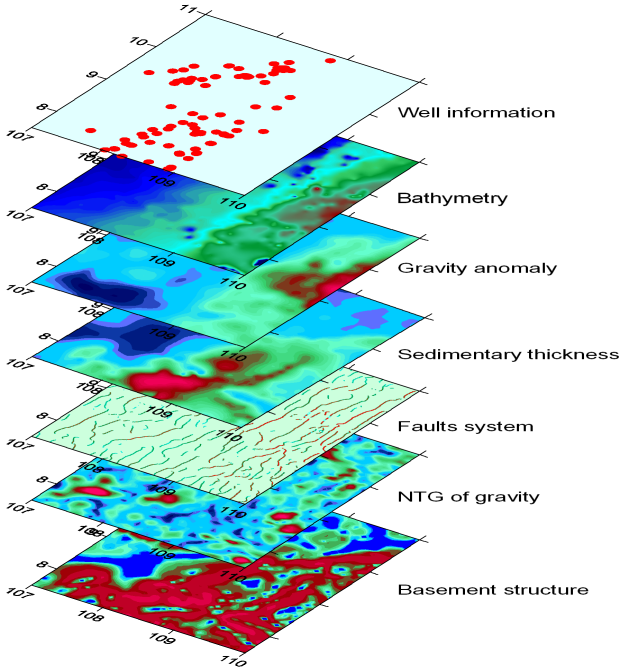

Figure 2. Integrated geophysical and GIS data

The oil-gas potentiality is a function of these thematic maps:

OG = f(Wl,Gra, De, Kz, Fa,Nor, Bs)

Where OG: Oil-gas potentiality; Wl: Well information; De: Depth, Gra: Gravity anomalies; Kz: Sedimentary thickness; Fa: Faults system; Nor: NTG of gravity; Bs: Basement structure.

The oil-gas potentiality in the area is evaluated for each thematic map on the basis of theory and real conditions in combination. The thematic maps have been ranked into a scale of 0 to 5 depending upon their suitability to oil-gas concentration. The different thematic maps have been assigned scores in a numeric scale 0 to 5 depending on their own properties. Now, the final oil-gas potential map can be defined as follows:

$$\overline{S} = \sum_i^n S_{ij} W_i$$

Where $\overline{S}$ - Weighted score for an area object in the final map; $S_{i,j}$ - Score for the j^{th} class of the i^{th} map. W_i - Weight for i^{th} map.

The resultant final weight map is integrated into grades (from low to high) to indicate the oil-gas potential zones in the southeast Vietnam continental shelf (fig. 3).

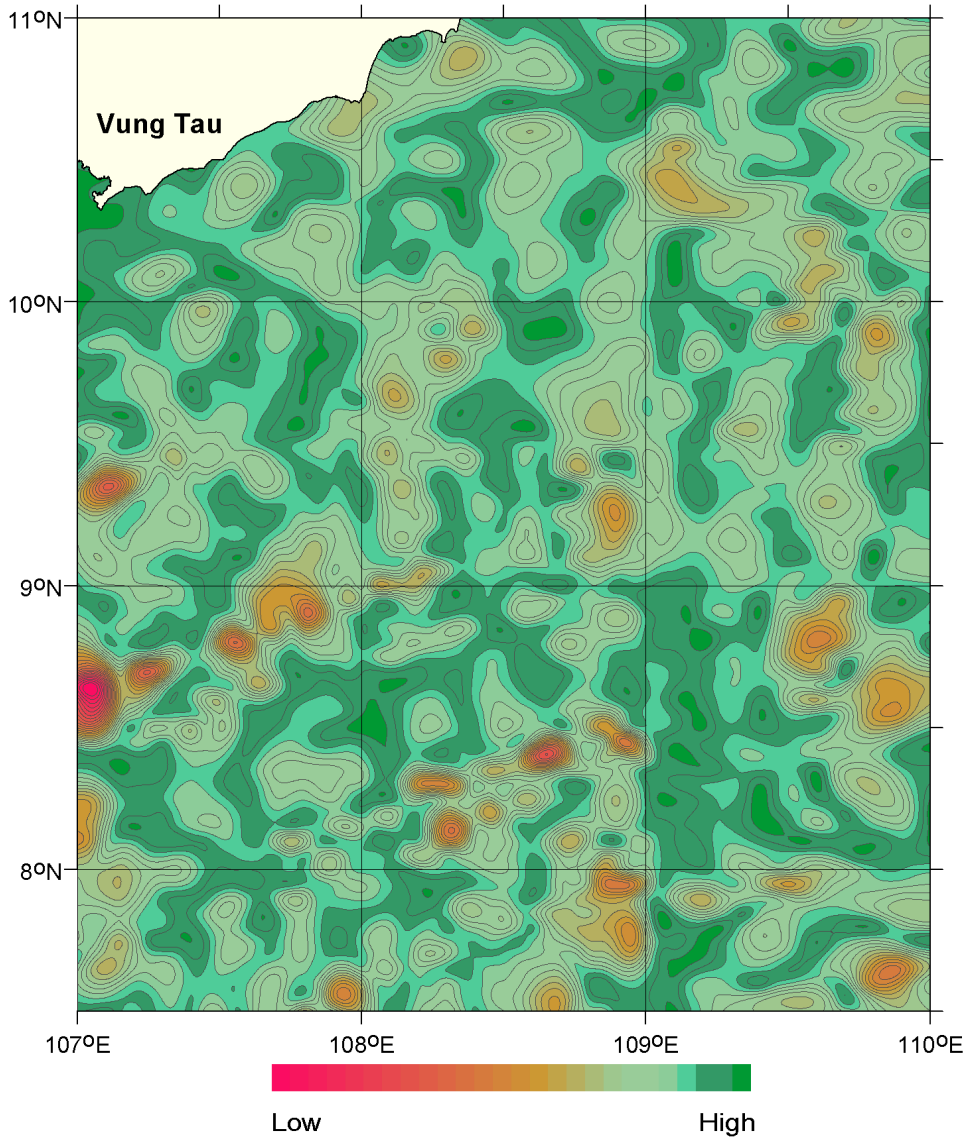

Figure 3. Oil-gas potential map in the southeast Vietnam continental shelf

6. CONCLUSION

The achieved results have manifested the oil-gas potential zones, which are detected through the integration of geographic information system and geophysics, are in agreement with the well and seismic data. It is very clear that almost of the known oil-gas discovered wells are coincided with the high potential zones in the southeast Vietnam continental shelf.

Integration of geographic information system and geophysics is a new approach that can be applied in oil-gas exploration in the Vietnam continental shelf. The results presented in this paper prove the significance and importance of the approach in delineating oil-gas potential zones, especially for offshore area. It is the best way to achieve information of oil-gas reservoir in acceptable time and cost.

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