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# Determing The Existence Depth Of Source Boundary

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***ABSTRACT:***

*The article introduce the rearch results of combination between methods to detect existence depth of source boundary. The methods is used here base on combination of derivation of the directional analytic signals amplitude of gravity gradient tensor and Euler deconvolution method with upward continuation method. Early results has built a deep fault segment diagram of faults system on the east sea. When we reference to faults system map which was built before. The results of the article has some advantages as follows :*

*1). By represents follow the depth of source boundary. The results supplement more information and do more clearly of the levels of faults system: 1$^{st}$ level fault, 2$^{nd}$ level fault, 3$^{rd}$ level fault.*

*2). The results had indicated multiple location on the continental shelf of Viet Nam that has depth above 20km, even over 30km as: The 109 meridian fault has Quang Ngai segment, Phu Yen-Khanh Hoa segment, Con Dao Island, Song Hau trench (segment below 7.5 latitude), Vung May trench, ...*

*3). The results also had indicated that the faults has depth in interval from 8km to 15km is prevail (55 %), while which has depth from 20km to 30km usage 8,7% and above 30km usage 4,75% (percent is caculated by point of data).*

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## I. INTRODUCTION

The faults system on the continental shelf of Vietnam in particular and on the East Sea in general is researched by many authors and it has been published by various documents by various methods by different data. From many publications that published on national and international journals had indicated that the methods are used plentiful from the use of standardized horizontal gradients: Berezkin, WM, 1967 [20], Aghajani.H, 2009 [16], Hoang Van Vuong, 2005 [15]. Horizontal gradient or maximal Horizontal gradient of Cordell, 1979 [22], Blakely, RJ, Simpson, RW, (1986 [21]), Tran Tuan Dung, [1],.. Analysis and using components of gravity gradient tensor : Beiki M, (2010,2011 [17,18]), Guo.CC, 2014 [23], Le Huy Minh [5,6], Vo Thanh Son [7,8], ... Not only on the reference books as well as on the reports of many projects also had shown that faults system is great interest: Nguyen Hiep, 2005 [4], Nguyen Trong Tin, 2010 [12], Mai Thanh Tan, 2005 [9], Phan Trong Trinh, 2012 [14] ... especially in the project of Nguyen The Tiep, 2006 [11] and Nguyen Thu Huyen, 2016 [3] has generalized and added more information about the faults system lay on the top of Pre-cenozoic basement or deep faults belong to the continental shelf of Vietnam, contributing to the clarification it's characteristics. However, the understanding of the faults system is not yet complete because we can only know a characteristic and can't know all its information. So, studying to provide more information about its characteristics is necessary. In this article, we present results of location and estimative existence depth of source boundary is determined based on application of gravity field transformations combine with the derivation of the directional analytic signs and Euler deconvolution method. For the results obtained, it is possible to predict about activity range and contribute to segments of real operation of the faults system on the continental shelf of Vietnam in the particular and on the general East Sea.

## II. THEORETICAL BACKGROUND.

Gravity gradient tensor (GGT) $\Gamma$ is determined as follows:

$$\Gamma = \begin{bmatrix} \frac{\partial^2 U}{\partial x^2} & \frac{\partial^2 U}{\partial x \partial y} & \frac{\partial^2 U}{\partial x \partial z} \\ \frac{\partial^2 U}{\partial x \partial y} & \frac{\partial^2 U}{\partial y^2} & \frac{\partial^2 U}{\partial y \partial z} \\ \frac{\partial^2 U}{\partial z \partial x} & \frac{\partial^2 U}{\partial z \partial y} & \frac{\partial^2 U}{\partial z^2} \end{bmatrix} = \begin{bmatrix} g_{xx} & g_{xy} & g_{xz} \\ g_{yx} & g_{yy} & g_{yz} \\ g_{zx} & g_{zy} & g_{zz} \end{bmatrix} \tag{1}$$

We might define an analytic signal for every single row, called directional analytic signals in x,y,y-, and z-direction. The directional analytic signal in matrix form can be written as:

$$\begin{bmatrix} A_x(x,y,z) \\ A_y(x,y,z) \\ A_z(x,y,z) \end{bmatrix} = \begin{bmatrix} g_{xx} & g_{xy} & g_{xz} \\ g_{yx} & g_{yy} & g_{yz} \\ g_{zx} & g_{zy} & g_{zz} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ i \end{bmatrix} \tag{2}$$

Consequently, the amplitudes of the directional analytic signals are:

$$\begin{aligned} |A_x(x,y,z)| &= \sqrt{(g_{xx})^2 + (g_{xy})^2 + (g_{xz})^2} \\ |A_y(x,y,z)| &= \sqrt{(g_{yx})^2 + (g_{yy})^2 + (g_{yz})^2} \\ |A_z(x,y,z)| &= \sqrt{(g_{zx})^2 + (g_{zy})^2 + (g_{zz})^2} \end{aligned} \tag{3}$$

Debeglia and Corpel (1997) showed that the derivatives of the analytic signal amplitude give a more efficient separation of anomalies caused by interfering structures than the analytic signal amplitude. Derivatives of directional analytic signals in x,y,y-, and z-directions can be expressed as:

$$\frac{\partial |A_\alpha(x,y,z)|}{\partial x} = \frac{\frac{\partial g_\alpha}{\partial x}\left(\frac{\partial^2 g_\alpha}{\partial x^2}\right) + \frac{\partial g_\alpha}{\partial y}\left(\frac{\partial^2 g_\alpha}{\partial x \partial y}\right) + \frac{\partial g_\alpha}{\partial z}\left(\frac{\partial^2 g_\alpha}{\partial x \partial z}\right)}{|A_\alpha(x,y,z)|}; \tag{4}$$

$$\frac{\partial |A_\alpha(x,y,z)|}{\partial y} = \frac{\frac{\partial g_\alpha}{\partial x}\left(\frac{\partial^2 g_\alpha}{\partial y \partial x}\right) + \frac{\partial g_\alpha}{\partial y}\left(\frac{\partial^2 g_\alpha}{\partial y^2}\right) + \frac{\partial g_\alpha}{\partial z}\left(\frac{\partial^2 g_\alpha}{\partial y \partial z}\right)}{|A_\alpha(x,y,z)|}; \tag{5}$$

$$\frac{\partial |A_\alpha(x,y,z)|}{\partial z} = \frac{\frac{\partial g_\alpha}{\partial x}\left(\frac{\partial^2 g_\alpha}{\partial z \partial x}\right) + \frac{\partial g_\alpha}{\partial y}\left(\frac{\partial^2 g_\alpha}{\partial z \partial y}\right) + \frac{\partial g_\alpha}{\partial z}\left(\frac{\partial^2 g_\alpha}{\partial z^2}\right)}{|A_\alpha(x,y,z)|}; \tag{6}$$

Where $\alpha$ is x, y and z indicator. Function that represents the combination of analytic signal derivatives $A_{xz}$ and $A_{yz}$ can be a function to detect the edges of source:

$$|ED| = \sqrt{|A_{xz}|^2 + |A_{yz}|^2} \tag{7}$$

ED function allows to detect edges of source better than HGA (horizontal gradient amplitude) function. HGA is a standard function which is widely used to detect edges:

$$HGA = \sqrt{(g_{xz})^2 + (g_{yz})^2} \tag{8}$$

Zhang et al (2000) showed that for GGT data, the standard Euler deconvolution can be extended to:

$$\begin{bmatrix} \frac{\partial A_x}{\partial x} & \frac{\partial A_x}{\partial y} & \frac{\partial A_x}{\partial z} & A_x \\ \frac{\partial A_y}{\partial x} & \frac{\partial A_y}{\partial y} & \frac{\partial A_y}{\partial z} & A_y \\ \frac{\partial A_z}{\partial x} & \frac{\partial A_z}{\partial y} & \frac{\partial A_z}{\partial z} & A_z \end{bmatrix} \begin{bmatrix} x_0 \\ y_0 \\ z_0 \\ n \end{bmatrix} = \begin{bmatrix} x\frac{\partial A_x}{\partial x} + y\frac{\partial A_x}{\partial y} + z\frac{\partial A_x}{\partial z} - A_x \\ x\frac{\partial A_y}{\partial x} + y\frac{\partial A_y}{\partial y} + z\frac{\partial A_y}{\partial z} - A_y \\ x\frac{\partial A_z}{\partial x} + y\frac{\partial A_z}{\partial y} + z\frac{\partial A_z}{\partial z} - A_z \end{bmatrix}; \tag{9}$$

For a window have N data points, equation (9) can be written as: $Gm = d$ (10)

and can be solved by the least-squares estimate $m^{est}$ as follows: $$m^{est} = \left(G^T G\right)^{-1} G^T d \qquad (11)$$

Where G and d are 3N x 4 and 3N x 1 matrices. Then the residual error of data is:

$$\Delta d = d^{pred} - d \quad (12); \qquad \text{where} \quad d^{pred} = Gm^{est} \quad (13)$$

Then, the covariance matrix of the estimate model is given as: $$\left[Covm^{est}\right] = \sigma_d^2 \left(G^T G\right)^{-1} \qquad (14)$$

where $$\sigma_d^2 \cong \frac{\sum_{i=1}^{N} \left(\Delta d_i\right)^2}{N} \quad \text{and} \quad \left[Covm^{est}\right] = \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} \\ c_{21} & c_{22} & c_{23} & c_{24} \\ c_{31} & c_{32} & c_{33} & c_{34} \\ c_{41} & c_{42} & c_{43} & c_{44} \end{bmatrix} \qquad (15)$$

and the standard error of source boundary location and structural index is given by :

$$\Delta r_0 = \sqrt{c_{11} + c_{22} + c_{33}} \; ; \quad \Delta n = \sqrt{c_{44}} \; ; \qquad (16)$$

*** Determining source boundary**: To determine source boundary, we determine maxima points of ED function (formula (7)) by using Blakely's method

*** Estimate depth of source boundary**: To rapid estimate the depth of source boundary, After m variable is determined according to (11) formula (m is a vector that contains 4 components, of which 1st, 2nd and 3rd components are the coordinates of source boundary and 4th component is the structural index n. For each m vector is a source boundary position and corresponding to a structural index), base on theorem of the Tikhonov's ill-posed problems, we have assigned the value of 4th component in the m vector (structural index) n:= 0.05 before enter calculating for formulas (13). By this way, we had tested success on modeling [2].

*** Detect about the existence of source boundary** : to perform this, the article combine derivation of the directional analytic signals amplitude of gravity gradient tensor and Euler deconvolution method with upward continuation method. Namely, we perform upward continuation at other elevations then Estimate depth of source boundary at each elevation. Collecting the depth obtained at other elevations and at each maximum point choice the depth value that is largest.

## III. DETERMINE LOCATION AND ESTIMATE EXISTENCE DEPTH OF THE FAULTS SYSTEM ON EAST SEA

### 3.1. Characteristics of deep faults system on the East Sea.

From many diagrams and maps of the faults system on the East Sea have been pointed out:

- The faults system on the central continental shelf is deep faults system that develops both length and width as well as depth. This system creates a powerful geodynamic regime and positive influence on both the land and continental shelf of Vietnam.

- The Vietnam continental shelf can be divided into at least seven regions with different faults structure. It is the northwestern of the Gulf of Tonkin, the southwestern of the Gulf of Tonkin, the northern part of the continental shelf, the Central Continental Shelf, the Cuu Long Basin, the Nam Con Son Basin and the Con Son Strip, the Northeast continental shelf of Thai Land Gulf.

- The north-east direction depth faults are the largest and most prominent. It is strongly influence on the tectonic change of East sea. It is faults system what along run the East sea axis, the faults system separates the center of the East Sea with the transition areas in the northwest and southeast. The faults system prolong from the northwestern part of Hoang Sa archipelago to Taiwan that dominates the Southeast continental shelf of China. The deep faults system prolong from the northwestern of Truong Sa archipelago and the deep faults system prolong and parallel to the coast of the Kalimanta and Palawan islands. These are deep faults system, have length of up to thousands of kilometers, and have the depth from 60-70 km to over 100 km.

- The deep faults what meridian direction are scattered on the East Sea, but are concentrated in two parts of Vietnam and Philippines. $109^0$E meridian fault on continental shelf of Vietnam and the deep faults system that the meridian direction and lie on the west sea coast of the Philippines is similar size.

### 3.2. Database

- The bougher gravity anomaly data source is used for the article is directly calculated from the satellite gravity data of Smith, WHF, and DT Sandwell (Version 20.1) and topography data (Version 15.1) [24]. It has the same ratio (one minute ratio, for this article, they is grided to 1:500.000 ratio for calculation).

### 3.3. Determine location and estimate existence depth of faults system.

To study the development of faults as well as their existence in the depth. Upward continue of observation field at different elevation levels (h = [10 20 30 40] km) is performed. At each of elevations, the location of source boundary was determined by the maxima points of the ED function (Equation 7), and the estimate depth was determined by the Euler deconvolution method according to Tikhonov's ill-posed problems. The results of the both boundary depth and location are shown in Figure 1. In which, the different colors represent different depths and the dots represent the boundary locaition respectively what is represented on XOY plane.

Observation of the results obtained (Fig. 1a) together with the sub charts (Fig. 1b, 1c) shows that the frequency of the different depths in which the depth from 10 to 15km is the dominant (approximate 55%), while faults has capable over 20km (approximate 13.5%) and over 30km are less than 5% (percent ratio is calculated by data points what the depth point appear per the depth point of the study area (from $100^0$ to $120^0$ E and from $5^0$ to $23^0$ N).

*** Question ?:** Maner of represents by upward continuation and by the depth is different ? It is really difference. Because, if we represents by upward continuation,we don't full identify geology characteristic of boundary (fig.2). But, if we represents follow the depth of source boundary, we can better imagine about geology structure characteristic (fig1, fig.3)

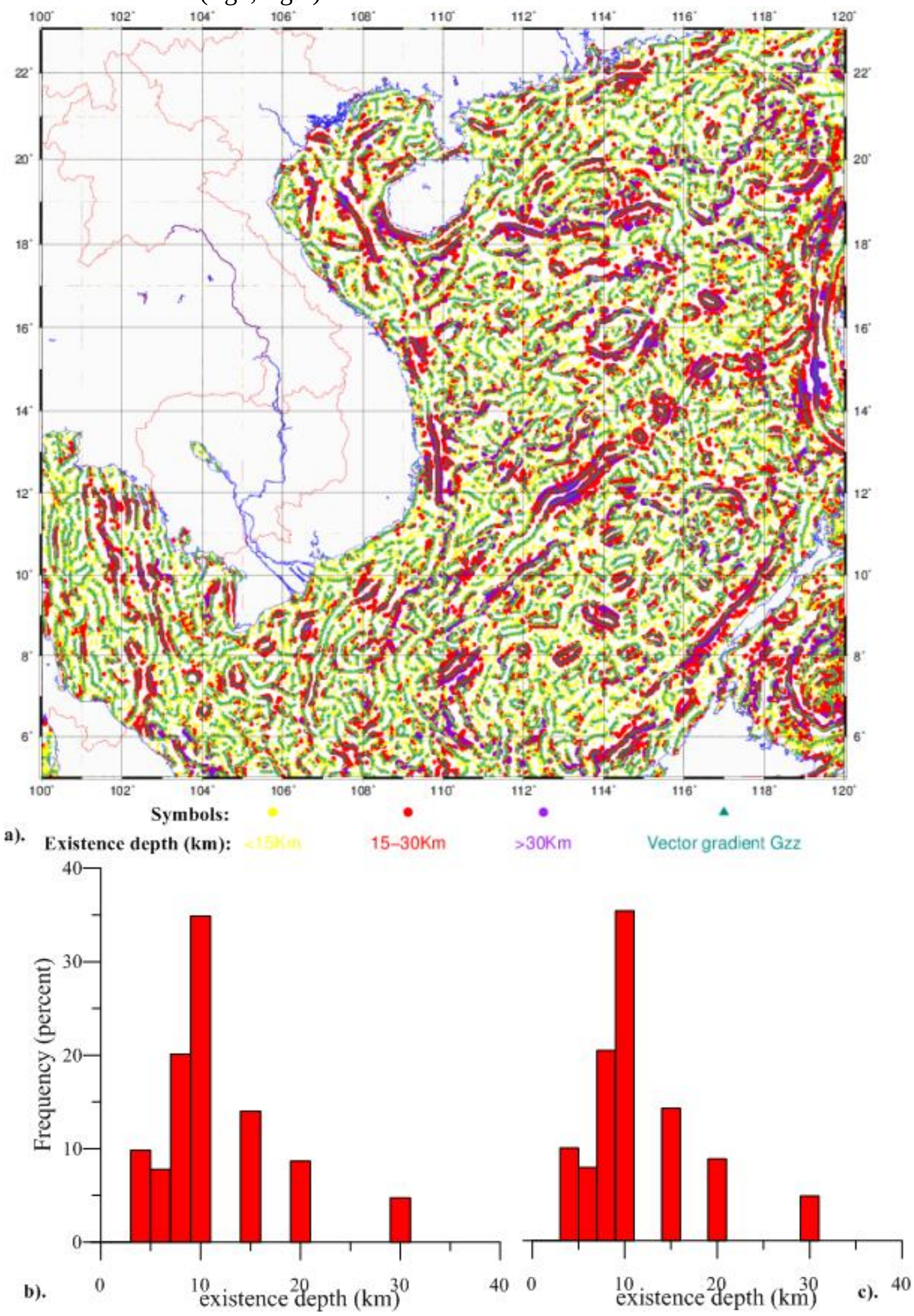


**Figure 1** : Diagram of the location and estimate depth of the source boundary on the East Sea

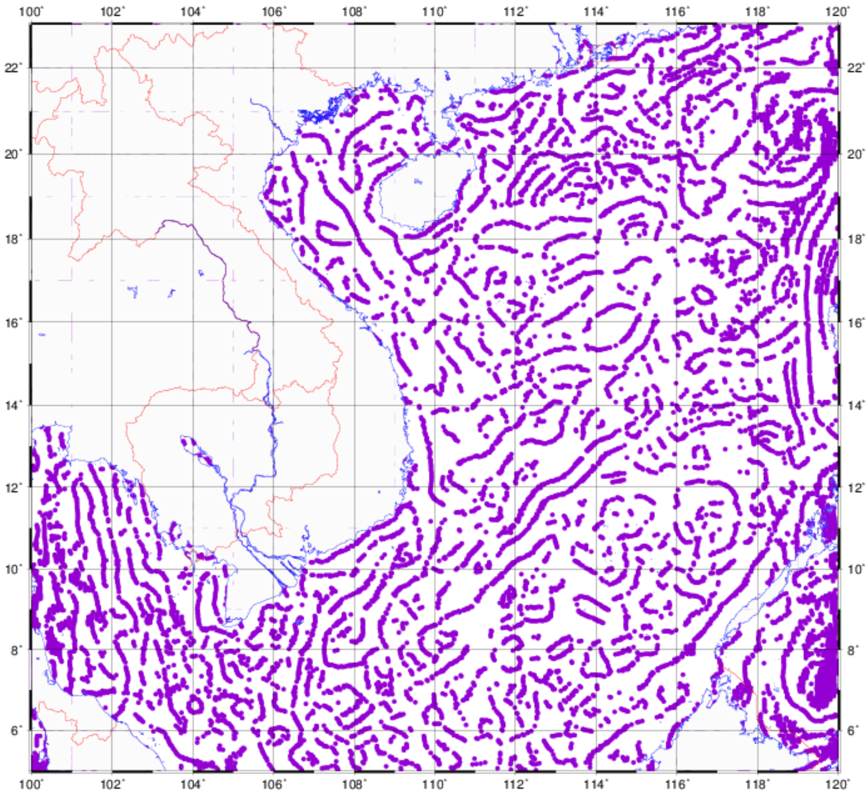


**Figure 2 :** Diagram of maxima points of ED function on the East Sea at 40km elevation levels

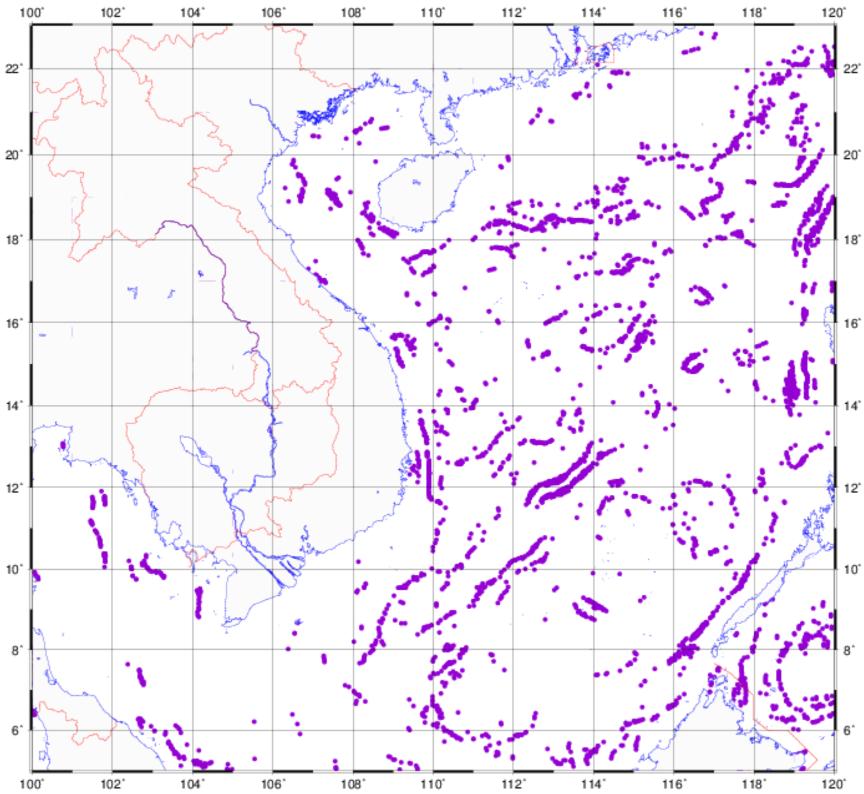


**Figure 3 :** Diagram of maxima points of ED function on the East Sea
that have depth larger 30km

## IV. DISSCUSSION

- On the continental shelf: along run the $109^0$ median fault (figure 4), according to the previous results, it is considered crust penetrating fault ($1^{st}$ level fault). But this results shows depth existence bellow 15km ($1^{st}$

and 2nd segment) and specialy on the 3rd segment it shows interruption of this fault (Tuy Hoa breakpoint), it is 30-40km long.

- The center of the East Sea: The extension shaft was not previously considered by the authors think that it is capability of crust penetrating (1st level fault). However, this result divede into two segment, in which, 1st segment (segment above) has the depth more than 30km and 2nd segment (segment underneath) has the depth less than 15km.

- In the Truong Sa and Hoang Sa archipelagos area, the source boundary exists in block form, there are many blocks in the Truong Sa archipelagos what has depth greater than 30 km, while the Hoang Sa archipelago has depth smaller.

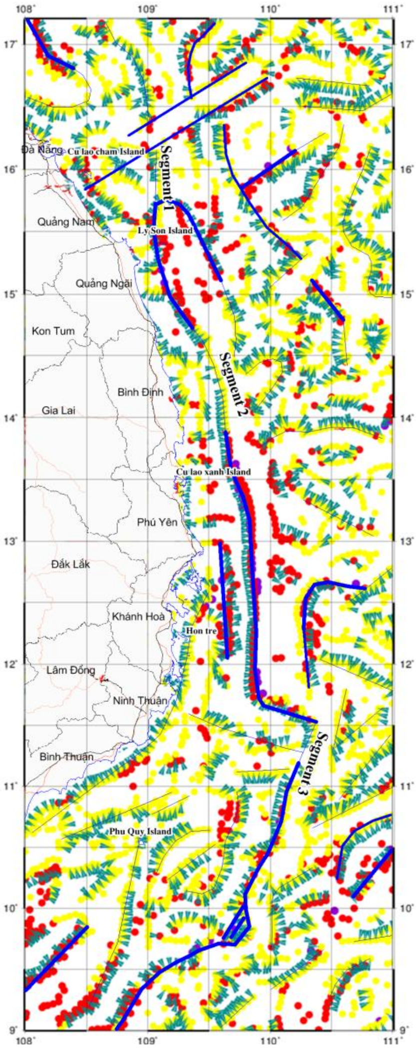


**Figure 4.** Results about location and estimate depth along the 109 meridian fault

## V. CONCLUSION

For the results that the article obtained. We has some conclusion as follow:

- Addition to information and do more clearly of segmentation of faults system: 1th level fault, 2nd level fault, 3rd level fault.

- The results had indicated some location on the continental shelf of Viet Nam that has depth above 20km, even on 30km as: Along $109^0$ meridian fault has QuangNgai segment, Phuyen-Khanhhoa segment, ConDao Island, Songhau trench (segment underneath $7.5^0$ latitude), Vungmay trench, ...

- The result also had indicated the faults that has depth in interval from 8km to 15km is prevail (55 %), while from 20km to 30km usage 8,7% and above 30km is 4,75% (caculated by point of data).


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## REFERENCE

[1]. Tran Tuan Dung, Bui Cong Que, et al, 2013. Cenozoic basement structure of the south china sea and adjacent areas by modeling and interpreting gravity data. Russian journal of pacific geology, vol 7, No.4, pp.227-236.
[2]. Nguyen Kim Dung, Do Duc Thanh, (2016), "Using the analytic signal method of gravity gradient tensor (GGT) to determine the location and depth of the faults in the Pre-Cenozoic basement rocks of the Red River trough", Vietnam Journal of Earth Sciences 38 (2), pp.143-152.
[3]. Nguyen Thu Huyen, Trinh Xuan Cuong et al. (2016), "Updating the structural map of the top of Pre-cenozoic basement base on the interpretation of 2D seismic data -PVN12", Petroleum Journal, No. 11,pp.16-20.
[4]. Nguyen Hiep (2005), Geology and Petroleum Resources of Vietnam, Vietnam Oil and Gas Corporation, Hanoi.
[5]. Le Huy Minh, Luu Viet Hung, Cao Dinh Trieu (2002), "Using the maximum horizontal gradient vector field to interpretation magnetic and gravity data in Vietnam", Journal of Earth Sciences, T.24 (1), pp. 67-80, Science and Technology Publishing House, Hanoi.
[6]. Le Huy Minh, Vo Thanh Son et al., 2005: The three-dimensional analytic signal method application to interpret the aviation magnetic anomaly map in Tuan Giao. Proceedings of the 4th geophysical scientific and technical conference of Vietnam. Publisher of Science and Engineering 2005.
[7]. Vo Thanh Son, Le Huy Minh, Luu Viet Hung (2005), "Determining horizontal position and the depth of the top of density boundary on Red River delta by vertical derivative methods and Euler's method by gravity data, Journal of Geology, Vol. A, No. 287, pp.39-52.
[8]. Vo Thanh Son, Le Huy Minh et al., 2007: Determining the location and depth of the contrast magnetic boundaries by using the 3D analytics signal method and higher derivatives. Proceedings of the 5th geophysical scientific and technical conference of Vietnam, pp.136-147.
[9]. Mai Thanh Tan (2003), Nation Oceanographic Research Program on Marine Science and Technology (1996-2000), East Sea III, Geology - Geophysics, Hanoi National University Publishing House, Hanoi
[10]. Hoang Dinh Tien, Hoang Thi Xuan Huong (2012)," Nam Con Son basin in geodynamic perspective", Petroleum Journal, No. 8, pp.15-23.
[11]. Nguyen The Tiep (2006), ATLAS for Natural and environmental conditions of Vietnam sea area and adjacent, KC.09-24 National Marine Research Program, phase 2000-2005.
[12]. Nguyen Trong Tin (2010), Report on synthesizing scientific and technological results of the project: Research on geological structure and assessment of oil and gas potential in Truong Sa and TuChinh - VungMay areas. Nation science and technology project KC.09-25 / 06-10
[13]. Cao Dinh Trieu, Nguyen Duc Vinh (2012),"Segmentation of fault for maximum earthquake assessment in Vietnam",Journal of Geology,No.331-332,Hanoi,pp.59-68
[14]. Phan Trong Trinh (2012),Young tectonic and modern geosynthetics on the Vietnamese sea and adjacent, Natural Science and Technology Publishing House, Hanoi.
[15]. Hoang Van Vuong (2005), "Expression of density boundaries according to GH extreme signal", Geological and geophysical research works, No.VI, pp.59-63, Natural Science and Technology Publishing House, Hanoi.
[16]. Aghajani.H, Ali Moradzadeh and Hualin Zeng (2009), " Normalized full gradient of gravity anomaly method and its application to the mobrun sulfide body, Canada", World applied sciences journal, Vol.6(3), pp.393-400.
[17]. Beiki M. (2010), "Analytic signals of gravity gradient tensor and their application to estimate source location", Geophysics, Vol.75(6), pp.159-174.
[18]. Beiki M. (2011), New techniques for estimation of source parameters, Uppsala Universitet.
[19]. Beiki M., Pedersen L.B. (2010), "Eigenvector analysis of gravity gradient tensor to locate geologic bodies", Geophysics,Vol.75(6), pp.137–149.
[20]. Berezkin.W.M.(1967), "Application of the full vertical gravity gradient to determination to sources causing gravity anomalies (in Russian)", Expl. Geopys.,18,pp.69-76.
[21]. Blakely R.J., and R.W.Simpson (1986), "Approximating edges of source bodies from magnetic or gravity anomalies", Geophysics,Vol.51(7), pp.1494–1498, doi: 10.1190/1.1442197.
[22]. Cordell. L, (1979), "Gravi Gravimetric expression of graben faulting in Santa Fe country and the Espanola Basin, New Mexico", New Mexico Geological Society 30th Annual Fall Field Conference Guidebook, pp.59-64.
[23]. Guo.C.C.,Xiong. Sh.Q.et al., (2014), "Improved Euler method for the interpretation of potential data based on the ratio of the vertical first derivative to analytic signal", Applied Geophysics,Volume 11(3), p.331–339.
[24]. http://topex.ucsd.edu/cgi-bin/get_srtm30.cgi.

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