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THE RESULTS OF DEEP MAGNETOTELLURIC SOUNDING FOR STUDYING THE NHA TRANG - TANH LINH FAULT

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ABSTRACT: The profile of deep magnetotelluric sounding (MT) from Duc Trong - Tuy Phong has been carried out in Lam Dong and Binh Thuan provinces. The length of the Duc Trong - Tuy Phong profile is about 80 km with 15 stations and the distance between the stations measures about 5 km. Two-dimensional MT inversion was used to find a resistivity model that fits the data. The 2D resistivity model allows determining position and development formation of the Nha Trang - Tanh Linh fault. This is the deep fault, which is showed by the boundaries of remarkable change of resistivity. In the near surface of the Earth (from ground to the depth of 6 km), the angle of inclination of this fault is about 60^o; in the next part, the direction of the Nha Trang - Tanh Linh faut is vertical. Geoelectrical section of the Nha Trang - Tanh Linh profile shows that the resistivity of mid-crust is higher than that of lower-crust and of upper-crust.

Keywords: Magnetotelluric, 2D resistivity model, fault.

INTRODUCTION

The magnetotelluric method in general is a geophysical method for studying the electrical structure of the Earth's crust based on the analysis of the transient variations of the magnetic and electric components recorded at the Earth's surface along two perpendicular horizontal directions. The method of deep magnetotelluric sounding is one of the geophysical methods with a surveyed depth up to tens of kilometers. The magnetotelluric soundings are used in many geological studies in the world [1-13]. This method has been applied effectively and provides new information on the structural characteristics and tectonic fault zone in the crust in some regions of Vietnam since the 1990s. In Vietnam, the magnetotelluric soundings have been carried out by Pham Van Ngoc et al., (1993, 1995) [14, 15], Van Ngoc Pham et al., (1993, 1994, 2002) [16-18], Nguyen Thi Kim Thoa et al., (1994) [19], Le Huy Minh et al., (2008, 2009, 2011) 20-22], and Vo Thanh Son et al., (2010, 2015) [23, 24].

The magnetotelluric Duc Trong-Tuy Phong profile in Lam Dong and Binh Thuan provinces has been carried out for the study of the state-independent project: “Research on earthquake and tsunami risks in Ninh Thuan and neighboring areas for the evaluation of the location of a nuclear power plant”. This paper presents the results of measurement, analysis and interpretation of the structural features of the Earth's crust in the study area.

INSTRUMENTATION AND MEASUREMENT TECHNIQUES

The instrument is a magnetotelluric station Géo-Instrument from the Institute of Physics of the Globe of Paris, France. The instrument consists of a central station, and other parts: electrodes, magnetic sensor, electrode wires, magnetic cabs,…. The electrode of MT is non-polarized electrode. The industrial electrode of the French manufacturer is very good (polarity voltage less than 1 mV), but the storage must be very careful, and very expensive; to reduce the cost, we made the electrode according to the method used at the Institute of Physics of the Globe of Paris with materials as plaster, the solution of PbCl2 and CaCl2. During the measurement and movement, electrodes are placed in water of clay to ensure good contact with the land, as well as being covered to prevent wind and rain. The electrodes must be carefully checked each morning before measurement and the polarity voltage of the pair of electrode is a few mV. For areas with high resistivity, large telua electric signals, telluric lines may only extend to 100 m; with low resistivity, small telua electrical signals, telluric line lengths must be increased to 160 - 180m; the place for measurement MT should be fairly flat. Before measurement, the polarity and the resistivity between the pairs of electrodes should be checked. If the polarization between the pairs of electrodes is less than 10 mV and the resistor is a few kΩ, the measuring process can get started.

The electromagnetic signal consists of two electrical components: Ex, Ey and two magnetic components Hx, Hy, which are inserted into the central station, after being amplified, filtered, displayed on the computer screen and recorded into memory. The Géo-Instrument magnetotelluric station can be amplified up to 3 million times, but with a 150m long telluric line maximum magnification of 30,000 times or less, this device is perfectly capable of recognizing an electromagnetic signal of a few thousands of mV. It should be noted that the higher the amplitude used, the greater the amplitude gain, the greater the measurement error. Therefore it is necessary to set the length of the telluric line enough, and to change accordingly depending on the point of measurement so that the gain does not have to be too large. In strongly disturbed days, strong electromagnetic signals, the amplitudes used are usually not as high as those of quiet days, the signal to noise ratio is large, so the magnetotelluric measurements in these days are relatively easy, the quality of data is usually better.

Magnetotelluric measurement points must avoid electromagnetic interference sources: residential areas, high-tension lines, industrial areas, roads, broadcast towers, especially telecom towers. Mangnetoteluric measurement is carried out only in weather conditions when it is not raining, no thunderstorm (source of electromagnetic wave due to lightning does not satisfy flat wave condition [1, 4, 6], no big wind). In the field, at each observation point, the NS-direction is chosen parallel to the profile, and the EW-direction is perpendicular to it. The working range of the Géo-instrument is 10^{-3} to 10^{3} seconds. In order to limit the measurement time and save the memory, French scientists have chosen the method of recording data in five cycles:

G1: from 10^{-3} to 10^{-1} second, sampling interval is 0.2 ms;

G2: from 10^{-2} to 1 second, sampling interval is 2 ms;

G3: from 10^{-1} to 10 seconds, sampling interval is 50 ms;

G5: from 1 to 100 seconds, sampling interval is 500 ms,

G7: from 10 to 1000 seconds, the sampling interval is 2500 ms.

RESULTS FROM THE MAGNETOTELLURIC DUC TRONG - TUY PHONG PROFILE

We measured 15 points on the Duc Trong - Tuy Phong profile. The length of the profile is about 80 km. The coordinates and names of each point of measurement are listed in table 1 and are shown in fig. 1. At each measurement point we measure two electric field components and two magnetic field components in two directions perpendicular to each other. A direction is chosen parallel to the structure

(N50°) called the NS component and a direction chosen perpendicular to the structure (N140°) is called the EW component. Each measuring point is carried out in five cycles: G1, G2, G3, G5 and G7 to cover the entire working telluric cycle (10^{-3} - 10^{3} sec).

Table 1. Coordinates of the magnetotelluric measurement points on the Duc Trong - Tuy Phong profile

Point	Coordinate		Height (m)
	Latitude	Longitude	
L01	11°35'20,46"	108°22'10,5"	910
L02	11°34'56,94"	108°22'40,08"	915
L03	11°34'49,56"	108°22'46,56"	915
L04	11°33'29,46"	108°23'25,86"	923
L05	11°35'32,1"	108°19'9,6"	895
L06	11°32'7,56"	108°23'12,3"	960
L07	11°35'53,7"	108°21'15,84"	917
L08	11°37'0,66"	108°18'28,14"	900
L09	11° 39' 19,98"	108°16'45,72"	835
L10	11°40'45,24"	108°15'1,44"	852
L11	11°43'42,66"	108°13'9,84"	945
L12	11°31'28,86"	108°25'57,84"	940
L13	11°17'13,98"	108°39'50,94"	60
L14	11°23'17,46"	108°38'2,28"	162
L15	11°23'39,84"	108°26'39,84"	100

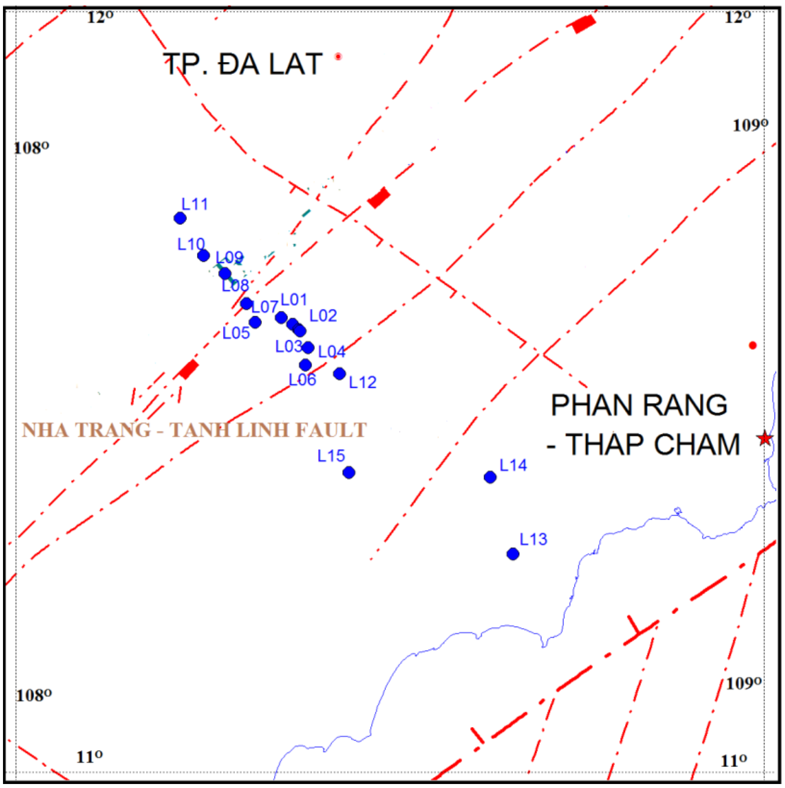

Fig. 1. Locations of the magnetotelluric measurement points on the Duc Trong - Tuy Phong profile

We draw the so-called pseudo-sections of the apparent resistivities of the EW component and the composition of NS line of Duc Trong - Tuy Phong profile. Pseudo-sections of the apparent resistivity of the EW component and the composition of NS of the profile Duc Trong - Tuy Phong are shown in fig. 2 and fig. 3. We can see that in most points on the profile the average frequency section has higher resistivity at high frequency and low frequency. The resistivity model of the Earth's crust will have three typical layers with resistivity at the top layer and bottom layer having a low resistance compared to the middle layer. On the profile there are the points that have lower resistivity than the surrounding points, for example the points L01, L02, L03, L06 and L09. We know that in the fault zones, the rock in the Earth's crust is broken out so that the resistivity at these zones is usually smaller than at the neighboring zones. Compared to other geological and geophysical signs, it can be concluded that the points L01, L02, L03, L06 near Nha Trang - Tanh Linh fault, particularly at the L06 point, low resistivity values occur in both low frequency and high frequency regions. Structural morphology of the two cross-sections is similar in form, which allows the measurement to have good quality materials, ensuring conditions for quantitative analysis.

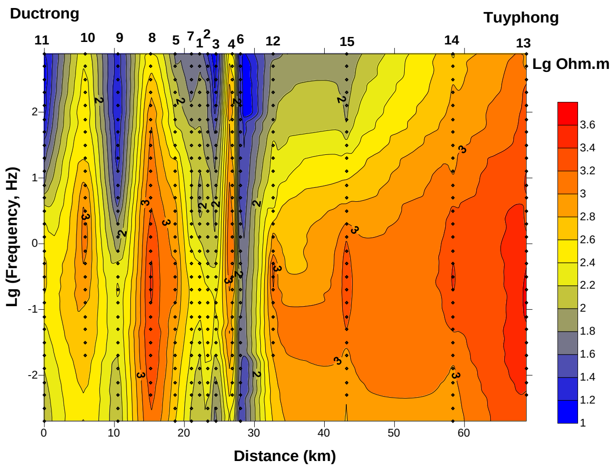

Fig. 2. Pseudo-sections of the apparent resistivity of the EW component of the Duc Trong - Tuy Phong profile

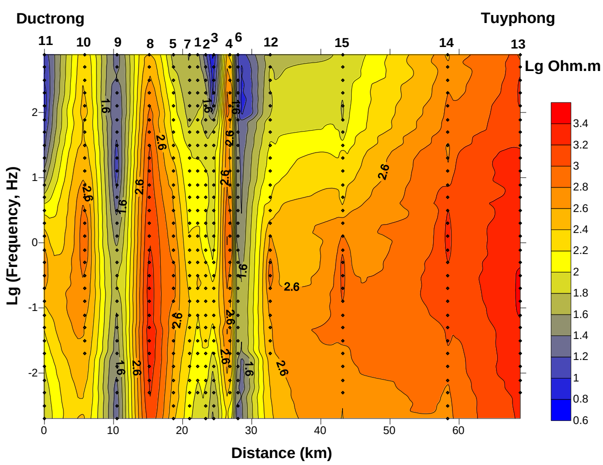

Fig. 3. Pseudo-sections of the apparent resistivity of the NS component of the Duc Trong - Tuy Phong profile

RESULT OF ANALYSIS BY 2D MODEL AND INTERPRETATION

The pseudo-sections of apparent resistivity demonstrate quite clearly the heterogeneity of the horizontal environment in relation to tectonic faults. Therefore, 2D document analysis is appropriate [5, 13].

We used Geotools software to allow the 2D inversion by Rapid Relaxation Inverse (RRI) [25,26] for the data MT of the Duc Trong - Tuy Phong profile. The analysis results by 2D inverse method with data measured on the Duc Trong - Tuy Phong profile are shown in fig. 4. We can see that the bottom crust has a resistivity of several tens Ω.m to one thousand Ω.m, which is lower than that in the middle crust (with resistivity from one thousand Ω.m to over three thousand Ω.m). The top crust at most points has lower resistivity than the middle crust (only from 50 Ω.m to one thousand Ω.m). Thus, the crust of the Earth on the profile is the typical Phanerozoic crust found in many places of the world. The boundary between the middle crust and the bottom crust is about 16 km, while the boundary between the middle crust and the top crust is nearly 1 km to nearly 2 km. According to geological information, the Duc Trong – Tuy Phong profile cuts through some faults, including Nha Trang - Tanh Linh fault. In figure. 4 we can see the manifestation of Nha Trang - Tanh Linh fault by the apparent change in resistance across the crust. The Nha Trang – Tanh Linh fault is plugged into the end of the profile to the depth of about 6 km, starting from near L01 point and extending down to L04 point; then at a depth of about 6 km below the L04 it is down to more than 20 km and has a nearly vertical orientation.

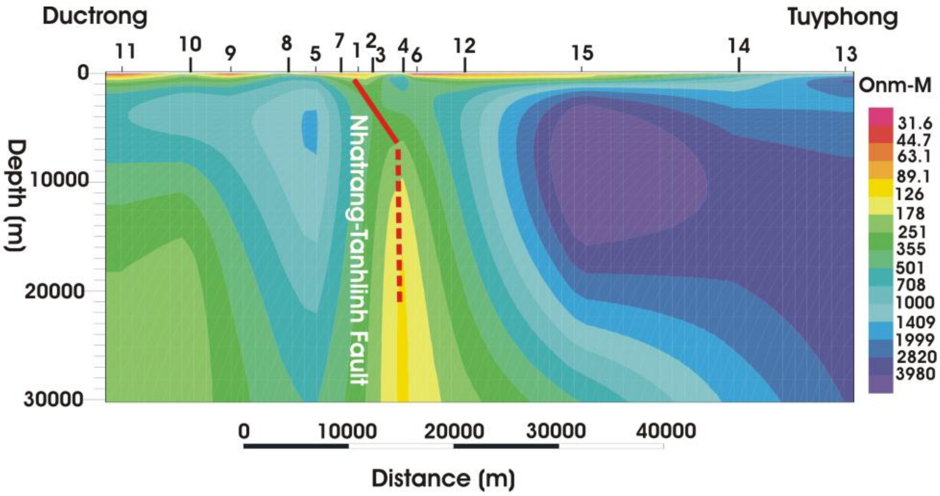

Fig. 4. The geoelectrical section of the Duc Trong - Tuy Phong profile

CONCLUSION

The magnetotelluric Duc Trong - Tuy Phong profile has been carried out with 15 measurement points in the area of Lam Dong and Binh Thuan provinces. The reverse 2D result by the Rapid Relaxation Inverse method has built the geoelectrical section of the Duc Trong - Tuy Phong profile. The geoelectrical section of the Duc Trong - Tuy Phong profile shows the apparent manifestation of the Nha Trang - Tanh Linh fault. However, the manifestation of Nha Trang - Tanh Linh fault on the Duc Trong - Tuy Phong profile is quite complicated. On the other hand, the resistivity of the Duc Trong - Tuy Phong profile is quite low. On the Duc Trong - Tuy Phong profile, the geoelectrical structure of the Earth's crust has three typical layers, with the middle layer having higher resistivity than the upper layer and lower layer. The conductivity structure of the Earth's crust on the Duc Trong - Tuy Phong profile is the typical Phanerozoic crust found in many places of the world.

The magnetotelluric method and magnetotelluric equipment of the Institute of Geophysics have been effective in studying the deep crust structure of the Earth and identifying the structural elements of the tectonic fault zone and may be applied to other areas in the territory of Vietnam.

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