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Deep geological structure of An Chau trough base on new study data

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ABSTRACT

An Chau trough with an area of about 10,000 km² located in the Northeast of Vietnam is the southwest tail of the Mesozoic Thap Van Dai Son basin and has a complex geological structure. The geological structure of An Chau trough has been studied since the 70s of the last century, however, previous studies were mainly surface geological studies. Deep structure studies only based on measurement gravity data at the scale of 1/200.000 with outdated machinery, equipment and processing technology. With the goal of re-searching, investigating and surveying oil and gas resources, from 2013 to 2017, Vietnam National Oil and Gas Group has deployed measuring over 9,000 km of the Airbone high-resolution Mag-Gravity survey with the resolution of measuring points on the measure-line from 6 m to 7 m/point, more than 450 ground gravimetric points and acquiring over 1,000 km 2D seismic survey. All magnetic-gravity and seismic data collected in the field is then processed at processing centers with modern technology such as Sander Geophysics - Canada, Institute of Geophysics - VAST, CGG Veritas Singapore. The results of interpretation and integration of these new documents together with the previous geological documents have initially allowed to identify and construct a deep geological model of An Chau trough. The results of this study will help clarify the history of geological development of the study area based on evidences that can only be observed on seismic data. Inaddition, these results also help to make orientation for explorating mineral resources in general and oil and gas resources in particular.

1. Introduction

Mesozoic An Chau trough is located in the Northeast of Vietnam with an area of about 10,000 km² and spreads over the provinces of Bac Giang, Lang Son and Quang Ninh. An Chau trough boundary to the northwest is the C-P limestone mountain range of Bac Son formation, to the south and southeast are the coal-bearing molas formations of Hon Gai formation and

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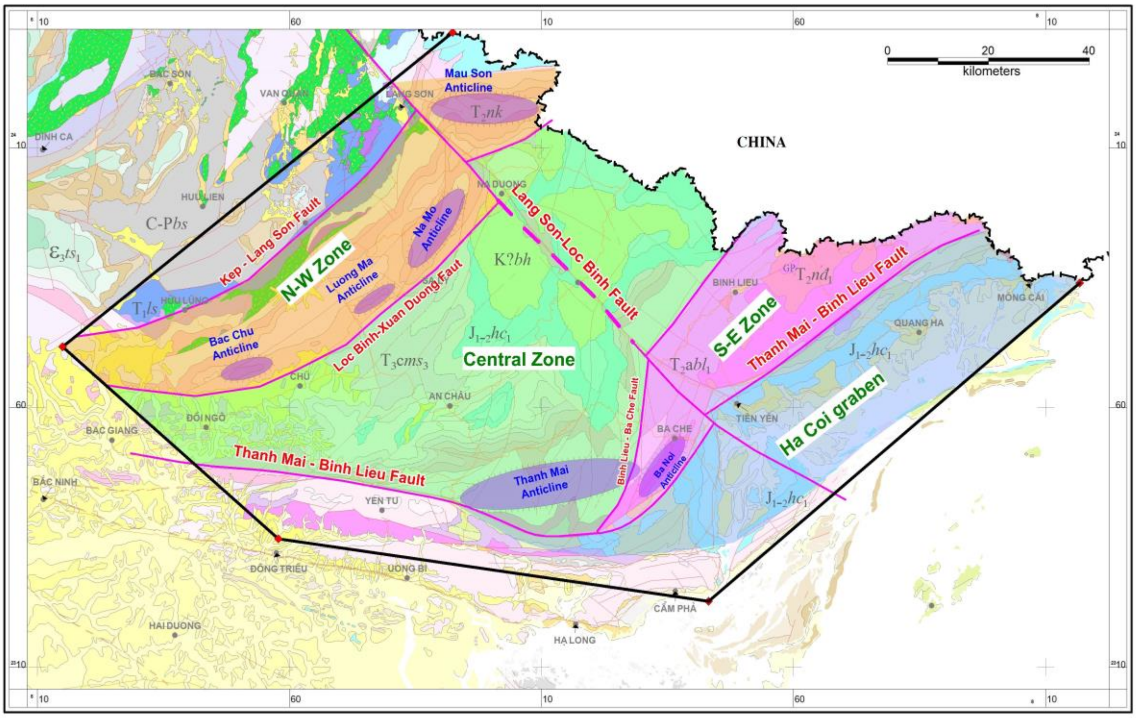

Figure 1. Geological map and structural zoning of An Chau trough.

metamorphic sediments aged O_3-S belongs to Tan Mai formation. An Chau trough is spreaded to the northeast to China (Figure 1).

The previous research results, which are mainly based on the surface data information, have divided An Chau basin into 03 structural zones: The Northwest zone, the central zone and the Southeast zone (Nguyen, 1970; Nguyen, 1971; Ngo, 1970; Vu, 2012). The boundary of these structural zones are faults/fault systems: Kep-Lang Son, Loc Binh-Xuan Duong, Thanh Mai-Binh Lieu and Binh Lieu-Ba Che (Figure 1).

The results of interpretation and integration of the magnetic-gravity data suveyed in 2013 (PVEP Songhong, 2014), seismic data acquired in 2017 (PVEP Songhong, 2018, 2019) and geological documents allow: (1) Accurating fault system as well as the role of the faults/fault systems in the structural zoning; (2) Zoning structures in detail; (3) Recognizing some deep structures; and (4) Precising the thickness of Mz sedimentary section.

2. Database and research workflow

2.1. Data base

The main data base used for this paper include:

- Approximately 9,000 km of high resolution aero gravity-magnetometers with a network of 1.5 x 5 km lines and over 450 ground gravimetric points (Figure 2). The recorded data is then calibrated, processed and mapped the Bouger gravity anomaly, magnetic anomaly and specialist maps (Gradient, Gradient Max, ect) (Figures 3a,b).
- Over 1,000 km of regional 2D seismic lines with a network of about 15 x 20 km covering the entire An Chau trough area (Figure 2).
- Geological maps with scale 1/200,000 in An Chau trough area (Hai Phong sheet, Hon Gai sheet, Lang Son sheet and Mong Cai sheet) and other reports, technical papers, sample analysis, synthetic stratigraphic columns, ect.

2.2. Workflow of research

1) Using the magnetic-gravity data in combination with surface geological data to identify fault systems, dip direction of faults, especially main faults.

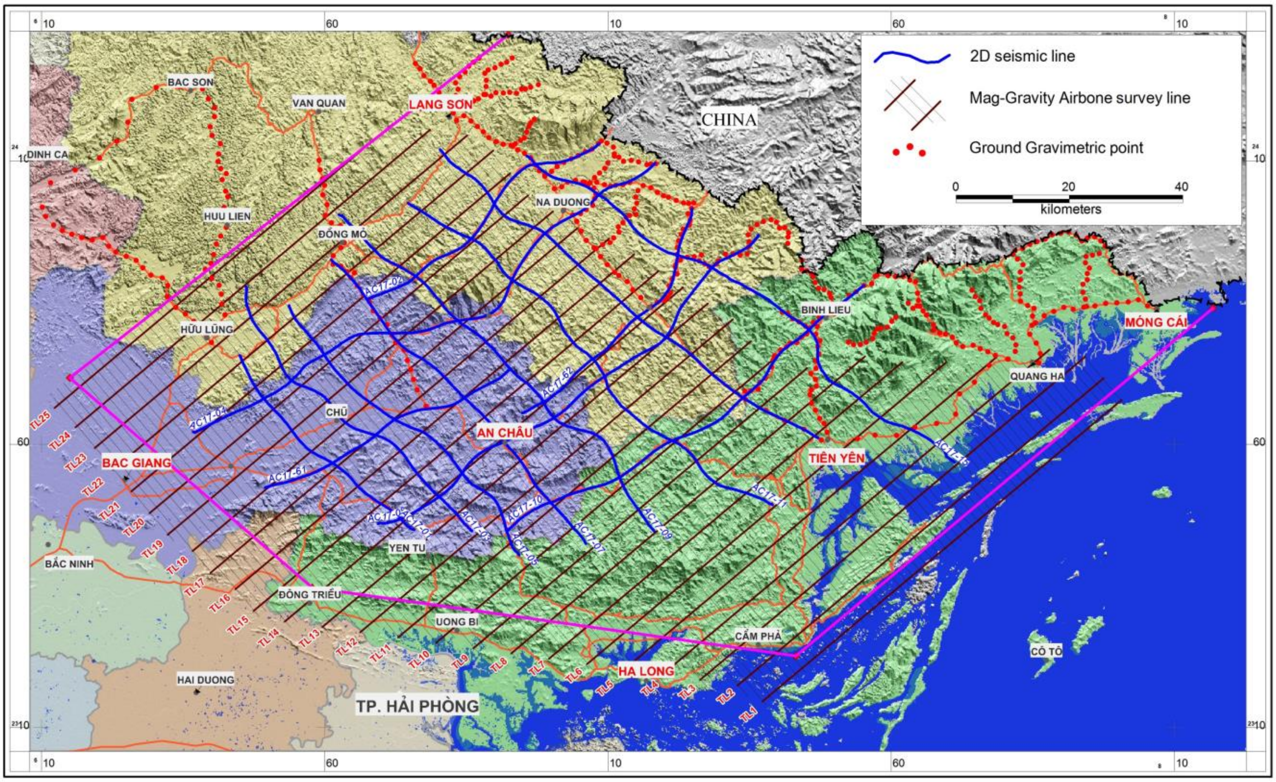

Figure 2. Seismic acquisition lines and Mag-Gravity survey lines in An Chau trough.

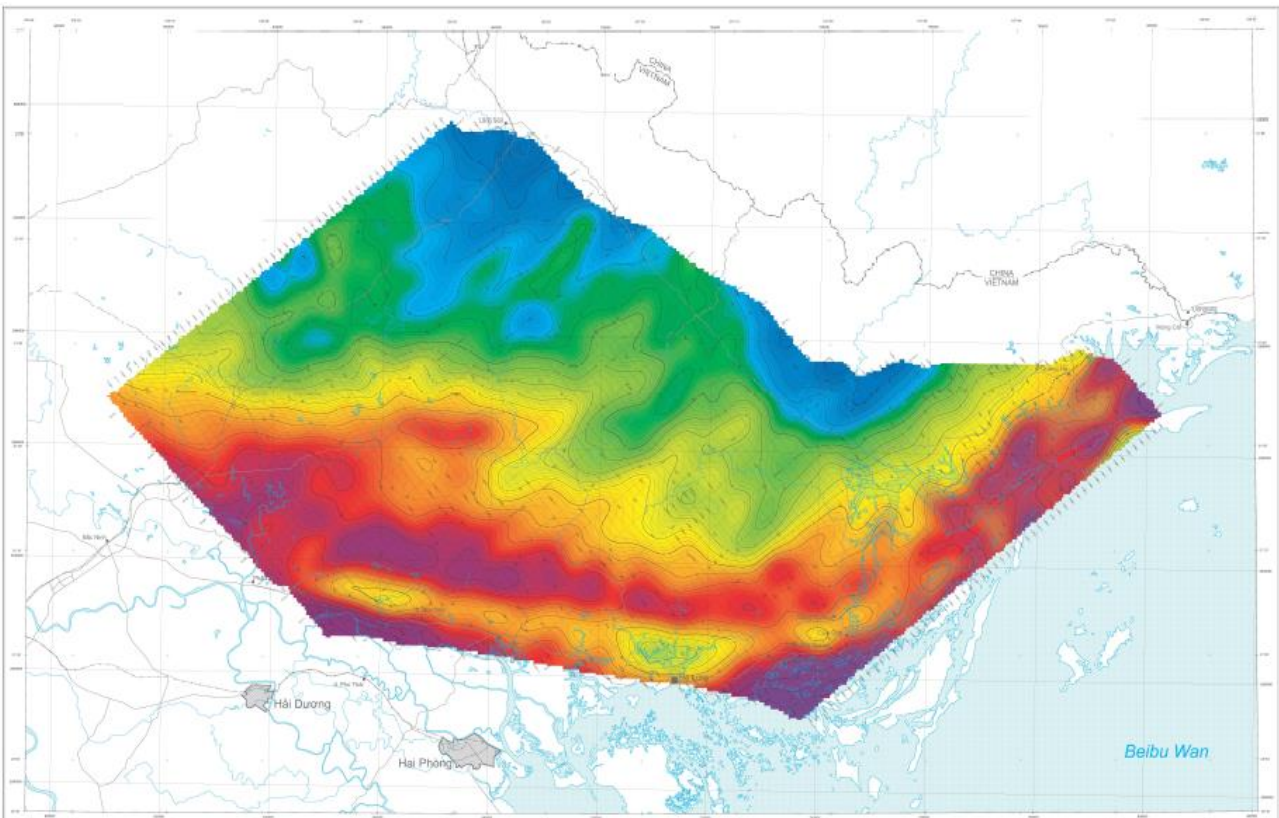

Figure 3a. Gravity Bouger anomaly Map of An Chau trough.

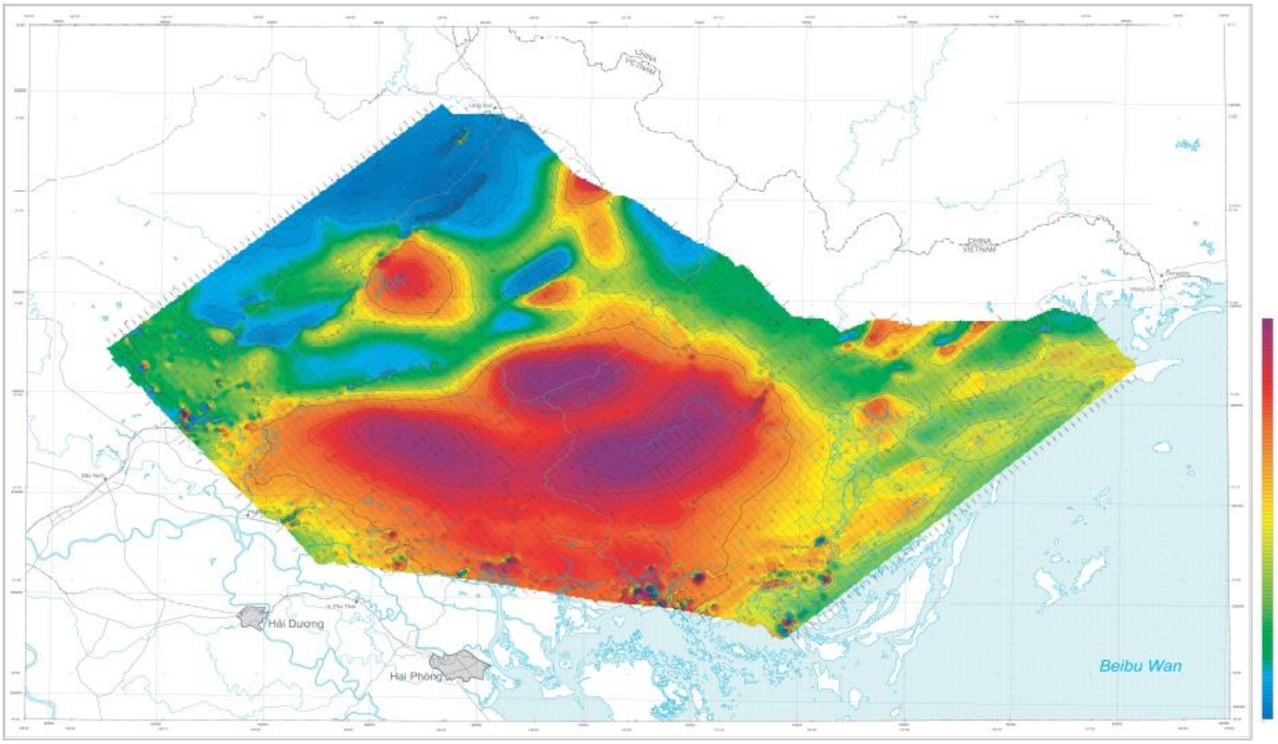

Figure 3b. Total field Magnetic Intensity Map of An Chau trough.

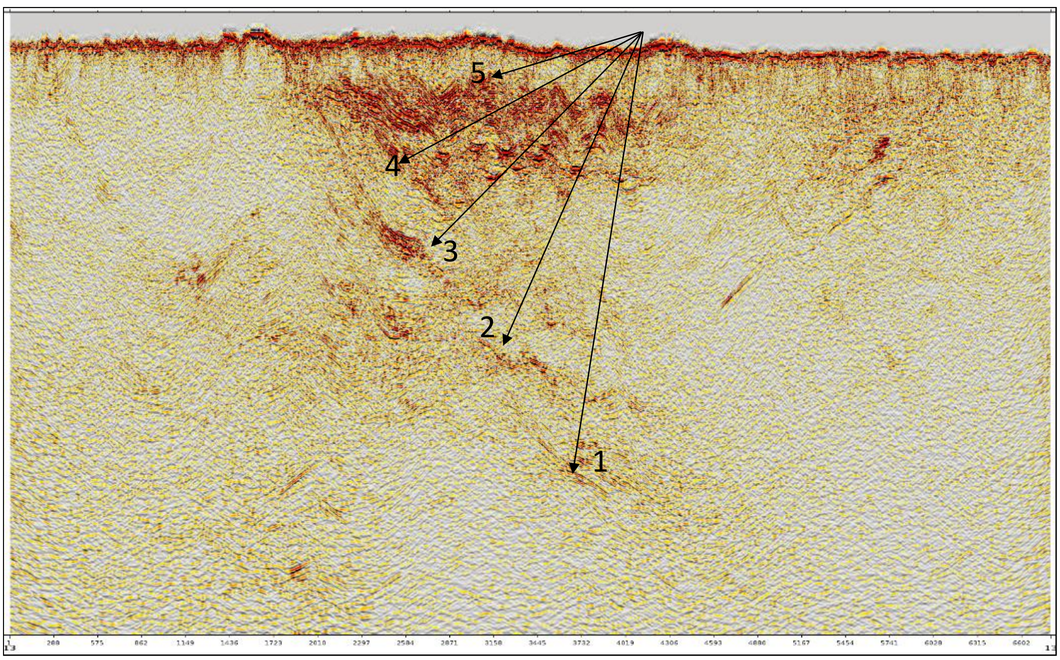

Figure 4. Define 5 main reflection surfaces on seismic data.

2) Defining the reflections (horizons) on seismic data (Figure 4) based on available geological maps (Doan, 2002; Hoang, 1999; Nguyen, 1999; Nguyen, 2000; Tran, 1982), stratigraphic columns and based on the previous study results about tectonic (Liang, 2005; Hoang, 2015), to assign these horizons with specific geological boundaries for interpretation (Figure 5).

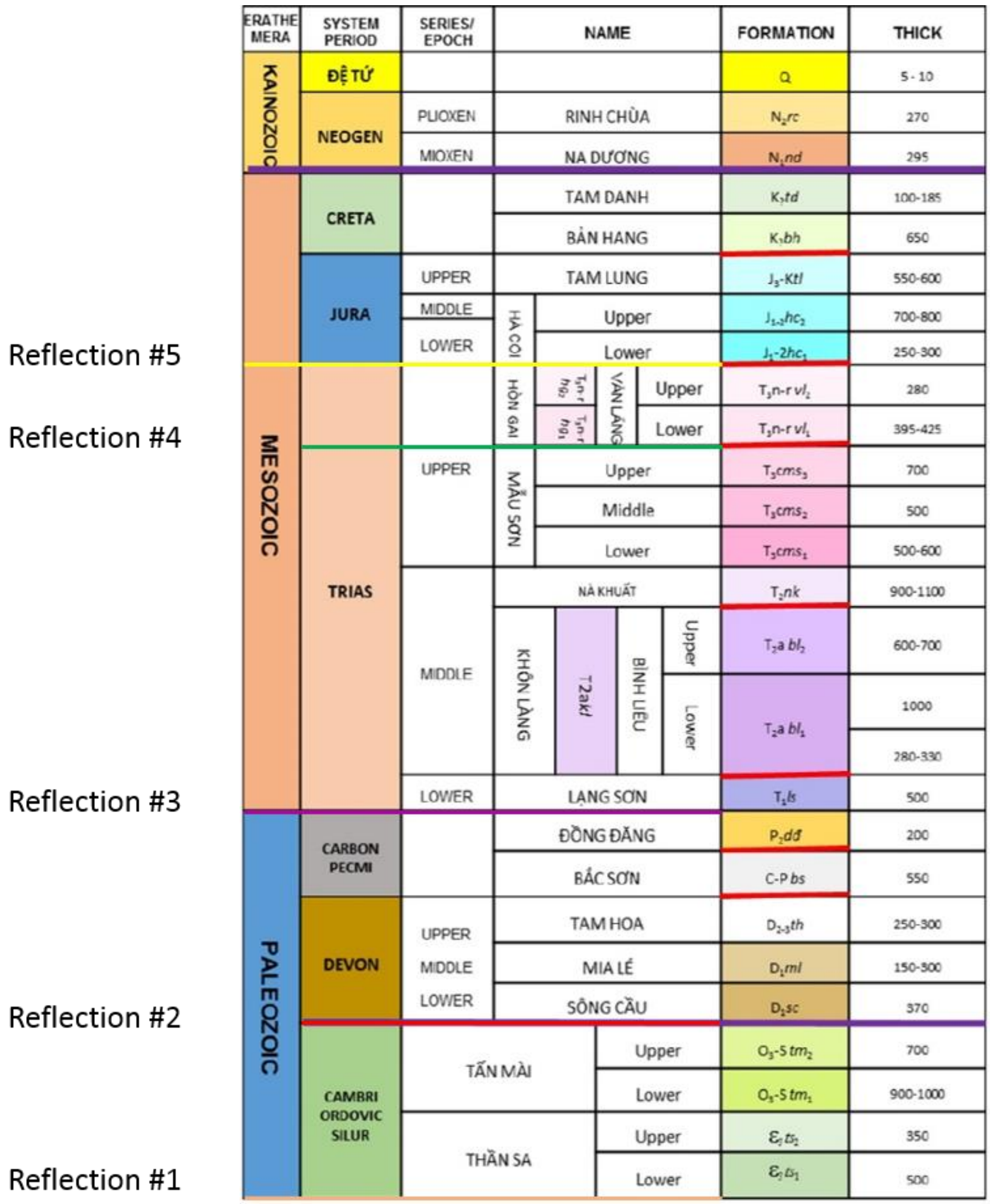

Figure 5. Assign seismic refections with geological boundaries in An Chau area.

The result of assigning the reflection to geological boundary as following:

Reflection #1: base of Paleozoic;

Reflection #2: base of Upper Paleozoic;

Reflection #3: base of Mesozoic;

Reflection #4: base of T_3n-r formation;

Reflection #5: base of Jurasic formation.

3) Interpreting the horizons and faults on seismic data, cross checking with fault systems from the geological map documents and gravity documents to correct fault systems.

4) Identifying the anticlinal structures in the deep part base on seismic data which have not been identified by the surface geological information and old magnetic-gravity data.

5) Making strutural maps, determining the thickness of Mz sedimentary; dividing structural zones based on integrating data sources.

3. Results

Based on the integration of all available data sources, research results on regional and deep structure are shown in the following main contents:

3.1. Results of interpretation of Magnetic-Gravity data

The fault systems are determined by analyzing/interpreting trend on the anomaly magnetic-gravity map. The fault dip direction is determined by the orientation of fault system's changing position on the maps at different depths (Figure 6).

Besides, the fault and its dip direction are also determinded by analyzing cross section of magnetic-gravity anomaly data (Figure 7).

The fault system determined by magnetic-gravity data is quite consistent with the fault system on the geological map of 1/200,000 scale.

The research results allow to identify the main fault systems in the study area with the fault-depth that can reach over 10 km, including faults: F0, F1, F2, F3, F4, F5, F6 & F7 (Figure 6).

3.2. Results of seimic interpretation

The quality of the seismic data is only moderate to fair for seismic interpreting. However, based on the geological concept built from the general information about the regional geological history, together with the results from analyzing magnetic-gravity data and surface information, the seismic interpretation results and structural map building from seismic data are reliable.

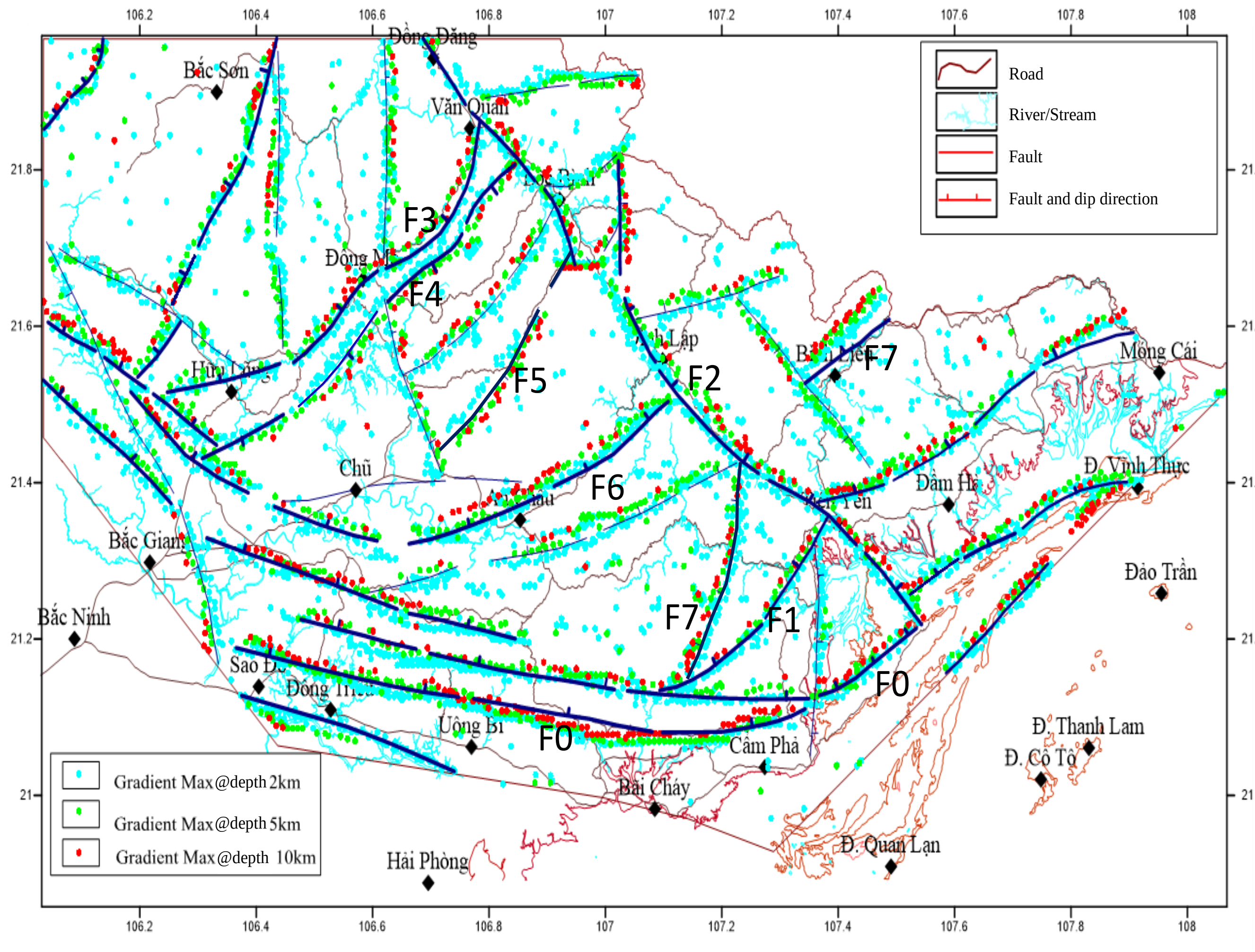

Figure 6. Defining faults systems and dip direction base on Maximum horizontal Gravity Gradient Map.

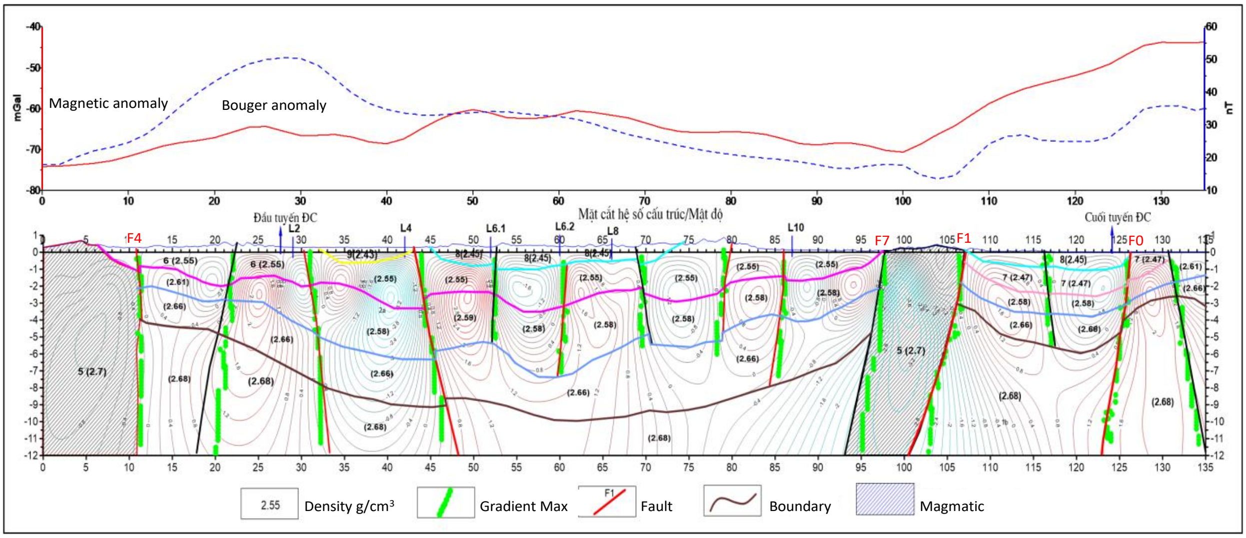

Figure 7. Defining faults and dip direction on Structure-Gravity density-Magnetic suscepcibility section.

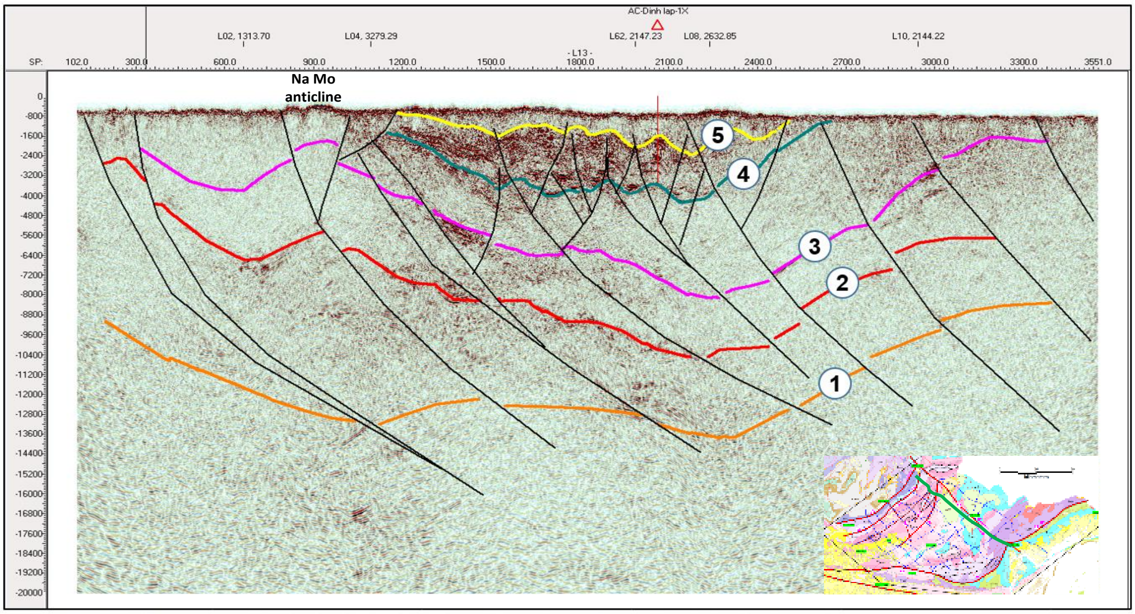

Figure 8. Fault systems, fault characters and folds defined on seismic data.

Major fault systems and their characters have been corrected and defined in the seismic data (Figure 8).

Deep structural elements are clearly identified on the interpreting seismic sections such as the basement uplift structures and folds (Figures 8 and 9). In addition, some anticline structures that were previously evaluated as good prospect for oil and gas accumulation such as Na Mo structure, however, on seismic data presently show that the structure has a chaotic seismic reflection, i.e. the structure has been destroyed and it has not got significant oil or gas potential (Figure 8).

In Figure 8, it is easy to see that the sediments located between horizon#5 (base of Jurasic) and horizon#4 (base of T_3n-r *vl*) are strongly folded, while the sediment above horizon#5 is not folded. Therefore, it suggests that there was possibly a compression phase occurring in the T_3n-r period in the study area.

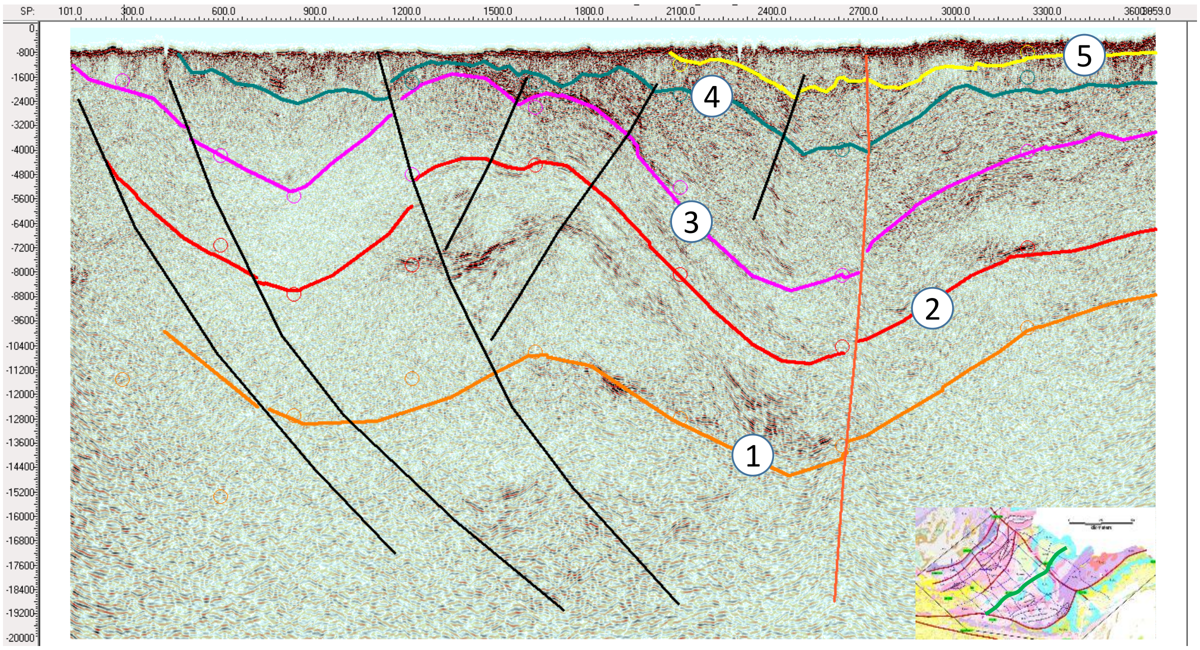

Figure 9. Paleozoic basement (horizone#3) was uplifted in center of seismic section.

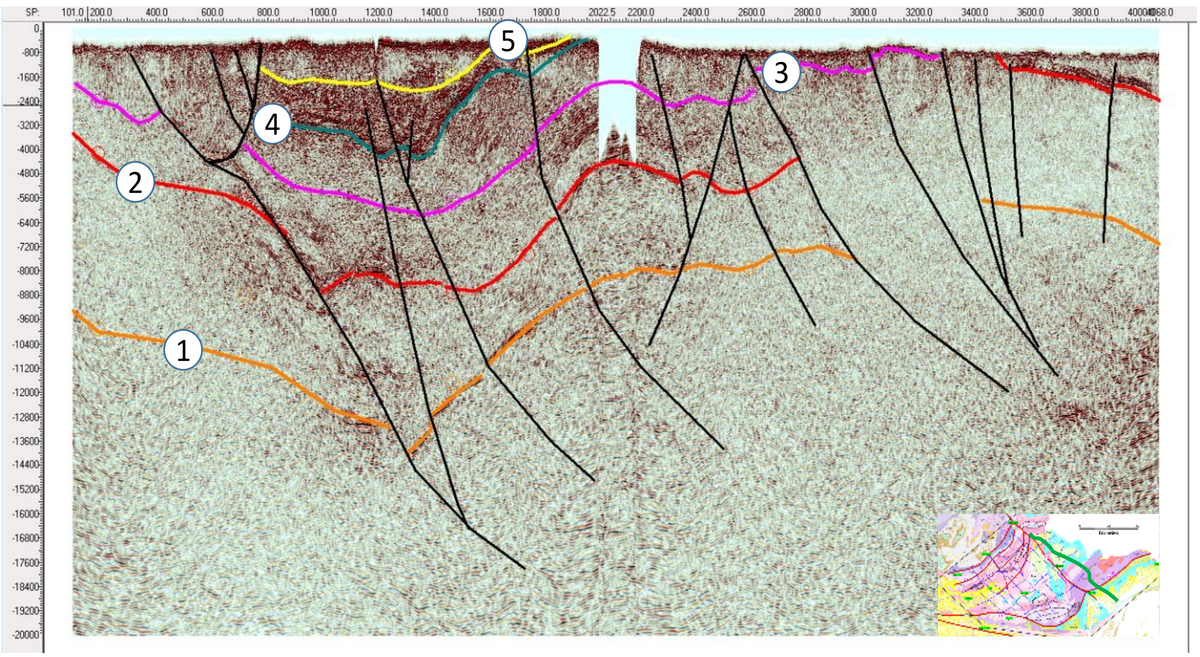

Figure 10. The seismic data shows that there is no fold in sediment located between horizon#4 and horizon#5.

The Observation on the seismic section (Figure 10) is in parallel to the section of Figure 8 but located to the Northeast of the F2 fault shows that there is no evidence of folding in the sediments located between horizon#4 and horizon#5. Thus, it can be seen that the compression phase creating folds which only affect the Southwest area of the F2 fault and the Northeastern area of the F2 fault is not affected.

On the Top Paleozoic (horizon#3) structural map, An Chau trough can be subdivided into 03 structural zones. This is appropriate with the interpretation from previous studies (Figure 11).

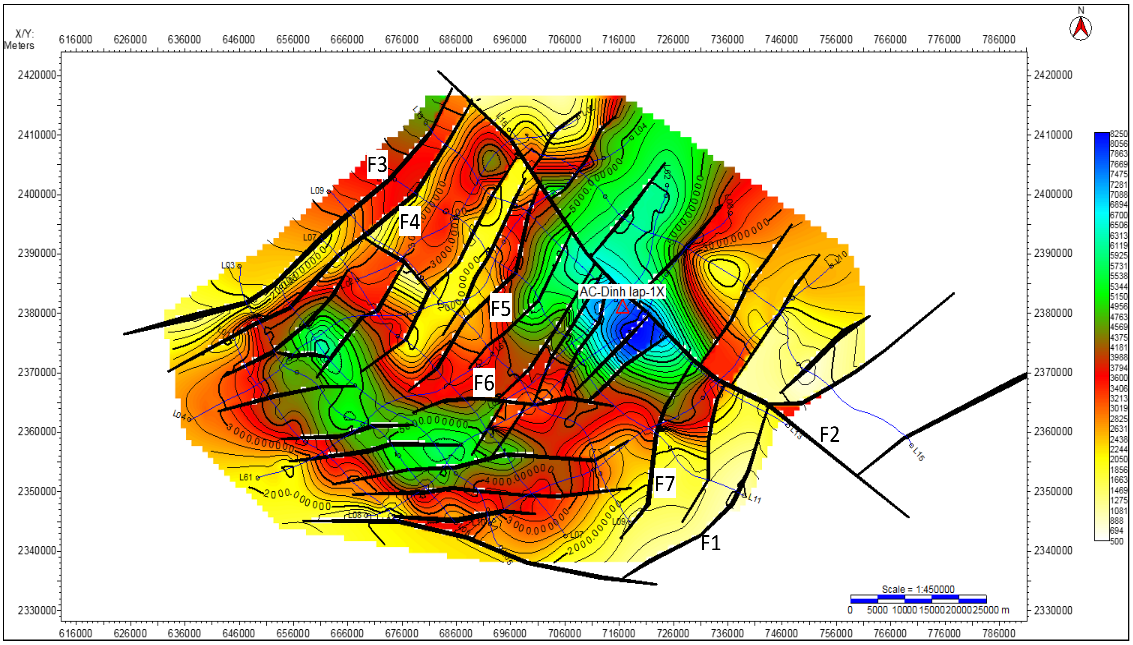

Figure 11. Top Paleozoic basement map.

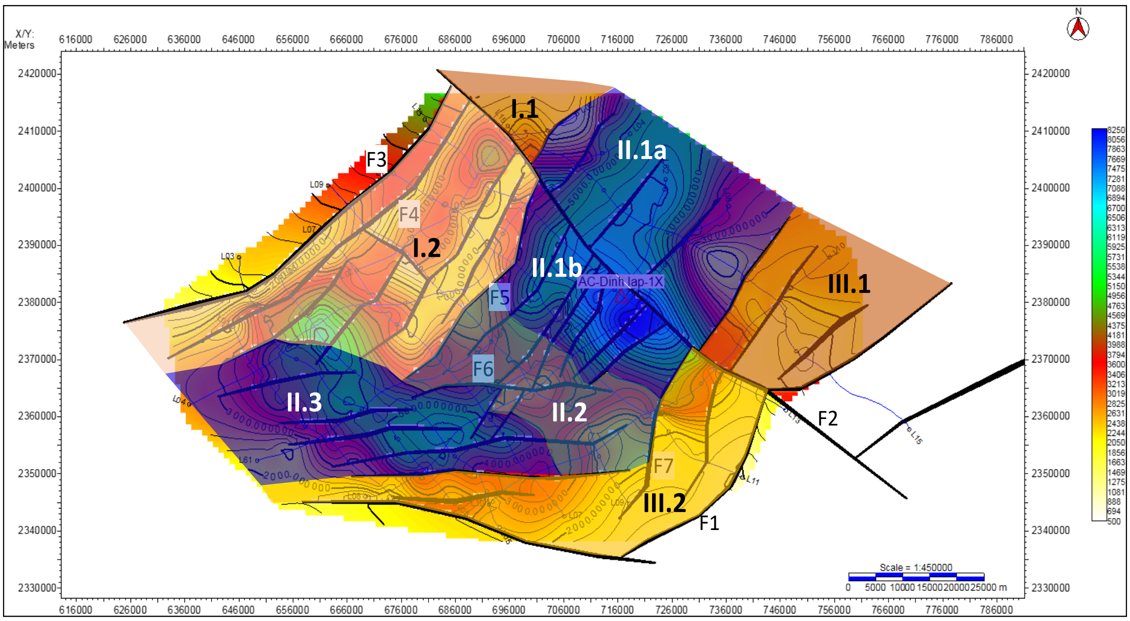

Figure 12. Structural zoning map in An Chau trough.

It is the fact that the structural zones have extended in Northeast-Southwest direction and have following characteristics:

- The Northwest zone bounded by F3 and F5 faults is an area with relatively high Pz basement. There are some of anticlines in central.

- The central zone bounded by faults F5 and F7 is the deepest part of the study area.

- The Southeast zone is limited by F7 and F1 faults, a typical Pz basement gradually inclined towards the center.

By integrating the results of analysis of gravity data and seismic interpretation, three structural zones of An Chau trough can be subdivided into high-order structural units as following:

- The Northwest marginal zone is sub-subdivided into 2 high-order structural units (Figure 12; I.1 & I.2): the I.1 part to the Northeast of the F2 fault, has a lower gravity anomaly field than the I.2 part to the Southwest of the F2 fault (Figure 3a).

- The central zone is subdivided into 3 high-order structural units (Figure 12; II.1, II.2 & II.3): parts II.1 and II.3 have deep Paleozoic basement and are separated by an uplift zone - II.2. The structure of II.2 and II.3 has an elongated form in the Northwest-Southeast direction. Structure II.1 is divided into 2 subzones: II.1a in the Northeast of the F2 fault is not compressed or folded during T_3n-r period; and II.1b is located in the Southwest of the F2 fault, which is compressed to create folds in T_3n-r period.

- The Southeast marginal zone is also subdivided into 2 higher-order structural units (Figure 12; III.1 & III.2) separated by the F2 fault.

Based on the pre-Mesozoic basement structure map and geological map, the deepest basement area potentially shows the significant sediment thickness. It is estimated that the Mz sediment thickness full-filled in the central An Chau basin can be thick up to 7,000÷7,500 m that much thicker than the investigated result from previous studies, approximately 5,000 m only.

4. Discussion

Although the new data set plays a great significance in studying the structure-tectonics in An Chau trough area, it is the fact that there are some unresolved and unclear issues, such as the geological complexity in the deep part, the difficult conditions in deploying to data collection and the disadvantage of each research method.

The F3 fault is the boundary between the C-P limestone range of Bac Son formation and the T_1 sedimentary rock (T_1 *ls*) which is considered as the northwest boundary of the trough. The characteristics of this fault have not been confirmed in the seismic data because the seismic lines do not reach to the fault. In addition, according to the interpretation of the results of the magnetic-gravity data, the fault has a dip direction to the Northwest. This is not consistent with the research results about fault systems in the Northwestern margin of Shiwandashan basin (Li et al., 2017). Therefore, the problem of the northwest boundary of An Chau basin still needs to be further studied and clarified.

5. Conclusion

The recent research results in combination with the previous surface geological studies have made more clear on the deep structure of An Chau trough - the southwestern part of the Shiwandashan basin.

An Chau trough is divided into 3 main structural regions and further subdivided into 7 higher order structural units. The structural regions are separated by the fault system with the NE-SW direction, while the high-order structural units of each structural region are separated by the NW-SE fault system or the NW-SE uplift tructure.

The new research results allow further identifying the folding system in the upper Triassic sedimentary interval and covered by the Jura-Creta sediment that was not mentioned in the previous studies.

The thickness of the Mz sedimentary in the central An Chau trough area is estimated up to 7,500 m while the previous studies show an estimation of 5,000 m only.

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Contribution of authors

Dr. Hiep Huu Hoang - conception, design, draft the article and revise for submission. Nam Huu Nguyen - Geological conceptulization, reviewing the article. Thang Van Nguyen - gravity/magnetic data review and analysis. Dr. Viet Tuan Le - supervision, seismic interpretation, reviewing and editing. Hoai Trung Pham - mapping, figure editing, writing.

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