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Application of "From Seismic Interpretation to Tectonic Reconstruction" Methodology to Study Pre-Tertiary Fractured Granite Basement Reservoir in Cuu Long Basin Southeast Vietnam Offshore*

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Abstract

Since 1987, when the first oil was discovered from Pre-Tertiary fractured Granite Basement reservoir in Cuu Long Basin, offshore Southeast Vietnam, more oil has been discovered and produced from this type of reservoir in the basin. Currently the Pre-Tertiary fractured Granite Basement is considered the primary objective in Cuu Long basin in particular and in Vietnam in general; it contributes more than 70 % of oil production from the Cuu Long Basin.

To explore and develop hydrocarbons from this particular type of reservoir, we face many difficulties, especially how to predict fracture systems and their features inside the Granite Basement. Integration of 3D seismic data interpretation and tectonic reconstruction has been applied to locate exploration and development wells in Vietnam. Results of the drilled wells have proved the efficiency of this methodology. In this article we present our current procedure and experience in using the methodology to study the fractured Granite Basement in the Cuu Long Basin. We also present a case study.

Introduction

Cuu Long Basin, which is located in offshore Southeast Vietnam, is a Tertiary rift basin. In the Cuu Long Basin, presence of hydrocarbons was proved by the first oil discovery from lower Miocene sandstone in 1974. Since 1987, when the first oil was discovered from Pre-Tertiary fractured Granite Basement, more oil has been discovered and produced from this type of reservoir in the basin. Currently the Pre-Tertiary fractured Granite Basement is considered the primary objective not only in the Cuu Long Basin but also in the entire country. It now contributes more than 70 % of oil production from the basin. Figure 1 illustrates the location of Cuu Long Basin with oil discoveries from the Pre-Tertiary fractured Granite Basement.

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Because fresh granite has almost zero porosity, the Granite Basement becomes a reservoir only if fractured, especially by tectonic activities. To explore and develop hydrocarbons from this particular type of reservoir, we need to know, in particular, how to predict fracture systems and their characteristics within the Granite Basement. At first, the oil was considered to be present in weathered and fractured granite. Correspondingly, the wells were located on the crest of the basement structures and were designed as vertical to penetrate only a few hundred meters into Granite Basement. It was learned later that the fractures generated and enhanced by tectonic activities were the main contributor to the reservoir features of the Pre-Tertiary Granite Basement. Based on this concept, the wells were designed to be deviated in order to penetrate the maximum number of fault planes, interpreted by 2D or 3D seismic data, inside the Granite Basement. However, the chance of success for the exploration well was still low because oil could flow only from a very small number of large, open, and connected fractures. Most fractures associated with certain fault systems are sealed. The big challenge for the geologic and geophysical study is how to predict the open fracture systems inside the Pre-Tertiary Granite Basement, their characteristics, and associated fault systems. The problem was addressed by using a combination of seismic interpretation and tectonic reconstruction, which was named “From Seismic Interpretation to Tectonic Reconstruction” methodology. The efficiency of the methodology was proved by increasing the chance of success for exploration wells and its wide application in the last five years in the Cuu Long Basin.

Methodology

The procedure (workflow) of the “From Seismic Interpretation to Tectonic Reconstruction” methodology could be described as:

1. Seismic Interpretation:
    - To apply all available new technologies to improve seismic imaging, especially inside the Granite Basement.
    - To carefully interpret and map key seismic horizons and to determine their ages.
    - To carefully conduct fault interpretation, especially inside the Granite Basement.
    - To classify all the interpreted faults.

2. Tectonic Reconstruction:
    - To measure all parameters of the interpreted faults.
    - To classify all the faults.
    - To reconstruct deformation phases of the block and structure.

3. Prediction of fracture systems and their characteristics:
    - To predict all possible fracture systems, their features, and their evolution.
    - To predict the most important fracture systems for drilling.

The most important problem for application of the methodology is how to achieve a detailed and accurate fault interpretation internally within the Granite Basement. Normally the Granite Basement is considered a homogenous acoustic medium, and the top of the Granite

Basement is lower limit of the reflection seismic. However, in certain cases we can get interpretable reflections from fracture zones associated with faults inside the Granite Basement. Figure 2 is an example.

The reflections from fracture zones inside the Granite Basement are characterized by low and variable amplitude, variable wave form, discontinuity, low frequency and high dip angle; therefore, all available techniques have to be applied to improve these reflections. For this purpose, the 3D Anisotropic Pre-Stack Depth Migration (especially CBM) and some Post-Stack processing tools are thought to be good choices (Figure 3).

Case History

The history of the Oil Field A, which is located in the northwestern flank of the Cuu Long Basin (Figure 1), is a good case study. The field is a Pre-Tertiary Granite Basement high, draped over by Tertiary clastics (in Figure 4A the red seismic horizon is top of the Granite Basement). On the structure, two exploration wells, A-1X and A-2X (Figure 4C), were drilled by a previous operator with negative results. The former well was drilled vertically in 1994 on the crest of the structure defined by 2D seismic data; it penetrated basement top at 3033 mss and drilled 350m inside the Granite Basement, with only 10 liters of oil recovered. In 1999, well A-2X was drilled vertically downdip of the basement crest based on 3D seismic data. It encountered basement top at 3274 mss and penetrated 696 m inside the Granite Basement; 1.5 barrels of oil were recovered.

In 2005, with expiration of the Oil Exploration and Production license covering the block, Thang Long Joint Operation Company (Talisman Energy and PVEP) acquired a large 3D seismic survey of all high potential areas of the block. The 3D seismic data was processed by state-of-the-art processing technologies including 3D APSTM and 3D APSDM, using both Kirchhoff and Control Beam Migration methods. The 3D seismic data quality was considered to be good for both clastic and basement objectives (Figure 3). The methodology “From Seismic Interpretation to Tectonic Reconstruction” has been applied to study the Granite Basement of the structure. The 3D seismic data was interpreted in great detail for both the clastic section and inside the basement (Figure 4A, 4B, and 4C) illustrate the results of fault interpretation of inside-the-basement). Based on results of the seismic interpretation and geological data, tectonic reconstruction study was conducted to classify all interpreted faults, to determine the main deformation phases, and to predict the most important fracture systems for oil exploration (Figure 4D illustrates the main deformation phases of the block and the structure). Based on results of the study, in 2007, well A-3X was drilled, deviated at location about 600 m northwest of A-1X well (Figure 4C). The well encountered basement top at 2998 mss and penetrated 2314m (along hole) inside the Granite Basement. Two DSTs of the fractured Granite Basement section resulted in commercial oil-flow rates.

The application results for Oil Field A and other oil discoveries in Cuu Long Basin have proved the efficiency of the “From Seismic Interpretation to Tectonic Reconstruction” methodology.

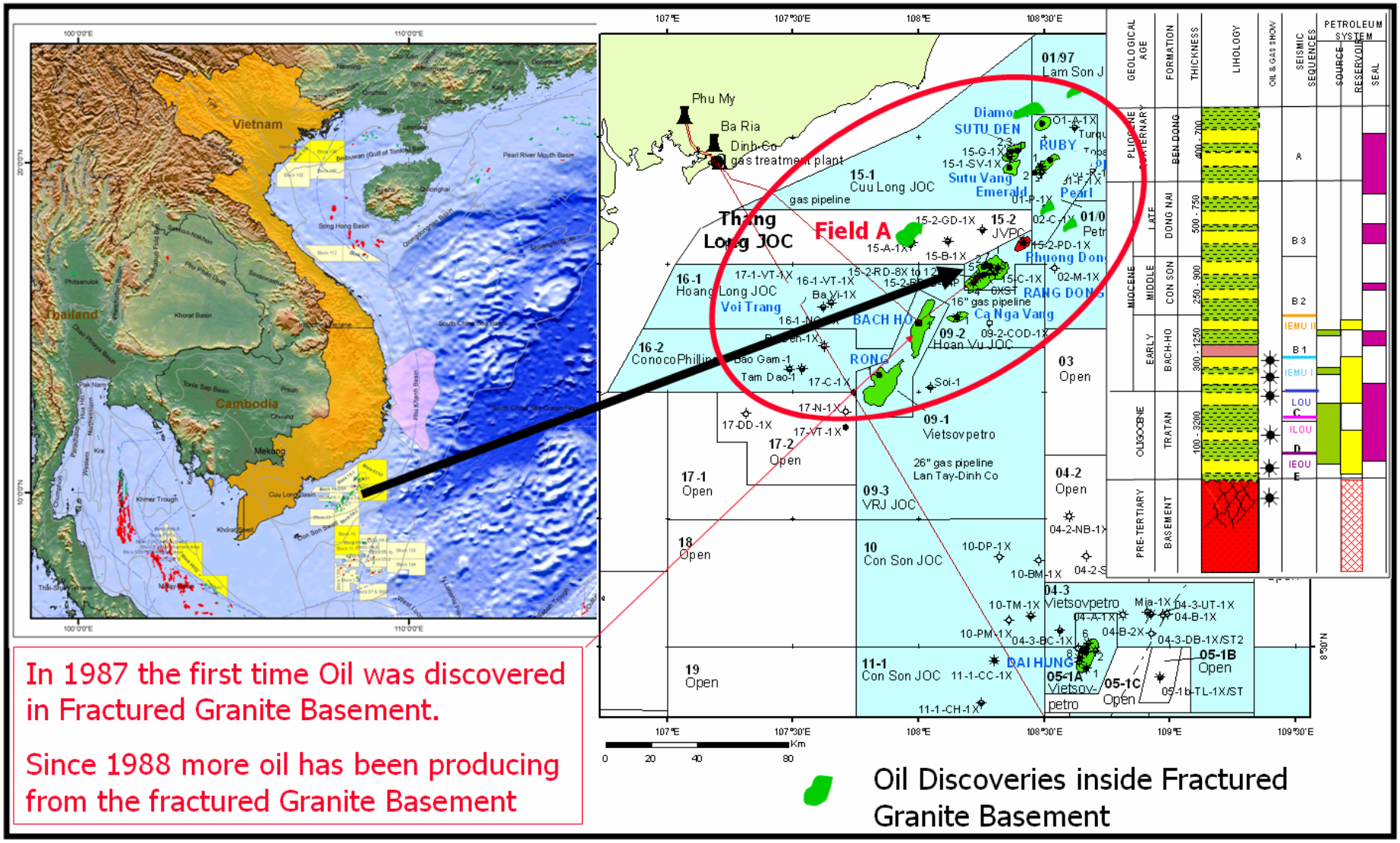

Figure 1. Location map of Cuu Long Basin with oil discoveries from Pre-Tertiary fractured Granite Basement.

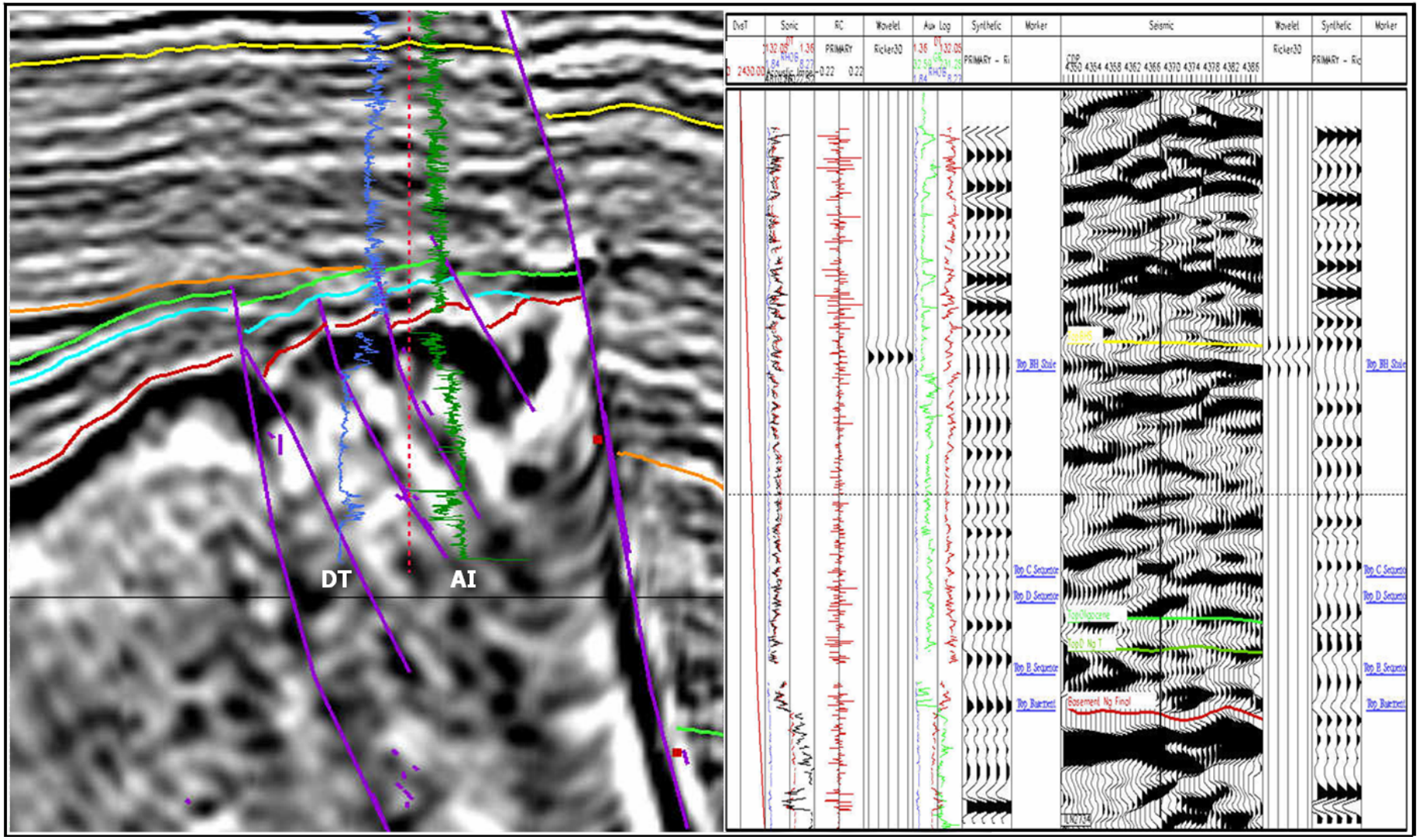

Figure 2. Geophysical responses from fracture zone associated with faults inside the Pre-Tertiary Granite Basement (the red seismic horizon is top of the Granite Basement).

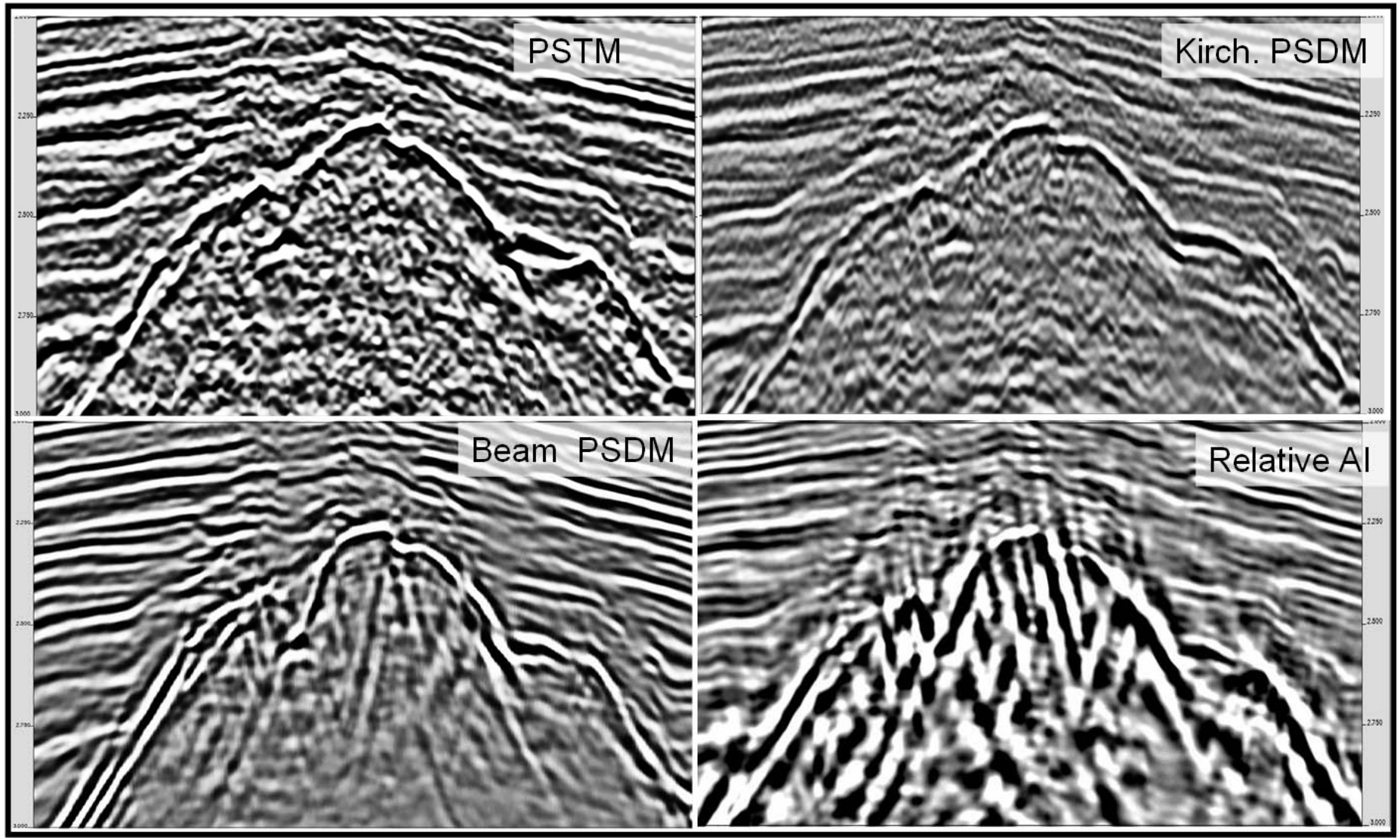

Figure 3. Improvement of Granite Basement reflections by applying different processing sequences.

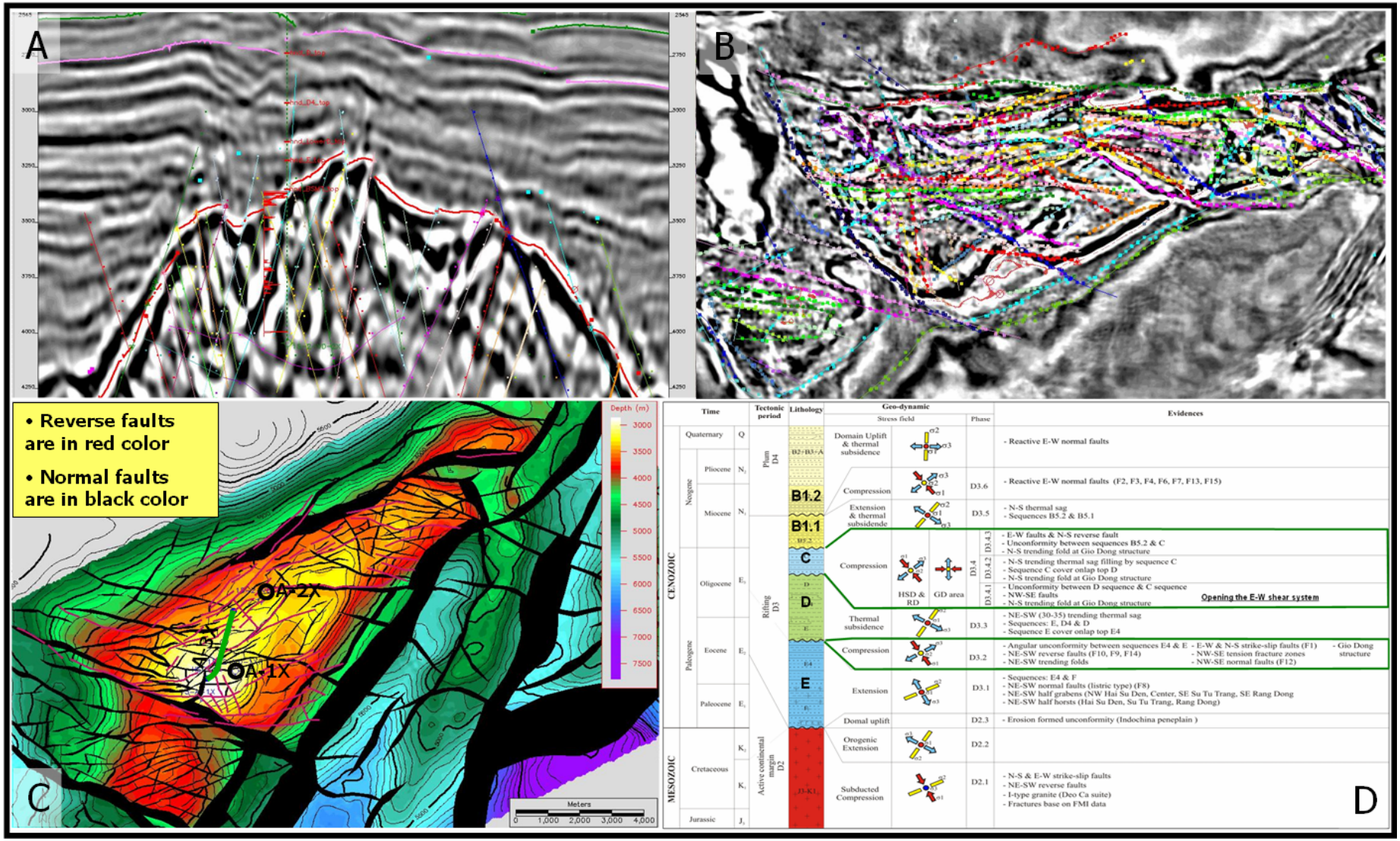

Figure 4. Oil Field A located on the northwestern flank of Cuu Long Basin. A, B, and C portray fault distribution and scale. D illustrates the main deformation phases.