SOME COMMENTS ON THE POSSIBILITY OF MIDDLE/LATE MIOCENE - PLIOCENE STRATIGRAPHIC TRAPS IN THE CENTRE OF NAM CON SON BASIN

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Summary

Stratigraphic traps are a new exploration target in Vietnam. To comment upon the possible existence of stratigraphic traps in the Nam Con Son basin and, in particular, of a Middle/Late Miocene - Pliocene stratigraphic trap in the centre of the Nam Con Son basin requires research on: (i) the regional tectonics which affected the existence and development of deposits; (ii) the sedimentary facies and sedimentary environments; and (iii) the process of formation of turbidite fans in the deep-sea environment in the region.

The deep-sea sediments of the Middle/Late Miocene - Pliocene age in the Nam Con Son basin constitute one of the hydrocarbon plays that are being studied by geo-scientists and international companies active in the oil and gas domain. Here, the present authors wish to introduce a case study which is summarised on the basis of geological, geophysical and drilling data from the centre of the Nam Con Son basin, the views of domestic and foreign geo-scientists of the characteristics of turbidites and the ability of deep-sea sediments to exist as turbidites of the Middle/Late Miocene - Pliocene age in the centre of the Nam Con Son basin.

1. Contents

A synthesis of researches conducted by geoscientists worldwide on the depositional conditions of stratigraphic traps shows that there are 3 main factors that affected the formation of stratigraphic traps: tectonics, sedimentary environment, the rise and fall of sea level. Each of the above elements will be analysed, then the possibility of the existence of deep-sea sediments as turbidite deposits in the Middle/Late Miocene - Pliocene in the centre of Nam Con Son basin will be discussed.

Based on the characteristics of sedimentary environments, including sediment supply and sediment type, in the Nam Con Son basin, there are 3 possible kinds of stratigraphic traps as below:

- Stratigraphic traps in the continental environment (Oligocene);

- Stratigraphic traps in the coastal environment (Early - Middle Miocene);

- Stratigraphic traps in deep-sea environment (Middle/Late Miocene - Pliocene).

This paper will focus on analysing the characteristics of the deep-sea stratigraphic trap of Middle/Late Miocene - Pliocene age, including its tectonic features, stratigraphy and sediment characteristics.

1.1. Tectonic characteristics

The main tectonic elements that affected the formation of stratigraphic traps in the Nam Con Son basin have been mentioned by Hoang Ngoc Dang in "*Geology and Potential Petroleum Resources*" [1] and in many of his research studies on the processes of deposition and development of sedimentary basins in Vietnam [2]. They can be summarised as follows (Fig.1):

- The influence of the East Sea spreading in the Southwest, toward the Nam Con Son basin during the early Miocene epoch;

- The subduction and the cessation of the East Sea spreading in the Middle Miocene epoch (15ma);

- The upwelling of asthenosphere causing uplift and erosion of the region (sub-aerial erosion) to create the Middle Miocene Unconformity (MMU).

After the second rift in late Middle Miocene times, forming the regional Middle Miocene Unconformity,

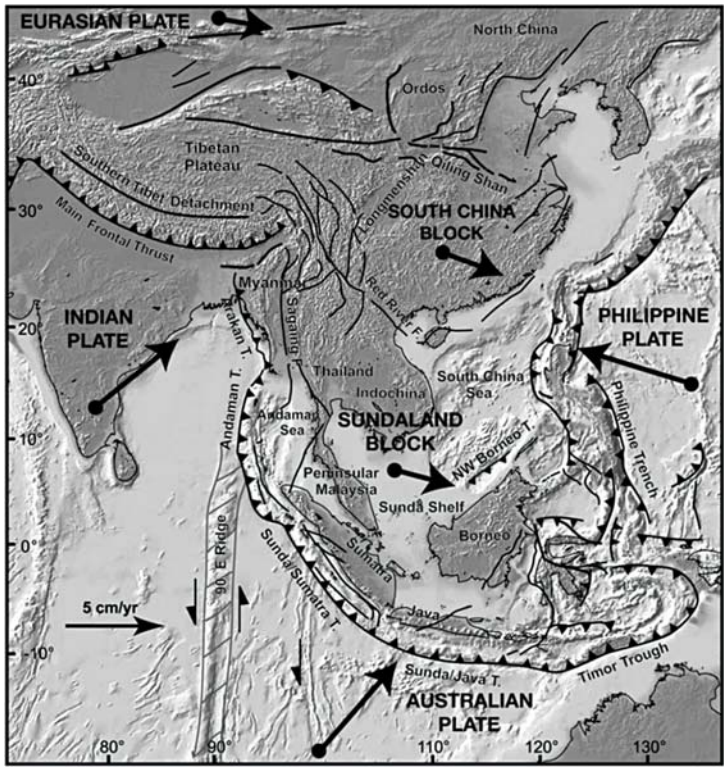

Fig.1. *The tectonic elements in South - East Asia that affected the Nam Con Son basin [3]*

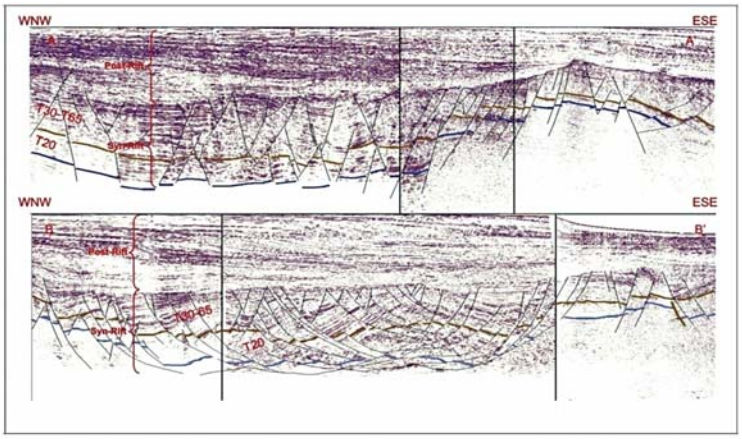

Fig.2. *Tectonic elements in the Nam Con Son basin (pre-rift, syn-rift and post-rift) [1]*

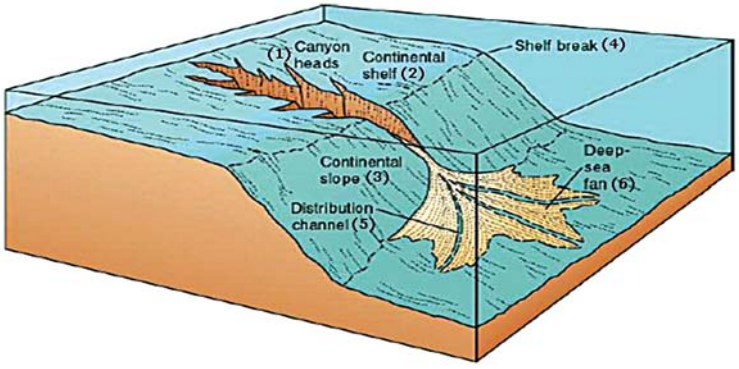

Fig.3. *Turbidite's system formation [12]*

tectonic activity throughout the region was quite stable, with the sea-level rising and floods prevailing on the entire basin area under the influence of a thermal subsidence regime. Most fault activities ended in Late Miocene times and the basin's boundary is almost uniform across the region [1, 2].

2. Sediment characteristics

Under the influence of the rapidly rising sea level, the source material transported from the West was deposited in the centre of the Nam Con Son basin with a high rate of sedimentation due to the increasing sea-floor depth, with the sea-bed topography changing suddenly… The deep-sea deposits had been formed and preserved since a tectonic influence no longer existed.

The process of erosion, transport and accumulation in deep water in the period after the Middle Miocene Unconformity had formed in the Nam Con Son basin was mainly controlled by gravity flows caused by subsidence, sedimentary sliding and turbulent flow related to the shelf - slope.

Many studies show that the turbidite formed at the edge of the basin related to high density currents. Characteristically in turbidity flows the transported material (under the turbulent currents impact) can move a long distance on a slight slope (low angle), usually onlapping the slope or underlying highs and are discontinuous and downlapping onto the underlying sediments, with diversified sizes. The formation and characteristics of deep-sea sediments reflect the complex interactions between internal and external factors, including the rise and fall of sea-level, tectonic processes at the edge of the basin, the type of the source material and the speed of supply.

2.1. Stratigraphy and sedimentary environments

In the sedimentary description, the turbidite of the Nam Con Son formation (N_1^3 ncs) is distributed in the central part of the Nam Con Son basin, with the sand component being moderately to well-rounded and sorted, containing marine fossils and glauconite.

According to the characteristics of these sediments and the palaeo-biology, the Nam Con Son formation generally formed in a deep-sea environment, on the inner-shelf of the western part and the middle - outer-shelf of the eastern part of the basin [4].

The depositional turbidite in the deep-sea environment shows the net pay distribution sets with different characteristics for each area (inner-fan and outer-fan) (Fig.4) [9].

2.2. Flow

The unstable flow, with high density and low transport efficiency, tends to result in increased accumulation of sand close to the shelf edge. The turbidity current creates well sorted sand bodies, which are reworked materials from coastal plains or redeposited remains of the screened shelf-edge, and usually deposited at downslope. The lack of fine-grained material causes a reduction of fluid density, buoyancy of the liquid and the turbulent flow so that the sand cannot be transported far from sediment source supply. The mechanism of turbidite formation and the sediment source supply is shown in Fig.5.

To consider the influence of ocean currents in the transportation and re-distribution of deep-sea sediments in the Middle/Late Miocene - Pliocene age in the Nam Con Son basin from all aspects requires very detailed analysis of the paleo-geographic environment in order to restore the slope-shelf's topography during this period, and analysis of the influencing factors related to ancient flows.

2.3. Sediment sources

A deep-sea turbidite can be divided into smaller components based on the volume, the particle size, and the characteristics of the sediment source supply. The sediment source study may indicate the volume and the general characteristics of the deep-sea fan, whereas the sediment supply will indicate the overall shape and distribution of the turbidite fan. The particle size reflects the composition of sediment source supply and the sedimentary processes: transportation efficiency, layered sedimentation, and the distribution of coarse and fine grain sizes in turbidite fans.

In fact, the channels formed will develop into a lobe when the slope-angle becomes reduced and reduces the flow rate, and/or a change of flow direction (degree of bending of the flow). Sediments that filled up the channel/lobe overflow and form new channels in the slope/deeper shelf. While the sand is deposited in the lower region, the lighter clay/shale then settles on the top of it (Fig.6).

As mentioned above, the process of erosion, transport and sedimentation in the deep-water environment in the period after MMU in the Nam Con Son basin is mainly controlled by gravity flow, which causes the slumping or sliding processes of shale and silt. Deposition changed from a continental environment to a shallow marine environment (at the West - Southwest of the basin) and the transported materials, which are well sorted grain sands from coastal plains or redeposited remains of the screened shelf-edge, usually accumulate at the foot of the slope. However, to confirm the fan's size as well as the composition and the grain size of the sand body in the fan

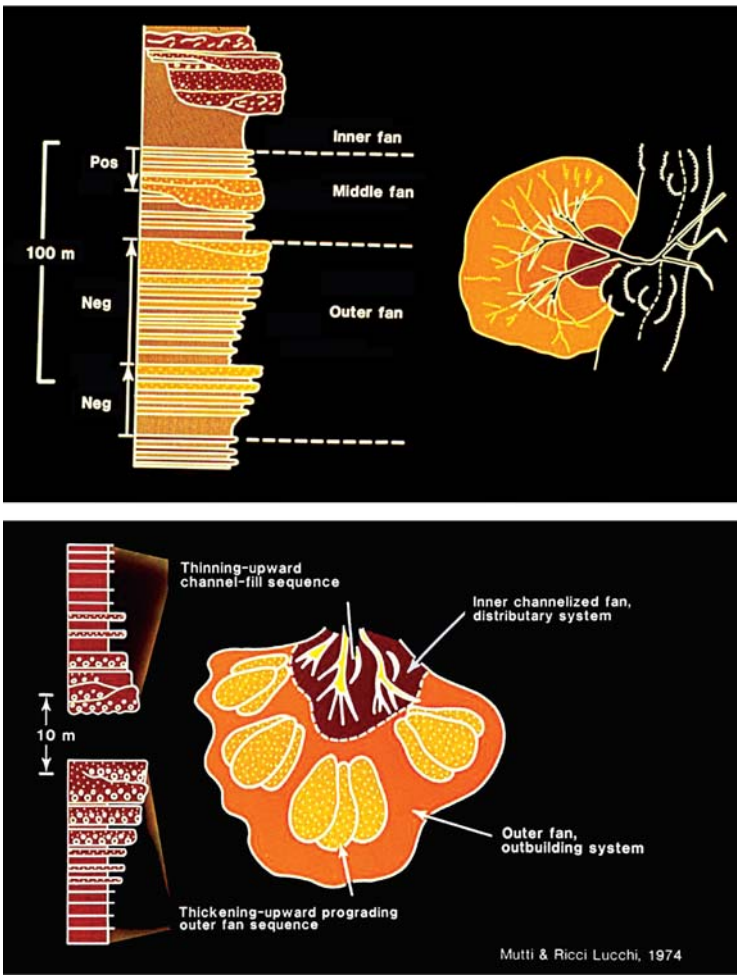

Fig.4. *Turbidite thickness distribution [9]*

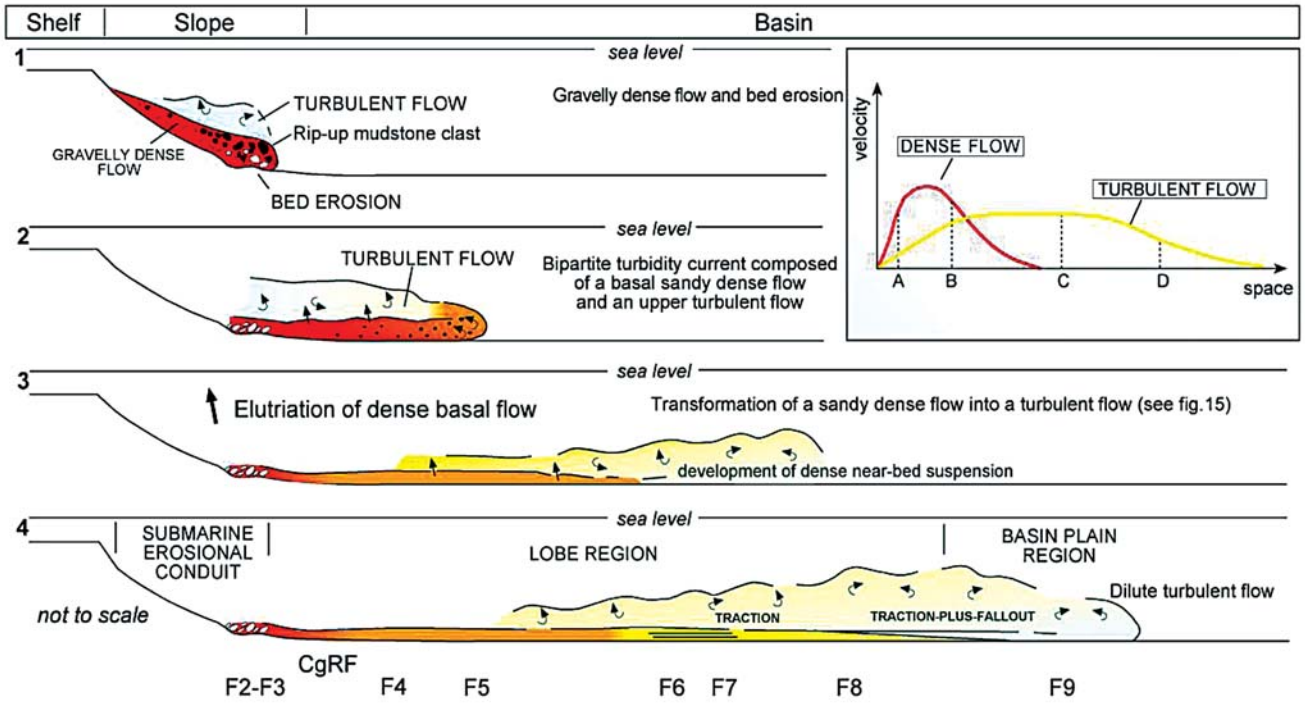

Fig.5. *The flow impact on turbidite deposition [9]*

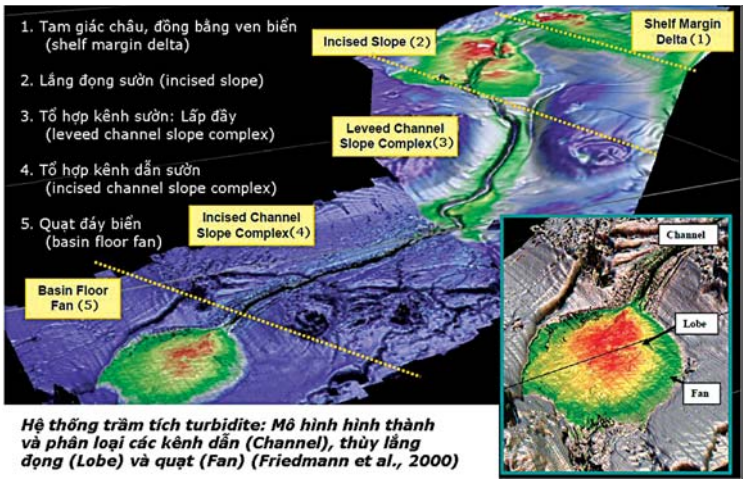

Fig.6. *Turbidite deep-sea sediments system [10, 11]*

based on the seismic analysis only (seismic interpretation attributes) needs further studies of the well-logs and the analysis of cores.

3 . The rise and fall of sea level

There is evidence that changes in relative sea level can affect turbidite formation and the development of deep-sea fans in the stratigraphic column of the Nam Con Son basin. Many examples in the world (Indus fan, Bay of Bengal fan, Mississippi and Amazon fan) show that the amount of continental sedimentary clastics suddenly fell when the sea level rose during the Holocene. Most of the hydrocarbon-bearing fans are related to the fall of relative sea level as lower sea levels have a profound impact on erosion of the continental, sea-edge and deep-sea sediments. Lowstand submarine fans or basin floor fans are believed to be systems with a high ratio of sand/clay; this formed during the time the river system rejuvenated with large transportation rates due to slope increases (related to the period of lower sea level). During this time, sea-shelf sediments were mainly material which was transported through, with the coarse-sand supply settling on the outer-shelf. This gradual shift towards the sea is related to the fall of relative sea levels, detected by the onlap backwards to the sea on the seismic records, the change of parasequence deposition type on the shelf or slope, and the sudden change from the deep-sea mudstone to clean sand on the well-logs' curve.

The joint study between Talisman and EPC/VPI (Fig.7) shows the sea-level fluctuations in the Oligocene - Miocene epochs and the effects of sea level on Oligocene - Miocene sediments in general and the deep-sea turbidite of the Middle/Late Miocene - Pliocene age (late stage of the syn-rift to post-rift) in the Nam Con Son basin in particular.

Based on the geochemical analysis, VPI has created a sedimentologic model of the Nam Con Son basin

following the rise and fall of relative sea levels and the environmental characteristics of the sediments (Fig.8) [4].

Through the specific examples of the results of the seismic attribute analysis based on the 3D PSTM seismic cube of Block 04-1 (Fig.9), the characteristics of the stratigraphic trap of the Middle/Late Miocene - Pliocene age in the centre of the Nam Con Son basin should be considered as follows:

- Turbidite fan of the Middle/Late Miocene - Pliocene age deposited in the deep-sea environment, in the centre of the Nam Con Son basin is located at the shelf edge, especially in the transition zone between the inner-shelf and the outer-shelf where the topography of the sea-bed changes abruptly. Source material was transported from the mainland (western) and with the sea-bed's sudden change of depth the sediments were deposited from a turbulent flow as a turbidite fan…

- Tectonic activity in the region was quite stable during this period, the sea level increased and floods prevailed on the entire area of the Nam Con Son basin. Tectonic regime of thermal subsidence does not much affect the formation and preservation of the turbidite fans.

- During the Tertiary era the rise and fall of global sea level in Southeast Asia in general, and the Nam Con Son basin in particular, is very limited, so it is not the main factor to influence the stratigraphic trap at this time.

- The deep-sea sedimentary environment of turbidite is established, based on the quantitative well logs analysis. The basin floor fans (inner fan and outer fan) which are distributed in the central region of the Nam Con Son basin formed in the shelf-slope and shelf-edges.

- The turbidite (coarse sand) is located at the base of the shelf-slope transition zone, as the inner-fan with medium to well rounded and sorted sand, with the net pay of a few tens of cm to 1m (reflected in the well-log analysis).

- In order to delineate the turbidite within the study area, it is necessary to use the analysis of seismic attributes as a tool, combined with Spectral Decomposition and well-log analysis, using an Artificial Neural Network (ANN).

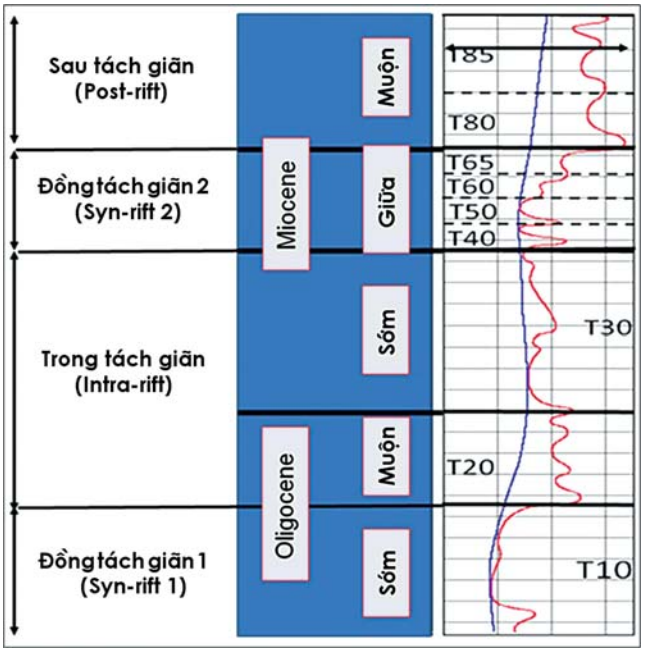

Fig.7. *The rise and fall of relative sea level in the Nam Con Son basin [4]*

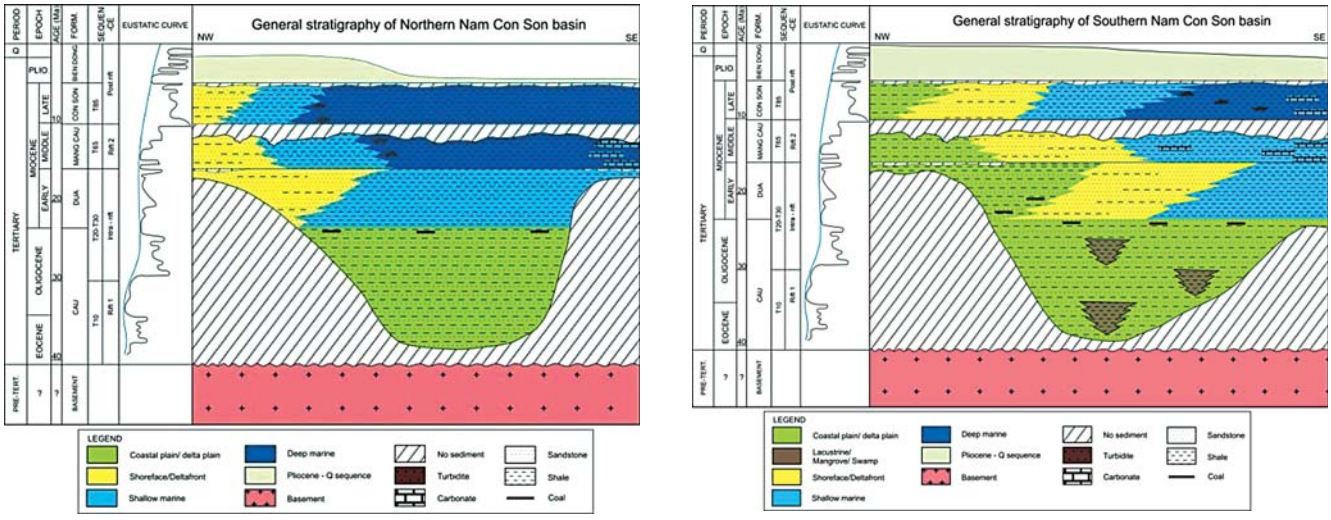

Fig.8. *Sea level variation in the North and South parts of the Nam Con Son basin [4]*

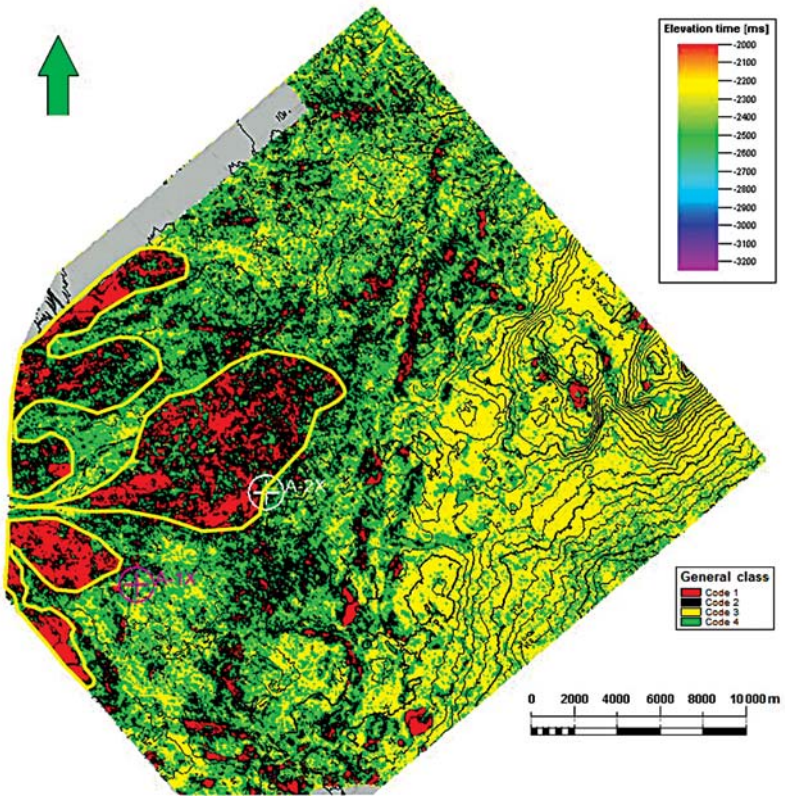

Fig.9. *The images of turbidites based on the results of seismic attribute analysis using ANN in Block 04-1 (top of Late Miocene)*

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