Buried Giant Arc-Type Structure System and Petroleum Exploration in Turpan-kumul Basin, Northwest of China*

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Search and Discovery Article #10378 (2011)
Posted December 12, 2011

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG International Convention and Exhibition, Milan, Italy, October 23-26, 2011

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Abstract

Based on analysis of regional stress fields and structure distribution in Yanshan and Himalayan periods, it is concluded that a giant arc-type structure belt mainly consisted of three local arc-type structure belts is buried in east-west direction in sedimentary covering of Turpan-kumul Basin. With the symmetric central of stress break belt in the middle of the basin, the petroleum geological features are comparable and symmetrical in west and east phases of the arc-type structure belt, which attached the three main hydrocarbon-rich sags (Shengbei, Qiudong, and Xiaocaohu sag). As the result, the structure of basin is obviously characteristic in different sections in west-east and various belts in north south. The changing of regional and local stress fields are the main reason for the formation of this type of structure scheme. Because of the different slip within strata from north to south in middle to later Yanshan and Himalaya movement, the structure belt of the west piedmont section is mainly distributed in northwest-southeast and the east, northeast-southwest. The left and right cycles of stress fields in west and east sections result in the formation of arc structure belts in plane. There are three different arc structure belts formed within Turpan depression from north to south, which formed a huge arc structure belt. The extrusion faults in EW development are good sealing elements of structure traps. The strike-slip faults in NS development are good hydrocarbon transporting elements of structure traps because they cut through the lower Jurassic hydrocarbon source rocks of Shuixigou Formation. This proposed buried giant arc structure system largely change the overall understanding of tectonic framework of Turpan-kumul Basin. The opinions of the comparability and symmetry in EW of this huge arc structure belt system are favorable to understand the future exploration domains of Turpan-kumul Basin.

Introductions of Turpan-kumul Basin

Turpan-kumul Basin, situated in northwest of China, the area of basin is more than 5.1×10^4 km^2. The exploration strata include: Triassic, Permian, Jurassic, Cretaceous, and Tertiary. It has produced crude oil more than 4500×10^4 t (about 3.33×10^8 b) (Figure 1). From the end of 1950's, the basin began petroleum exploration, to the end of 1980's and the beginning of 1990's, the basin began large-scale systemic petroleum exploration. The Turpan depression, situated in the west partition of Turpan-kumul Basin, is always the focus of exploration. All of it is due to the Turpan depression development of 3 petroleum-rich sags, which are Shengbei, Qiudong, and Xiaocaohu sag, and there occurs many different types of favorable structure traps.

With the development of petroleum exploration in Turpan-kumul Basin, the understanding about the structural scheme of the whole basin, tectonic evolution during the formation of the basin, and the generation and the distribution of the main structural belts have gradually become clear. The Turpan-kumul Basin, especially the Turpan depression is a front depression of Bogeda-balikun foreland basin and its evolution is directly controlled by the movement of Tianshan orogenic belt.

In order to systemic and effective carry out petroleum exploration of Turpan depression and the whole Turpan-kumul Basin, discovery of the accumulation and regulation of petroleum distribution in vertical strata and plane structure, it is necessary to analysis the structural genetic mechanism of the whole basin, tectonic evolution of different structural belts, and distribution of structural traps.

Oil and gas mainly accumulated in Turpan depression (especially in Taibei sag). The area of Taibei sag is about 1.1 x 10^4 km2 and it has 3 oil-rich sub-sags (Shengbei, Qiudong, and Xiaocaohu sub-sag). The oil is mainly produced in Taibei sag. The producing strata include: Triassic, Permian, Jurassic, Cretaceous, and Tertiary. Previous study show oil production mainly controlled by different structural belts and not study the structural belts in a whole structural background.

Previous study divided Turpan depression into 5 different structural belts: the foothill belt, shanshan arc-type belt, west arc-type belt, central anticline belt, and south slope belt (Figure 2). This type of division in geography is not advantageous to totally understanding the generation, migration, and accumulation of petroleum in a united depression and it hasn't geologic instruction to effective petroleum exploration.

Promotion of Buried Giant Arc-type Structure Systems in Turpan Depression

Considering the structural feature of Turpan depression in a united vision, a buried giant arc-type structural system is promoted. Including at least 3 arc-type belts, from south to north, they are the Huoyanshan arc-type belt, Shengbei-Qiketai arc-type belt, Baka-shanshan arc-type belt, and Aketashi-hongqikan arc-type belt (Figure 3). Petroleum has been found in each arc-type belts at present.

Evidence 1: Surface Fault distribution in Turpan depression, all are Transpressional fault, the west part is in NW-SE and the east part is in NE-SW (in red color), the SN faults (black color) mainly are strike-slip faults and cut the basement and most of the sedimentary covering (T, P, J, K, T) of the basin (Figure 4).

Evidence 2: The Tianshan Mt. in the north of Turpan-kumul Basin is distributed in arc-type (Figure 5).

Evidence 3: CEMP (Continuous electromagnetic profile) from north to south shows different arc-type structural belts in Turpan-kumul Basin (Figure 6).

Evidence 4: In S-N sections, there are more than 3 anticline or fault-anticline belts occurring (Figure 7).

Generation of Arc-type Structural System

New thrusts develop in the hanging wall and detachment on the surface of coal beds within lower Jurassic. The detachment surfaces of fault are coal beds within lower Jurassic strata (to upward including formations of Badaowan, Sangonghe, and Xishanyao) (Figure 8).

Changing of regional and local stress fields in Himalaya period is the main reason for the formation of this type of arc structural system (Figure 9). The seismic section (EW direction) in Qiudong sag obviously shows the occurring of the break through belt of alpha, which is the weak zone of the basin and accumulated much of hydrocarbon in adjacent area of structural belts (Figure 10).

General Feature of Arc-type Structure System

In west part of the giant arc-type structure belt, the faults and blocks between faults are mainly extended in NW-SE, and in east, in NE-SW. They are nearly in Symmetrical state on west and east side of stress through belt (Figure 11). As the result, the structure of the basin is obviously characteristic in different sections in west-east and various belts in north-south.

The NS faults mainly are oil-source fault, which connect the source rock and reservoir. The NW-SE or NE-SW faults mainly are seal fault and constitute fault-anticline traps.

The left and right cycles of stress fields in west and east sections result in the formation of arc structure belts in plane. There are three different arc structure belts formed within Turpan depression from north to south, which formed a huge arc structure belt. This proposed buried giant arc structure system largely change the overall understanding of tectonic framework of Turpan-kumul Basin.

Tectonic Evolution of Turpan Depression in Spatial

With the technique of axis plane mapping and structure trend analysis (John Shaw et al., 2005) to simulate the tectonic evolution of Turpan depression in spatial (Figure 12). The simulation process shows the generation turn of the first, second and third arc-type structure belts in plane.

Tectonic evolution period of Turpan-kumul Basin: Wide lake basin (T_{2+3}) → Uniform depression (North, P_3-T_1) → Separation of depression (P_{1+2}) Peripheral foreland (J_1) → Foreland (North, J_{2+3}) Now scheme (Figure 13).

Two periods of tectonic evolution: the weak extension in Yanshan movement (Jurassic) and strong compression in Himalaya movement (Tertiary to Quaternary) (Figure 14). From break through belt of alpha in stress field in middle of Turpan depression to the west and the east respectively, the nappe thrust structural style of foothill in Turpan depression are changing gradually, The existing state of structural styles in foothill (geographic) show they are generated in various tectonic periods. But the Himalaya tectonic movement has deep influence to the previous structure scheme and they are mirror symmetrical on both sides of the break through belt of alpha.

Potential exploration domains in new sight of regional structural scheme: the downhill position of each arc-type structural system and the foothill of Turpan depression in Turpan-kumul Basin.

Conclusions

Because of the thrust nappe southward of Tianshan orogenic movement and the blocking of paleo-uplift in the south, a buried giant arc-type structural system belt developed in the sedimentary covering of Turpan-kumul Basin, the structural system belt is composed of at least 3 individual arc-type belts and they formed gradually from south to north.

Changing of regional and local stress fields in Himalaya period are the main reason for the formation of this type of arc-type structural system.

Two periods of tectonic evolution during formation of this arc-type structural belt: the weak extension in Yanshan movement (Jurassic) and strong compression in Himalaya movement (Tertiary to Quaternary). The NS faults mainly are oil-source faults, which connect the source rock and reservoir. The NW-SE and NE-SW faults mainly are seal fault and part of fault-anticline traps.

The promotion of this type of arc-type structural belt is effective to future petroleum exploration. It expands the exploration domains especially the foothill partition of Turpan depression is advantageous to oil-gas exploration in future.

Acknowledgement

I truly thank Vice Professor Liang Hao, Research Institute of Petroleum Exploration & Development, Tuha Oil Field, PetroChina, kindly to help our entire authors to complete this paper. At the same time, I appreciate Geology Engineer Guo Jingyi, Han Xiaofeng, Huang Xiaopeng, Northwest Branch, Research Institute of Petroleum Exploration & Development, PetroChina, to provide personal opinions on relative title with the authors. And I deeply thank the fund provided by the Exploration and Development Bureau, PetroChina, so this paper is part of researches of the project issued in 2009, 2010, and 2011 in the Turpan-kumul Basin by the bureau.

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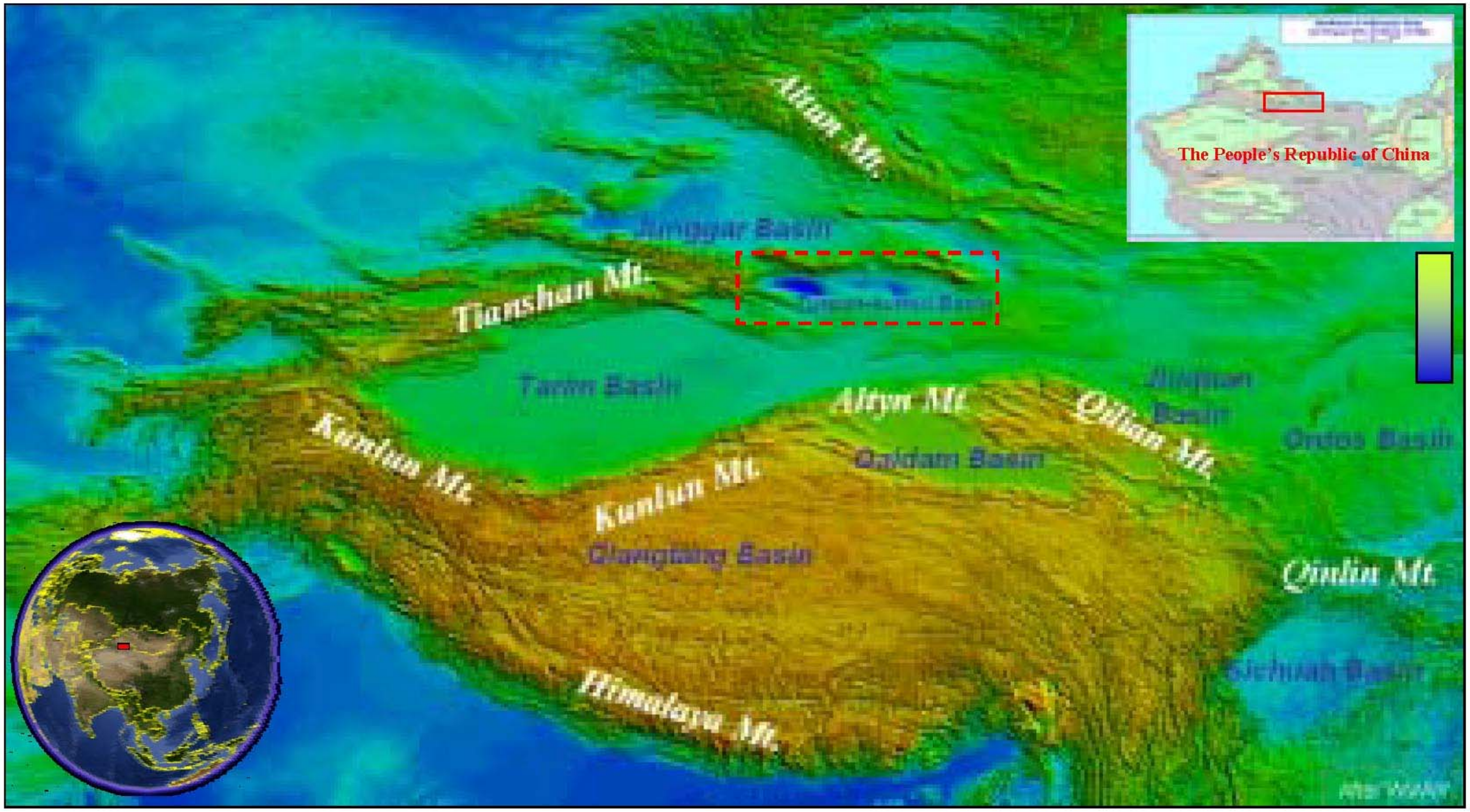

Figure 1. Location of Turpan-kumul Basin in China and on the Earth.

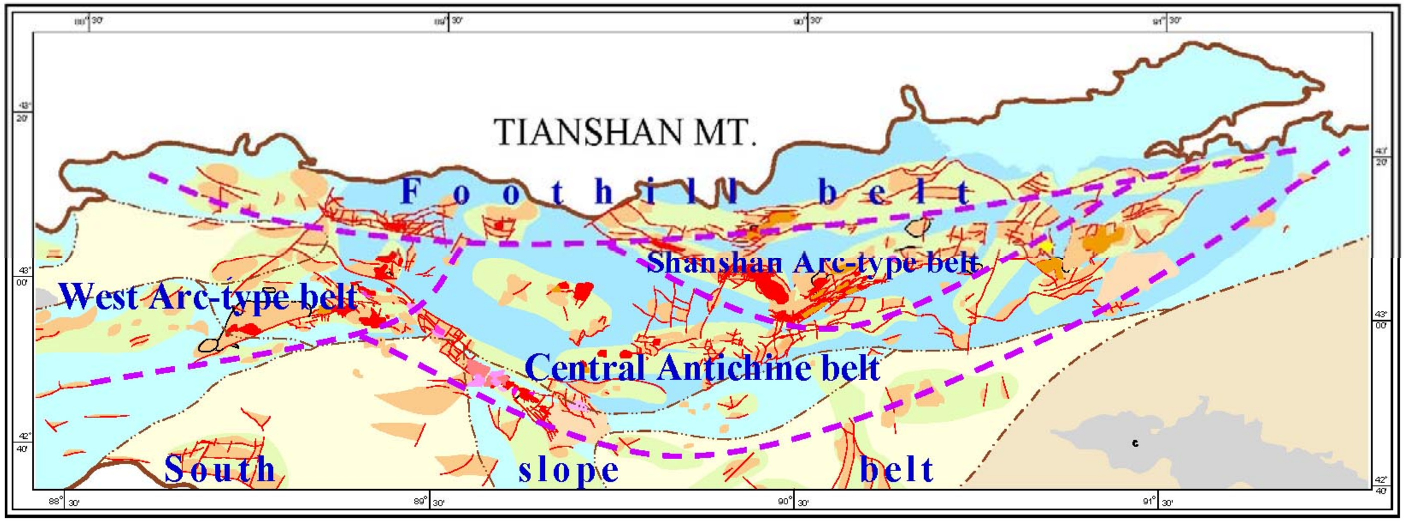

Figure 2. Previous Structural belts division of Turpan depression in Turpan-kumul Basin.

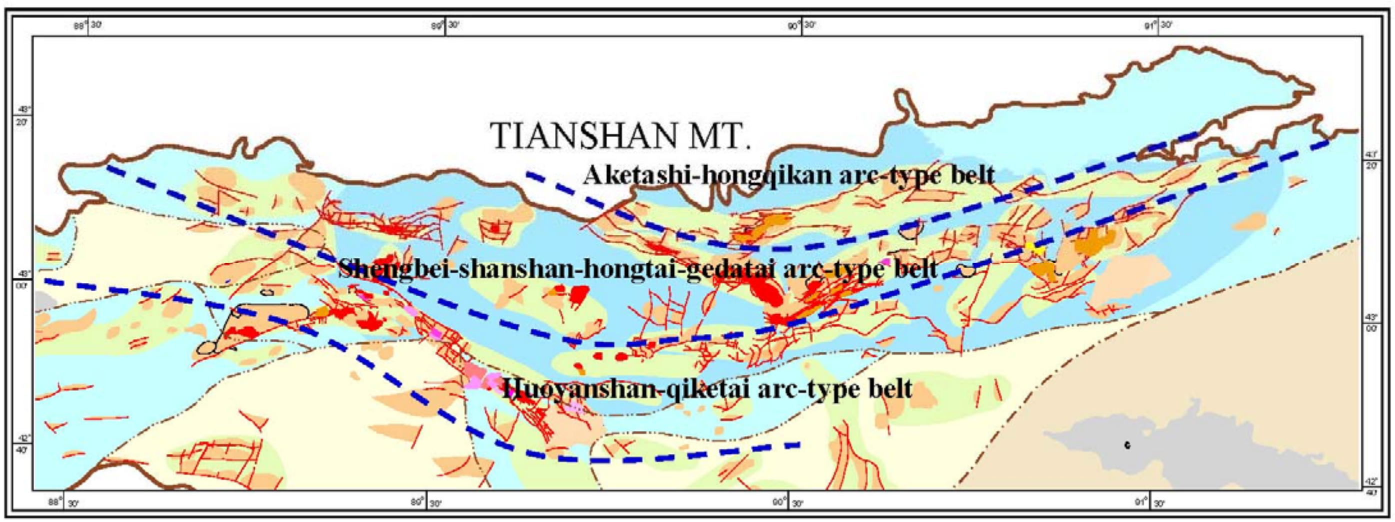

Figure 3. Buried Giant Arc-type structural belts division of Turpan depression in Turpan-kumul Basin.

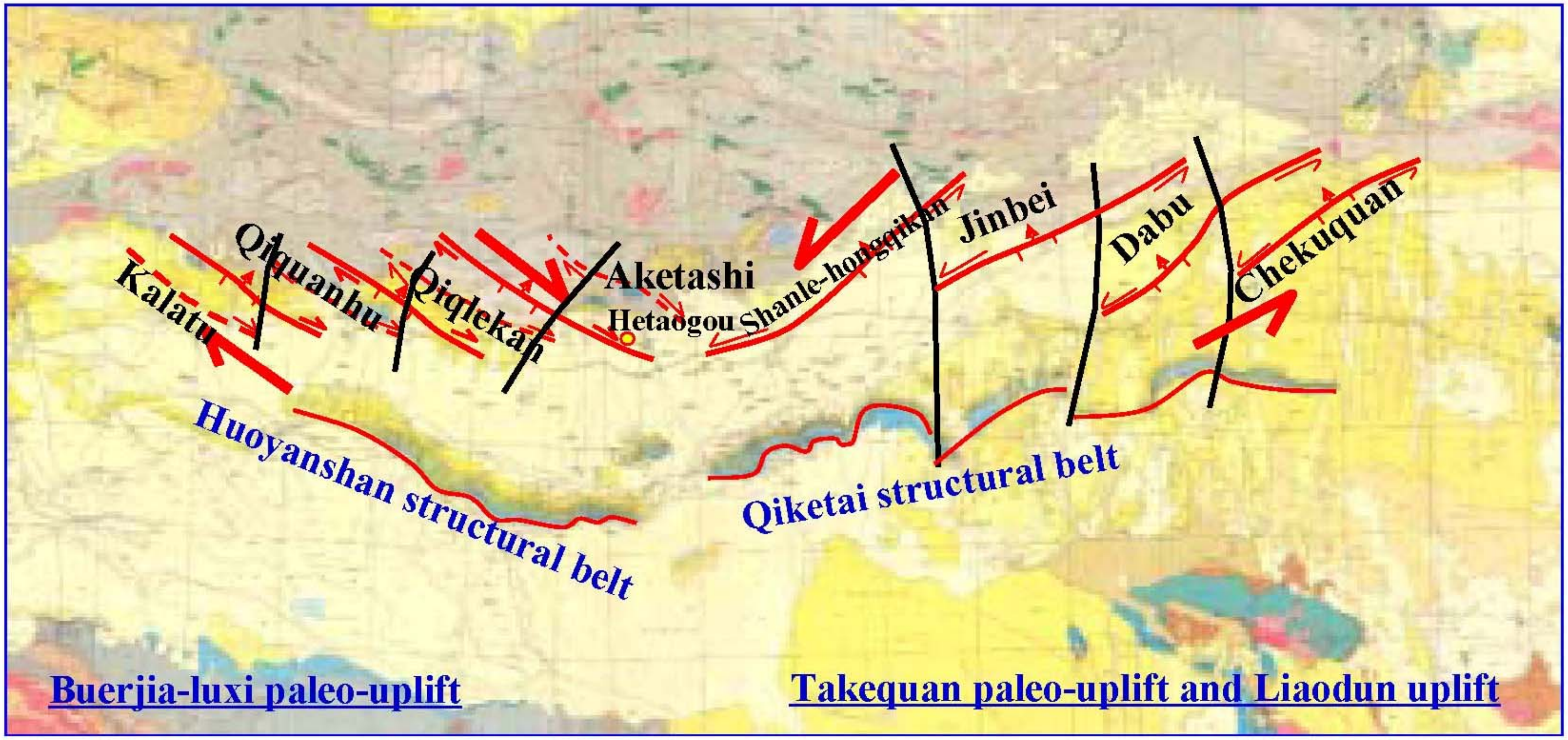

Figure 4. Surface fault distribution of Turpan depression in Turpan-kumul Basin.

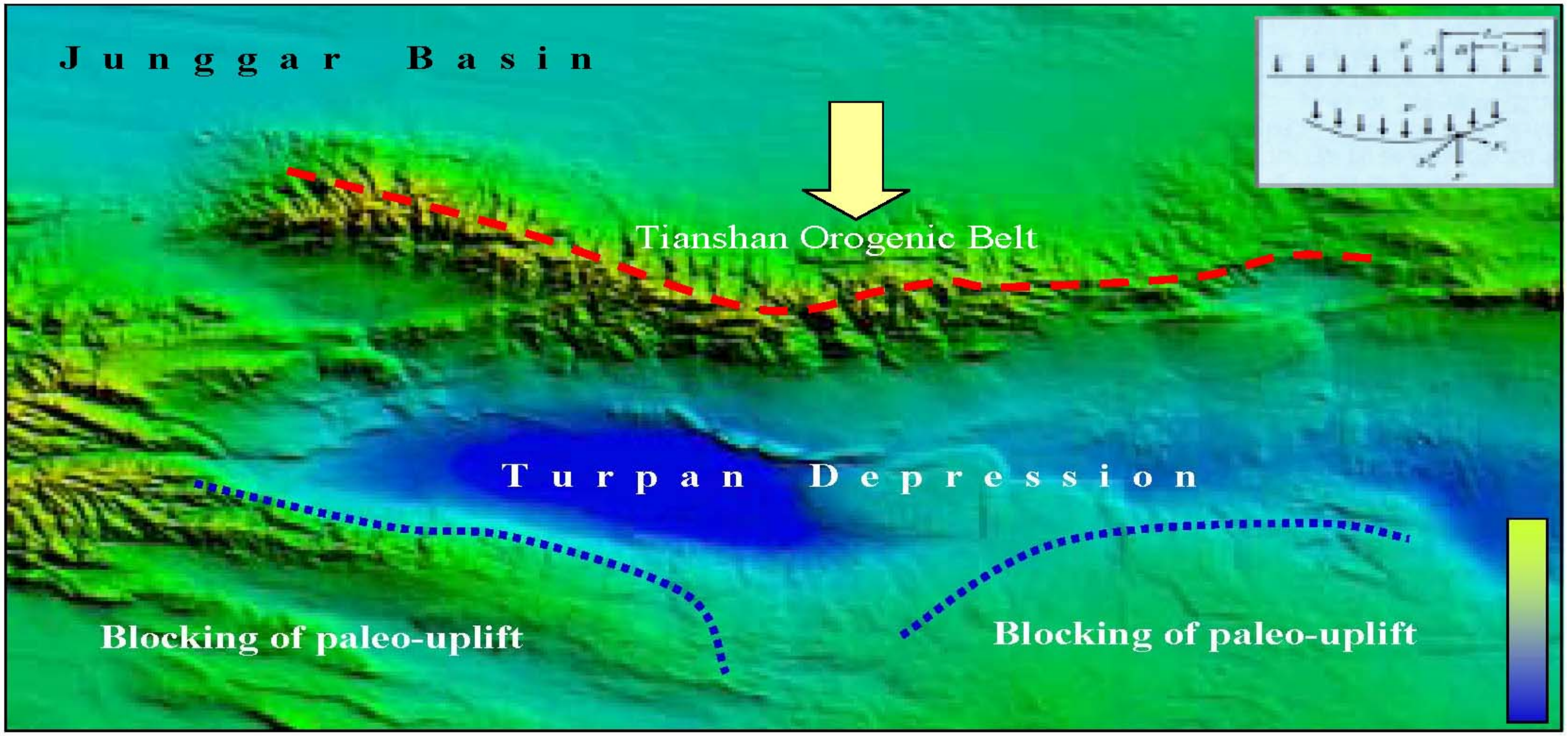

Figure 5. Distribution map of Tianshan orogenic belt in the north of Turpan-kumul Basin.

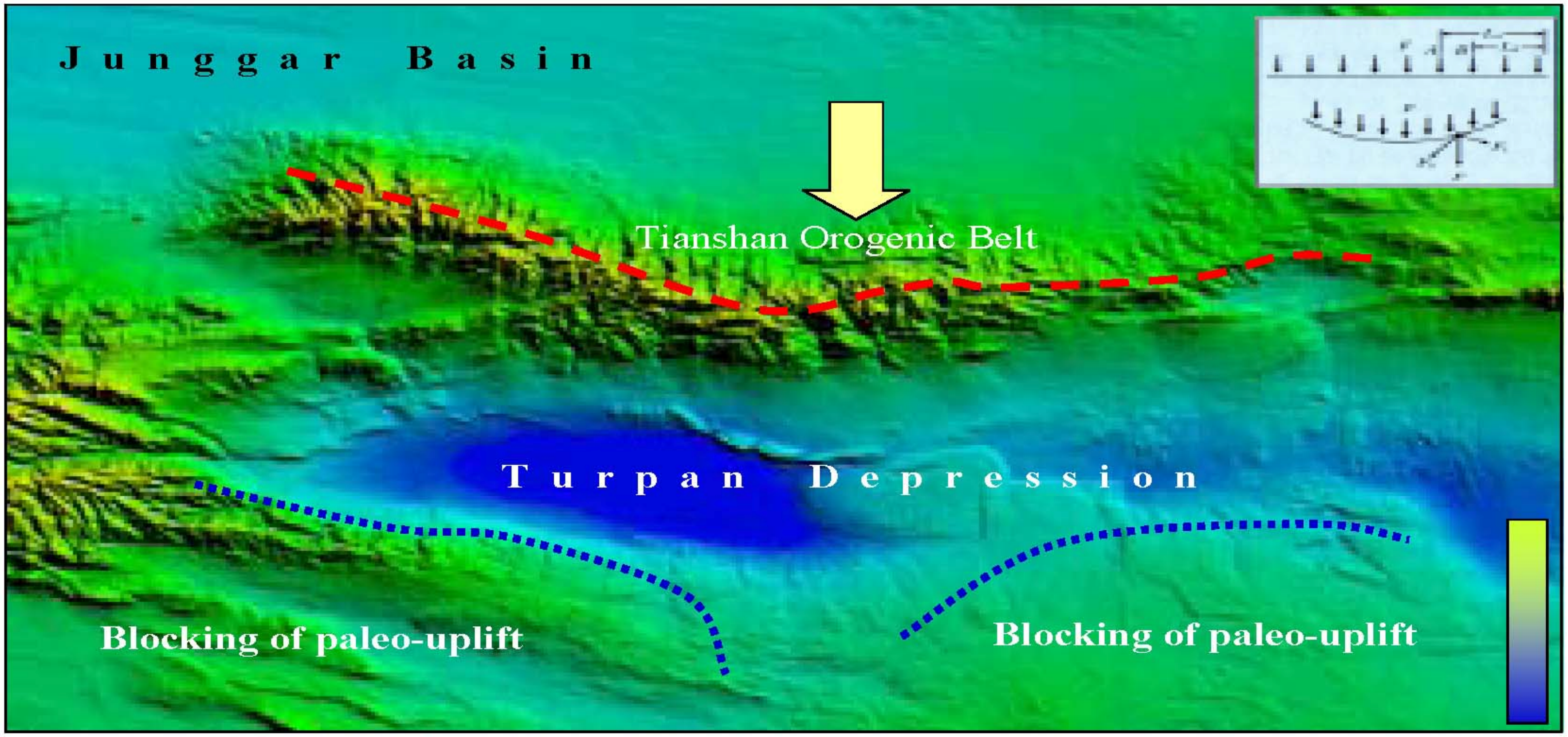

Figure 6. Continuous electromagnetic profile (CEMP) of TB07E-146.

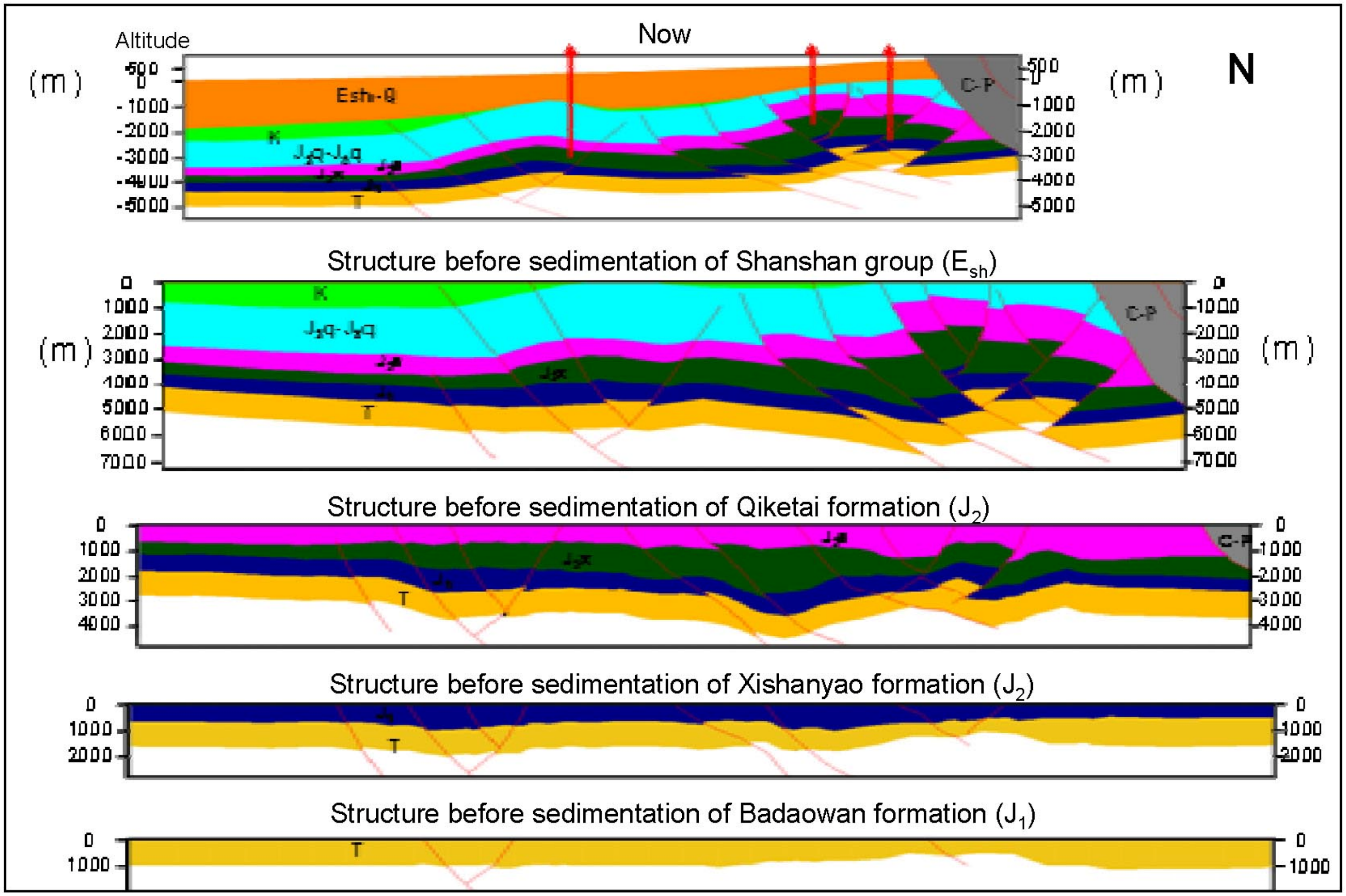

Figure 7. Seismic section from north (right) to south (left) in Turpan depression.

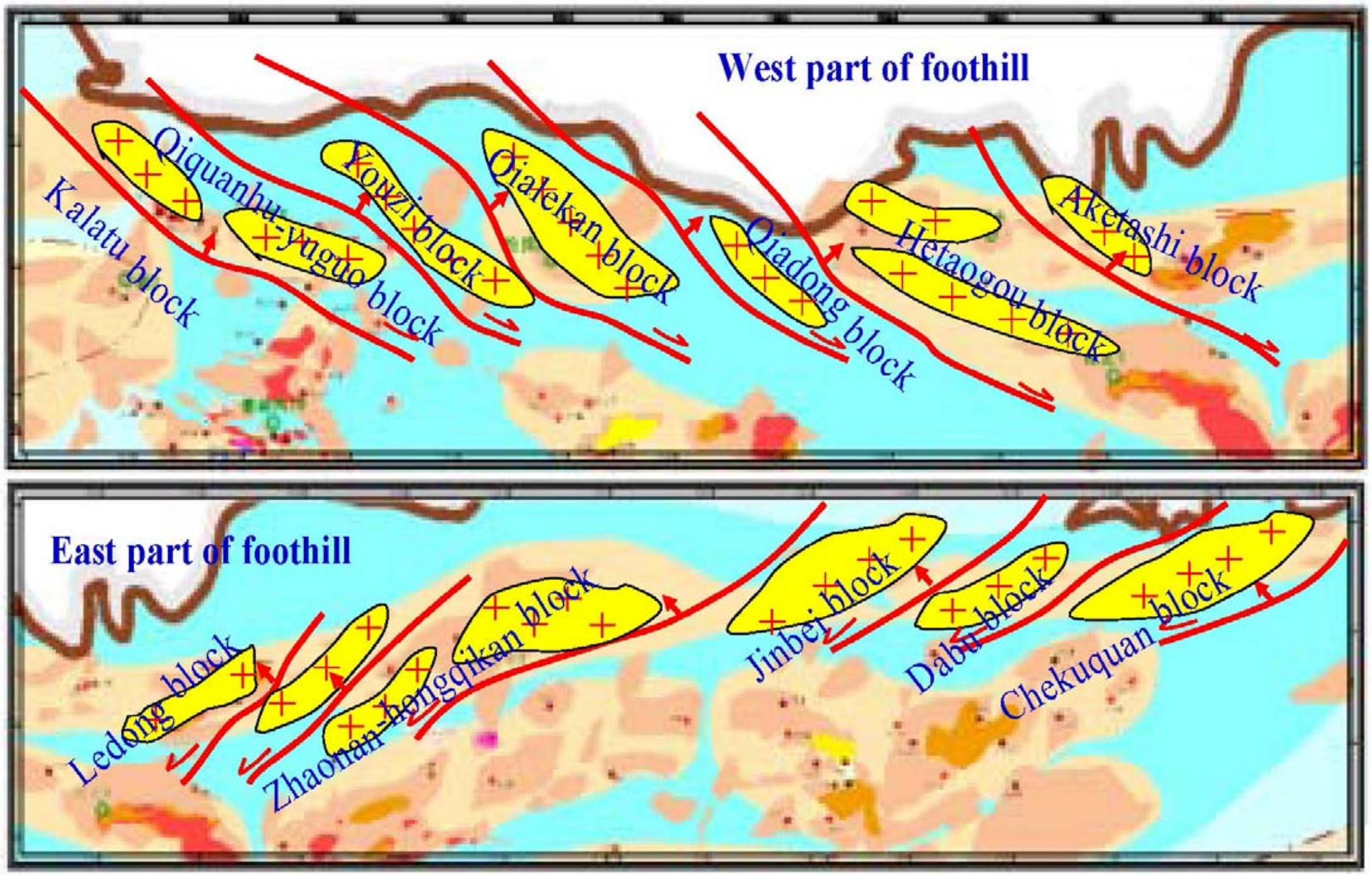

Figure 8. Processing of arc-type structural belts formation.

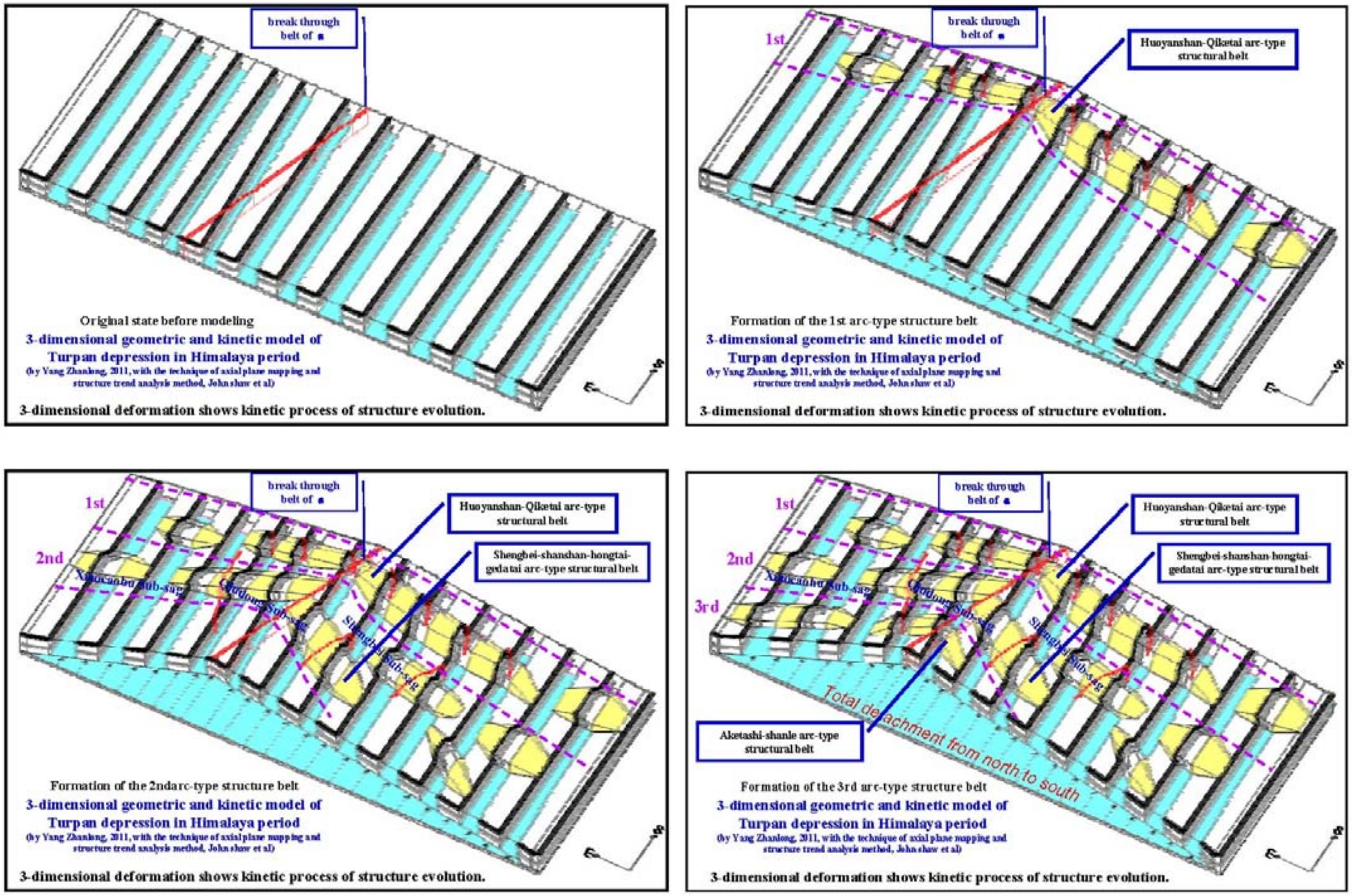

Figure 9. Stress field recovery of Turpan depression in Himalaya period.

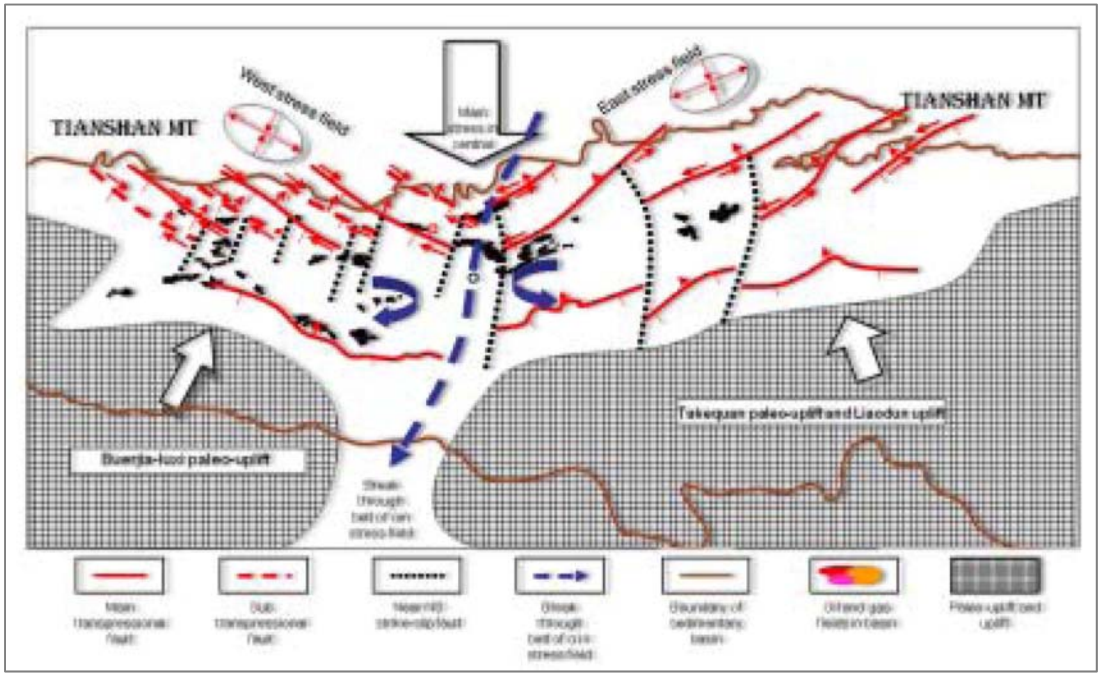

Figure 10. Seismic section (W-E) shows the Break through belt Alpha.

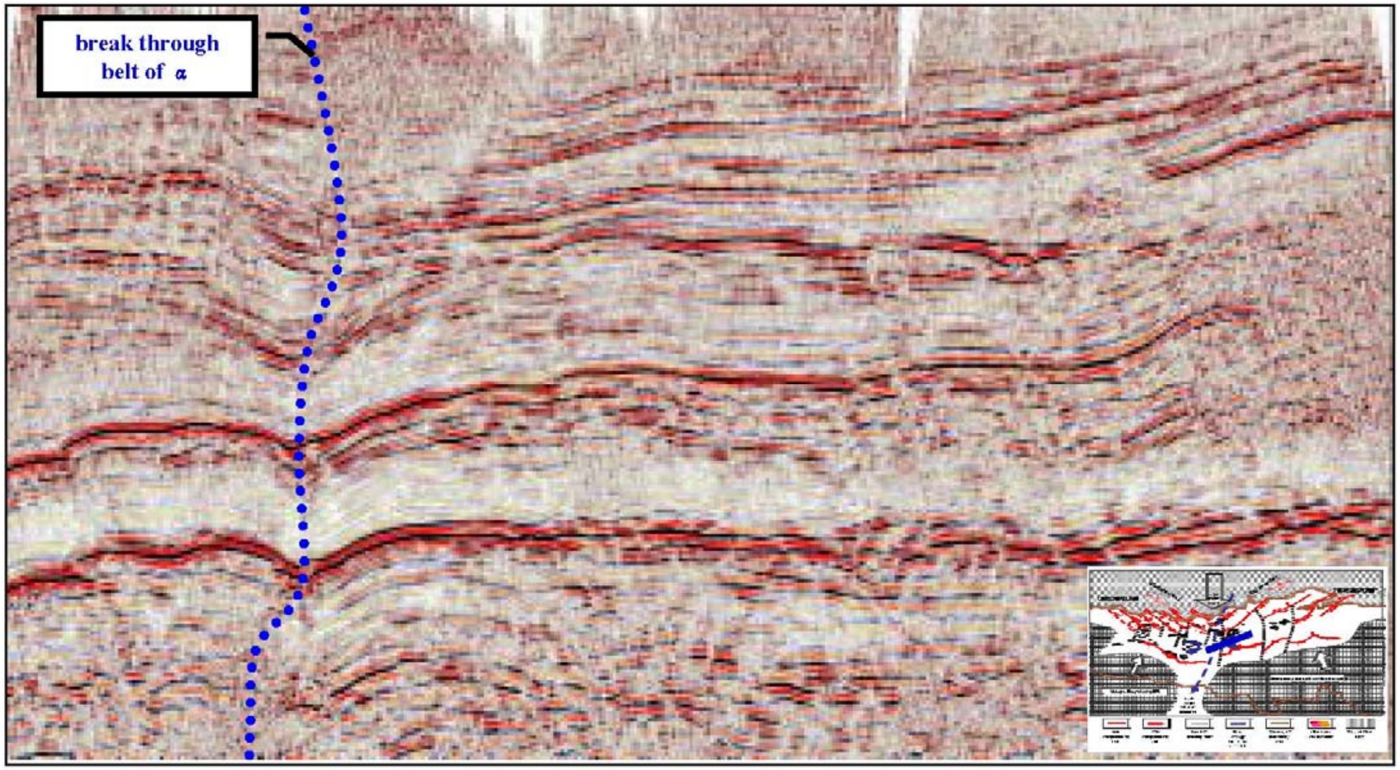

Figure 11. Faults and blocks distribution of foothill in Turpan depression.

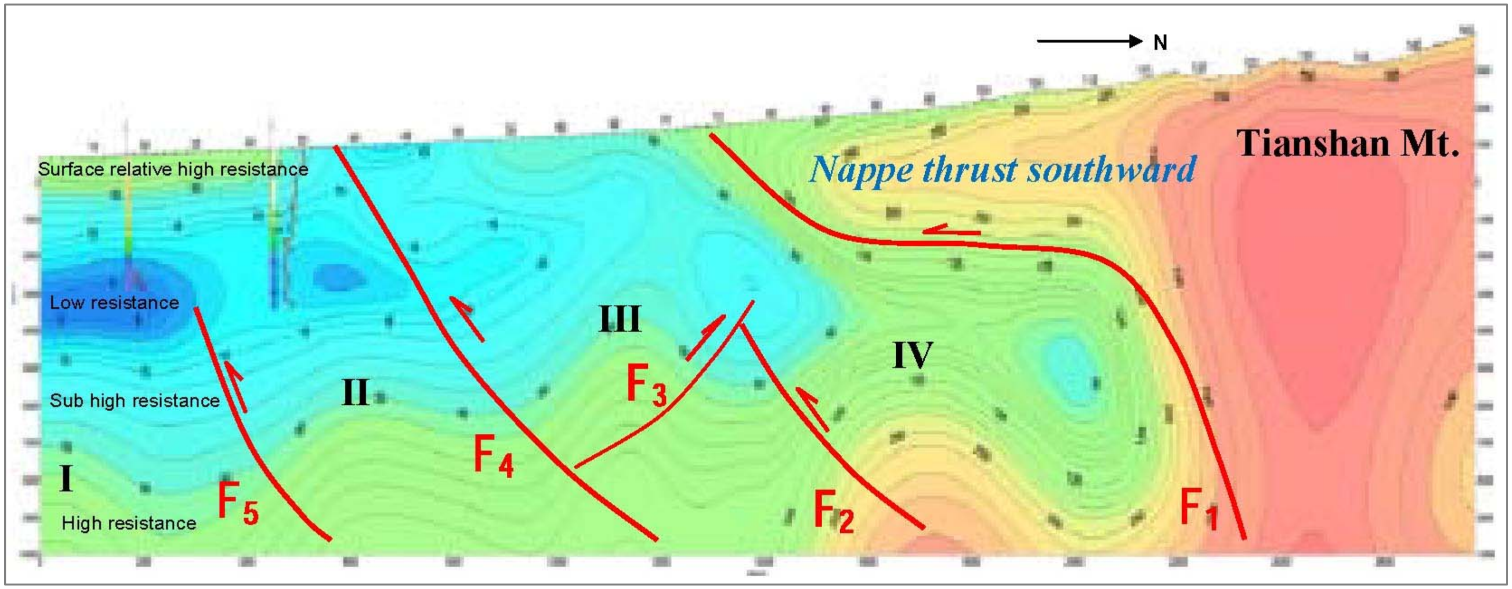

Figure 12. 3-dimensional deformation shows kinetic process of structure evolution.

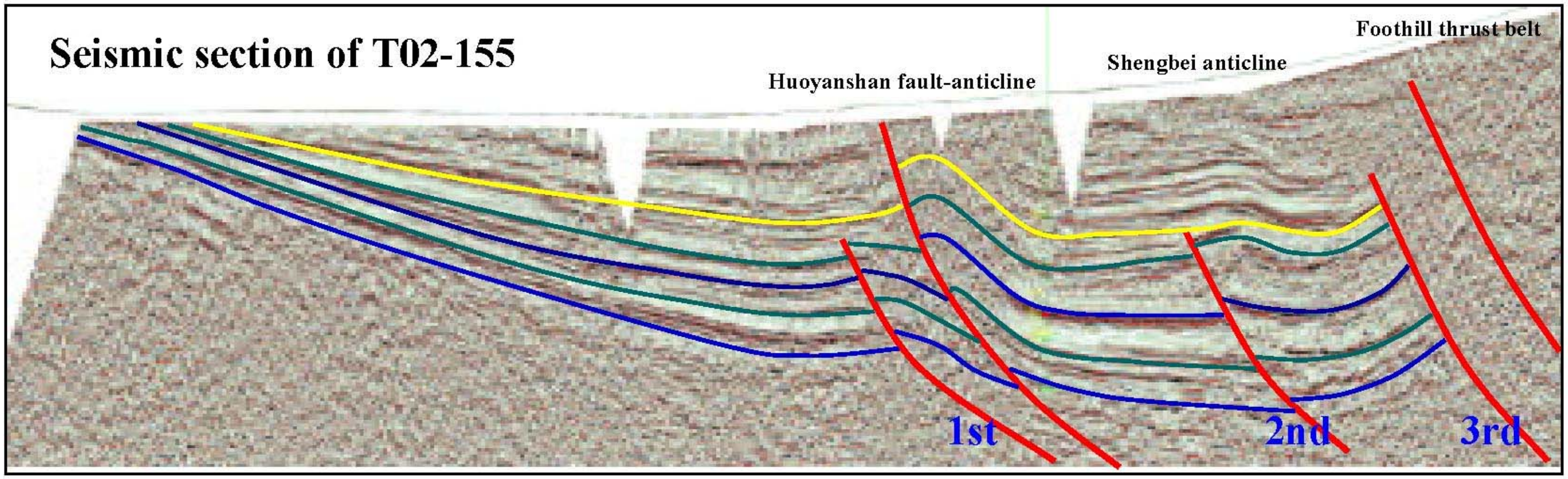

Figure 13. Tectonic evolution of Turpan-kumul Basin in plane.

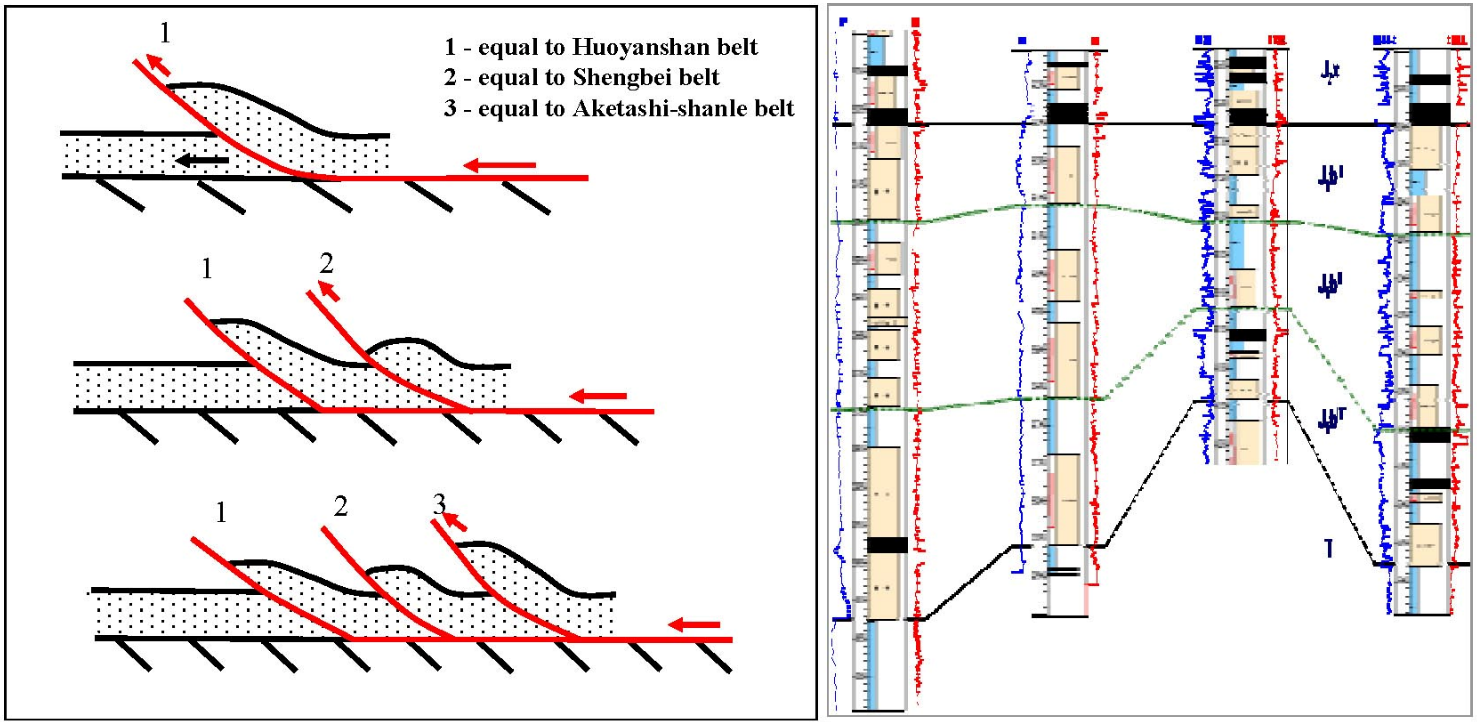

Figure 14. Tectonic evolution sections of Turpan depression (NS).