Differential Deformed Salt-Related Tectonics of the Kuqa Foreland Fold-Thrust Belt, Tarim Basin, Northwest China*

By

Liangjie Tang[1], Yixin Yu[1], Chengzao Jia[2], and Zhijun Jin[3]

Search and Discovery Article #30052 (2007)

Posted September 23, 2007

*Adapted from extended abstract prepared for presentation at AAPG Annual Convention, Long Beach, California, April 1-4, 2007

[1]Basin & Reservoir Research Center, China University of Petroleum, Beijing 102249, China (tanglj@cup.edu.cn)

[2]PetroChina Company Limited, Beijing 100011, China

[3]Petroleum Exploration and Production Research Institute, SINOPEC, Beijing 100083, China

Abstract

The differential deformed salt-related tectonics in the Kuqa foreland fold-thrust belt have been observed by field geological observation, geographic information system (GIS) analysis, 3-D visualization, analysis of the salt-related structural styles, and restored cross-sections, as well as estimation of the shortening rates. The differentially deformed salt-related tectonics is mainly displayed as the structurally differentiation in various levels, the zonation in transverse, and the segmentation in longitudinal sections. The boundaries between the structural segments are mainly strike-slip faults or tear faults revealed by terminal facets, scratches, steps, misplaced hills and river valleys. The GIS analysis may indicate some characteristic details about structural segmentation. Several segments of buried residual salt pillows are revealed by 3-D visualization. Distinct structural styles occur in different segments. The analysis of balanced cross-sections may estimate the differential amounts and rates of shortening in different segments. The origin of differentially deformed salt-related tectonics may have a bearing upon the segmentation of Tianshan Mountains, the differential sedimentation and distribution of the salt beds, the pre-existent faults and basement uplifts as well as paleotectonic-ramps.

Geological Setting

Tectono-Stratigraphic Sequences

The Kuqa foreland fold-thrust belt is located in the northern Tarim basin and strikes east-west approximately. With an area of about 2.85×10^4 km^2, it is a foreland depression south of the Tianshan Mountains and north of the north Tarim uplift. Three tectono-stratigraphic sequences--subsalt, salt, and suprasalt sequences--can be recognized. The subsalt sequences include the Upper Permian—Lower Cretaceous and their main characteristics are summarized as follows: (1) The 300-m-thick Upper Permian Biyelbaoguz Group is composed of continental purple sandy mudstone with interbedded gray conglomerate, sandstone, and black carbonaceous shale. It overlies the Lower Permian volcanics or the Carboniferous limestones. (2) The Lower Triassic consists of pluvial-alluvial purple granulite with interbedded sandstone and mudstone. The Middle-Upper Triassic is composed of flood-plain/shallow-lakeshore/deltaic dark mudstone with interbedded gray-green granulite. The thickness of the entire Triassic is up to 2000 m. (3) The Jurassic, with a thickness of 400-2000 m, consists of fluvial/delta/swamp/lacustrine gray conglomerate, sandstone, dark mudstone, shale, and coal seams. (4) The Lower Cretaceous, with a thickness of 400-2000 m, is composed of pluvial-fluvial/delta/lakeshore/lacustrine purple conglomerate, sandstone, and mudstone.

The salt sequences are special successions in the middle part of Kuqa foreland fold belt and are characterized by thick halite and gypsum beds. Plastic flow was clearly observed in the sequences. The main detachment surface was developed within the salt sequences, which controlled structural deformation of the Kuqa foreland fold belt. The Paleocene—Eocene salt sequence, 110-3000 m thick is mainly composed of light gray halite, gypsum, marl, mudstone, sandstone and conglomerate.

The supra-salt sequences include the Oligocene—Quaternary and has the following main features: (1) The Oligocene Suwiyi Formation is characterized by red siliciclastics with thin, interbedded halite and gypsum with a thickness of 150-600 m. (2) The lower Miocene Jidik Formation consists of purple sandstone and mudstone and has a thickness of 200-1500 m. (3) The upper Miocene Kanchun Formation, 650-1500 m thick, is dominated by interbedded brown sandstone and mudstone. (4) The Pliocene Kuche Formation, 450-4000 m thick, is composed of gray-yellow sandstone, silty mudstone with interbedded conglomerate. (5) The Quaternary is dominated by fluvial-pluvial loose gravel, sand, and clay beds.

Structural Units

The Kuqa foreland fold-thrust belt can be divided into six structural units (Figure 1):

(1) **Northern monocline belt** is mainly composed of Mesozoic strata. The south-dipping Triassic and Jurassic monocline was formed because of uplifting and thrusting of the south Tianshan Mountain wedge.

(2) **Klasu—Yiqiklik structural belts** can be divided into Klasu belt in the west and Yiqiklik belt in the east. A series of surface and subsurface anticlines occur in the belts, and they are controlled by Kumglimu—Bashijiqik and Tuzmaza—Kasantukai thrust faults. The structures in deep horizons of the belt display a number of salt-associated anticlines and thrust faults.

(3) **Baicheng—Yanxia sags** contains over 9000 meters of Meso-Cenozoic sediments. One of the reasons for its intense subsidence is that the deep salt flowed plastically toward the Klasu structural belt to the north and Qiulitag structural belt to the south (in the west). It resulted in thinning of the salt in the sag and the syn-depositional subsidence.

(4) **Qiulitag structural belt** is a frontal intense deformation belt and mainly composed of major salt nappes, thrust salt sheets, salt glacier, salt pillows, thrust faults, back-thrusts, and competent folds.

(5) **Northern Tarim forebulge** is at the northern part of the north Tarim uplift and is composed of the Yaken anticline belt, Yaha fault belt, Luntai structural belt, and Yangtak-Yinmaili structural belt.

(6) **Wushi sag** is the western segment of the Kuqa foreland fold-thrust belt. It contains thick Meso-Cenozoic and deep-seated pre-Sinian basement. A series of anticlines, fault-anticlines, and fault-nose traps were developed in the sag.

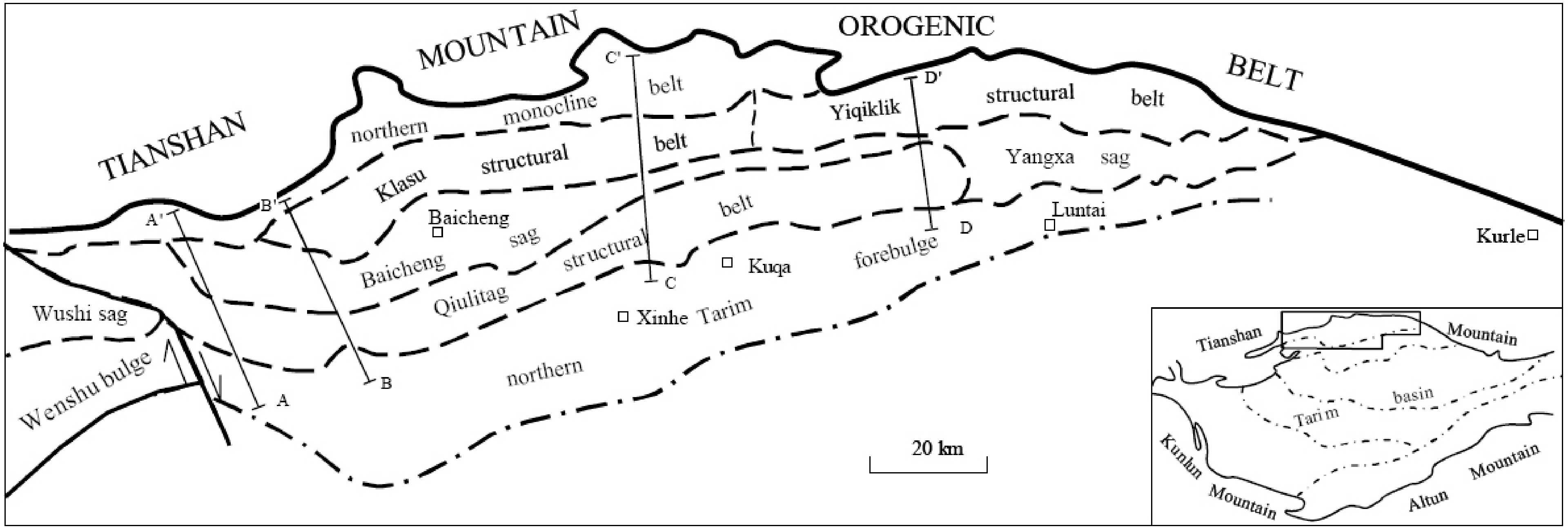

Figure 1. Sketch map of structural units in the Kuqa foreland fold-thrust belt.

Main Characteristics and Marks of the Differentially Deformed Salt-Related Structures and Segmentation

Difference in Salt Distribution

The salt strata occur in the Lower Paleogene in the western part of the Kuqa foreland fold-thrust belt; they were developed in the Neogene Jidik Formation in the eastern part of the belt. It is characterized by pure salt and gypsum in the west and interbedded gypsum and mudstone in the east. It is more widely distributed and thicker in the west than in the east.

Surface Characteristics and GIS Analysis

The strike-slip faults or tear faults perpendicular to the regional structural strike were developed in the Kuqa foreland fold-thrust belt, such as Kalayugun fault. These faults may accommodate the shortening and divided the fold-thrust belt into several segments.

Terminal facets, scratches, steps, misplaced hills and river valleys are commonly observed on outcrop. The terminal facets are perpendicular to the regional tectonics. The scratches are mainly horizontal.

The GIS analysis is thought to indicate some characteristic details about structural segmentation. The digital elevation model (DEM) and Triangulated Irregular Network (TIN) (Figure 2) can be established according to the contour map of the Kuqa fold-thrust belt. It can be seen that the

Kuqa fold-thrust belt is characterized by zonation along south-north direction, and segmentation along east-west direction. The main transfer zones are Kuche and Klasu rivers.

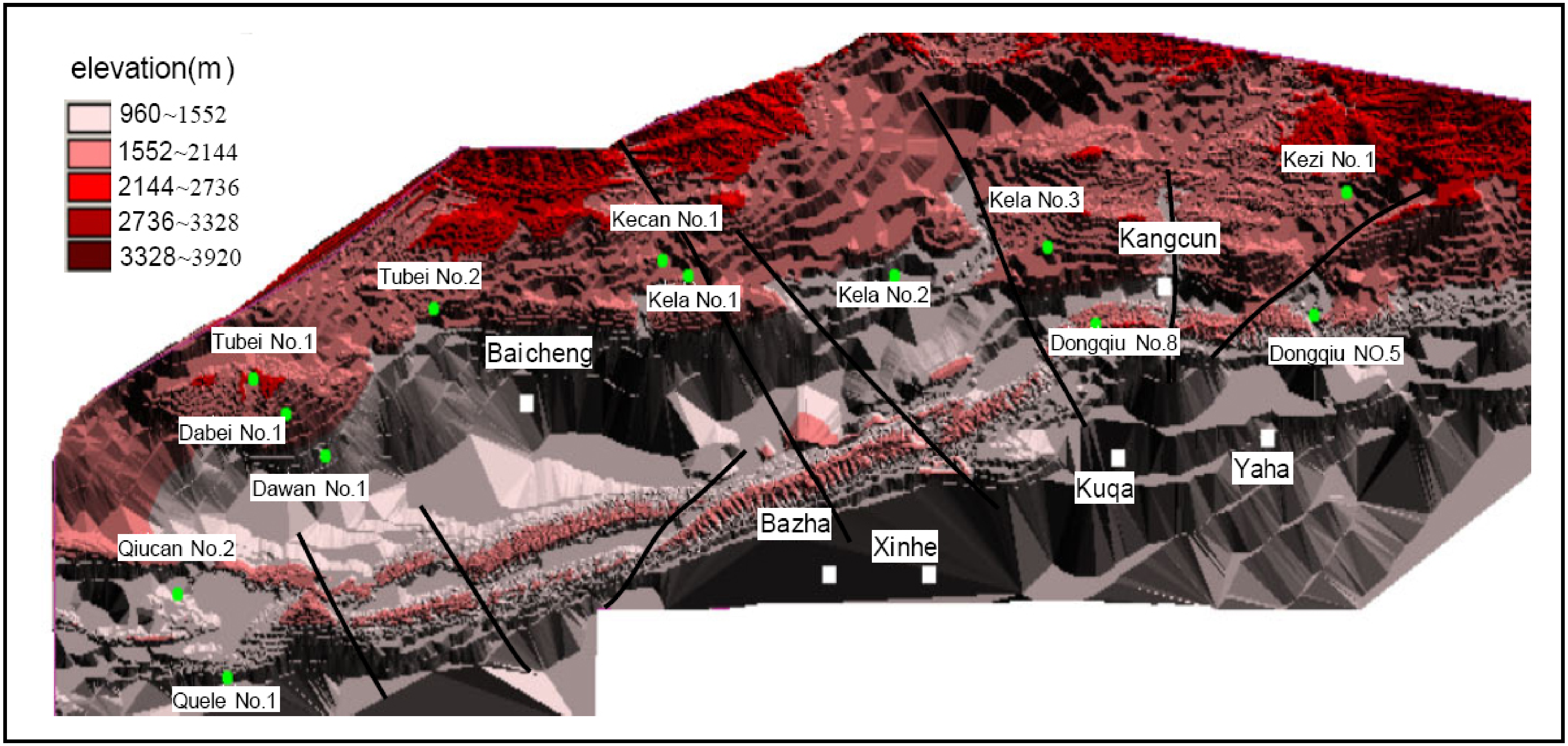

Figure 2. Triangulated Irregular Network model of the Kuqa foreland fold-thrust belt.

3-D Visualization

The 3-D visualization of the thickness of the Paleogene Kumglimu Formation in the Kuqa foreland fold-thrust belt indicates that the salt bed thickens in the Klasu and Qiulitag belt and thins in the Beicheng sag. Salt-related structures are distributed irregularly around the Baicheng sag. The well developed salt pillows are mainly distributed along the Qiulitag belt, whereas the relict salt pillows, which are distributed along the Klasu belt, are apparently transected by strike-slip fault and segmentation.

Differentiated Deformed Structural Styles

The difference of the salt-related structural styles is apparent in the Kuqa foreland fold-thrust belt. In the western segment of the belt, the salt beds are developed mainly in the Paleogene. It is characterized by salt nappes in the thrust fronts, huge salt pillows in the west Qiulitag and Klasu structural belts, and sub-salt, imbricated thrust fault belts and duplex structures in the foothill of the thrust faults. The salt weld structures, complex faulted folds within the salt horizons, triangle zones, forced folds, and pop-up structures are also developed in the western part of the Kuqa foreland fold-thrust belt (Figure 4 A-A', B-B', and C-C').

The alternating salt beds and clastics are developed in the Miocene Jidik Formation in the eastern part of the Kuqa foreland fold-thrust belt. The flowage of the salt beds is weaker and the salt pillow is smaller than in the west segment. No salt nappes, sub-salt imbricated thrust faults, or duplex structures exist in the eastern part of the belt. The broad synclines and anticlines were formed in the supra-salt Kacun Formation (N_1k), Kuqa Formation (N_2k), and Quaternary. It is thought that the complex thrusts, fault-blocks, and folds were developed in the foothills of the south Tianshan Mountains (Figure 4 D-D').

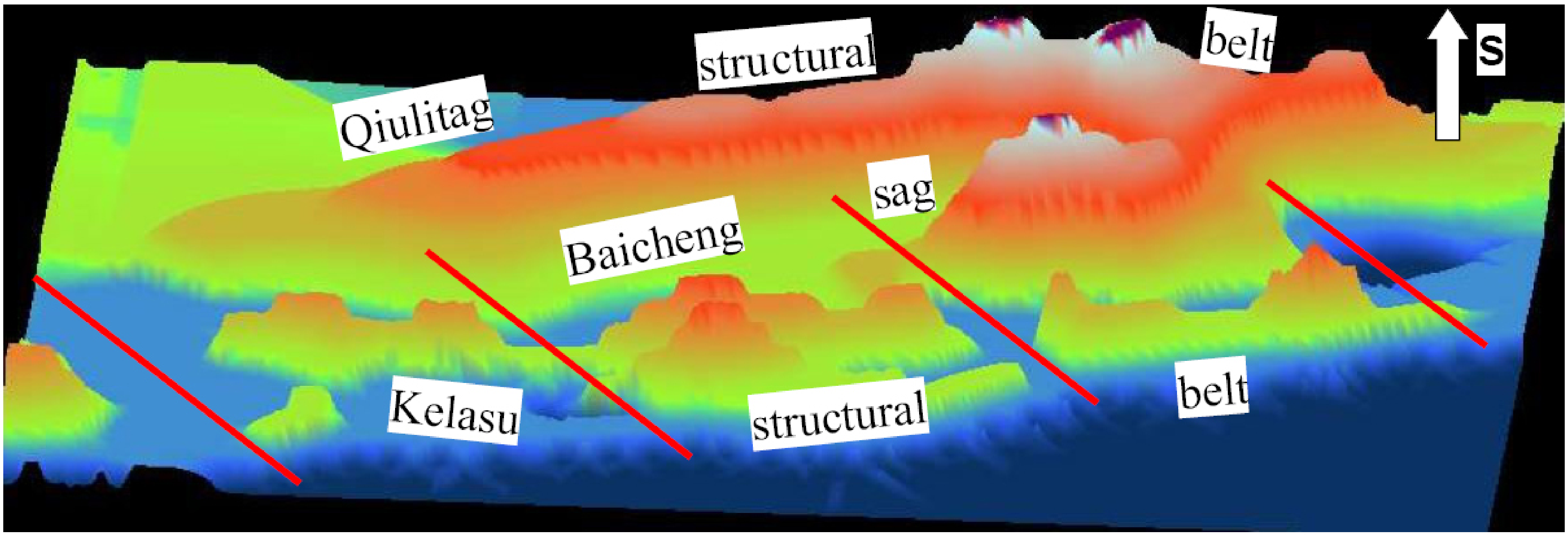

Figure 3. 3D visualization showing differential salt tectonic deformation and segmentation of the Klasu structural belt.

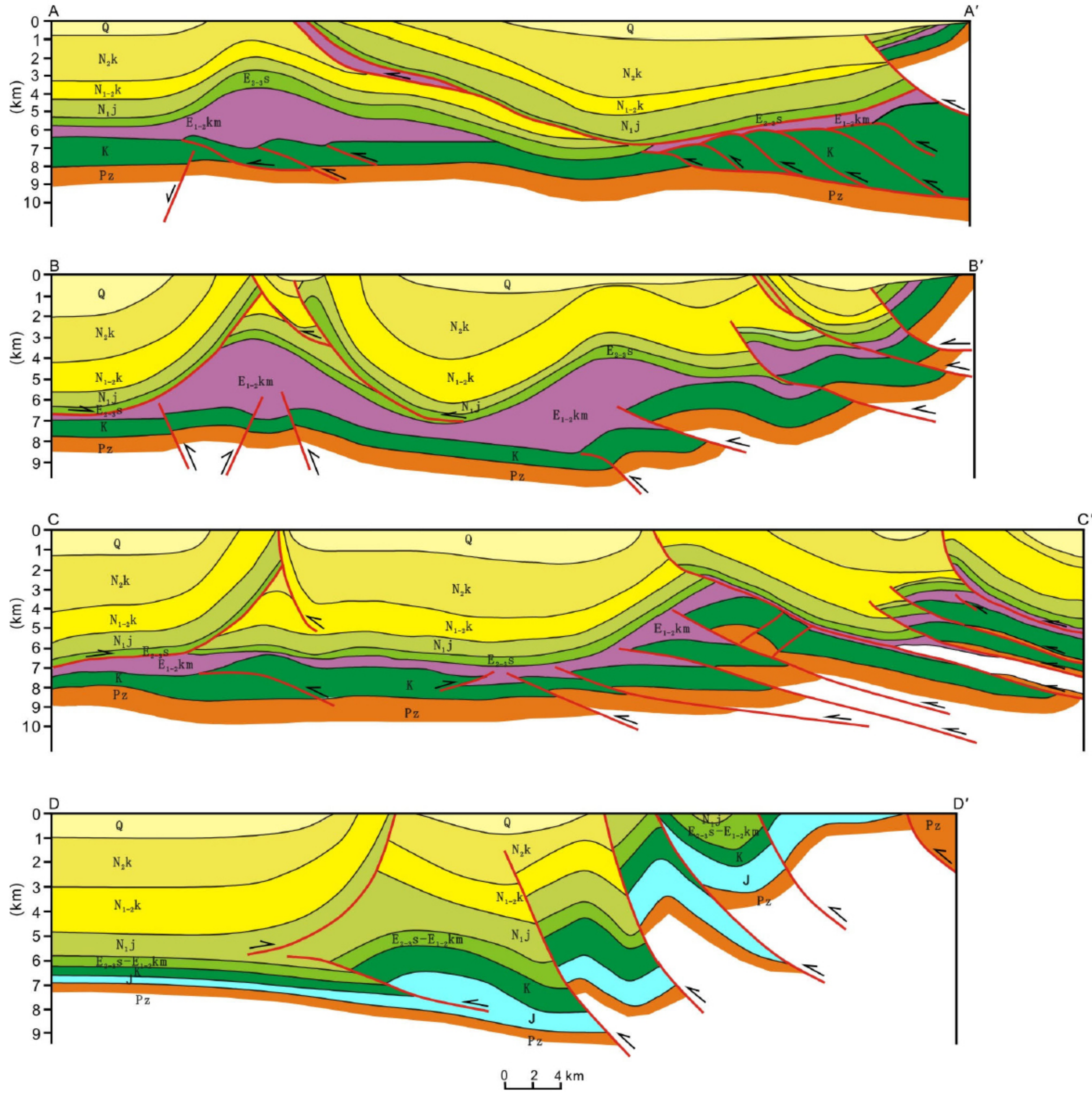

Figure 4. Cross-sections of the salt-related structures showing the differential structural styles in different segments of the Kuqa foreland fold-thrust belt (locations in Figure 1). Q—Quaternary; N2*k*—Pliocene Kuche Formation; N1-2*k*—Miocene Kanchun Formation; N1*j*—Miocene Jidik Formation; E2-3*s*—Oligocene Suweiyi Formation; E1-2*km*—Paleocene-Eocene Kumugeliemu Formation; K—Cretaceous; J—Jurassic; Pz—Paleozoic.

Shortening Differences

Balanced cross-section analyses indicate that there exists distinct shortening difference for the supra-salt, salt, and sub-salt strata in west Qiulitag belt. The shortening rate of the supra-salt is as much as 28.6%, while the shortening of the sub-salt is only 7.2%. The shortening difference is accommodated by plastic flow of the salt bed and imbricated thrusts and duplex structures in the foothills of the Tianshan Mountains. The segmentation in the west Qiulitag belt may be indicated by the shortening rate. The supra-salt shortening is about 28.6% in the western part of the west Qiulitag because of the existence of the salt nappes, and the shortening is less than 20% in the east part of the belt.

Mechanisms of Differentiated Deformation and Segmentation of the Salt-Related Structures

Differentiated Deformation of Tianshan Orogenic Belt and Kuqa Foreland Fold-Thrust Belt

There exists segmentation in the Tianshan Mountains and adjacent basins. The difference of the texture and habitat of structural movement of Tianshan Mountains controlled the segmentation of the adjacent basins, such as Tuha, Yanji, south margin of the Jungar basin, Yinin, Kuqa, and southwest Tarim basins.

Basement Controls

Pre-existing basement structures controlled differentiated deformation and segmentation of salt-related structures of the Kuqa foreland fold-thrust. Pre-existing basement fault belts exist in the Qiulitag and Klasu, and they controlled the development of salt pillows and salt nappes. The mechanisms of basement tectonics controlling the development of the salt-related structures are as follows: (1) The development of the salt pillows is in accordance with the existence of the sub-salt paleo-uplifts; (2) The pre-existing basement faults are present in both limbs of the salt pillows; and (3) The formation of the salt nappes may have a bearing on the paleo-structural ramps.

Conclusion

The differentially deformed salt-related tectonics in the Kuqa foreland fold-thrust belt has been observed by field geological studies, geographic information system (GIS) analysis, 3-D visualization, analysis of the salt-related structural styles, and restored cross-sections, as well as estimation of the shortening rates. The differentially deformed salt-related tectonics is mainly displayed as the structural differentiation in various levels, the zonation in transverse, and the segmentation in longitudinal sections. The boundaries between the structural segments are dominated by strike-slip faults or tear faults revealed by terminal facets, scratches, steps, misplaced hills and river valleys. The GIS analysis may indicate some characteristic details about structural segmentation. Several segments of buried residual salt pillows are revealed by 3-D visualization. Distinct structural styles occur in different segments. The analysis of balanced cross-sections may be used to estimate the amounts and rates of shortening in different segments. The origin of differentiated deformed salt-related tectonics may have a bearing on the segmentation of the Tianshan Mountains, the different sedimentation and distribution of the salt beds, the pre-existing faults, and basement uplifts, as well as paleo-tectonic-ramps.