



Dual influence of the rejuvenation of Southern Tianshan and Western Kunlun orogen on the Cenozoic structure deformation of Tarim Basin, northwestern China: A superposition deformation model from Bachu Uplift*

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Abstract: Based on new high-resolution seismic profiles and existing structural and sedimentary results, a superposition deformation model for Cenozoic Bachu Uplift of northwestern Tarim Basin, northwestern China is proposed. The model presents the idea that the Bachu Uplift suffered structure superposition deformation under the dual influences of the Cenozoic uplifting of Southern Tianshan and Western Kunlun orogen, northwestern China. In the end of the Eocene (early Himalayan movement), Bachu Uplift started to be formed with the uplifting of Western Kunlun, and extended NNW into the interior of Kalpin Uplift. In the end of the Miocene (middle Himalayan movement), Bachu Uplift suffered not only the NNW structure deformation caused by the Western Kunlun uplifting, but also the NE structure deformation caused by the Southern Tianshan uplifting, and the thrust front fault of Kalpin thrust system related to the Southern Tianshan orogen intrudes southeastward into the hinterland of Bachu Uplift and extends NNE from well Pi1 to Xiaohaizi reservoir and Gudongshan mountain, which resulted in the strata folded and denuded strongly. In the end of the Pliocene (late Himalayan movement), the impact of Southern Tianshan orogen decreased because of the stress released with the breakthrough upward of Kalpin fault extending NE, and Bachu Uplift suffered mainly the structure deformation extending NW-NNW caused by the uplifting of Western Kunlun orogen.

Key words: Superposition deformation model, Bachu Uplift, Southern Tianshan, Western Kunlun, Cenozoic

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INTRODUCTION

Since Molnar and Tapponnier (1975) proposed the "slide line" theory of collision between India and Asia plate, as well as Guo *et al.* (1992) presented the "long distance effect" of India-Asia plate collision,

many important advances on the Cenozoic structure deformation of Tarim, Tianshan, Kunlunshan and Pamir in northwestern China has been made in recently years (Windley *et al.*, 1990; Hendrix *et al.*, 1994; Tian, 1996; Jia, 1997; Sobel and Dumitru, 1997; Jia *et al.*, 1998; Lu *et al.*, 2000; Liu *et al.*, 2000; Burtman, 2000; Jolivet *et al.*, 2001; Wang, 2005; Wang *et al.*, 2001; Yang and Liu, 2002; Tang *et al.*, 2003; Wu *et al.*, 2004; Buslov *et al.*, 2007). However, the relationship between the Cenozoic structure de-

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formation and the uplifting orogens around, especially between Bachu Uplift related to the Western Kunlun orogen and Kalpin Uplift related to the Southern Tianshan orogen has been still kept in debate in recent years.

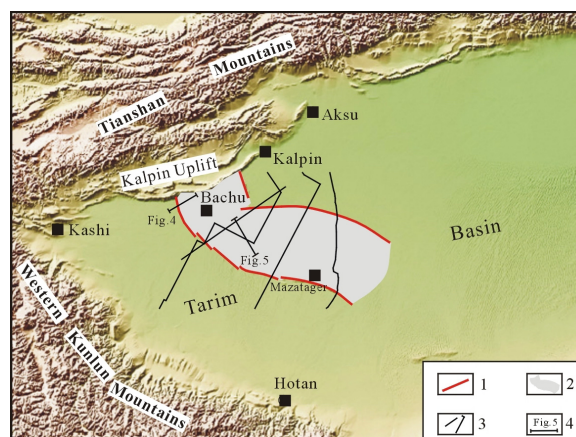
Some experts think that the structure superposition deformation exists between Bachu Uplift and Kalpin Uplift, and that the Bachu Uplift extends northwestward and was buried partly under the Kalpin Uplift (Yin *et al.*, 1998; Allen and Vincent, 1999; He *et al.*, 2002; Yang and Guo, 2003; Xiao *et al.*, 2005; Yang *et al.*, 2006). But other experts think that the structure superposition deformation does not exist between Bachu Uplift and Kalpin Uplift, and that the relationship between the two uplifts was shear extrusion rather than structure superposition caused by thrust fault (Jia *et al.*, 1998; Lu *et al.*, 1998; Xie *et al.*, 1998; Fan *et al.*, 2000).

Based on the new high-resolution seismic profiles, this paper not only makes sure the idea that the northwestward extension of Western Bachu Uplift was buried under the Kalpin Uplift, but also find out the fact that the Kalpin thrust system intruded south-eastward into and was buried under the hinterland of western Bachu Uplift. In addition, it also limits the location of the frontal thrust fault that belongs to the Kalpin thrust system and is hidden under the Bachu Uplift. Here we report this achievement and try to discuss the geodynamical significations of the above structural phenomena.

GEOLOGICAL SETTING AND DESCRIPTION OF SEISMIC PROFILES

Bachu Uplift is located at the northwestern Tarim Basin in Xinjiang Province, northwestern China, and belongs to the west part of Central Uplift of Tarim Basin. It can be divided into two segments: eastern Bachu Uplift extending NW and western Bachu Uplift extending NNW. To the northwest it is separated from the Kalpin Uplift by the Kalpin Fault, to the southwest it is separated from the Maigaiti Slope by the Selibuya-Kangtakumu-Mazhatage faults, and to the northeast it is separated from the Awati sag by the Aqia-Tumuxiuke faults respectively (Fig. 1).

Bachu Uplift and Kalpin Uplift experienced such geological evolution phases as Caledonian, Hercynian,

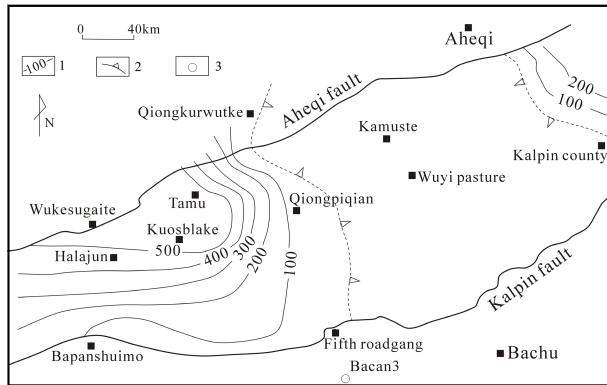


1: fault; 2: Bachu Uplift; 3: regional seismic profile; 4: local seismic profile and section location

Fig.1 Structure location and distribution of seismic profiles in the study area

Indosinian-Yanshan and Himalayan movements on the Pre-sinian crystalline basement (Kang and Kang, 1996; Jia, 1997). The Tarim Plate was entered into the evolution phase of stable craton during the Cambrian to the Permian, and accepted the deposition of vast thickness of marine carbonatite (Zhang *et al.*, 2003; Jia *et al.*, 1992). But in the Late Ordovician, because of the subduction of Southern Tianshan Ocean on the north (Windley *et al.*, 1990), the Middle Caledonian movement happened, and the Kalpin Fault extending NE started to become active and then the Kalpin was separated from the Bachu. To the end of the Middle Devonian, Bachu and Kalpin uplifted together and suffered denudation strongly because of the closure of Kunlun Ocean and the formation of Kudi suture correspondingly resulted by the collision between the Early Paleozoic volcanic arc of West Kunlun and the Tarim continent (Mattern and Schneider, 2000; Tang, 1994; He *et al.*, 2001).

In the Late Devonian-Carboniferous, with the open of Paleo-tethys (Wang, 2004), Tarim Plate was under the slight stretch environment and subsided entirely, and thus in Bachu and Maigaiti, it is large in thickness for the deposition of Upper Devonian and Carboniferous. However, in Kalpin it kept uplifting and thus missed the above deposition. In the late stage of Early Permian, the crust stretch became more violent than ever, as a result large-scale magma activity happened (Jia, 1997; Chen *et al.*, 1998). During the late stage of Early Permian to early stage of Late Permian, the Southern Tianshan Ocean closed like a



1: contour; 2: wedgeout; 3: well

Fig.3 Thickness contour of Paleocene in Kalpin Uplift (Xiao et al., 2005)

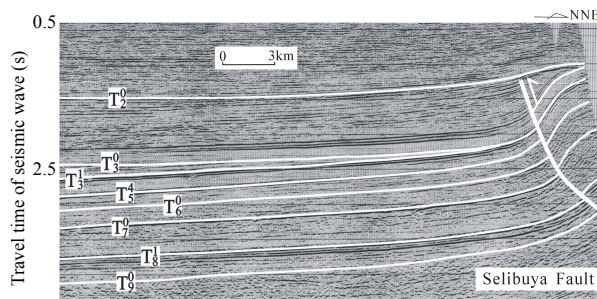


Fig.4 Selibuya fault in seismic profile (For location, see Fig.1)

T₂⁰, T₃⁰, T₃¹, T₄⁰, T₅⁰, T₆⁰, T₇⁰, T₈¹ and T₉⁰: the bottom of Pliocene, Miocene, Paleogene, Lower Permian, Upper Devonian, Upper Ordovician, Upper Cambrian and Lower Cambrian respectively

Southward extension of Kalpin thrust system

The further analysis indicates that the Kalpin thrust system did not been limited by the Kalpin Fault, the south boundary fault of the Kalpin Uplift, and the thrust deformation from the NNW to SSE spreads to the interior of the Western Bachu Uplift. As a result, the Western Bachu Uplift is uplifted and denuded strongly (Fig.5).

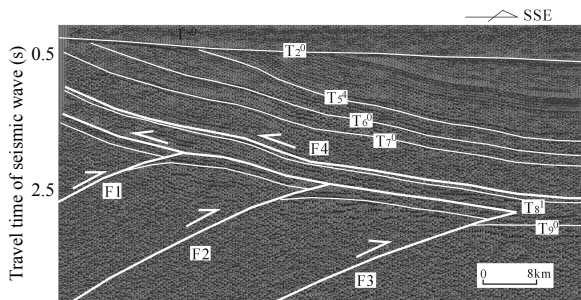


Fig.5 Kalpin thrust system in Bachu Uplift (For location, see Fig.1)

For T₂⁰, T₅⁴, T₆⁰, T₇⁰, T₈¹ and T₉⁰, see Fig.4; F1, F2: Kalpin thrust fault; F3: Kalpin frontal thrust fault; F4: anti-thrust fault

In addition, the thrust movement above also caused the upper strata in Western Bachu Uplift to thrust NNW passively along to the gypsum-salt detachment layer at the bottom of the Upper Cambrian. So, in Western Bachu Uplift the Middle and Lower Cambrian move to SSE and the Upper Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian, Paleogene and Miocene move to NNW in Cenozoic.

The detailed deformation time can be obtained based on synthesis of structural and sedimentary results in Western Bachu Uplift. Because only the strata between the bottom of Pliocene and the bottom of Paleogene suffered uplifted, eroded and folded deformation (Fig.4), and the Pliocene and Quaternary strata became stably thin from the southeast to the northwest (Fig.5), so the thrust deformation mentioned above mainly happened in the end of Miocene (the middle of Himalayan movement).

Since the Pliocene, the activity of Kalpin Fault had strengthened, the fault had thrust over to the ground, a southeastward stress force derived from Kalpin arc thrust system released. Therefore, the effect from Kalpin thrust system decreased obviously.

The analysis above demonstrates that in the end of the Miocen structure deformation and uplifting in Western Bachu Uplift were affected by both West Kunlun orogen and a southeastward stress force derived from Kalpin thrust system of which belongs to the Southern Tianshan orogen. The stress force above led the Western Bachu Uplift to uplift higher and made the strata undergo folded and eroded, which resulted in the wide distribution of Paleozoic outcrop.

All in all, the Cenozoic structure deformation in Bachu Uplift was under the influence of both Southern Tianshan and Western Kunlun orogen, and belongs to the style of structure superposition deformation.

Frontal thrust fault of Kalpin thrust system

Based on the geology interpretation on six new high-resolution seismic profiles (Fig.1), the paper also makes sure that the location of the frontal thrust fault belongs to the Kalpin thrust system and is hidden under the Western Bachu Uplift (Fig.6). As shown in Fig.6, the frontal thrust fault, an arc fault that intrudes southeastward into the hinterland of Bachu Uplift and extends NNE from well Pi1 to Xiaohaizi reservoir and

Gudongshan mountain, and ends at the Luonan fault near southward to the well Luonan 1. It is no doubt that the distribution above of the frontal thrust fault must be controlled by the Permian dolerite developed in Xiaohaizi reservoir of Western Bachu Uplift (Jia, 1997; Chen *et al.*, 1998).

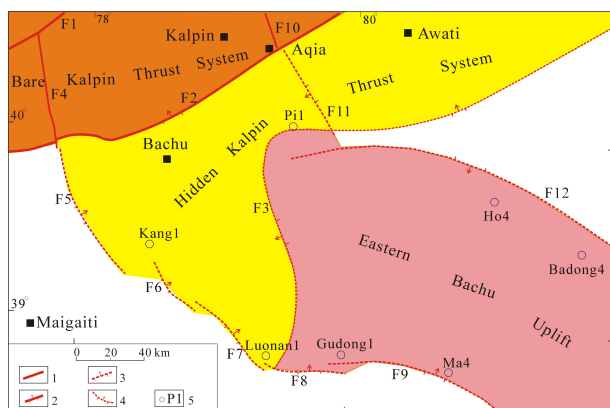


Fig.6 Distribution map of Kalpin thrust system

F1: Aheqi (root) fault; F2: Kalpin (main thrust) fault; F3: Kalpin thrust front fault; F4: Piqiang fault; F5: Selibuya fault; F6: Kantakumu fault; F7: Luosi fault; F8: Luonan fault; F9: Mazatager fault; F10: Yingan fault; F11: Aqia fault; F12: Tumuxiuke fault; 1: fault; 2: thrust fault; 3: hidden transpression fault; 4: hidden thrust fault; 5: well

The analysis above indicates that the frontal thrust fault of Kalpin thrust system is not the Kalpin fault accepted previously but the arc fault mentioned above, and that the Kalpin fault is only the main-thrust fault. Therefore, the area between Kalpin fault and the arc frontal thrust fault, as well as the westward extension of Bachu Uplift mentioned above should be the interaction region of Southern Tianshan and Western Kunlun orogen, namely the region of structure superposition deformation.

STRUCTURE DEFORMATION MODEL

Based on the analysis above, the Cenozoic structure deformation model of superposition in Bachu Uplift is established here (Fig.7). As shown in Fig.7, the northwestward extension of Bachu Uplift is buried under the Kalpin Uplift, and the frontal part of Kalpin thrust system is buried under the Western Bachu Uplift. The former is mainly related to the West Kunlun orogen, and started to form in the end of Paleogene, while the latter is related to the Southern Tianshan orogen, and formed mainly in the end of

Miocene. Consequently, between them there are different structural trends and deformation time, and they belong to typical superposition structural deformation.

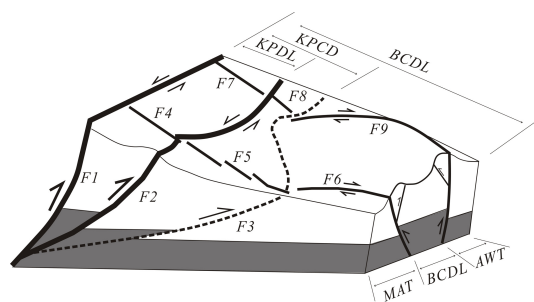


Fig.7 Superposition deformation model of Bachu Uplift

F1: Aheqi (root) fault; F2: Kalpin (main thrust) fault; F3: hidden Kalpin frontal thrust fault; F4: Yingan fault; F5: Aqia fault; F6: Tumuxiuke fault; F7: Piqiang fault; F8: Selibuya-luosi fault; F9: Mazhatage fault; BCDL: Bachu Uplift; KPDL: Kalpin Uplift; KPCD: Kalpin Thrust System; AWT: Awti Depression; MGT: Maigaiti Slope

CONCLUSION

(1) In Bachu Uplift the structure superposition deformation of Cenozoic is very obvious. Not only the northwestward extension of Bachu Uplift is buried under the Kalpin Uplift, but also the Kalpin frontal thrust system is buried partly in the interior of Bachu Uplift, which resulted that the strata folded and denuded strongly.

(2) The northwestward extension of Bachu Uplift buried under the Kalpin Uplift started to form in the end of Paleogene, while the Kalpin thrust frontal buried under the Western Bachu Uplift formed in the end of Miocene, and between them there are different structural trends and deformation time, and they belong to typical superposition structural deformation.

(3) The structure superposition deformation above is closely related to the Cenozoic rejuvenation of Southern Tianshan and Western Kunlun orogen derived from the collision between India and Eurasian Plate happened in the Late Eocene.

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