Reply to 'Calculation of depth to detachment and its significance in the Kuqa Depression: A discussion'

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Abstract: This paper mainly replies to the discussion by Li et al (2009) on the calculation of the detachment depths in the Kuqa Depression. We think that viscous material flowing into or out of the cross section can affect the validity of the calculation method, yet the number of detachment levels does not bring any drawbacks to the calculation. In the Kuqa Depression, the salt flow influenced the structural deformation to some extent, and affected slightly the accuracy of the calculated depths of the true detachment levels. However, it does not mean that the calculation method loses effectiveness in the study area. Therefore, the calculation results are still relatively believable.

Key words: Excess area, detachment level, reply, discussion, Kuga Depression

1 Introduction

Li et al (2009) have commented on fundamental aspects of our paper (Yu et al, 2006). In that paper, we used the excess areas of multiple horizons presented by Epard and Groshong (1993) to calculate the depths to detachment in the Kuqa Depression, and we concluded that the true depths to detachment levels in the Kela-2, Misikantage and Dongqiu-8 regions were 5.3 km below, 0.25 km above and 3.2 km below the Cretaceous bottom, respectively. Li et al claim that our conclusion was unreasonable, because of the nonzero intercepts of the excess areas, salt flow into or out of the cross sections, and multi-level detachment. Their detachment depths of the Kela-2, Misikantage and Dongqiu-8 structures are 115.74 km, 14.17 km and 75.48 km below the reference level (Cretaceous bottom).

We appreciate the interest of Li et al in our work and their comments. This exchange of opinions is always a good opportunity to seek rigorous solution, and thus increase the knowledge gained in the past years in the Kuqa Depression. Nevertheless, in our opinion, the discussion of Li et al (2009) may suffer from some incorrect assumptions. In this reply, we will try to answer their comments on the basis of our understanding and knowledge.

2 Intercepts of excess area

and Groshong (1993), the intercepts of the excess area are referred to the values of intersection points when the straight line equation $S=Dh+S_a$ intersects the h and S axes in the excess area diagram plotted by excess area versus depth to

According to the calculation method presented by Epard

detachment (Fig. 1). In the excess areas of multiple horizons, the bed length and area must be constant, yet it does not mean that the intercepts of the excess area must be zero. It can be concluded that only when the arbitrary reference level is exactly the true level of detachment, does the straight line $S=Dh+S_a$ go through the origin (i.e. the intercept of the excess area = 0), and vice versa. Epard and Groshong (1993) used the intersection types of the straight line with the axes to calculate the depth to the true detachment level.

3 Multi-level detachment

The excess area results from the presence of the detachment level. According to the method of Epard and Groshong (1993) (Fig. 1), the calculated true detachment level should be the detachment, which results in the measured excess areas. If there are multiple levels of detachment, the various excess areas should be measured individually, and it also means that one detachment should have one group of separately measured data of excess areas (Fig. 2).

For example, the excess areas of S_1 and S_2 are produced by the No.1 detachment level, so the calculation depth should be the depth of the No.1 detachment level in Fig. 2(a). Similarly, the excess areas of S_{11} and S_{12} can only be used to calculate the depth of the No.1 detachment level, and S_{21} and S_{22} can be used to calculate the depth of the No.2 detachment level in Fig. 2(b).

In addition, in our opinion, the detachment level should usually be a flat and un-deformed level. In Fig. 2 of Li et al (2009), however, they considered the black layer (salt layer) bottom and the model bottom as the upper and lower detachment levels, respectively. We think it is unquestionable that the salt layer acts as the detachment during the structural deformation, but how can the bottom of the model also be regarded as the detachment? Even though there are two true 22 Pet.Sci.(2009)6:21-23

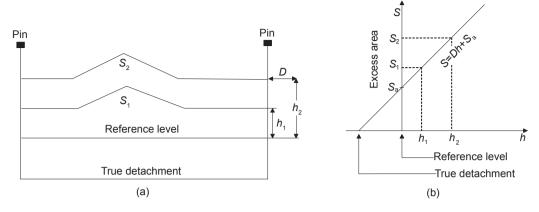


Fig. 1 Excess area balance at a reference level (a) and excess area diagram (b)

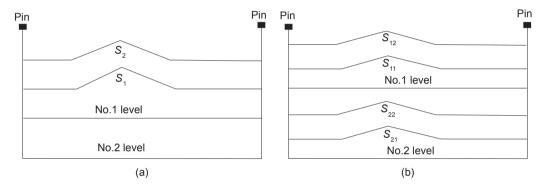


Fig. 2 Excess areas of multi-level detachment

detachment levels in the model, the excess areas above and below the salt layer should be measured separately as shown in Fig. 2, and can not be calculated as mentioned by Li et al in their discussion.

4 Detachment levels in the Kuqa Depression

For better explanation and understanding, only the Misikantage anticline is used to make a detailed illustration in this reply. According to the seismic line through the structure (Fig. 3), the top and bottom of the Cretaceous

are relatively flat, and the deformations above and below the Cretaceous are different. The upper strata were folded, forming the Misikantage anticline.

It has been demonstrated that the salt of the Kumugeliemu Formation (E_{1-2km}) flowed from the Baicheng Sag to the adjacent Qiulitage and Kelasu structural belts (Yu et al, 2007; 2008). According to actual geological features in the Kuqa Depression, the viscous flowage of salt happened only along the S-N direction, and the area should be constant in the seismic sections with the S-N strike.

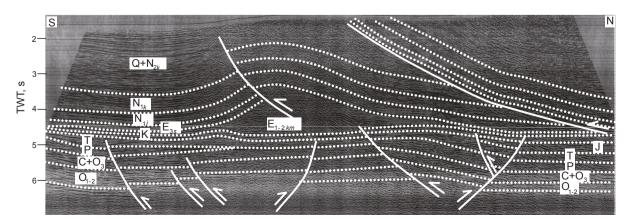


Fig. 3 Interpreted seismic section across the Misikantage anticline. The deformation features of the covers above and below the Cretaceous (K) are apparently different, and the upper part was folded, yet the lower part was faulted and relatively flat

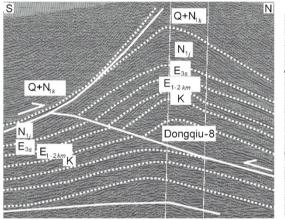
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We consider the Cretaceous bottom as the reference level, and the excess areas of the Kumugeliemu Formation (E_{1-2km}) , Suweiyi Formation (E_{3s}) , Jidike Formation (N_{1j}) , and Kangcun Formation (N_{1k}) are 15.5 km², 15.96 km², 16.55 km² and 17.375 km² (Table 1 of Yu et al, 2006). As a result, the true detachment of the Misikantage anticline is 0.25 km above the reference level by using the method from Epard and Groshong (1993). Because the thickness of the Cretaceous is about 230 m, the true detachment can also be regarded as the bottom of the Kumugeliemu Formation. This result is also corresponding to the special attributes of the salt bodies and the interpretation of seismic profiles.

Li et al pointed that the true detachment of the Misikantage anticline was 14.17 km lower than the reference

level. If their conclusion is correct, the detachment level with the depth of 14.17 km lower than the Cretaceous bottom should lie in the basin basement. However, it can be found that the strata below the Cretaceous are flat and only faulted in the seismic profiles. How did the detachment level in the basin basement influence the excess area above the Cretaceous? Moreover, there is almost no excess area in the sedimentary covers between the basement and the Cretaceous.

Fig. 4 indicates the deformation features of the Dongqiu-8 and Kela-2 structures, and it shows that the salt flow has little influence on the structural deformation. Based on the interpretation of the seismic profiles across the two basement-involved structures, we think that the calculation results (Fig. 5 of Yu et al, 2006) are close to the reality.



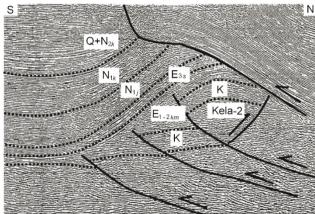


Fig. 4 Interpreted seismic sections across the Dongqiu-8 (left) and Kela-2 structures (right)

In short, we quite agree with Li et al (2009) that viscous material flowing into or out of the cross section can affect the validity of the calculation method proposed by Epard and Groshong (1993). However, the number of detachment levels does not bring any drawbacks to the method, as illustrated in this reply. For the Kela-2, Misikantage and Dongqiu-8 structures in the Kuqa Depression, the salt flow influenced their deformation to some extent, and then affected slightly the accuracy of the calculated depths of the true detachment levels. Nevertheless, as addressed in this reply, we think that our results are still relatively believable.

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References

Epard J L and Groshong R H. Excess area and depth to detachment. AAPG Bulletin. 1993. 77(8): 1291-1302

Li S Q, Feng L and Bao Y H. Calculation of depth to detachment and its significance in the Kuqa Depression: A discussion. Petroleum Science. 2009. 6(1): 17-20

Yu Y X, Ma B J, Tang L J, et al. Major factors controlling salt structures in western Kuqa Depression, Tarim Basin. Petroleum Exploration and Development. 2008. 35(1): 23-27 (in Chinese)

Yu Y X, Tang L J, Yang W J, et al. Structural segmentation of salt structures in the frontal ranges of Kuqa foreland fold and thrust belt, northern Tarim Basin. Acta Geologica Sinica. 2007. 81(2): 166-173 (in Chinese)

Yu Y X, Tang L J, Yin J Y, et al. Calculation of depth to detachment and its significance in the Kuqa Depression. Petroleum Science. 2006. 3(2): 34-38

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