Salt Structure in Kuqa Depression, Tarim Basin, China: Insights from Deformation, Syn-kinematic Strata Record and Analog Modeling*

Xin Wang[1], Shiqin Li[2], Pengcheng Tang[1] and Zhaoming Wang[3]

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[1]Department of Earth Science, Zhejiang University, Hangzhou, China. (wx@zju.edu.cn)
[2]Department of Geosciences, Western Petroleum University, Chendu, China.
[3]Tarim Oilfield Company of Petro China, Korla, China.

Abstract

The synkinematic strata of the Kuqa foreland basin record a rich history of the Tian Shan reactivation during the Cenozoic era. Here, we present new constraints on the deformation time in the southern Tian Shan area, based on an analysis of interactions between tectonics and sedimentation in the western Kuqa basin. Integrating surface geology, well data and a grid of seismic reflection profiles, we constructed six balanced cross sections of the basin.

Our balanced profiles show that the Qiulitage fold belt on the southern edge of the Kuqa basin developed thin-skinned compression salt tectonics. These tectonics have been influenced by two factors: (1) several pre-existing diapirs that developed in the western Kuqa basin. These were initiated soon after the Kumugeliemu salt deposition and had different growth histories, localizing the contraction strain of later shortening. If a diapir had a short development time and was overlain by a thick overburden, it was likely to evolve into a salt dome, comprising 3,000-7,000 m of allochthonous salt. Conversely, if a diapir was overlain by a thin overburden, it was more likely to form a salt nappe, with the northern flank of the diapir thrust over its southern flank. (2) The distal pinch-out of Kumugeliemu salt located at the Qiulitage fold belt, which resulted in an increase in frictional resistance, was prone to allochthonous salt accumulation.

The synkinematic strata (6-8 km thick) of the Kuqa basin indicate that since the regeneration of the Tian Shan, the shortening deformation of the western Kuqa basin accumulated mainly in the hinterland until the early Miocene. Then, compression stress spread simultaneously southwards to the Dawanqi anticline, the Qiulitage fold belt and the southernmost blind detachment fold at the end of Miocene. The western Kuqa basin has ~23 km of shortening displacements. We assume that ~9 km of them were

consumed from the end of the Miocene (5.2/5.8 Ma) to the early Pleistocene (2.58 Ma), and another ~14 km have been absorbed since then. Thus, we obtain a ~3.4/2.8 mm/yr average shortening from 5.2/5.8 Ma to 2.58 Ma, and a ~5.4 mm/yr average shortening rate since 2.58 Ma. Therefore, we suggest that the modern Tian Shan has experienced at least two accelerated events, beginning in the late Miocene/early Pliocene and early Pleistocene, respectively.

Selected References

Giles, K.A., and T.F. Lawton, 2002, Halokinetic sequence stratigraphy adjacent to the El Papalote Diapir, northeastern Mexico: AAPG Bulletin, v. 86/5, p. 823-840.

Hubbert-Ferrari, A., J. Suppe, J. Van der Woerd, X. Wang, and H.F. Lu, 2005, Irregular earthquake cycle along the southern Tianshan front, Aksu area, China: Journal Geophysical Research, Solid Earth, v. 110/B6, 18 p., doi:10.1029/2003JB002603.

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Salt structure in Kuqa depression, Tarim Basin,China：Insights from deformation, syn-kinematic strata record and analog modeling

Xin Wang[1], Shiqin Li[2] , Pengcheng Tang[1], and Zhaoming Wang[3]

1. Department of Earth Science, Zhejiang University, Hangzhou, China
2. Department of Geosciences, Western Petroleum University, Chendu, China
3. Tarim Oilfield Company of Petro China, Korla, China

With contributions from
Bruno.Vendeville (France) , Jaume Verges (Spain) and Hongwei Yin(China)

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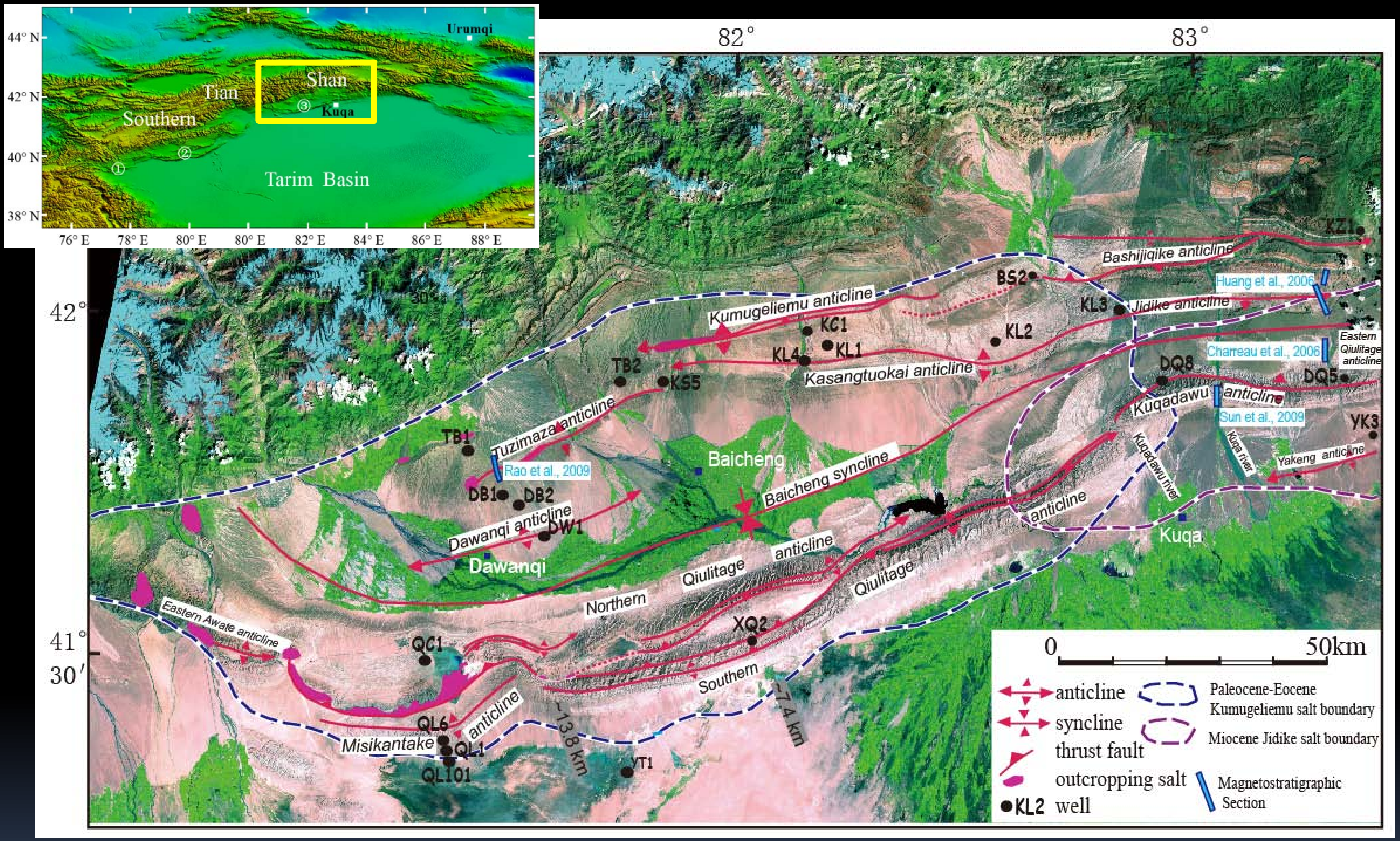
Outline

- Introduction
- Salt deformation in Kuqa
- Patterns of syn-kinematic sedimentation in Kuqa
- Analog modeling
- Conclusion



ETM image showing main structures in Kuqa depression

1. The Kuqa depression is located along north Tarim basin, China , It is a foreland thrust and fold belt of the southernTianshan orogenic wedge.

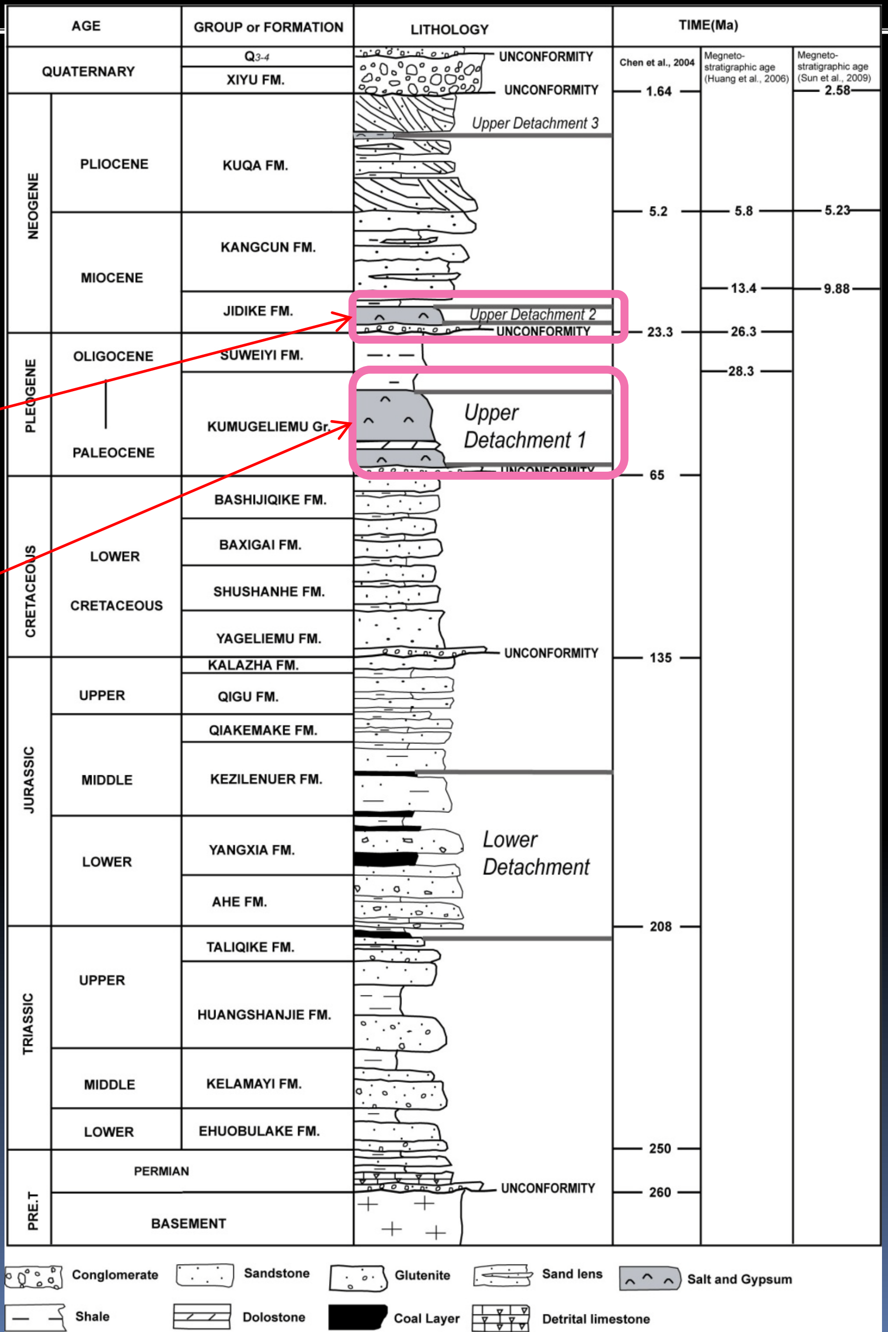
2. The Kuqa depression developed two E-W trending anticline belts: Northern belt and Southern belt, intermediated by the Baicheng syncline.

Introduction: stratigraphic framework

The Kuqa **depression** strata mainly consists of Mesozoic-Cenozoic terrestrially clastic rocks, including coal and evaporite beds. There are two evaporite layers in Kuqa.

Miocene evaporite

Paleocene evaporite

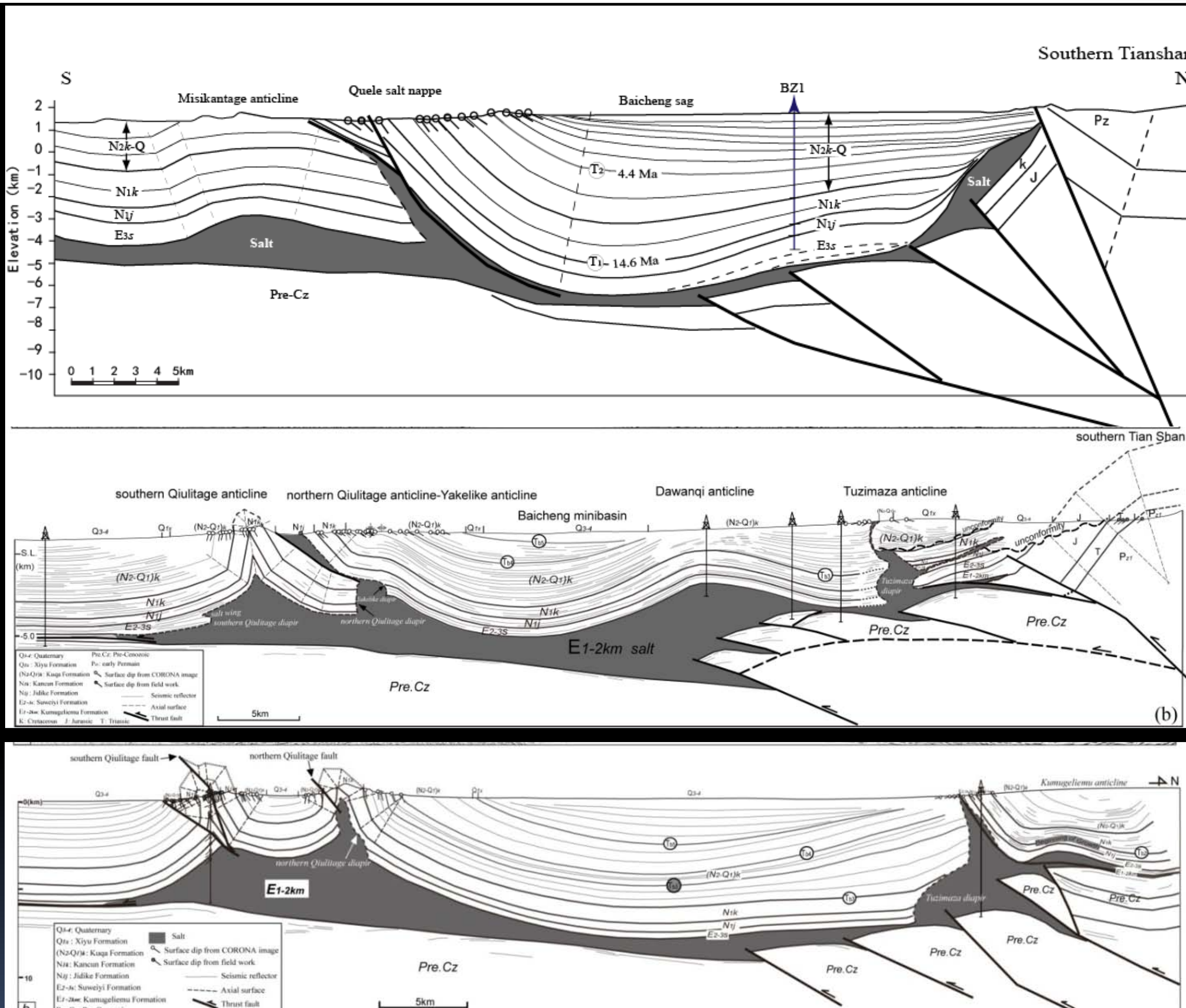


Introduction: salt deformation styles

A

B

C



South anticline belt | Baicheng syncline | North anticline belt

Seismic profile and interpretation of Kuqa depression

There are two types of salt structures in Kupa, diapir and pillow.

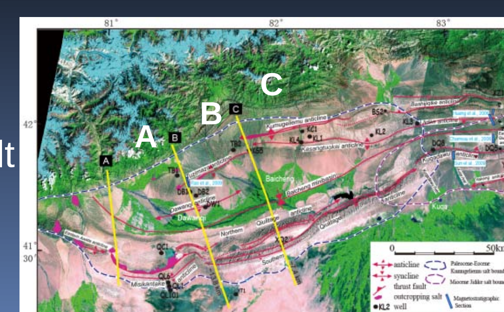
Diapirs directly developed after salt deposition.

In Pliocene, the Kuqa depression experienced strong compression deformation.

There are imbricate thrust and duplex structure beneath salt.

Diapirs has been thrusted at the northern flank and turn into thrust and salt nappe.

Pillows were formed at the south front of diapirs.



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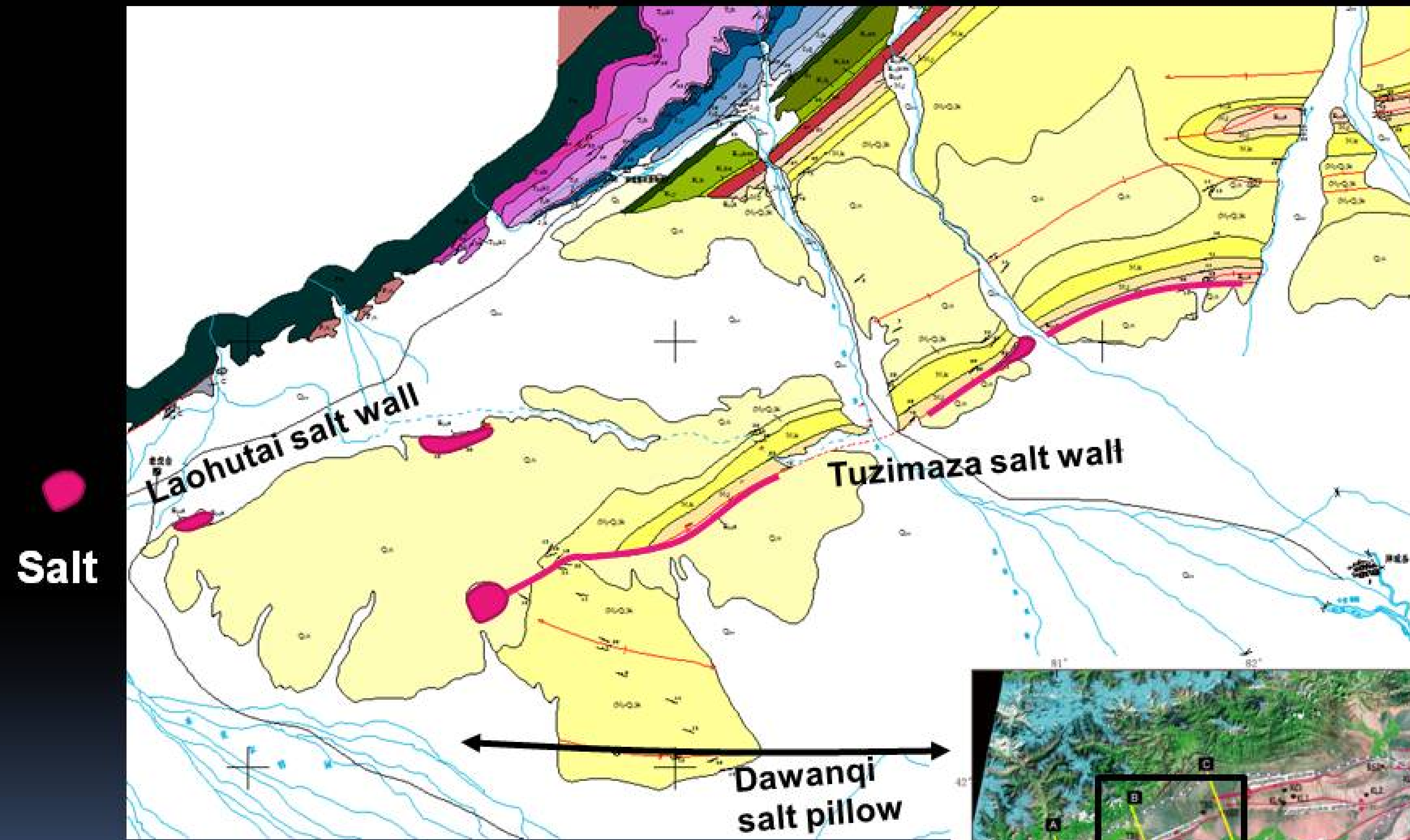
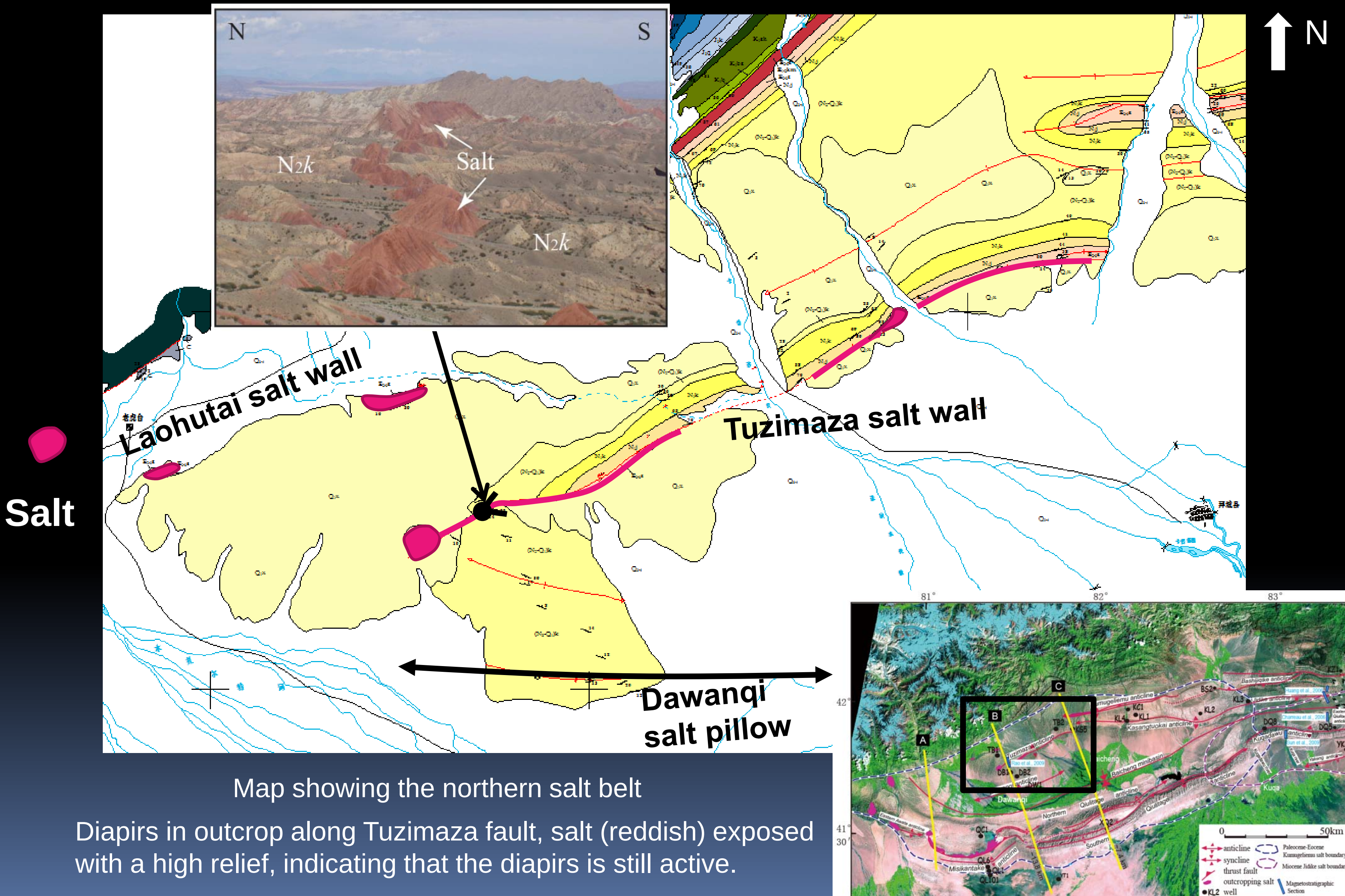
Northern salt belt



Map showing the northern salt belt

Diapirs in outcrop along Tuzimaza fault, salt (reddish) exposed with a high relief, indicating that the diapirs is still active.

Northern salt belt



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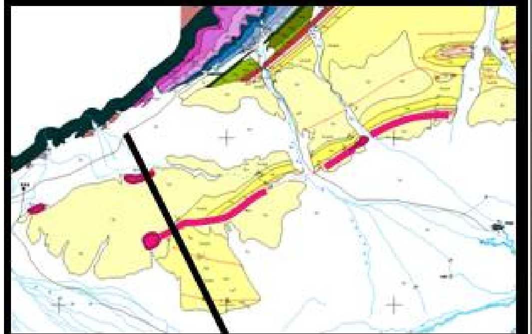
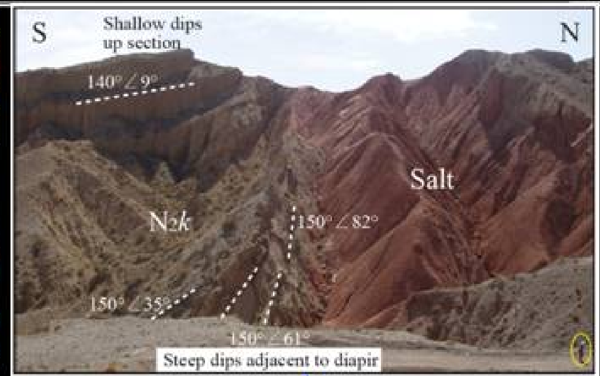
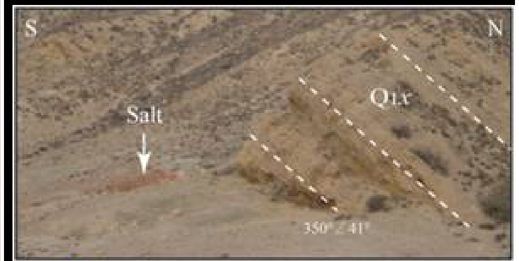
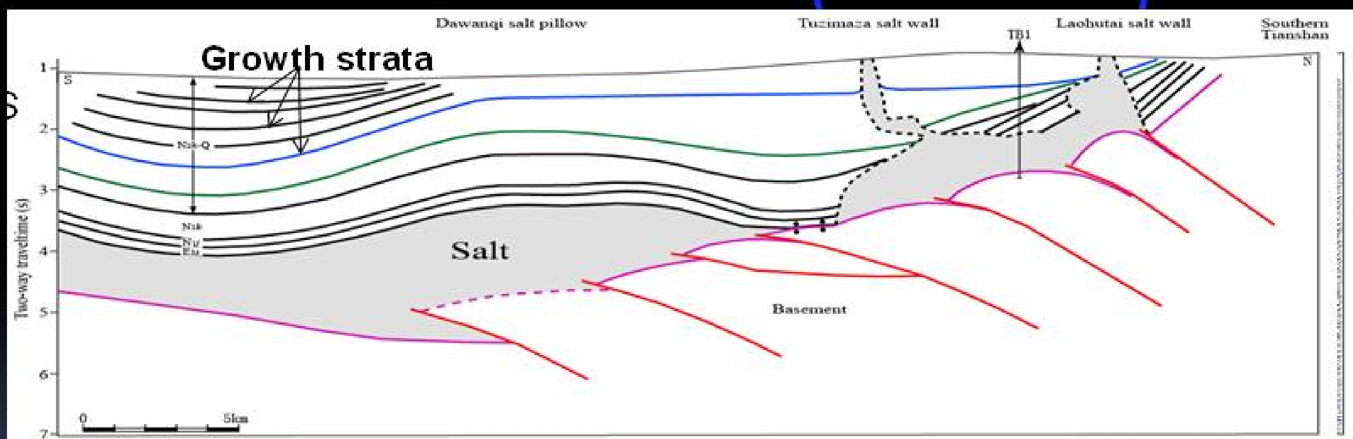
Northern salt belt







Diapirs outcrop



Seismic profile and interpretation of Kuqa depression

Diapiring directly developed after salt deposition and is still active.
Tuzimaza diapir from outcrops shows Pleistocene growth strata and Pillows were formed in same time at the south front of diapir.

Notes by Presenter: Laohutai salt wall, Tuzimaza salt walls, and Dawanqi salt pillow. Field photographs showing growth strata (Kuqa formation) formed adjacent to southern contact of the Tuzimaza salt wall and Xiyu formation adjacent to Laohutai salt wall was deformed. We constrained the geometry of salt structures based on surface (geological map, field survey) and subsurface data (well and seismic data). Patterns of syn-kinematic layers adjacent to salt diapirs indicates that they formed soon after salt deposition (Giles and Lawton, 2002; Rowan et al., 2003). Growth strata of the upper Pliocene Kuqa formation at the southern side of the Dawanqi salt wall indicates that the fold was formed in Late Pliocene.

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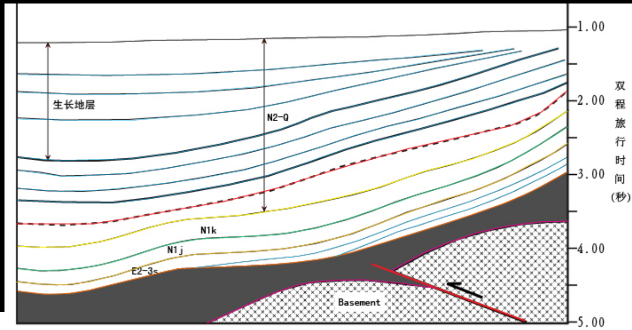

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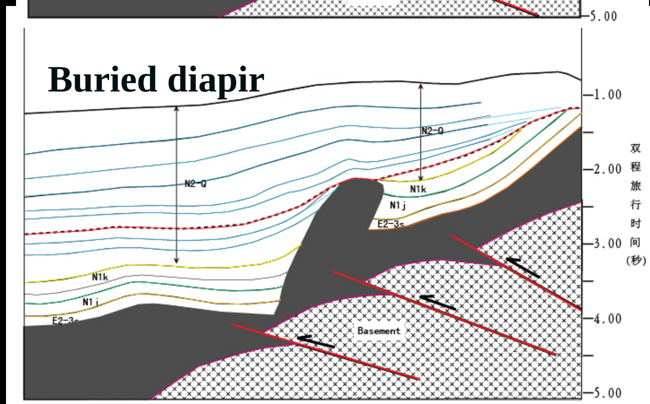

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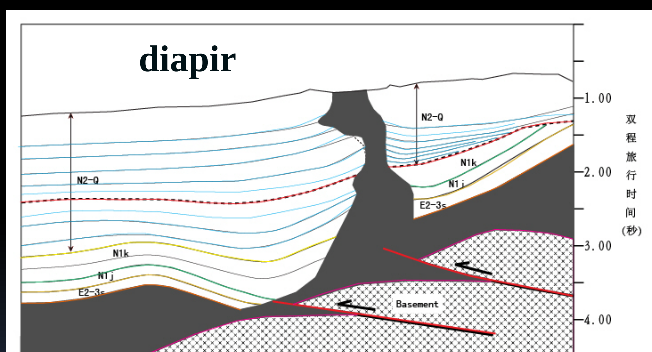

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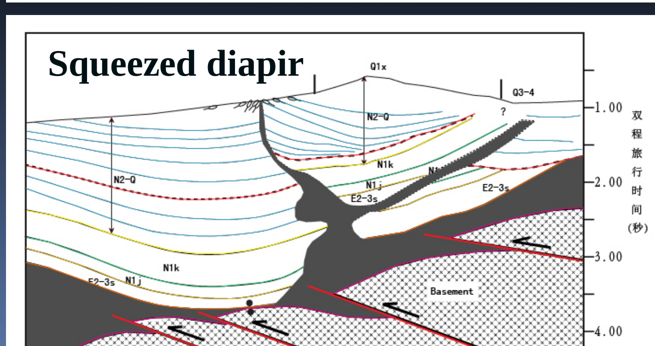

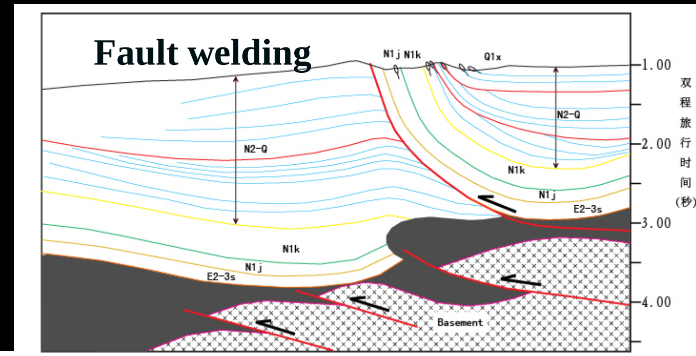

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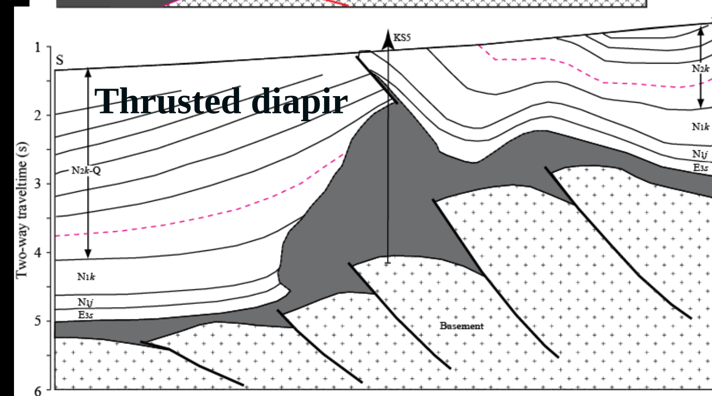

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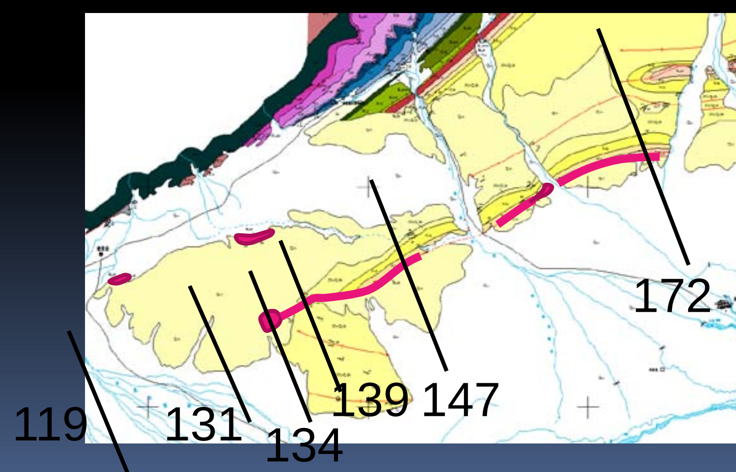
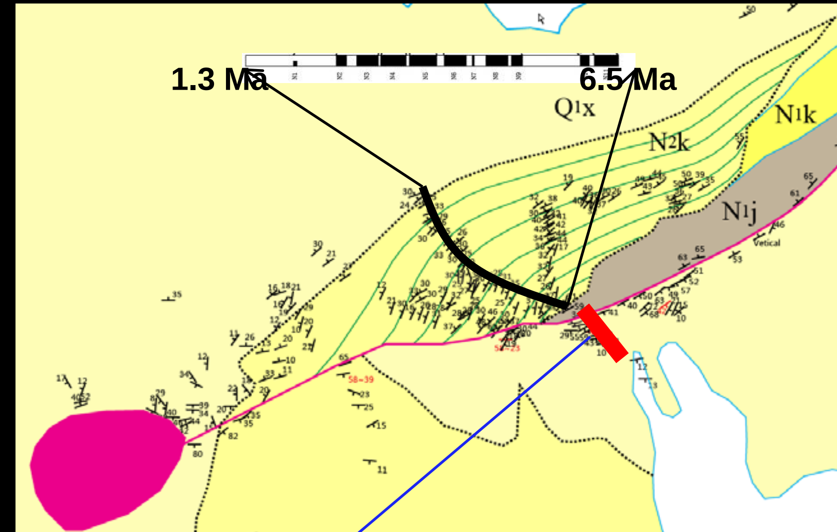
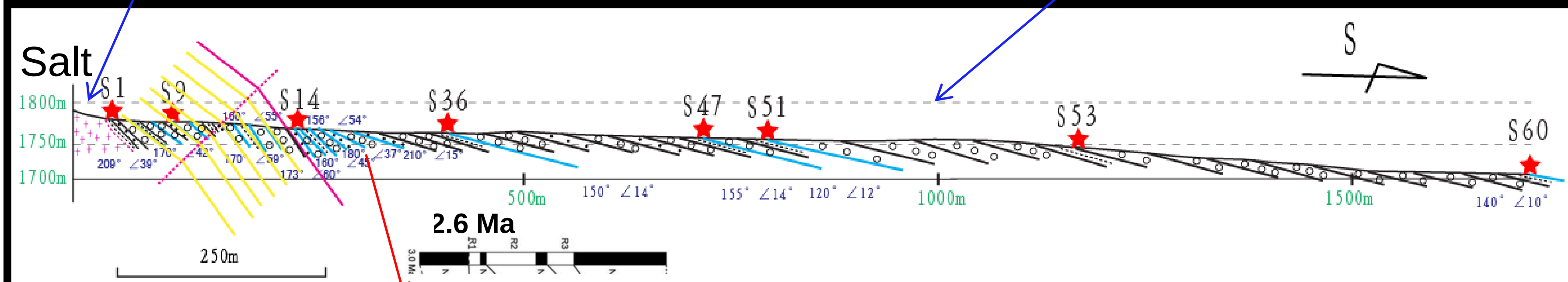
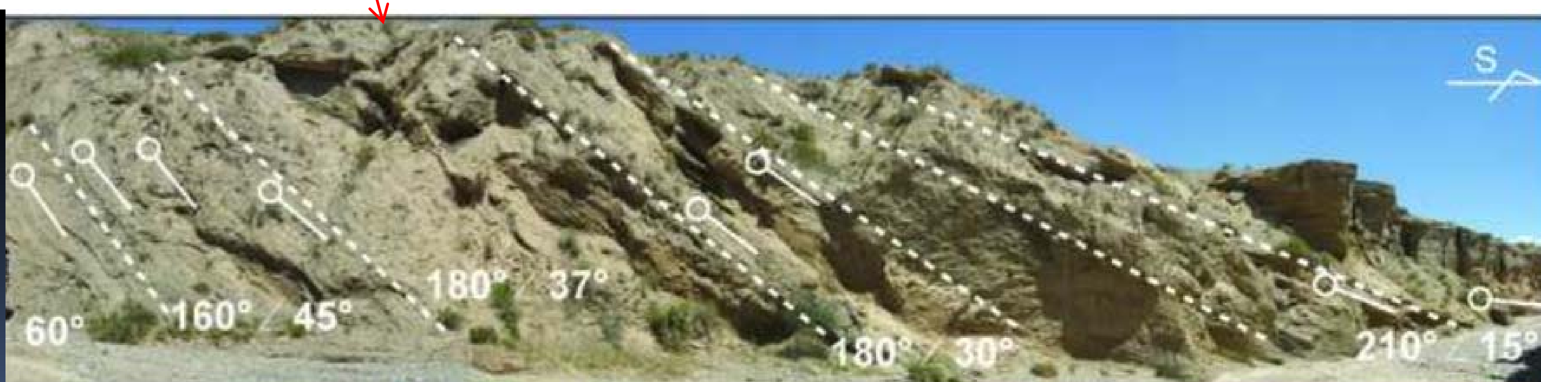


Tuzimaza diapir varied along strike





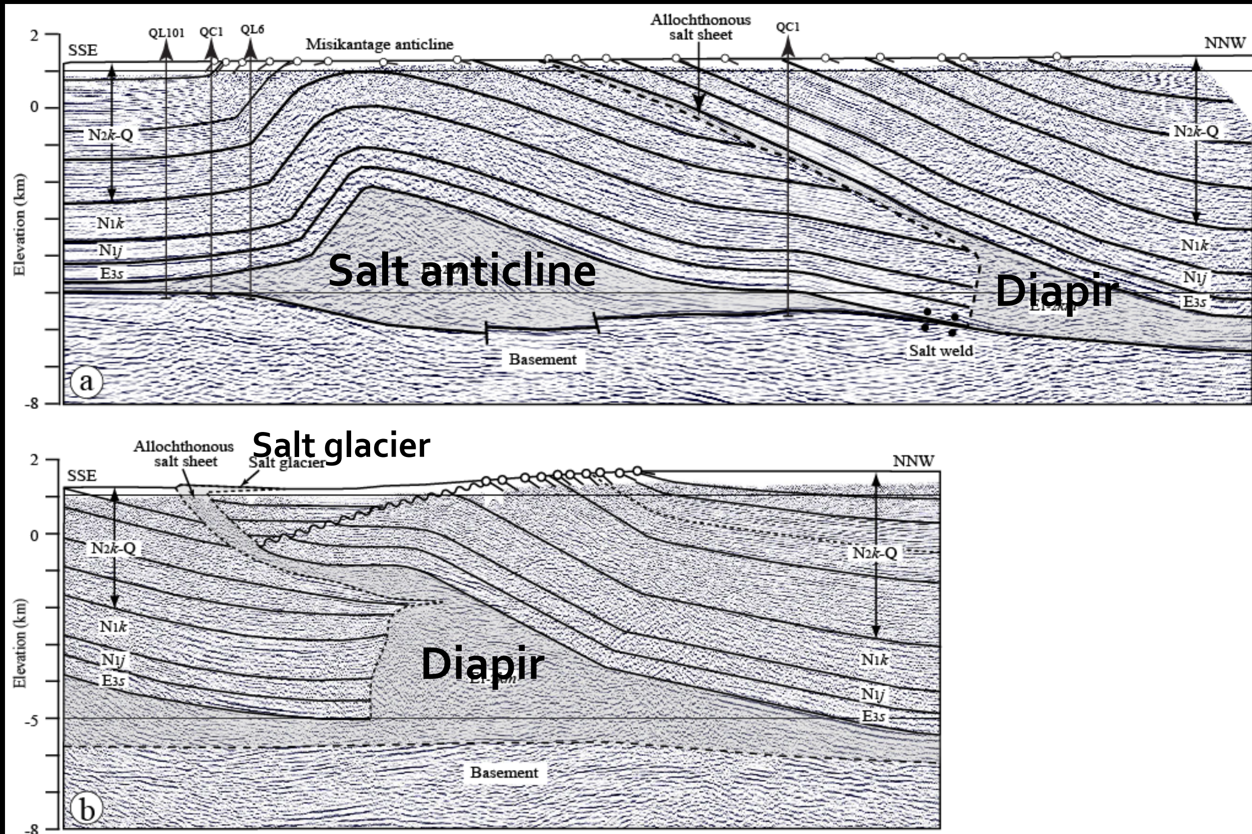


Pleistocene growth strata (~2.6Ma) was observed at the south border of Tuzimaza diapir. The north border of Tuzimaza diapir was ruptured by fault. The Hangingwall strata from outcrop shows a trend of younger westward along fault strike.

Southern salt belt

X

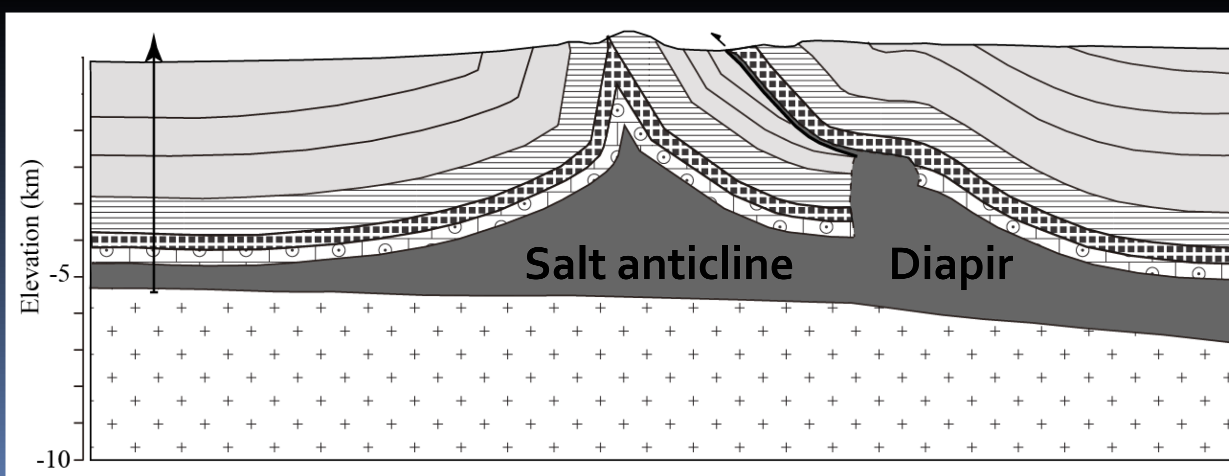
Y

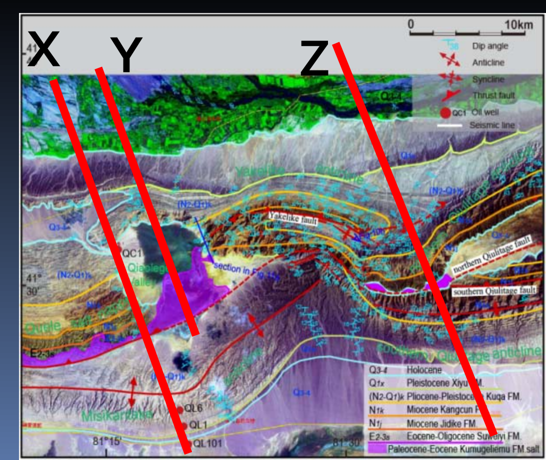


There are two types of salt structures: diapir and pillow

Diapirs formed at early stage evolved into thrust and salt nappe at the late stage, and with the development of Pillows at the south front of diapirs.

Z





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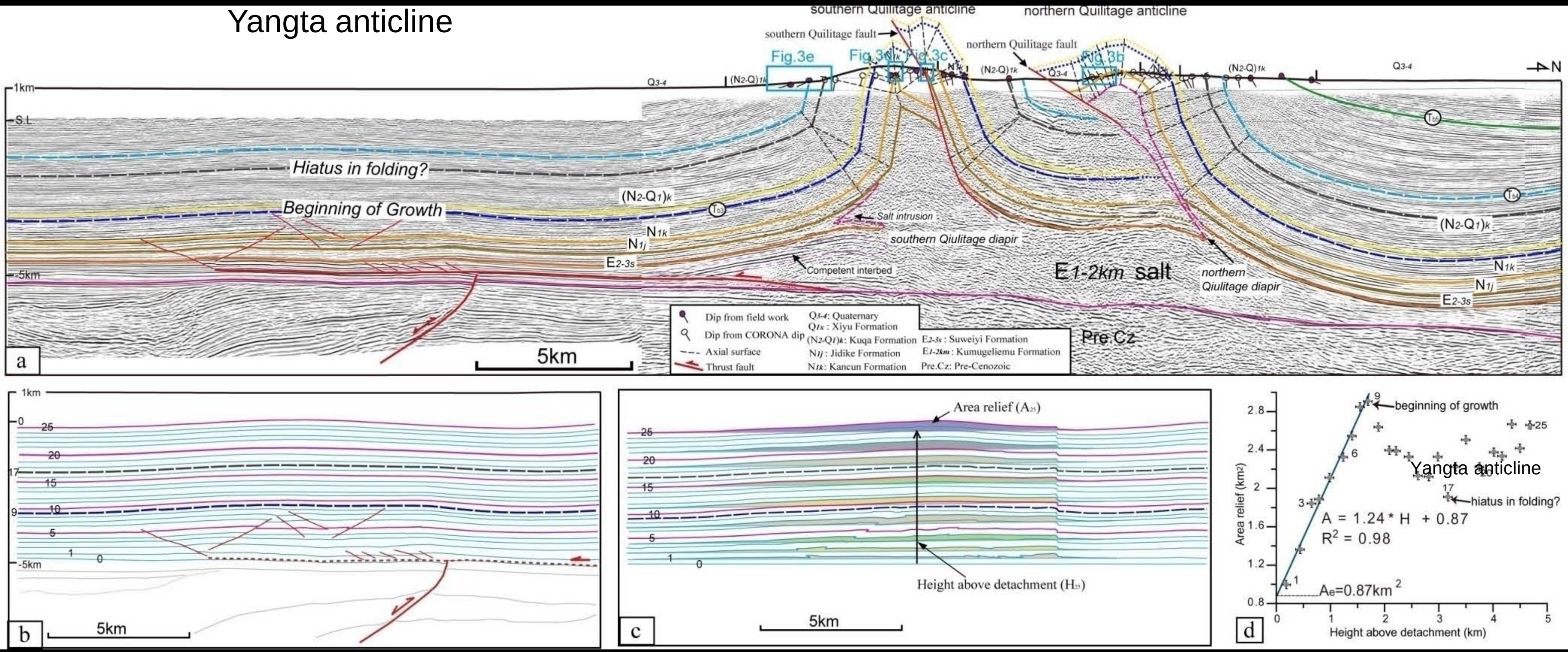
Compression deformation time

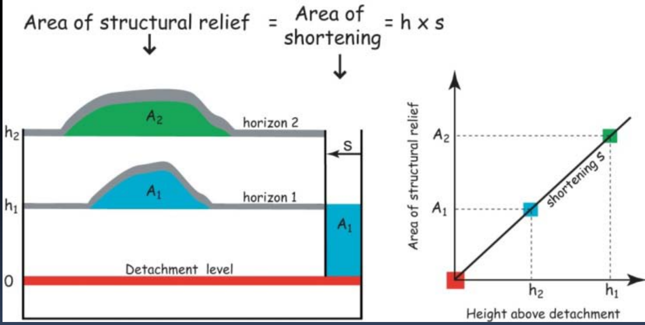


(a) Seismic profile and interpretation of Qulitake- Yangta anticline

(b) Drawing lines of the blind Yangta anticline

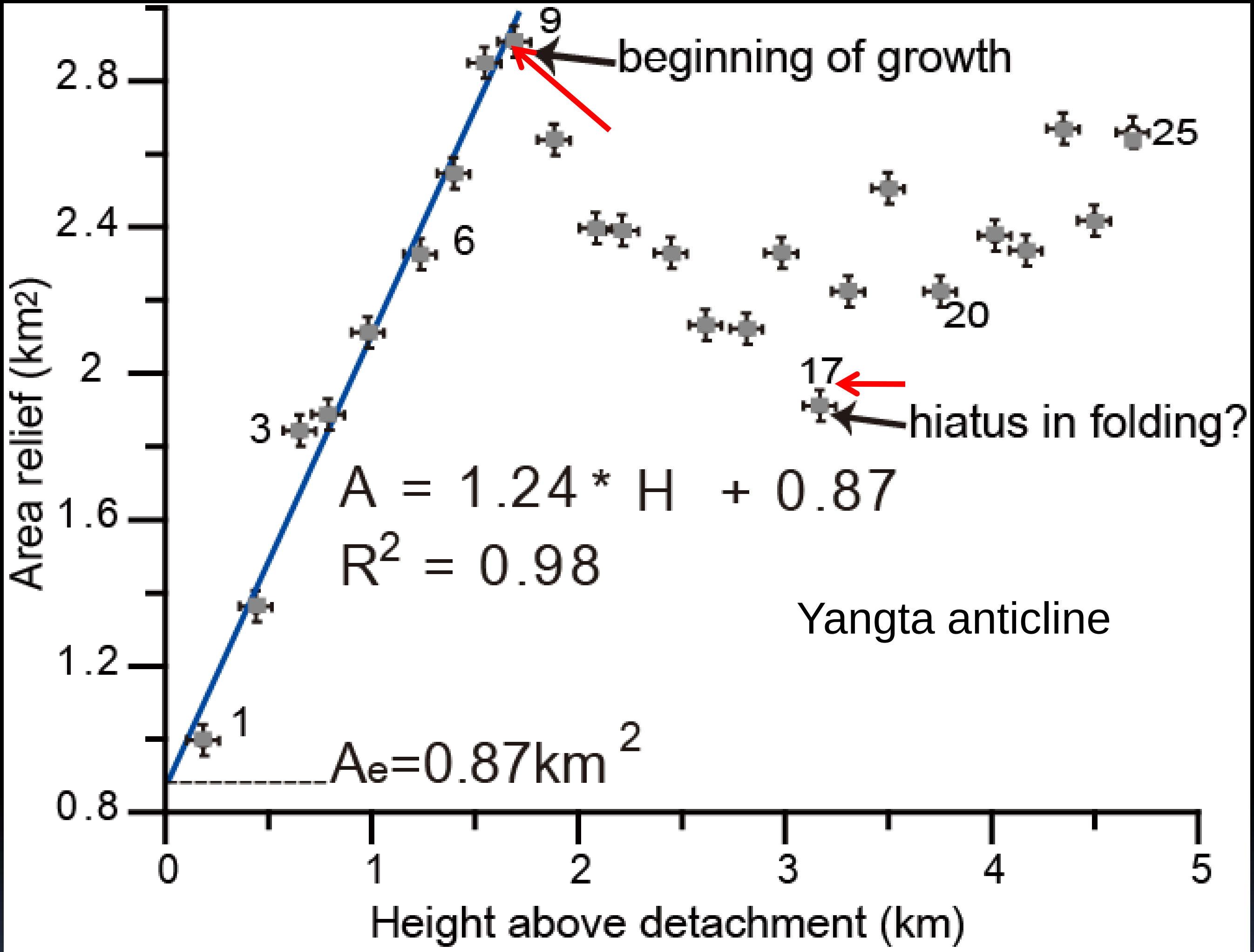
(c) Digitized 26 horizons of the Yangta anticline and flattened them to horizon 0 by vertical simple shearing in the thickness domain

(d) 0btaining areas of relief (*A*) and height above detachment (*H*)



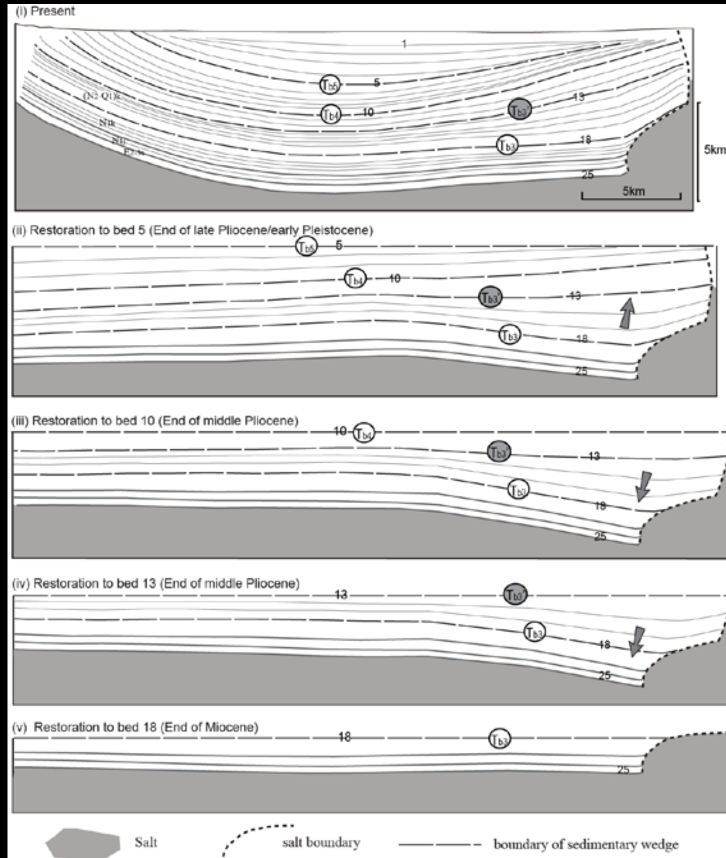
Get shortening & shortening history by measuring area of relief as a function of height (Hubbert-Ferrari *et al.*, 2005).

area of relief as a function of height



1， Beginning of folding at 9 layer (Pliocene 5~6Ma)

2，Hiatus in folding at 17 layer



Present

The Baicheng syncline started in early Pleistocene.

End of late Pliocene / early Pleistocene

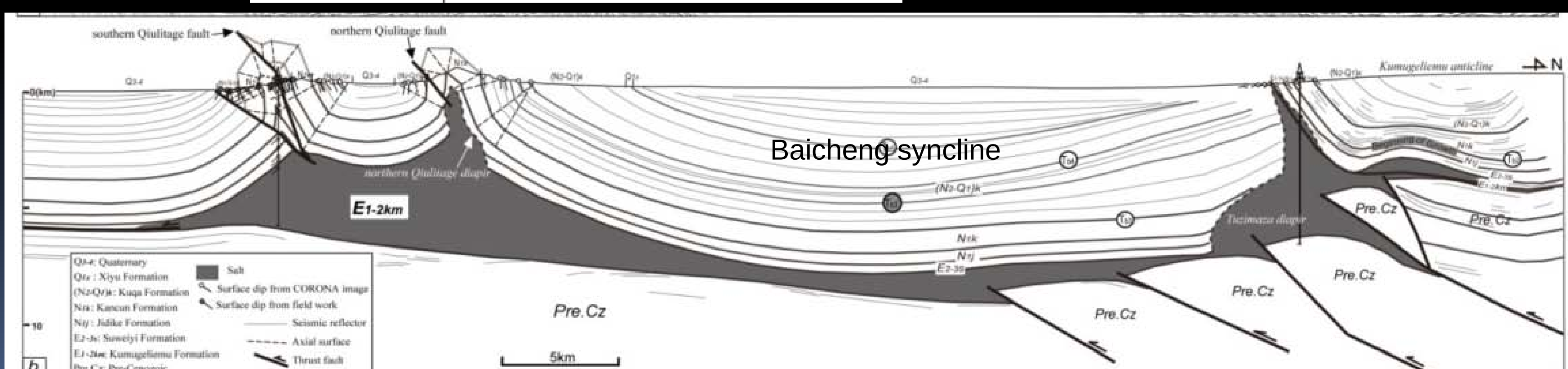
The north flank of the Baicheng syncline was uplifted, indicating an influence of compression deformation on these areas in late pliocene.

End of middle Pliocene

The north flank of the Baicheng syncline had subsided in Poliocene, accompanied by salt withdrawal from the flanks of diapir.

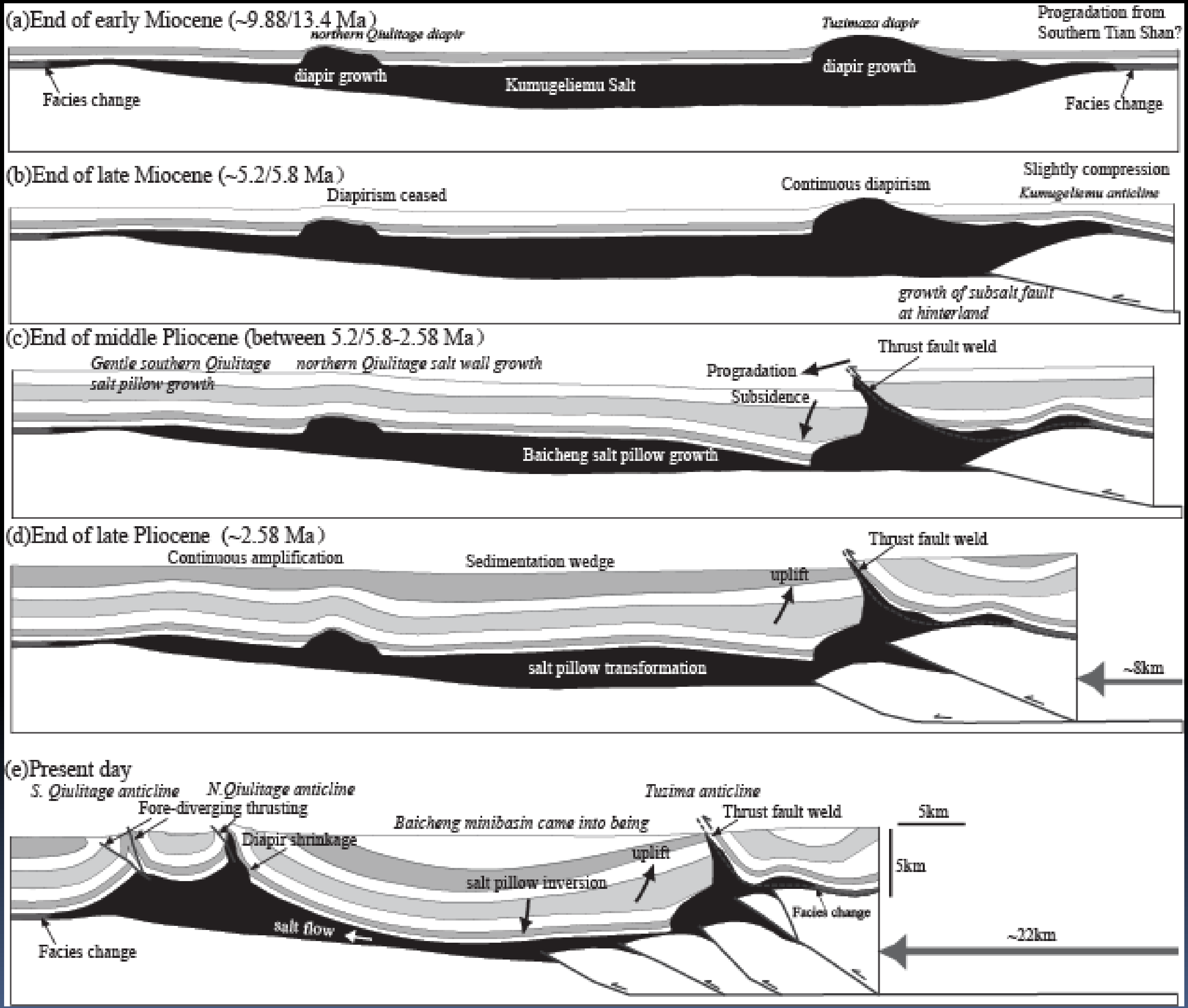
End of Miocene

Thickness of Suweiyi and Jidike formations in Baicheng syncline is uniform.



bed-by-bed restored map of Baicheng syncline

Evolution of salt structures in Kuqa depression



Early diapirs

compression deformation occurs in the front of Tianshan

compression deformation migrated basinward, the north diapirs were thrustted at the northern flank.

Salt flowed southward and was accumulated in Qiulitage anticline. At the same time, the Baicheng syncline starts to be developed.

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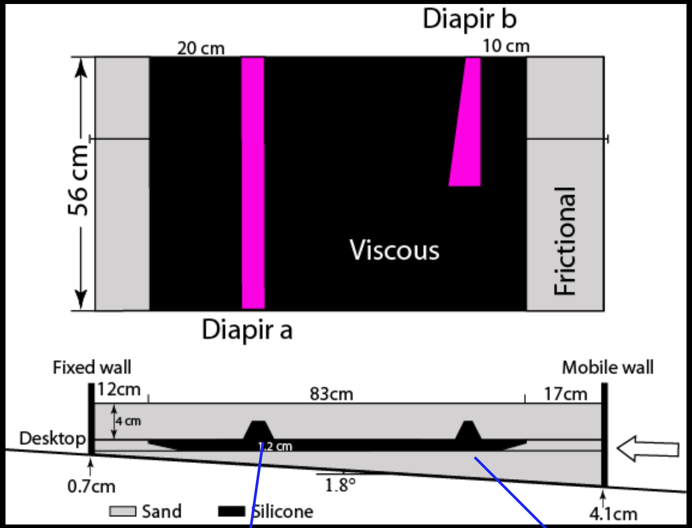
Influence of pre-existing diapir on compression deformation of salt basin

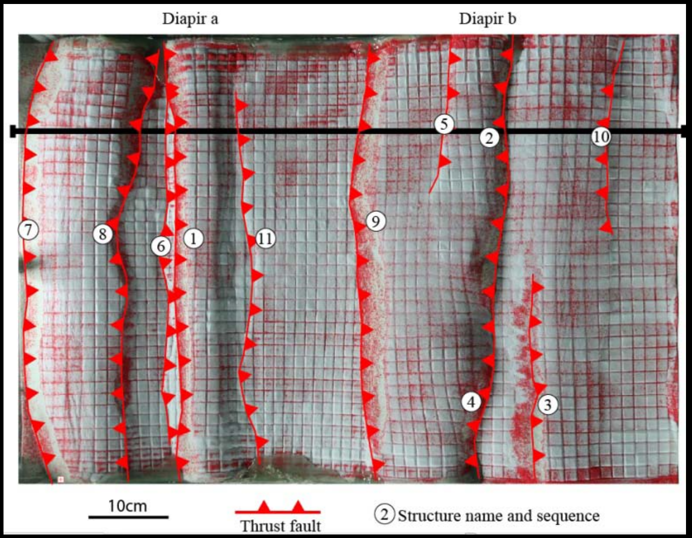
Shortening rate:
0.5 cm/h

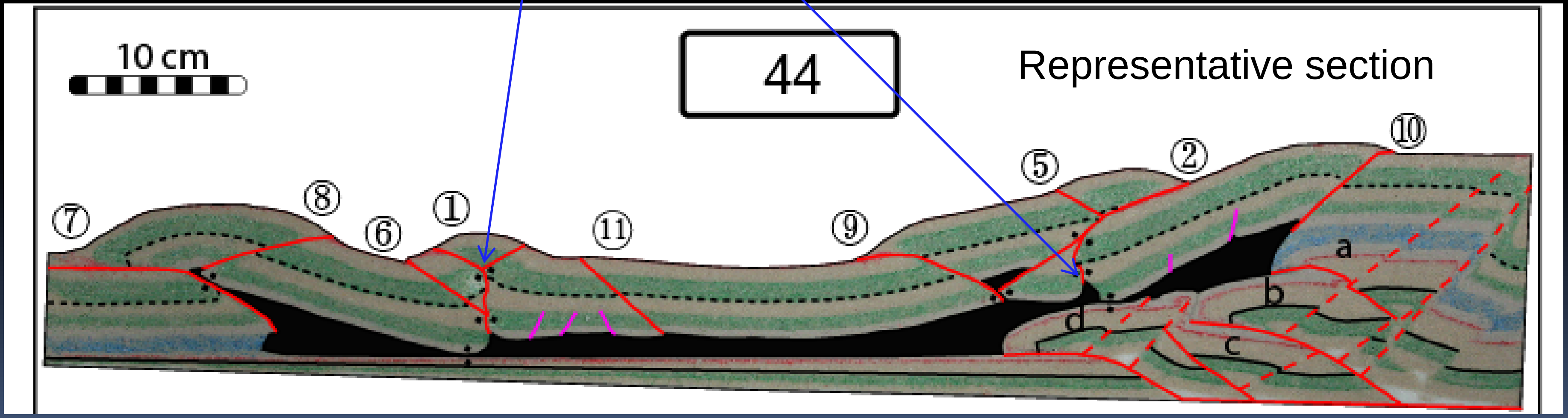
Shortening:
29.9 cm

Model setup



Result





A pre-setted diapir before shortening was used during the lab simulation. The results showed that diapirs was deformed first (Numbers represent deformation sequence) and followed by fault welding.

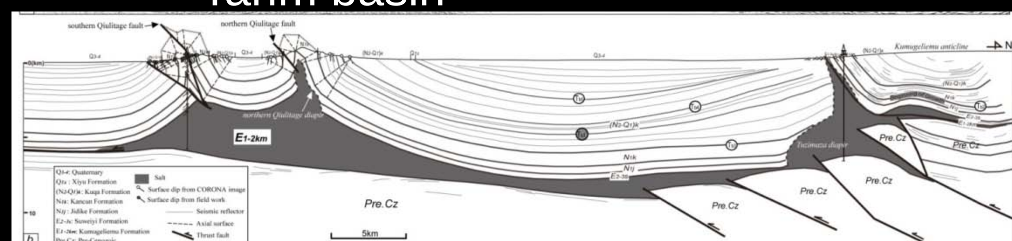
Influence of syn-kinematic sedimentation on compression deformation of salt basin

Experiment 1：without growth strata

Experiment 2：with growth strata

Tarim basin

closely spaced thrusts and high taper angel near the backstop



Tianshan

Kuqa salt section

The experiment 2 exactly modeled the salt types discovered in the Kuqa depression.

The basement-involved sub-salt faults occurred in rear part near backstop in the lab simulation. In the Kuqa depression, these sub-salt faults occurred in the front of Tianshan mountain.

The growth strata has a significant effect on the distribution and propagation of deformation. There is no fault in the region with development of growth strata.

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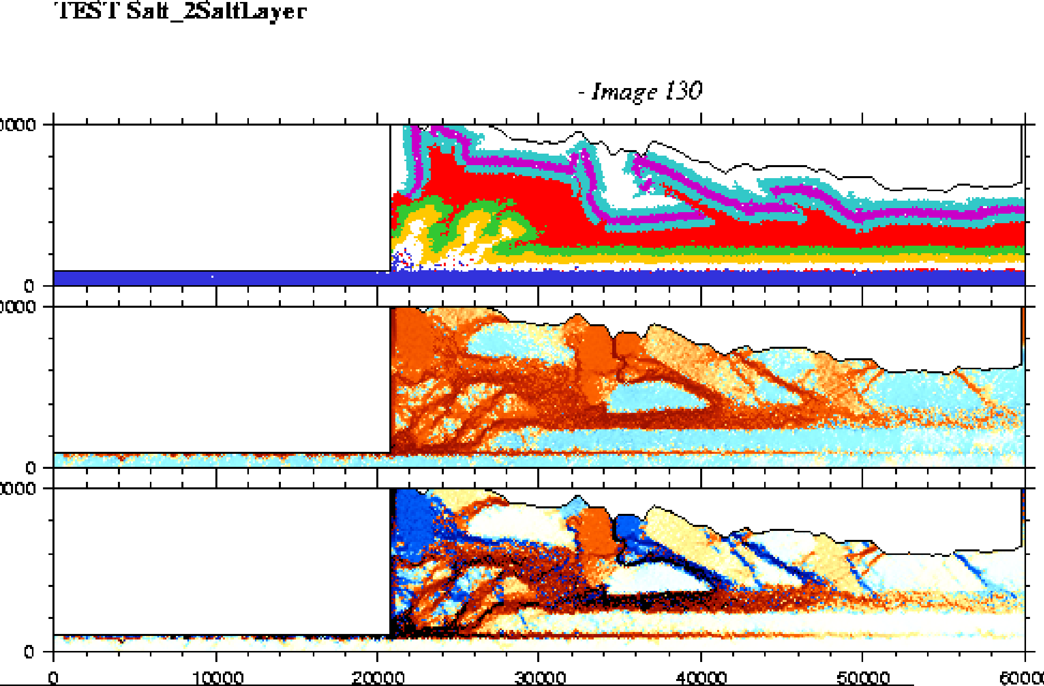
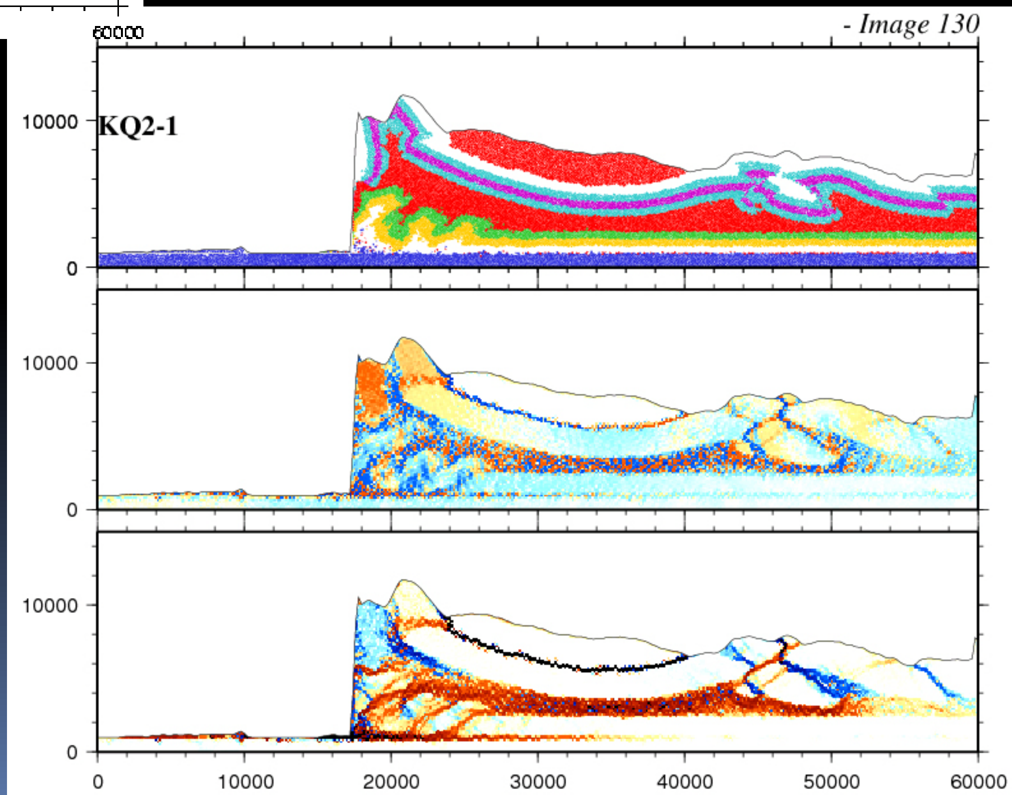


Discrete element modeling

Influence of syn-kinematic sedimentation on compression deformation of salt basin

With sedimentation

Without sedimentation



By Hongwei Yin (2011)

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1, Thin-skinned compression salt structures developed in the Kuqa depression has Paleogene salt as a decollement, except the region in the forefront of Tianshan, where the faults below the salt might be involved in the Paleozoic basement.

2, There are two types of salt structures in the Kuqa depression, diapir and pillow. The diapir directly initiated after salt deposition. During compression deformation, diapirs were thrusted at the northern flank and then followed by thrust and salt nappe. The pillows were formed at the south front of diapirs in the same time.

3, The lab simulation results demonstrated that the pre-existing diapirs had significant effects on the development of thrust during the compression deformation, and the distribution of growth strata played an important role with respect to the formation and location of salt anticlines in Kuqa.

Thank you