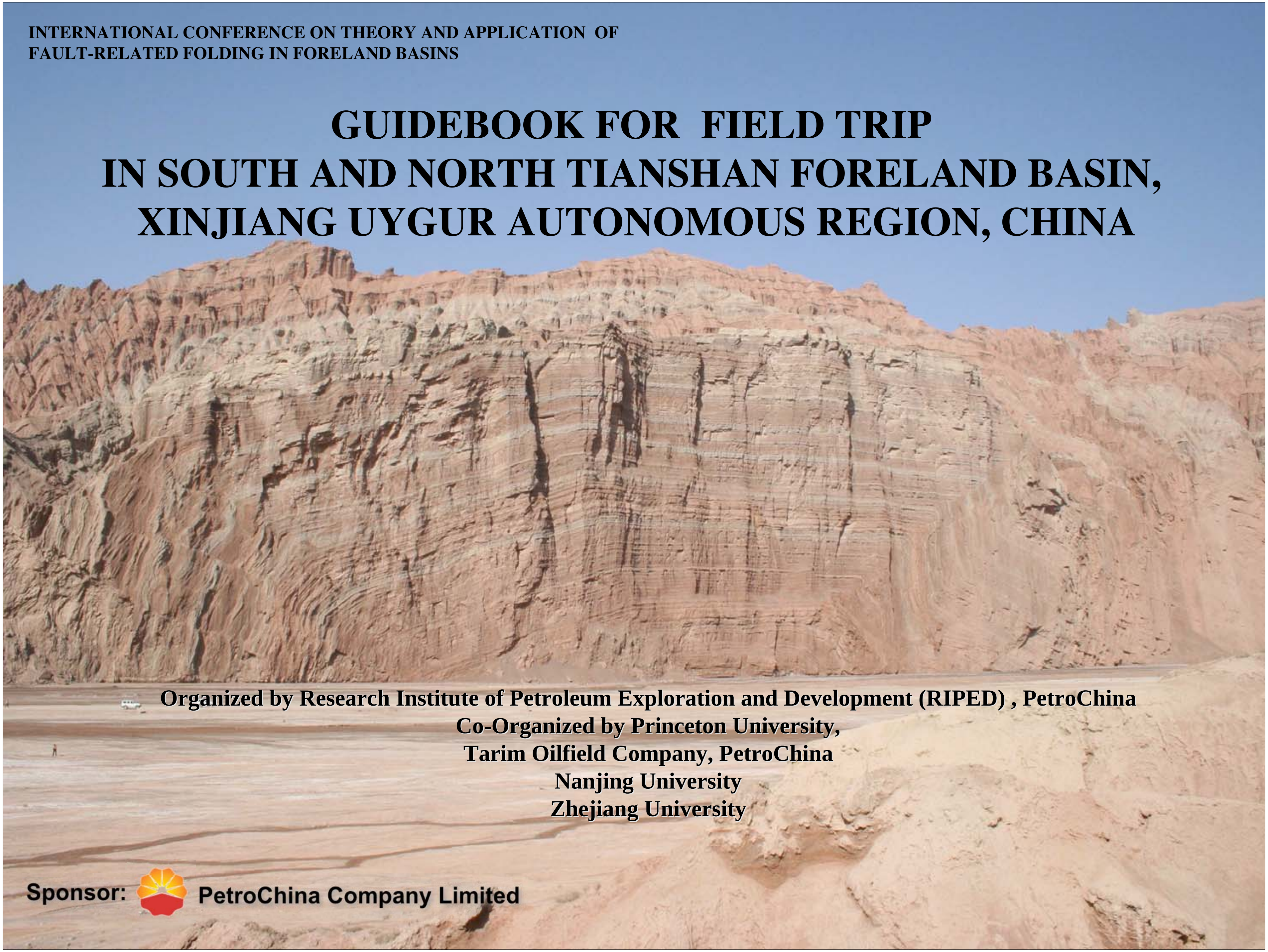
INTERNATIONAL CONFERENCE ON THEORY AND APPLICATION OF FAULT-RELATED FOLDING IN FORELAND BASINS

GUIDEBOOK FOR FIELD TRIP IN SOUTH AND NORTH TIANSHAN FORELAND BASIN, XINJIANG UYGUR AUTONOMOUS REGION, CHINA



Organized by Research Institute of Petroleum Exploration and Development (RIPED) , PetroChina

Co-Organized by Princeton University,

Tarim Oilfield Company, PetroChina

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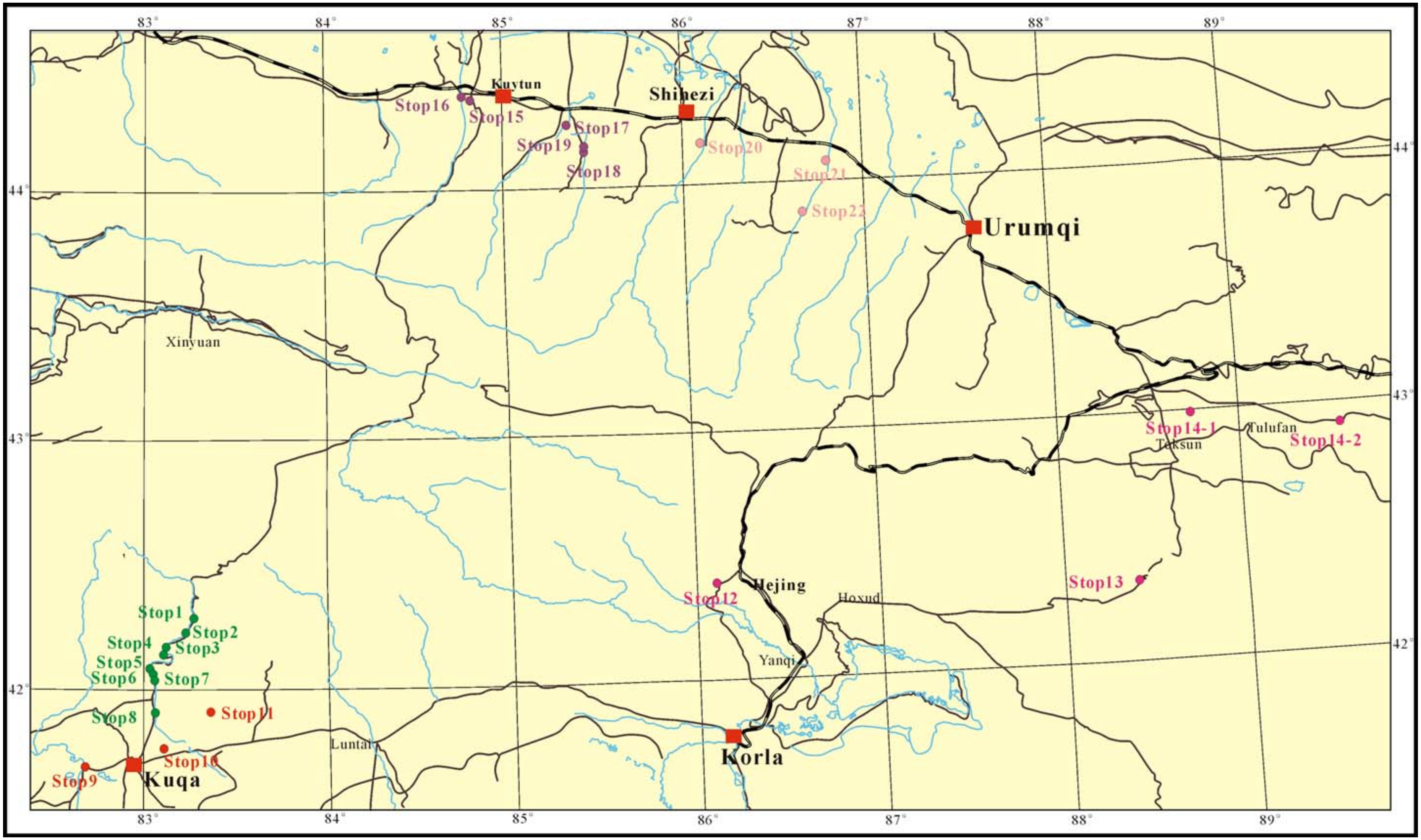
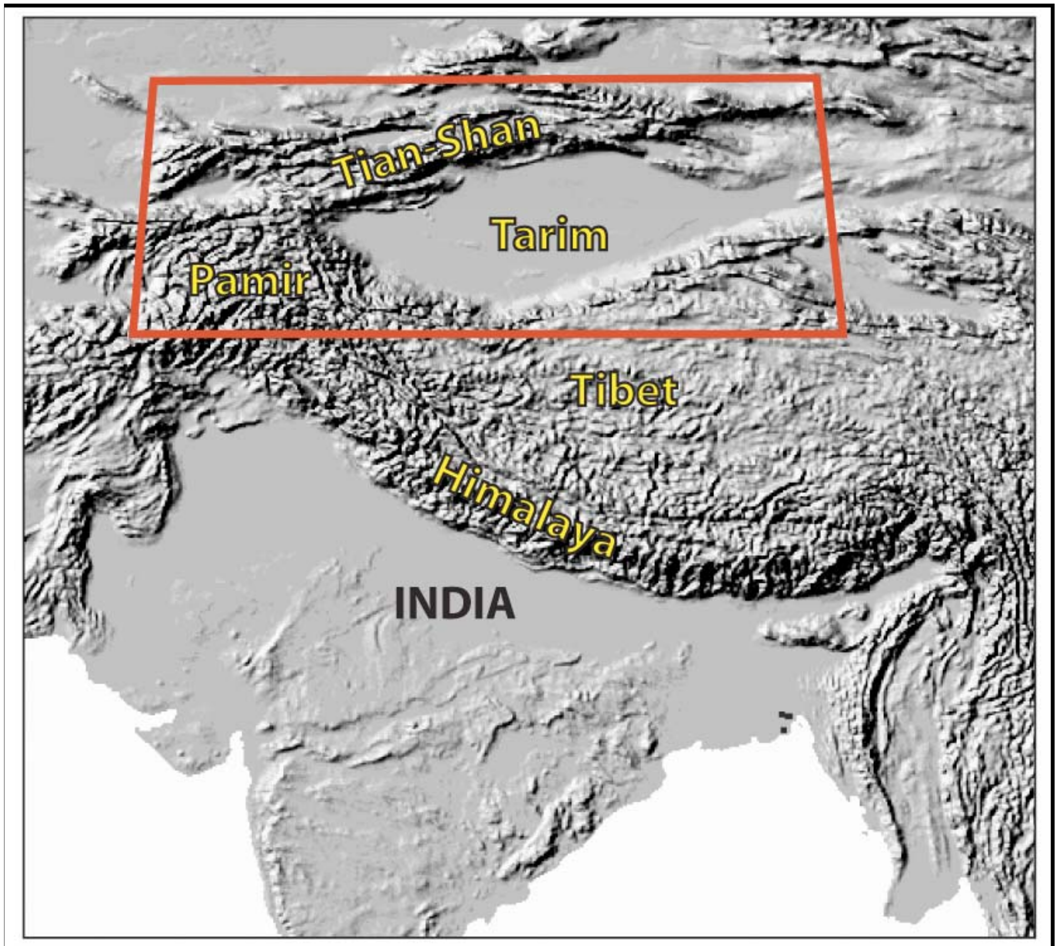
Field Stop Overview



The stops for the same day are in same colour

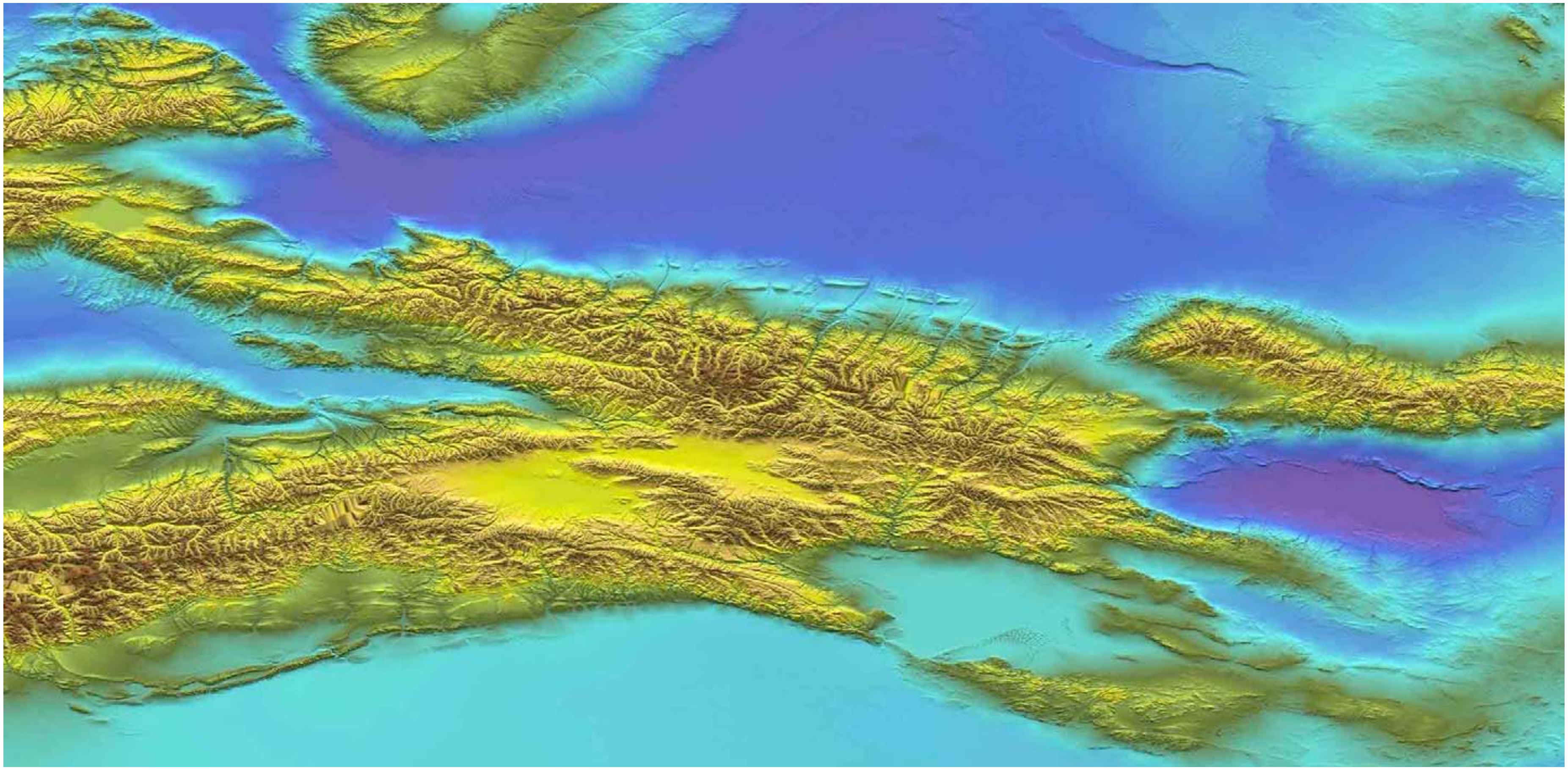
Tianshan Orogenic Belt



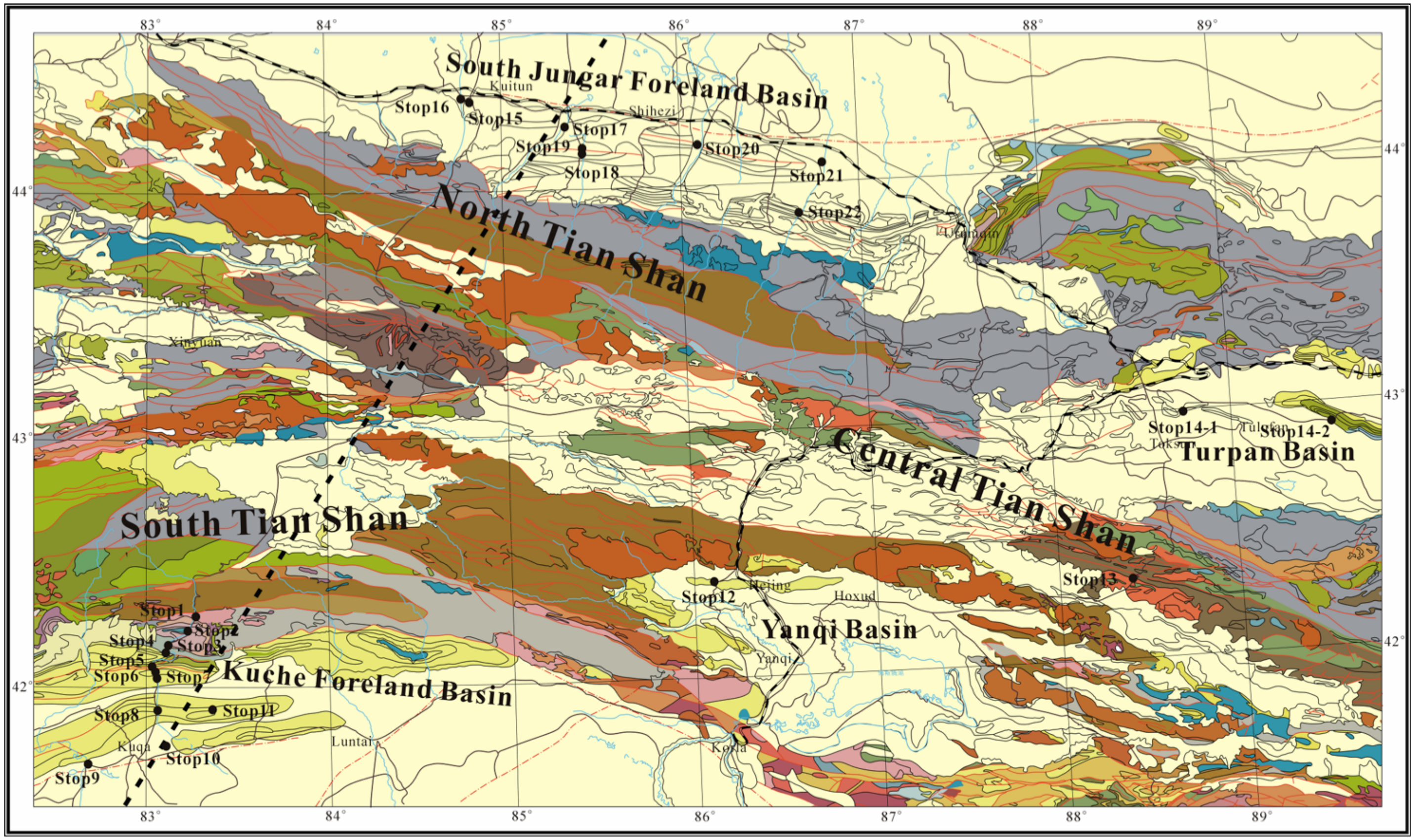
Geological Setting of Tianshan Orogenic Belt

Since Eocene, the collision and continuous compression between the India plate and the Eurasia plate has resulted in extensive intracontinental deformation in Asia, especially in the central Asia, of which, the Paleozoic Tianshan orogenic belt reactivated and uplift rapidly, developing the Kuqa and the South Junggar foreland basins and fold-and-thrust belts in its two flanks (Molnar and Tapponnier,1975; Tapponnier, et al,1986). Sedimentological data from basins to the north and the south of the central and eastern Tian Shan indicate that the Tian Shan Range has been a positive geographical feature since the Triassic (Hendrix et al. 1992; Hendrix 2000; Greene et al. 2001). Fission-track and structural data across Tian Shan region in China indicate that the Tian Shan Range has been repeatedly uplifted and structurally reactivated since the amalgamation between basement blocks in the late Paleozoic (Windley et al.1990; Dumitru et al. 2001). It is suggested that Cenozoic shortening of Tian Shan Mountains began at Late Oligocene or Early Miocene (25 Ma~20Ma) (Allen et al. 1991; Avouac et al. 1993; Hendrix et al. 1994; Sobel and Dumitru, 1997; Yin et al., 1998; Burchfiel et al., 1999; Sobel et al., 2000; Abdrakhmatov et al., 2002; Thompson et al., 2002) , almost 35Ma later than the collision between the India plate and the Eurasia plate. The geodetic date proves that the shortening rate of Tianshan Mountains is roughly only half of the total shortening between the India and Eurasia (20~24mm/yr).

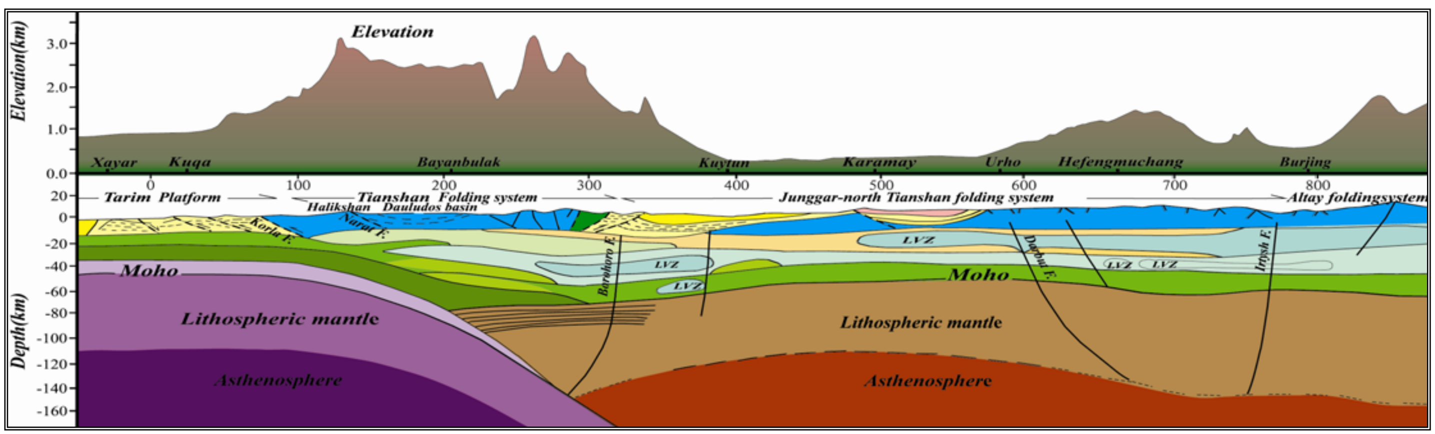
The field trip mainly focus on the styles of fault-related folding and active structural deformation in two flanks of Tianshan(the Kuqa basin,Yanqi basin,Turpan basin and South Junggar basin to understand the process and geodynamic mechanism of the deformation in Cenozoic era., and to find out how these active tectonics has played a part in the late-stage oil-gas accumulation.



Foreland basins on the flanks and within the Tianshan orogenic belt. DEM visualization by Karl Mueller.



Field Stops in foreland Basins on the flanks and within the Tianshan orogenic belt (After Geological map of Xinjiang, 1:1,000,000, Xinjiang Geological Bureau, 2003)



The surface line in the upper part of the figure is elevation in km. LVZs in the lower part of the figure are low-velocity zones. The heavy lines are interfaces determined by deep seismic sounding, MT sounding, and gravitational inversion. The dotted lines are inferred interfaces. Some lines at high angle are faults determined by seismic sounding, MT sounding, and gravitational analyses. The complicated crust–mantle transitional zone of the Tianshan orogenic belt is determined by using wavelet transform. The lithosphere–asthenosphere transition zone (shown in broken lines) is inferred based upon seismic tomography for the northern margin of the Tarim basin and MT sounding for the Tianshan orogenic belt, Junggar basin, and Altay orogenic belt. (After Zhao et al, 2003)

Kuqa Foreland Basin

The Kuqa foreland Basin, located in the northern part of Tarim Basin, south of South Tianshan, extensd west to east from Aksu city to Korle city. Its area is 21000 km2 with 40-90km width and 550km length (Jia Chengzao,1997; Wang Xin et al., 2002a; Yin et al., 1998；Brown et al., 1998; Burchfiel et al., 1999). It is composed of terrestrial Triassic, Jurassic, Lower Cretaceous, Paleogene, Neogene and Quaternary strata in the Kuqa Foreland Basin. Seismic lines show that total Mesozoic-Cenozoic thickness is up to 12km in the Baiche Depression, with the Cenozoic strata exceeding 8000m. The results show that the structural deformation in the Kuqa Foreland Basin initiated since Miocene or 23-25Ma (Sobel and Dumitru 1997; Yin et al. 1998). A series of south vergent thrust and fold belts in the Kuqa Foreland Basin were developed sequentially form north to south (Yang Geng et al., 2003; Lu Huanfu et al.,1999; Wang Xin et al. 2002a, 2002b; Guan Shuwei et al, 2003, 2004), and can be subdivided into five structural belts according to structural deformational styles: (1) North Monocline; (2) Kelasu-Yiqikelike Anticline belt; (3) Wushi-Bache depression; (4)Qilitake Anticline belt; (5) Yaken Anticline. Several oilfields or gasfields have been found by Tarim Oilfield Company, PetroChina Limited Company, such as Kela 2, Dina 2, Yinan 2, Dabei 1, Tubei 1 gasfields and Dawanqi oilfield.

Stop 1

Location: At the 987km milestone mark of the Road 217 from Dushanzi to Kuche and about 110km north of Kuche ctiy. Standing on the east bank of the Kuqa river and looking west. GPS coordinate: N42°16.737'，E83°16.015'，H1846m.

The depositional boundary between the Kuqa foreland basin sequence and Paleozoic basement rocks of the South Tianshan orogenic belt. Late Paleozoic granite can be found to the north (the intrusion took place in Late Carboniferous, according to the geological surveying report of Xinjiang,1965). From north to south, the outcrops show the Upper Permian, Lower Triassic, Middle Triassic and Upper Triassic strata, comprising a south-dipping monocline as a whole with a dip of 50°to 65°.

The south dipping Biyoulebaoguzi group of Late Permian, which is interbedded purple sandstones and shales with a thickness of 10m. The overlying strata are brown conglomerate with scour at the base, which is the Lower Triassic Ehuobulake Formation, and is in conformable contact with the underlying shallow lacustrine grey-green mudstones interclated with greenish sandstones of Upper Permian Biyoulebaoguzi Group.

The Lower Triassic Ehuobulake Formation may be subdivided into five lithologic members as follows: the basal part of brown-grey conglomerate intercalated with purple-red fine siltstone, the lower green sandstones members, lower red sandstone member, upper green sandstone member and upper red sandstone member, with a total thickness of 296m.

The Middle Triassic Kelamayi Formation is in comformable contact with the Ehuobulake Formation at the base, and may be divided into two members. The lower member is green beds interclated with red beds of sandstones, mudstones, and conglomerate. The lower part of the upper member is conglomerate with the distinct scour surface and with a sharp change between sandstones and mudstones at the top of the underlying member. The upper part of the Upper member is a interval of black carbonacous mudstones with cone-in-cone structure with a thickness of 32m, which is a marker bed for regional correlation. Vertically, it is generally coarser below and fine above, and red below and green above. The Kelamayi Formation, with a thickness almost of 534m, is in comformable contact with the Upper Huangshanjie Formation at the top.

Stop 2

Location:It is 3km south of Stop 1 and near the 993km mark of Road 217. Standing on the west bank of the Kuqa river and looking east.

Stop 2-1:The Kuruli syncline. GPS coordinate: N42°13.893'，E83°14.033'，H1771m.

The Kuruli syncline extends 24km from east to west and about 2km wide in the core. The eastern upward end of the syncline is located at the east bank of the Kuqa river. The core of the Kuruli syncline is the grey-white conglomerates and sandstones of Upper Triassic Taliqik Formation, while the two limbs are the black carbonaceous shale intercalated with coal seam of the lower member of Taliqike Formation. The steep slope of its northern limb is the boundary between the Taliqike Formation of the Upper Triassic and the Kelamayi Formation of the Middle Triassic. The steep slope consists of weathered TaliqikeFformation, composed of black carbonaceous shale intercalated with coal seam and gray sandy mudstones, and appearing a purple-red color because of the auto-burning of the coal beds. The strata at the foot of the slope are black mudstones of the Upper Triassic Huangshanjie Formation. Seismic data shows that the Kuruli syncline is resulted from backthrusting of structural wedge at depth.

The Upper Triassic Huangshanjie Formation is chiefly composed of two suites of depositional cycles grading from coarse to fine, with massive sandstones and conglomerates at the basal part of each cycle, and grey-green and grey-black mudstones and carbonaceous mudstones intercalated thin-bedded limestone in the middle and upper parts. It is of 838m thick and is in comforable contact with the underlying Kelamayi Formation and the overlying Taliqike Formation.

Stop2-2

Contents: The Jiesidelike anticline.GPS coordinate: N42°13.323'，E83°13.864'，H1768m。

Almost 1km south of the Kuruli syncline, the Jiesidelike anticline extends 15km from west to east, and almost 1km wide in the core. The core is grey-black mudstones of Upper Triassic Huangshanjie Formation, composed of grey-black mudstones. The two limbs are the Upper Triassic Taliqike Formation with grey-white sandstones, and black carbonacous mudstones intercalated with coal seam. The Upper Triassic Taliqike Formation has three depositional cycles grading from coarse to fine, consisting chiefly of grey-white conglomerate, medium to coarse-gained lithic sandstones, grey sandy mudstones, argillaceous sandstones, and black carbonaceous shales intercalated with coal seam. The Taliqike Formation is 256m in thick and is in comformable or pseudoconformable contact with the Ahe Formation at the top and conformable contact with the Huangshanjie Formation at the base.

Stop 3

Location: 10km south of Stop 2 and in the north of the Dongfeng coal mine.

GPS coordinate: N42°09.335'，E83°06.636'，H1638m.

The boundary between the Triassic and the Jurassic and the A’ge fault. The Taliqike Formation is conformable with the overlying Ahe Formation. The Ahe Formation consists chiefly of greyish pebble conglomerate, conglomerate gritstone, and gritstone, intercalated with grey-green fine to medium-grained sandstones, grey-black mudstones and coal streak, with a total thickness of 358m. The Taliqike Formation dips to the south at up to 55°. The Taliqike Formation is thrust onto the Ahe Formation with the coal measures as the hangingwall flat. The A’ge fault extends 10km from east to west, and the A’ge anticline developed at its western termination. The A’ge fault increases its displacement eastward; the fault is still unknown when going further to the east.

Stop 4

Location:500m south of Stop3, beside the A’ge village.

GPS coordinate: N42°08.858'，E83°06.438'，H1637m.

The Jurassic strata of Kuqa river. In the north is the lower Jurassic Ahe Formaton, consisting of greyish microconglomerate to pebble conglomerate and the lower Jurassic Yangxia Formation, composed of grey-white conglomerate, sandstones and dark grey sandy mudstones and coal streak. In the middle is the Middle Jurassic Kezilenur Formation, consisting of white microconglomerate and conglomeratic sandstones, and the Middle Jurassic Qiakemak Formation of grey-green and purple mudstones and sandy mudstones. In the south is the Upper Jurassic Qigu Formation of red mudstones and the Upper Jurassic Kalazha Formation of brown-red sandstones and purple-red argillaceous siltstones intercalated with silty mudstones.

The Yangxia Formation is chiefly composed of grey, grey-white sandstones and conglomerates, grey argillaceous siltstones, dark grey, grey-black sandy mudstones and coal streak constituting many postive rhythmites. It is 531m thick with a marker bed of 38m thick black carbonaceous shale at the top. It is in conformable contact with the overlying Kezilenur Formation at the top.

The Kezilenur Formation is comprised of grey-while, conglomeratic sandstones and mudstones, with a total thick of 773m. It is conformable with the Qiakemake Formation at the top and with the Yangxia Formation at the base. The Kezilenur Formation has with many intervals of coal beds developed in the lower part and has favorable source rock intervals. There is no coal in the upper part.

The Qiakemake Formation consists of mudstones, silty mudstones intercalated with sandstones and marls, with marl lenticules intercalted in the top part. It is 120m thick and a promise oil generation beds. Its top and base are conformable with the Qigu formaiton and Kezilenur Formation respectively.

The Qigu Formation is a suite of grey-purple, brown-red mudstones sediments, with grey-green, grey-white siltstones and marl bands intercalated in the lower part, about 273m thick. Its top and base are conformable with the Kalazha and Qiakemake Formations respectively.

Stop 5

Location: At the corner of the Kuqa river. Stop5 is located at the west bank of the river and positioned for looking east. GPS coordinate: N42°05.208'，E83°02.083'，H1481m.

The Bashijiqike anticline. The north limb of the Bashijiqike anticline is maked up of the Bashijiqike Formation, the Baxigai Formation and the Shushanhe Formation of the Lower Cretaceous.

The south limb of the anticline include the Bashijiqike Formation of the Lower Cretaceous, the Kumugeliemu Formation ane Suweiyi Formation of the Paleogene. The strata in the back limb dip 46 to 65°toward the north, and the south dipping forelimb is steep with a dip up to 85 to 88º. In outcrops, the Shushanhe Formation is thrust onto the Baxigai Formation in the core of the anticline.

The Shushanhe Formation consists mainly of mudstones, and is red in below while variegated above, totally 694m thick, and is conformable with the underlying Yakeliemu Formation.

The Baxigai Formation is composed chiefly of yellow-brown sandstones, 164m thick and is conformable with the underlying Shushanhe Formation.

The Bashijiqike Formation consists chiefly of purple-red thick-bedded massive conglomerates in the lower part. It is 224m thick and conformably overlies the Kapushalianghe Formation, and is pseudoconformable with the overlying Kumukeliemu Group. The sandstones and conglomerates of the Bashijiqike Formation are excellent for oil-gas reservoir.

The Kumugeliemu Group consists of grey-white, light grey marl in its basal part and purple-red sandy conglomerate intercalated with mudstones, siltstone, and gypsum in its lower part, and purple-red mudstones in its upper part. It is 130 to 500m thick and can be divided into three members. The lower part of the lower member is grey micritic limestone and the upper part is purple-red sandstones and conglomerates intercalated with mudstones. The middle member consists of grey sandstones and conglomerates. The upper member is composed of purple-red thick-bedded mudstones intercalated with thin-bedded argillaceous siltstones.

Stop 6

Location: At the corner of the Kuqa River. Stop6 is locating at the west bank of the river and situated for looking east. GPS coordinate: N42°04.395'，E83°02.513'，H1458m.

The contact between the Paleogene and the Miocene.

The Oligocene Suweiyi Formation is composed chiefly of interbedded brown-red sandstones and mudstones intercalated with conglomerate, generally ranging in thickness from 200 to 400m, and being gradational between the both Jidike Formation and the Kumugeliemu Formation.

The Miocene Jidike Formation is composed of grey-green, purple-red, thin- to thick-bedded argillacous siltstones, siltstones, fine- to medium-grained sandstones, microconglomerates

Stop 7

Location: At the west bank of the river and situated for looking east. GPS coordinate: N42°01.306'，E83°03.363'，H1442m.

Contents 1:The core of the Jidike anticline

The core of the Jidike anticline is Kuche Formation. Both limbs of the anticline are symmetric and are 30°in dip. The southern limb is composed of the Quaternary Pleistocene Xiyu Formation conglomerates. The Kuche Formation consists mainly of grey, grey-brown sandstones and siltstones intercalated with conglomerates, and is conformable with the underlying Kangcun Formation. Its thickness is from 300 to 700m. From seismic reflection data, the Jidike anticline is controlled by the backthrust in front of wedge.

Contents 2: The growth wedge of the Quaternary Xiyu Formation in the southern limb of the Jidike anticline. GPS coordinate: N42°00.716'，E83°03.478'，H1438m.

The southern limb is the Quaternary Xiyu Formation. The top of the anticline is composed of growth strata of the Lower Pleistocene Xiyu Formation consisting mainly of grey-brown, thick-bedded conglomerates. The Xiyu Formation is composed of thick-bedded grey to dark-grey conglomerates intercalated with yellow sandstones, having pebble of different composition , a diameter from 5 to 20cm, ranging in thickness from 350 to 2370m. The Xiyu Formation in the southern limb has a thicker bed to the south, having the same dip as the underlying Kuqa Formation at the base and becomes horizontal at the top.

Stop 8

Location: At the core of the Quchetawu anticline. GPS coordinate: N41°55.097'，E83°03.280'，H1309m.

The Kuchetawu anticline. The surface of the anticline has the Jidike Formation in the core and the Miocene Kangcun Formation, Pliocene Kuqa Formation and the Lower Pleistocene Xiyu Formation in the two flanks. The Jidike Formation is composed of purple-red mudy siltstones, siltstones, microconglomerates intercalated with grey-green mudstones, argillaceous mudstones. The

Kangcun Formation is consisting of interbedded grey sandstones and brown mudstones, intercalated with grey-green member. The Kuche Formation is made up of grey and green-grey sandstones and conglomerates unequally interbedded with grey, brown-grey and light green-grey mudstones and argillaceous siltstones and is gradational with the underlying Kangcun Formation.

The Kuchetawu anticline is a tight fold, consisting of steep strata in the core and gentle dip strata in the limbs. From seismic reflection data, the anticline is controlled by both the south dip back thrust in the forelimb, developing in the Miocene Jidike Formation, and the south vergent thrust fault in the backlimb. The two faults merged and were emergent in the surface. The deeper fold of the anticline is a typical fault-bend fold, whose lower detachment fault is in the coal bed at the base of the Jurassic and upper detachment fault is located in the gypsum layer of the Paleocene Kumugeliemu Formation. The ramp cuts upward through the Jurassic, the Cretaceous and Paleogene, indicating a displacement of almost 10km.

Stop 9

Location: At Yanshuigou beside the Road 217, 9km northwest of Kuqa city. Going across the river bed and climbing up the ridge tothecrest of the terrace, then looking east. GPS coordinate: N41°50.050'，E82°51.881'，h1228m.

This location shows young growth strata exposed by post-incision erosion within the active fold scarp of southern limb of the east Qiulitage anticline. The growth strata record progressive folding as they move through the 115m wide active synclinal hinge zone. The south limb of the east Qiulitage anticline is composed of the Pliocene Kuche Foramtion with a vertical core and 60°to 70°of dip in the limb. In the distant, the landform is turn to smooth elevation from a steep slope with a dip of 60-70°to 20-30°. The steep Kuche Formation, consisting of grey sandstones, conglomerates intercalated with silty shales, shows a series of triangular facets during the later period of uplift and differential erosion. The observation Stop locates at the mouth of the Yanshuigou river where thick-bedded alluvial fans of sandstones and conglomerates developed in Quaternary. The cross section of Yanshuigou river with two grade terrace, the strata of the Pliocene Kuche Formation and the lower Pleistocene Xiyu Formation shows a fanning upward shape, and indicates a syntectonic deposition.

Stop 10

Location: On the west side of the Kelagesai bridge, 10km east of the Kuqa city. GPS coordinate: N41°45.714'，E83°06.642'，H1112m.

The Yaken anticline is in the front of the Kuqa fold-and-thrust belt, with a length of 80km and a width of 8 to 10km and appearing as a hill with a 50 to 100m in hight. The strata in the outcrop are the grey, white-grey sandstones intercalated with mudstones. Two flanks are very wide and gentle, dipping in 3 to 5°,inclulding the deformed Miocene Jidike and Kangcun Formation, the Pliocene Kuqa Formation and the Pleistocene Xiyu Formation. There are syntectonic growth strata in two flanks, decreasing in the thickness from the limbs to the core. Its bottom is the base of the Pliocene Kuqa Formation (Suppe,2004), indicating the initiation of deformation since the early Pliocene. The folded modern terrace is 5 to 10m higher in the core than that in the by GPS data showing that the Yanken anticline is forming at present. Suppe(2004) consider that the Yanken anticline is a detachement fold with a detachement within the gypsum of the Miocene Jidike Formation, about 5.2km in depth, including the deformed Miocene Jidike and Kangcun Formation, the Pliocene Kuqa Formation and the Pleistocene Xiyu Formation. The growth strata include the Pliocene Kuqa Formation and the overlying strata until the modern deposits. Both of the deformed modern deposits and the folded river alluvial terrace indicate that the Yaken anticline is forming at present.

Stop 11-1

Location: At the Kezilenur river. GPS coordinate: N41°54.210'，E83°19.398'，H1310m.

The core of the East Quilitak Anticline. The core of the east Quilitak anticline is composed of the Jidike Formation and both limbs are composed of the Kuangcun and Kuqa Formation. The Jidike Formation is composed chiefly of purple-red muddy siltstones, siltstones intercalated with grey-green mudstones, and siltstone. The Kangcun Formation is 1483m thick, consisting predominantly of rhythmites of green-grey siltstone, and argillacous mudstones. The Kuche Formation is 2722m thick, consisting chiefly of grey and green-grey sandstones and conglomerates

The south limb of the East Quilitak Anticline is narrow and steep, with a dip of 70º to 80º, developing several breaking thrusts in it, with horizontal strata on top of it and steep strata in the core. The north limb of the anticline is long and gentle, with a 50º to 60º dip. But in the core of the anticline two accomodation faults on the north limb form a narrow and vertical kink band and make the anticline take a box shape at the surface.

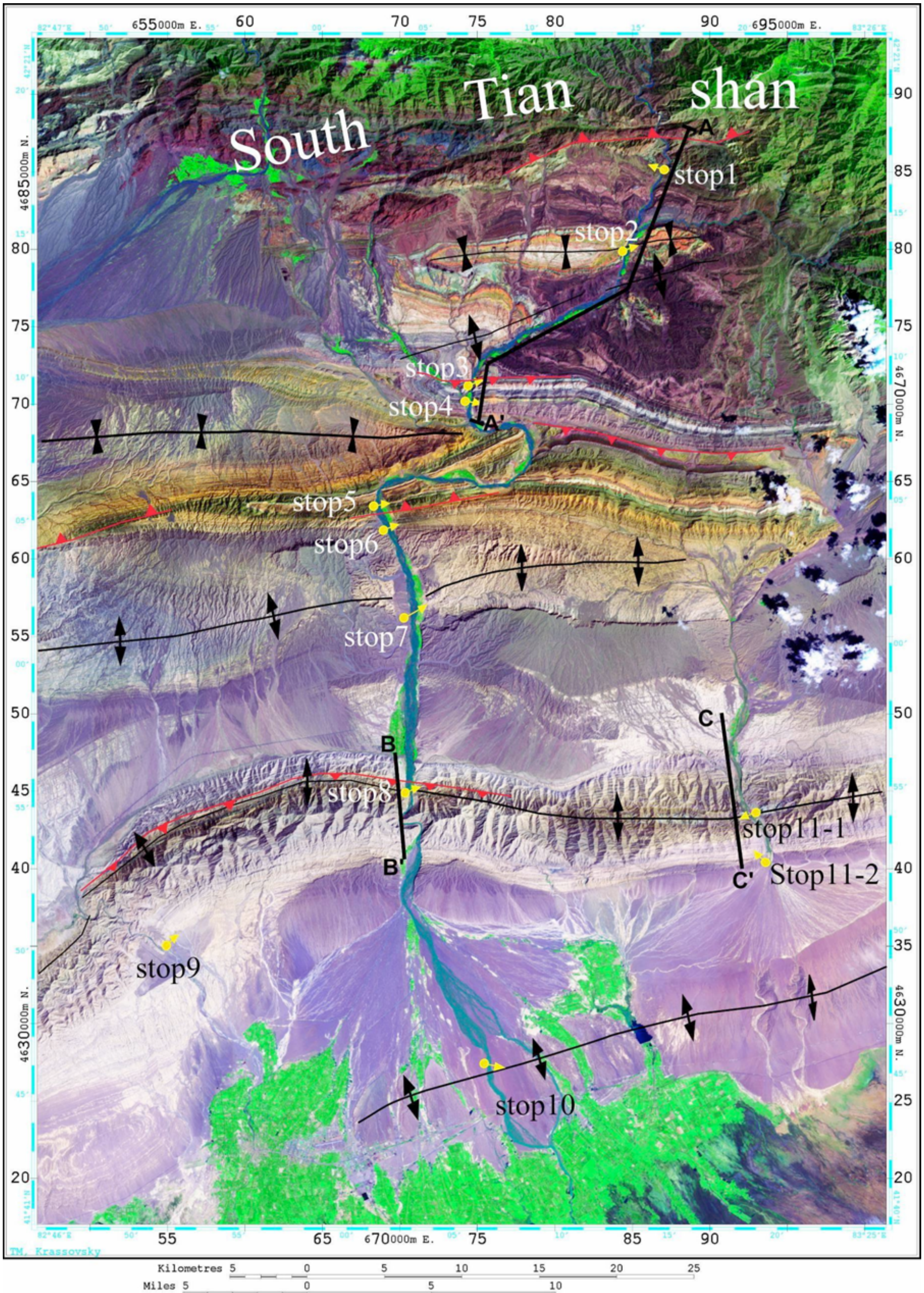
In seismic the 350km long Quilitak anticline shows substantial along-strike variation (Guan 2004), but characteristically it is composed two distinct structural levels: [1] a relatively simple deep thrust ramp that produces a broad deep fault-bend fold anticline with limb dips of 15-20 degrees and [2] an overlying complex wedging system that produces the steep dips of the surface anticlinal core. The east Quilitak section shows these two structural levels. A deep thrust ramp results steps up southward from a 9 km-deep lower detachment level in Upper Jurassic coal horizons that rises to the south and flattens to a 5 km-deep upper detachment in evaporates of the Miocene Jidikeh Formation. The Quilitak upper detachment level extends to the south and corresponds to the Yakeng basal detachment. Slip on the deep ramp (~5km), plus deeper folding of the fault, has generated a 7 to 8 km wide north-dipping kink band imaged in the seismic profile.

The shallower structure of Quilitak is necessarily complex because Yakeng, which is located above the same Jidikeh detachment, has consumed only 1.2 km of the 5 km slip coming from the deep ramp of Quilitak. The remaining 3.8 km is wedged back in the anticlinal core of Quilitak. Above the deep ramp, additional wedging occurs at a shallower level in the anticlinal core, located at the intersection between the backthrust and an upper bedding-parallel detachment level. At this shallower wedge tip the thrust system splits into two main faults. The upper thrust reaches the surface in the south limb of Quilitak. Slip on the lower thrust is consumed in folding. Additional deep detachment folding and associated wedging in the north syncline completes the slip budget of Quilitak.

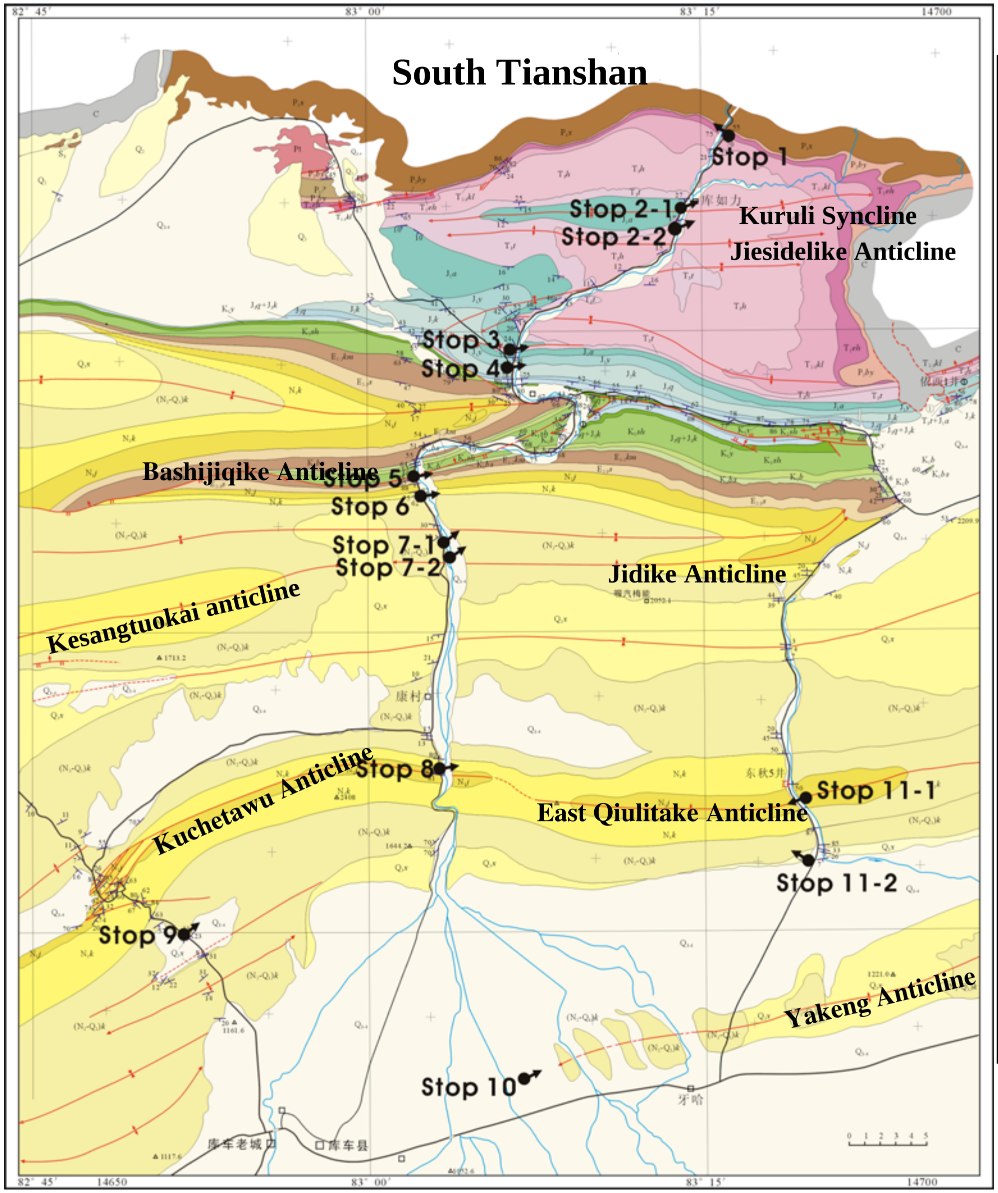
Stop 11-2

Location: At the mouth of the Kezilenur river. GPS coordinate: N41°52.398'，E83°19.736'，H1250m.

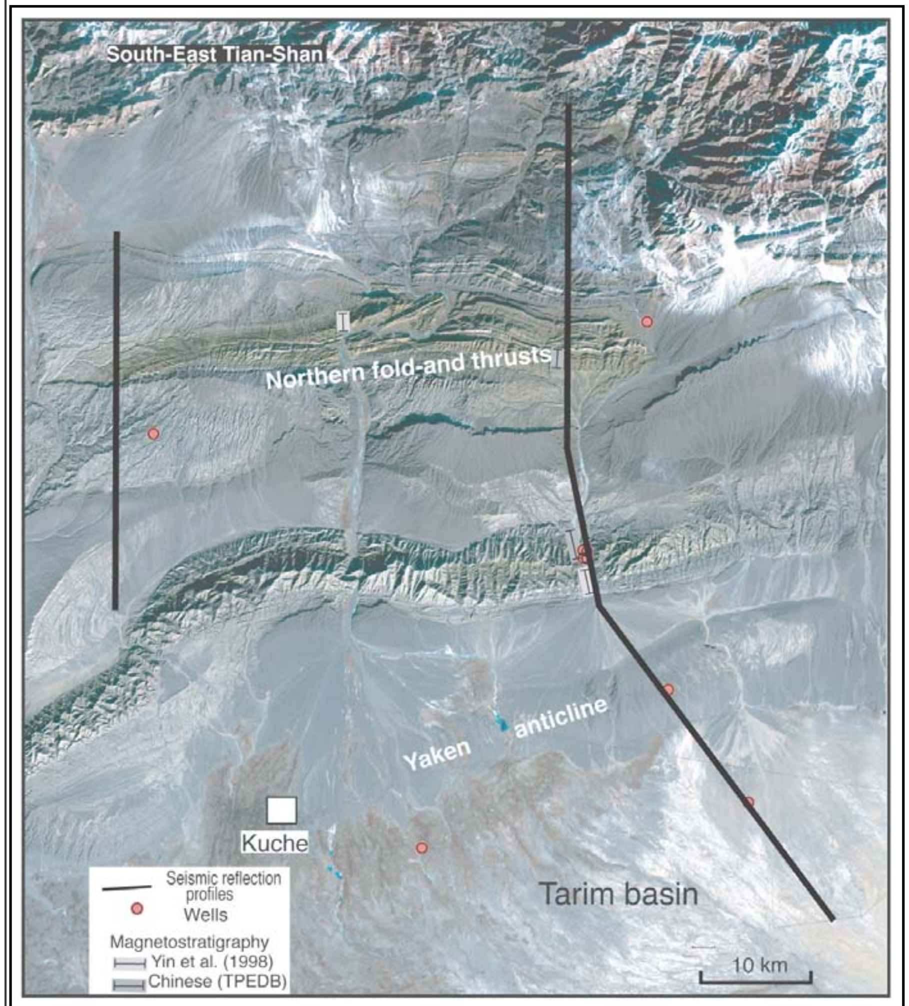
Active progressive folding in the south limb of the East Quilitak Anticline. Outcrops on the east side of the river display the progressive folding of sandstones and conglomerates of the Kuqa Formation and overlying dark conglomerates of the Xiyu Formation. The Xiyu conglomerates overlie the Kucqa Formation with strong angular unconformity through much of the outcrop but become conformable at the southern end of the outcrop, where the active hinge-zone exists, similar to Field Trip Stop 9.



Enhanced Thematic Mapper (ETM) remote sensing imagery (Bands 741) of the Kuqa Foreland Basin, showing the location of the stops and the section AA', BB' and CC'

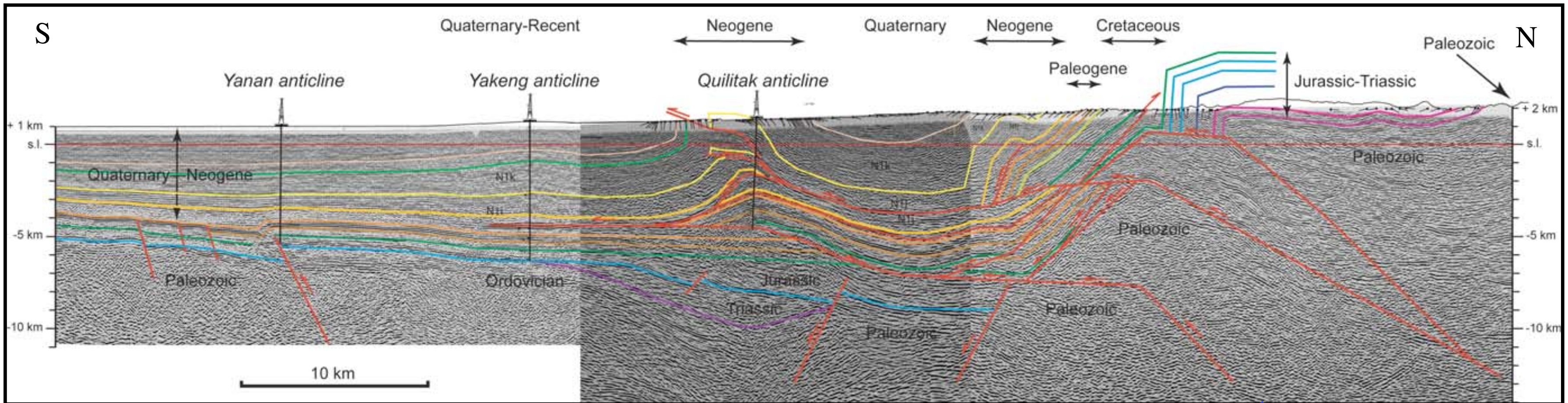


Simplified geological map showing location of the Stops in the Kuqa Foreland Basin (After Tarim Oilfield Company, PetroChina, 2004)

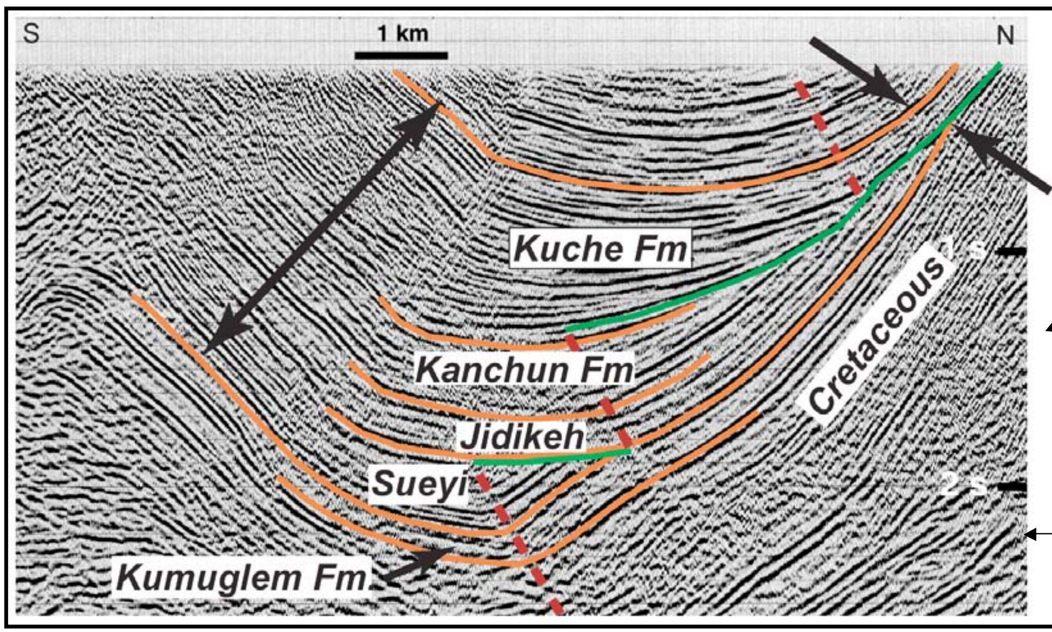


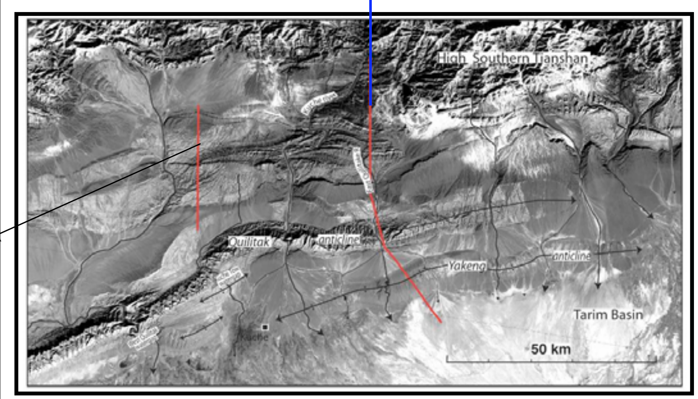
CORONA imagery of the Kuqa foreland basin (After Suppe et al., 2004)

Kuqa Foreland Fold and Thrust Belt



80 km long section, east line of the CORONA imagery of the Kuqa foreland basin



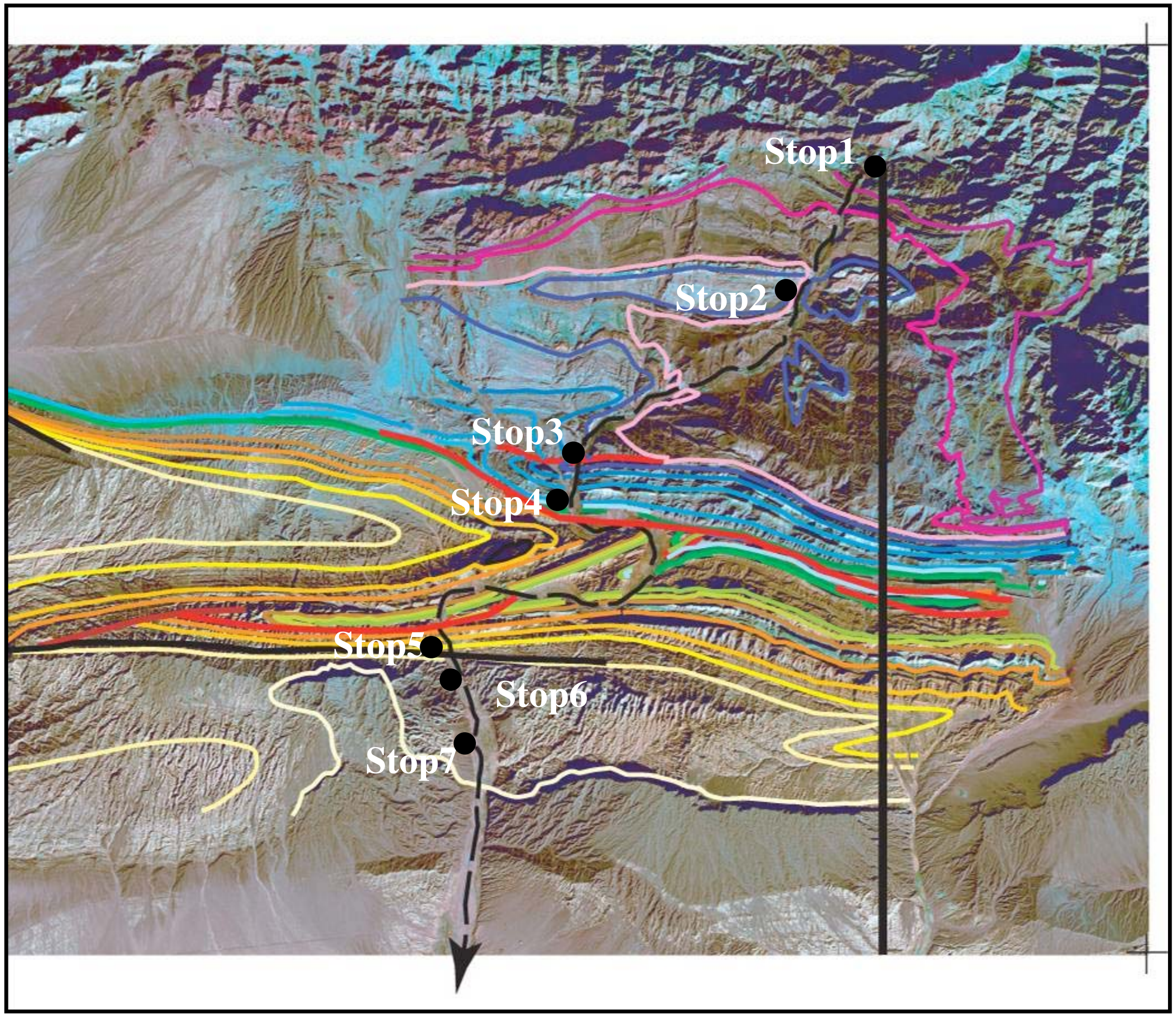


Deformation initiated since Suweiyi time: 25~30m.y.

Two unconformities related to the early phase of deformation in the north area of Kuqa fold-and-thrust belt

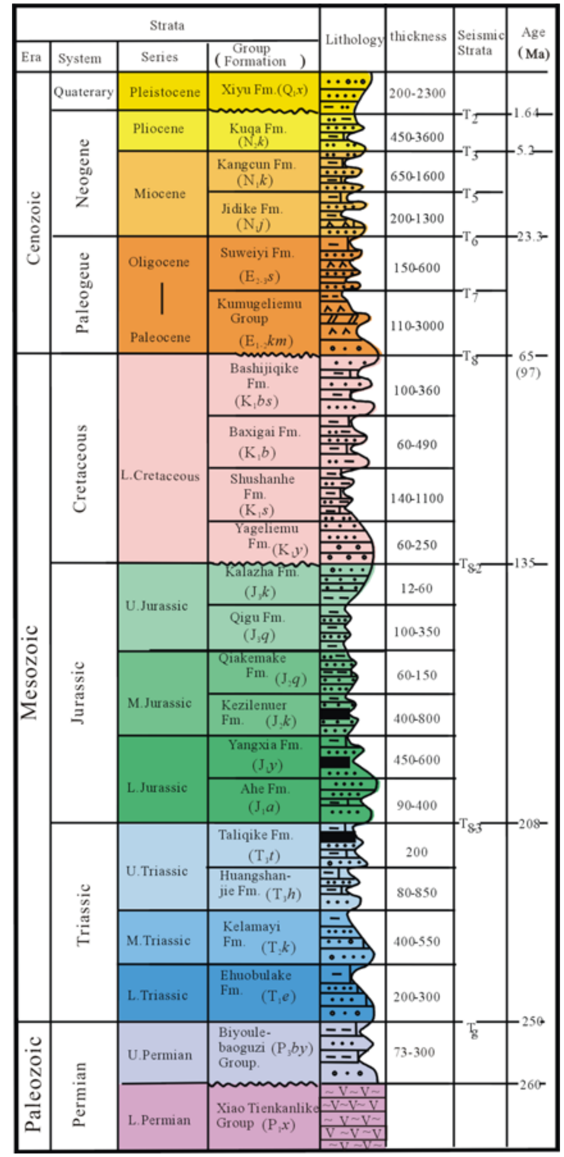
(After Suppe et al., 2004)

Stop1 Boundary between the Kuqa Foreland Basin and South Tianshan



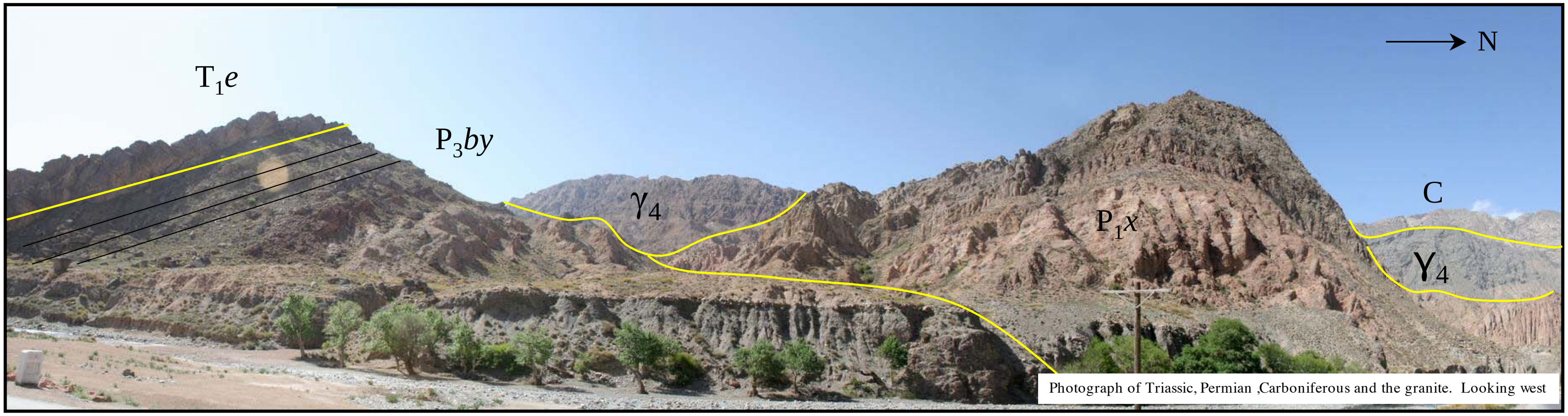
Triassic to Neogene in north Kuqa Basin

(After Suppe et al., 2004)

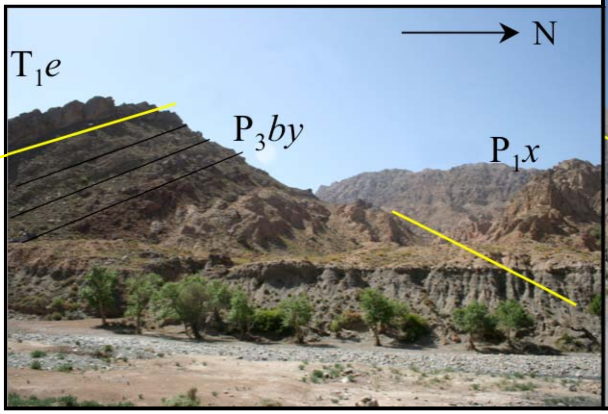


Stratigraphic column of Kuqa Basin

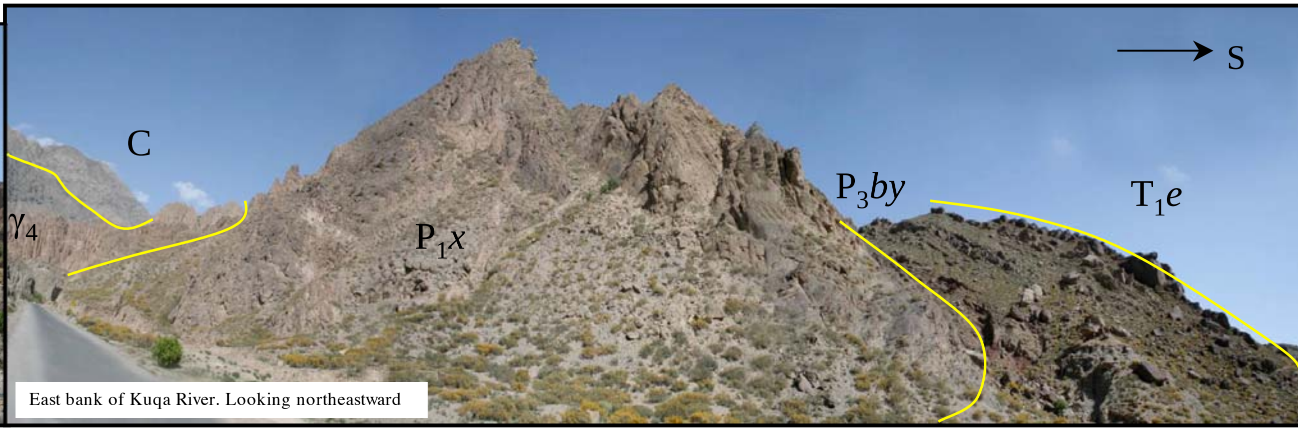
Stop1 Boundary between the Kuqa Foreland Basin and South Tianshan Mountains



The boundary between south Tianshan Mountains and Tarim Basin. The Carboniferous is exposed in the north mountains. The Biyoulebaoguzi group of Late Permian and the Ehuobulak formation of Early Triassic in the south, with the conglomerate beds as its boundary. Photograph is shown the west bank of the Kuqa river.

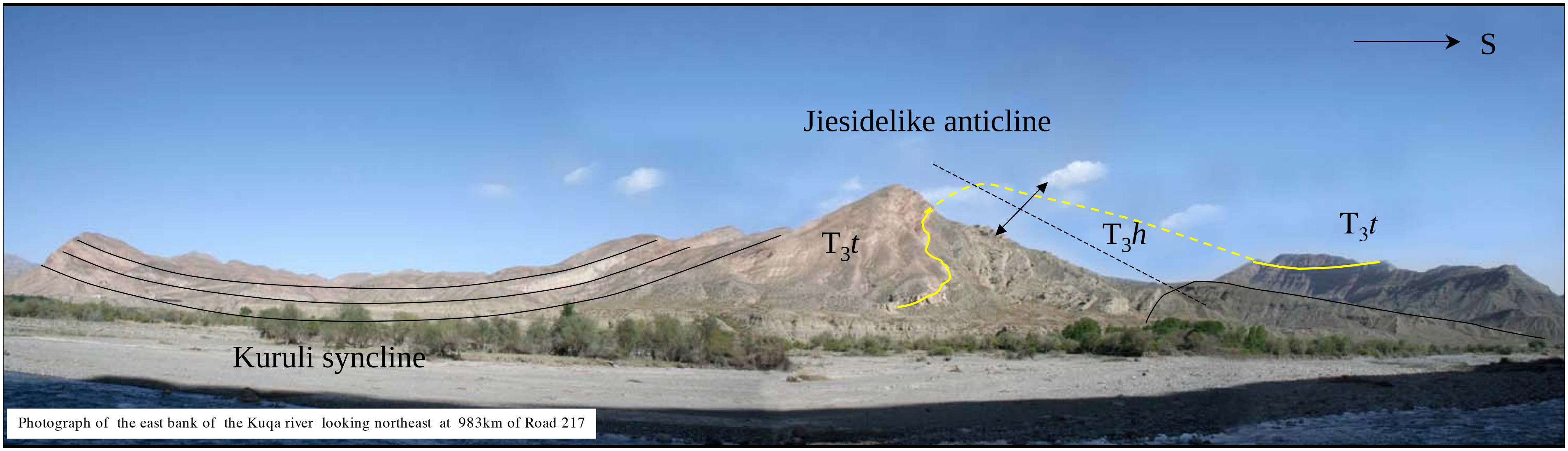


Contact between the late Permian Biyoulebaoguzi group and the early Triassic Ehuobulak formation

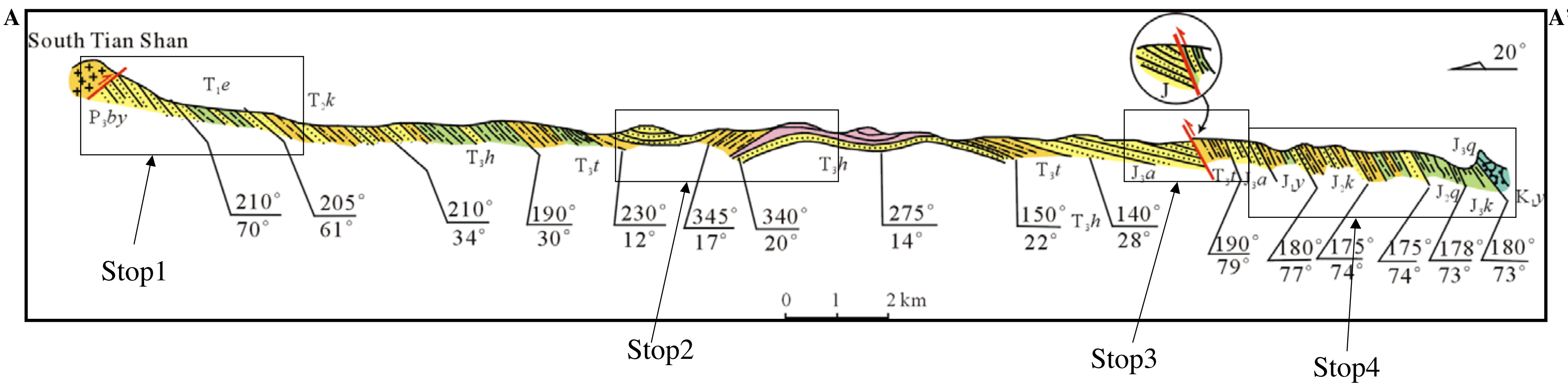


Lithology of Permian and Lower Triassic, east bank of Kuqa River

Stop 2 Kuruli Syncline and Jiesidelike Anticline

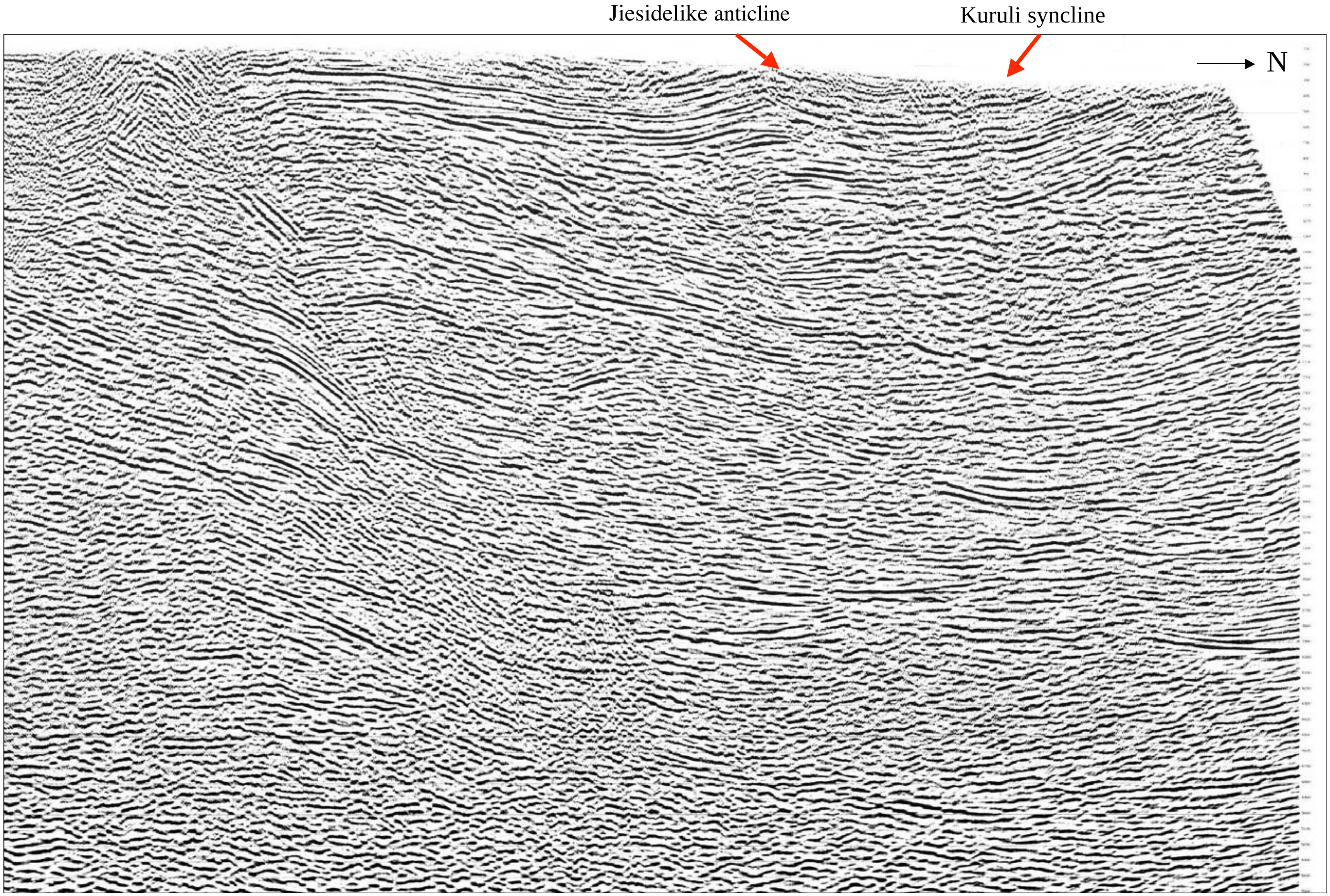


The core of Kuruli syncline is composed of the late Triassic Taliqike formation, both limbs late Traissic Huangshanjie formation(black shales), which is the core of Jisidelike anticline



The geological cross section AA' showing Mesozoic strata and structural styles along the Kuqa river (After Yang et al., 2003). The location is shown in the ETM remote imagery of the Kuqa foreland basin.

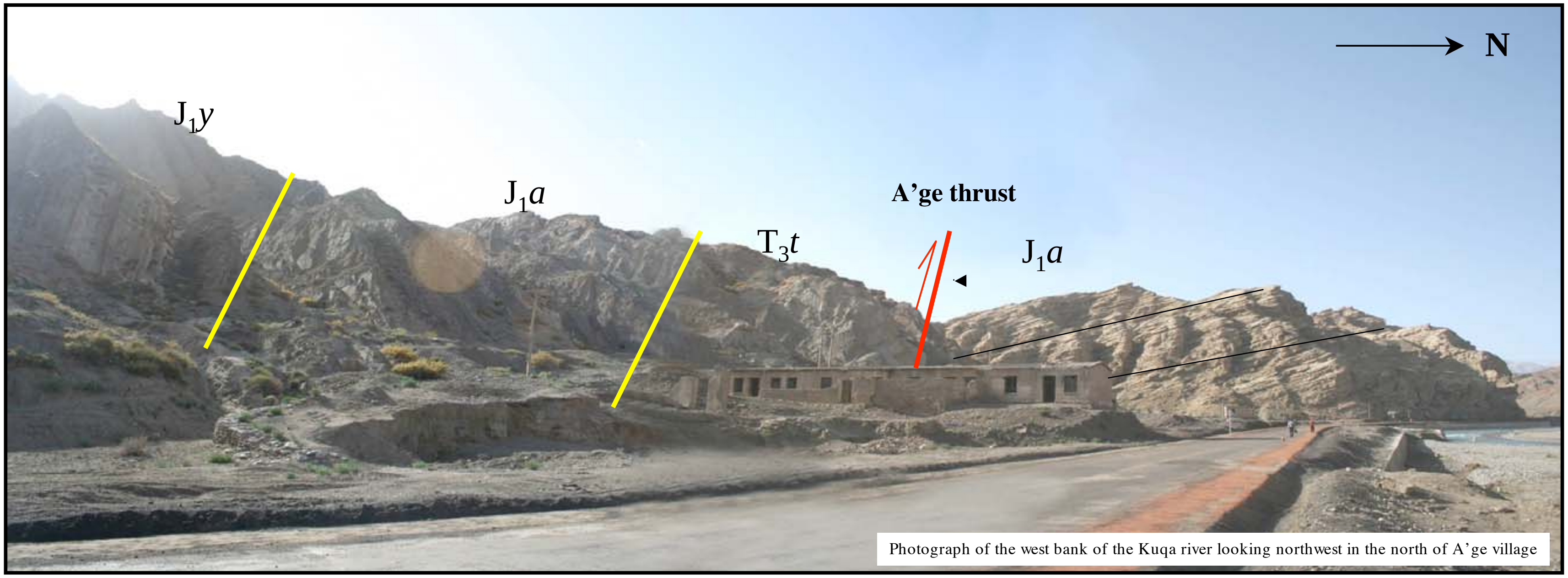
Stop 2 Kuruli Syncline and Jiesidelike Anticline



Seismic line crossing the Kuruli syncline and Jiesidelike anticline

（Seismic data are provided by Tarim Oilfield Company ）

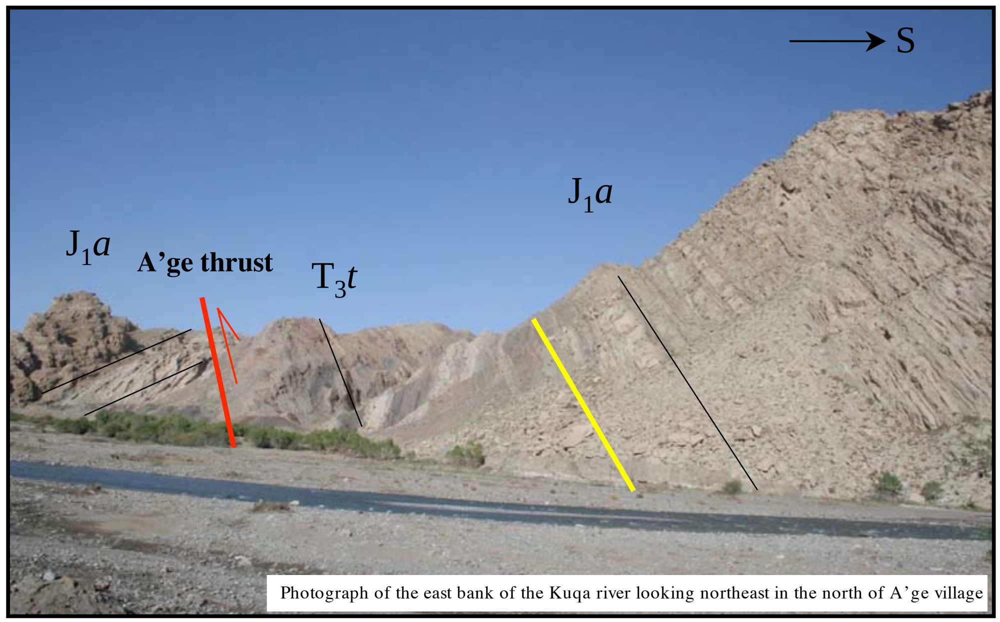
Stop 3 Lithology of Upper Jurassic and Lower Triassic and A'ge Thrust Fault



Photograph of the west bank of the Kuqa river looking northwest in the north of A'ge village

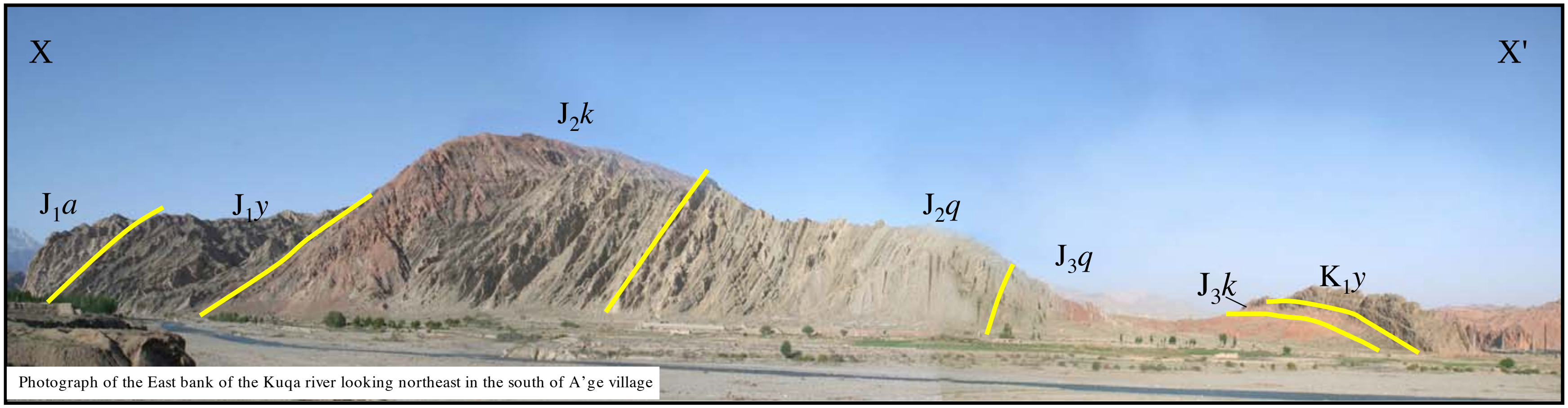
Stratigraphic Column

Strata: Era	Strata: System	Strata: Series	Strata: Group (Formation)	Lithology	thickness	Seismic Strata	Age (Ma)
Mesozoic	Jurassic	M.Jurassic	Qiakemake Fm. (J_2q)		60-150		
			Kezilenuer Fm. (J_2k)		400-800		
		L.Jurassic	Yangxia Fm. (J_1y)		450-600		
			Ahe Fm. (J_1a)		90-400	T_{83}	208
	Triassic	U.Triassic	Taliqike Fm. (T_3t)		200		
			Huangshanjie Fm. (T_3h)		80-850		
		M.Triassic	Kelamayi Fm. (T_2k)		400-550		



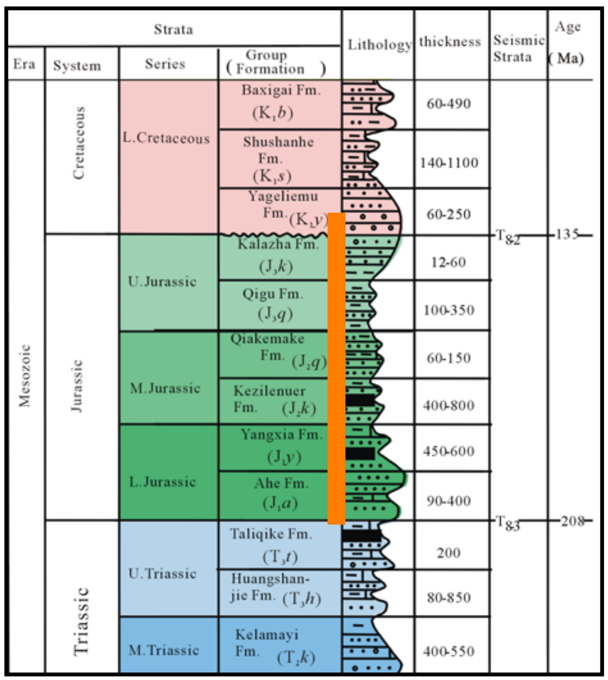
Photograph of the east bank of the Kuqa river looking northeast in the north of A'ge village

Stop 4 Jurassic Strata



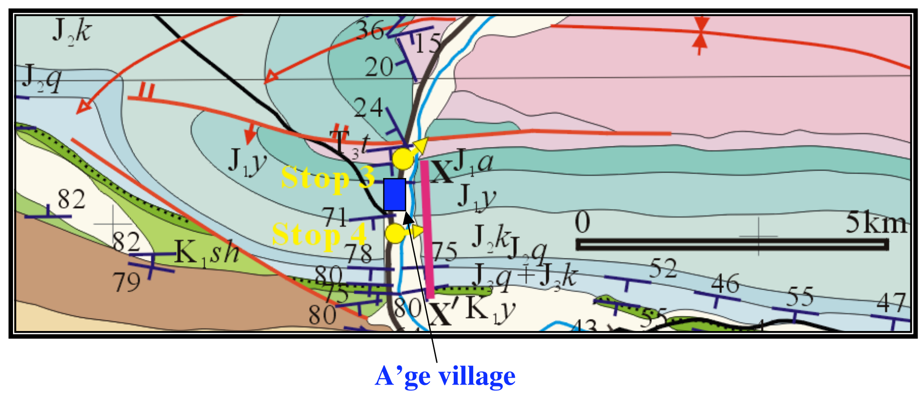
Photograph of the East bank of the Kuqa river looking northeast in the south of A'ge village

Stratigraphic column

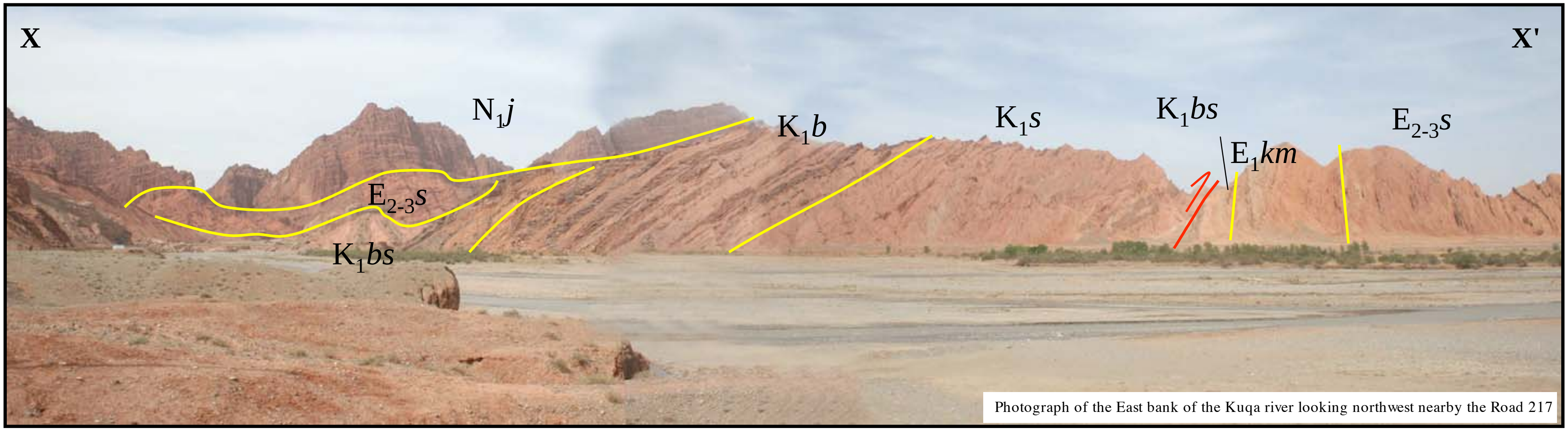


Sketch the geology of this outcrop along section X-X', showing Jurassic stratigraphic contacts.

Stop3 & Stop 4 location map



Stop 5 Bashijiqike Anticline



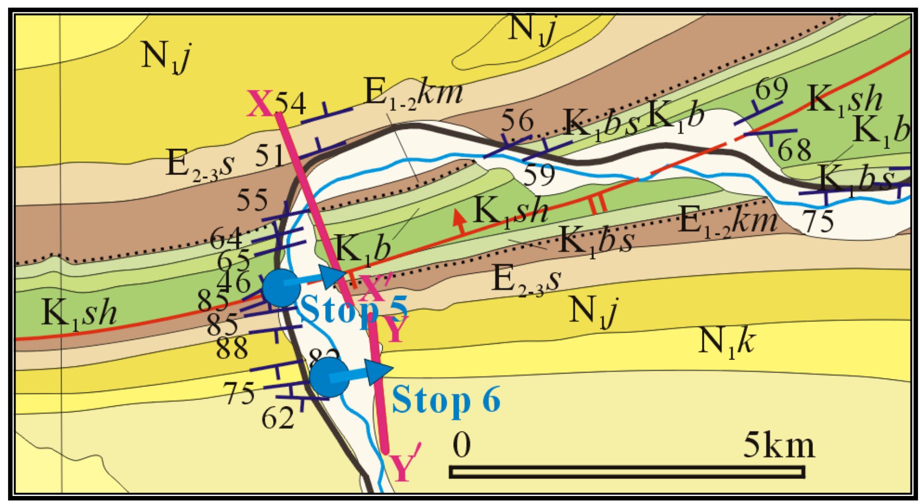
Photograph of the East bank of the Kuqa river looking northwest nearby the Road 217

Sketch of the geology of this outcrop along section X-X', showing the Bashijiqike anticline.

Stratigraphic column

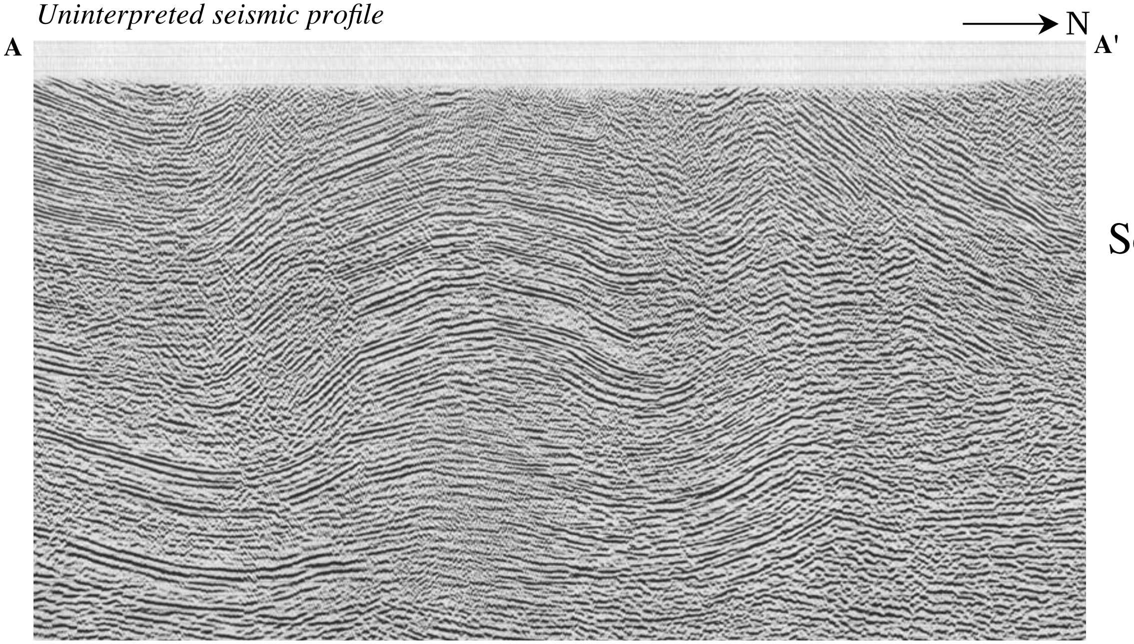
Strata: System	Series	Group (Formation)	Lithology	thickness	Seismic Strata	Age (Ma)
Neogene	Miocene	Kangcun Fm. (N_1k)		650-1600	T3 / T5	5.2
		Jidike Fm. (N_1j)		200-1300	T6	23.3
Paleogeue	Oligocene | Paleocene	Suweiyi Fm. ($E_{2-3}s$)		150-600	T7	
		Kumugeliemu Group ($E_{1-2}km$)		110-3000	T8	65 (97)
Cretaceous	L.Cretaceous	Bashijiqike Fm. (K_1bs)		100-360		
		Baxigai Fm. (K_1b)		60-490		
		Shushanhe Fm. (K_1s)		140-1100		

Stop 5 & Stop 6 location map



Stop 5 Bashijiqike Anticline

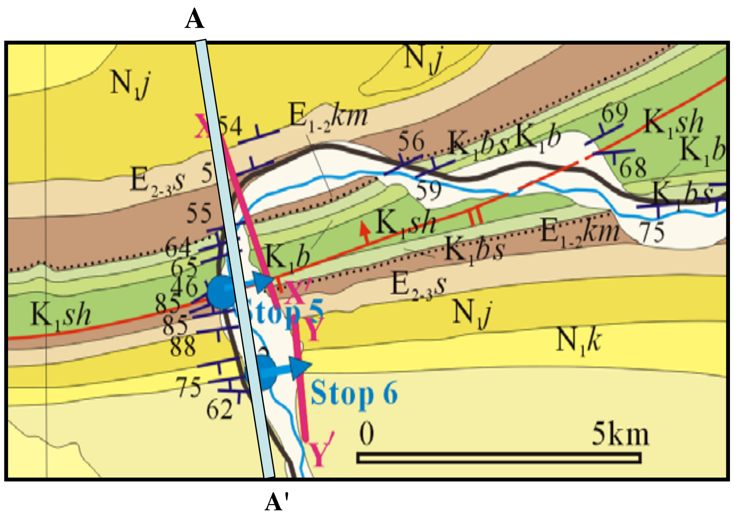
Uninterpreted seismic profile

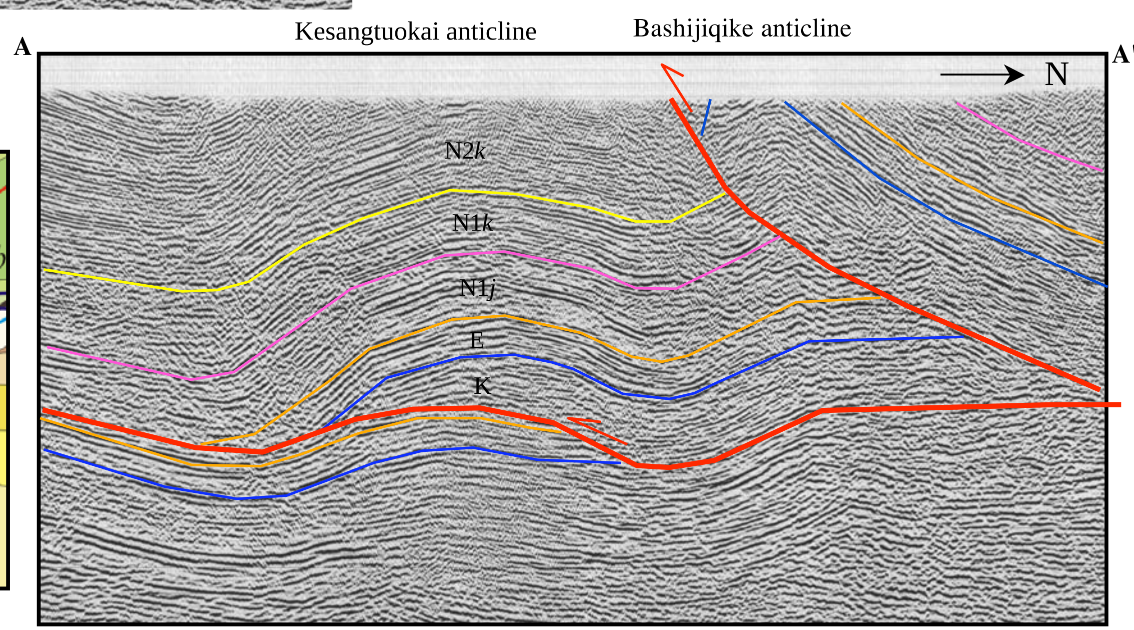


Seismic line AA' crossing the Bashijiqike anticline and Jidike anticline

N_2k-Pliocene Kuche formation
N_1k-Miocene Kangcun formation
N_1j-Miocene Jidike formation
E-Lower Tertiary
K-Cretaceous

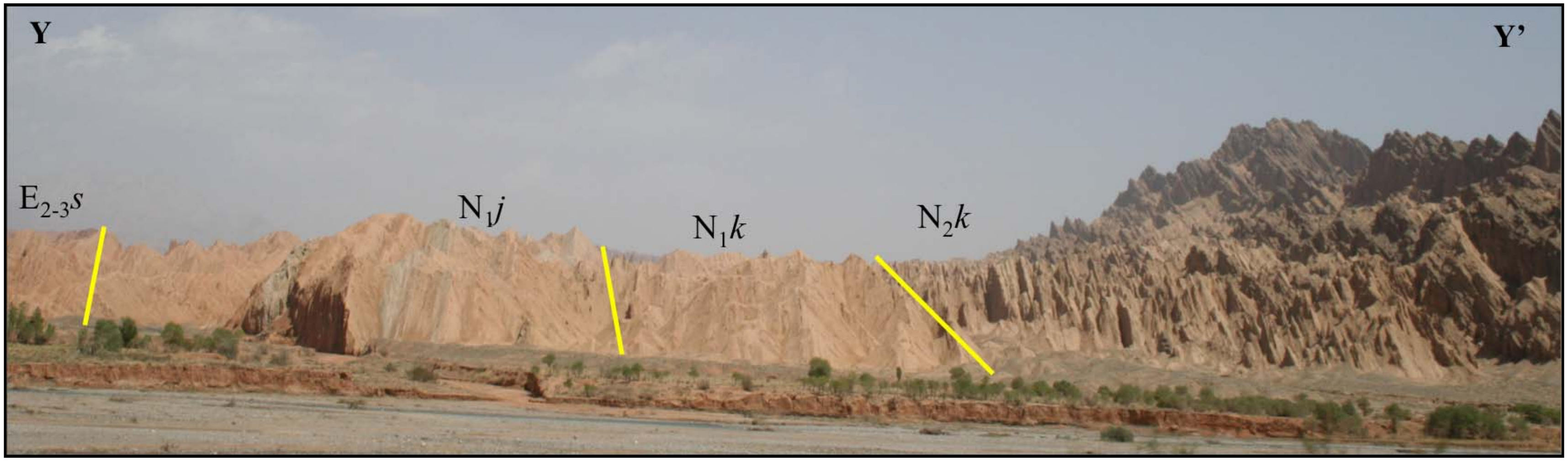
Stop 5 & Stop 6 location map





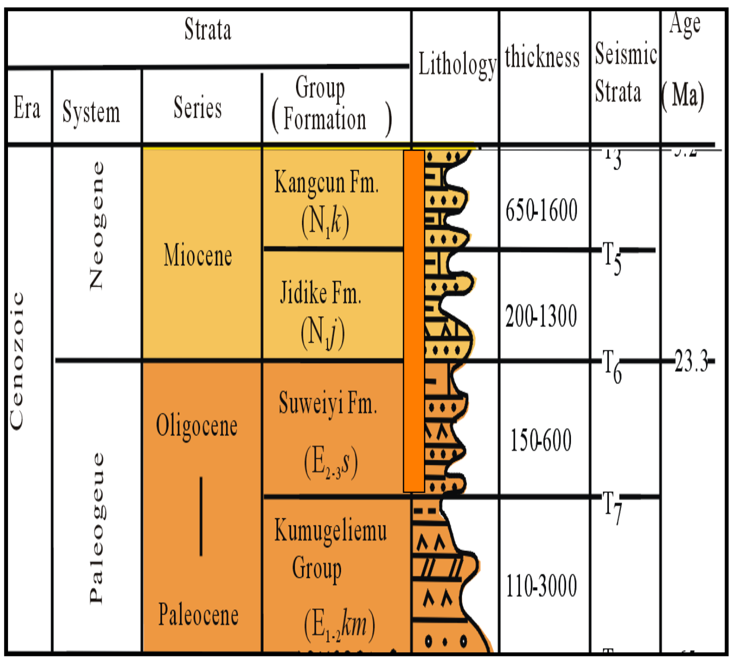
（Seismic data are provided by Tarim Oilfield Company ）

Stop 6 Miocene and Pliocene Strata

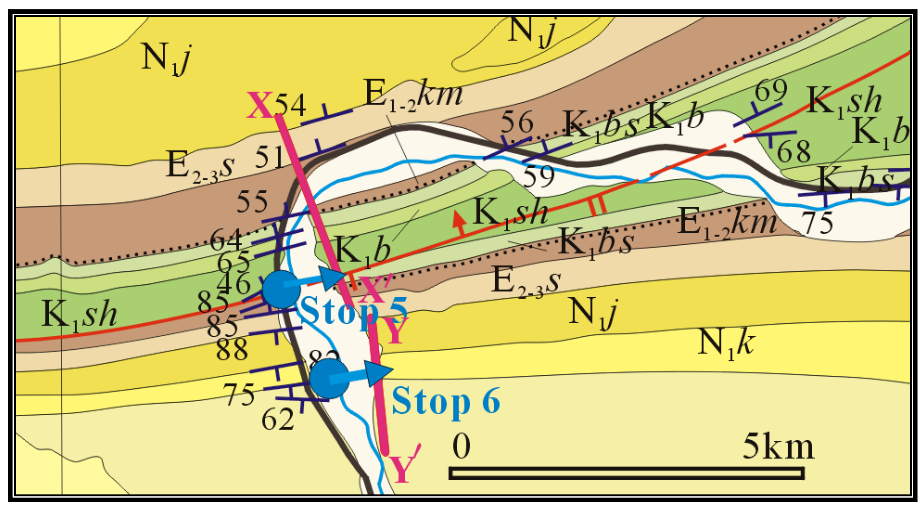


Photograph of the East bank of the Kuqa river, looking east at the 217 highway

Stratigraphic column

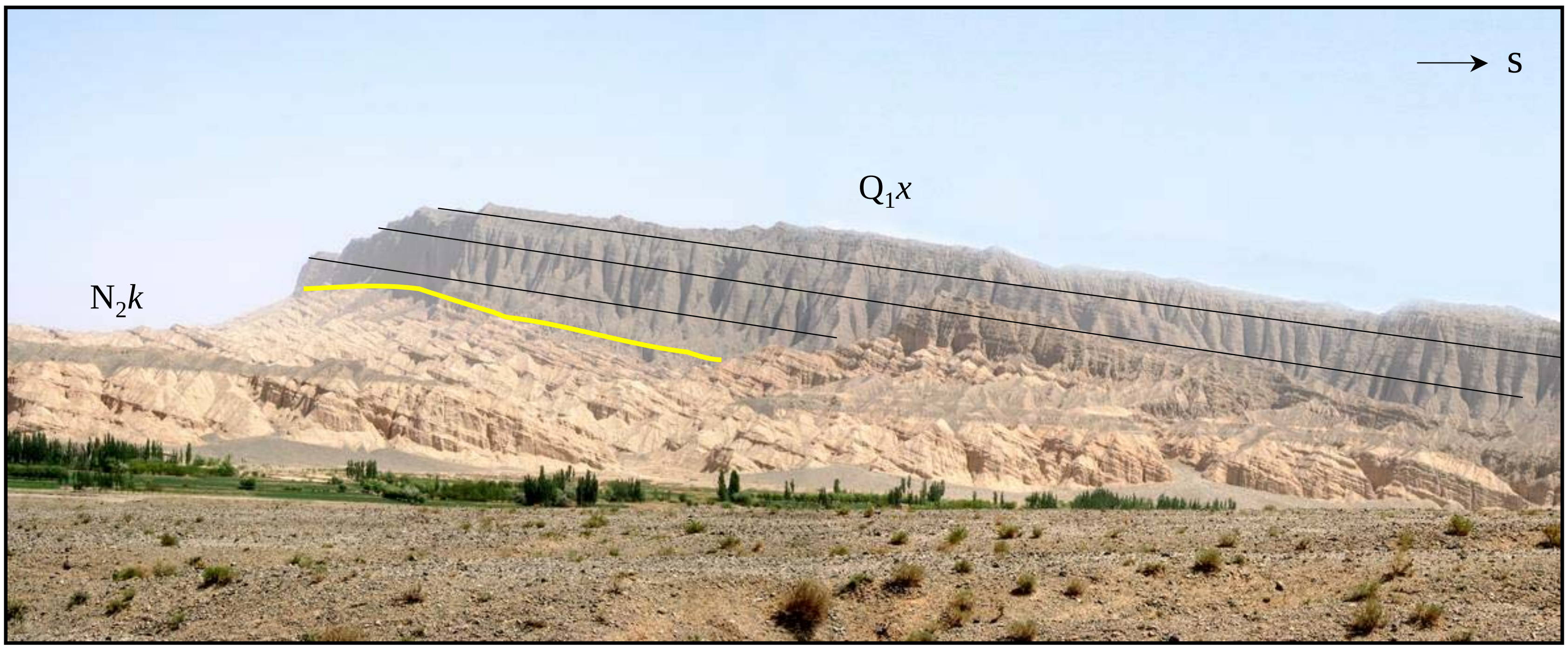


Stop 5 & Stop 6 location map



Stop 7 Jidike Anticline

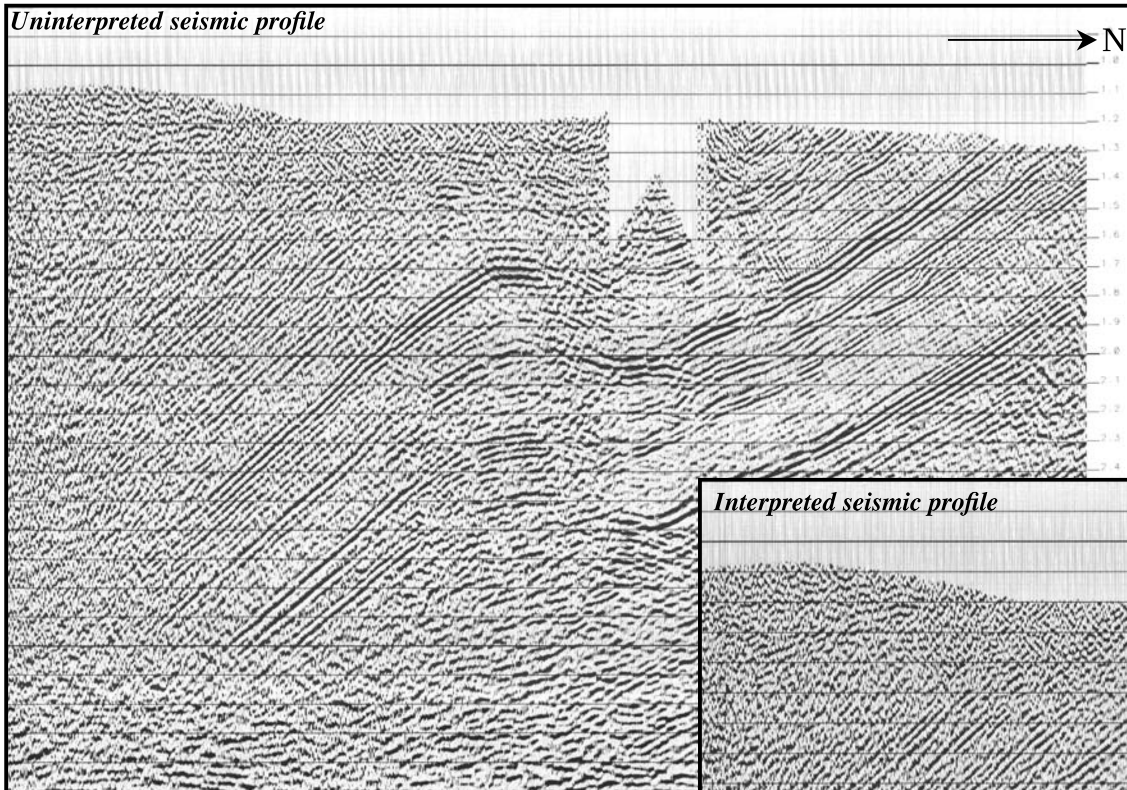
Photograph of the east bank of the Kuqa river looking east at the 217 highway. The core and the limbs of Jidike anticline are composed of Pliocene Kuqa formation.

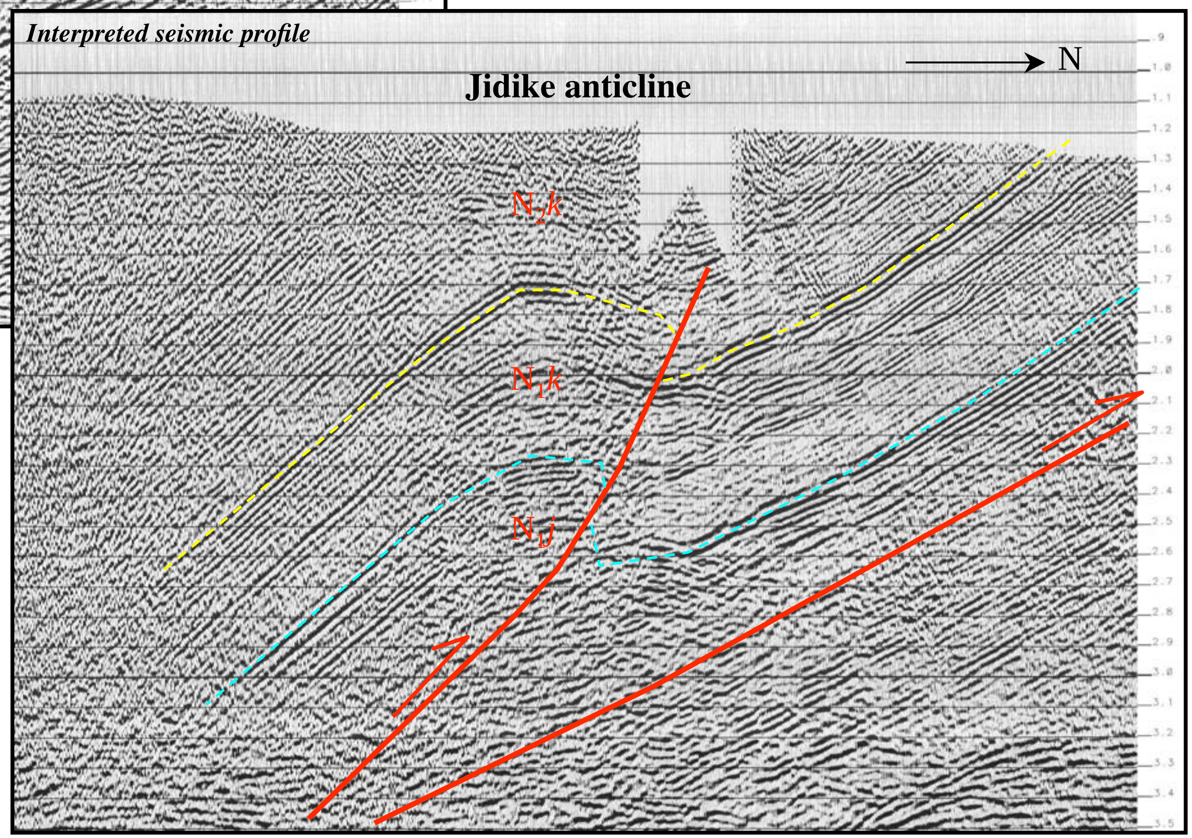


Photograph of the east bank of the Kuqa river, looking east at the 217 highway. Growth strata of the early Pleistocene Xiyu formation was deposited on the south limb of Jidike anticline. Thickness of the Xiyu formation increased southward, and fanning upward

Stop 7 Jidike Anticline

Seismic line crossing Jidike anticline located near the east line of the Landsat imagery of the Kuqa Foreland Basin.

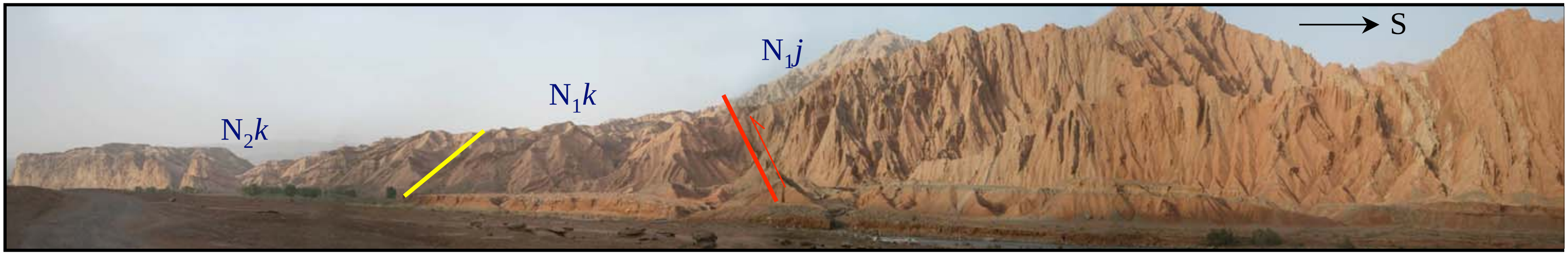




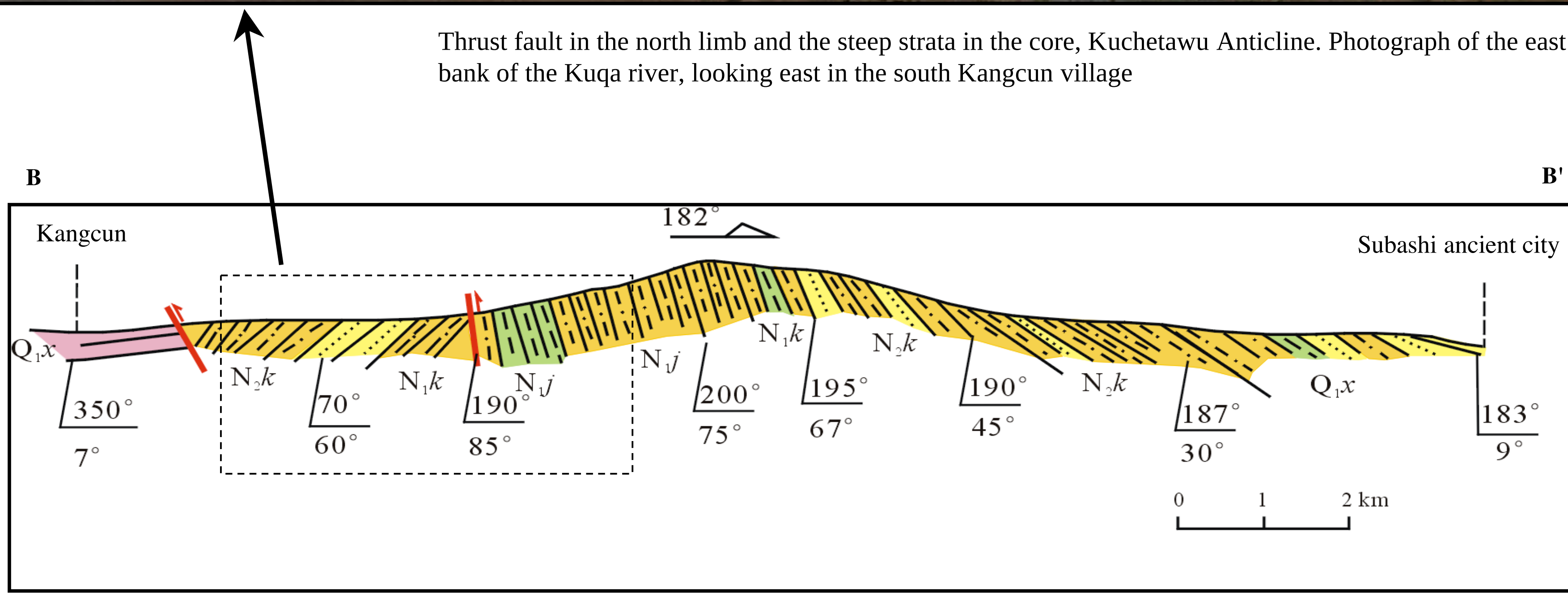
（Seismic data are provided by Tarim Oilfield Company ）

N_2k-Pliocene Kuche formation
N_1k-Miocene Kangcun formation
N_1j-Miocene Jidike formation

Stop 8 Kuchetawu Anticline



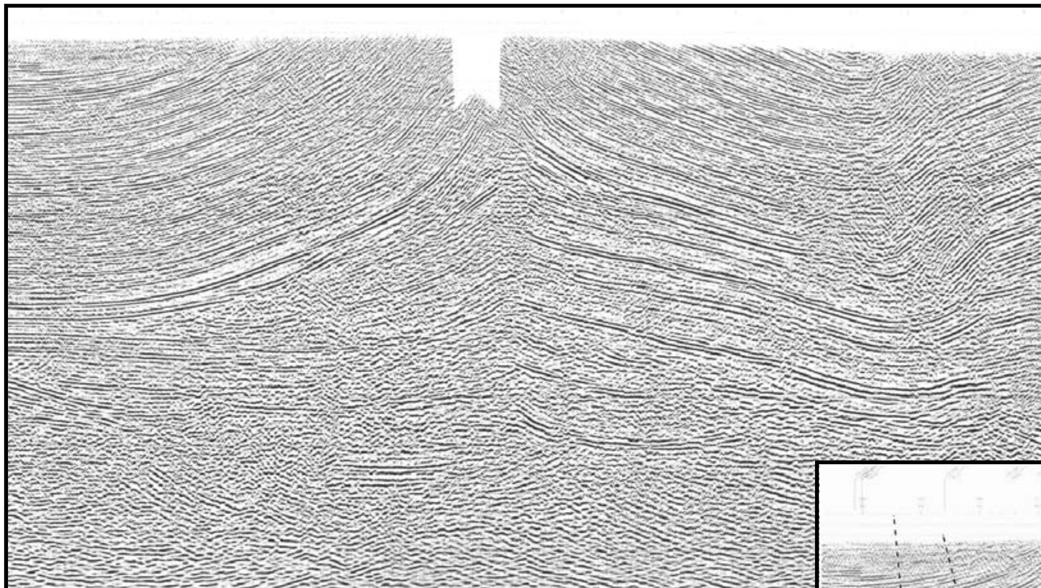
Thrust fault in the north limb and the steep strata in the core, Kuchetawu Anticline. Photograph of the east bank of the Kuqa river, looking east in the south Kangcun village



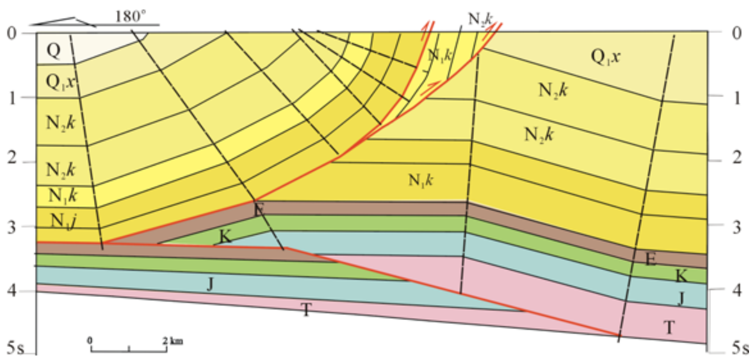
Geological profile of the Kuchetawu anticline along Kuqa river (After Yang et al., 2003). The location can be found in ETM remote sensing imagary of the Kuqa Foreland Basin.

Stop 8 Kuchetawu Anticline

Uninterpreted seismic profile



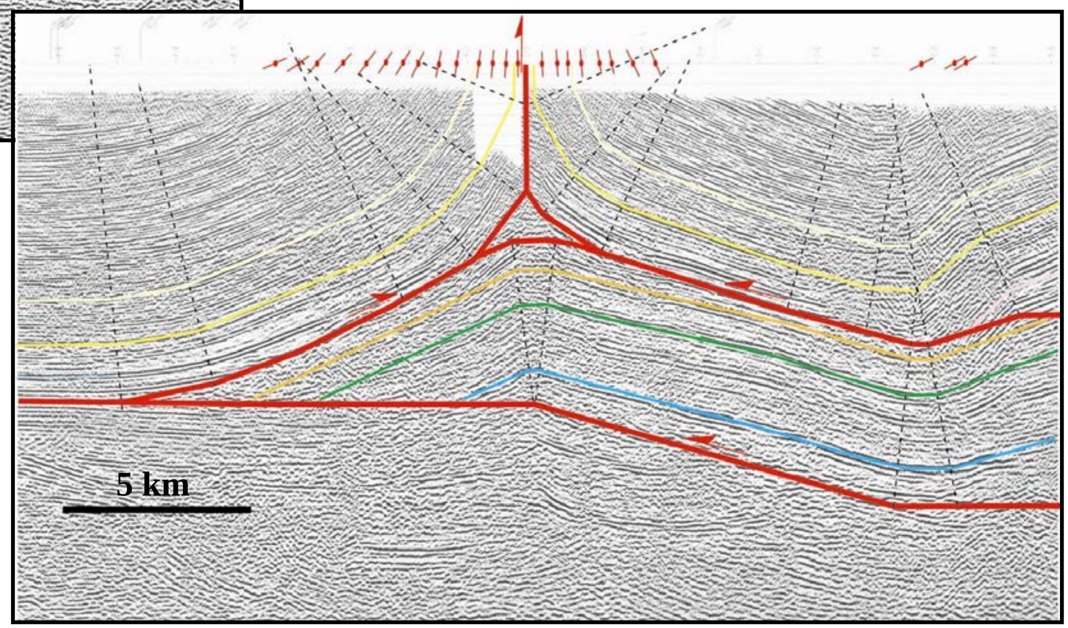
（Seismic data are provided by Tarim Oilfield Company ）



Interpretation of seismic line crossing Kuchetawu Anticline
(After Yang et al., 2003)

Interpreted seismic line crossing
Kuchetawu Anticline

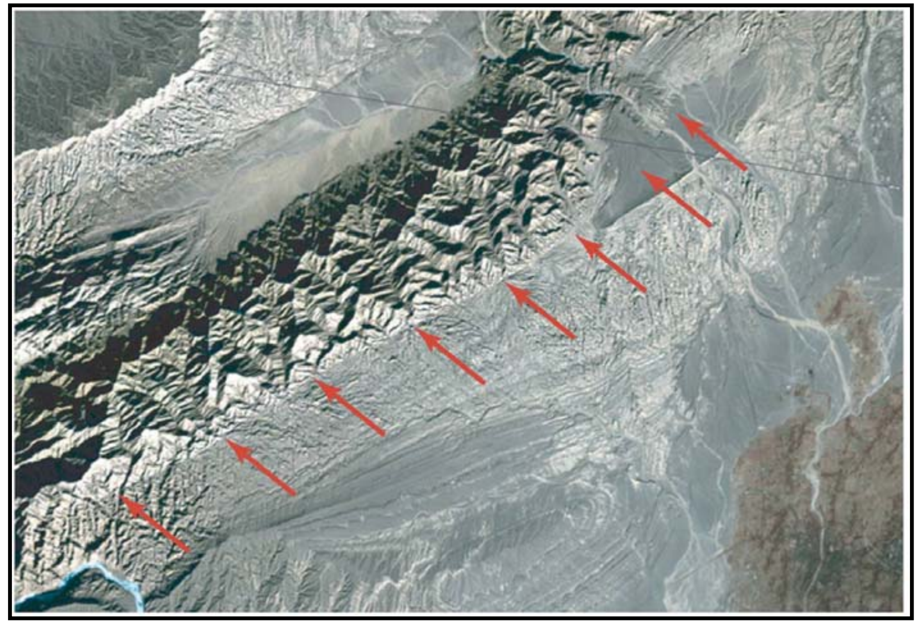
Interpreted seismic profile

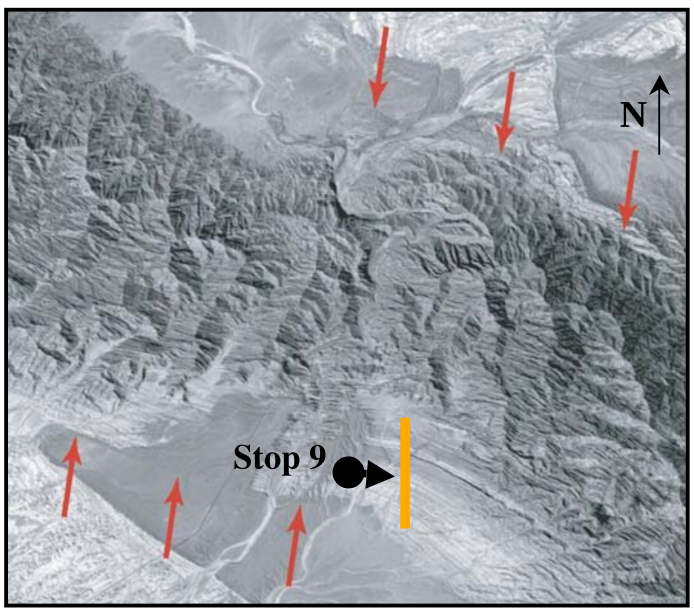


(After Wang et al., 2002)

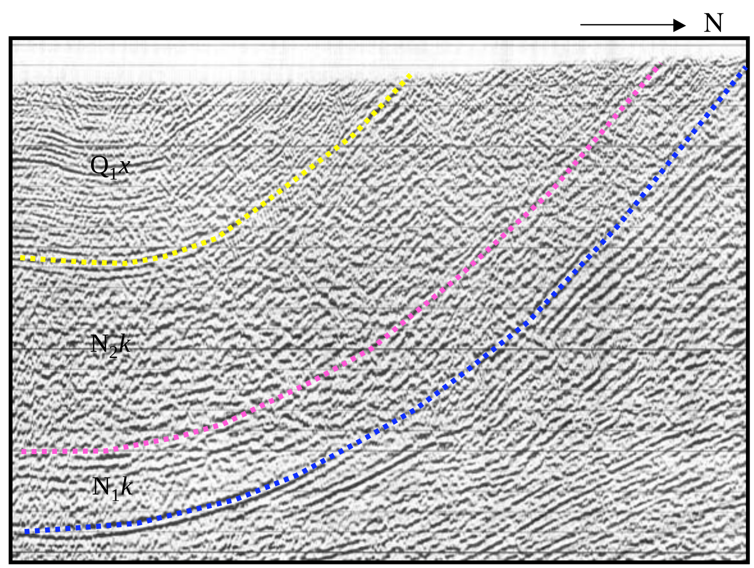
Stop 9 Growth strata & fold scarps formation in the south limb of Kuchetawu Anticline

The locus of active folding along the north and south limbs of the Kuchetawu (Quilitak) Anticlne is shown by red arrows, which mark a line of fold scarps. The synclinal active axial surfaces form the boundary between shallow dips of the flanks of Quilitak and steep dips that generally marks the edge of steep topography that characterizes the core of the anticline.
Stop 9 is in a more depositional environment where gravels of the Xiyu Formation overlie the steeply dipping sandstones of Kuche Formation and record the continued and progressive folding by kink-band migration and fold-scarp formation.
In less depositonal locations the fold scarps have grown to become >500m high and show characteristic triangular facets recording progressive folding.





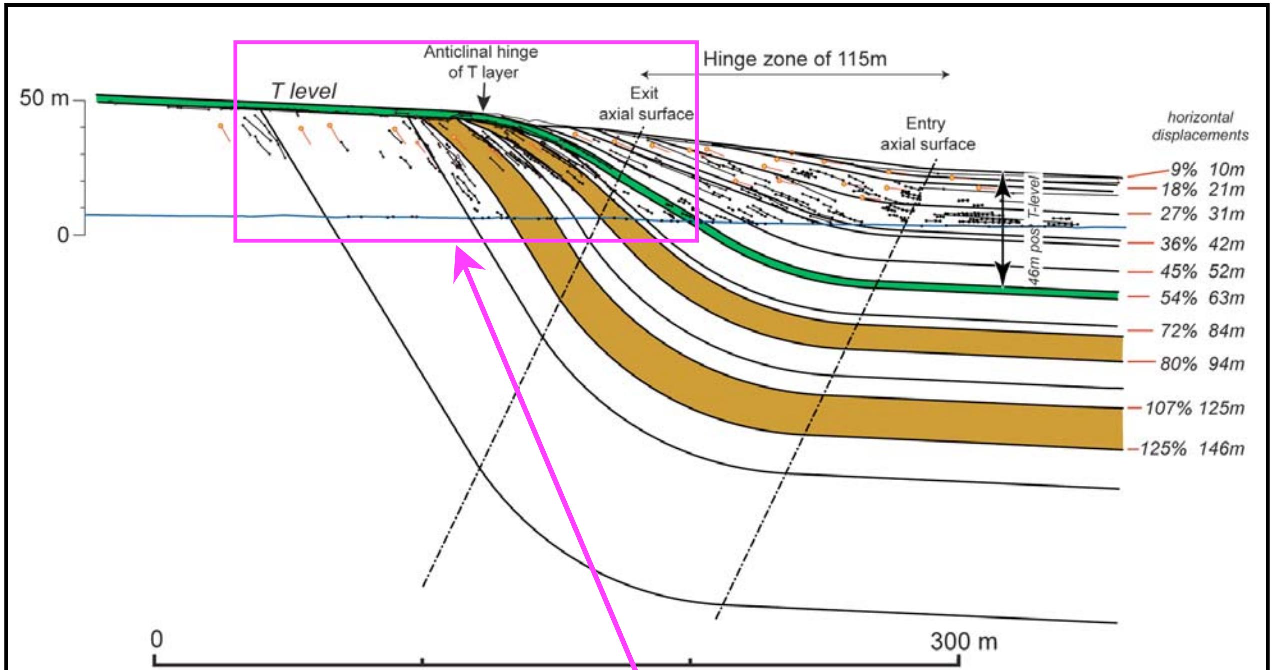
Fold scarps on the southern flanks of west Qiulitake anticline (After Hubert-Ferrari & Suppe)



Q_1x-Pleistocene Xiyu Formation
N_2k-Pliocene Kuche Formation
N_1k-Miocene Kangcun Formation

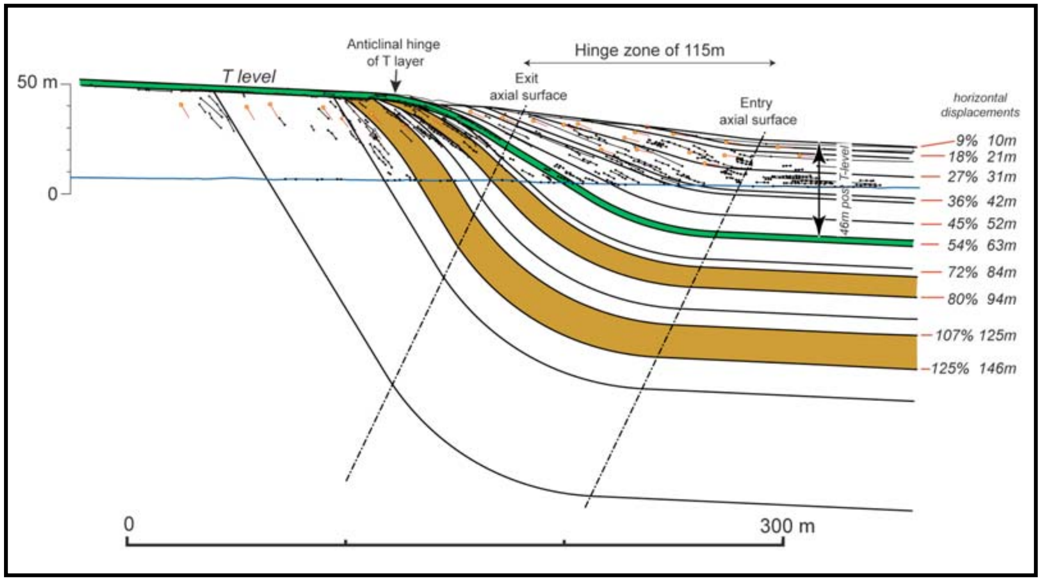
Seismic line crossing the south limb of Kuchetawu Anticlne

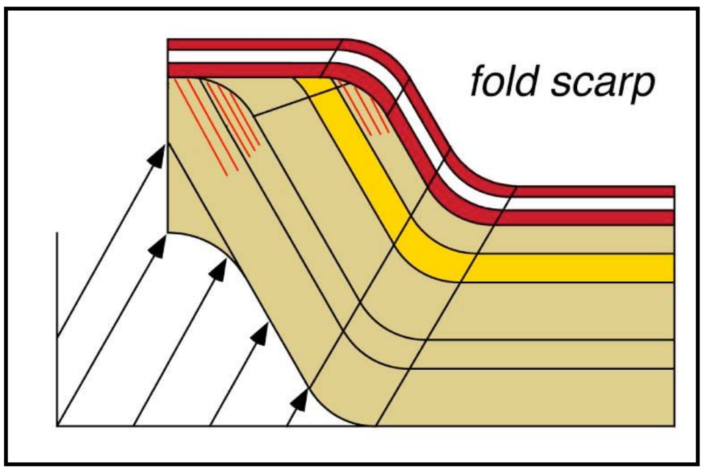
Stop 9 Growth strata & fold scarp formation in the south limb of Kuchetawu Anticline

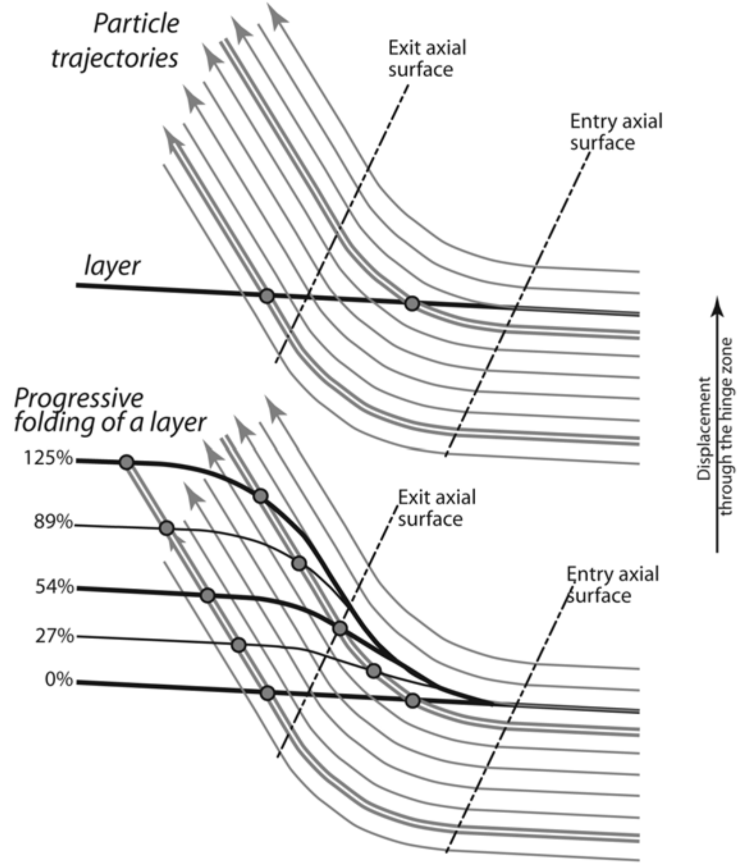


(After Hubert-Ferrari & Suppe, 2005)

Stop 9 Growth strata & fold scarp formation in the south limb of Kuchetawu Anticline

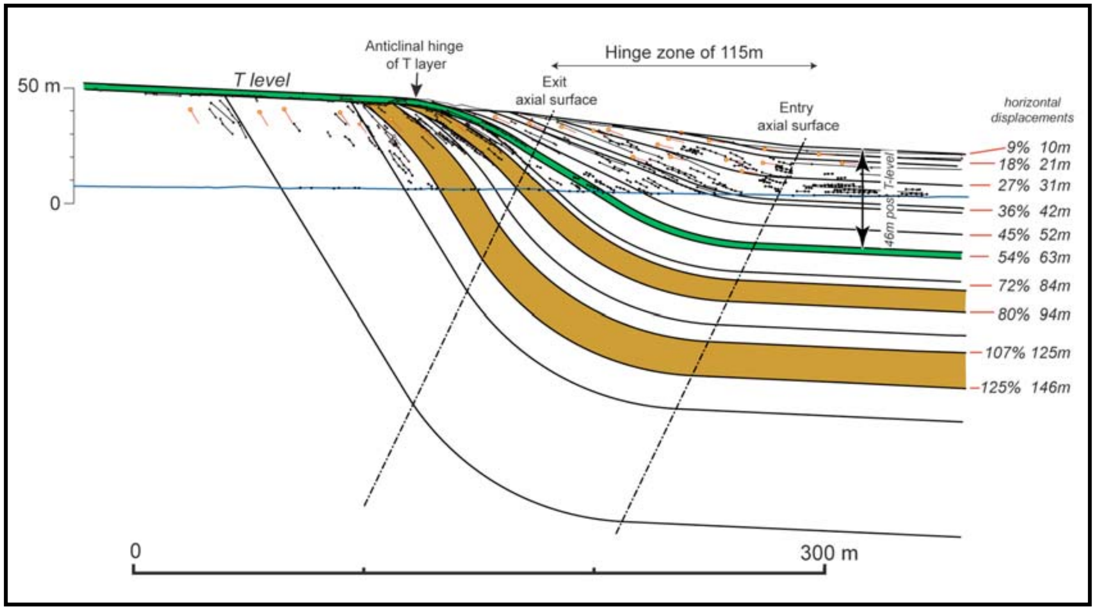


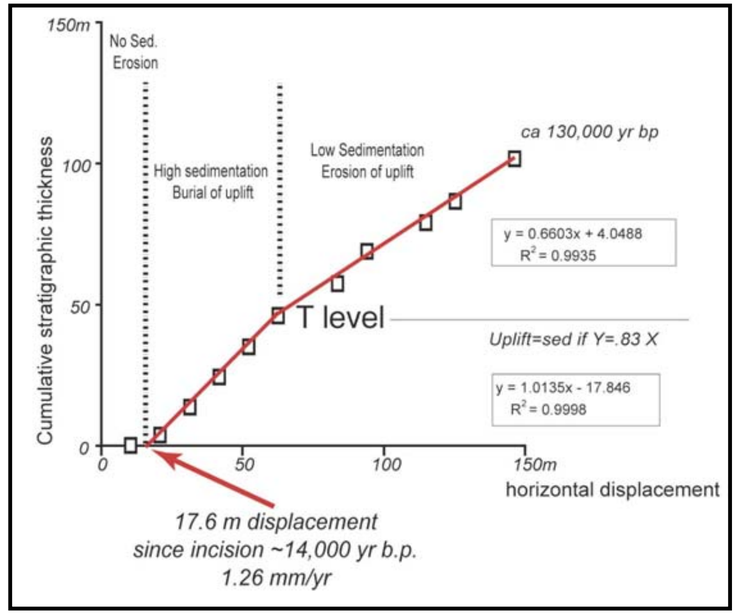




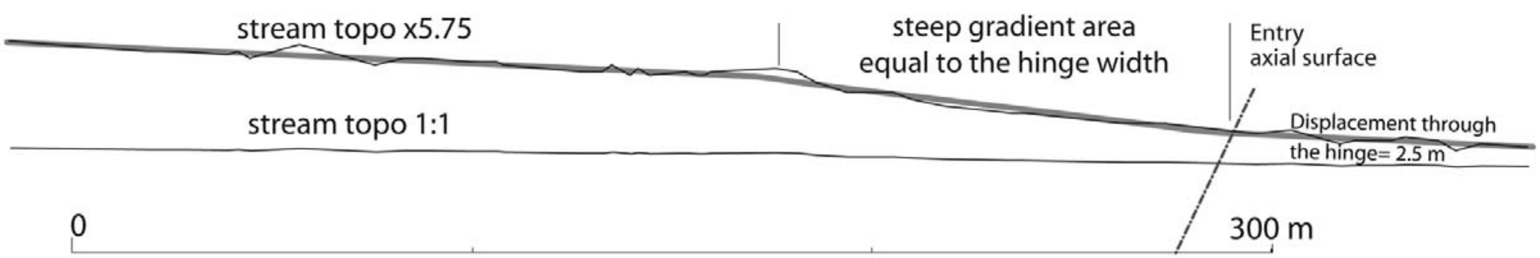
Developing the dimensionless fold-hinge model for the Kuchetawu foldscarp (56° change in dip across hingezone). (Hubert-Ferrari & Suppe, 2005).

Stop 9 Growth strata & fold scarp formation in the south limb of Kuchetawu Anticline





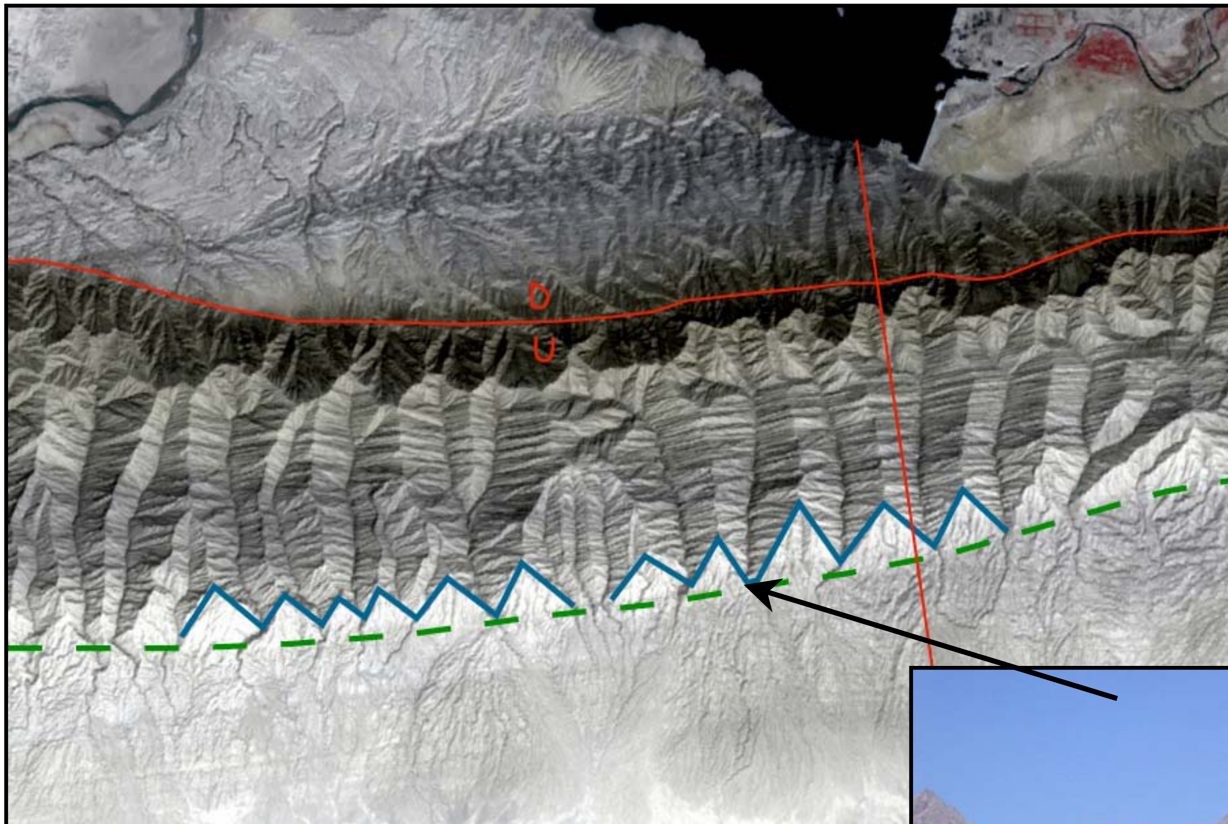
Fitting the dimensionless fold-hinge model to the shape of the continuous "T" layer gives the width of the hinge zone as 115m. Fitting the remaining outcrop data gives an estimate for each mapped bed of the horizontal displacement through the hinge zone. This shows a regular displacement rate relative to sedimentation rate. There is about 18m of displacement since incision, assumed here to be ~14,000 yr b.p.

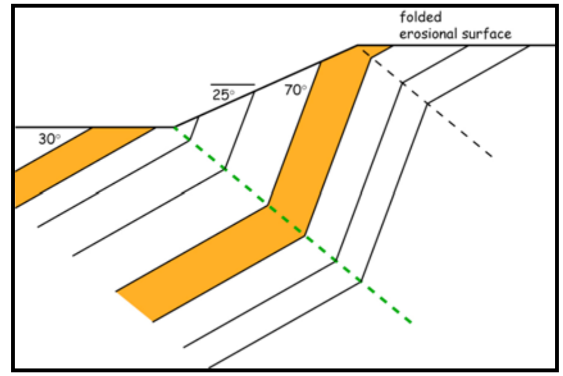


A localized reach of increased stream gradient coincides with 115m wide hinge-zone location. Increased gradient corresponds to 2.5m of horizontal displacement through the hinge zone.

(Hubert-Ferrari & Suppe, 2005).

Stop 9 Triangular fold-scarp facets in the south limb of Kuchetawu Anticline



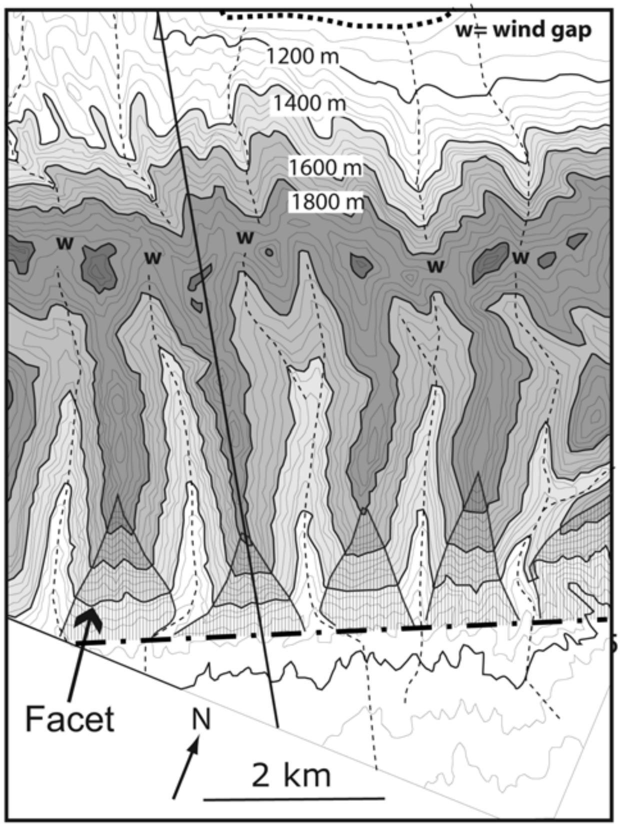


Large-scale folding of the land surface

(After Suppe & Hubert-Ferrari, 2004)

Triangular fold-scarp facets

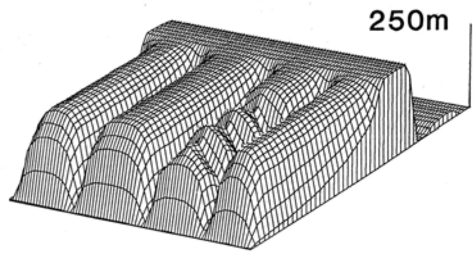
Stop 9 Triangular fold-scarp facets in the south limb of Quilitak Anticline

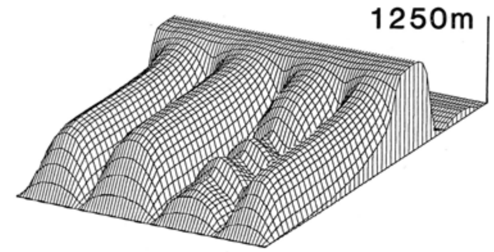


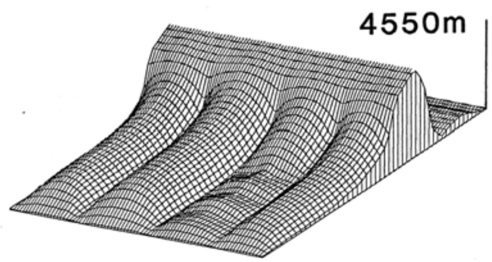
Triangular facets have dips that agree well with the predicted dips from folding.

	initial bedding dip δ_o	folded bedding dip δ	axial surface dip δ_{as}	unconformity dip δ_u	observed facet dip δ_{fo}	computed facet dip δ_f [1]
West Quilitak	26-29°	80°	35-37°	–2°	31°	32-37°
Kuche River East	30°	67°	41-42°	–2°	23°	25°
West Kuchetau W	27°	70°	41-42°	–3°	26°	32°
West Kuchetau E	35°	67°	39°	–3°	19°	20°

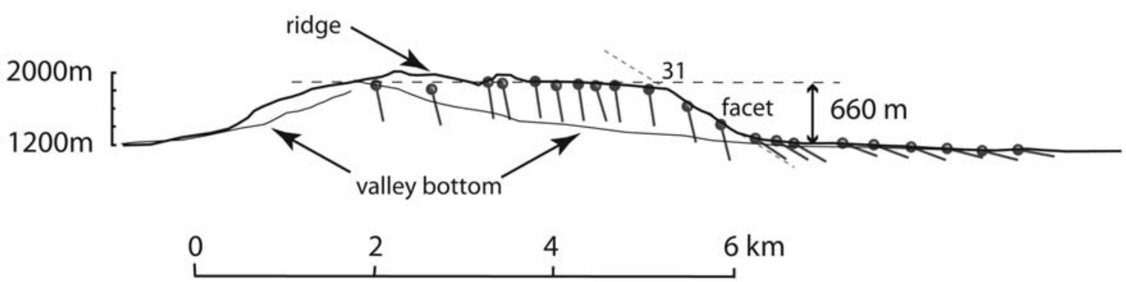
[1] $\cot(\delta_f - \delta_u) = \dfrac{\sin^2\gamma}{\sin 2\gamma \sin^2(\gamma - \delta_o + \delta_u)} - \cot(\gamma - \delta_o + \delta_u)$, where $\gamma = 90° - (\delta - \delta_o)/2$







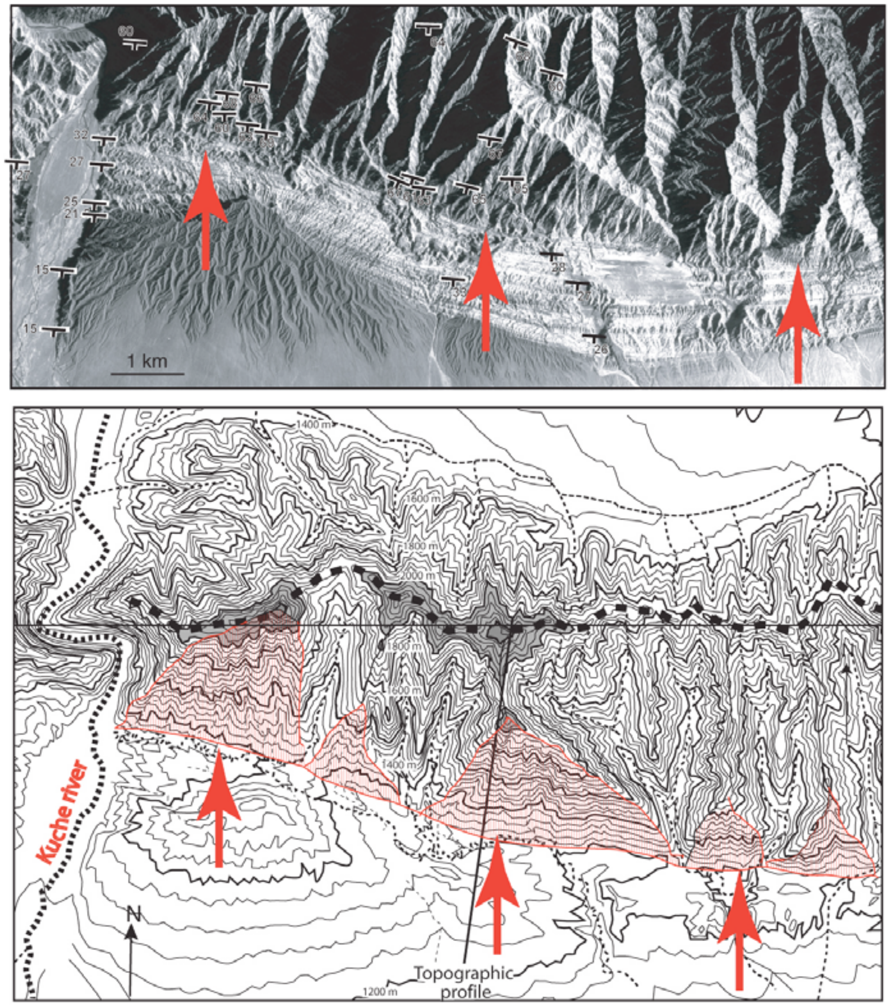
Numerical erosion model for constant uplift with pre-existing drainage (Koons, 1989). The ridge-line profiles approach the stream profiles as memory of the initial flat surface is erased by erosion. Quilitak anticline still preserves a memory of an initially flat erosion surface. This pre-existing surface and drainage is also siggested by the wind gaps, labled "W" on the topographic map.



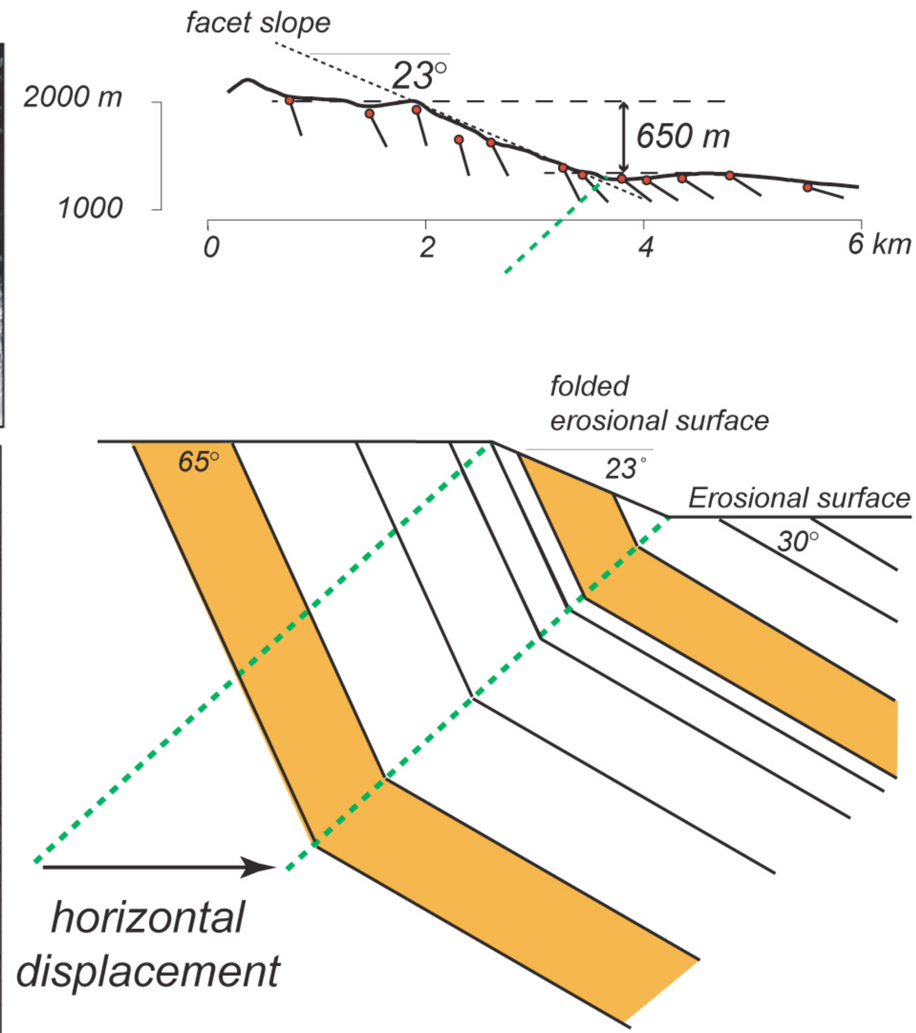
Nearly horizontal ridge lines, in contrast with stream profiles, indicates a disequilibrium topography and a major increase in deformation rate ~0.25-0.5Ma. A similar acceleration is seen in Yakeng anticline (Stop 10).

(After Hubert-Ferrari & Suppe)

Stop 9 Triangular fold scarp facets on the south limb of West Quilitak Anticline

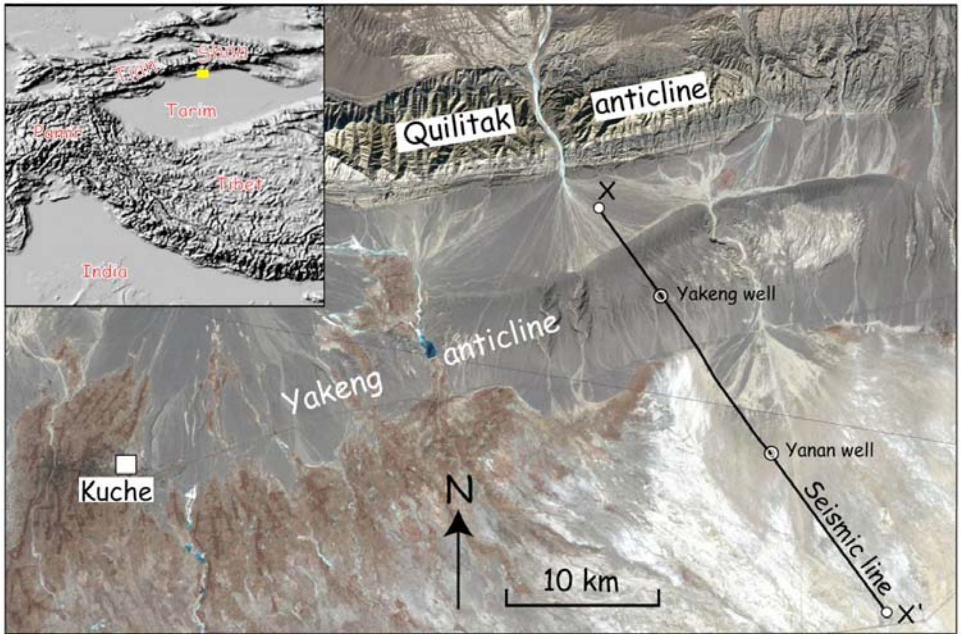


Fold-scarp facets east of Kuqa river



Facets have the predicted dip

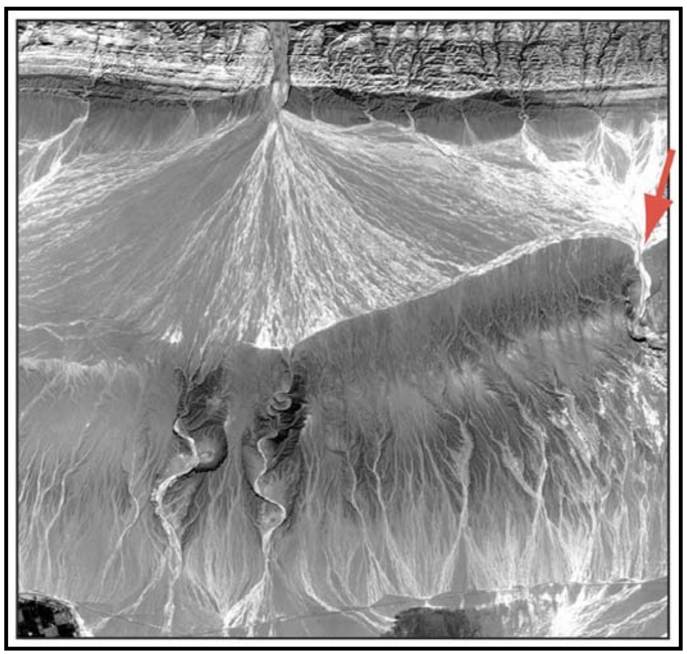
Stop 10 Yakeng Anticline

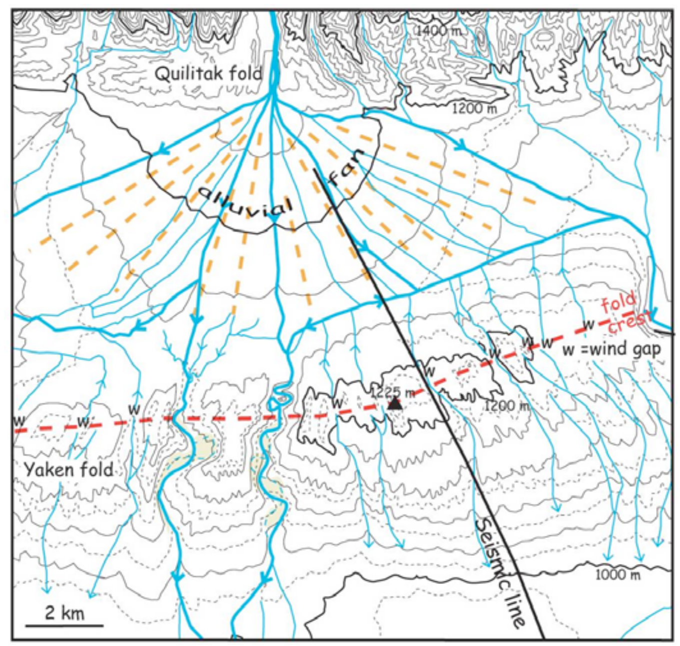


Landsat remote sensing imagery of Quilitak Anticline and Yaken Anticline

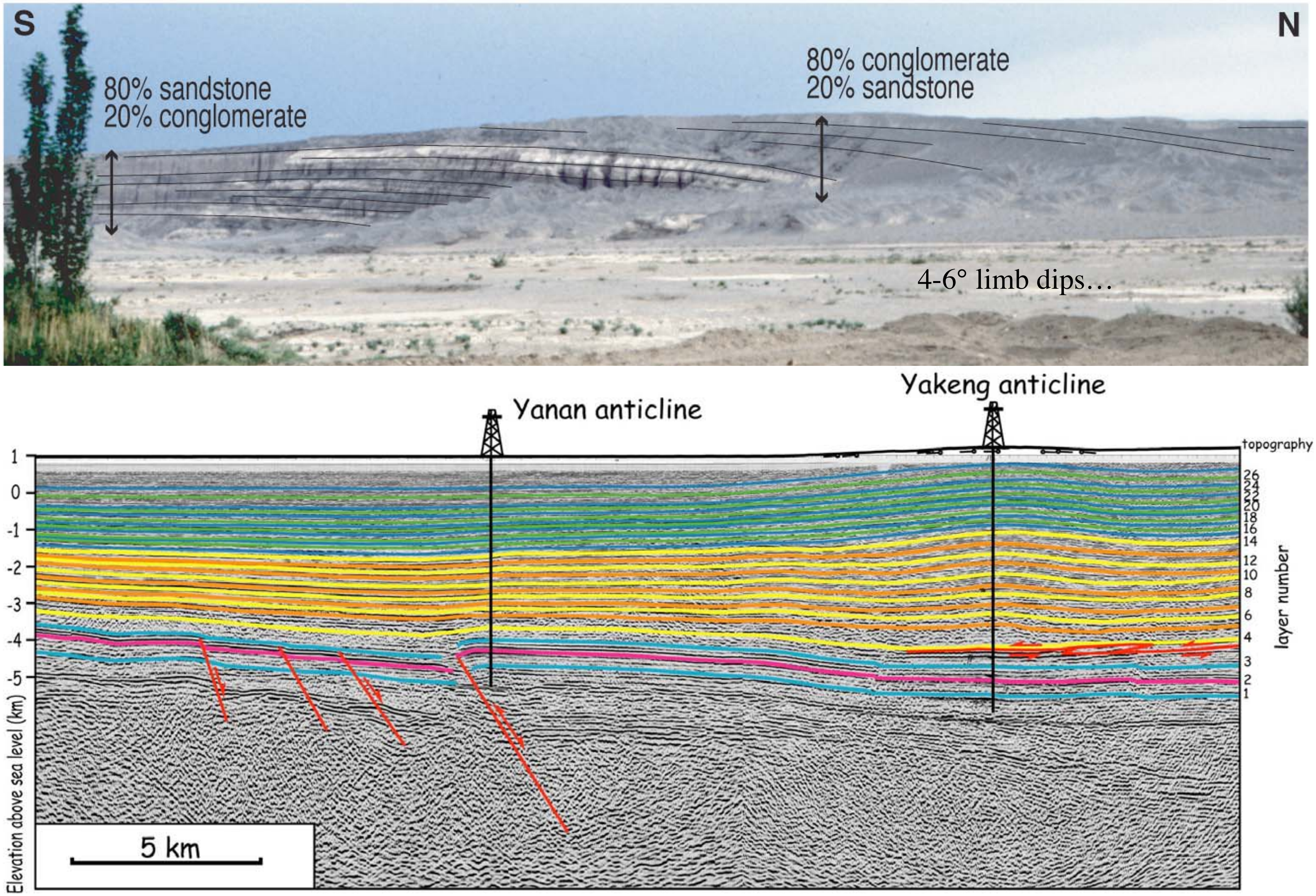
(After Hubert-Ferrari et al. 2005)

Modern aluvial fan and channels of older fan drainage, uplifted by growth of Yakeng anticline. "W" symbols indicate wind gaps in folded channels. Red arrow shows location of photograph on next page.





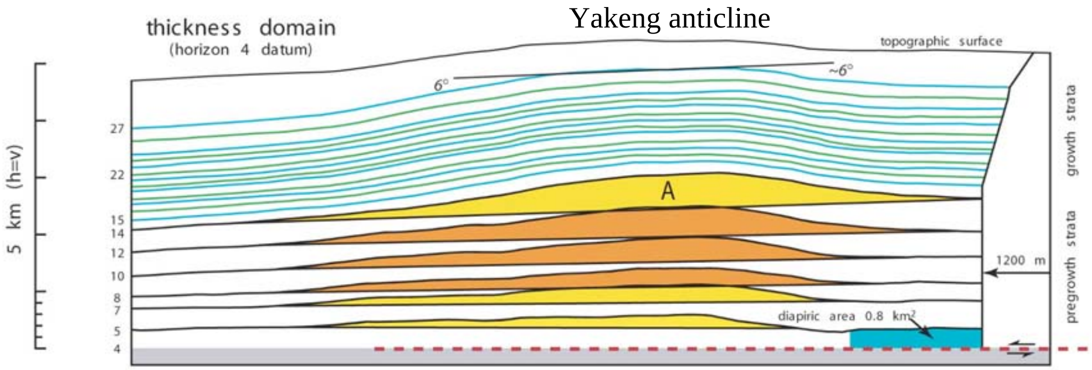
Stop 10 Yakeng Anticline

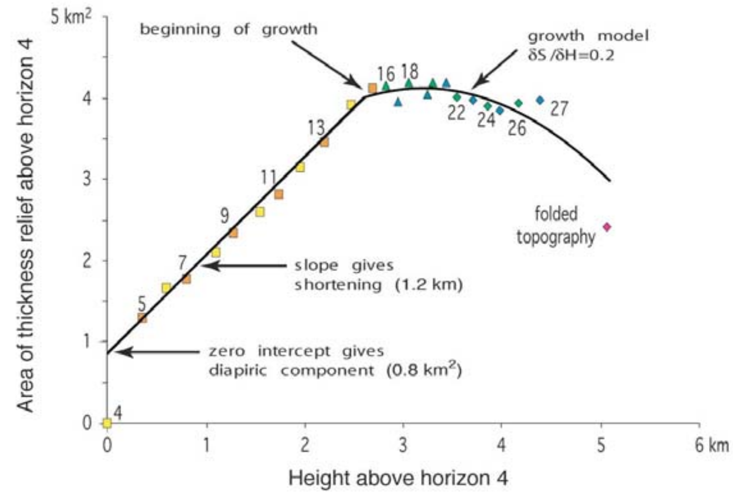


Yanan—a subtle inversion structure; Yakeng—a classic detachment fold

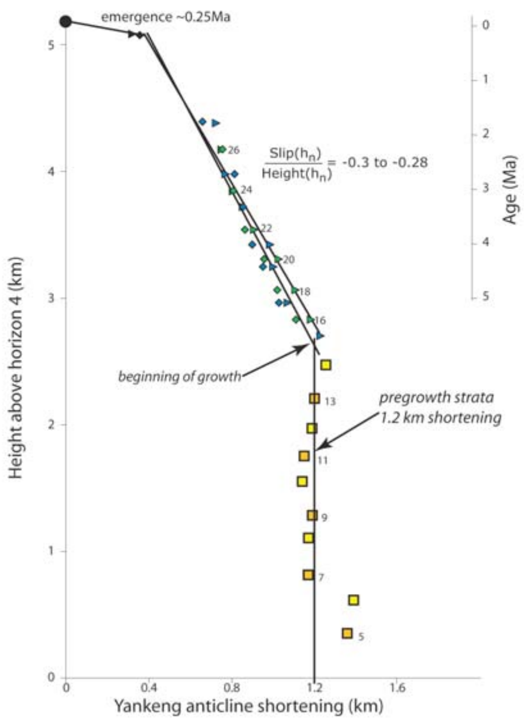
(After Hubert-Ferrari et al. 2005)

Stop 10 Yakeng Anticline

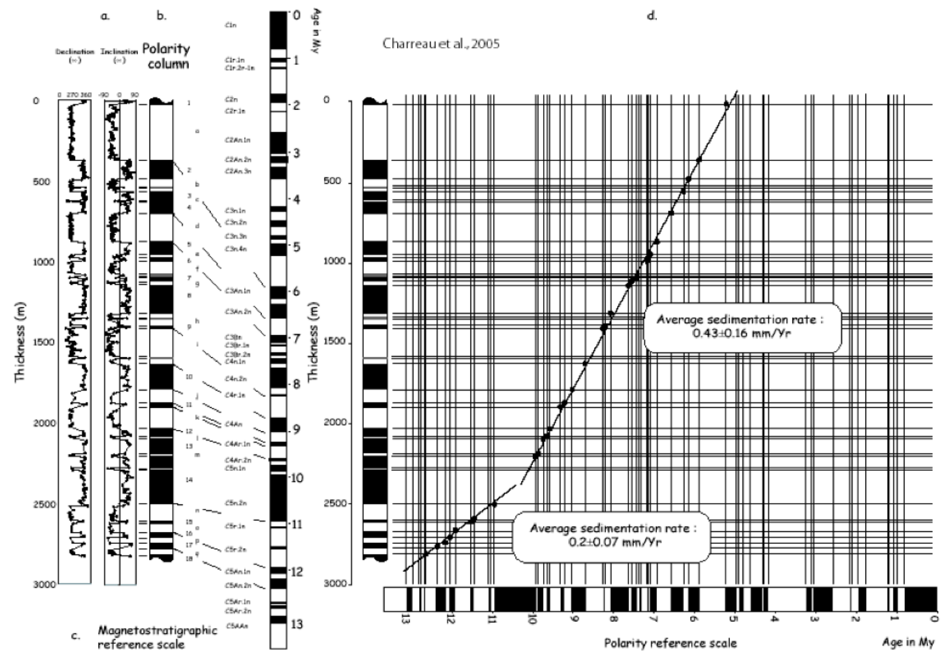




(After Hubert-Ferrari et al. 2005)

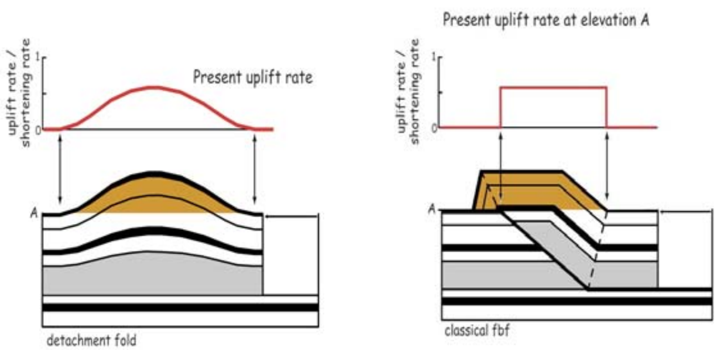


(After Hubert-Ferrari & Suppe,2005)

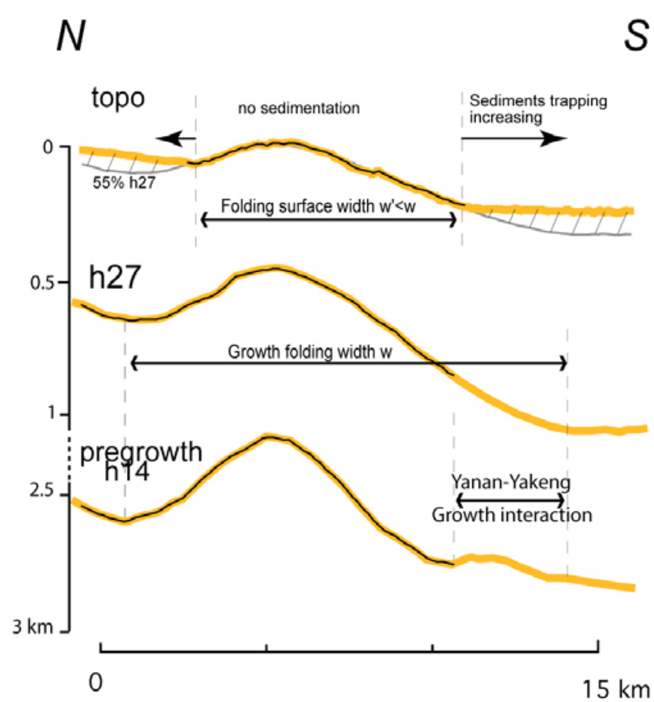


Magnetostratigraphy north limb of Quilitak (After Charreau et al., 2005)

Stop 10 Yakeng Anticline

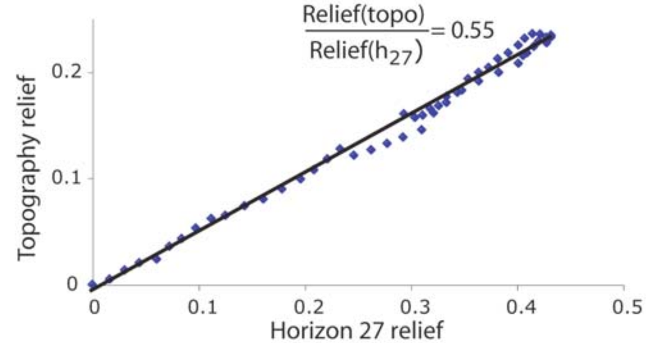


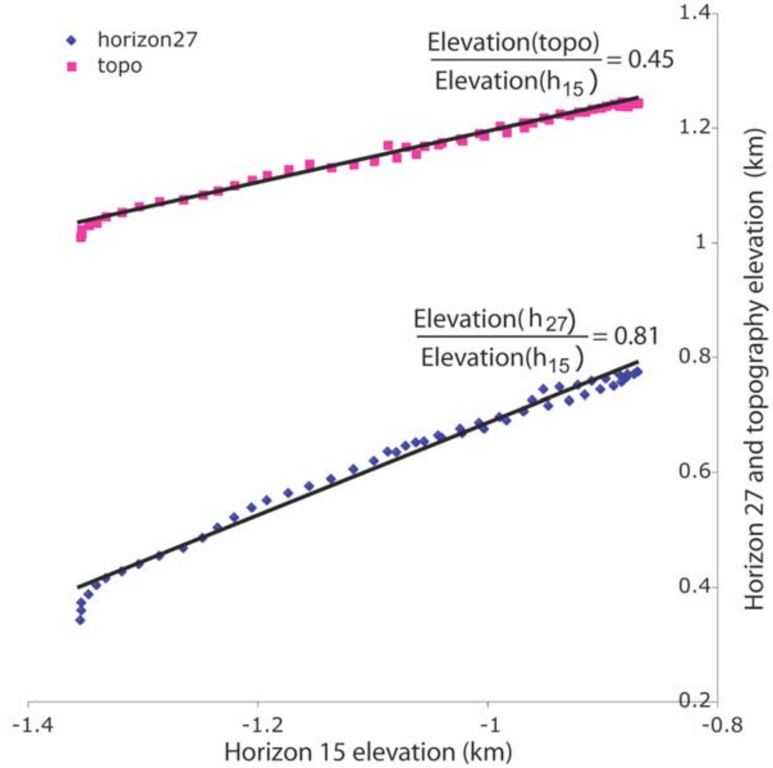
proportional uplift “slug” uplift



Upward decrease in amplitude, Yakeng growth section

Linearly proportional uplift of the Yaken anticline

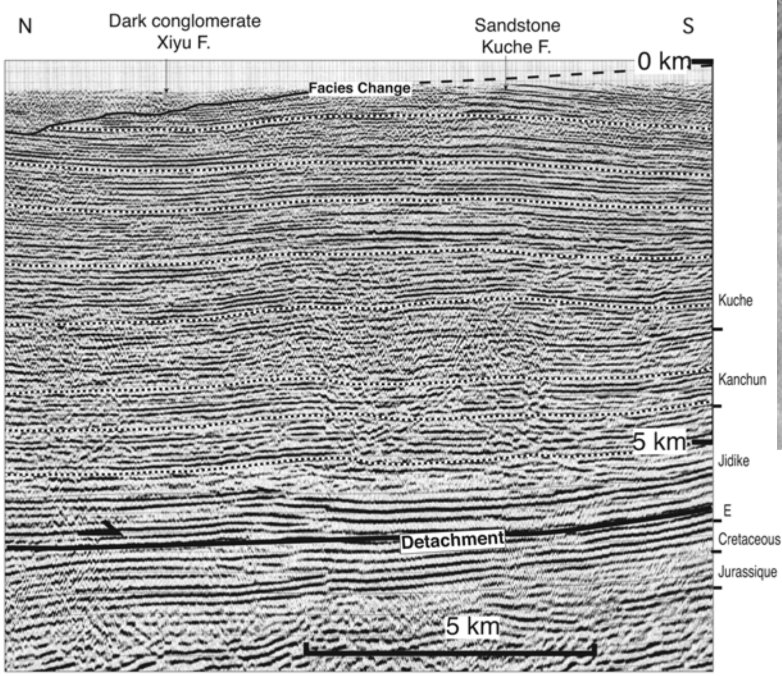




(After Hubert-Ferrari & Suppe,2005)

Stop 10 Yakeng Anticline:
western section near field trip stop

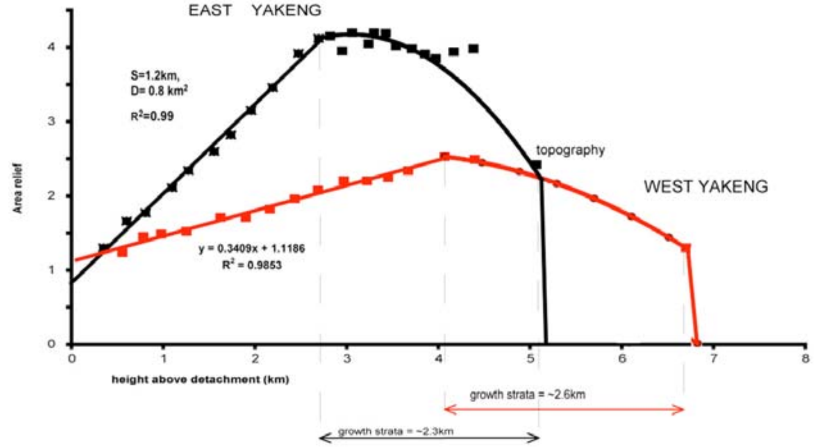
Seismic image Yakeng detachment fold, western section.

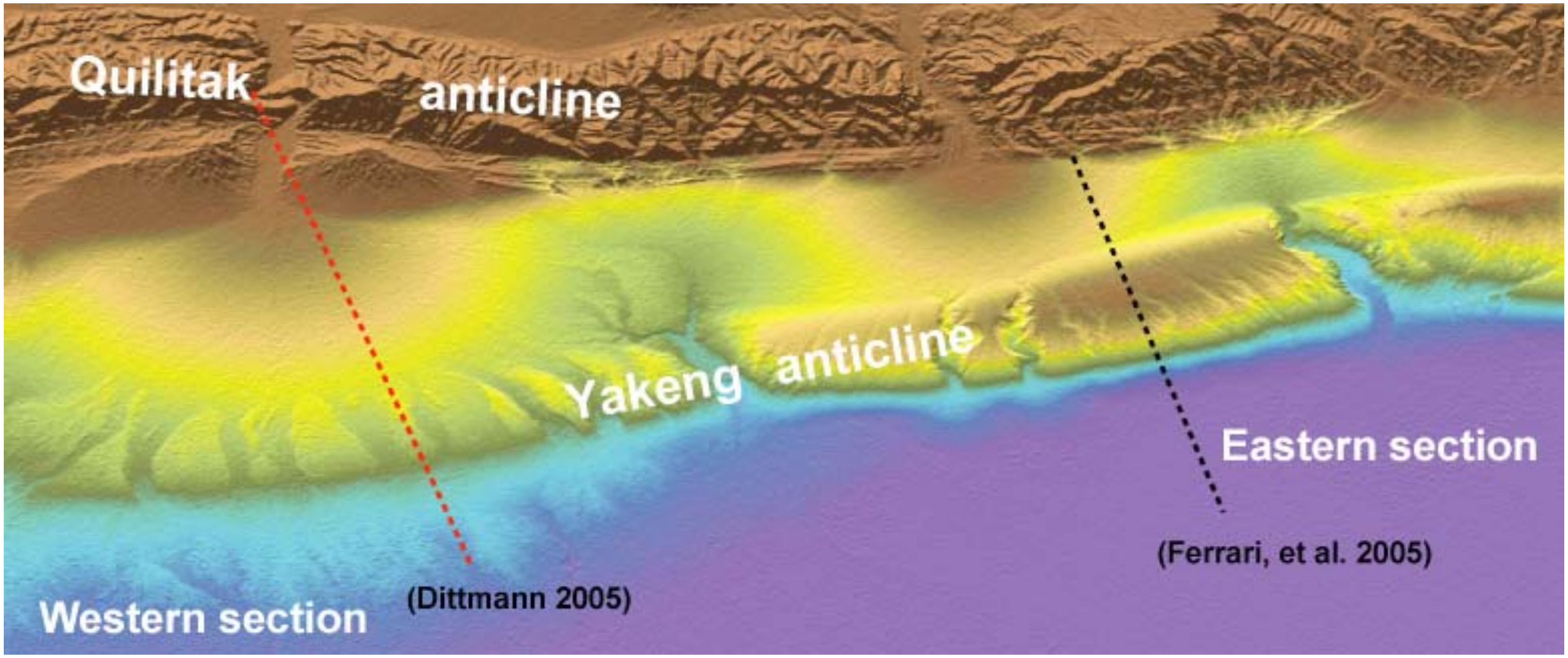


Corona image of Yakeng detachment fold showing progressively folded terraces near field trip stop.

Stop 10 Yakeng Anticline

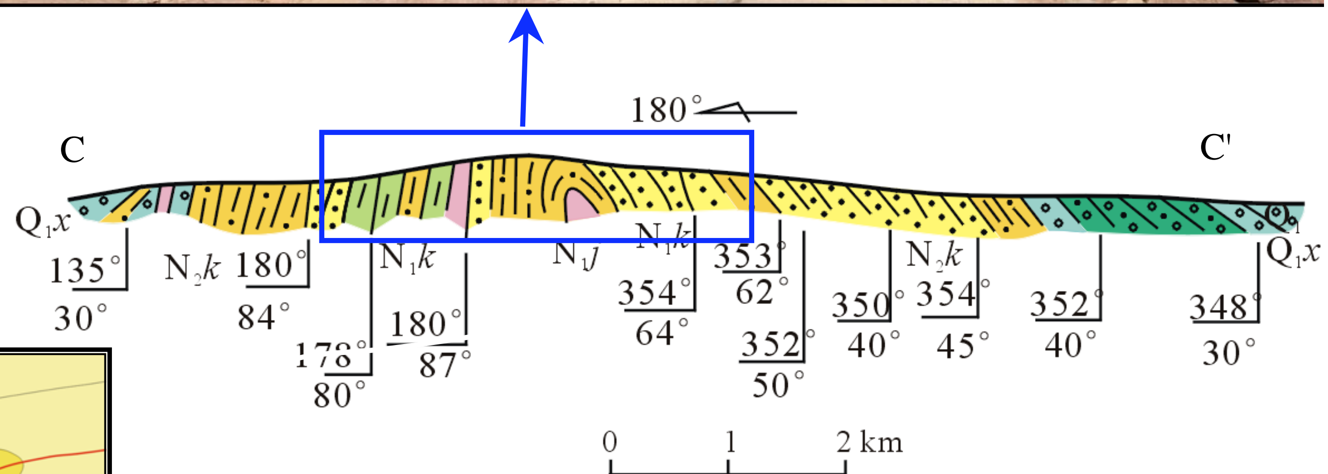
The lower-amplitude western section of Yakeng has ~340m of shortening in contrast with ~1200m in the higher amplitude eastern section. The two sections have similar diapiric components of ~1 sq. km.
(After Dittmann et al., 2005)



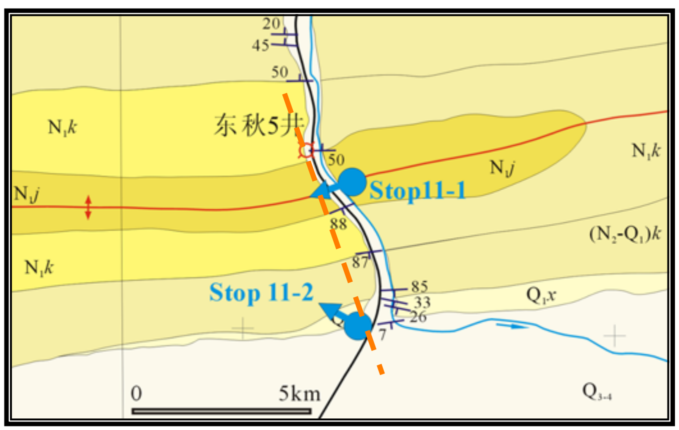


Stop 11-1 East Qiulitake Anticline

East Quilitak Anticline is a box fold. The core of the anticline is composed of the middle and upper Jidike Formation, both limbs of Kangcun Formation and Kuqa Formation with a steep or overtured south limb.

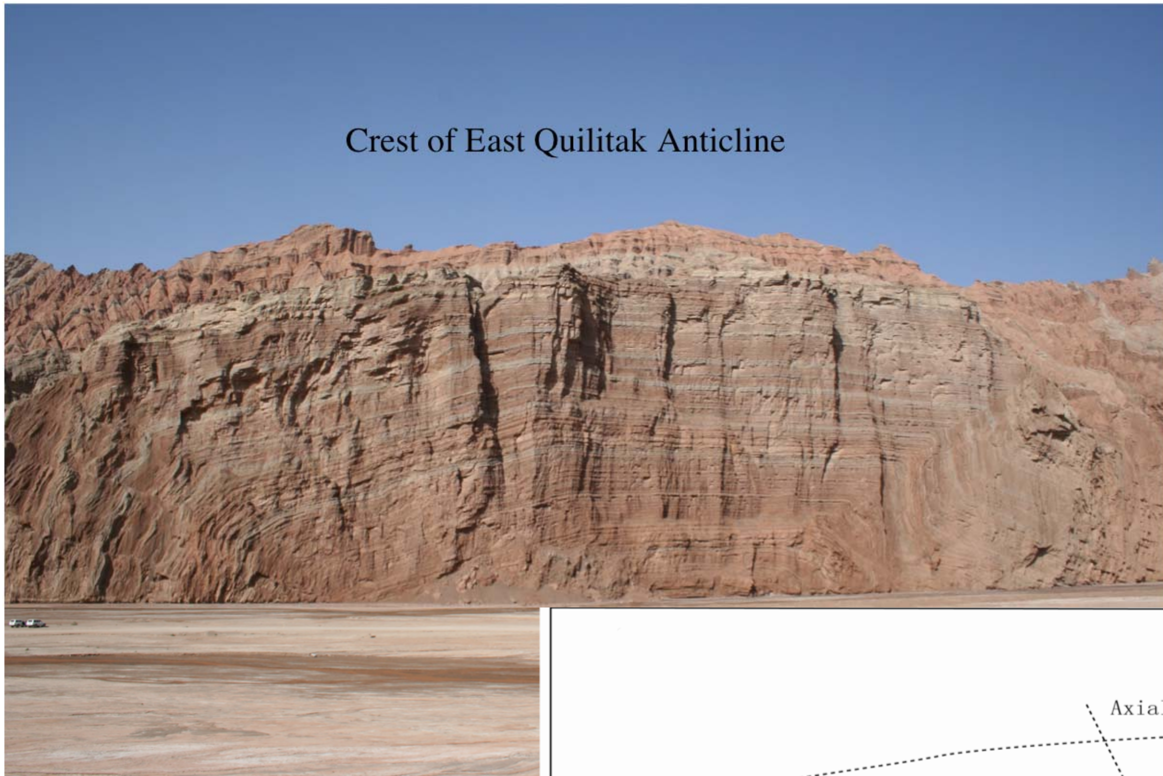


Stop 11 location map

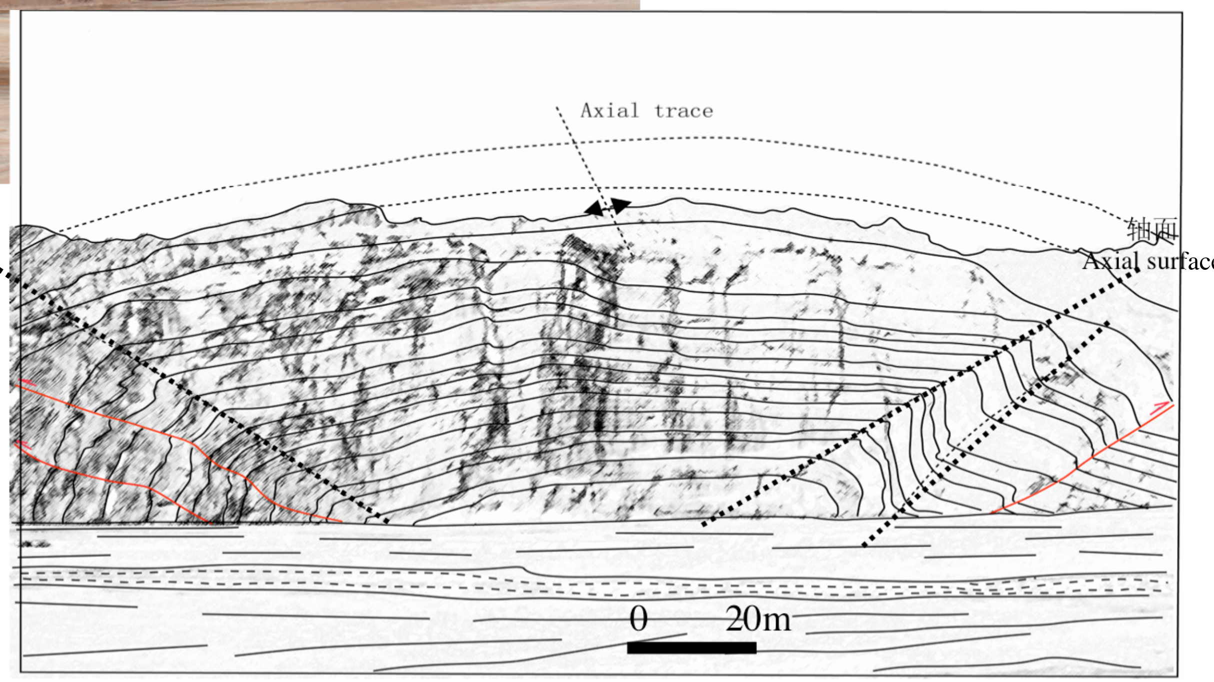


Geological profile across the East Qiulitake Anticline along Kezilenuer River (After Yang et al.,2003)

Stop 11-1 East Qiulitake Anticline



Photograph of east Qiulitake anticline, looking west along Kezilenuerg River

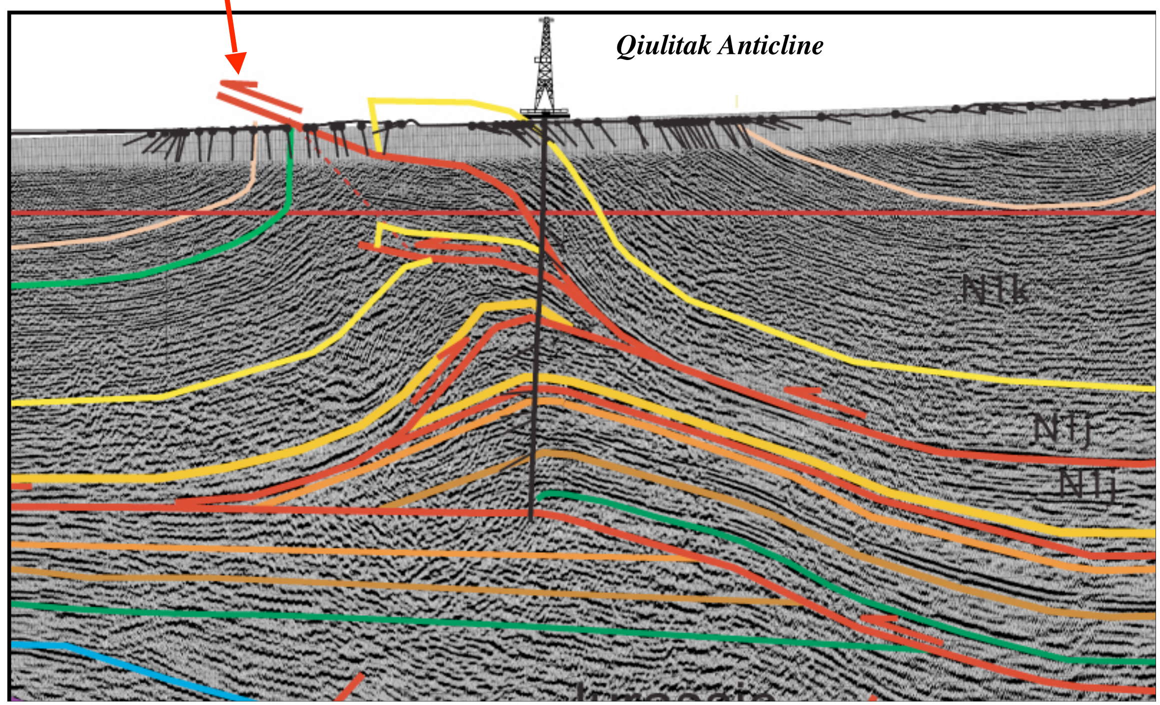


Sketch showing the core of East Qiulitake Anticline

Stop 11-1 East Qiulitake Anticline

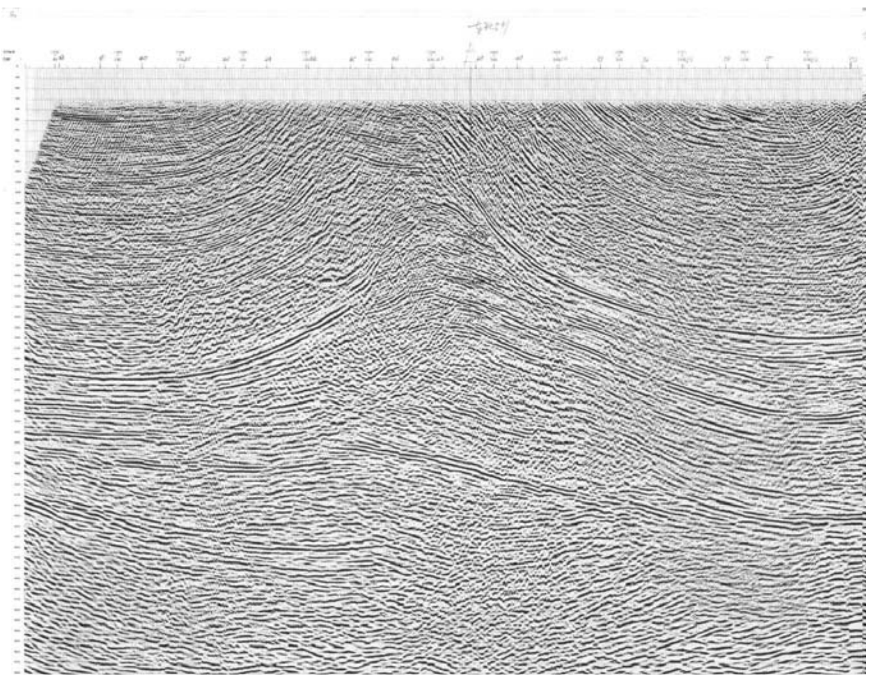
NE

Photograph of forelimb of east Quilitak anticline
looking northwest

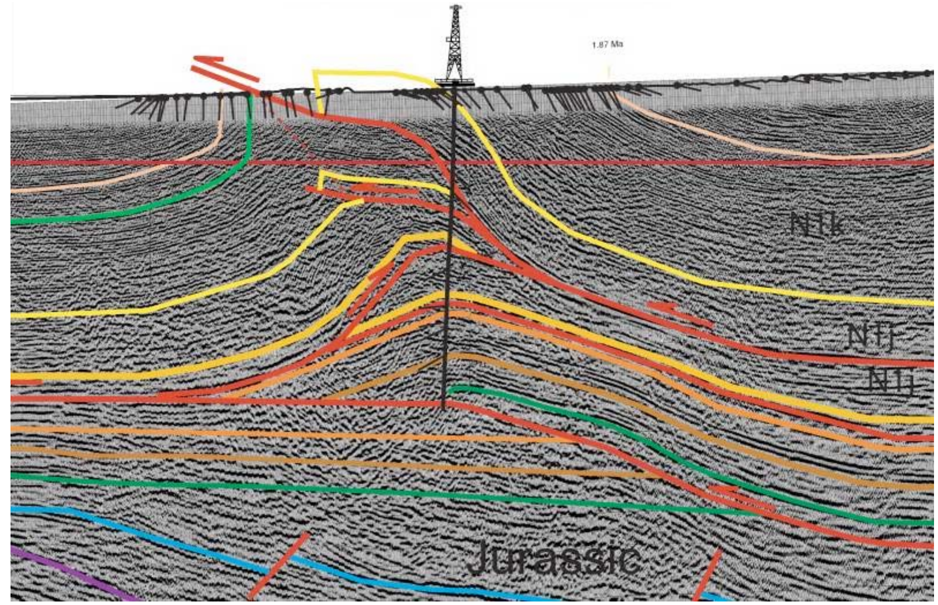


Interpretation of seismic cross section
across the east Qiulitake anticline
(After Suppe et al., 2004)

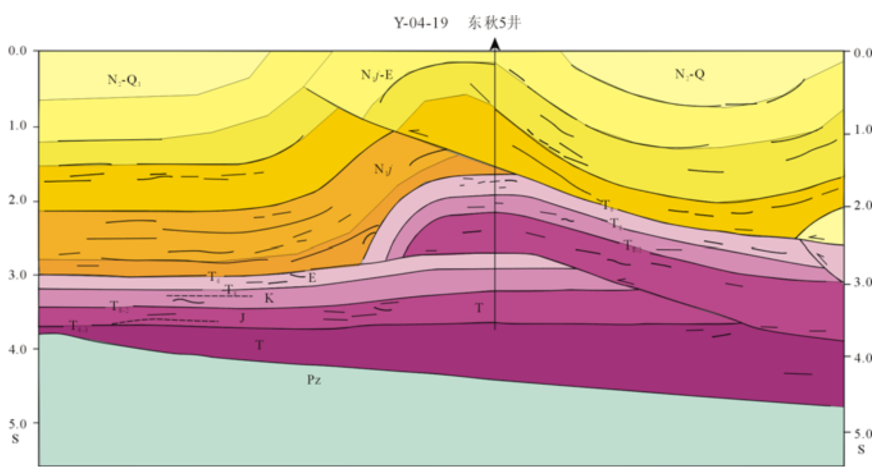
Stop 11-1 East Qiulitake Anticline



Seismic cross section across the east Qiulitake anticline

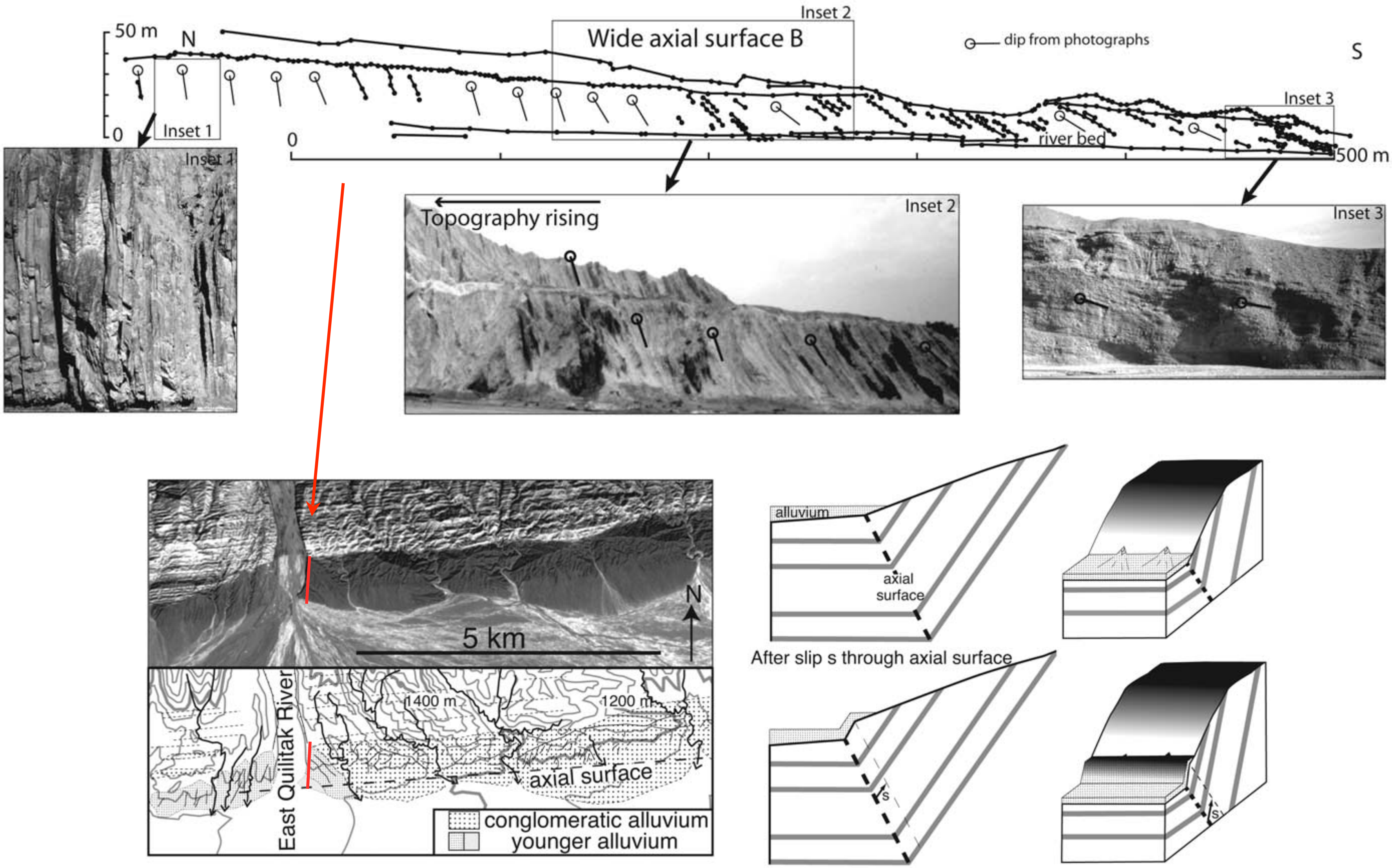


Interpretation of seismic cross section across the east Qiulitake anticline (After Suppe et al., 2004)



Interpretation of seismic cross section across the east Qiulitake anticline (After Yang et al., 2003)

Stop 11-2 Active folding at southern edge of East Qulitake Anticline



(After Hubert-Ferrari & Suppe, 2005)

Korla~Urmqi Stops along 218 highway (East Tianshan)

From Korla to Stop12, spending almost 3 hours going through Tashidian to north Yanqi Basin.

Stop12

Location: 15km northwest of County city. GPS coordinate: N42°22.346‘，E86°11.981’，H1221m。

Hejing anticline at the northern edge of the Yenqi basin shows active folding of river channels and alluvial fans. It is characterized by a long gentle back limb with progressive limb rotation and a steeper narrow front limb, which is similar to many shear fault-bend folds. The front limb is more steeply dipping with an emergent set of fault scarps. Stop 12 shows forelimb fault scarps and terrace deformation.

Forelimb fault scarps of Hejing anticline are called North Hejing fault scarps, also called the Duoerjuelun Tuergoong fault scarps (Deng Qidong et al,2000), extending east-west almost 22km. Triangular fault scarp facets can be observed in the field. Hejing anticline was developed above the fault, with a width of 2-3km. Deng Qidong et al(2000) held that the east fault scarps of Hejing anticline was composed of two-stage terraces of different hights, the higher of which extended 20km and incised fluvial conglomerate beds of terrace-II, and decreased from 20m in the central part to10m at the western and eastern ends. The lower fault scarps developed over the lower fluvial fans and surface of terrace-I, 50-260m south of the higher fault scarps, with a height generally of tens of centimeter, with the highest up to 1.8m.

The Hejing anticline shows that active deformation is going on in the Yanqi basin, which deformed Pliocene to early Pleistocene sandstones and gravels. Both limbs and the core of the anticline are composed of grey sandstones and gravels of late Miocene-Pleistocene Ajiran formation. The anticline is gentle in the core and has a shallow limbs of 4°～10°in dip, which decreased gradually from upward. It is indicated that the Hejing anticline is active at present, across which 3 steps of terraces are folded.

Stop 13

Location: Located north 10km from Kumishi town. GPS coordinate: N42°17.917'，E88°28.924'，H1331m

Boundary faults between south and central Tianshan Mountains. Along Highway 314 north of Kumishi Town, late Paleozoic granites are intruded into Devonian grey-green biotite-quartz plagioclase schist, reddish andesite and quartz schist (Xinjiang Geological and Mineral Bureau, 1965). Boundary fault zones of late Silurian-early Devonian rocks are characterized by foliation (penetrative *S* surfaces) and discrete shear bands. Foliations striking SE130° are well developed and spaced with 1-0.1cm in the Devonian strata with striking 95° lentoid and steeper white quartz veins, even late quartz veins. Also relict grey-green volcanic rock is present. NW-SE striking, multi-colored plutons and veins were arranged sequentially.

Stop 14-1

Location: Dacaohu valley near the highway, west end of the Turpan Basin. GPS coordinate: N43°01.360'，E88°44.898'，H272m.

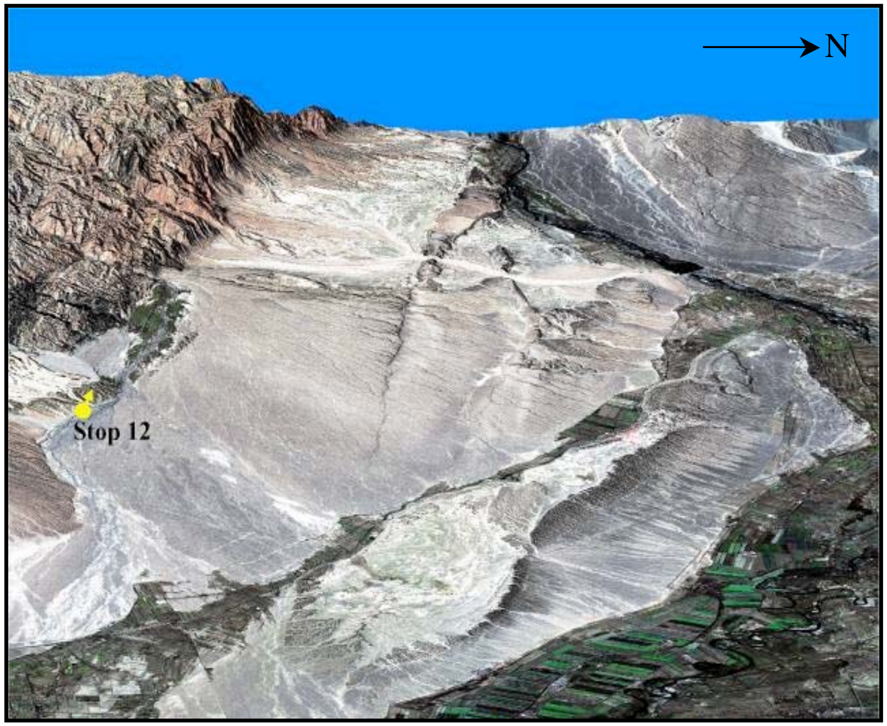
Yanshan thrust and anticline. Yanshan anticline is a linear fold with gentle north limb and steeper or overturned south limb, which is composed of Miocene Taoshuyuan Formation with maroon, brown, brown reddish, grey green mudstones, salts and siltstones, Pliocene Putaogou Formation with khaki, primrose mudstones, siltstones, gravels, and early Pleistocene Xiyu Formation with gravels. Thin upper Pleistocene fluvial desert conglomerates are covered in the north limb, of which is perfectly exposed and dips 20°～35°. The south limb not shown in outcrops, which could indicate existence of underlying thrust faults. NW-striking north Yanshan thrust, extending 14km, dipping 70°, is developed in the core of the Yanshan anticline (Deng Qidong et al, 2000). The north limb is a northward dipping monocline, and the thrust fault which is not emergent at this stop.

Stop 14-2

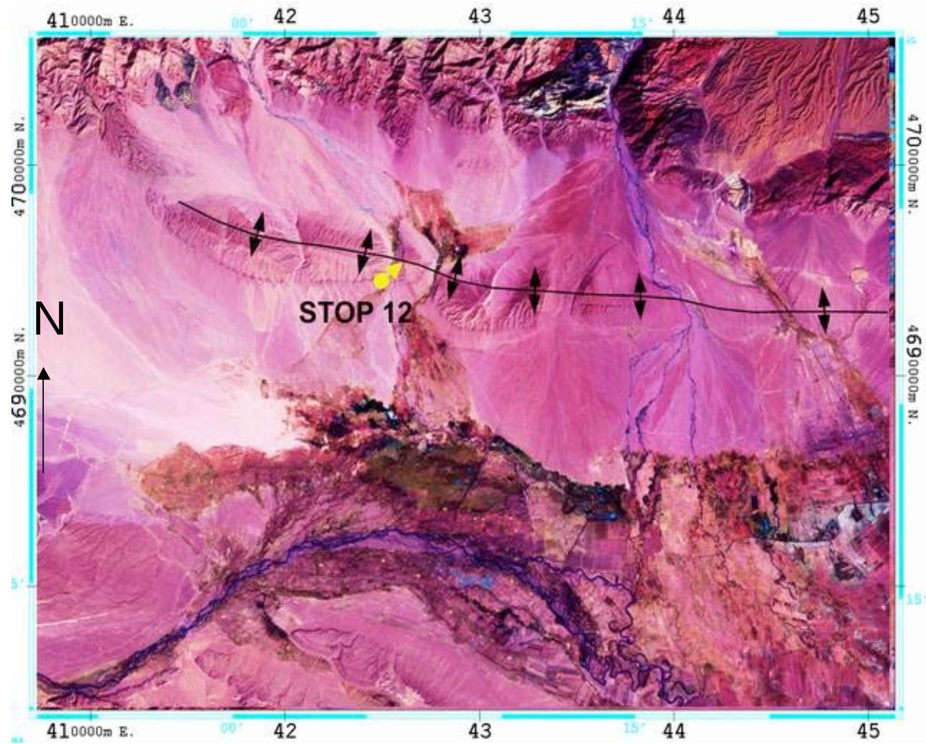
Location: Shengjinkou small village near the Huoyanshan (Flaming Mountain) to the north of the Highway 312. GPS coordinate: N42°54.744'，E89°33.185'，H-19m (below sea level).

Huoyanshan anticline and thrust fault. Huoyanshan anticline, located in the central part of Turpan basin, extends 90km from west to east, 5～8km from north to south, with Jurassic in the core and Cretaceous, Paleogene, Neogene and Quaternary in the limb. Jurassic strata are kelly sandstones, siltstones; Cretaceous strata are varigated mudstones and sandstones; Paleocene strata are maroon sandstones with gravels and mudstones; Neogene strata are wine-colored mudstones in the basal part, khaki mudstones in the upper part; early Pleistocene and Holocene are unconformably over all the above strata. Early Pleistocene strata is mainly composed of grey gravels, primrose yellow silt and dust, and glacial deposits; Holocene strata is brown and brown detritus. The anticline is asymmetric with gentle north limb (20°~30° in dip) and steeper or overturned south limb (80°~85° in dip), middle-lower Jurassic core of which is believed to be a fault-propagation fold. Both limbs are composed of Middle Sanjianfang Formation, Cretaceous, Paleocene, Neocene and Quaternary deposits. Huoyanshan thrust fault emerges along strike of Huoyanshan, and is exposed in the surface, formed fault scarps in modern deposits. Deng Qidong (2000) considers that it is a typical of fault-propagation fold. Huoyanshan thrust fault is identified by seismic data under the forelimb of the anticline, on which cliffs or fault scarps are developed.

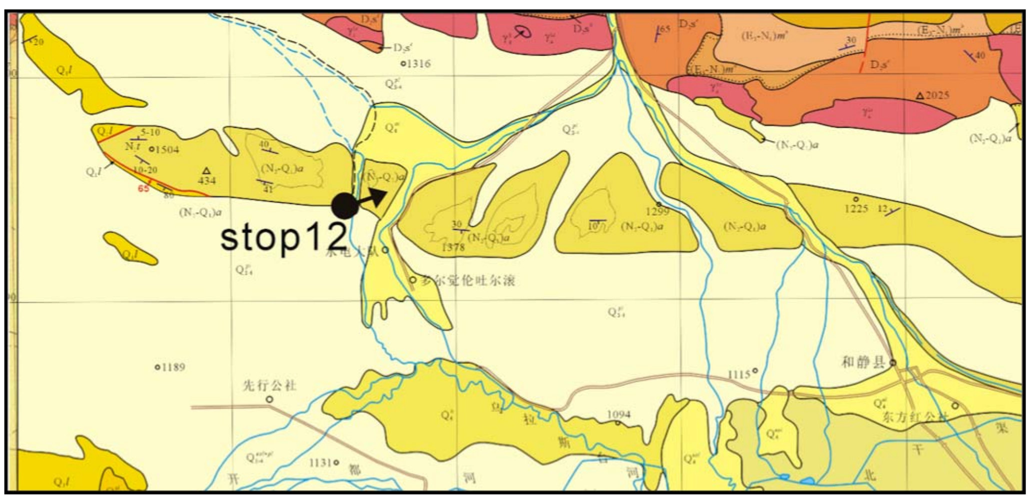
Stop 12 Hejing Anticline



3D remote sensing imagery of the southwest Yanqi basin, showing active folding & strike slip (Stop 12 incorrect)

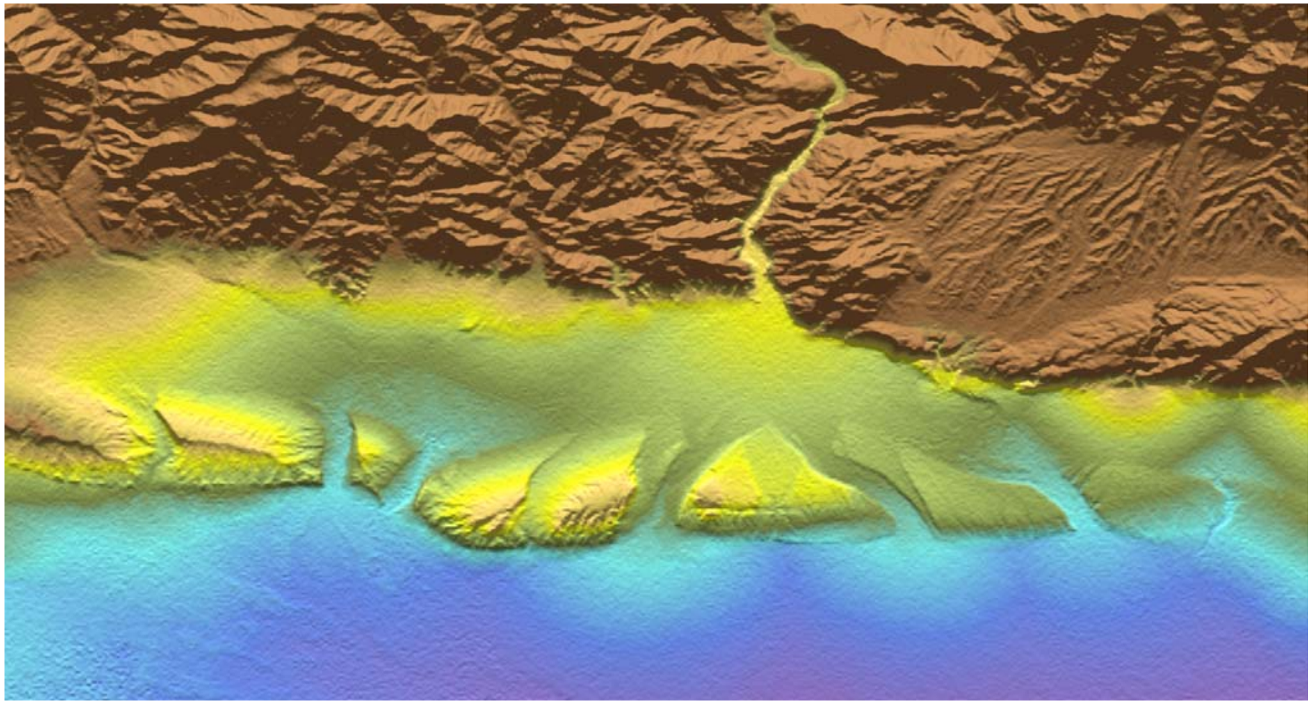


ETM remote sensing imagery of the Hejing anticline (Bands 7.4.1), 3D image to left overlaps southern part of this image.

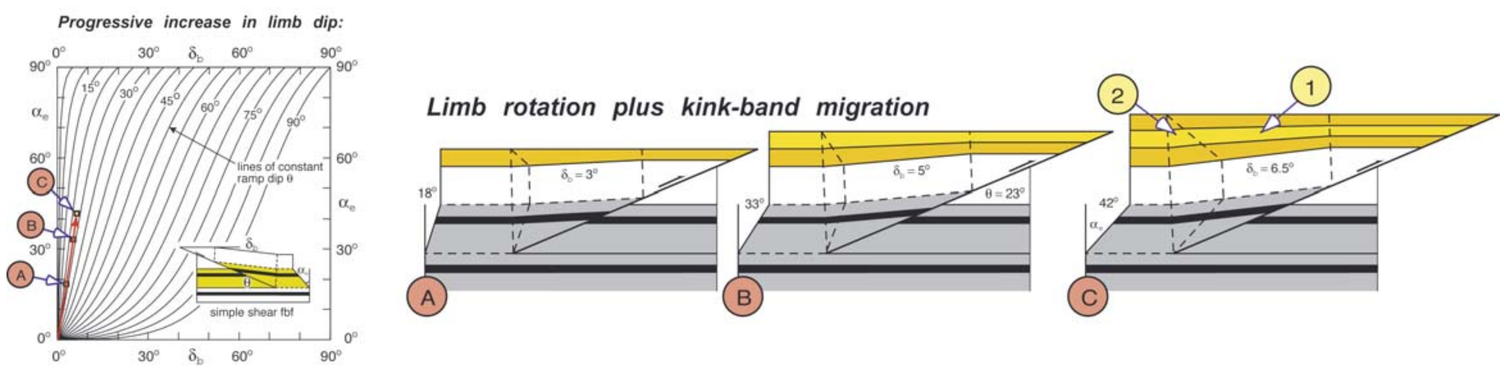


Simplified geological map (modified from Geological map of Yanqi, 1: 200,000, Regional Survey Team, Xinjiang Geological and Mineral Bureau 1965.)

Stop 12 Hejing Anticline

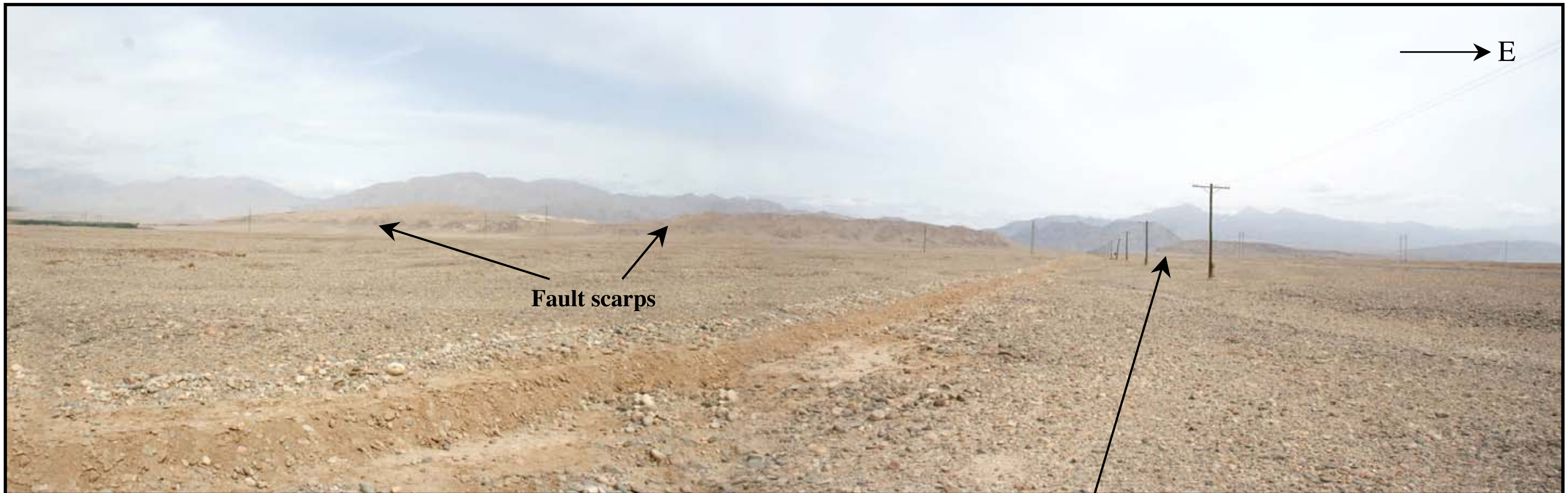


Hejing anticline at the northern edge of the Yenqi basin shows active folding of river channels and alluvial fans. It is characterized by a long gentle back limb with progressive limb rotation and a steeper narrow front limb, which is similar to many shear fault-bend folds. It has a width of 2-3k. In the central part there are several sets of fault scarps, called as North Hejing fault scarps, extending almost of 10km with a height reaching 8-10m. DEM image from KarlMueller.



Shear fault-bend fold models show a progressive back-limb rotation similar to Hejing anticline. This figure shows the progressive back-limb rotation of a simple-shear fault-bend fold model. The front limbs can form by a variety of independent mechanisms. From Shaw et al. 2005.

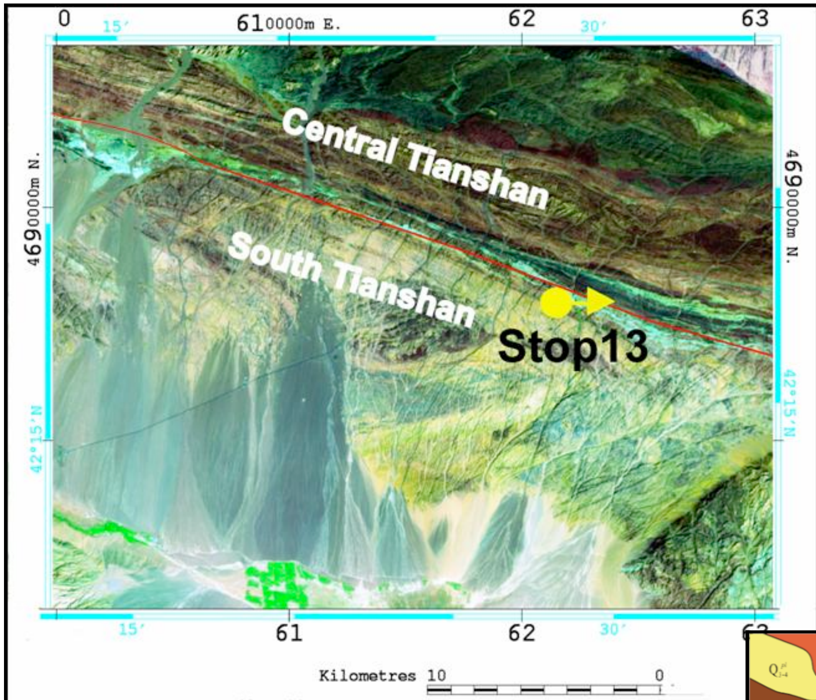
Stop 12 Hejing Anticline



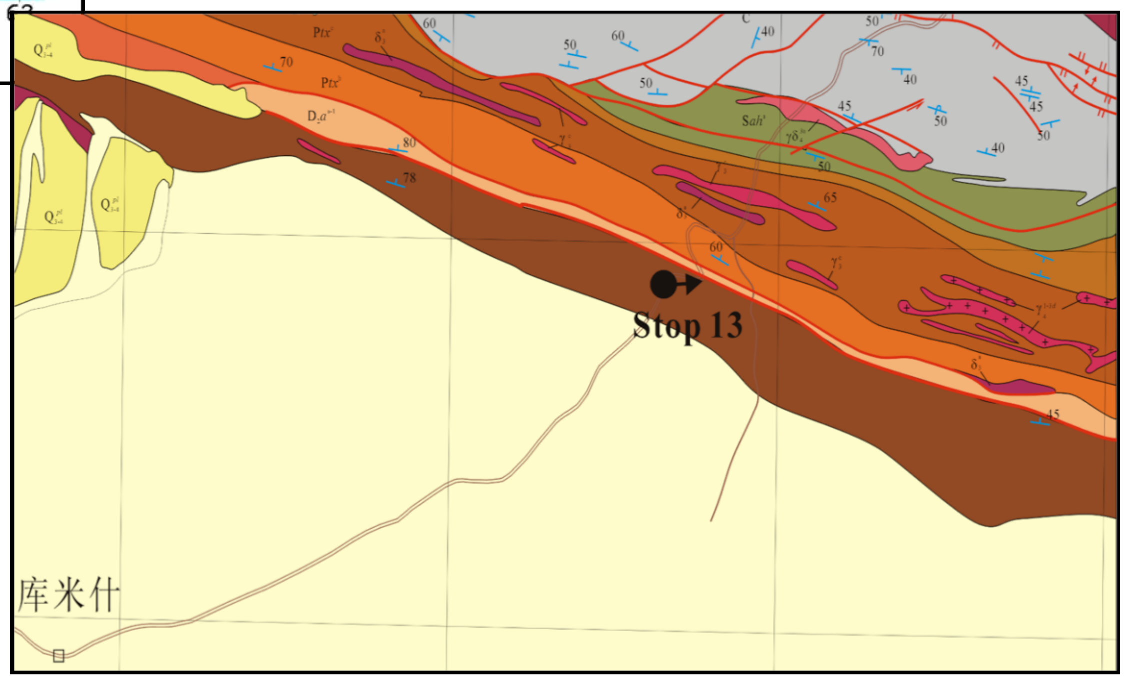
Hejing anticline has a width of 2-3km, situated above a thrust fault, which resulted in a series of fault scarps. These are called the North Hejing fault scarps, with the emergent section extending almost of 10km and the height of 8-10m.

The Hejing anticline is composed of the Quaternary terraces. The fold geometry of terraces-III or II is very clear. A slightly deformed terrace-I indicates that the Hejing anticline is active at present.

Stop 13 Boundary between South and Central Tianshan Mountains



ETM remote sensing imagery (Bands 741) of the boundary between south and central Tianshan Mountains



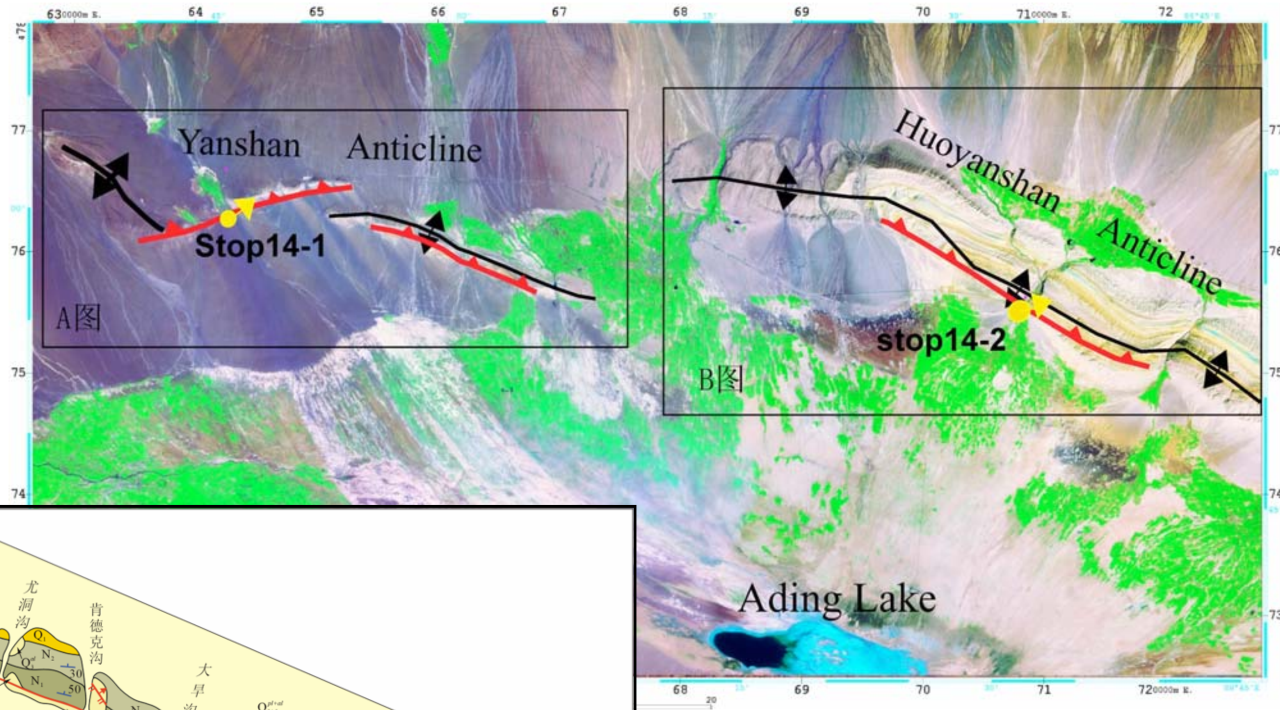
Simplified geological map of the boundary between south and central Tianshan Mountains (after Geological map of Kumishi with a scale of 1: 200,000, Regional Survey Team, Xinjiang Geological and Mineral Bureau 1965)

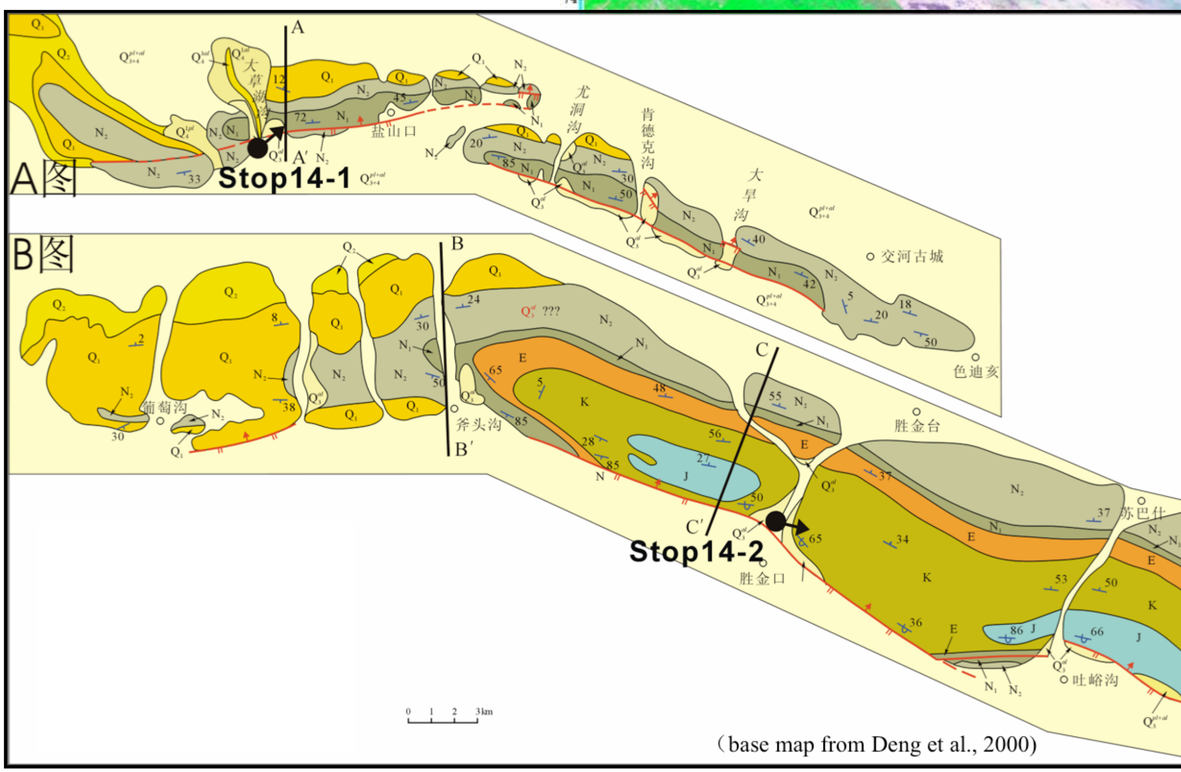
Stop 13 Boundary between South and Central Tianshan Mlountains

NW-striking veins and pluton , quartz–biotite schists, cleavage dips 70º–80ºS, probably reflecting striking-slip movement

Stop 14 Huoyanshan Anticline

ETM remote sensing imagery (Bands 741) of the Huoyanshan and Yanshan anticlines in the Turpan basin

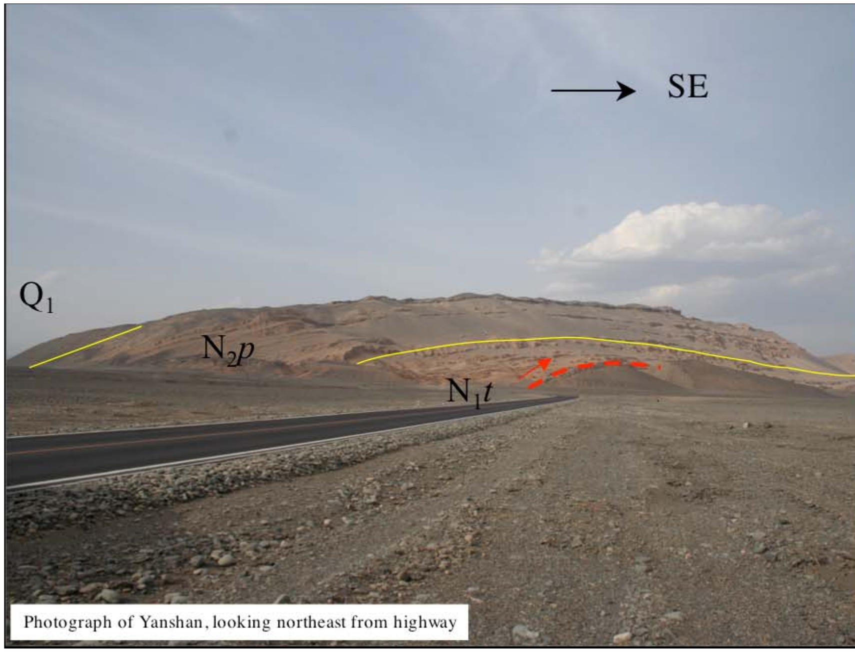




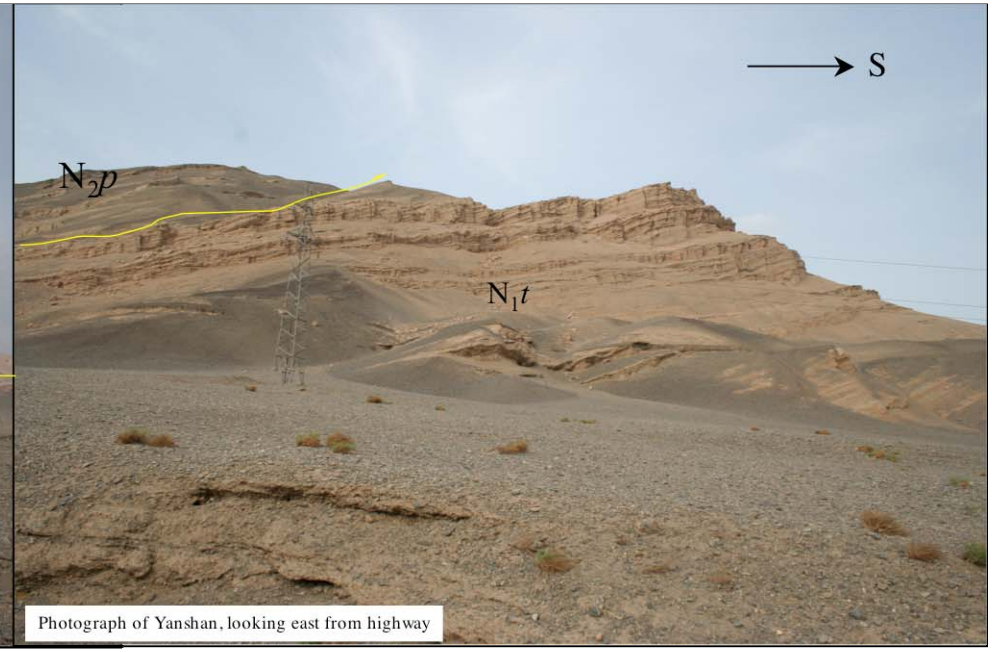
（base map from Deng et al., 2000)

Simplified geological map of Yanshan anticline (A) and Huoyanshan anticline (B) See above for location of A and B

Stop 14-1 Yanshan Thrust and Anticline

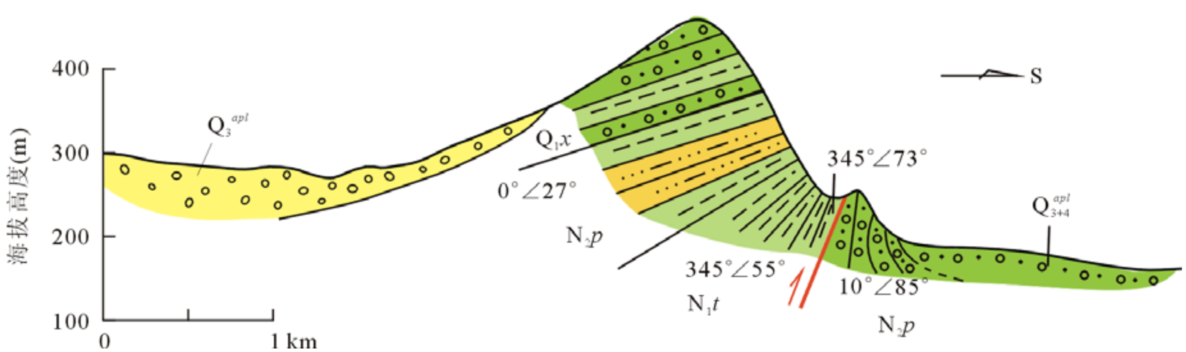


Photograph of Yanshan, looking northeast from highway



Photograph of Yanshan, looking east from highway

Miocene Taoshuyuan Formation is brown, brown mudstone and siltstone in the west part of the Huoyanshan anticline. The Pliocene Putaogou Formation is exposed as khaki, primrose yellow mudstones, siltstones and conglomerates. The north limb is completely exposed, dips 20-35°; the south limb was narrowed by the thrust fault at the far-east 200m of the spot (AA' section), and consists of the steep Putaogou Formation conglomerates, not exposed elsewhere.



Geological section along Dacaohugou valley in west Huoyanshan (After Deng et al., 2000) AA'Cross section, see the previous page for location

Stop 14-2 Huoyanshan Anticline

Photograph of Huoyanshan looking north from highway

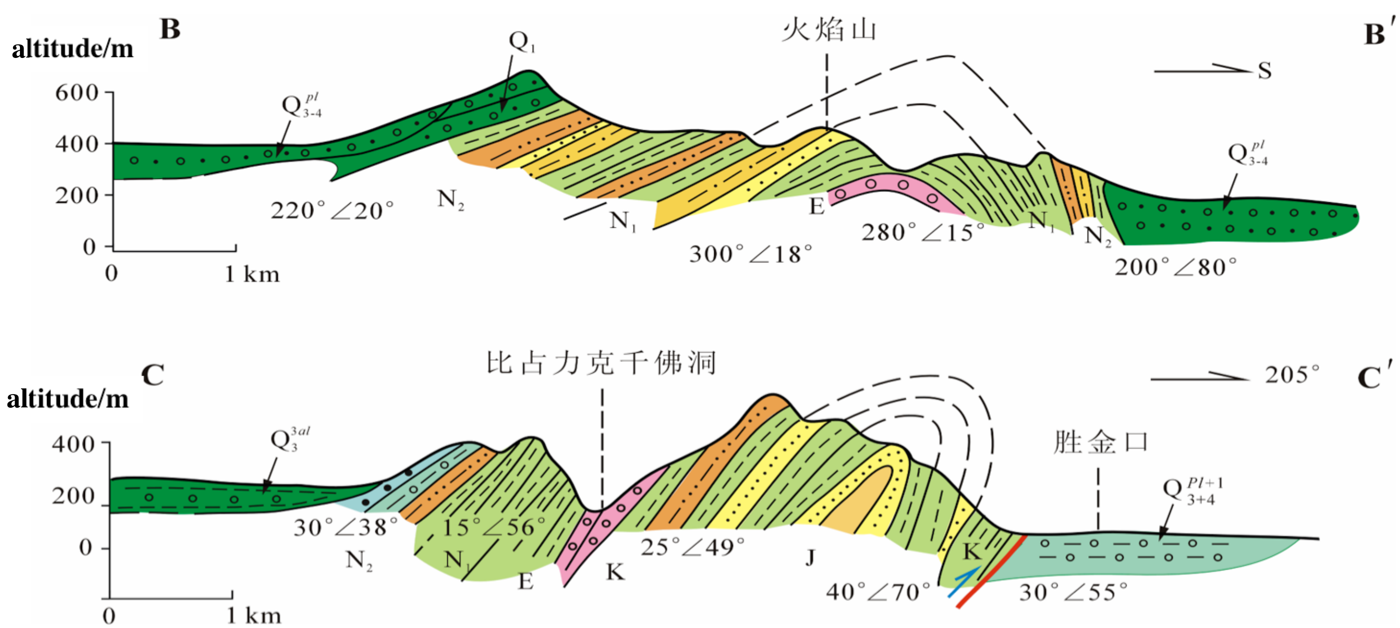
Photograph of Huoyanshan Cretaceous strata looking north, 5km west of Stop14-2. Maroon sandstones interbedded with conglomerates and mudstones, which looks like a flaming fire under the sunshine.

Photograph of Huoyanshan looking southeast from highway

Photograph of Huoyanshan Cretaceous strata looking northeast, 1km west of Stop14-2, Shengjinkou profile. The back-limb of the Paleogene and Cretaceous strata is dipping 20°-15 °. The forelimb is steep and vertical. The core of the anticline is of Jurassic strata, while the Huoyanshan thrust is buried below.

Stop 14-2 Huoyanshan Anticline

The backlimb of Paleocene sandstones dips 30-55 °. The Cretaceous reddish sandstones and mudstones of forelimb is much more steep or overturned. Photograph was taken at the junction of Shengjinkou with the sub-highway, 500m east of CC' profile



Geological cross sections of Futougou BB' and Shengjingkou CC'(After Deng et al., 2000). The locations can be found in Simplified geological map of Yanshan anticline and Huoyanshan anticline

South Junggar Foreland Basin

South Jungar Foreland Basin lies in the north side of the Tian Shan Mountains. It stretches east-west from Jimusaer to Jinghe for nearly 500 km with a north-south width of 30~50 km and has an area of about 22500 km2. The South Junggar Foreland Basin may be divided into three segments between Urumqi on the east and Dushanzi on the west. They are the Fukang thrust belt, the middle thrust belt and the Sikeshu depression. South Jungar Foreland Basin is mostly covered by Mesozoic and Cenozoic, which are fluvio-lacustrine clastic deposits and mainly composed of sandstone and mudstone, reaching a thickness of about 10 km. Quaternary is molassic deposits related to thrusting and folding. The age of these strata become younger from south to north. The Meso-Cenozoic strata in South Junggar Foreland Basin are strongly folded since Miocene (Molnar et al., 1994; Deng et al., 1999, 2000; Avouac et al, 1993). The deformation, which is characterized by flat-ramp-flat faults and its related folds, created three NWW trending structural belts from south to north. They are ⑴ the mountain front wedge belt, characterized by monocline in surface and blind wedge structures; ⑵ Huoerguosi-Manashi-Tugulu fault propagation fold belt, which stretches NWW trending for nearly 120 km and is consisted of three elongate range in remote sensing image. Paleogene Anjihaihe Formation outcrops in the anticlinal core, the younger Neogene and Quaternary Formations are strongly folded on both flanks of the anticline. The south-dipping active thrusts in the anticlinal core and north flank are targets for the field trip; ⑶ Hutubi-Anjihai-Dushanzi anticline zone, including the Dushanzi anticline which is a key stop for the field trip. The above structural belts obliquely intersect the northern TianShan. It has been inferred that the thrusts activities in South Junggar Foreland Basin may be involved in strike-slip movement.

South Junggar Foreland Basin is one of the earliest petroleum exploration areas in west China. In 1937, Dushanzi oilfield was found. In 1950s, 1:200000 preliminary gravity-magnetic prospecting and 1:50000 geological detailed survey were carried out. In 1958, Qigu oilfield was found. From 1980s, the digital seismic exploration were carried out, this brought about a succession of oil and gas discoveries, as exemplified by the Xiaoquangou oilfield, Santai oilfield, Hutubi gas field and Kayindike oilfield et al. Recently, Huoerguosi and Tugulu oilfields were found.

Stop15

Location: 2 km south of highway in the southwest of Dushanzi City. GPS Coordinate: N44°18.730'，E84°48.889', H821m.

Dushanzi anticline. Dushanzi anticline is composed of the lower Pleistocene Xiyu Formation, Pliocene Dushanzi Formation and Miocene Taxihe Formation. The surface anticline is wide and gentle, the southern limb dips 15-25°S, but beds in the northern limb dip most steeply near the underlying thrust. In seismic profile, the Dushanzi anticline is imbricated by the shallow fault propagation fold and the deep detachment fold, the shallow anticline is developed above the south-dipping thrust, which reaches the surface and offsetting the youngest sediments (Avouac et al, 1993), with main decollement located just below the characteristic strong reflections corresponding to the mud layers of the Paleogene Anjihaihe Formation. The Pliocene Dushanzi Formation and its above strata thin gradually from the flank toward the crest and display fanning of dips, these phenomena suggest that the deformation of Dushanzi anticline may have started since Pliocene, and also indicate that the Dushanzi anticline has a component of limb rotation in fold growth.

Stop16

Location: west of the Kuitun River. GPS Coordinate: N44°18.792'，E84°46.627'，H849m.

Dushanzi anticline and the Kuitun River terraces. The north-flowing Kuitun River incises the Dushanzi anticline perpendicular to strike. River terraces are preserved on both sides of the present river valley along the piedmont reach. Three major levels, labeled I to III are identified. Level I is 10-40m higher than the river valley. Within level I in the northern flank of anticline, there are three sub levels. Level II is distributed in succession along both sides of the river, but absent in the Dushanzi anticline east of riverside. Level III is distributed above the crest of anticline. These terraces are covered by the dark gravel layer, which is unconformably overlying the lower Pleistocene Xiyu Formation and Pliocene Dushanzi Formation. The terraces of the anticlinal core and flanks are deformed, and a several meter high fault scarp is observed in the level II terrace of the northern flank. These phenomena imply the Dushanzi anticline is active. Poisson & Avouac (2004) have studied the deformation and incision of these Kuitun River terraces in detail. They demonstrate that only ~10% of the incision is due to deformation; most is due to climate change. The *T3* (II) terrace was abandoned after 7Ka with 130m incision and a maximum structural uplift of ~20m at the crest, indicating a maximum uplift rate of ~3mm/y averaged over the last 7Ka. Deep seismic imaging along the Kuitun River indicates two structural levels with a deep detachment fold and a shallower bedding thrust on the back limb that reaches the surface on the north side of the anticline, forming the fault scarp. The shape of the deformed terraces in relation to the seismic imaging indicates the importance of limb rotation in the present growth of the anticline, which implies active growth of the deep detachment fold.

Stop17

location: the mouth of Ajihaihe River. GPS Coordinate: N44°19.428'，E85°22.152'，H849m.

The northern limb of Anjihai anticline. The surface anticline is composed of the lower Pleistocene Xiyu Formation and Pliocene Dushanzi Formation, the crest of anticline is covered by Quaternary. The surface anticline is wide and symmetrical (15-25° dip). In seismic profile, the Anjihai anticline is a detachment fold with the main detachment located in the lower Cretaceous, the sediments on both limbs present fan-shaped, thinning toward the anticlinal core, which is deposited during the growth of the fold.

Stop18

Location: west bank of Jingou River. GPS Coordinat: N44°10.955'，E85°27.002'，H858m。

Faults that cut through the Huoerguosi anticline and fault scarp on the surface. The surface anticline is asymmetric with the south limb dipping 50-60° and the north limb steeply dipping or overturned. The thrust cut through the northern limb and produces about 3m high fault scarp on the surface. The seismic profile shows the deep Huo'erguosi anticline is a fault bend fold with the upper decollement horizons of underlying thrust located in the mud layers of lower Cretaceous and lower decollement horizons located below the coal layers of lower to middle Jurassic Xishanyao Formation. The southern limb dips consistently, but the northern limb is composed of three dip domains, which may be caused by wedge thrust in the hinge of anticline. Growth strata are recognized on the northern limb of deep anticline, the base of growth strata is located in the lower of Pliocene Dushanzi Formation, which suggests the deformation of Huoerguosi anticline start in early Pliocene.

Stop19

Location: almost 500 m northeast of the mouth dam station of Jingou River. GPS Coordinate: N44°11.081'， E85°27.631'， H799m.

The thrust in the northern limb of Huo'erguosi anticline. Fault scarps are well-displayed on several alluvial terraces west of the river, which have been surveyed in detail by Avouac et al. (1993). The fault itself is well exposed in outcrop on the east side of the river where a several meters-wide fault zone was observed in a small side valley 500 m northeast of the dam station, the fault-plane dips about 60°S. Beds in Pliocene Dushanzi Formation of hanging wall dip steeply, but beds in middle to upper Pleistocene and Holocene are nearly level and 1-2m thick loess were found in the middle and upper of these strata. This fracture zone produces about 3 m high fault scarp on the surface, ESR ages of Quartz veins sampled from the fracture zone is about 44.7 ×104a (He et al., 2003).

Stop20

Location: west bank of the Manasi River. GPS Coordinate: N44°09.720', E86°06.168', H662m.

The thrust in Manasi anticlinal core. The Manasi anticline is a fault propagation fold, the surface anticline displays asymmetry, with the north limb much steeper and narrower than the south limb. Three south dipping faults cut through the anticline, and caused the multi-repetition of Eocene-Oligocene Anjihaihe Formation, Miocene Shawan Formation and Taxihe Formation. The fault in north limb produces a fault scarp in the high *T0* alluvial terrace of ~10m and is ~3m in younger alluvium (Avouac et al. 1993). ESR ages of quartz veins and gypsum veins sampled from the faults is about 3.8~14.2×104a (He et al., 2003). Southward along the Manashi River valley, the western termination of Tugulu anticline can be observed, the two anticlines were interpreted to be imbricate structure in seismic line.

Stop21

Location: west bank of the Hutubi River. GPS Coordinate: N44°02.663', E86°47.953', H757m.

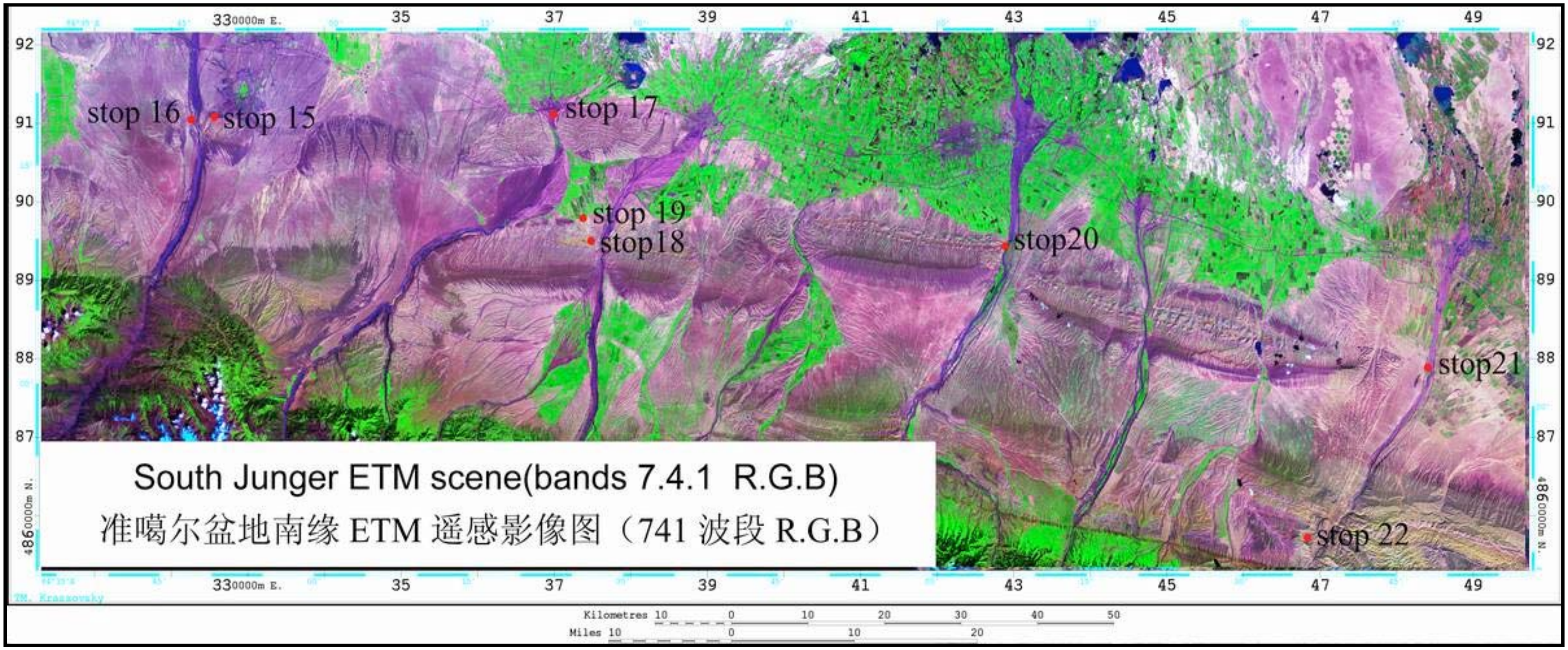
Tugulu thrust and fault scarp. The thrust in the north limb of Tugulu anticline produces well-developed fault scarps in alluvial terraces west of the river (Avouac et al. 1993). Also the terraces of the anticlinal core and flanks are deformed. These phenomena imply the Tugulu anticline is active. ESR ages of gypsum veins sampled from the fault zone is about 12.5~64.3×104a (He et al., 2003).

Stop 22

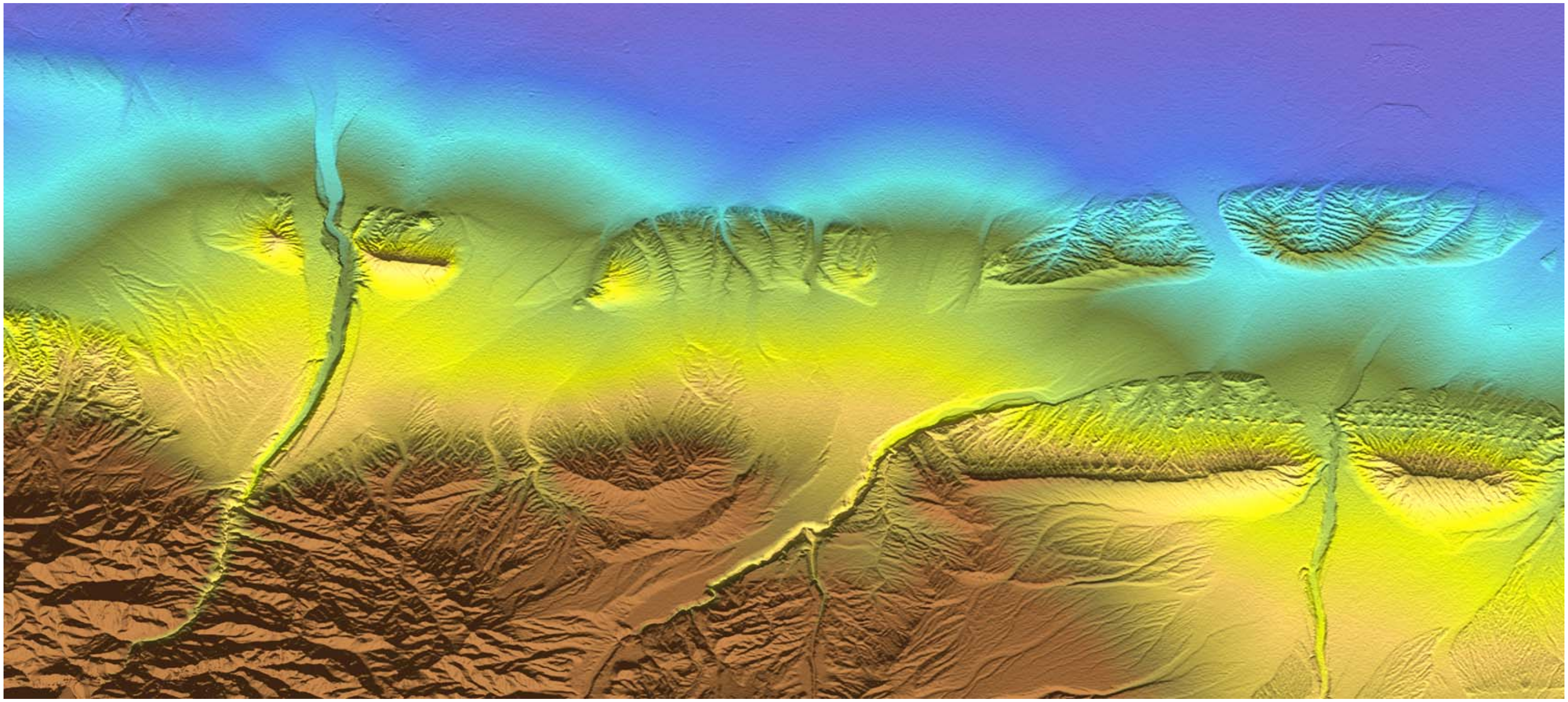
Location: west bank of the Hutubi River, almost 50 km south of Hutubi County city. GPS Coordinate: N43°51.100', E86°38.174', H757m.

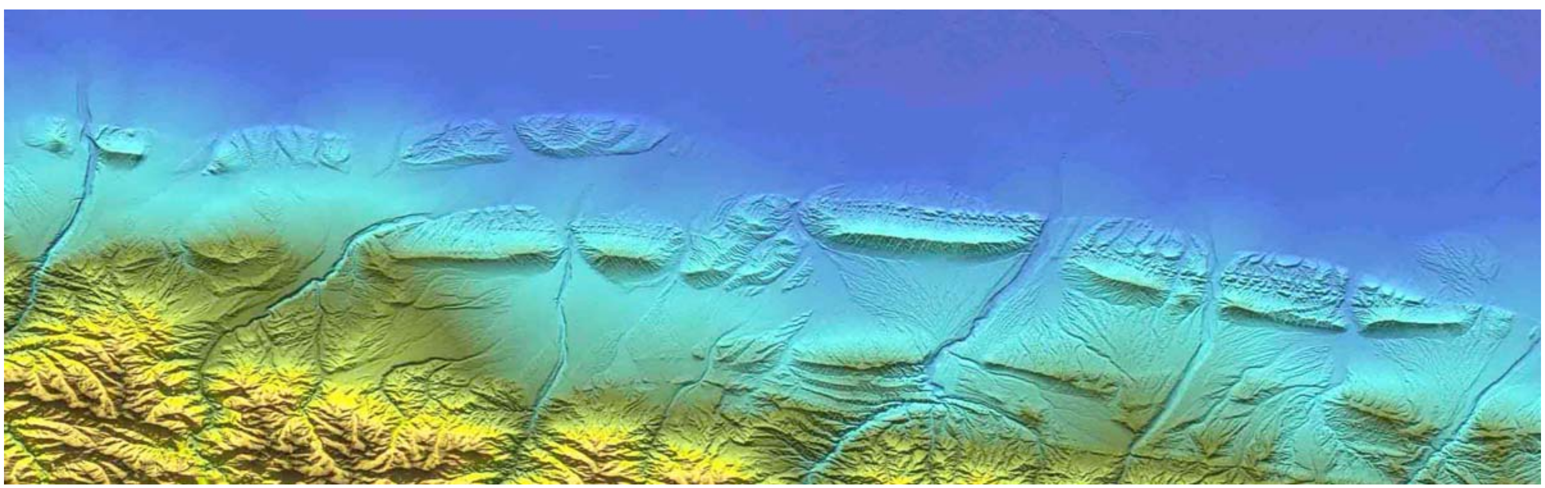
The Qigu anticline. There are a series of nose-shaped anticlines in Mesozoic in the southern South Junggar Foreland Basin, from east to west, Kalazha-Changji anticline, Qigu anticline, Qinshuihe anticline, South Anjihai anticline, and Tuoshitai anticline etc. These anticlines are called “the first anticlinal zone” in petroleum exploration. In remote sensing images and geological maps, it can be observed that the Kalazha-Changji anticline and Qigu anticline are en echelon and plunging westward, which indicate the anticlines may developed above the back thrust of the deeper wedge structure. On the surface, the Qigu anticiline trends east-west (280°) for more than 17 km, the north limb dips (24~45°) more steeper than the southern limb (30°-56°), the crest of anticline is Lower Cretaceous, which is marked unconformity with the underlying strata. Northward along the Hutubi river, Jurassic, Cretaceous, Paleogene, Neogene and Holocene outcrop in the north limb in turn. Within this section the unconformity between Cretaceous and Paleogene can be observed.

South Junggar Enhanced Thematic Mapper (ETM) Imagery (Bands 7.4.1 R.G.B)



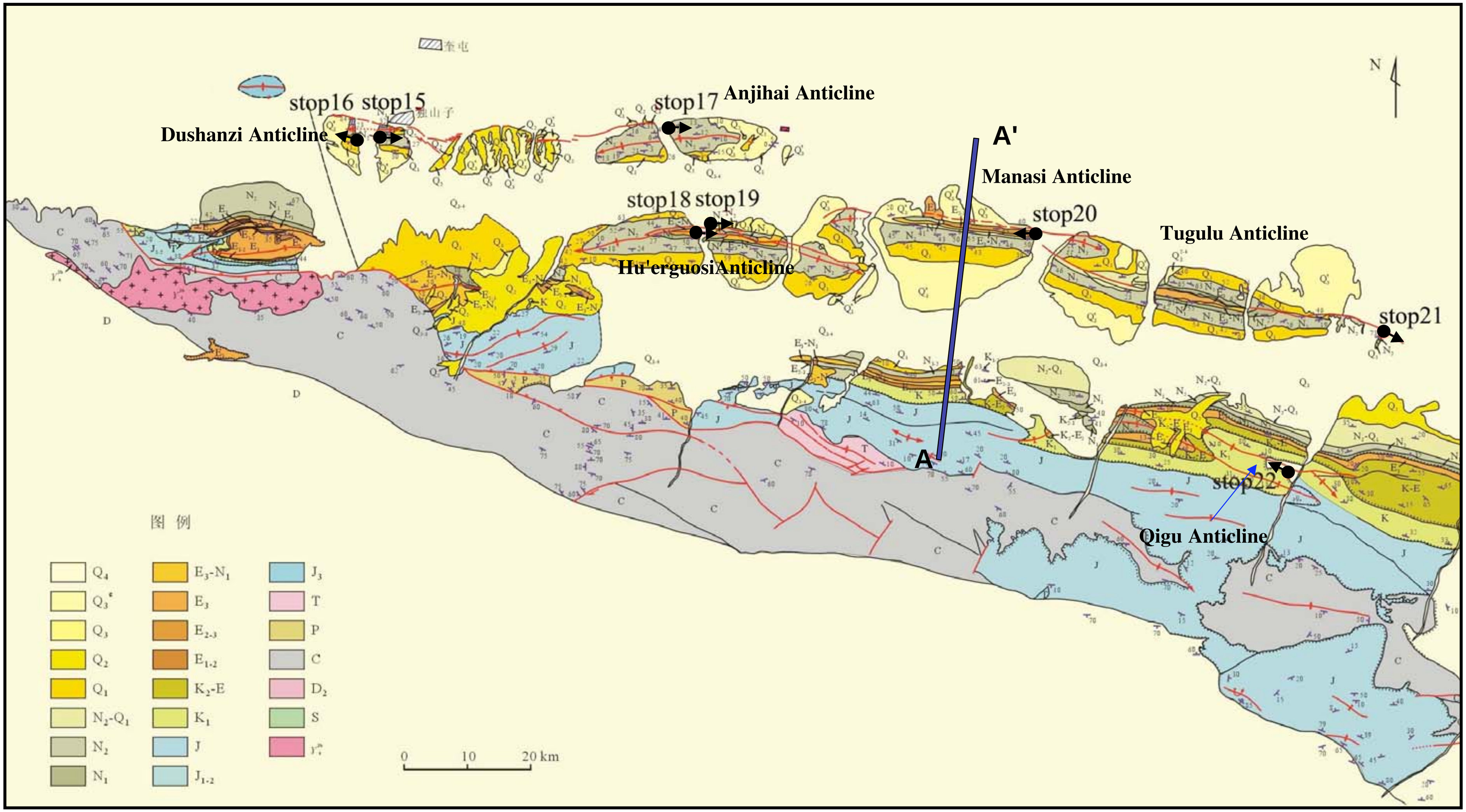
Regional Morphology of the South Junggar Fold Belt





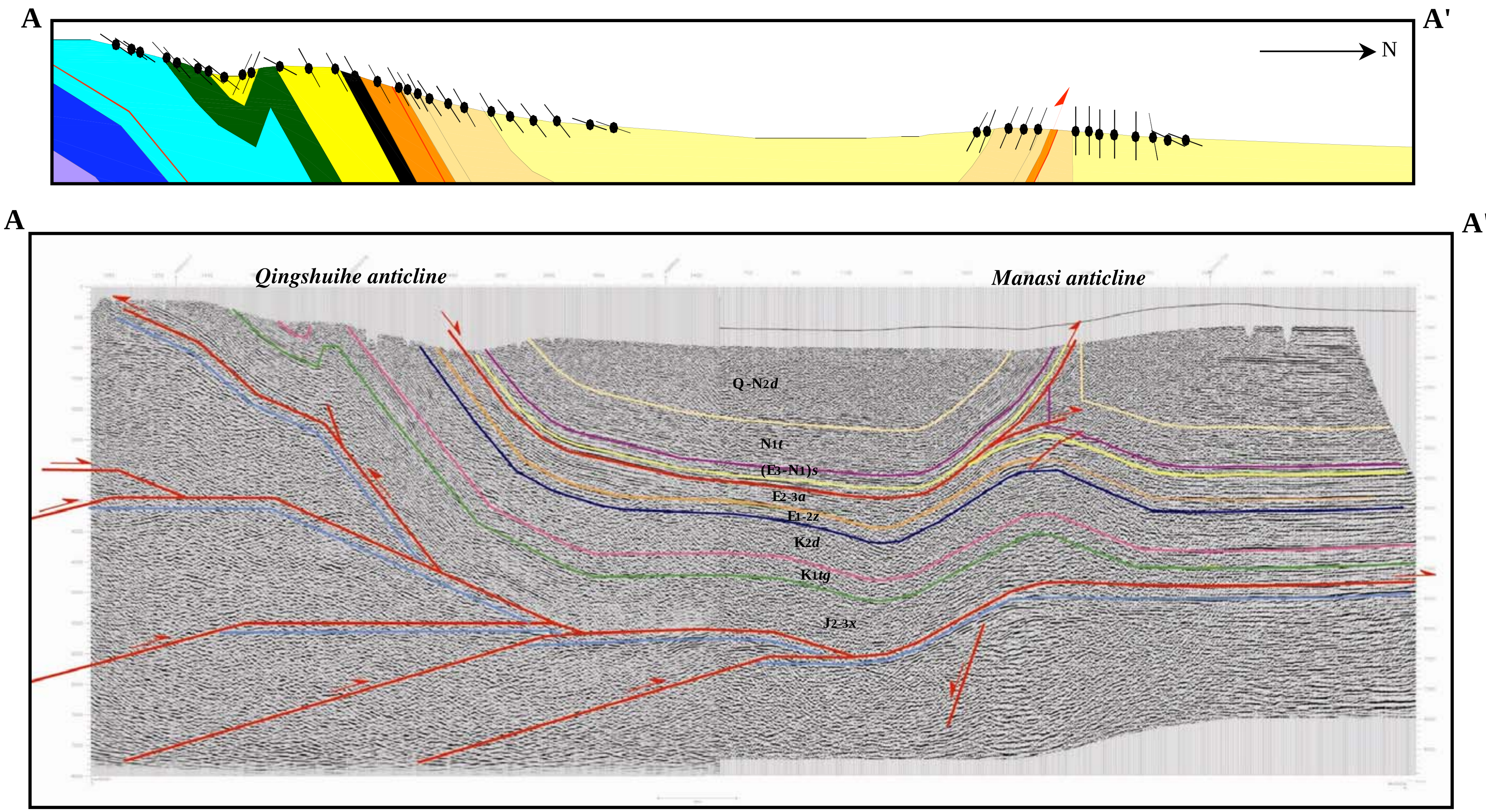
DEM
visualization
by Karl Mueller

Simplified Geological Map of South Junggar Foreland Basin



Base map from Deng et al., (2000), black dots indicate the sites of field trip, A-A' indicates regional geological profile and seismic line

Regional geological-topographical section and interpreted seismic profile (A-A')



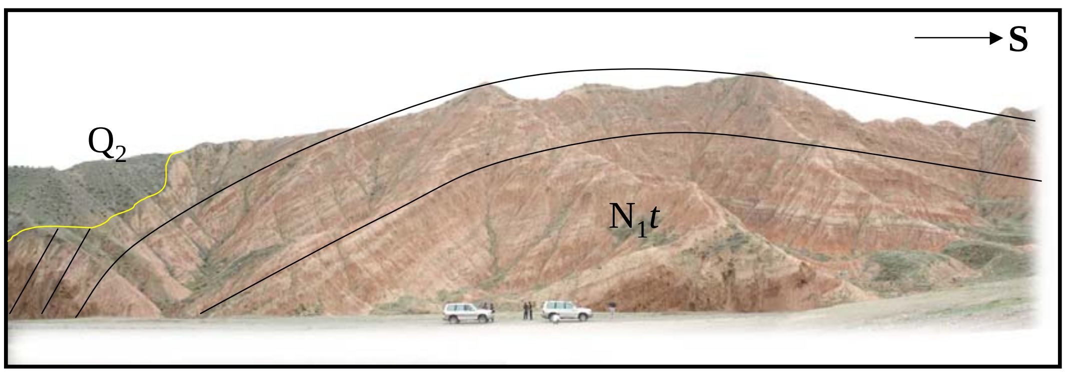
（Seismic data are provided by Xinjiang Oilfield Company） (After Guan & He)

Q-N_2d—Pliocene-Quaternary; N_1t—Miocene Taxihe formation; (E_3-N_1)s—Eocene-Miocene Shawan formation; $E_{2\text{-}3}a$—Eocene-Oligocene Anjihaihe formation; $E_{1\text{-}2}z$—Paleocene Ziniquanzi formation; K_2d—Upper Cretaceous Donggou formation; K_1tg—Lower Cretaceous Tugulu formation; J_2x—Middle Jurassic Xishanyao formation

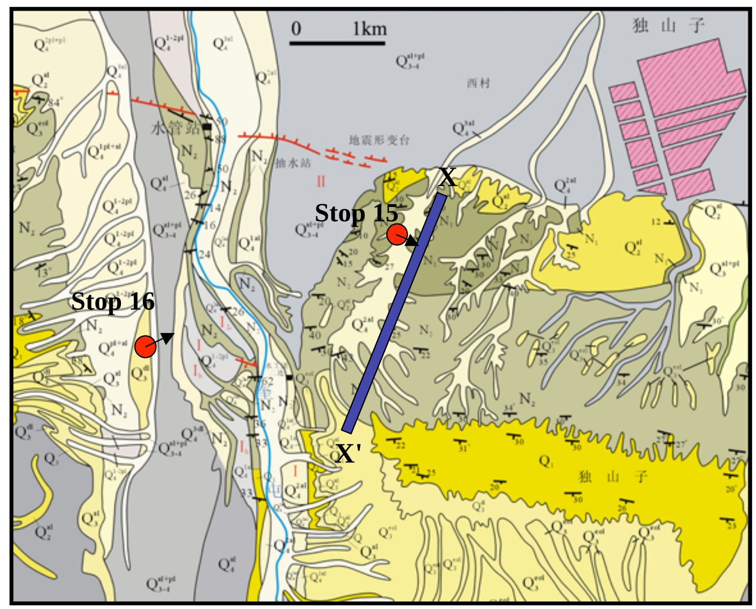
Stop15 Dushanzi Anticline

Dushanzi anticline is composed of the lower Pleistocene Xiyu formation, Pliocene Dushanzi formation and Miocene Taxihe formation. The surface anticline is wide and gentle, the southern limb dips 15-25°S, but beds in the northern limb dip more steeper near the thrust fault.

The core of Dushanzi anticline

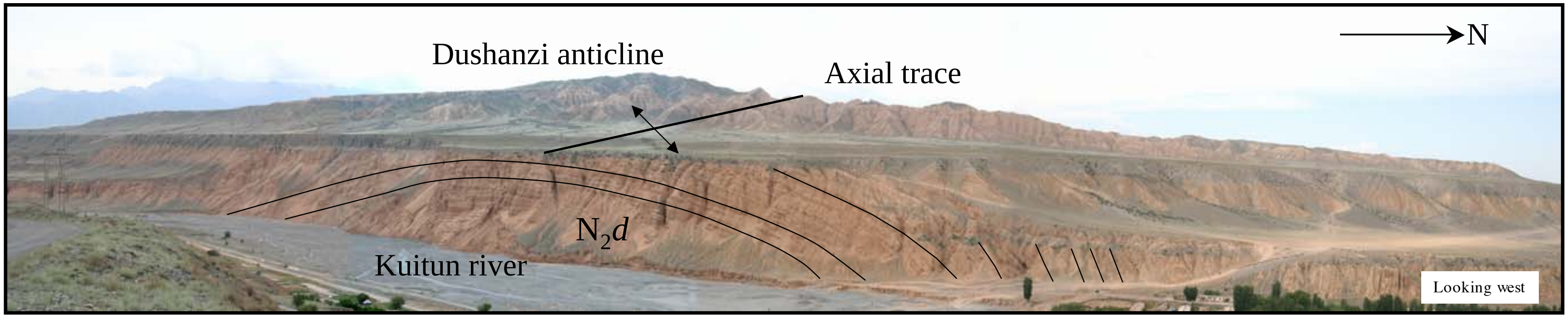


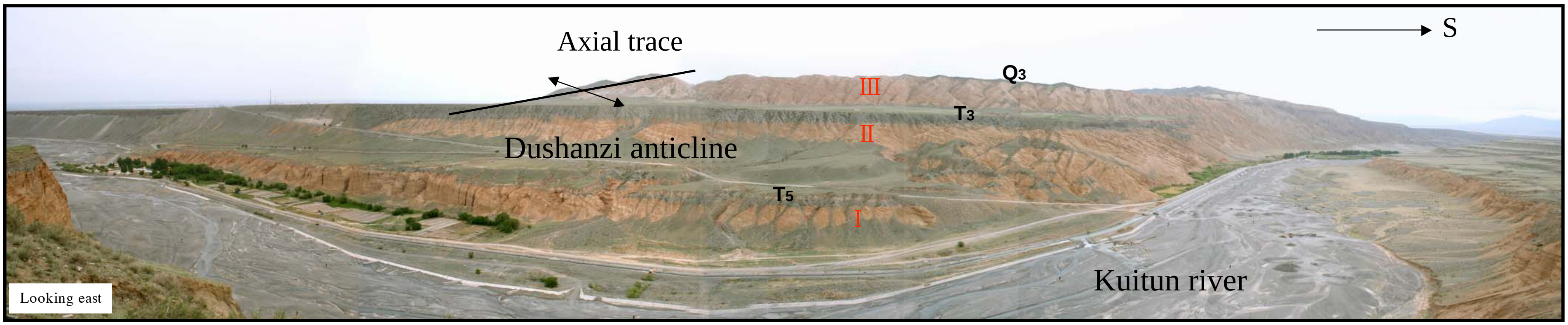
Stop15 location map



（base map from Deng et al., 2000)

Stop 16 Dushanzi Anticline and Kuitun River Terraces

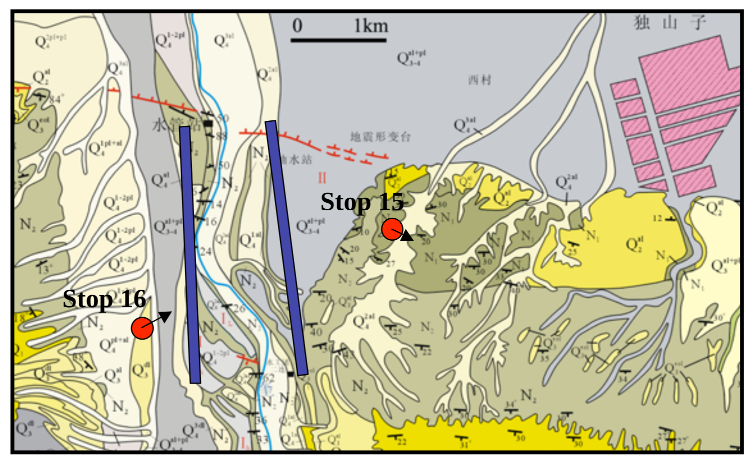




The north-flowing Kuitun river incises the Dushanzi anticline perpendicular to the strike. River terraces are preserved on both sides of the present river valley along the piedmont reach. Three major levels, labeled I to III are identified, level I is 10-40m high than the river valley. Within level I of the northern flank of anticline, there are three sub levels. Level II is distributed in succession along both sides of the river, but absent in the Dushanzi anticline east of riverside. Level III distributes above the crest of anticline. These terraces are covered by the dark gravel layer, which is unconformably overlying the lower Pleistocene Xiyu Formation and Pliocene Dushanzi Formation. The terraces of the anticlinal core and flanks are deformed, and a several meters high fault scarp is observed in the level II of the northern flank, indicating that Dushanzi anticline is active.

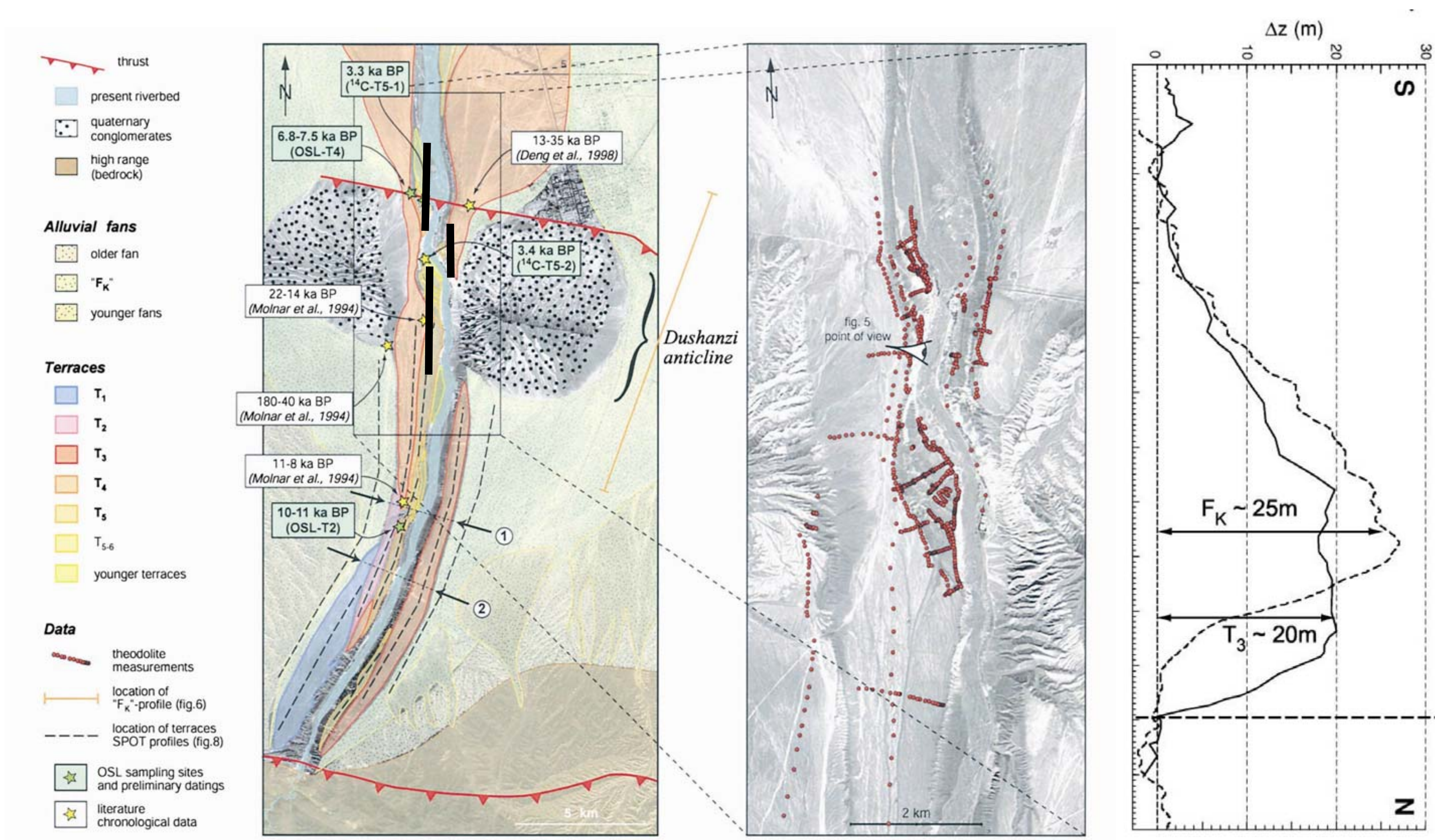
Poisson & Avouac (2004) have studied the deformation and incision of the Kuitun River terraces in detail, as shown on the next page. Terrace T3 was abandoned after 7Ka with 130m incision and Terrace T5 around 3.3Ka with 55m of incision in the area east of the river shown in the lower photograph above. Only about 10% of the river incision is due to deformation, whereas most reflects post-glacial climate change. The terrace profile shown on the next page, which has the regional fan gradient removed, indicates a maximum uplift at the anticlinal crest for the T3 terrace of ~20m and an area of structural relief of about 0.12 km^2, with an average crestal uplift rate of ~3 mm/yr for the last 7Ka.

Stop 16 Location Map



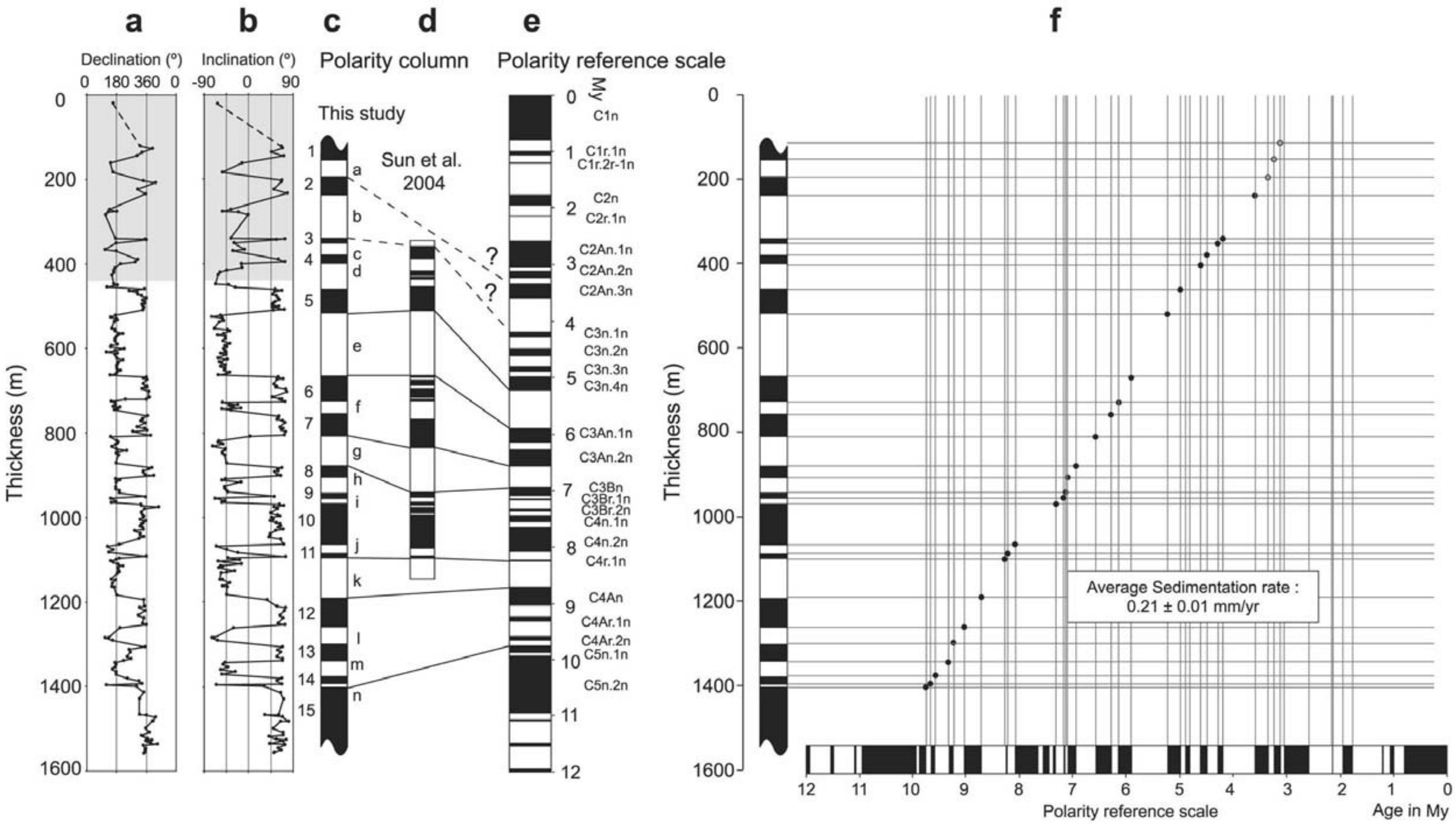
（base map from Deng et al., 2000)

Stop 16 Dushanzi Anticline and Kuitun River Terraces



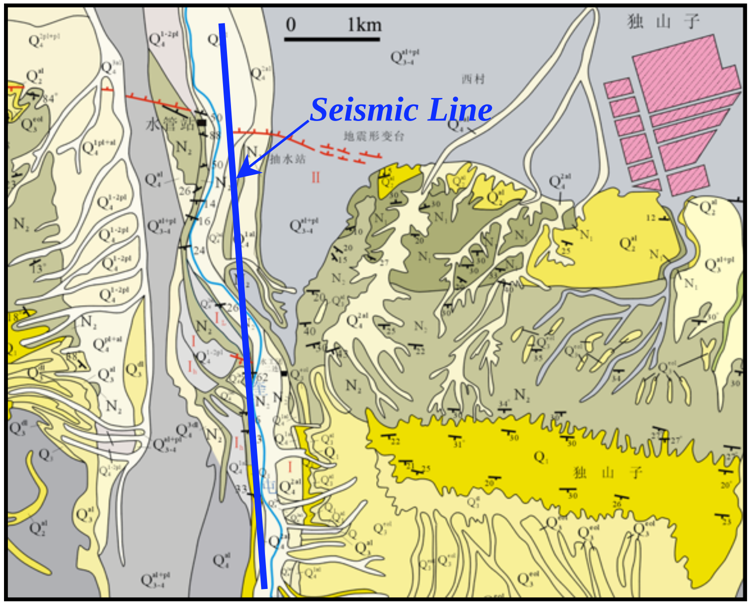
Geomorphic interpretation of the KuitunRiver terraces superimposed on Landsat 7 (*left*) and SPOT (*right*) panchromatic images, and location topographic field surveys (after Poisson and Avouac, 2004). The two topographic profiles have the normal alluvial gradient removed to show the structural growth since the deposition of the F_k and T_3 surfaces. Black line represents magetostratigraphic section made by Charreau et al (2005).

Stop 16 Dushanzi Anticline and Kuitun River Terraces



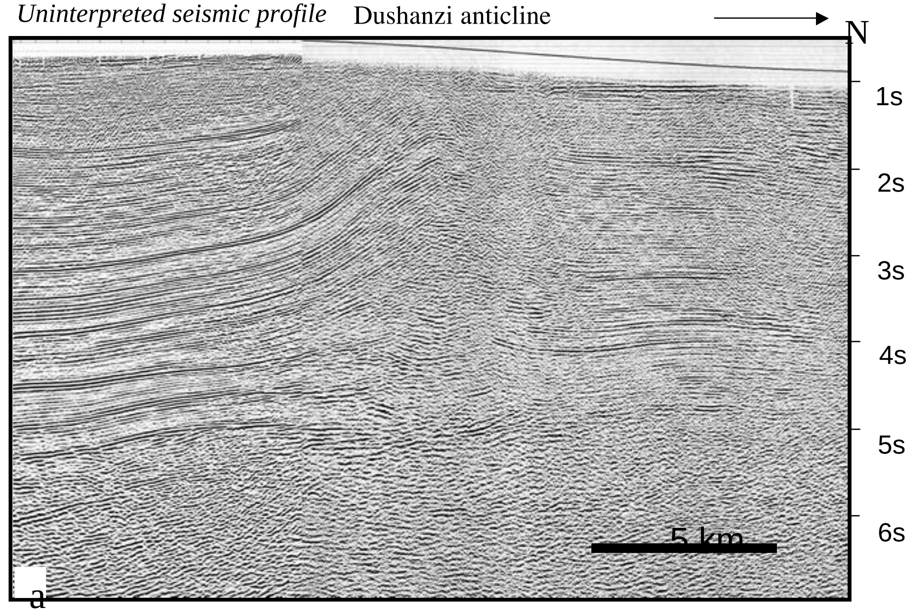
(a) Magnetic declination and (b) magnetic inclination corresponding to the samples fit with principal component analysis. The shaded area corresponds to the conglomerate-rich Xiyu Formation. (c) magetostratigraphic column from Charreau et al. and (d) from Sun et al. (e) Reference polarity time scale after Berggren et al. (f) age versus depth plot of the Kuitun section (After Charreau et al., 2005)

Stop 16 Dushanzi Anticline and Kuitun River Terraces

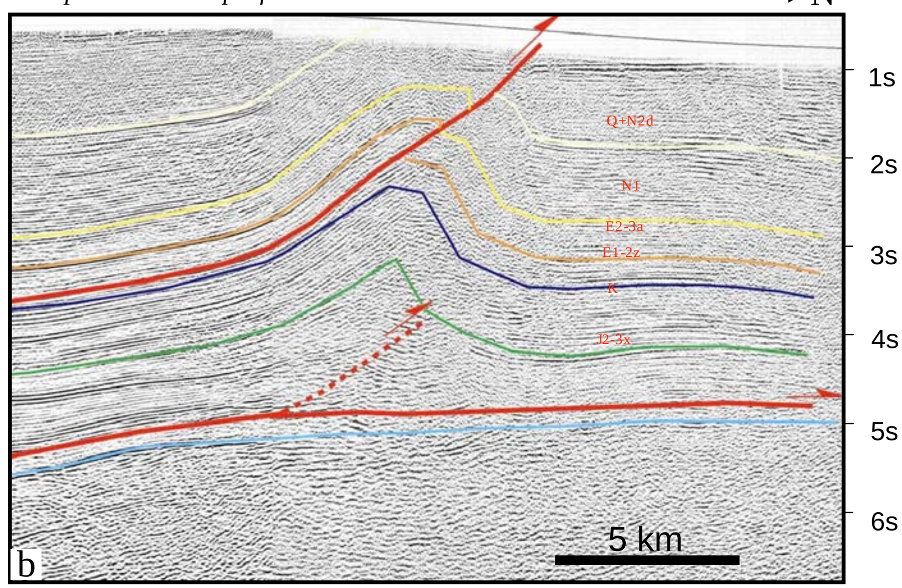


（base map from Deng et al., 2000)

Uninterpreted seismic profile Dushanzi anticline



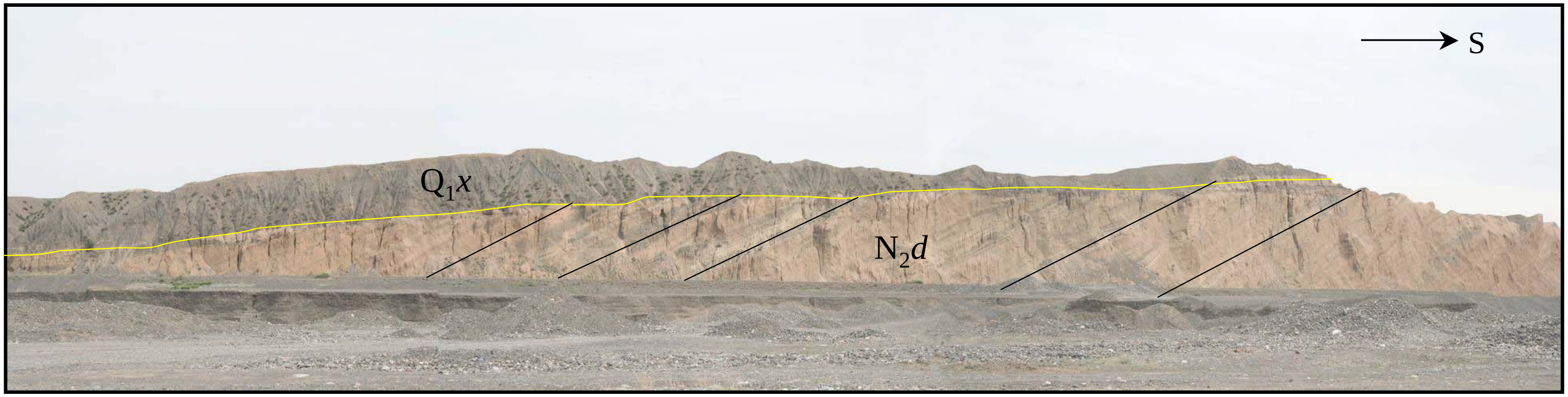
Interpreted seismic profile



（Seismic data are provided by Xinjiang Oilfield Company）

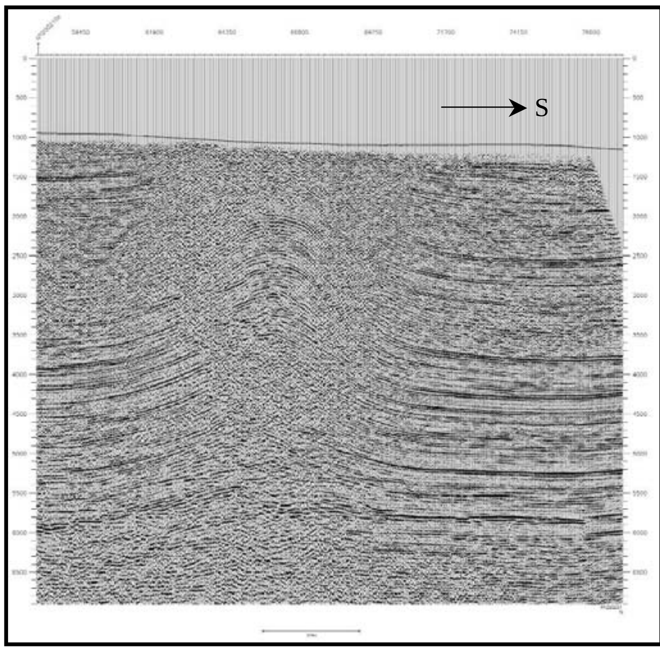
In seismic profile, the Dushanzi anticline is imbricated by the shallow fault propagation fold and the deep detachment fold, the shallow anticline is developed above the south-dipping thrust, which reach the surface and offsetting the youngest sediments, with main detachment located just below the characteristic strong reflections corresponding to the mud layers of the Paleogene Anjihaihe Formation. The Pliocene Dushanzi Formation and overlying strata thin gradually from the flank toward the crest and display fanning of dips, these phenomena suggest that the deformation of Dushanzi anticline may have started since Pliocene, and also indicate that the Dushanzi anticline has a component of limb rotation in fold growth.

Stop17 Anjihai Anticline

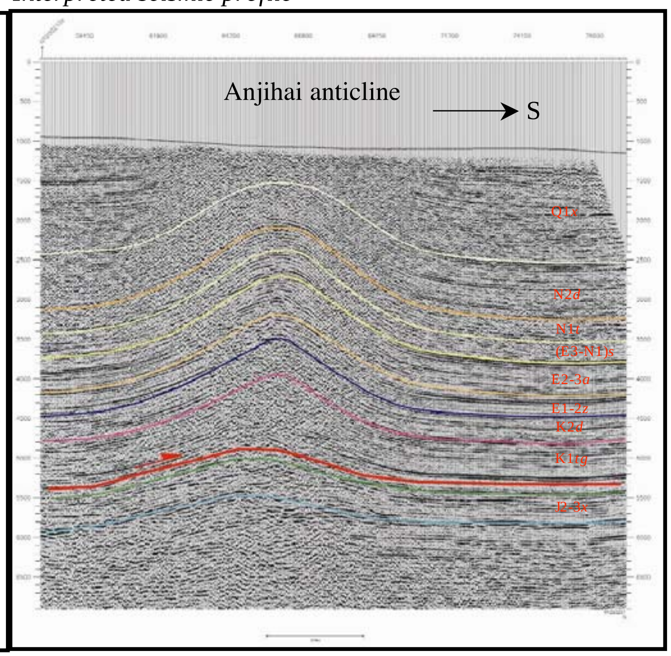


The surface anticline is composed of the lower Pleistocene Xiyu Formation and Pliocene Dushanzi Formation, the crest of anticline is covered by Quaternary. The surface anticline is wide and symmetrical (15-25º dip). Photographs show early Pleistocene Xiyu Formation uncomformable on the Pliocene Dushanzi Formation in the north limb of Anjihai anticline.

Uninterpreted seismic profile



Interpreted seismic profile



（Seismic data are provided by Xinjiang Oilfield Company）

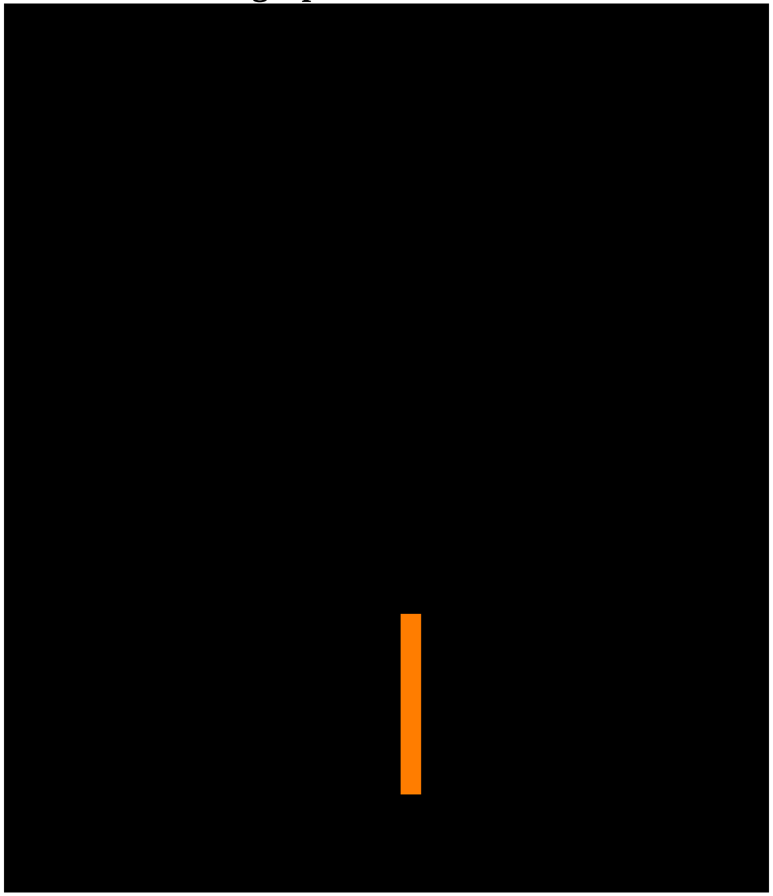
(After Guan & He)

In seismic profile, the Anjihai anticline is a detachment fold with the main detachment located in the lower Cretaceous. The upper strata on both limbs present fan-shaped dips, thinning toward the anticlinal core, which indicate they were deposited during the growth of the fold.

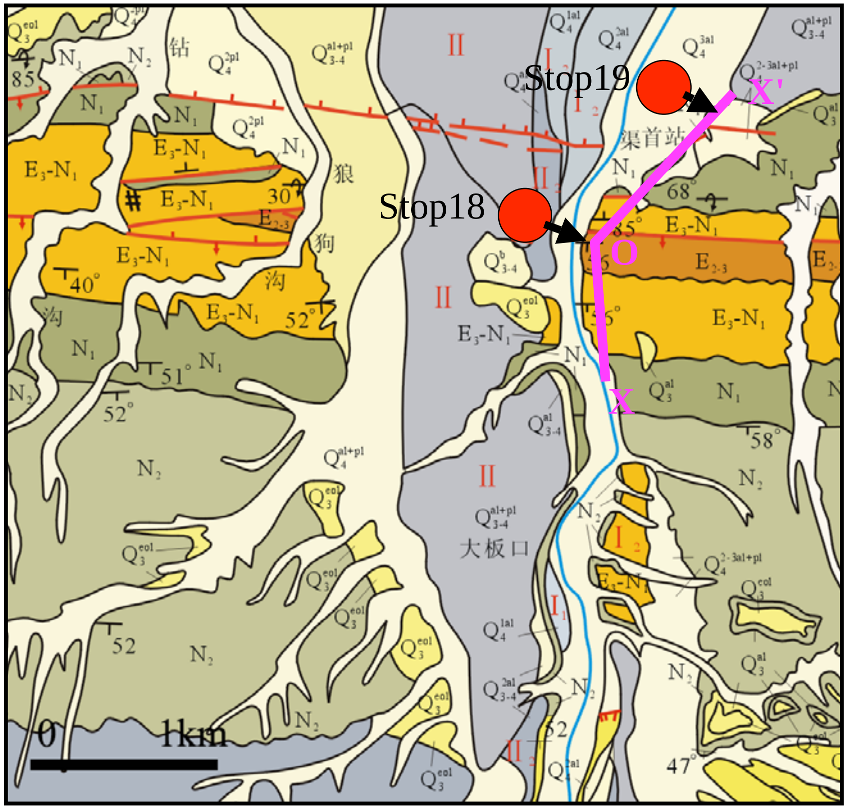
Q_1x-Pleistocene Xiyu Formation ; N_2d-Pliocene Dushanzi Formation; N_1t-Miocene Taxihe Formation; $(E_3$-$N_1)s$-Miocene Shawan Formation; $E_{2\text{-}3}a$-Eocene-Oligocene Anjihaihe Formation; $E_{1\text{-}2}z$-Paleocene Ziniquanzi Formation; K_2d-Upper Cretaceous Donggou Formation; K_1tg-Lower Cretaceous Tugulu Formation; J_2x-Middle Jurassic Xishanyao Formation

Stop18 Huo’erguosi Anticline

Stratigraphic column

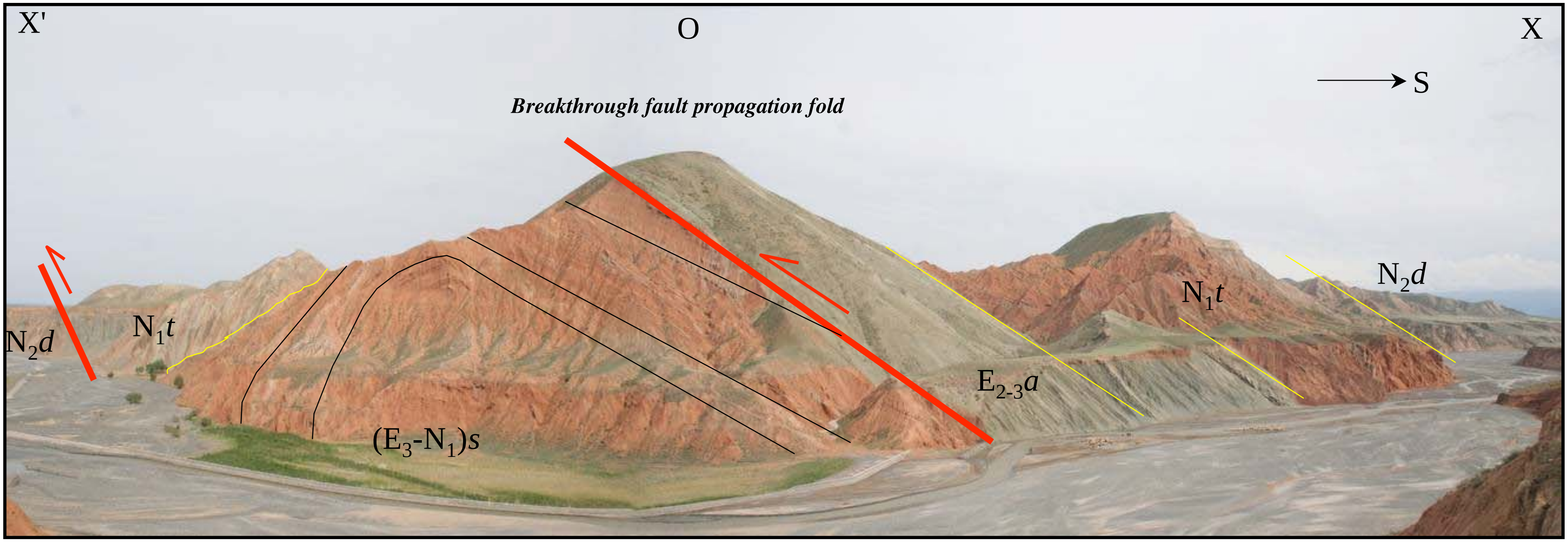


Stop 18 & Stop 19 location map



（base map from Deng et al., 2000)

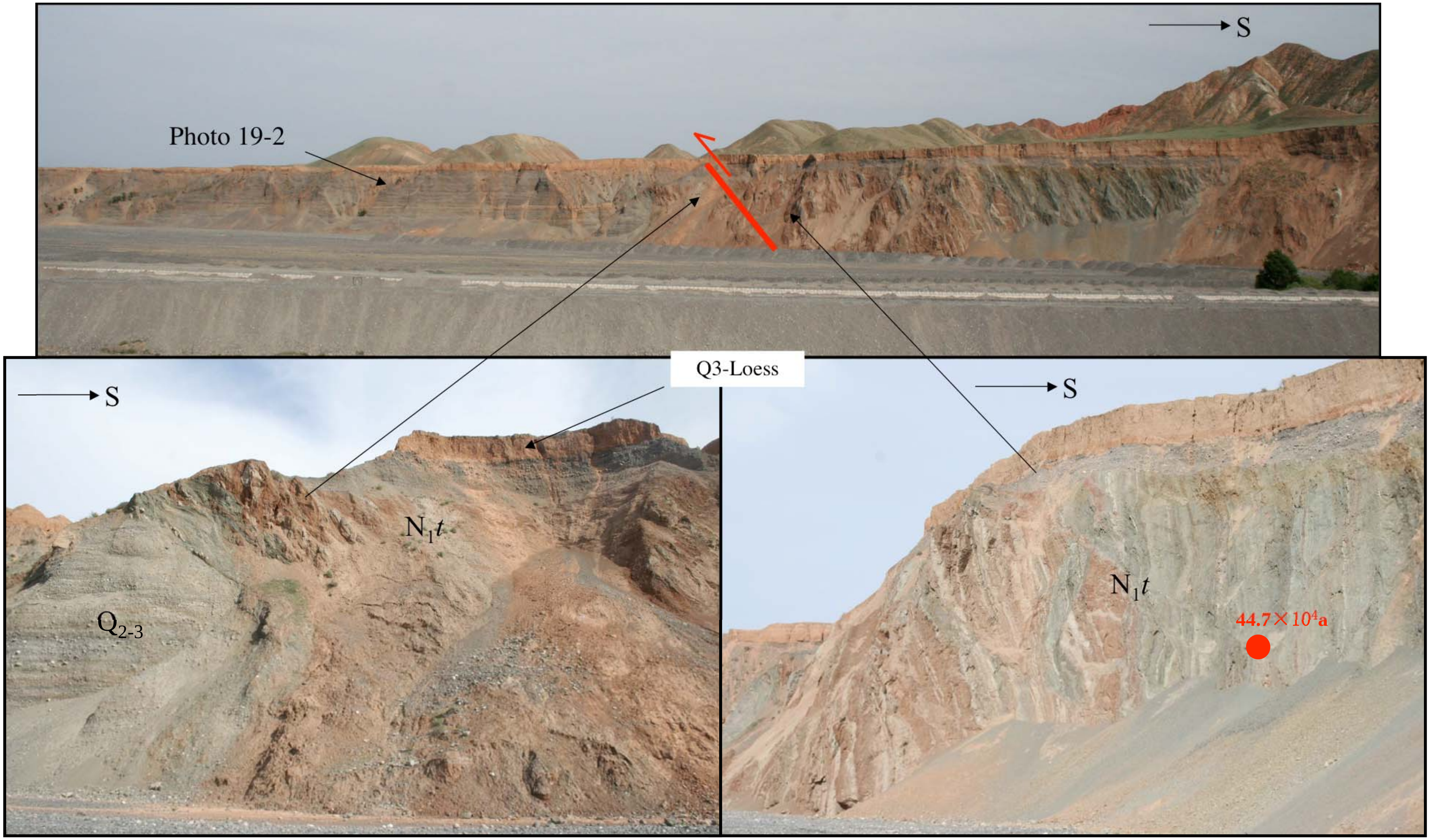
Stop 19 Faults that Cut through the Huo'erguosi Anticline and Fault Scarp on the Surface



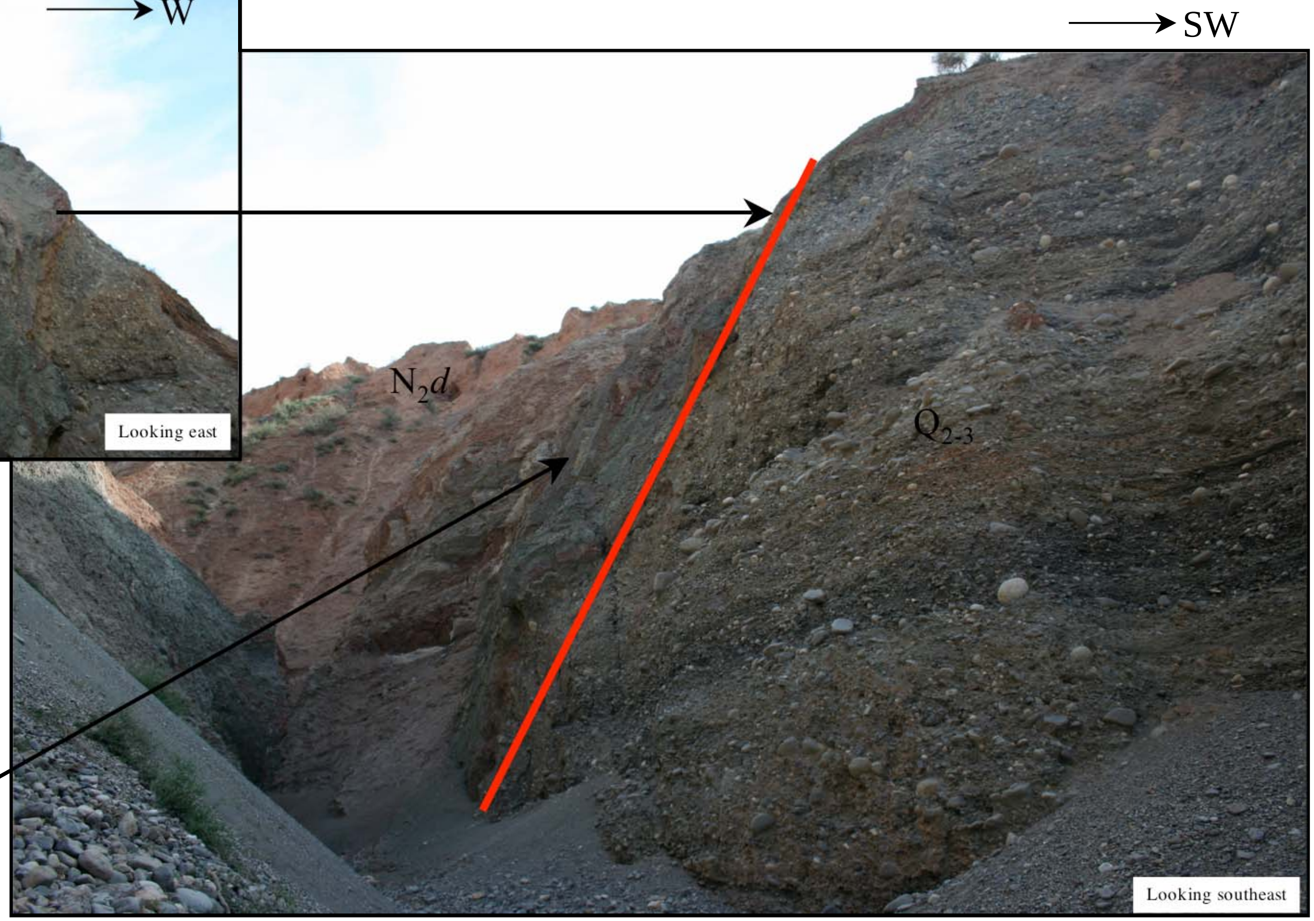
The surface anticline is asymmetric with the southern limb dipping 50-60º and the northern limb steeply dipping or overturn. The thrust cuts through the northern limb of anticline and produces a well-displayed fault scarp in alluvial surfaces west of the Jigou River. The highest T_0 terrace is offset 11.4m, the T_1 offset 4.6m, the T_2 offset 4.0m, and T_3 offset 2.4m (Avouac et al. 1993).

Stop 19 Faults that Cut through the Huo’erguosi Anticline and Fault Scarp on the Surface

A several meters wide fracture zone was observed in a small side valley about 500m northeast of the dam station, the fault-plane dips about 60ºS. Beds in Pliocene Dushanzi Formation of hanging wall dip steeply, but beds in middle to upper Pleistocene and Holocene are nearly level and 1-2m thick loess were found in the middle and upper of these strata. This fracture zone produces about 3 m high fault scarp on the surface, ESR ages of Quartz veins sampled from the fracture zone is about 44.7×10^4a(He et al., 2003).



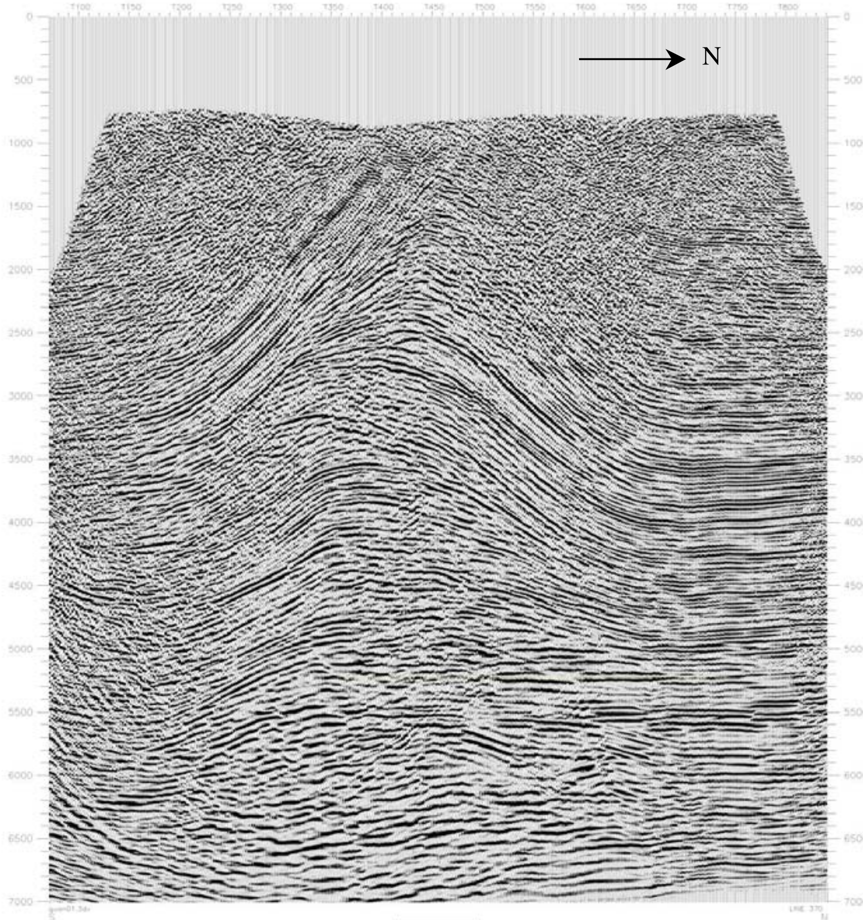
Stop 19 Faults that Cut through the Huo'erguosi Anticline and Fault Scarp on the Surface



The characteristic of fault zone in the northern flank of Huoerguoshi anticline (see the photo in previous page for location)

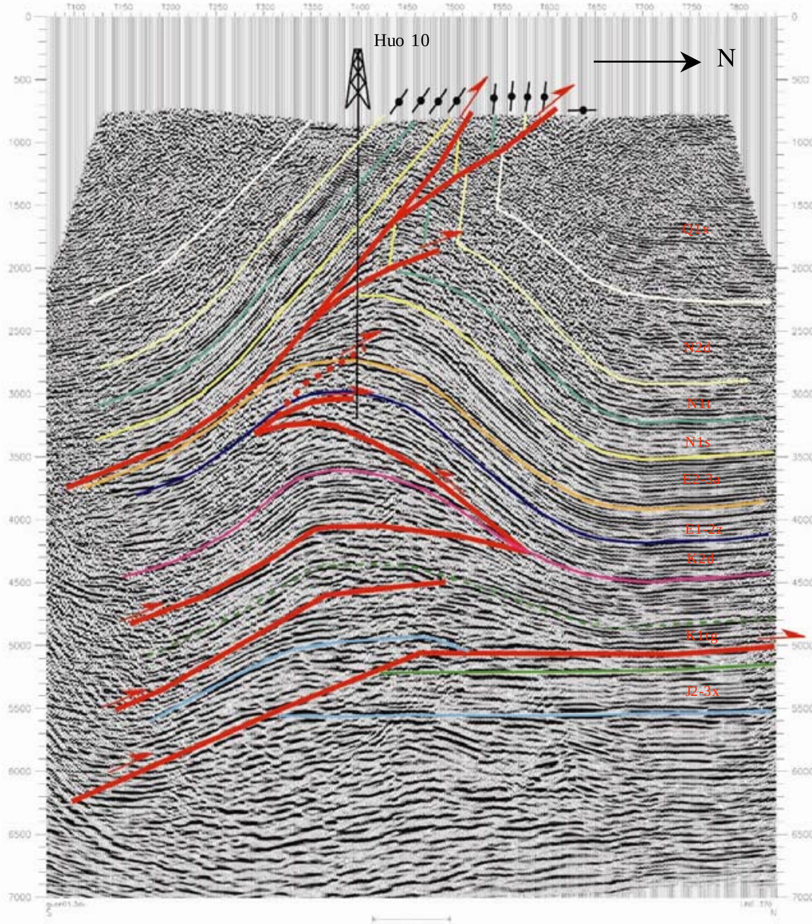
Stop 19 Faults that Cut through the Huo'erguosi Anticline and Fault Scarp on the Surface

3D Uninterpreted seismic profile



（Seismic data are provided by Xinjiang Oilfield Company）

3D Interpreted seismic profile



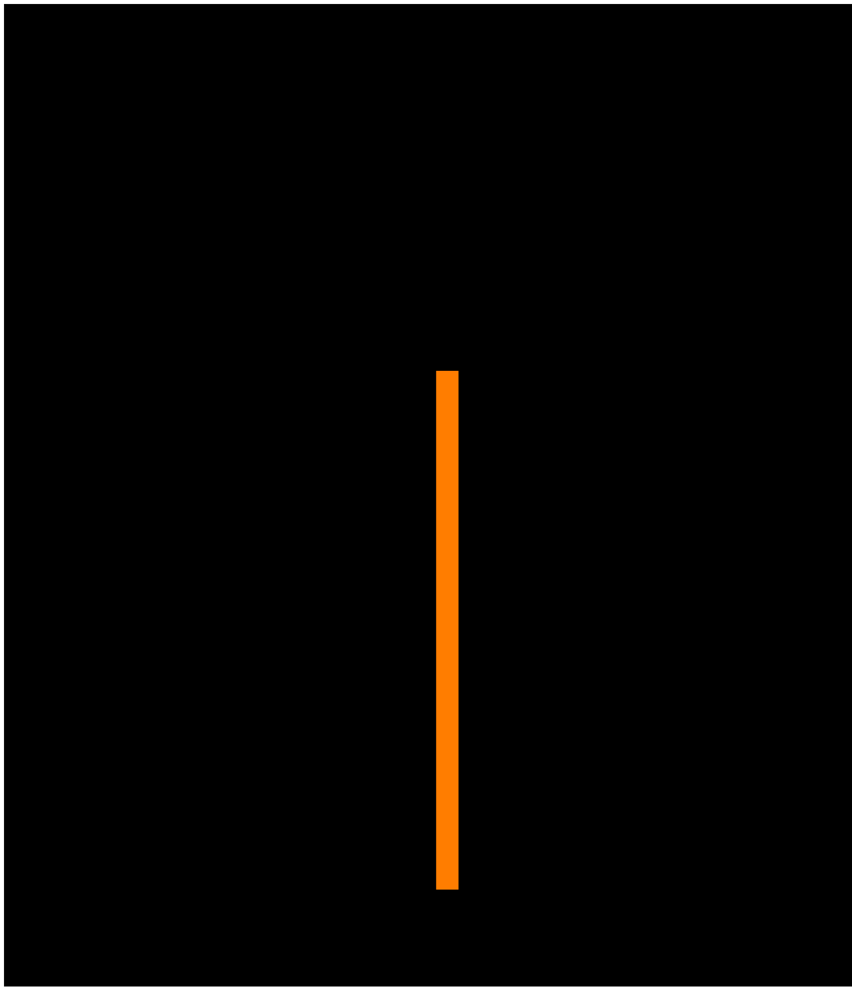
(After Guan & He)

The deep Huoerguosi anticline is a fault bend fold with the upper decollement horizons of underlying thrust located in the mud layers of Lower Cretaceous and lower decollement horizons located below the coal layers of Lower to Middle Jurassic Xishanyao Formation. The southern limb dips consistently, but the northern limb is composed of three dip domains, which may be caused by wedge thrust in the hinge of anticline. Growth strata are recognized on the northern limb of deep anticline, the bottom boundary of growth strata is located in the lower part of the Pliocene Dushanzi Formation, which suggests the deformation of Dushanzi anticline started in the early Pliocene.

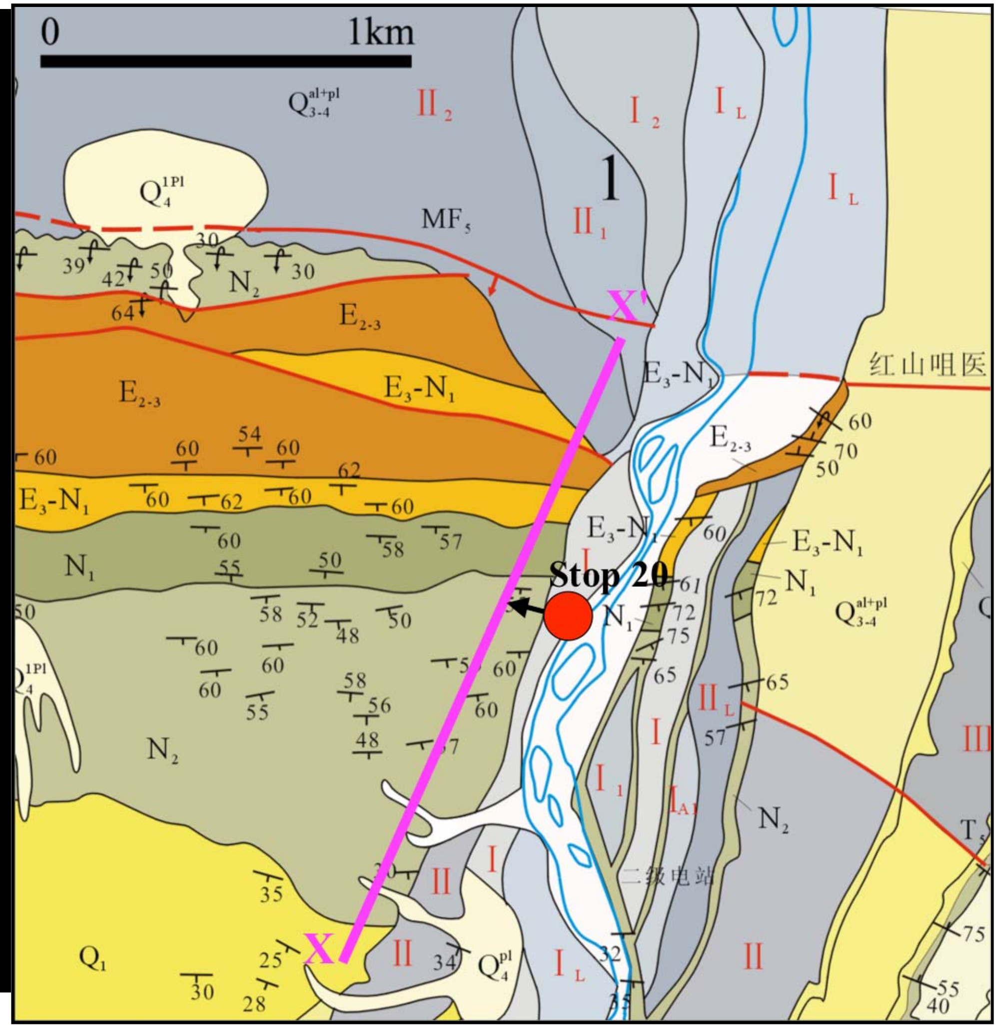
Q_1*x*-Pleistocene Xiyu Formation ; N_2*d*-Pliocene Dushanzi Formation; N_1*t*-Miocene Taxihe Formation; (E_3-N_1)*s*-Miocene Shawan Formation; E_{2-3}*a*-Eocene-Oligocene Anjihaihe Formation; E_{1-2}*z*-Paleocene Ziniquanzi Formation; K_2*d*-Upper Cretaceous Donggou Formation; K_1*tg*-Lower Cretaceous Tugulu Formation; J_2*x*-Middle Jurassic Xishanyao Formation

Stop 20 Manasi Anticline, west bank of Manasi River

Stratigraphic column

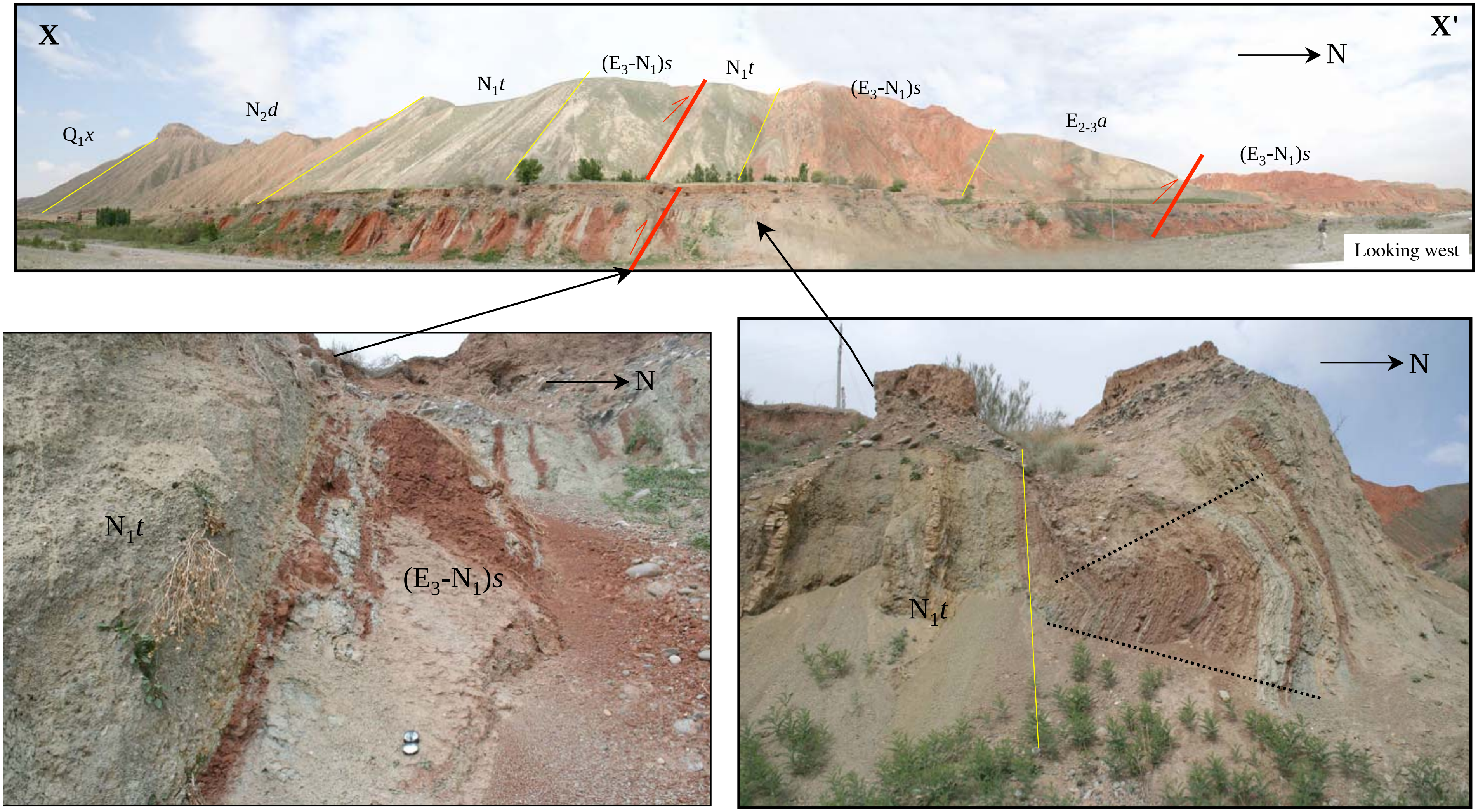


Stop 20 location map



(base map from Deng et al., 2000)

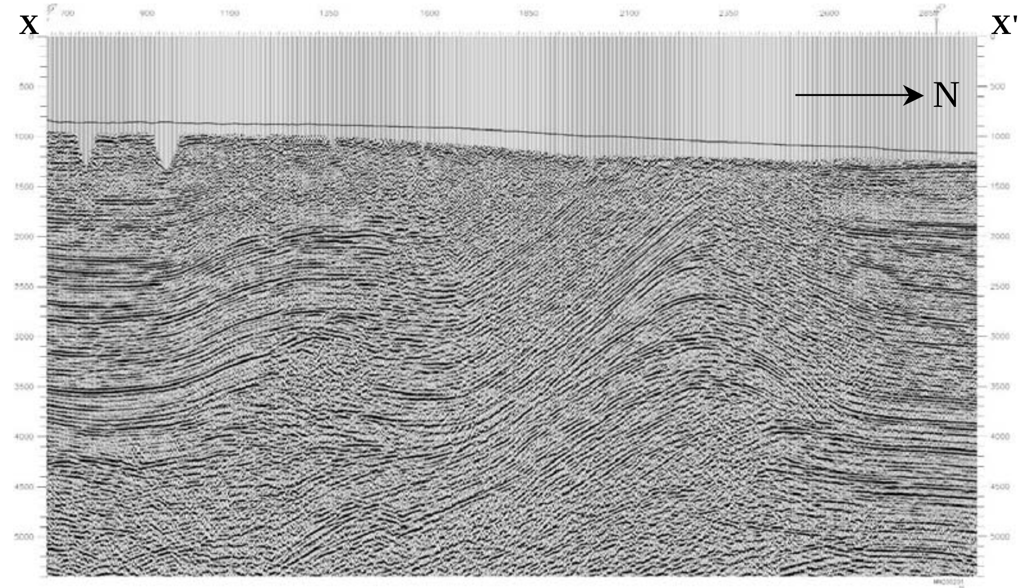
Stop 20 Manasi Anticline, west bank of Manasi River



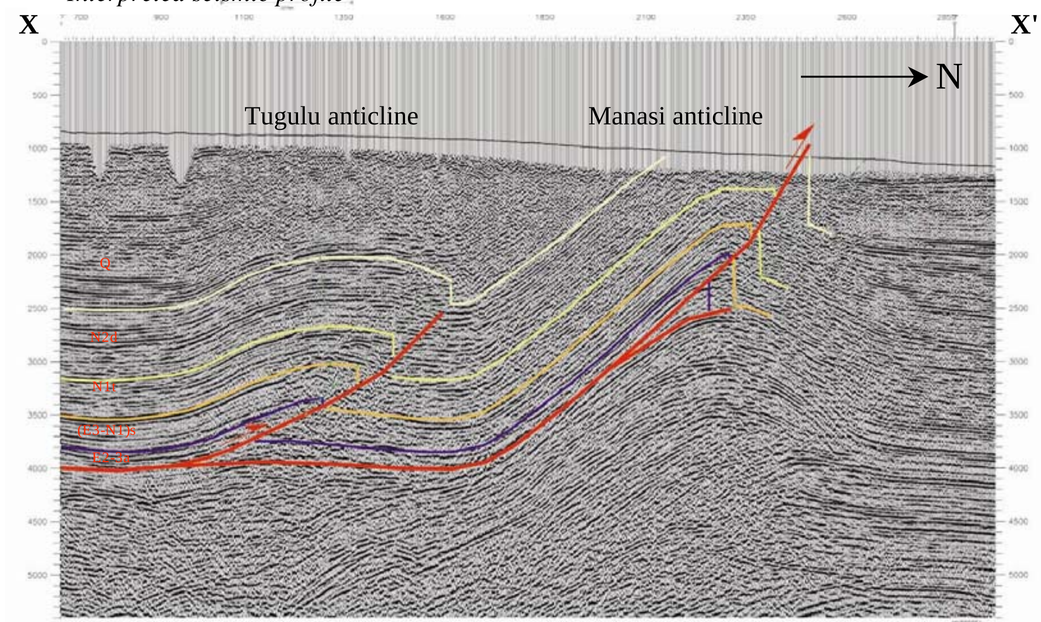
The Manasi anticline is a fault propagation fold. The surface anticline displays asymmetry, with the north limb much steeper and narrower than the south limb. Three south dipping faults cut through the anticline, and caused the multi-repeat of Eocene-Oligocene Anjihaihe Formation, Miocene Shawan Formation and Taxihe Formation. The fault in north limb produces fault scarp almost of 3m high on the surface. ESR ages of quartz veins and gypsum veins sampled from the faults is about $3.8\sim14.2\times10^4$a (He et al., 2003).

Stop 20 Manasi Anticline, west bank of Manasi River

Uninterpreted seismic profile



Interpreted seismic profile

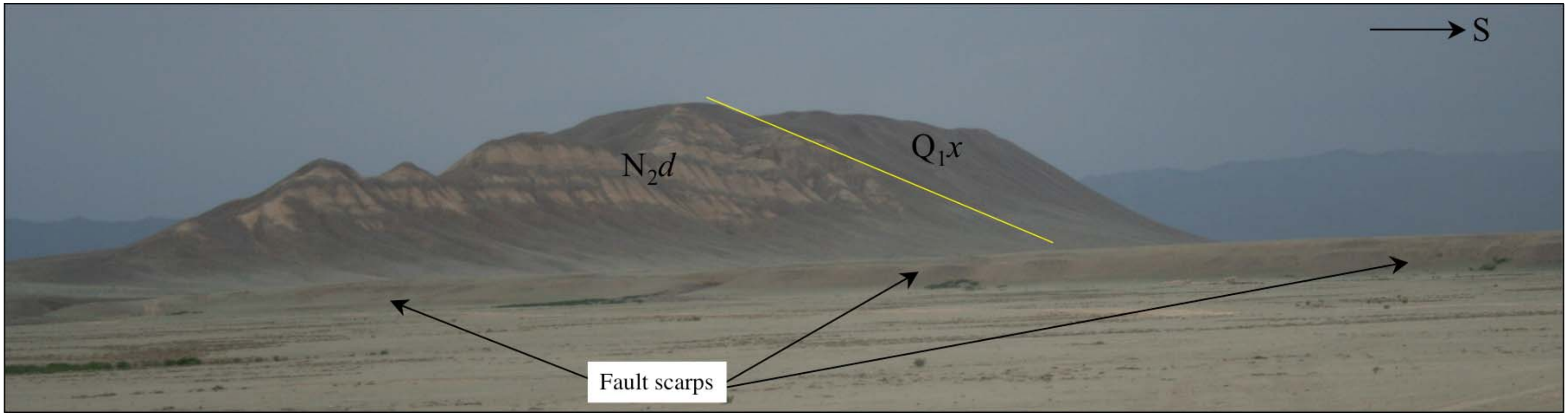


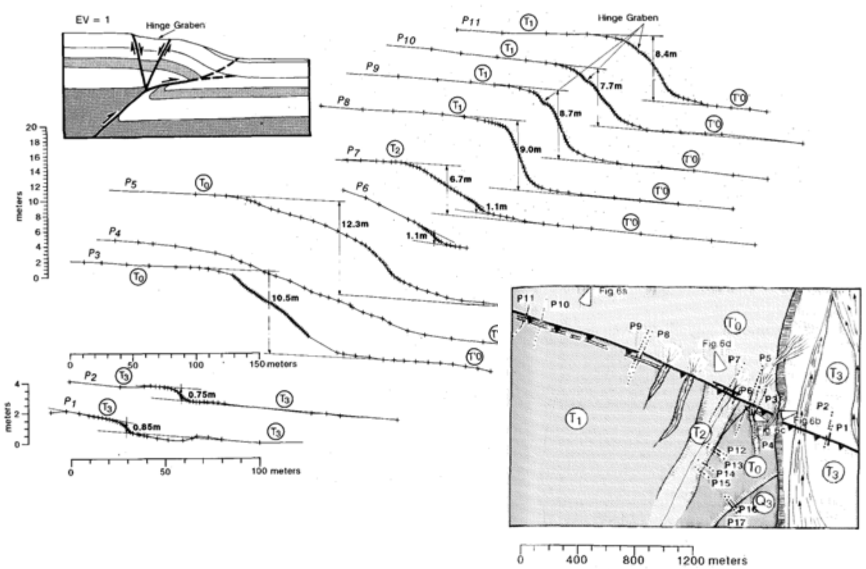
（Seismic data are provided by Xinjiang Oilfield Company） (After Guan & He, 2005)

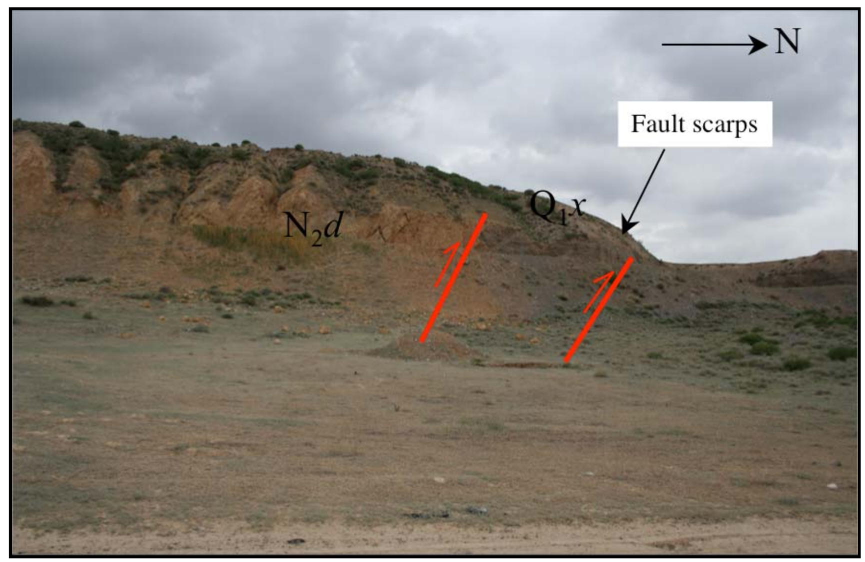
Southward along the Manashi River valley, the western termination of Tugulu anticline can be observed, the two anticlines were interpreted to be imbricate structure in seismic line(see remote sensing image for location).

Q-N_2d: Pliocene-Quaternary; N_1t:Miocene Taxihe Formation; $(E_3$-$N_1)s$:Eocene-Miocene Shawan Formation; $E_{2\text{-}3}a$:Eocene-Oligocene Anjihaihe Formation; $E_{1\text{-}2}z$:Paleocene Ziniquanzi Formation

Stop 21 Tugulu Thrust Fault and Fault Scarps



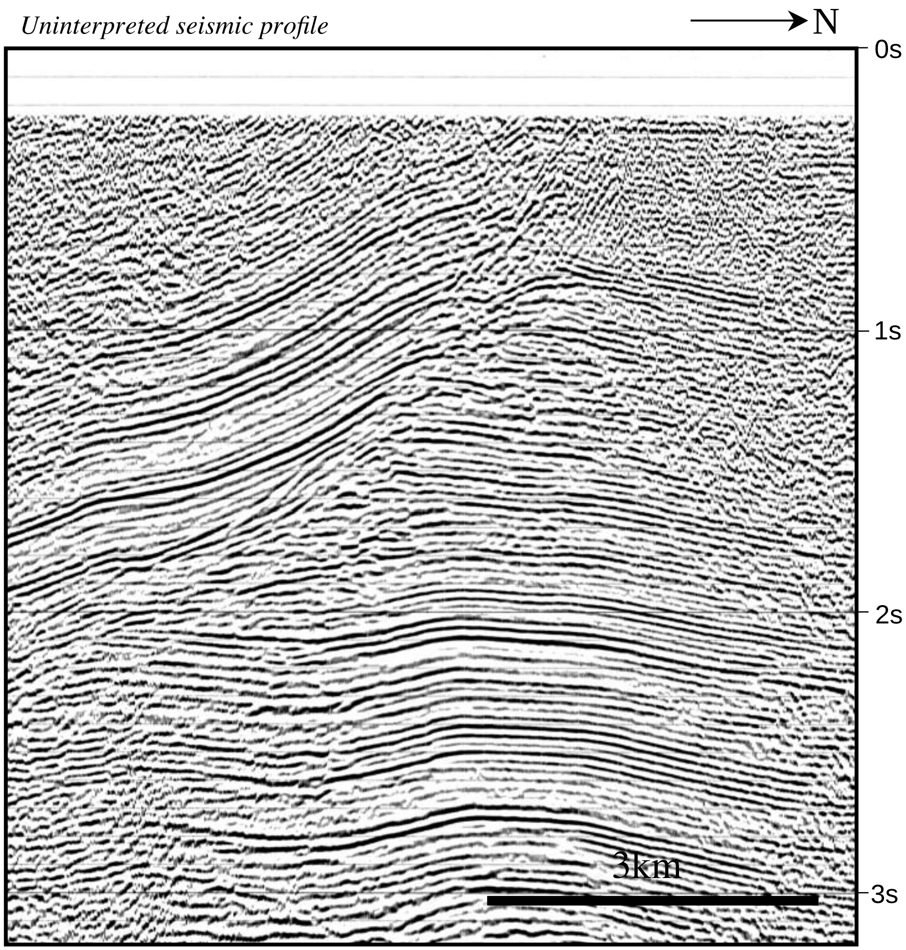




The thrust in the north limb of Tugulu anticline produces well-preserved fault scarps west of the HutuBi River. The highest Q_0 terrace is offset 15.6m, the T_0 terrace offset 11.1m, the T_1 offset 8.5m, the T_2 offset 6.7m, and T_3 offset 0.83m (Avouac et al. 1993). The terraces of the anticlinal core and flanks are deformed, indicating that the Tugulu anticline is actively folding. ESR ages of gypsum veins sampled from the fault zone is about $12.5\sim64.3\times10^4$a (He et al., 2003).

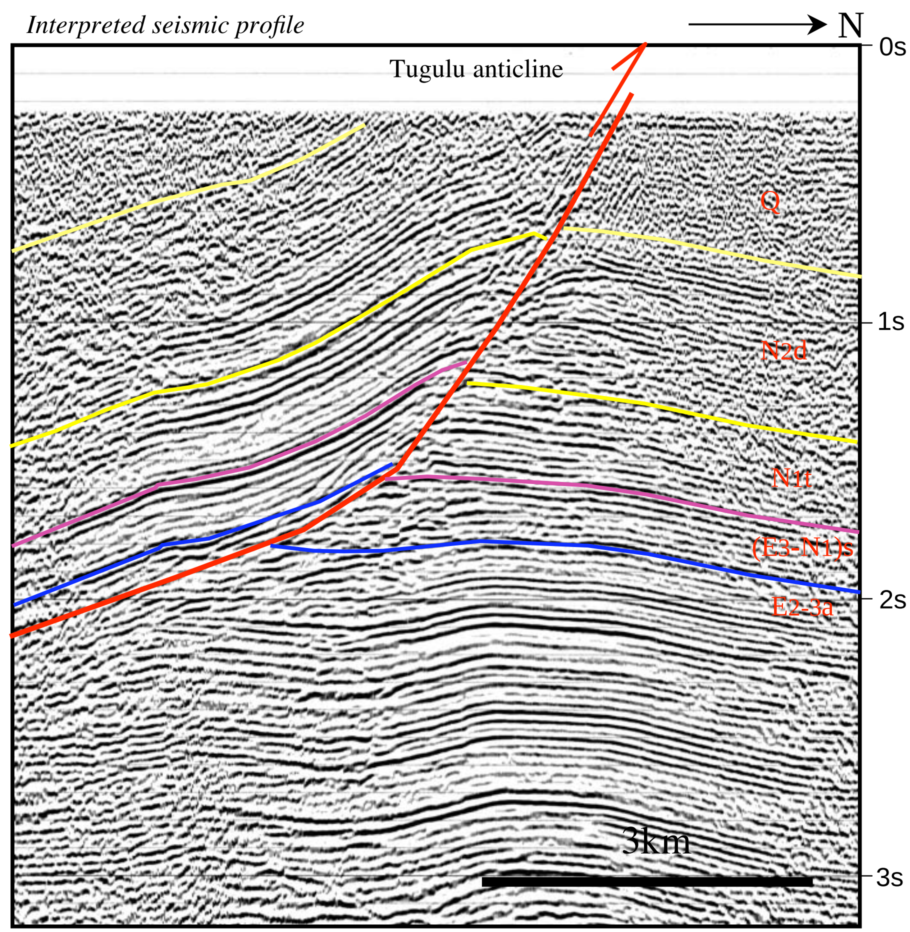
Stop 21 Tugulu Thrust Fault and Fault Scarps

Uninterpreted seismic profile



Seismic line cross Tugulu anticline

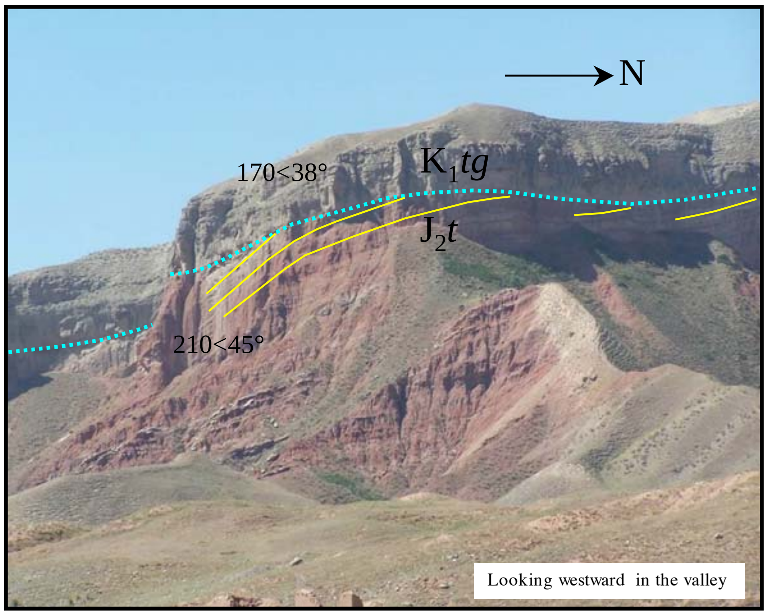
Interpreted seismic profile



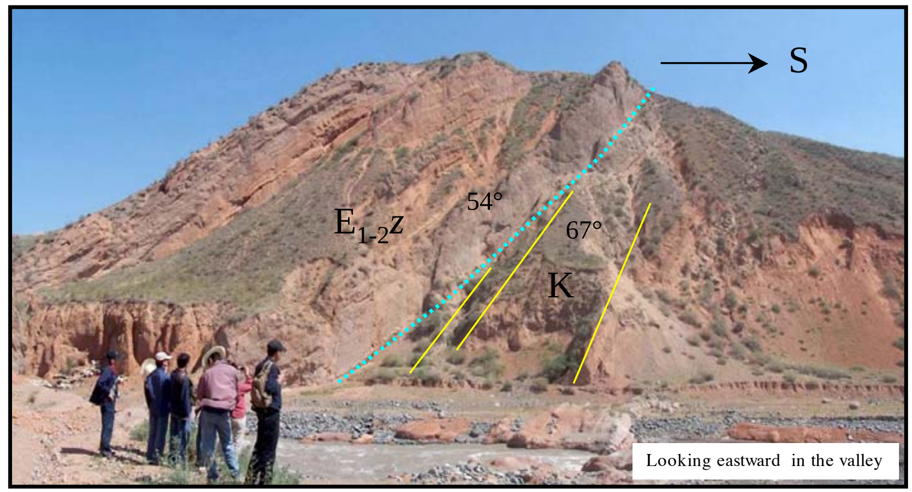
（Seismic data are provided by Xinjiang Oilfield Company）

Q_1x-lower Pleistocene Xiyu formation ; N_2d-Pliocene Dushanzi formation; N_1t-Miocene Taxihe formation; $(E_3$-$N_1)s$-Miocene Shawan formation; $E_{2\text{-}3}a$-Eocene-Oligocene Anjihaihe formation

Stop 22 Qigu Anticline



Unconformity between middle Jurassic and lower Cretaceous



Unconformity between Paleogene and upper Cretaceous

The Qigu anticiline trends east-west (280º) for more than 17 km, the northern limb dips (24~45º) more steeper than the southern limb (30-56º), the crest of anticline is lower Cretaceous, which is marked unconformable with the underlying strata. Northward along the Hutubi river, Jurassic, Cretaceous, Paleogene, Neogene and Holocene outcrop in the northern limb in turn, thereinto, the unconformity between Cretaceous and Paleogene can be observed.

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