The Altyn Tagh Fault

edited by

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Note: In PDF format most of the images in this web paper can be enlarged for greater detail.

The Altyn Tagh Fault and Integrated Science

The study of the Altyn Tagh fault and the geology of China's deserts is an example of the emerging field of Earth systems science, in which geologists and chemists try to document changes in Earth's environment throughout the planet's history, and biologists try to understand how the core metabolic processes of life are distributed on the planet's surface (Falkowski, 2007). China's northwest region, which includes the provinces Xinjiang and Qinghai, is situated near the center of the Eurasian continent. The region's great distance from the ocean and extreme geomorphic features have resulted in some of the Earth's oldest and driest deserts (Guo, et al., 2002). These deserts are a legacy of the collision of the Indian and Eurasian plates, which started ~50 Mya (Zhu, et al., 2005) and continues today. The collision of India with Asia has had profound effects on the Earth that include widely distributed deformation and extrusion of continental blocks, the inception of the Indian monsoon, changes in seawater geochemistry, and the uplift of the world's highest mountains, and largest and highest plateau, the Himalayas and the Qinghai-Tibetan Plateau. The high altitude deserts in the Qinghai-Tibetan Plateau have been shown to have the coldest and driest recorded extremes for lithic cyanobacterial communities on Earth (Warren-Rhodes, et al., 2007).

For all these reasons, understanding the geomorphology of the Altyn Tagh fault integrates our understanding of our world from plate tectonics, to desertification, to the limits that global ecology places on humanity's attempts to use nature beyond sustainable limits. Both Xinjiang and Qinghai provinces suffer from modern anthropogenic impacts that accelerate desertification. The degradation has been made worse by steadily increasing economic demands within this region of China. These demands are the result of a population exceeding the land's carrying capacity and depleting the already limited water resources (Gu & Seiler, 2006; Yang, Dong & White, 2006).

This web paper is part of a series of papers on freshwater shortage and desertification in Asia. In addition to this paper the series includes:

Freshwater Shortage and Desertification
http://fire.biol.wwu.edu/trent/alles/WaterShortage.pdf

China's Deserts
http://fire.biol.wwu.edu/trent/alles/ChinaDeserts.pdf

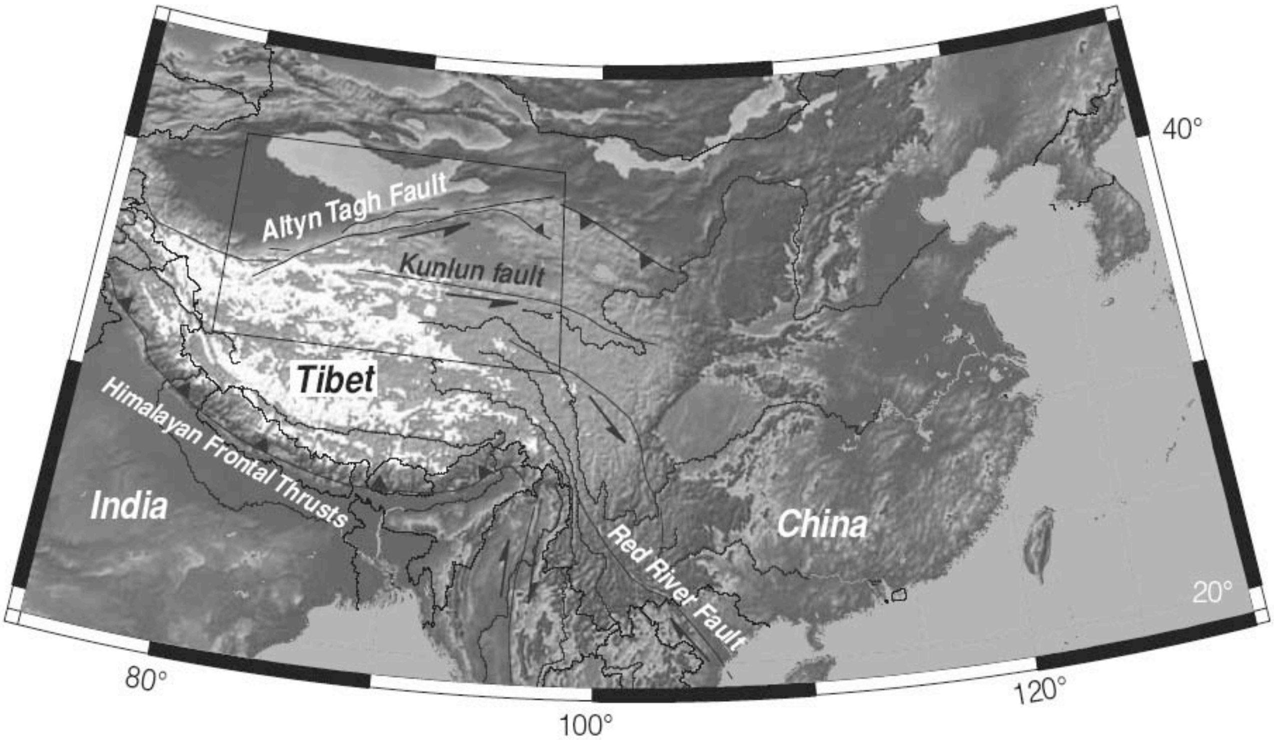
The Aral Sea
http://fire.biol.wwu.edu/trent/alles/AralSea.pdf

This case study on freshwater shortage in Asia is in addition to my series on freshwater shortage in the American southwest.

The Colorado River: An Ecological Case Study
http://fire.biol.wwu.edu/trent/alles/ColoradoRiver.html

The common thread in all of these papers is to show how coupled natural systems and human interactions have led to what may be the defining ecological crisis of our times—a chronic shortage of freshwater in large parts of the world.

This paper also represents an attempt to integrate new technology into science education. I have made extensive use of Google Maps and Google Earth in the paper and have provided latitude and longitude coordinates so anyone with internet access can go directly to the locations shown and explore them further.



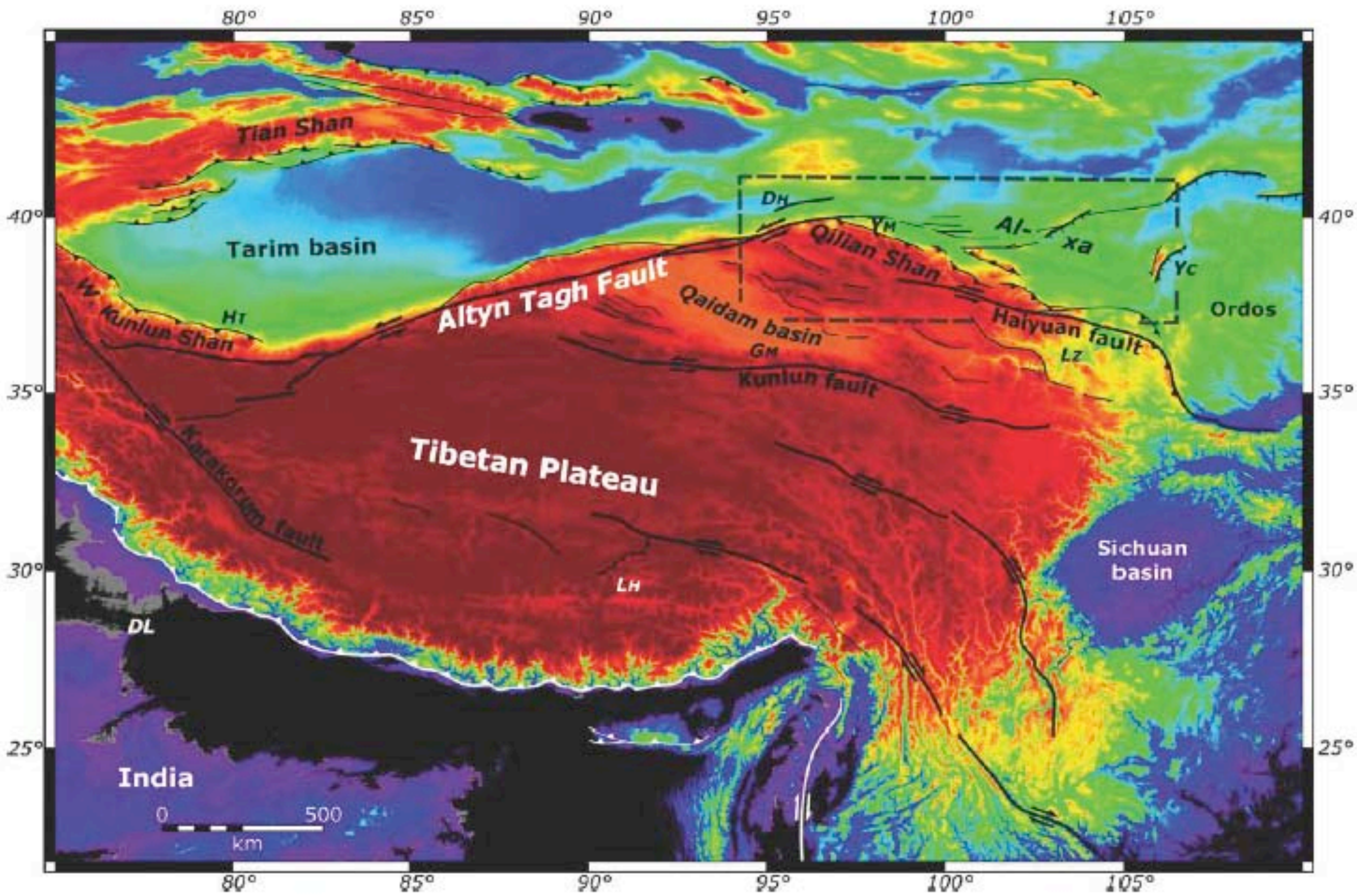
The Altyn Tagh fault (ATF) is the geologic boundary between the Tibetan Plateau and the Tarim Basin in northwest China. As such it is one of the major geomorphologic boundaries on Earth and marks the abrupt transition from the world's highest plateau to the world's second largest desert basin. The Tibetan Plateau covers an area of ~1,000 by 2,500 kilometers (km), with an average elevation above sea level of over 4,500 meters (m). The Tarim Basin is much lower with an average elevation of ~1000 m and occupies an area of roughly 400 by 1400 km. The total length of the fault is more than 1500 km long (up to 2500 km, see Mériaux, et al., 2005; Darby, et al., 2005) and runs the length of the northern edge of the Tibetan Plateau from the Pamir mountain range on the west to the Qilian mountain range on the east. The focus of this paper is the central and eastern sections of the ATF from the western edge of the Altun mountain range to the northeast corner of the Qilian range and the Alxa Plateau.

(Map from Washburn, et al., 2003)

Web References

http://en.wikipedia.org/wiki/Tibetan_Plateau

http://www.britannica.com/eb/article-70974/China



Topography of the Tibetan Plateau and adjacent regions with some of the major faults. Colors: black <200 m, light blue ~1000 m, yellow ~2000 m, orange ~3000 m, maroon >4000 m. Towns: Dl=Delhi, Lh=Lhasa, Ht=Hotan, Gm=Golmud, Dh=Dunhuang, Lz=Lanzhou, Yc=Yinchuan, Ym=Yumen (Fig. 1, Darby, et al., 2005).

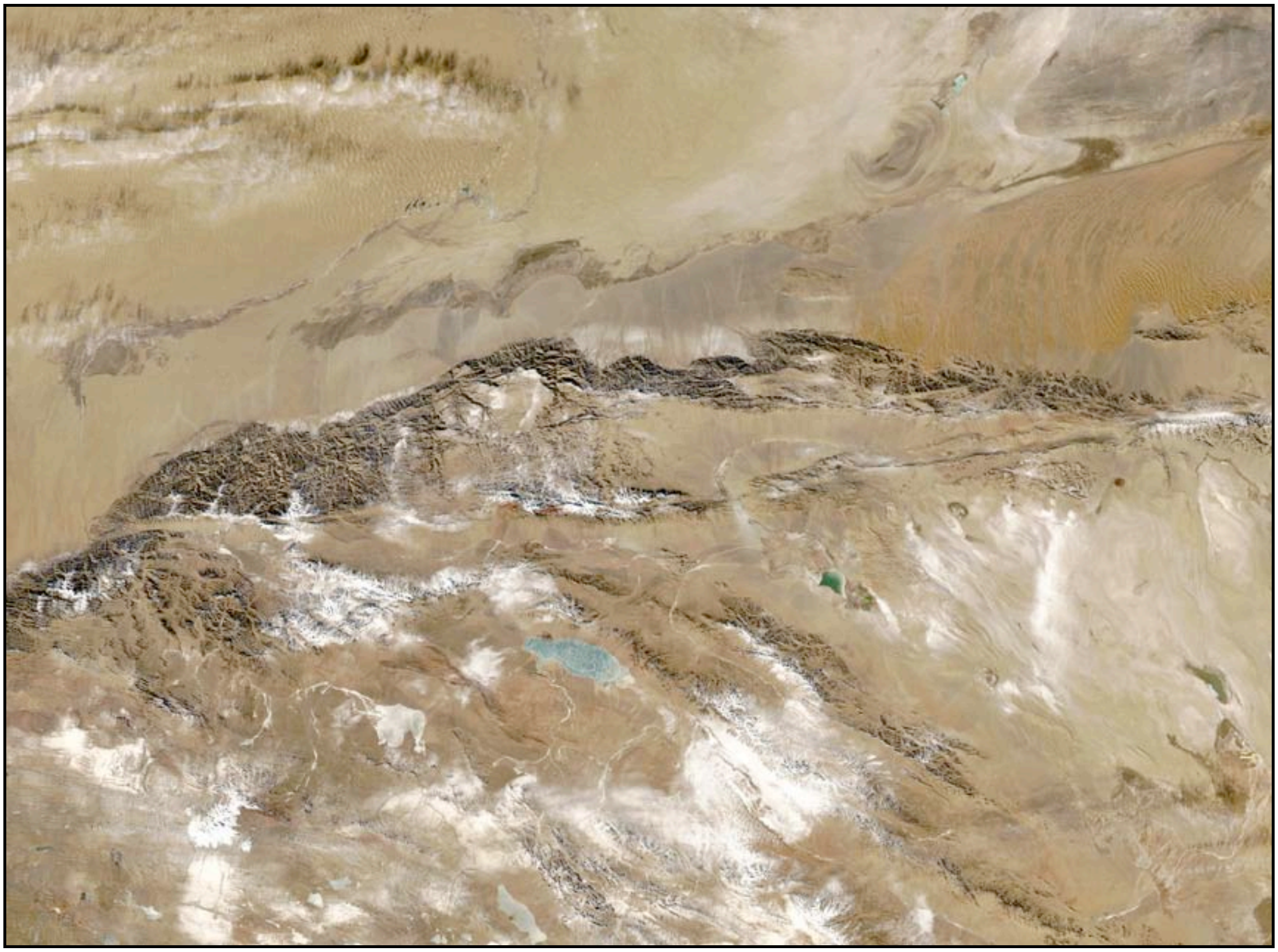
The ATF is a left-lateral, strike-slip fault that accommodates the relative horizontal plate motion between the Indian and Eurasian plates (Dupont-Nivet, et al., 2004). The Tarim Basin is underlain by the rigid Tarim micro-continent (craton or block) which accreted to the Eurasian plate before the onset of the Indo-Eurasian collision (Liu, 2005). The Tibetan Plateau is the fold zone of the Indo-Eurasian collision. Studies of the ATF have demonstrated a relative displacement of 350–400 km on the eastern and central segments, and 475 +/-70 km at the western end of the fault (Darby, et al., 2005).

Web References

http://en.wikipedia.org/wiki/Geologic_fault

http://en.wikipedia.org/wiki/Indian_Plate

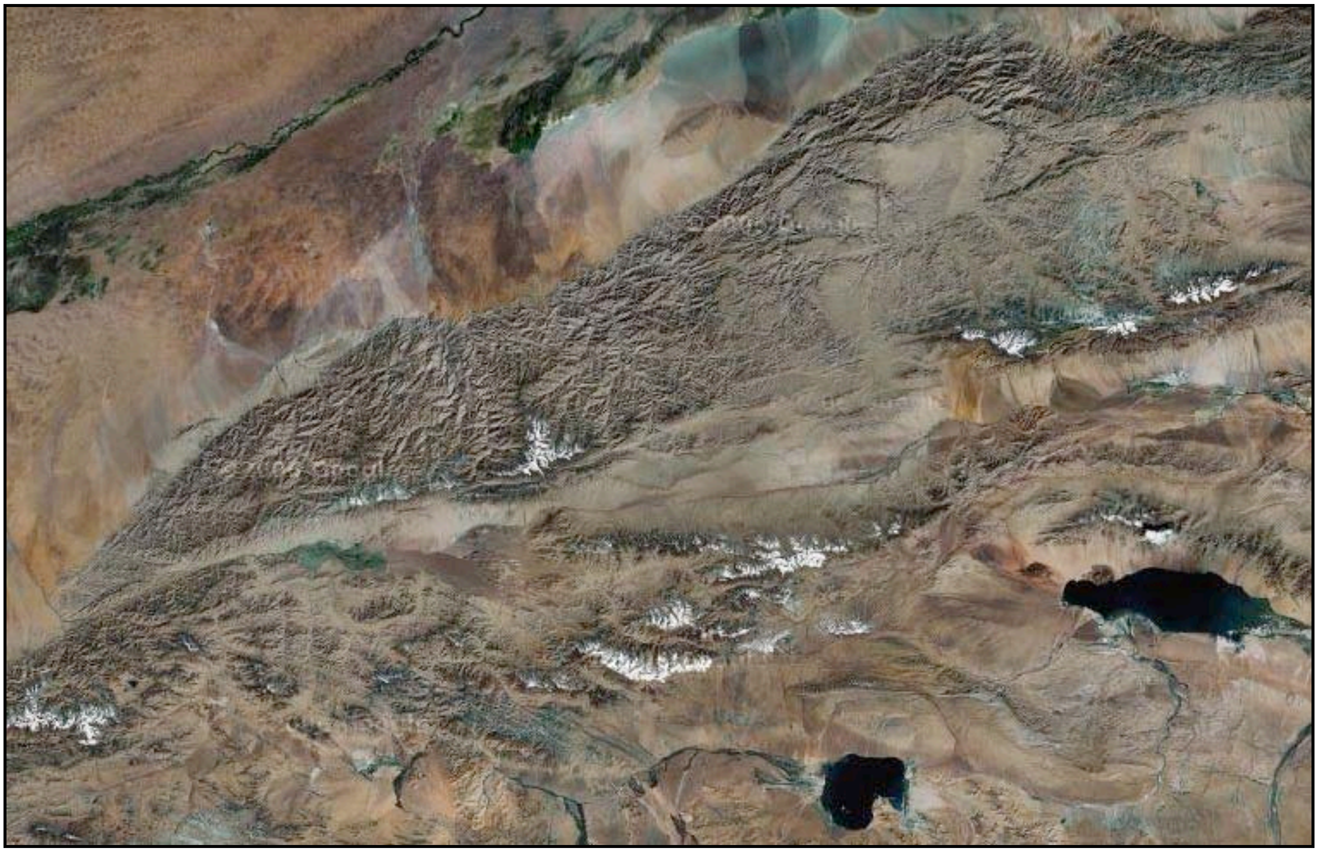
http://pubs.usgs.gov/gip/dynamic/understanding.html



Running across the center of this image is the Altun mountain range with the Altyn Tagh fault along its southern edge. The Taklimakan (left) and Kumtag (right) deserts are north of the range. Southwest is the eastern extension of the Kunlun mountain range. Southeast is the Qaidam Basin. Both lie south of the ATF. The snow covered section on the far right is the ATF just east of Lapeiquan.

The Altun range stretches ~ 607 km from the Cherchen River at 37.50°N latitude, 85.86°E longitude, to 39.13N, 92.49E near Lapeiquan. Guo, et al. (2001) propose that the present day ATF is the past suture between the south Tarim block and the Qaidam block making this portion of the Altun range a coherent tectonic unit. From Lapeiquan east to the Aksay River canyon and Dangjin Shankou (pass), at 39.35N, 94.35E, marks an extension of the Altun range by ~ 162 km to include the Altun Shan push-up (Mériaux, et al., 2005). This makes the overall length of the range ~770 km as the crow flies. Geographically, then, Highway 215, Dunhuang to Golmud, which runs through the east Aksay River canyon, reasonably marks the boundary between the Altun and Qilian mountain ranges.

(MODIS/Terra true color image from January 7, 2007)



Western Altun Range including Sulamu Tagh and Akato Tagh

"Between 85°E and 95°E longitude, the principal active trace of the Altyn Tagh system constitutes an en échelon set of five, northeast striking straight fault sections punctuated by four shorter, right-stepping, east-west trending segments in the Sulamu Tagh, Akato Tagh, Mangnai [Pingding Shan], and Aksai [Altun Shan] regions. We follow Crowell (1974) in referring to such geometric complexities as restraining double bends because the fault trace bends first to the right and then to the left when followed along strike. Because the straight segments are systematically right stepping, there are no releasing double bends of equivalent size to the transpressional jogs along the Altyn Tagh fault. Flanking each restraining double bend are mountain ranges that are anomalously high relative to the surrounding regions." (Cowgill, et al., 2004)

In the image above the western portion of the Altun range and the ATF run diagonally from lower left to upper right. Along the ATF the snow covered Sulamu Tagh is left of center, and the three sections of the Akato range are far right and above center. The Kunlun mountains run south of the ATF across the lower portion of the image.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)

Shown above is the Sulamu Tagh, the western most of the four "restraining double bends" described by Cowgill, et al. (2004). From the west the ATF swings first to the right and then to the left along the southern base of the Sulamu Tagh. The high point of the range is east of Tura (Tula) at ~37.915N, 87.39E, and ~ 6100 m elevation, making it one of the highest peaks in the Altun mountain range.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)

Another of the highest mountains in the Altun range is referred to as "Akato Tagh" (Washburn, et al., 2003; Cowgill, et al., 2004). Its summit is ~ 6100 m, at ~38.19N, 88.91E in the western section of the Akato mountains. (Photograph from Cowgill, et al., 2004)

The Akato range is the location of the second restraining double bend. The ATF runs along the north side of the uplift in this image of the western section.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)

This view is looking north to the middle section of the Akato mountain range. After passing along the north side of the western section, the ATF goes through the center of the middle section, then passes along the south side of the eastern section of the Akato mountains to complete the second double restraining bend. The Akato mountains lie west of Lake Wuzunxiao and Highway 315, the road from Ruoqiang (Qarkilik or Charkhlik) to Huatugou (Youshashan).

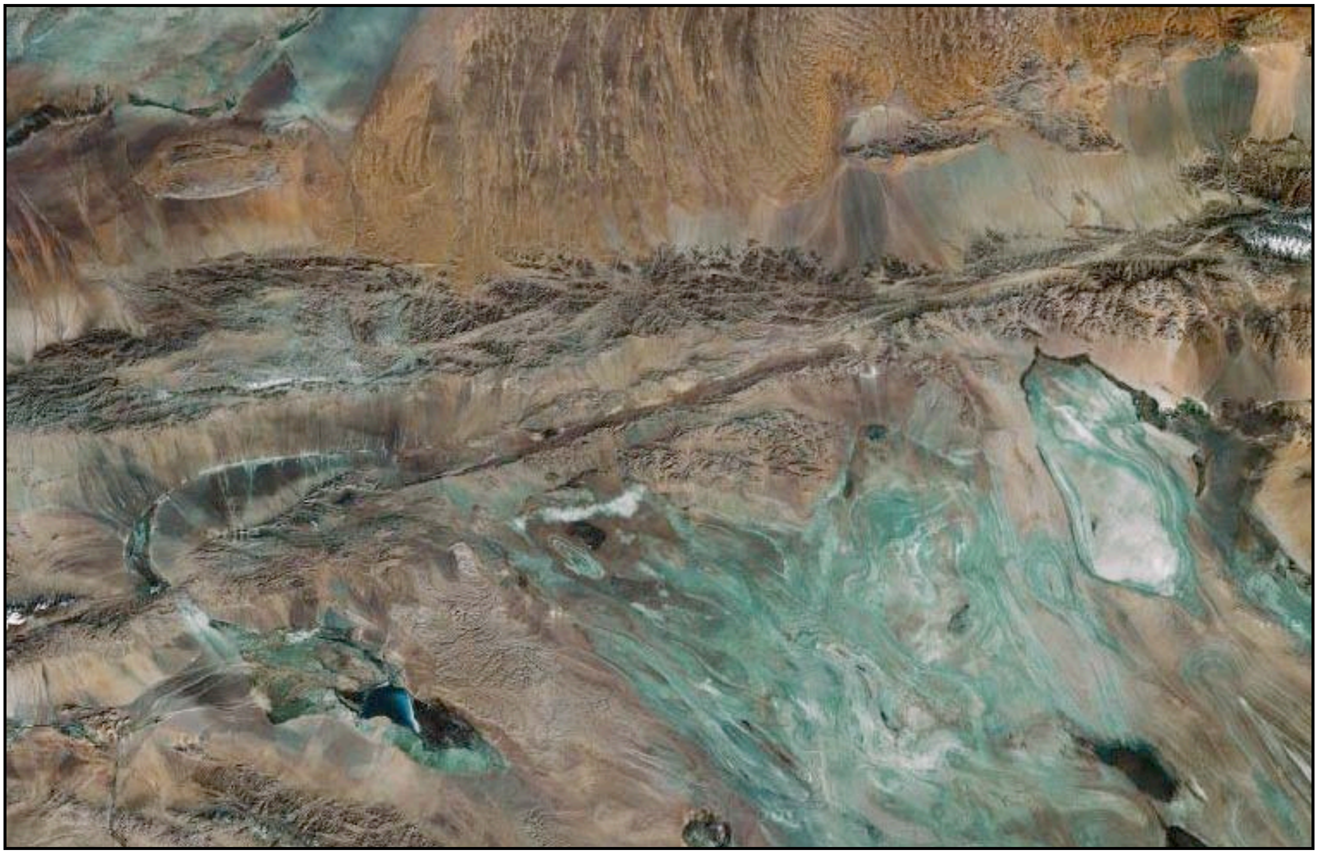
(Photograph taken from 38.06N, 89.33E by Eugene Potapov)

Web Reference
http://www.panoramio.com/user/245038

This view is looking northeast to the south side of the eastern Akato mountains. Note the fault scarp of the Altyn Tagh Fault at the base of the mountains and the tilt and uplift of the red sedimentary deposits opposite the fault scarp (bottom center).

(Photograph taken from 38.03N, 89.21E by Jeremy Winterson)

Web Reference
http://www.flickr.com/photos/aroundtheworls/2425139844/sizes/l/in/set-72157604616357888/

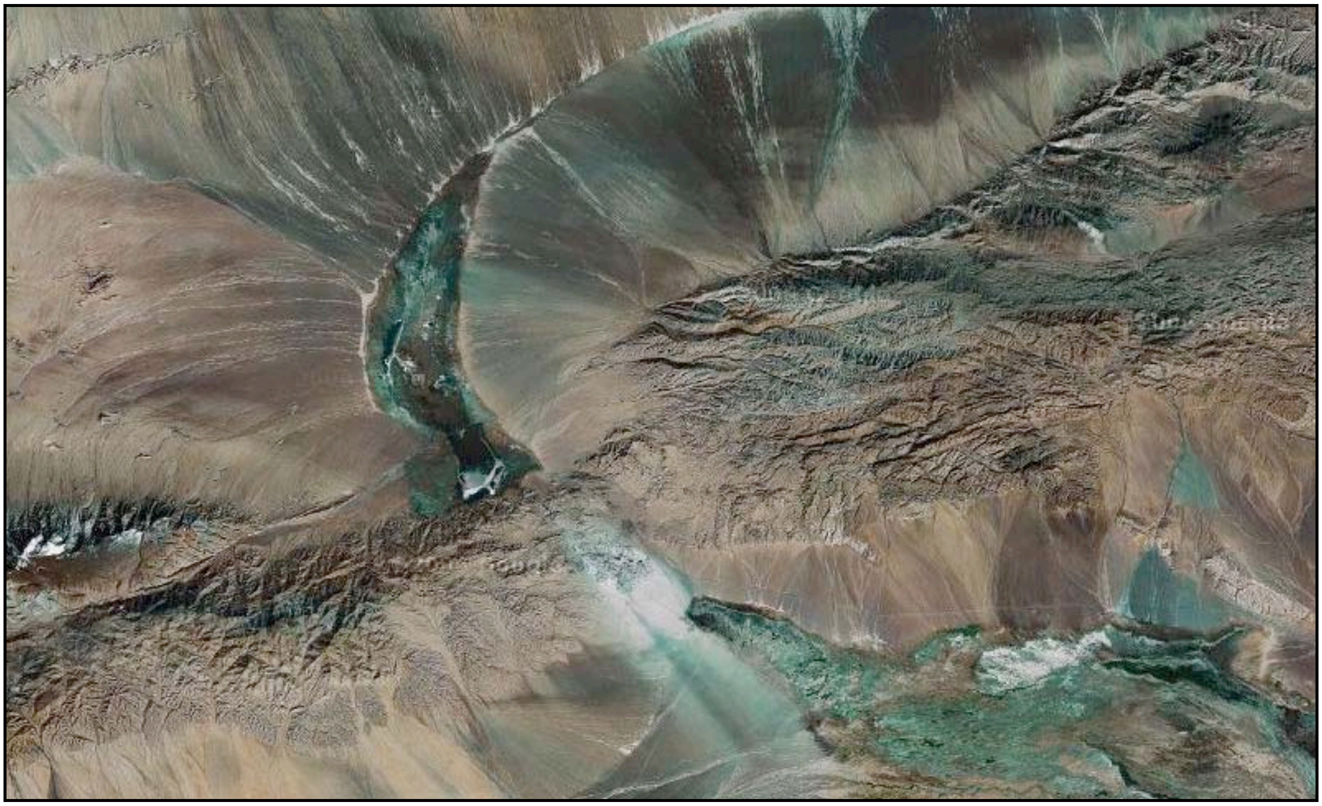


Eastern Altun Range including Pingding Shan and Altun Shan

The eastern Altun mountain range includes Pingding Shan and Altun Shan, respectively, the third and fourth restraining double bends along the central ATF. Pingding Shan is below and left of center. The snow-capped Altun Shan is on the far right edge above center. The eastern end of the Akato mountains is on the lower left edge. Lake Wuzunxiao and Highway 315, Ruoqiang to Huatugou, are just east of the Akato range (Cowgill, et al., 2004).

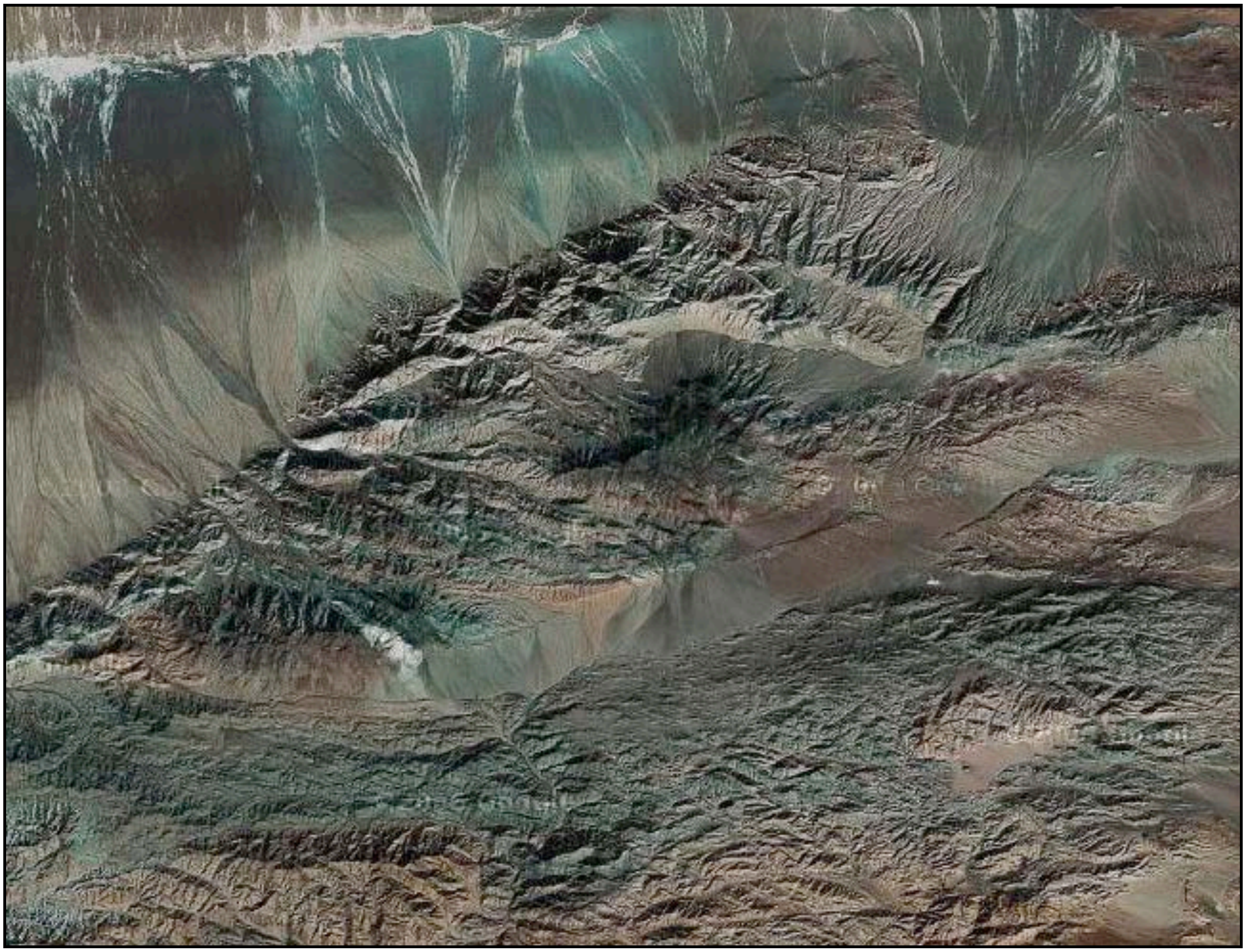
Along the central and eastern portion of this image the ATF forms a remarkably straight, strike-slip fault basin (Li, et al., 2002). The fault basin runs from Xorkol, east of Pingding Shan, to the west end of the Annanba triple junction. Xorkol is where the road from Dunhuang splits north to Miran and south to Huatugou. Annanba is a small village just west of the Altun Shan push-up.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



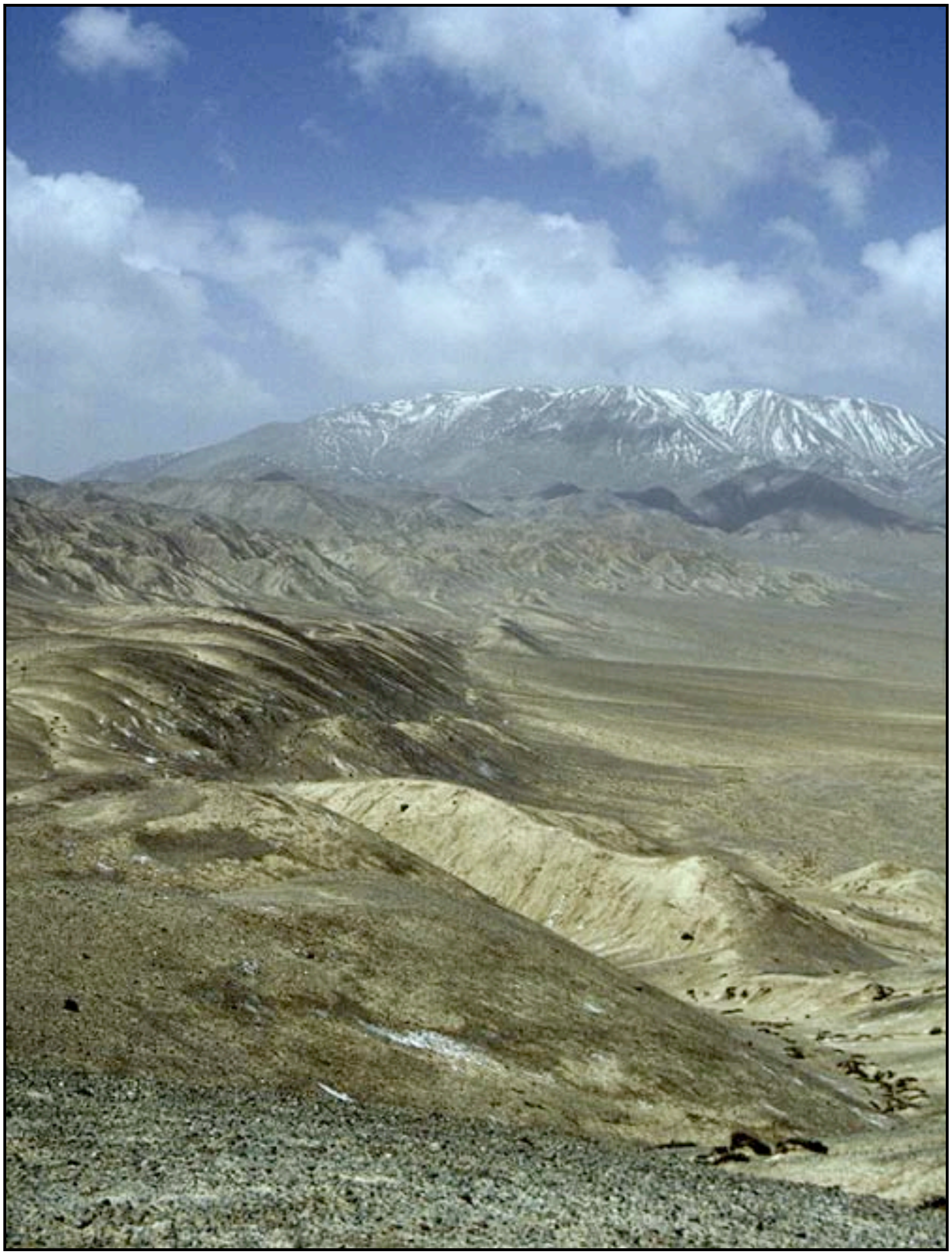
The ATF crosses Lake Wuzunxiao just east of the Roquiang to Huatugou road at 38.41N, 89.94E (Washburn, et al., 2001). The south end of the lake is left and below center. Note the wind gap and white streaking from Lake Wuzunxiao to the Qaidam Basin. The road from Ruoqiang to Huatugou runs through this gap after climbing over the mountains at the south end of the lake. The east end of the Akato mountains is on the far lower left. Pingding Shan is on the far upper right. The ATF runs diagonally across the center.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



Pingding Shan (the dark area just right of center) is east of Lake Wuzunxiao and west of Xorkol. In this image the ATF starts below center on the left, crosses diagonally through the center, and exits above center on the right. The high point of the range is at ~38.63N, 90.64E, and 4780 m (Mériaux, et al., 2005).

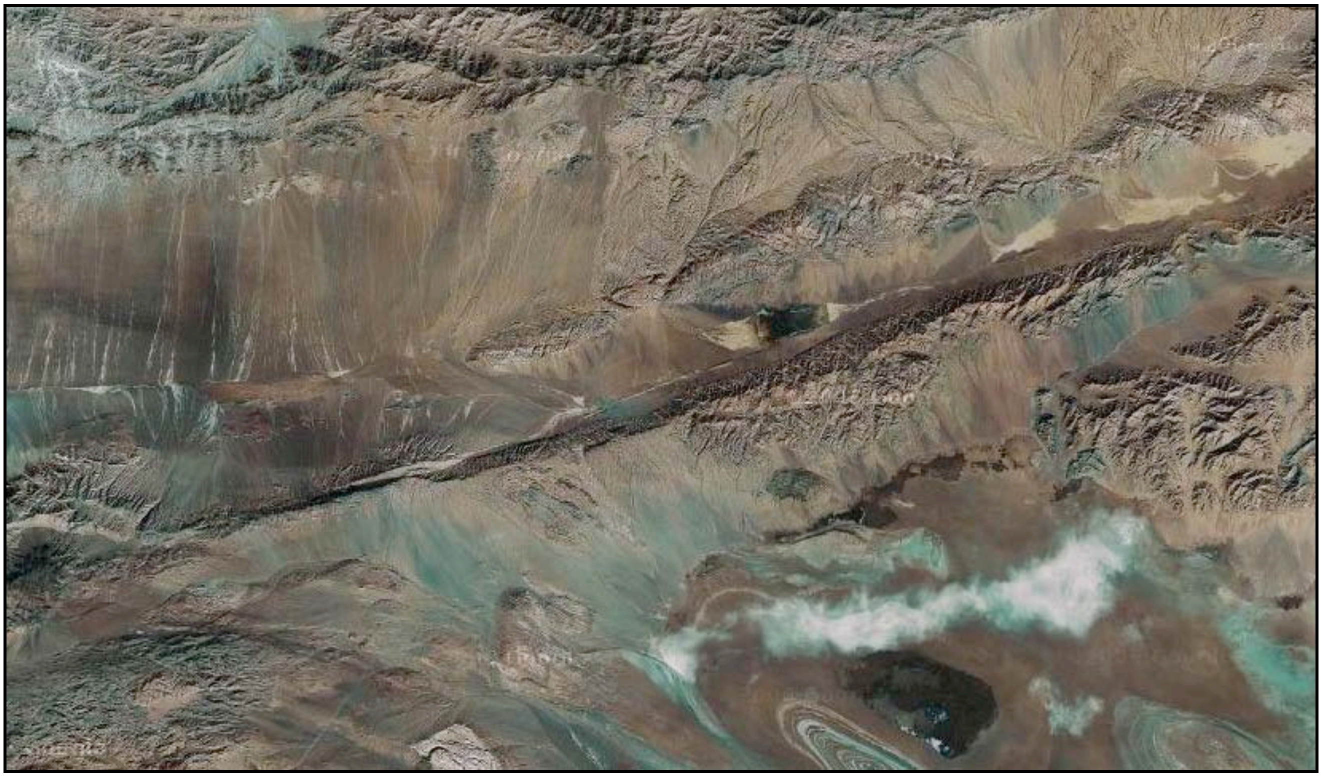
(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



This view is looking west to Pingding Shan (literally flat topped mountain). The mountain range is bound on the southeast by a large normal fault escarpment (foreground) that bridges a left step in the Altyn Tagh fault trace to the range's south side (far left in this view).

(Photograph by Ramon Arrowsmith and Zack Washburn)

Web Reference
http://activetectonics.asu.edu/atf/ATFPhotos/index.html

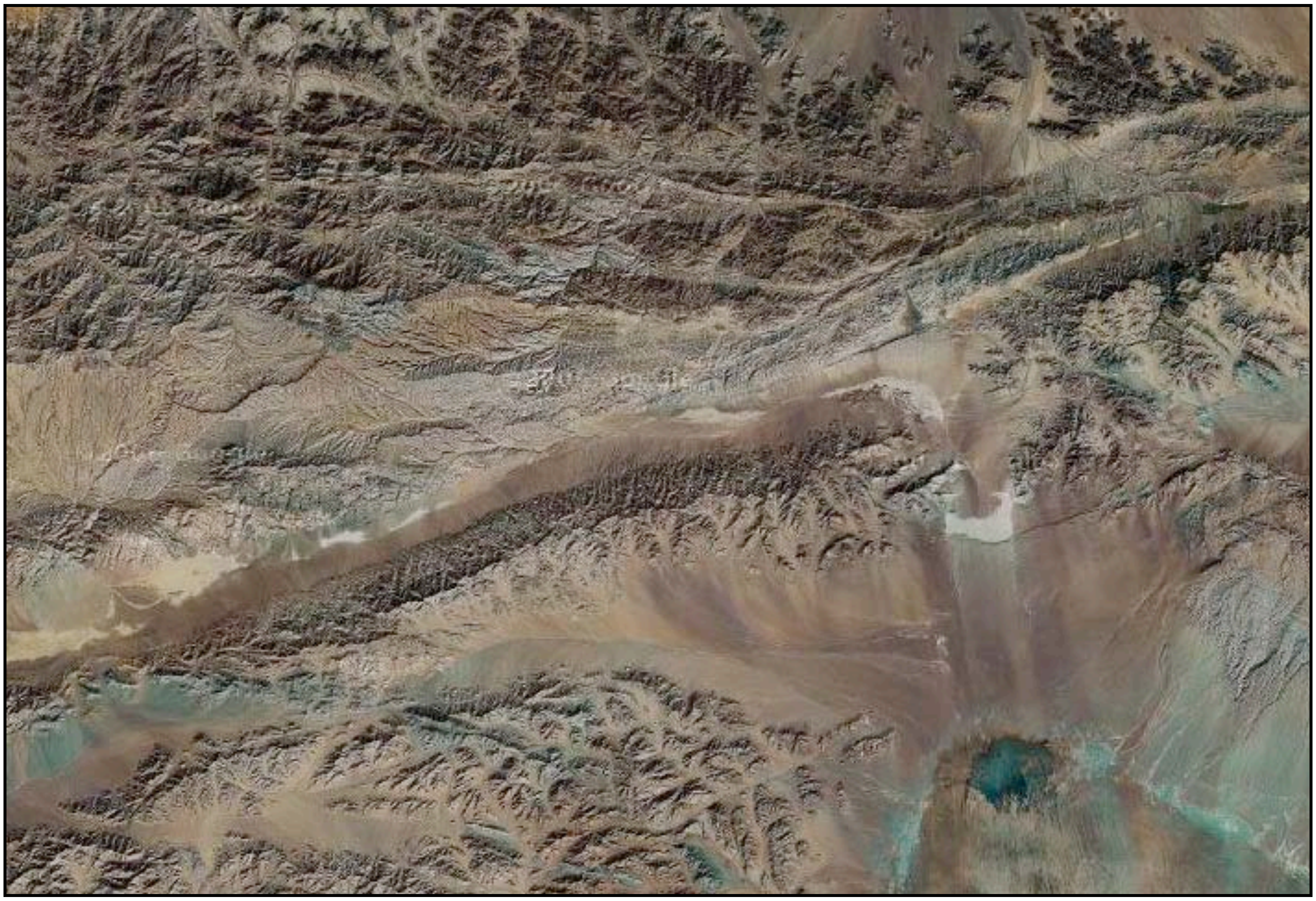


West End of the ATF Strike-slip Fault Basin

From left to right across this image is: Pingding Shan in the lower left; Xorkol at 38.76N, 91.09E (Li, et al., 2002), just left of center; and right of center an intermittent salt lake called the "Bitter Sea" by Washburn, et al. (2001). The only junction on the road between Xorkol and Lapeiquan is on the upper right, at 38.90N, 91.66E. The junction is where the road splits south through a pass called the Xingfu Gate (Ritts, et al., 2004), then on southwest to the town of Huatugou at 38.25N, 90.87E.

From Xorkol to the road junction is the west end of the ATF strike-slip fault basin (also, called the "Xorkol corridor" or "Xorkol fault valley"). The fault basin extends east to the Annanba triple junction at 39.21N, 92.94E. Along its ~180 km length the basin varies from 1 to 5 km wide with an average width of 2 to 3 km (Li, et al., 2002).

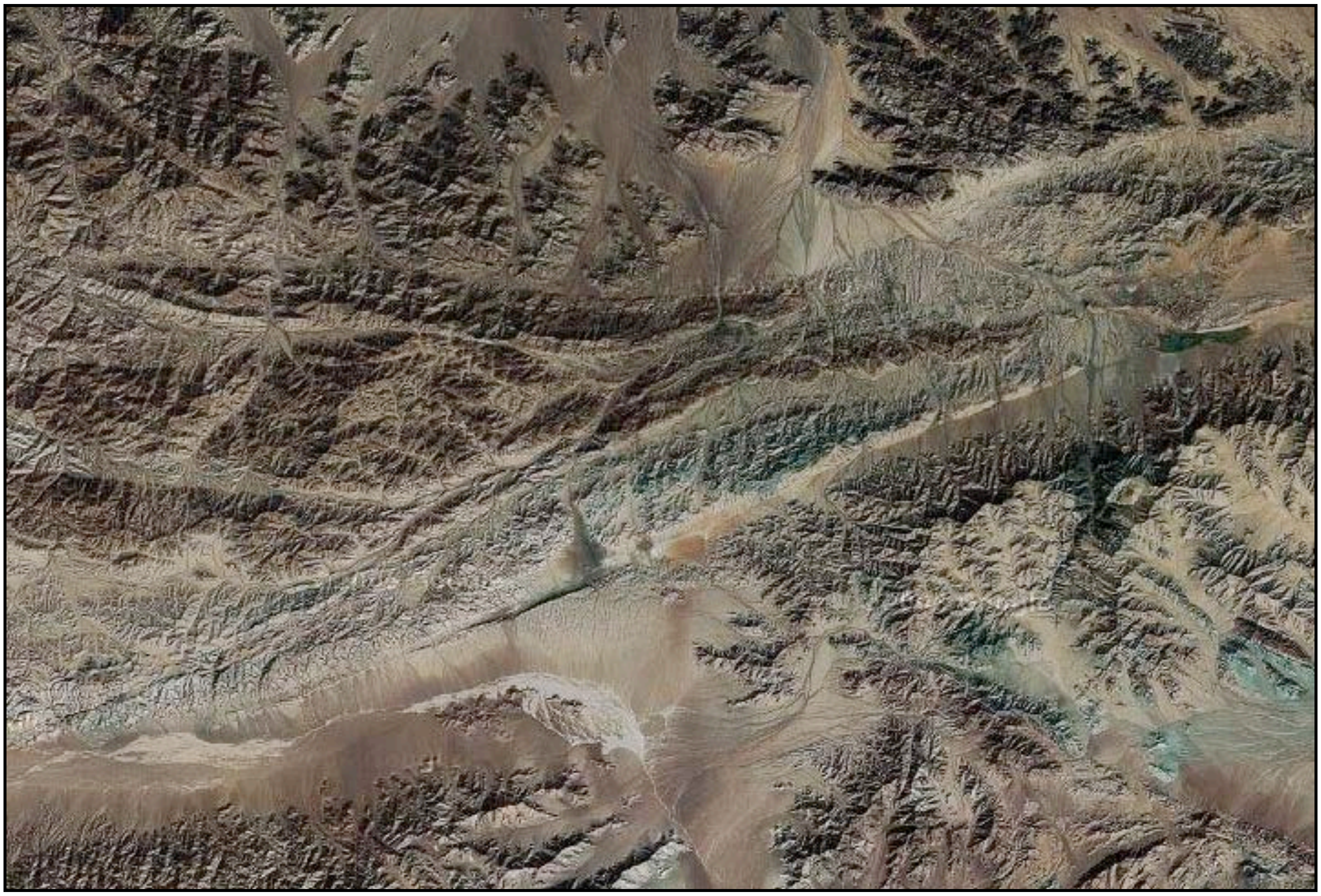
(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



Middle Section of the ATF Strike-slip Fault Basin

The road junction at 38.90N, 91.66E, where the road splits south to the Xingfu Gate, is on the lower left. Left of center, near 39N, 92E, the Altyn Tagh fault splits into two parallel strands, the north (NATF) and the south (SATF) (Mériaux, et al., 2005). The gap in the mountains on the south side of the fault basin, to the right and below center, is called the "Qaidam Gate" by Ritts, et al. (2004). (Note the white salt pan and wind streaks running north-south to the Qaidam Basin.) Lapeiquan is north of the gap (Ritts, et al., 2004; Mériaux, et al., 2005). Lapeiquan, at 39.11N, 92.27E, is where the road from Dunhuang crosses south from the piedmont of the Altun range to the ATF fault basin. East of Lapeiquan note the small ephemeral salt lake above center near the right edge.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



The AFT at Lapeiquan

Where the AFT splits into north and south strands, near 39N, 92E, is just off the lower left edge of this image. The small salt lake at 39.13N, 92.49E is above center on the far right. Roughly half way between these two points the road from Dunhuang enters the ATF fault basin from the north (below and to the left of center). The road starts just right of center at the top, then travels south through Lapeiquan to the fault basin. In the process it crosses the NATF on its way to the SATF. The road then makes a 90 degree turn and follows the fault basin southwest to Xorkol.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)

This image was taken just north of the ATF along the middle section of the strike-slip fault basin. NASA scientists have installed an environmental sensor (lower foreground) to monitor climate conditions year-round at their high altitude (3440 m) "Sorkuli" study site. ("Sorkuli" is also written as "Xorkol", see Washburn, et al., 2003; Cowgill, et al., 2004).

A major conclusion of the NASA research is that the high-altitude deserts in the Qinghai-Tibetan Plateau region of China have the coldest and driest recorded extremes for cyanobacteria on Earth, and may be a model for Martian habitat studies (Warren-Rhodes, et al., 2007).

(Photograph courtesy of K. Warren-Rhodes, NASA)

Web Reference
http://www.nasa.gov/centers/ames/multimedia/images/2007/chinadesert_feat.html

East End of the ATF Strike-slip Fault Basin

On the western edge of this image is the small lake at 39.13N, 92.49E. On the eastern edge is the start of a wedge, at 39.21N, 92.94E, that marks the beginning of the Annanba triple junction. This section of the fault is 44 km long, and 2 km wide at its widest point. The SATF runs along the inside of the fault basin, while the NATF runs parallel to the SAFT north of the basin (Mériaux, et al., 2005).

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)

The Annanba Triple Junction

The village of Annanba is just north of the NATF at 39.29N, 93.00E (above and left of center). The Annanba triple junction runs northeast across the center of the image from the SAFT to the NAFT.

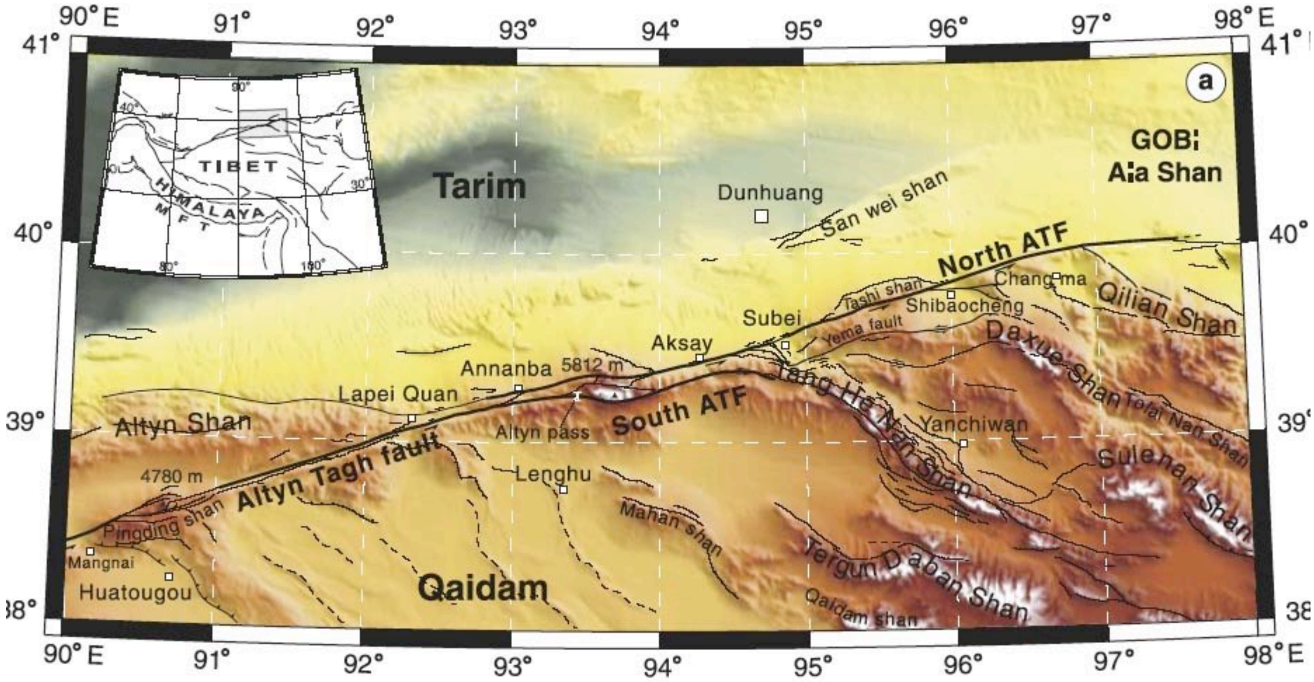
"In terms of their cumulative geomorphic signature in the field, and hence qualitatively their relative slip rates, a significant difference is clear on either side of the Altyn Shan push-up along the NATF and SATF. West of Annanba, the trace of the NATF is subdued. The same holds for the trace of the SATF east of the Altyn pass. Thus significant transfer of slip must occur from the South to the North Altyn Tagh fault across the Annanba junction and the Altyn push-up." (Mériaux, et al., 2005)

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)

The ATF at Altun Shan

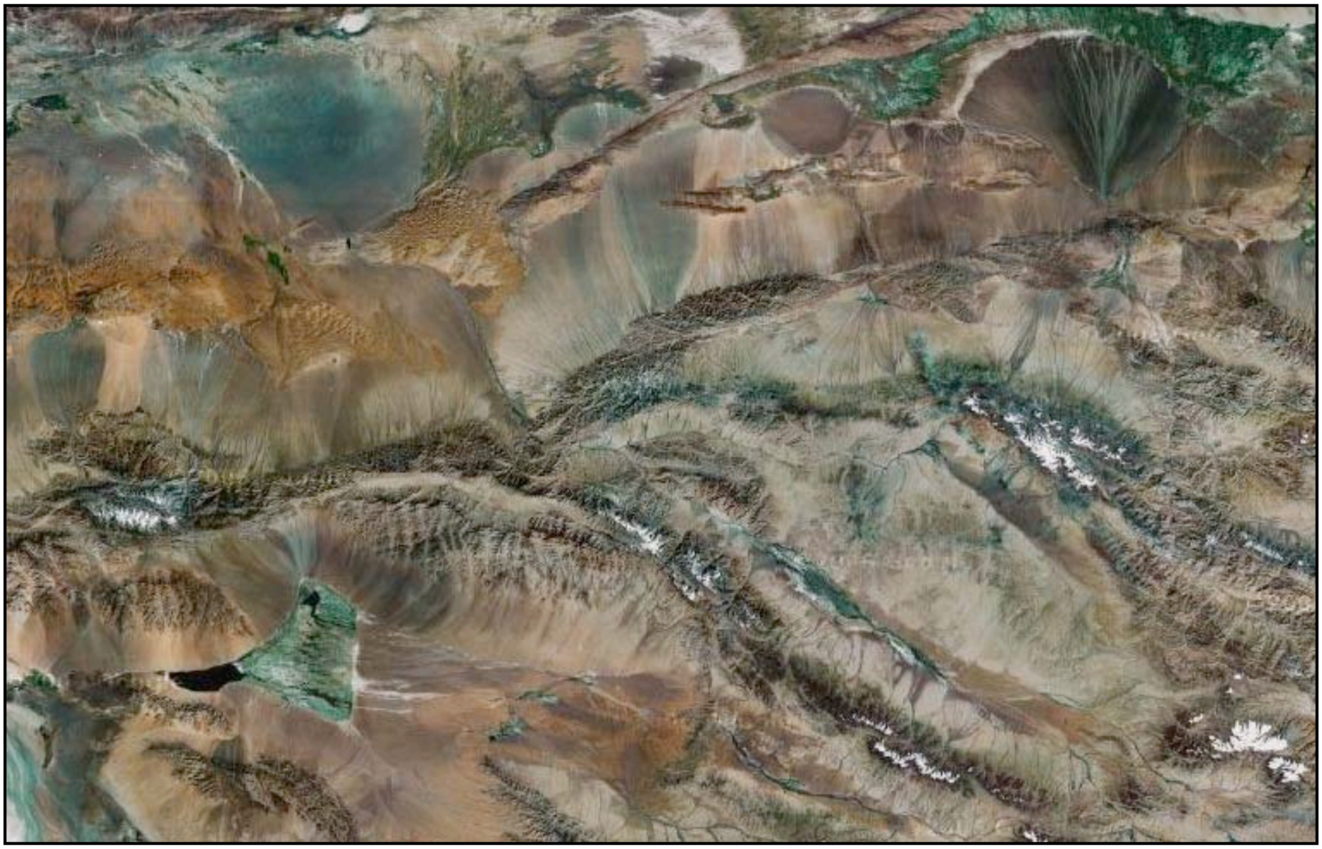
Above is the Altun Shan push-up and restraining double bend. Its high point is at 39.25N, 93.69E, and ~ 5800 m elevation. Altun Shan is the fourth of Cowgill's double restraining bends between 85E and 95E (Cowgill, et al., 2004).

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



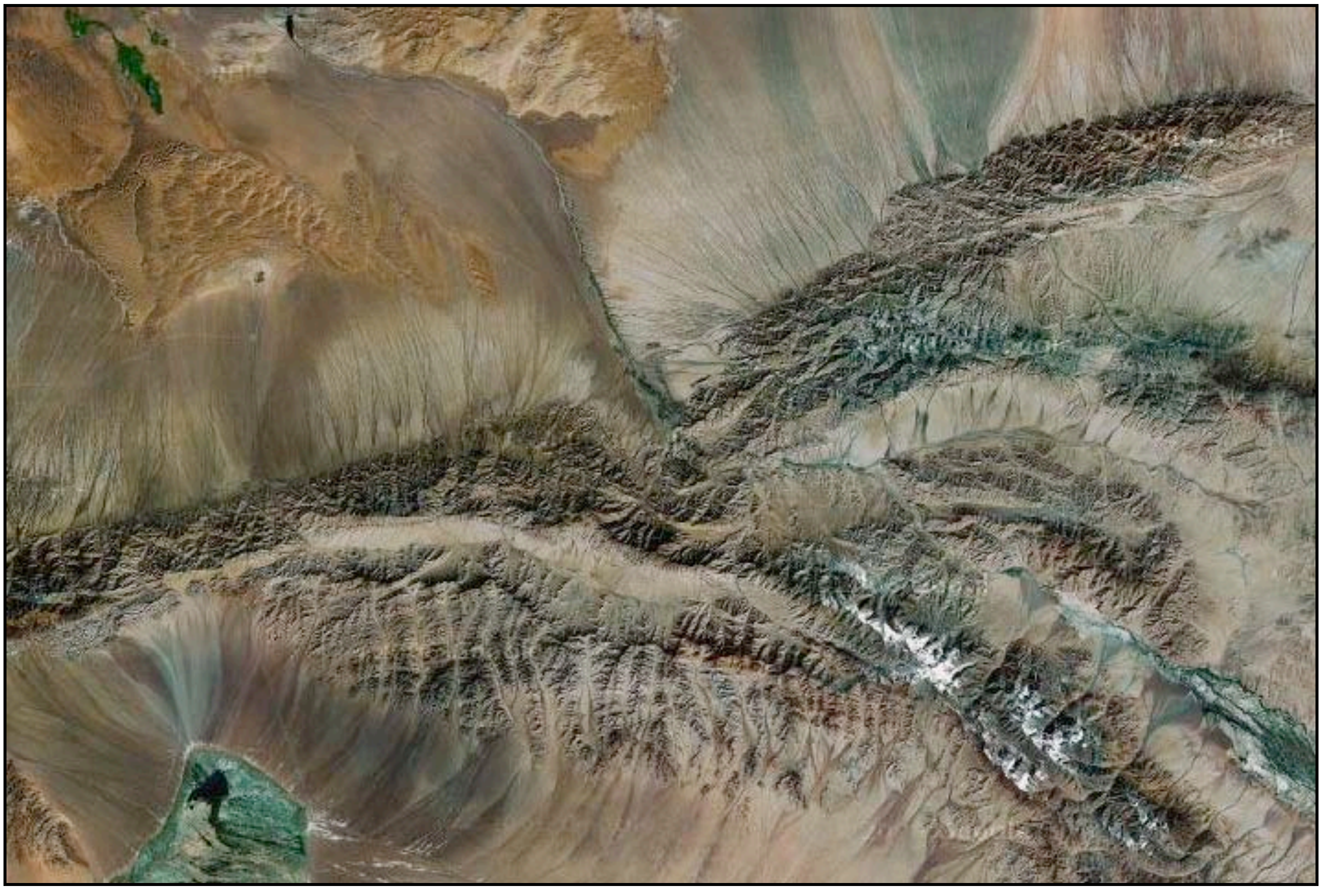
Geometry and Segmentation of the Eastern Altyn Tagh Fault

"From 90°E to 97°E, the eastern stretch of the Altyn Tagh fault strikes N70°E overall, but has a complex geometry. Between the western edge of the Qaidam basin and the Qilian range, the fault system comprises three principal parallel strands. The three main strands branch off one another or merge with other faults at several consecutive triple junctions. The Annanba junction, between the SATF and NATF, lies west of the Altyn Shan. The Subei junction is located near the particularly sharp, N130°E striking restraining thrust bend where the Danghe Nan Shan meets the fault. The central strand or Yema fault jogs southward at the Subei junction and continues northeastward to the Daxue Shan thrust front. Finally, the Yumen junction is the high-angle meeting point between the North Altyn Tagh fault and the N120°E striking Qilian range front thrust. East of the Qilian Shan front, the northern strand continues with a N96°E strike north of the Hexi corridor." (Map and text from Mériaux, et al., 2005)



In this image the snow covered Altun Shan is on the far left just below center. The SATF follows the Qaidam side of the Altun Shan, then veers southeast into the Danghe Nan Shan (literally the Dang river south mountains) which run diagonally below center. The central strand or Yema fault jogs south from the NATF at the Subei triple junction (left of center), then continues northeast before turning southeast into the Daxue Shan (right of center). The NATF follows the edge of the Tarim block from Altun Shan to the Qilian Shan thrust front at the Yumen triple junction (right and above the Daxue Shan). Note the playa of the Shule River in the upper right corner.

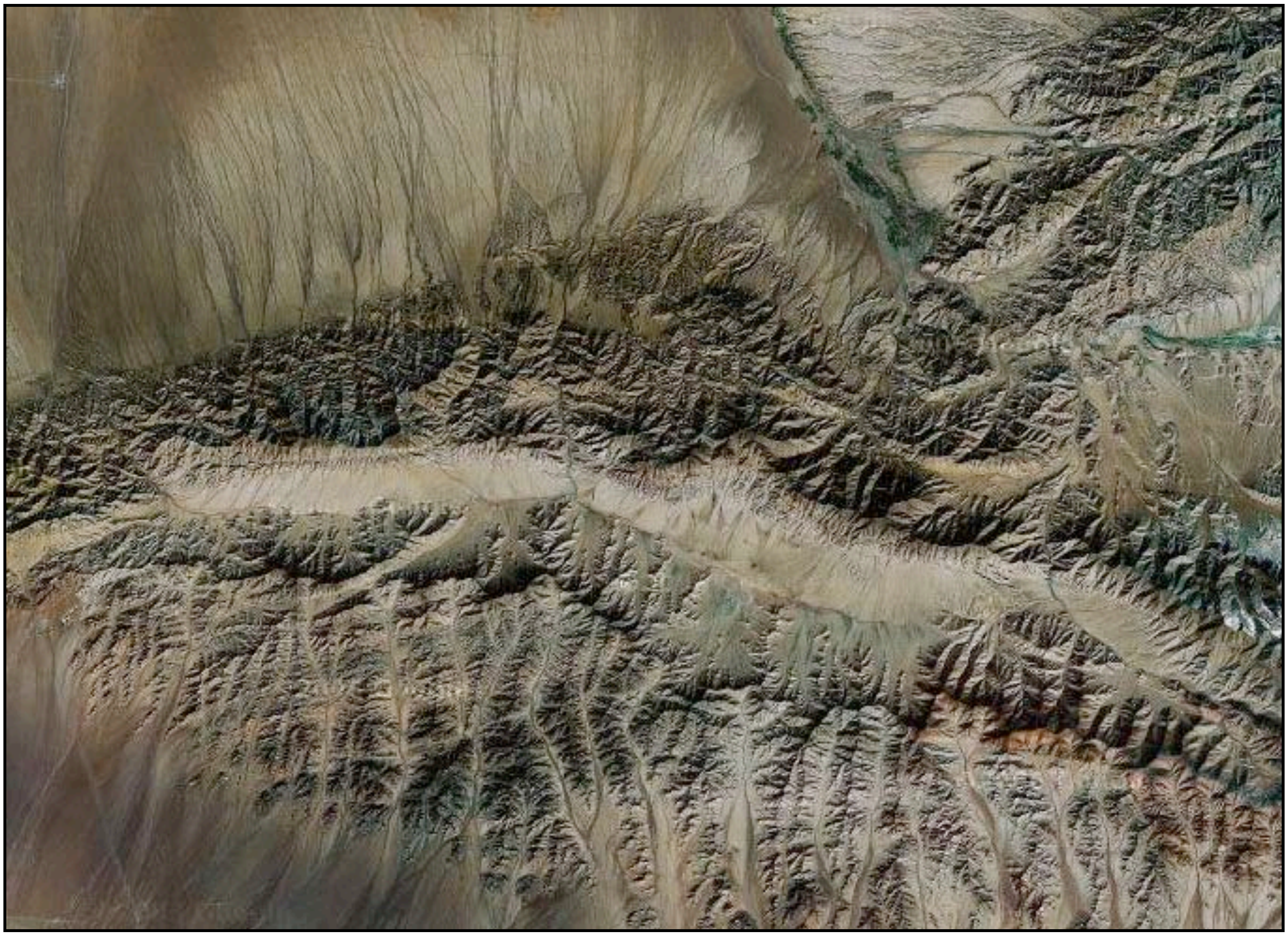
(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



Subbei Triple Junction of the ATF

East of Altun Shan and centered on 39.40N, 94.91E is the Subei triple junction and "restraining thrust bend" (Mériaux, et al., 2005). The town of Subei (a.k.a. Dangchengwan or Lucaogou) is on the Dang River ~72 km southeast of Dunhuang, just north of where the river exits the mountains (center above).

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



The NATF runs N70°E diagonally across the upper half of this image and crosses the Dang River north of the town of Subei. Just above center on the far left is the abandoned town of BoloZhuanJing (old Aksay) at 39.41N, 94.27E. BoloZhuanJing is on the NATF near the mouth of the east Aksay River canyon and Dangjin Shankou (pass). The canyon runs southeast from the NATF across the massif and meets the SAFT near 39.35N, 94.35E. From here the SATF starts to swing right along the south side of the Danghe Nan Shan (Mériaux, et al., 2005). East of BoloZhuanJing near 39.44N, 94.46E the NATF starts to splay southeast along the north side of the Danghe Nan Shan (Wang, et al., 2003). Mériaux, et al. (2005) refer to this splay as the "N130°E striking restraining thrust bend."

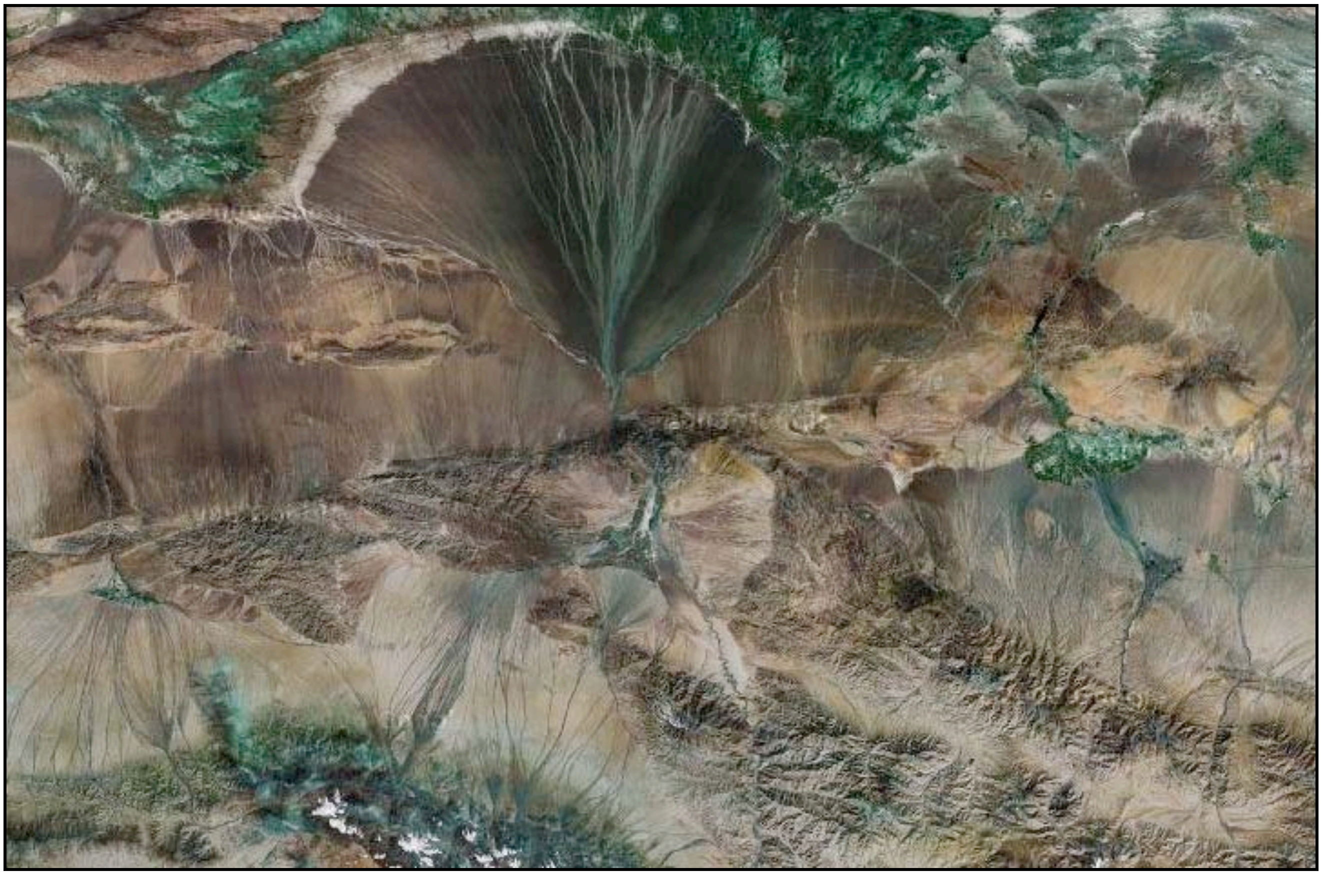
(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)

Bottom left in this image the SAFT runs along the southern base of the Danghe Nan Shan. Just west of this image the NAFT has already splayed south. The southern most splay of the NAFT runs along the northern base of the Danghe Nan Shan, then swings sharply left along the base of the south of two restraining thrusts and meets the Yema fault at 39.43N, 95.02E. From this point the Yema fault runs northeast from the junction (above center on the right).

The north restraining thrust is near the center of this image (look for its almost square corners). It starts as the middle splay of the NAFT splits off the main fault near 39.51N, 94.76E (upper left) and makes an abrupt right turn just west of the town of Subei (Wang, et al., 2003). This fault travels southeast to the north restraining thrust, then makes a sharp turn to the northeast. At this point it becomes (or meets) the Yema fault.

As it flows north the Dang River follows the Yema fault southwest. It then makes almost a 45 degree turn and cuts directly across the north restraining thrust. Once across, it makes another ~ 45 degree turn for almost a full 90 degree turn northwest toward Dunhuang.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



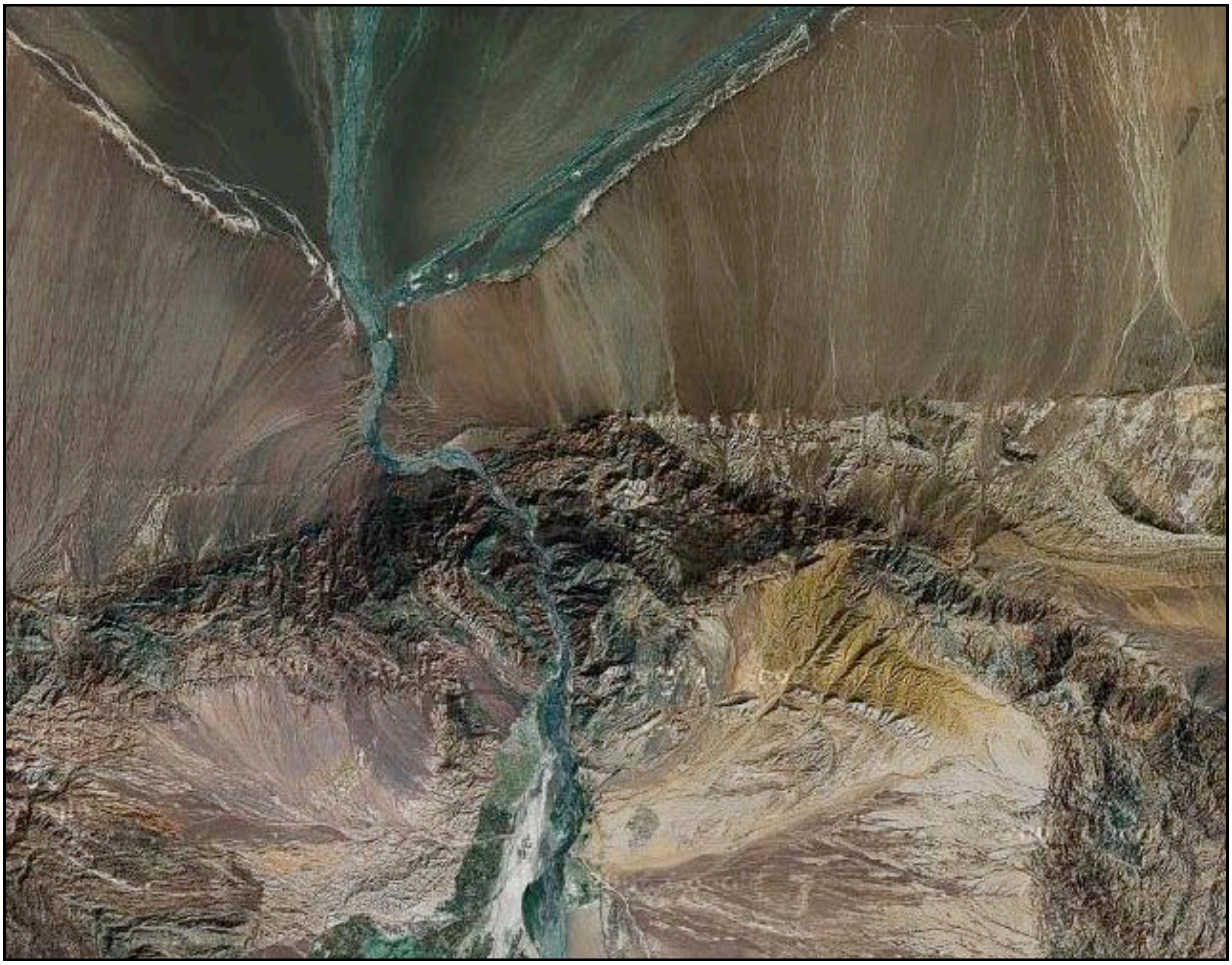
Yumen Triple Junction of the ATF

The Yumen triple junction at 40.02N, 96.84E is where the NATF splits and swings south to the frontal thrust fault of the Qilian Shan. The Shule River runs north across this image from the Daxue Shan (bottom left) to the Shule River playa (above and left of center). The junction is just east of the river in the center of the image.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)

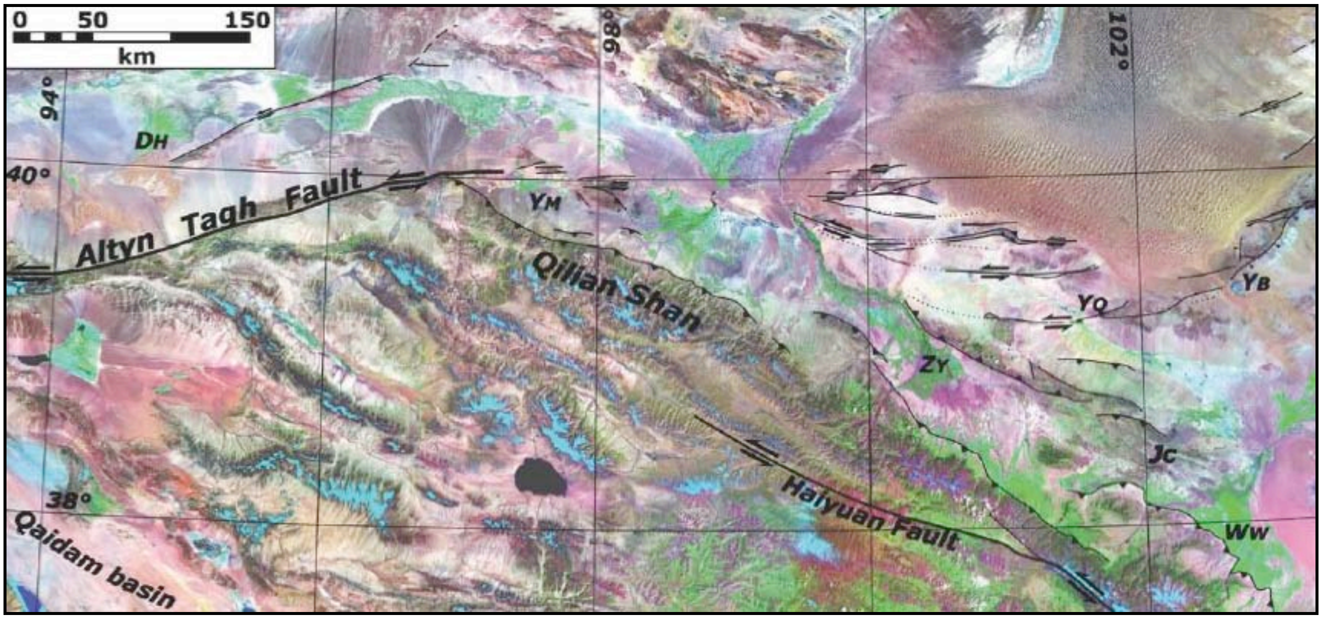
In this image the city of Yumen is below center on the far right. The Shule River and playa are on the far left. Note the lighter colored wedge that starts just east of the Shule River. The top of the wedge is the eastward extension of the ATF; the bottom is the Qilian thrust front.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



Like the Dang River, the Shule cuts across a tight knot of uplift just adjacent to the triple junction itself.

(Satellite False Color Imagery from Google Maps, TerraMetrics, NASA, 2006)



Did the Altyn Tagh fault extend beyond the Tibetan Plateau?

"Our data demonstrate the presence of multiple large, post-Cretaceous, left-lateral faults [in the Alxa block] that likely have a slip history that is similar to that of the ATF." "We suggest that the ATF splayed into at least five strike-slip faults east of ~98E longitude. This change from a single well-developed structure to multiple, linked structures may reflect the transition from juxtaposition of different basement terranes west of ~98E (e.g. Tarim to Qaidam/Qilian terranes), to dissection of the North China block (e.g. the same terrane on both sides of the fault) east of ~98E. The results from previous studies on the ATF and our data from the Alxa region suggest that pre–mid-Miocene tectonics of northeast Tibet and the Alxa region was dominated by lateral extrusion of crustal blocks on large-scale strike-slip faults that included the ATF as well as structures within the Alxa block" (Map and text from Darby, et al., 2005)

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Appendix One: Related Articles Researched for this Paper

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