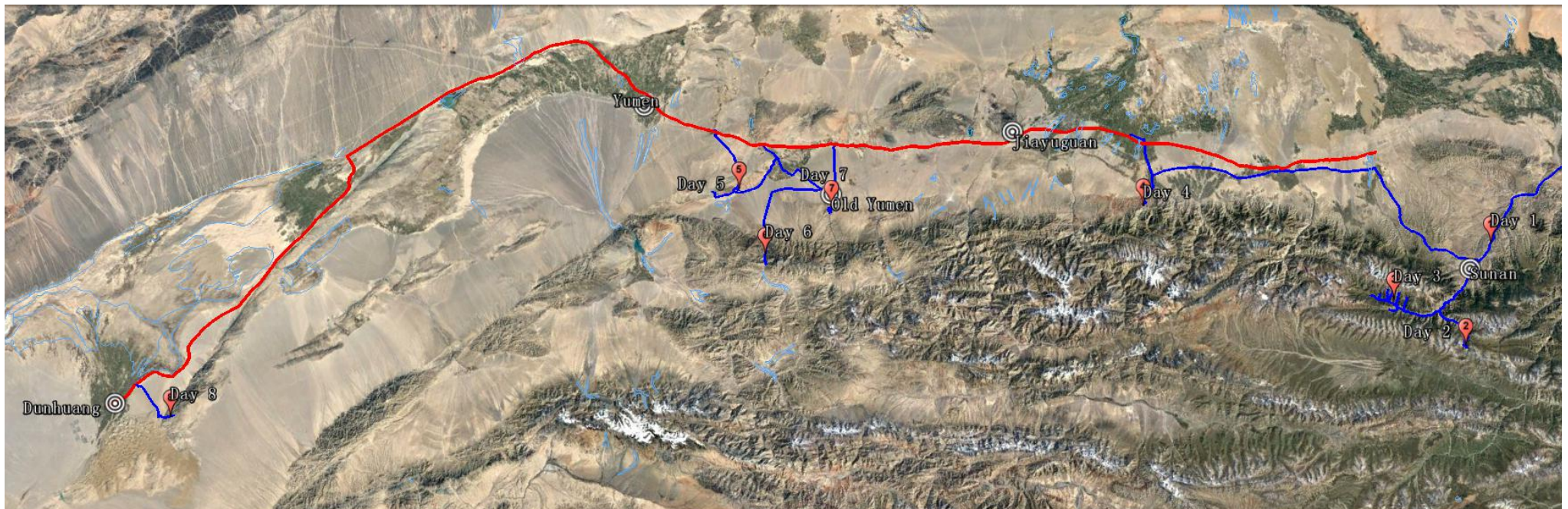


Tectonic evolution of the North Qilian Mountain:

From Paleozoic oceanic subduction to Cenozoic plateau expansion

A 8-days fieldtrip from Sunan to Dunhuang



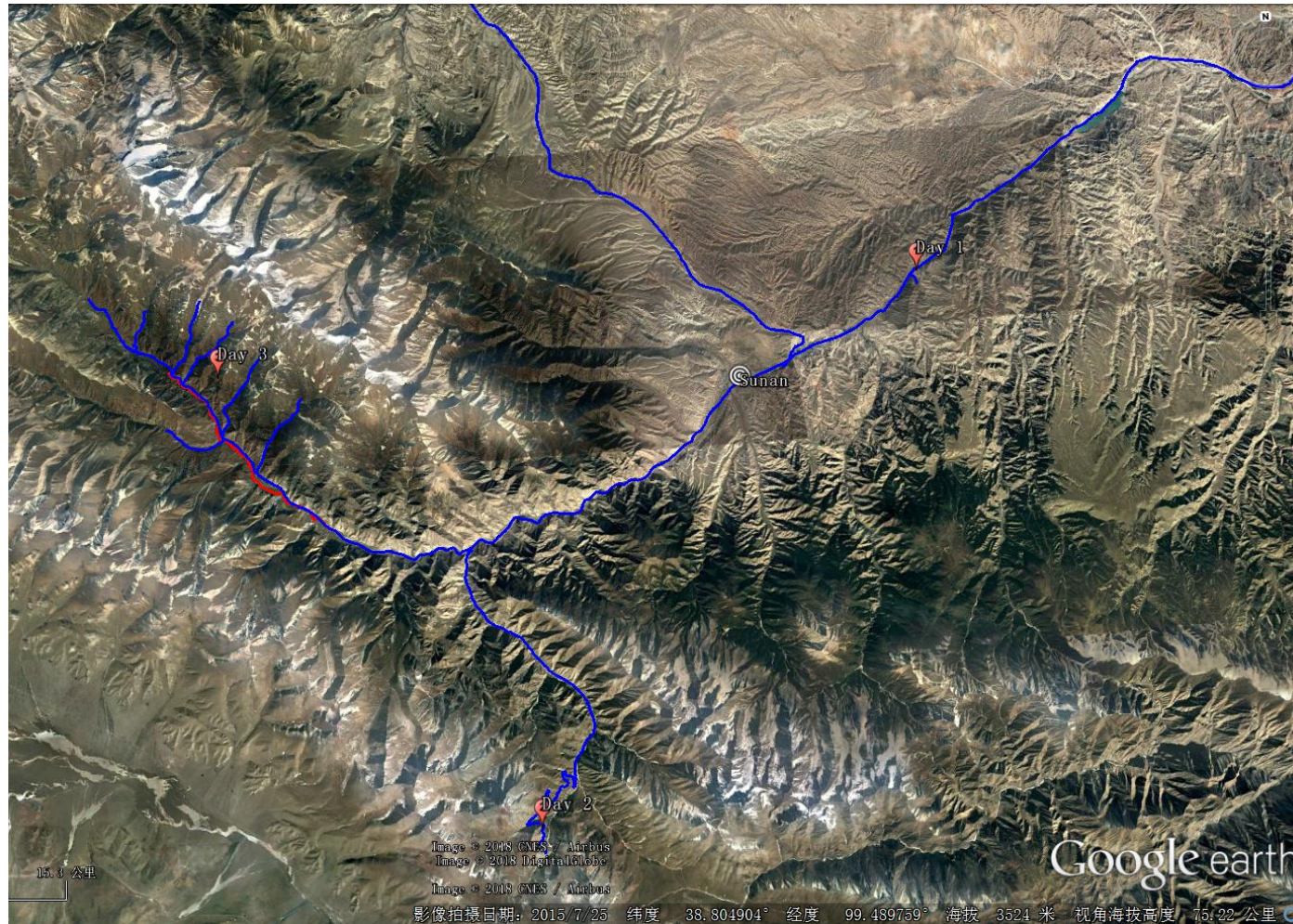
Why the North Qilian Mountain?

- **Early Paleozoic orogenic belt** preceded with a ***cold oceanic subduction zone*** with a subduction history from 520 Ma to 440 Ma
- Reactivated as an **intra-continental orogenic belt** flanked on its northern side by a typical foreland fold-and-thrust belt due to the far-field effect of ***the India-Eurasia collision in the Cenozoic era***
- Excellent outcrops and landscapes
- Convenient traffic conditions

Summary

- Day 0: arriving at Jiayuguan by air
- Days 1 – 3: early Paleozoic oceanic subduction and the subsequent orogeny (*Sunan County*)
 - Day 1: Oceanic subduction-related flysch (silurian), the overlying unconformity related to subsequent arc-continental collision (*northeast of Sunan*)
 - Day 2: Early Paleozoic ophiolite-like boninite-tholeiite sequence and felsic volcanic rocks (*along the road to Dachadaban*)
 - Day 3: Oceanic subduction-related metamorphic rocks, island arc granite and post-collisional deposits (*Jiugequanzi*)
- Days 4 – 7: The Cenozoic North Qilian Thrust Belt (NQTb) (*Yumen County*)
 - Day 4: The Jinfosi fold-and-thrust belt involving in a large granite pluton on the road to Yumen
 - Day 5: Cretaceous and Cenozoic sequences: initial timing (*Hongliuxia*)
 - Day 6: Long-distance nappes in the NQTb (*Kulong Shan*)
 - Day 7: Frontal thrusts of the NQTb (*Laojunmiao*)
- Day 8: Early Paleozoic metamafic rocks south of the *Dunhuang*

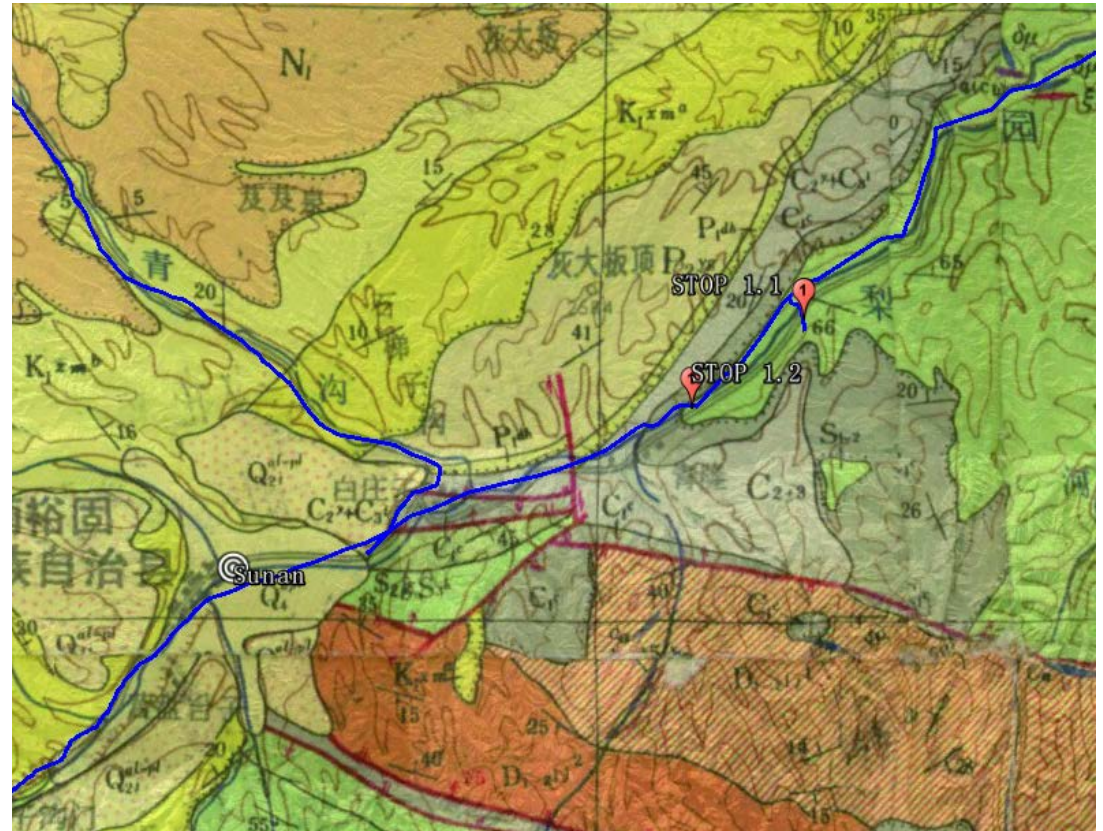
Part 1



Days 1 – 3:
early Paleozoic
oceanic
subduction
and the
subsequent
orogeny
(*Sunan County*)

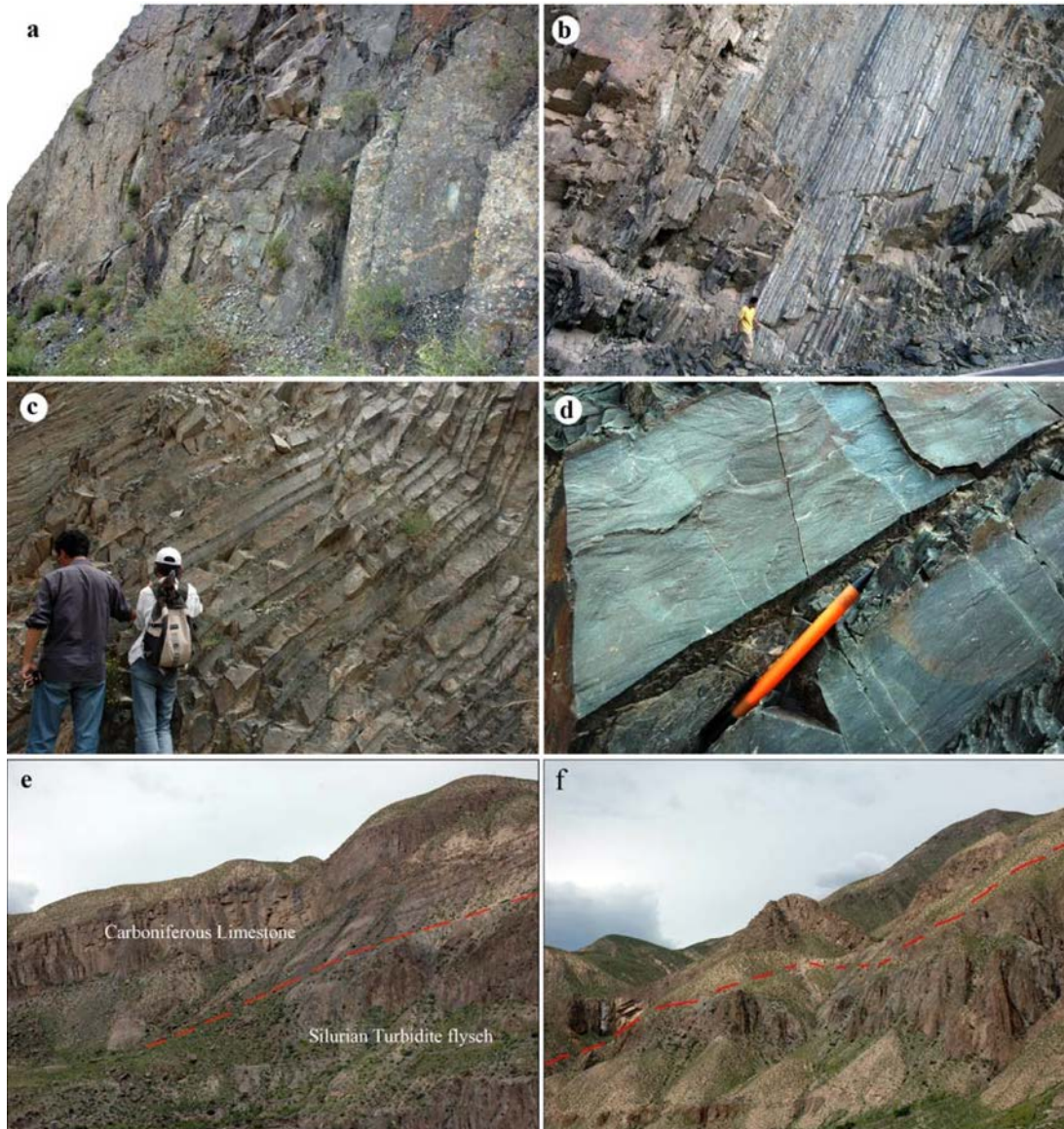
Day 1

- Jiayuguan to Sunan (~3 hours driving)
- **Oceanic subduction and subsequent arc-continental collision**
 - Stop 1.1: Silurian flysch related to early Paleozoic oceanic subduction
 - Stop 1.2: the unconformity between the flysch and the overlying Carboniferous sequences related to subsequent arc-continental collision



Sunan for the night

The Silurian flysch north of Sunan



(a) Conglomerate interbedded with sandstone.

(b) Thin-layered fine-grain turbidite.

(c) Turbidite rhythm layers.

(d) Enlarge view of turbidite rhythm layers showing grain-sized change from siltstone to shale and the nonparallel wavy laminations.

(e) and **(f)** The Carboniferous limestone layers with wavy folds unconformably overlie on the deep-angled Silurian turbidite layers

The Silurian flysch south of Sunan



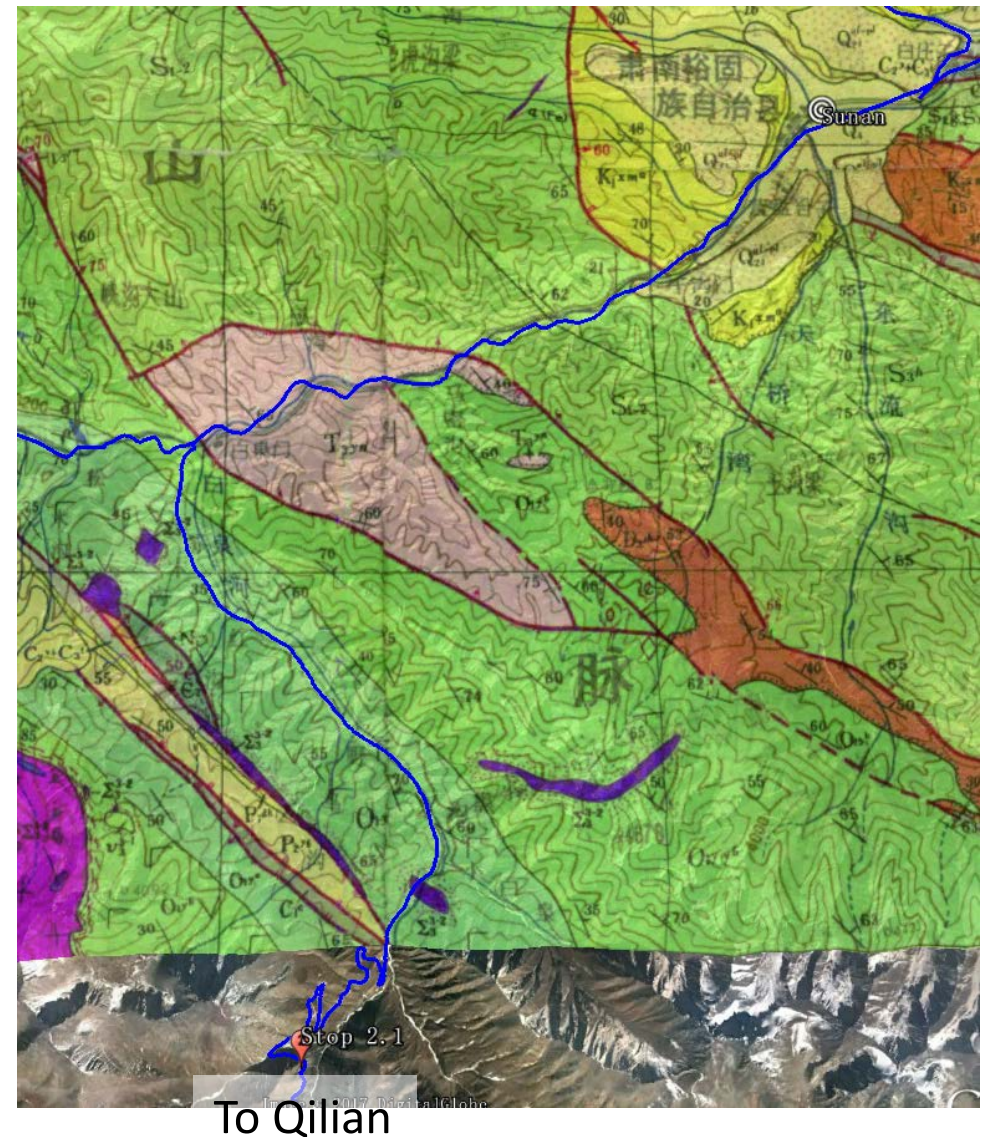
(left) the Early – Middle Silurian **submarine fans**: green conglomerate and sandstone with upward-fining rhythm;

(right) the Late Silurian **turbidities**: grayish purple sandstones with wavemarks and crossbeddings.

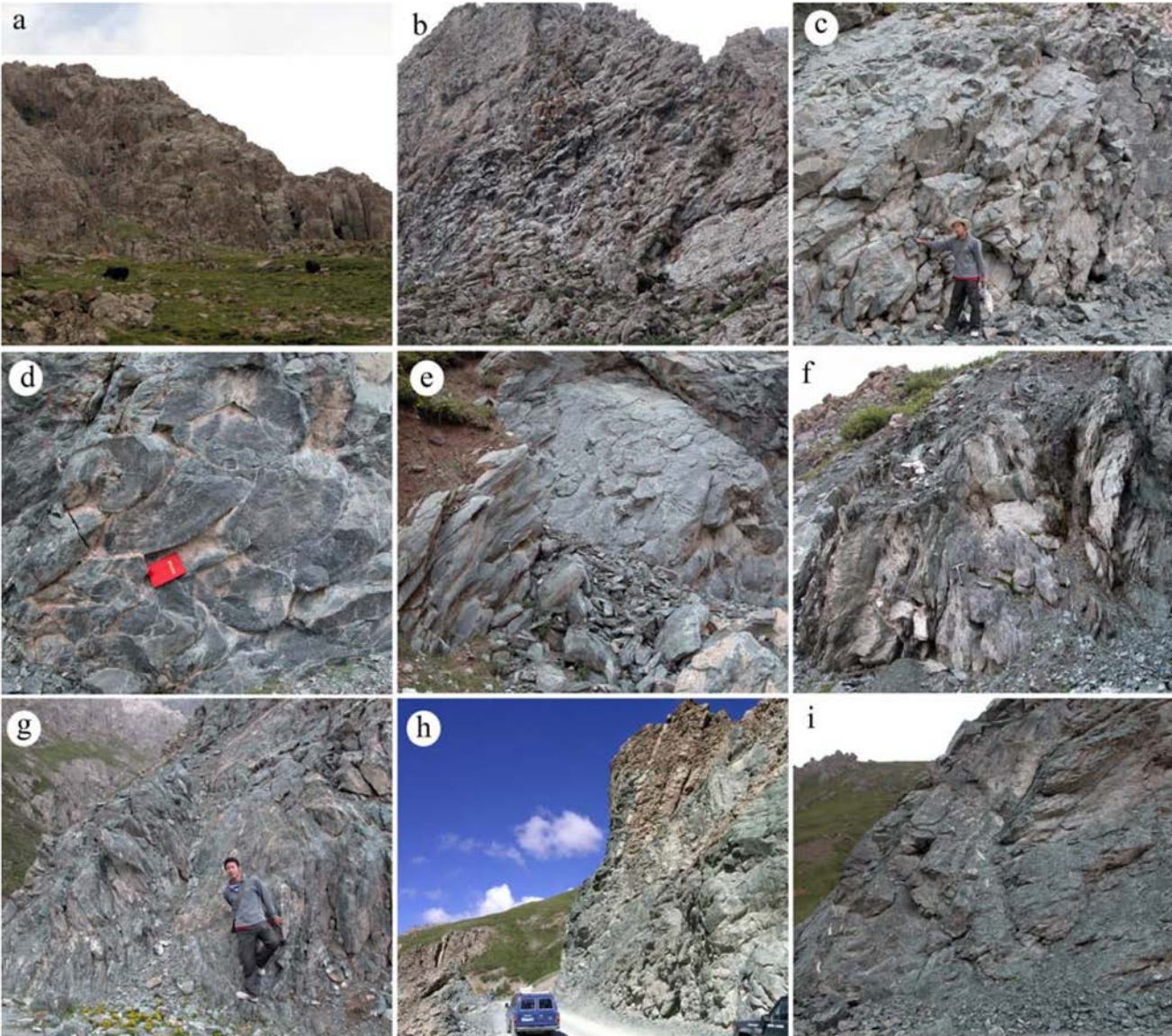
Day 2

- Sunan to Dachadaban (Along the road to Qilian)
- **Early Paleozoic ophiolite-like boninite sequence**
 - Stops 2.1 – 2.3: Pillow lava, metallization, diabase dyke intrusions, massive dolerite and gabbro
 - Stop 2.4: Felsic volcanic rock
- **Sunan for the night**

Need to check the accurate positions of the **stops** with Prof. Shuguang Song.



Photographs showing the boninite sequence



(a) Sheeted dykes with single-chilled margins;

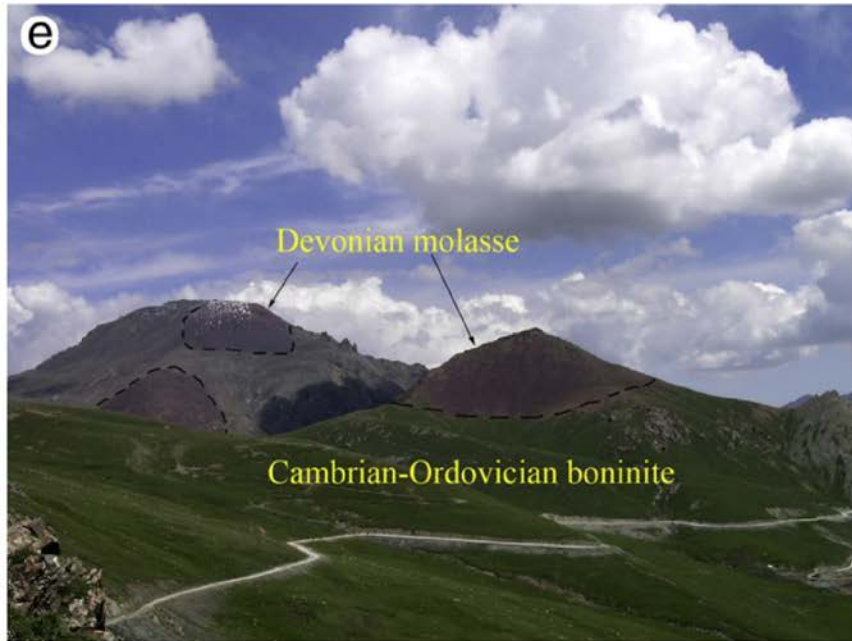
(b) – (d) Boninitic pillow lava, note that the pillows in panel (d) are overturned;

(e) – (g) Strong flattened and mylonitized pillows within thrusting fault belt;

(h) Boninitic intruded in boninitic pillow lava;

(i) Sheeted dyke swarm

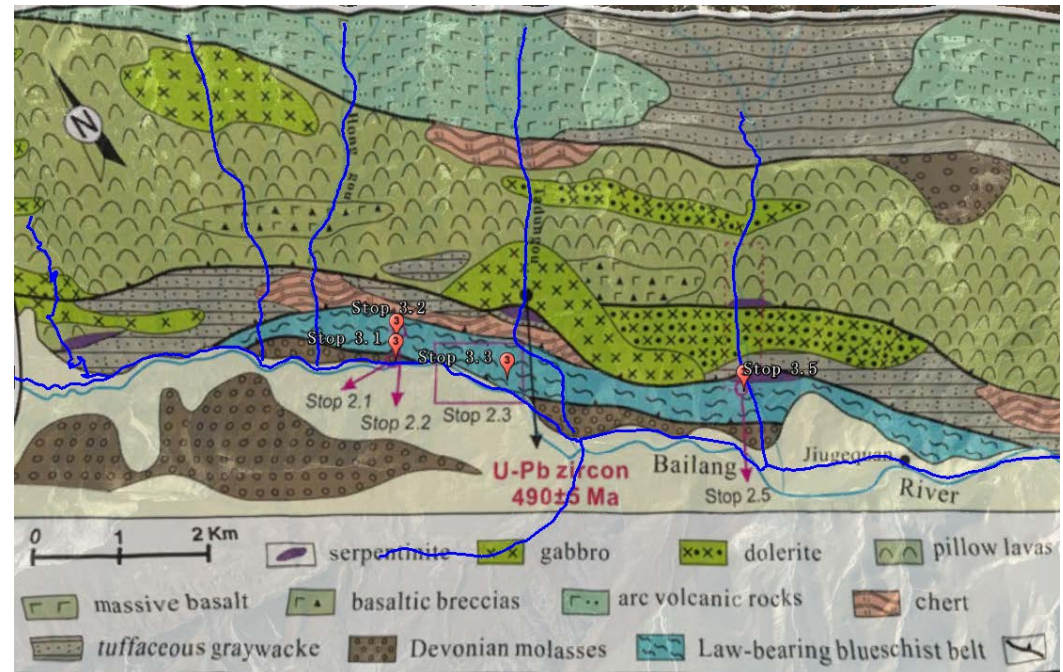
Devonian molasse along the road to Dachadaban



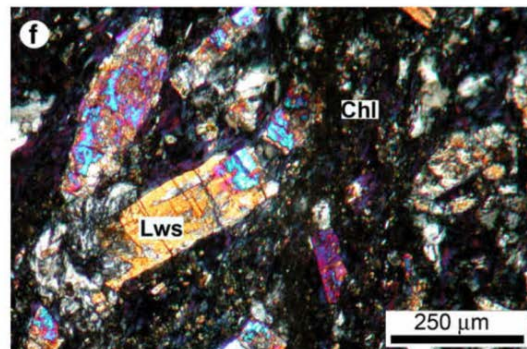
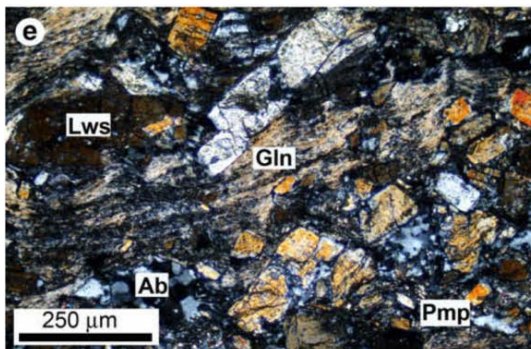
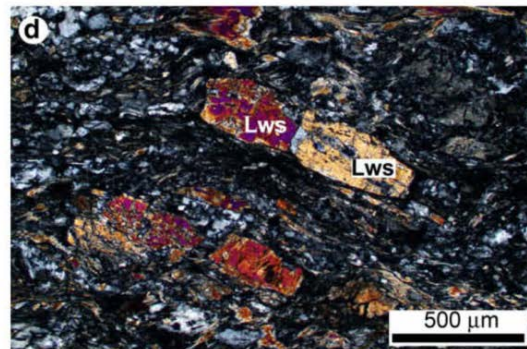
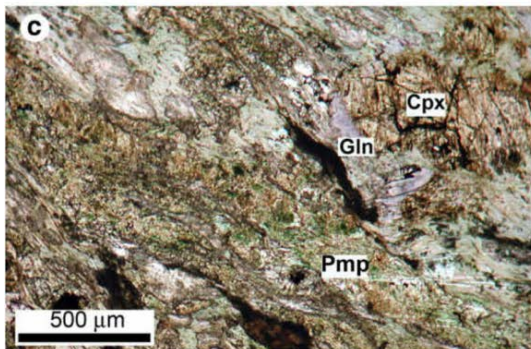
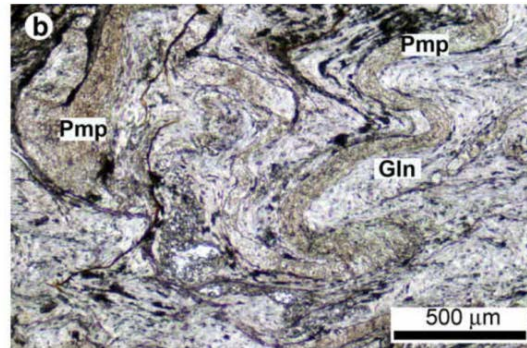
(left) the Devonian molasse deposited on the boninite complex;
(right) Oligomictic conglomerate in the Devonian molasse

Day 3

- Sunan to Jiugequanzi
- **Subduction-related metamorphic rocks and post-collisional deposits**
 - Stop 3.1: Devonian Molasse
 - Stops 3.2 and 3.3: Low-grade blueschists with mineral assemblage of Lws-pmp-gln-ab
 - Stop 3.4: Peraluminous Granite and their enclaves
 - Stop 3.5: (optional) Cu-ore (if possible)
- **Sunan for the night**



Low-grade blueschists.



(a) Low-grade blueschist outcrop showing isoclinal folds.

(b) Micro-folds of glaucophane (Gln) and pumpellyite (Pmp) segregation bands.

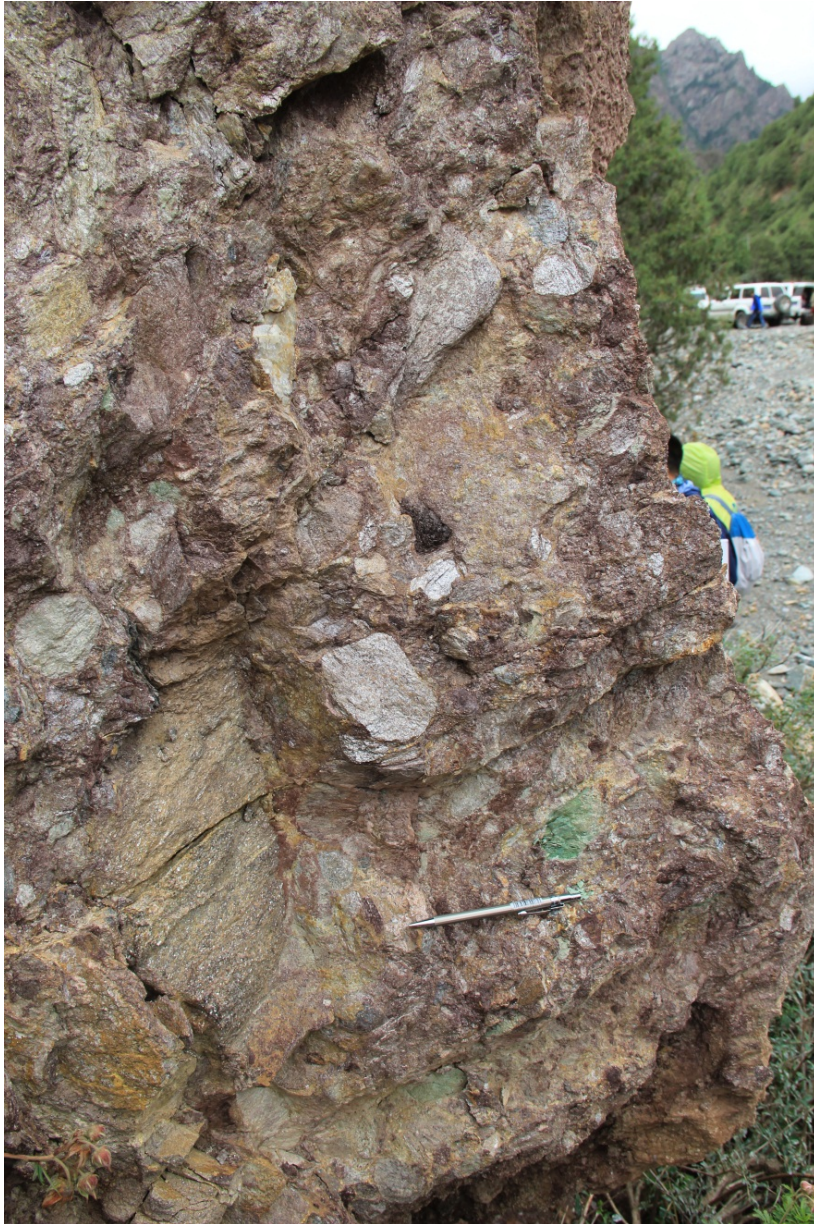
(c) Pmp + Gln overprinting the primitive Cpx.

(d) Lws + Gln in the felsic blueschist;

(e) Lws + Gln + Pmp + Ab (+Chl) assemblage with intensive schistosity.

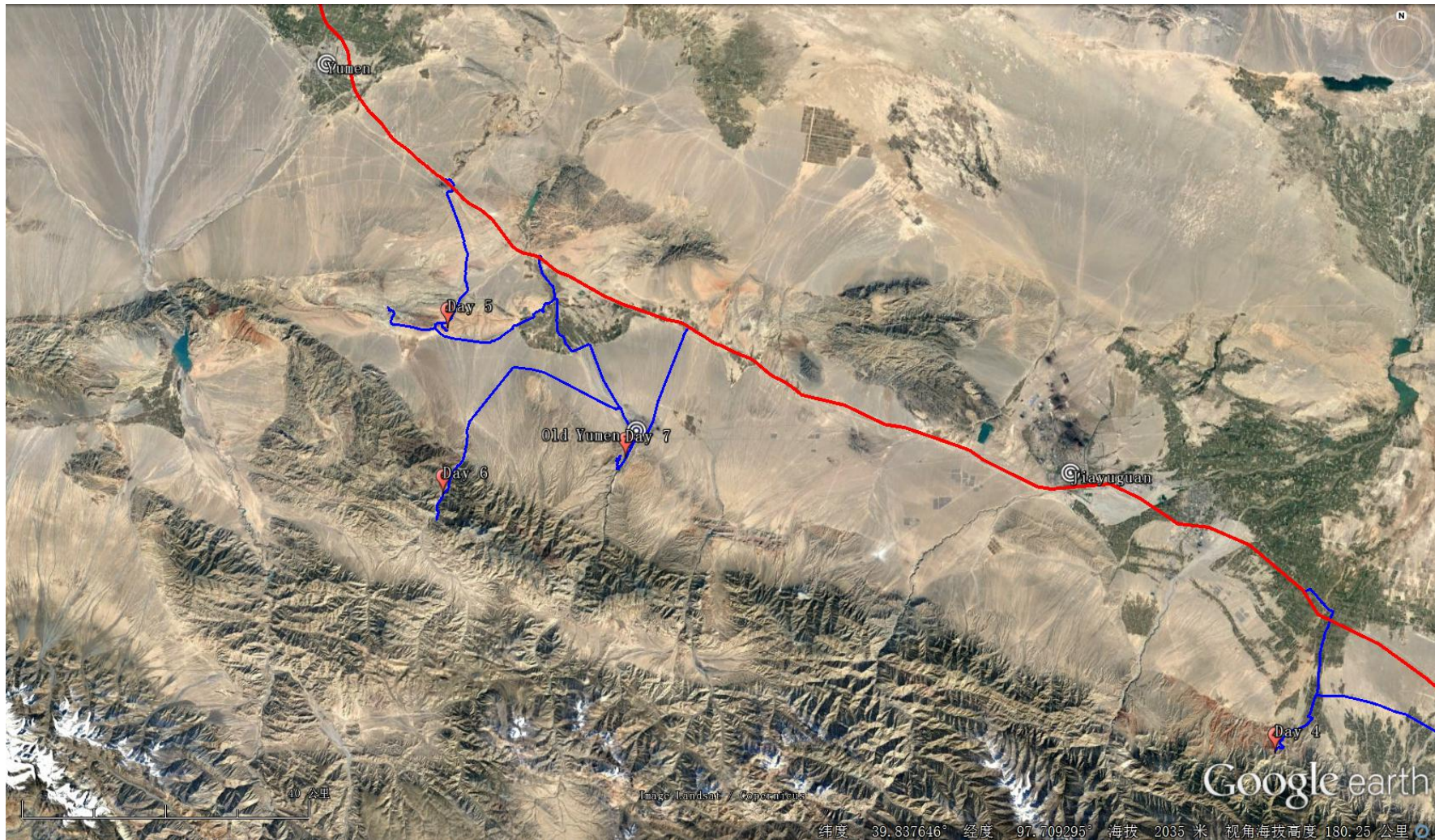
(f) Lws + Chl (+Ab) assemblage.

Devonian molasse



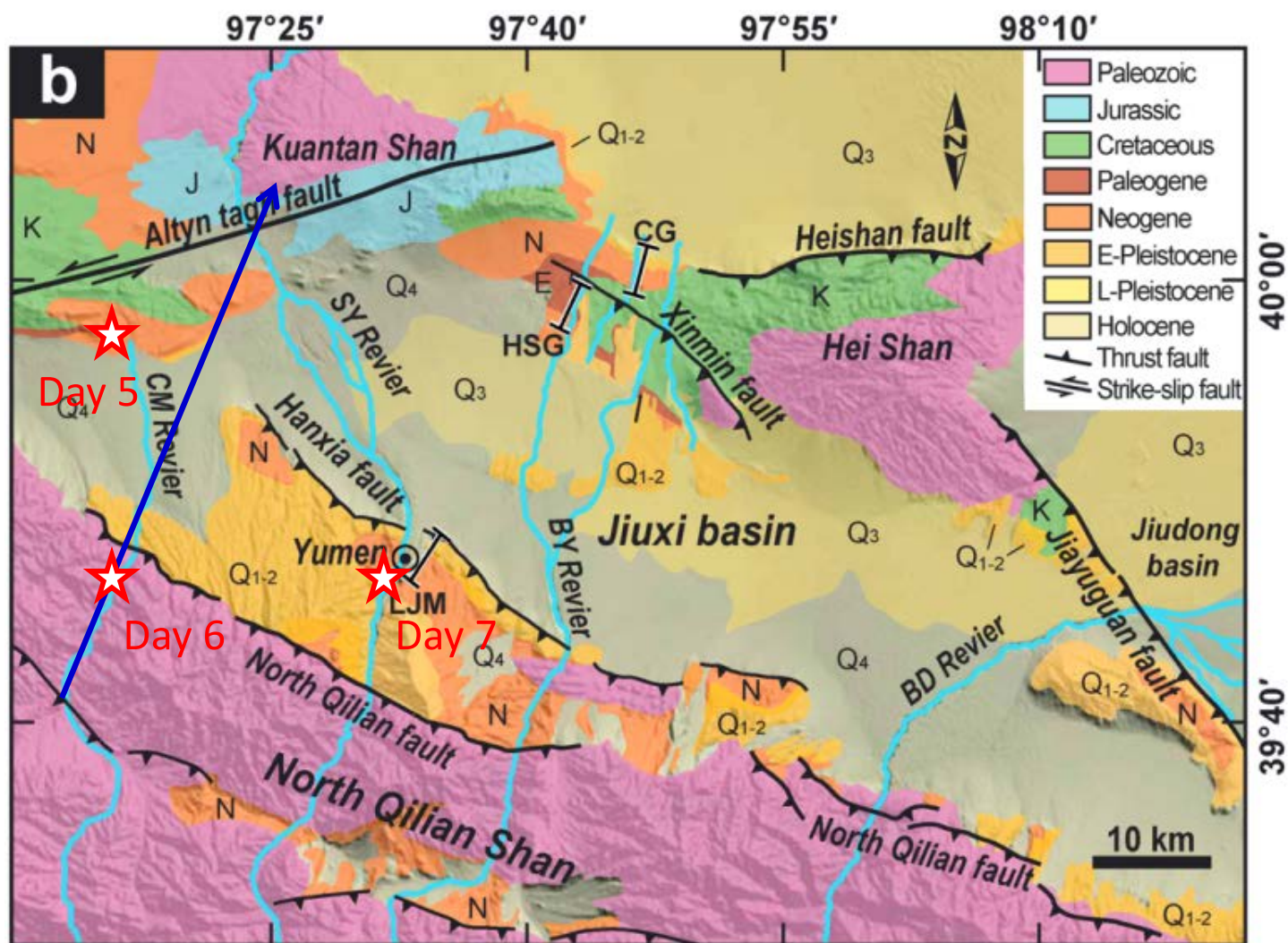
(Left) The Devonian **molasse**: grayish purple conglomerate

Part 2



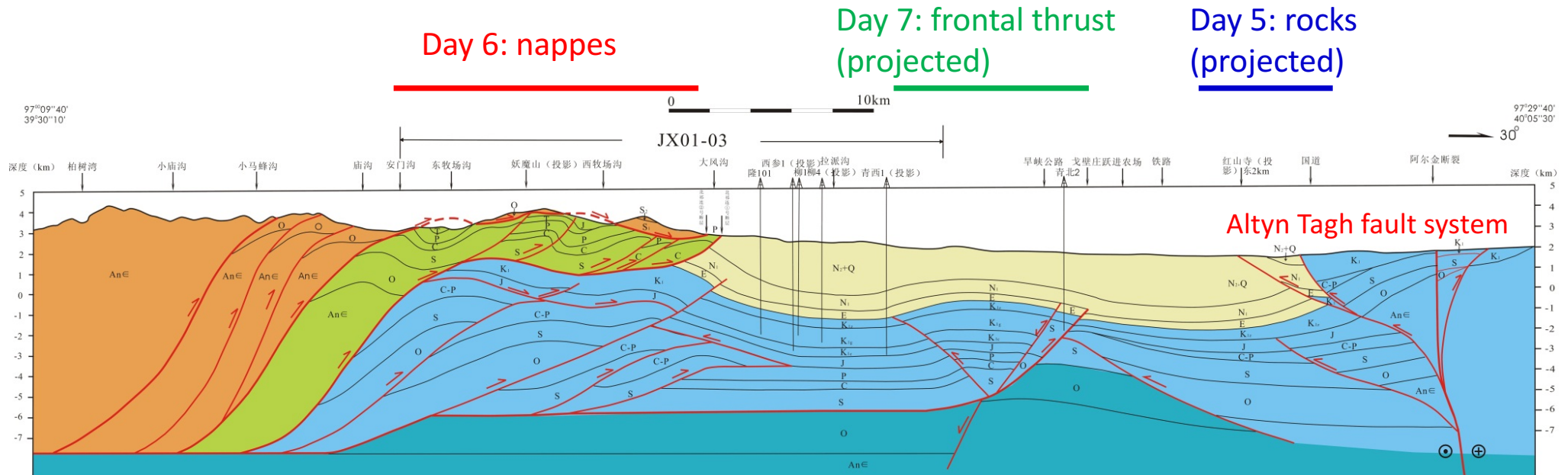
Days 4 – 7: The Cenozoic North Qilian Thrust Belt (NQTB) (*Yumen County*)

Simplified geological map



Wang et al., 2016, JGR, v. 121, p. 2235-2257.

Geological section

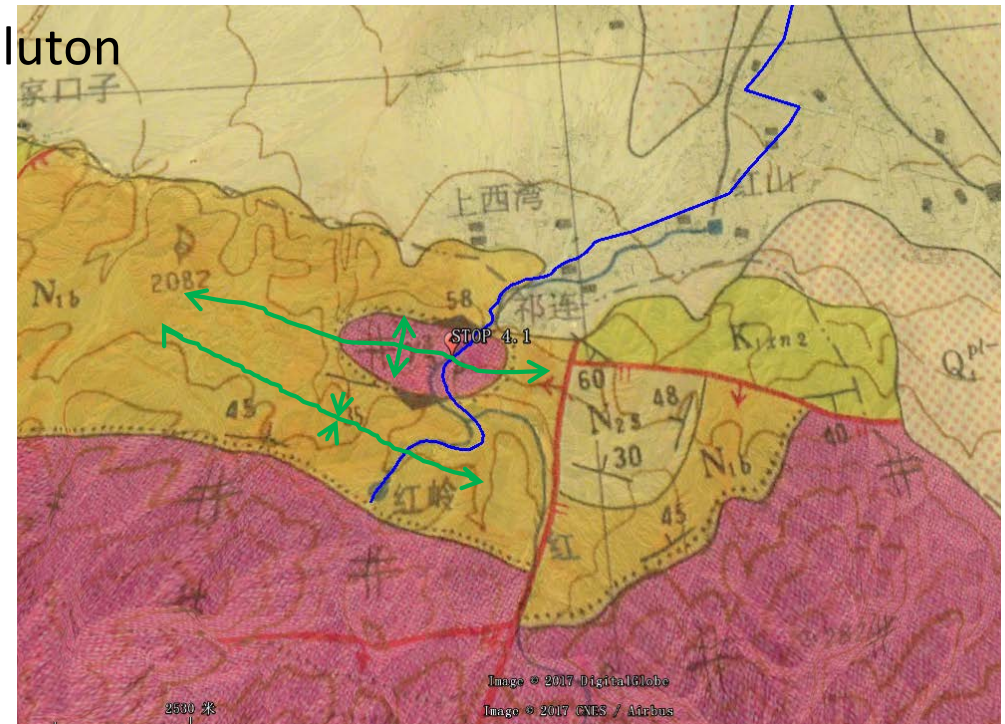
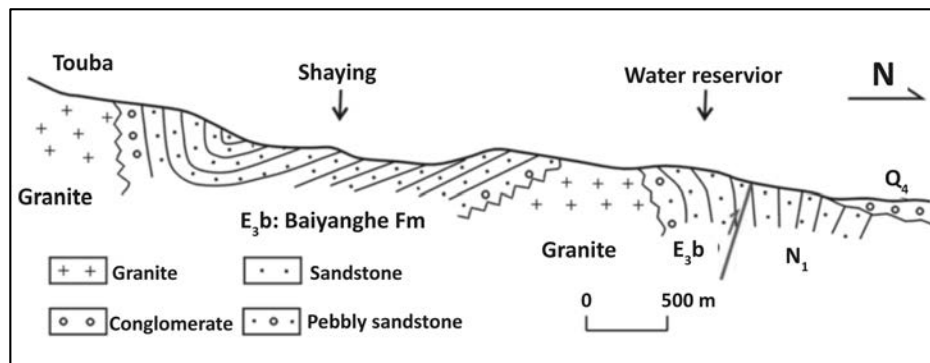


(Top) A geological section across the NQTB, the Jiuxi Basin and the Altyn Tagh fault system, showing the subsurface structure.

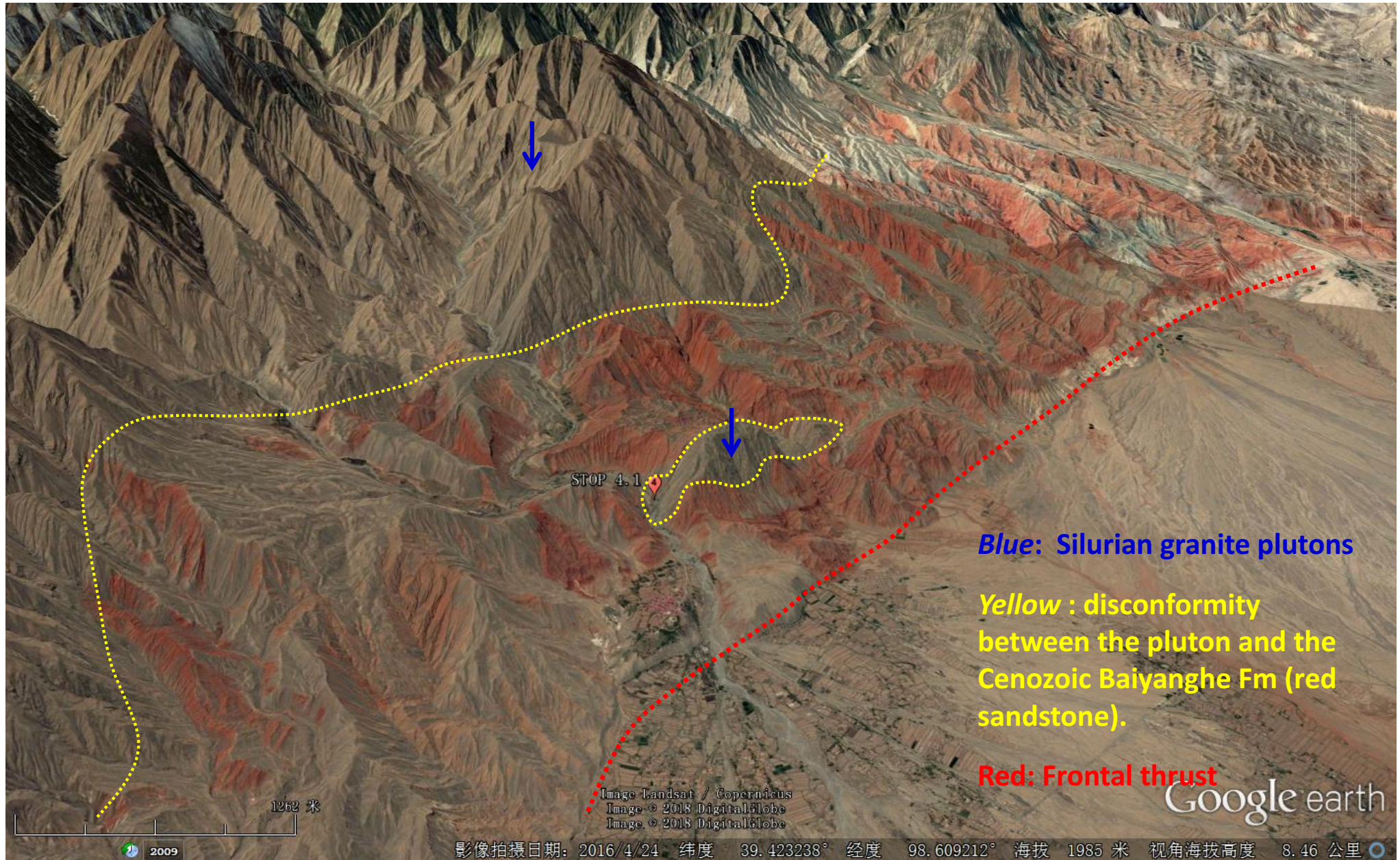


Day 4

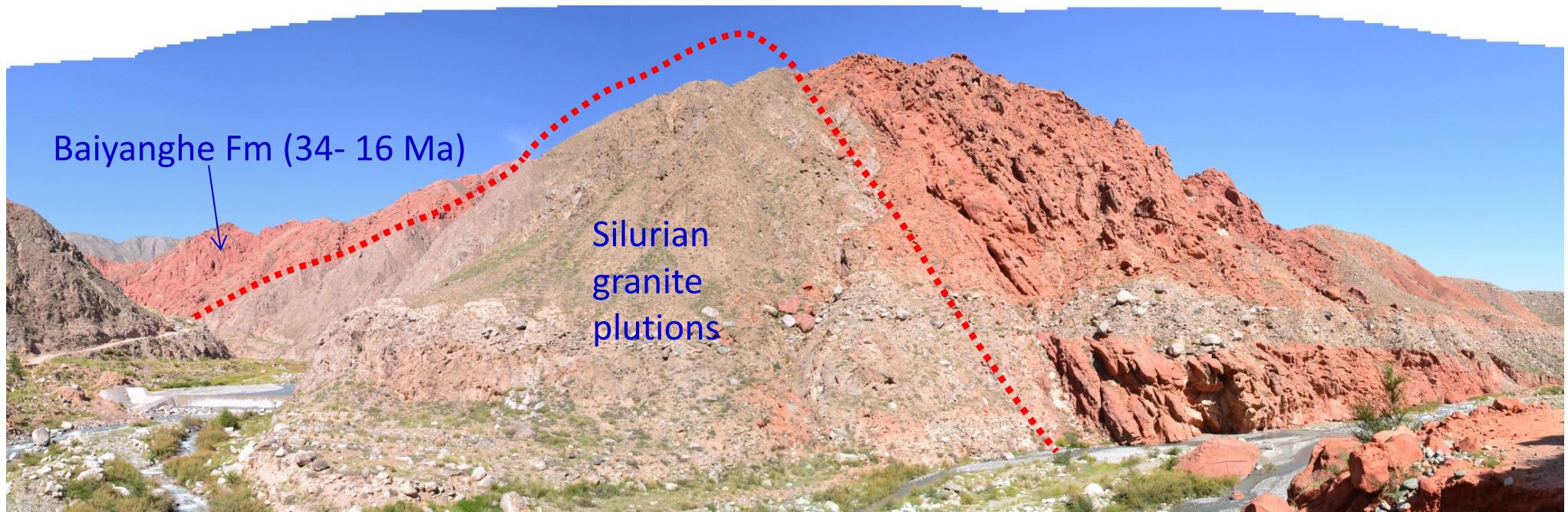
- Sunan to Yumen (5.5-hours driving)
- **Examine the front thrust of the North Qilian Thrust Belt (NQTb) along its east segment**
 - Stop 4.1: The Jinfosi fold-and-thrust belt involving in a large granite pluton
- **Yumen for the night**



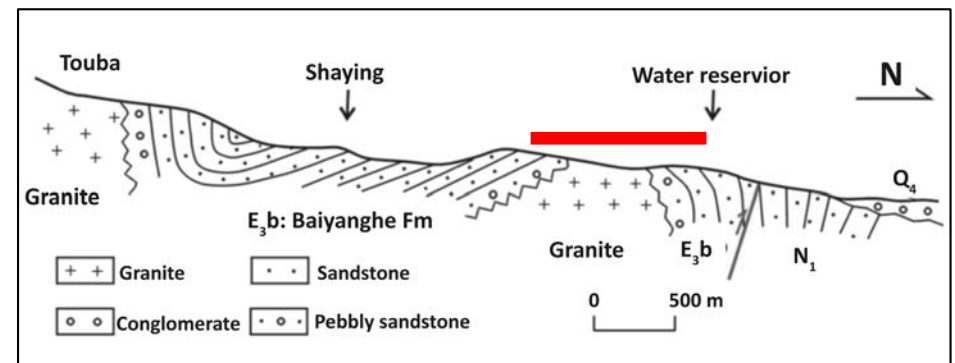
Jinfosi thrust belt



Jinfosi thrust belt

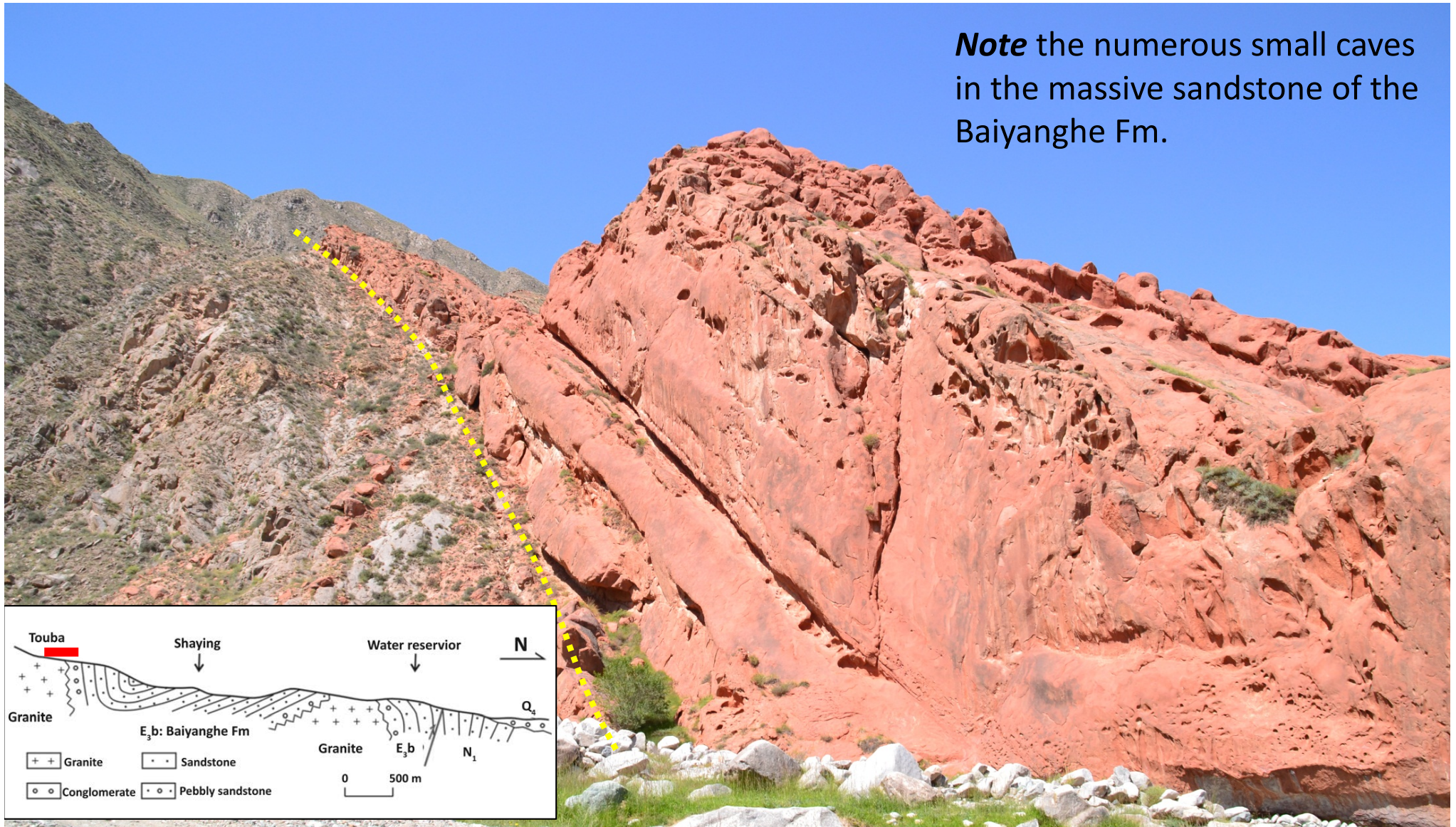


(Top) The *Hongshancun anticline*. The Silurian granite is exposed in the core and overlain disconformably by the red sandstone of the Cenozoic Baiyanghe Fm. Note that the anticline has a steeper northern limb. *North is on the right.*



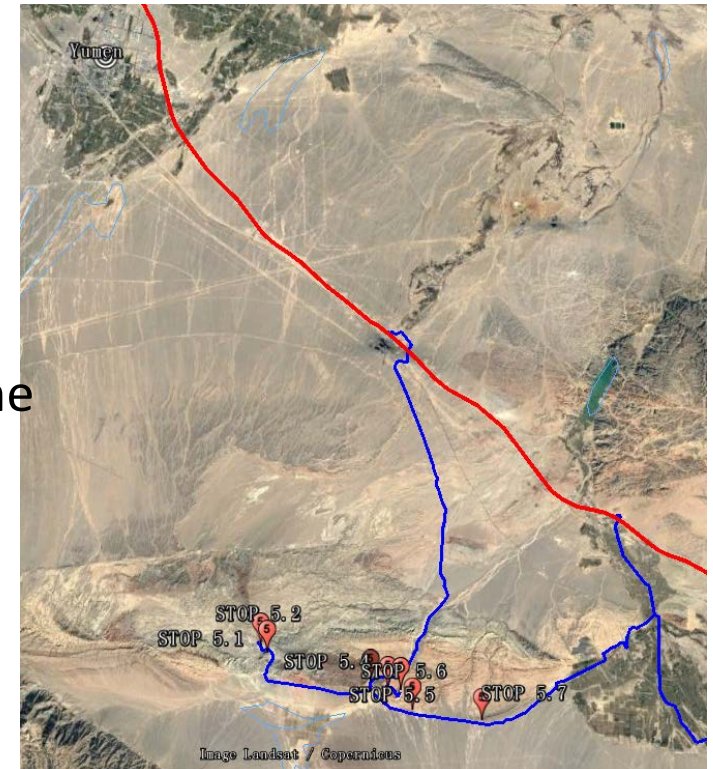
Disconformity between the Silurian granite pluton (left) and the Baiyanghe Fm (right).

Note the numerous small caves in the massive sandstone of the Baiyanghe Fm.



Day 5

- Yumen to Hongliuxia
- **Cretaceous and Cenozoic sequences in the front of the NQTB: initial timing**
 - Stop 5.1: Cretaceous mudstone and sandstone
 - Stop 5.2: K₁ volcanos and dikes
 - Stop 5.3: Huoshaogou Fm. (40 – 34 Ma)
 - Stop 5.4: Baiyanghe Fm. (34 – 16 Ma)
 - Stop 5.5: Top of the Baiyanghe Fm. and the overall deformation on high
 - Stop 5.6: Shulehe Fm. (16 – 4.5 Ma)
 - Stop 5.7: Yumen Conglomerate (< 4.5 Ma)
- **Yumen for the night**



Cretaceous volcano and sedimentary rocks



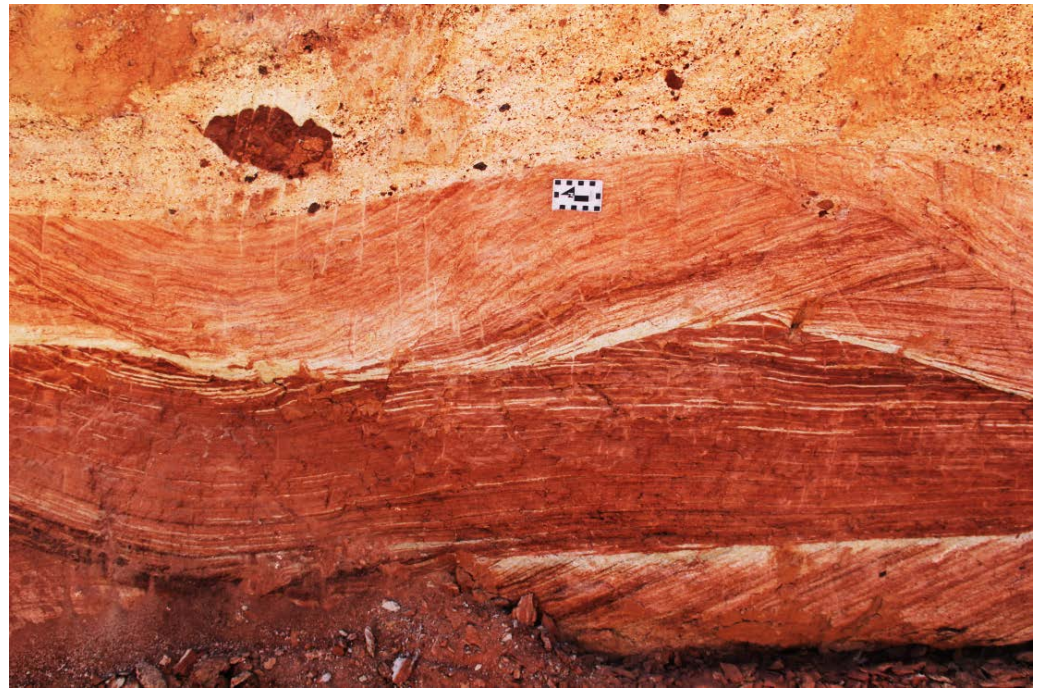
(Top) Cretaceous **volcano** (highland in the background) and sedimentary rocks (**sandstone and mudstone** in the foreground)

Huoshagou Fm. (40 - 34 Ma)



(Top) Conglomerate and sandstone in the Huoshagou Fm.

Baiyanghe Fm. (34 - 16 Ma)



(Top) Tough cross-beddings;

(Left) Stone pillars consisting of massive pebbly sandstone.

Upper part of the **Shulehe Fm.** (16 - 4.5 Ma):
sandstone interbedded with conglomerate



Yumen Fm. (< 4.5 Ma)

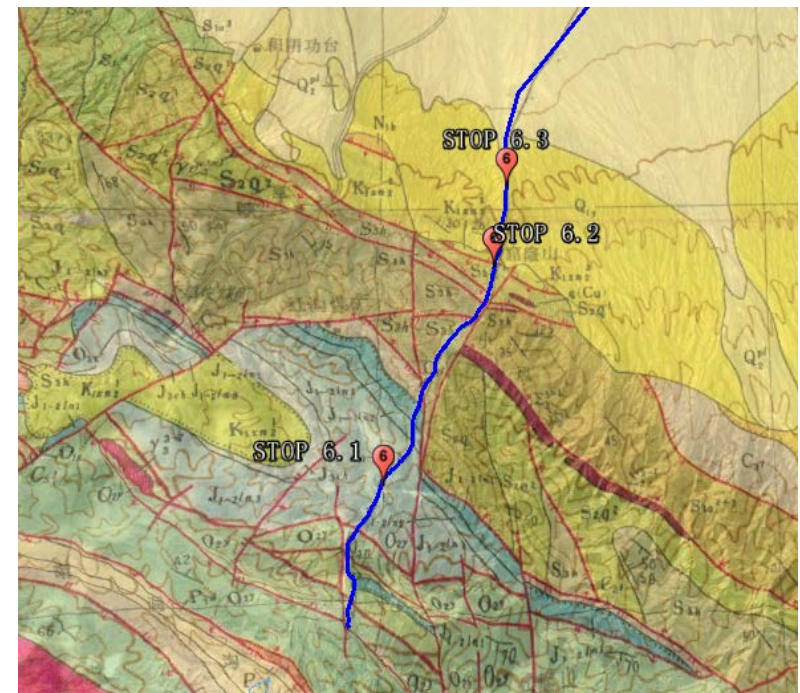
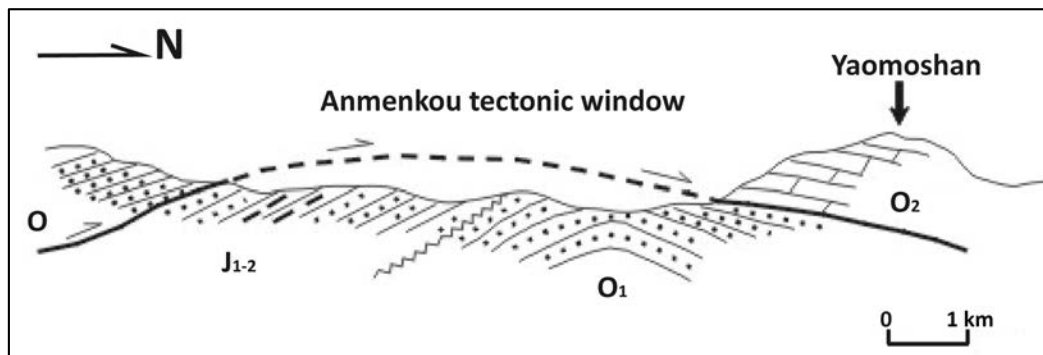


Clast-supported massive conglomerate

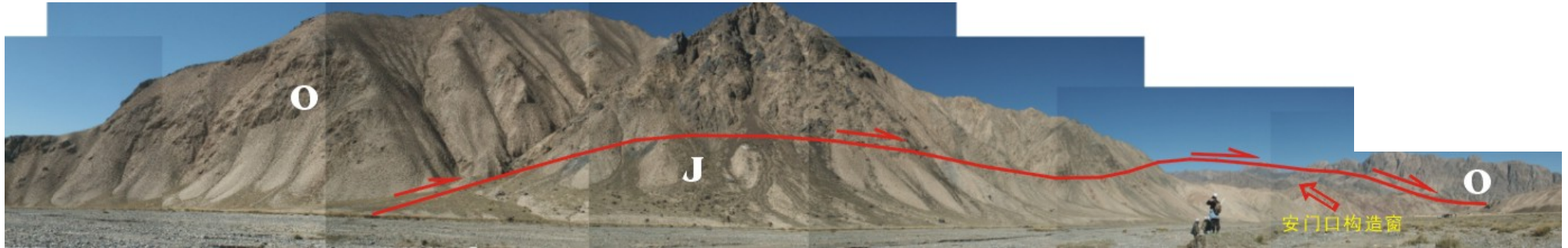
Need to check the specific stops
in the field in advance

Day 6

- Yumen to Kulongshan
- **Long-distance nappes in the NQTB**
 - Stops 6.1: tectonic windows
 - Stop 6.2: thrust in the front of the North Qilian Mountain
 - Stop 6.3: deformed Yumen conglomerate
- Yumen for the night

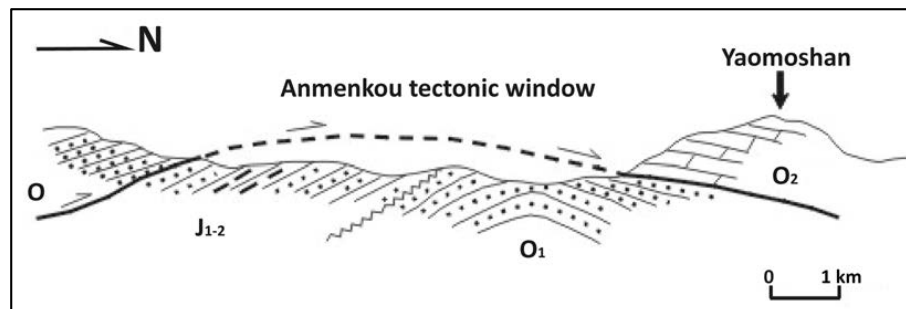
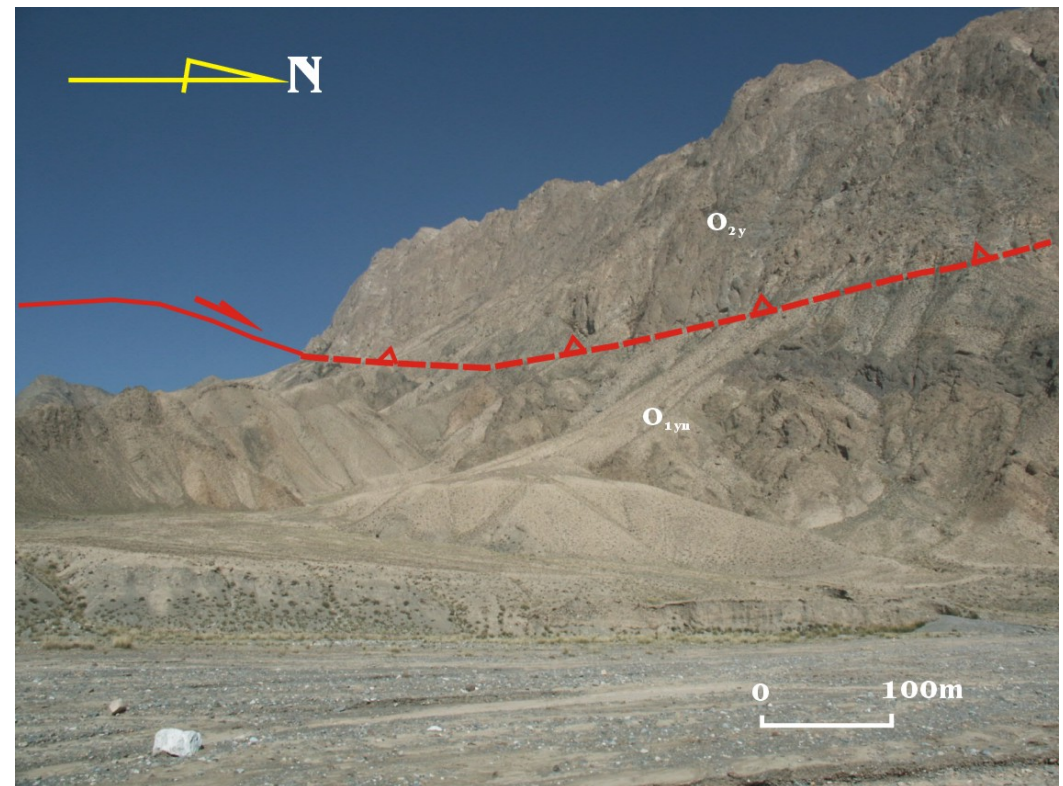


Anmenkou nappes in the NQTB



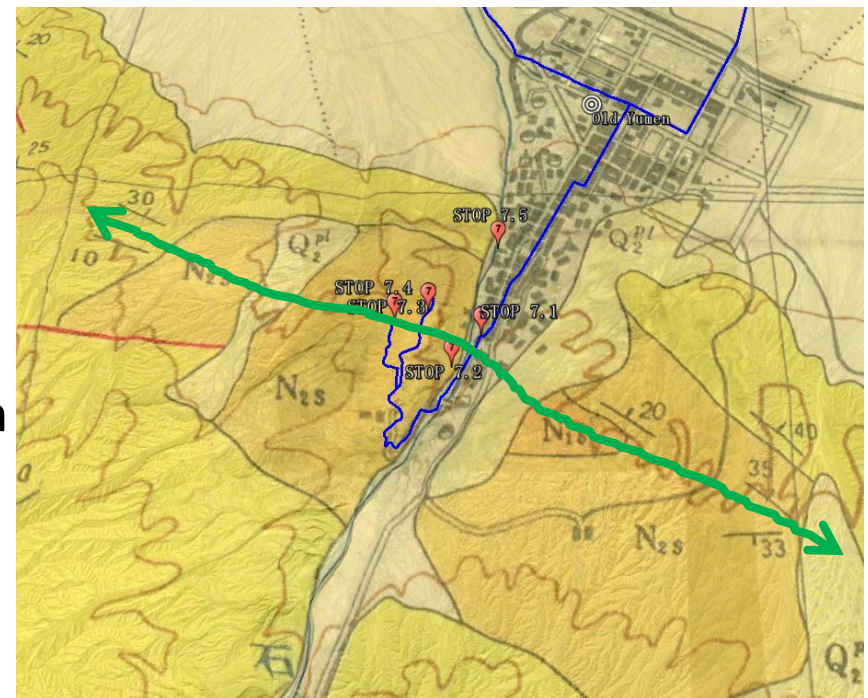
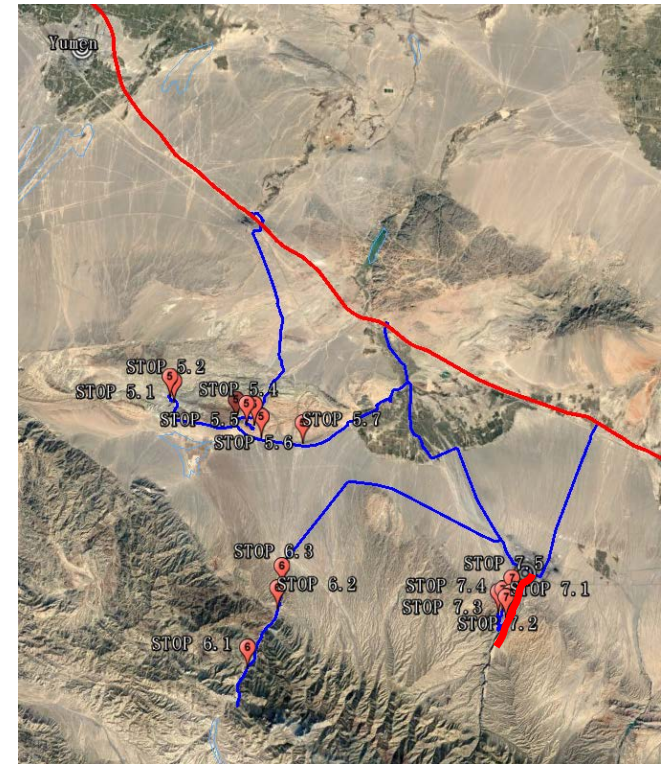
(Upper) an overview of the Anmenkou tectonic window; *North is on the right*;

(Right) northern part of the tectonic window; *North is on the right*.



Day 7

- Yumen to Laojunmiao
- **Frontal thrust of the NQTB**
 - Stop 7.1: A whole view of the Laojunmiao anticline, the Shiyou river and related terrace
 - Stops 7.2, 7.3 and 7.5: upward coarsening rhythm of the Cenozoic sequences
 - Stop 7.4: the northeastward-inclined Laojunmiao anticline
 - Stop 7.6: history of the first oilfield in China
- Yumen for the night



Laojunmiao anticline and the terraces related to Shiyou River (Stop 7.1)



Kink-band in the northern limb of the Laojunmiao anticline



Stop 7.2: fine-grained sandstone and mudstone in the lower part of
the Shulehe Fm. (prodelta)



Stop 7.3: Massive sandstone in the middle - upper part of the
Shulehe Fm. (delta front)

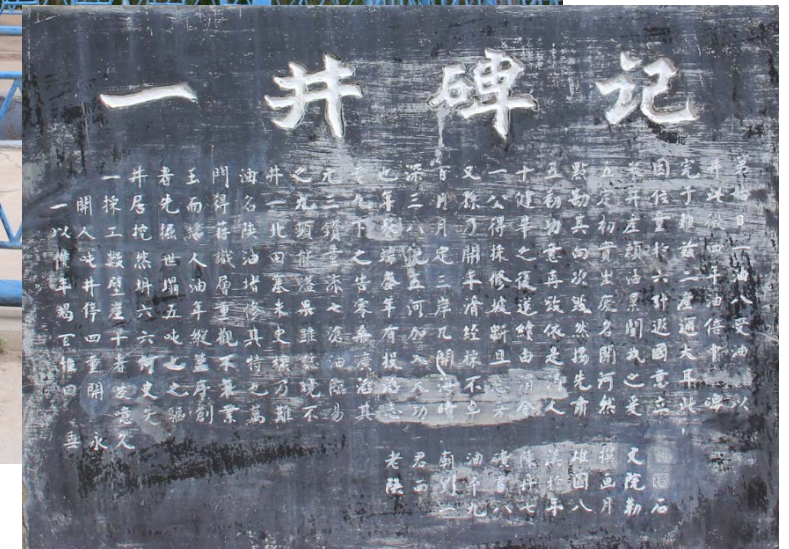


Note the lens-shaped sand bodies

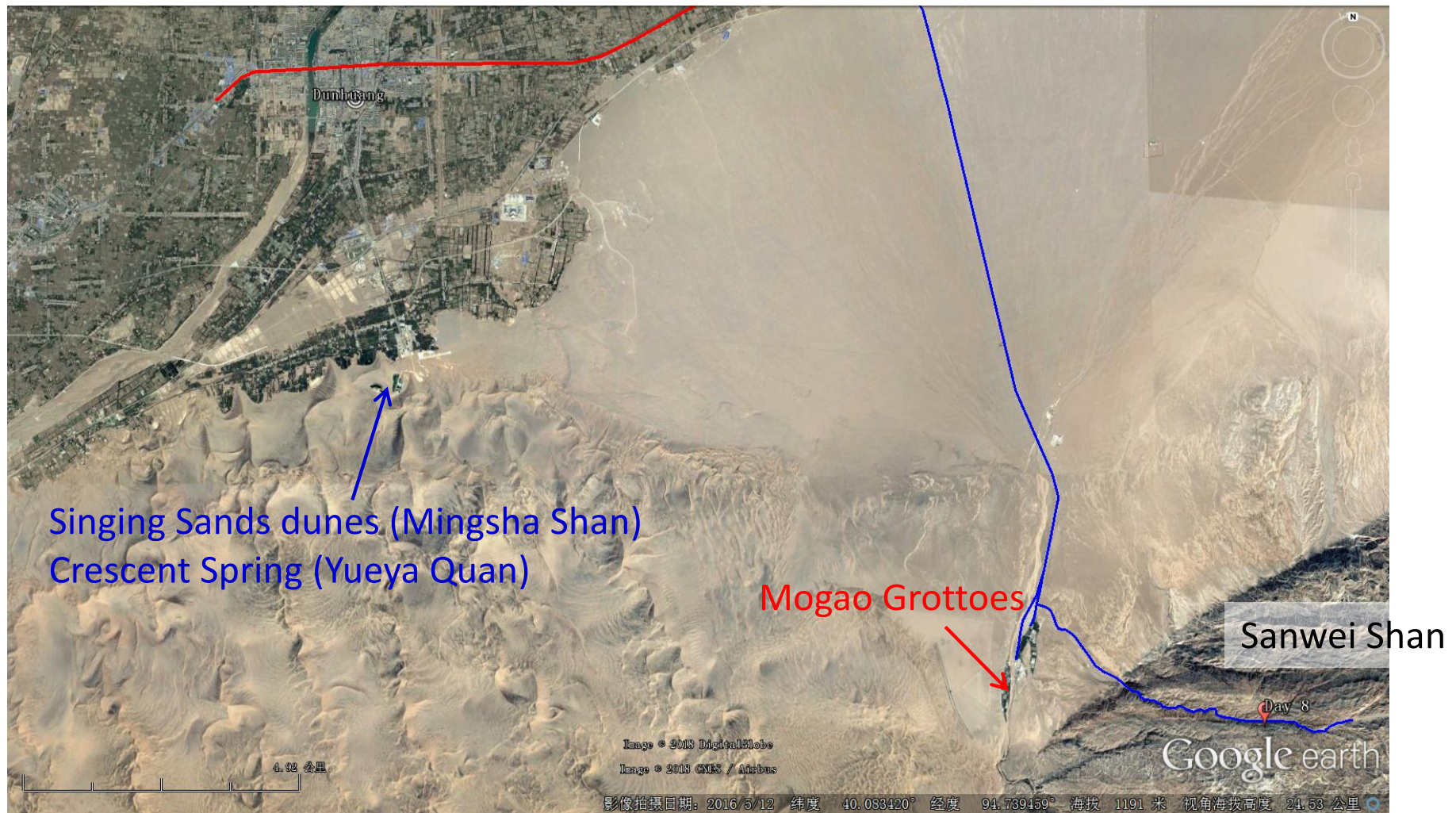
Stop 7.5: Conglomerate in the lower part of the Yumen Fm. (fluvial
- alluvial fan)



Stop 7.6: first oil well in China (1939.3, 115.5m)



Part 3

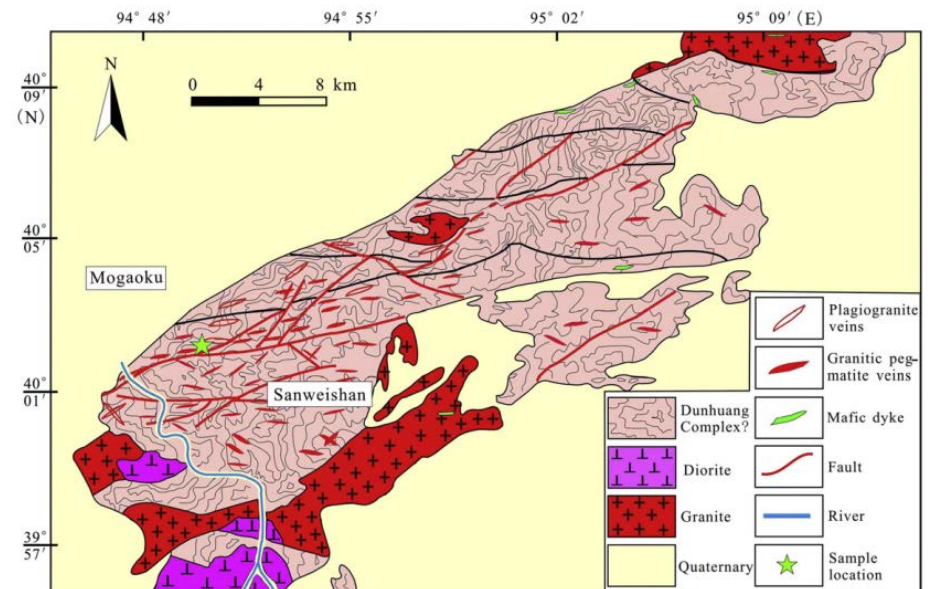


Day 8: Early Paleozoic metamafic rocks south of the *Dunhuang*

Need to check the specific stops in the field in advance

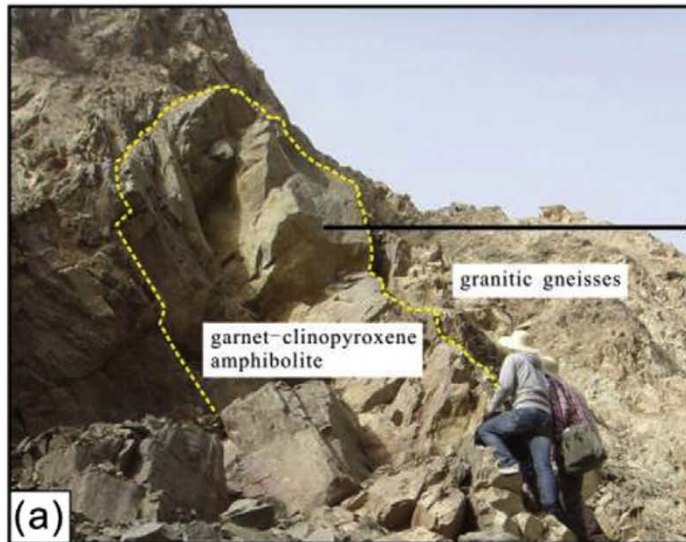
Day 8

- Yumen to Dunhuang
- **Bedrock south of Dunhuang (along the road to Sanweishan)**
 - Stop 8.1: metamafic rocks, including garnet–clinopyroxene amphibolites (410 ± 11 Ma), garnet-free amphibolites (403 ± 8 Ma), and garnet–mica amphibolites (441 ± 3 , 408 ± 12 , 370 ± 2 Ma)
- **Dunhuang for the night**



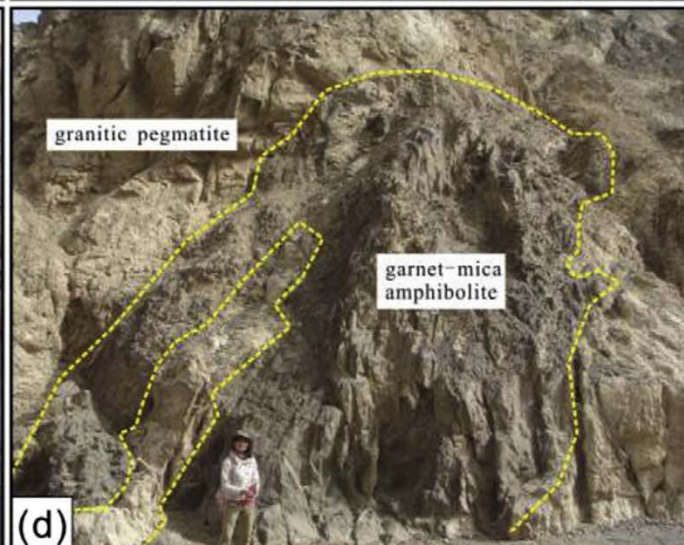
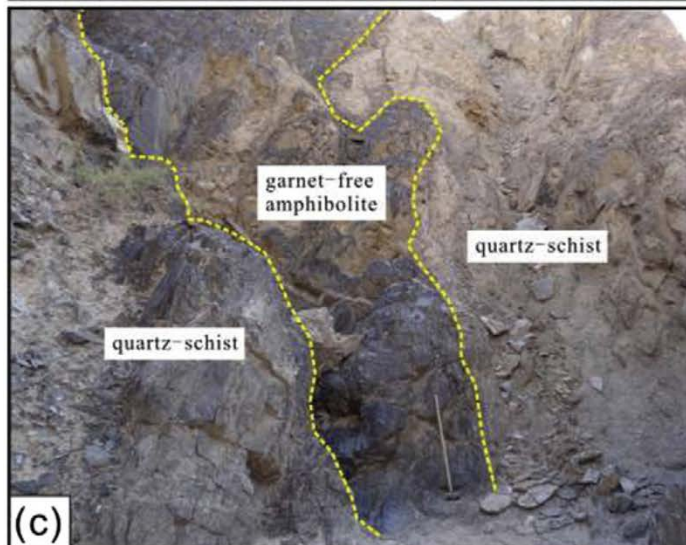
Zhao, et al., 2016, GR, 30, 207-223

Photoes of the metamorphic rocks in the Sanweishan near Dunhuang



(a) garnet-clinopyroxene amphibolite in granitic gneiss as lens;

(b) a garnet-clinopyroxene amphibolite from Sanweishan area;



(c) a garnet-free amphibolite in quartz-schist as layer;

(d) a garnet-mica amphibolite in granitic pegmatite as lens.

Further reading

Part 1 (Days 1 – 3)

- Song, S., Niu, Y., Su, L., and Xia, X., 2013, Tectonics of the North Qilian orogen, NW China: Gondwana Research, v. 23, p. 1378-1401.
- Xia, X.H., Song, S.G., Niu, Y.L., 2012. Tholeiite-Boninite terrane in the North Qilian suture zone: Implications for subduction initiation and back-arc basin development. Chemical Geology 328, 259-277.
- Song, S., Niu, Y., Zhang, L., Wei, C., Liou, J.G., and Su, L., 2009, Tectonic evolution of early Paleozoic HP metamorphic rocks in the North Qilian Mountains, NW China: New perspectives: Journal of Asian Earth Sciences, v. 35, p. 334-353.

Part 2 (Days 4 – 7)

- Wang, W., Zhang, P., Yu, J., Wang, Y., Zheng, D., Zheng, W., Zhang, H., and Pang, J., 2016, Constraints on mountain building in the northeastern Tibet: Detrital zircon records from synorogenic deposits in the Yumen Basin: Scientific Reports, v. 6, p. 27604.
- Zuza, A.V., Cheng, X., and Yin, A., 2016, Testing models of Tibetan Plateau formation with Cenozoic shortening estimates across the Qilian Shan-Nan Shan thrust belt: GEOSPHERE, v. 12, p. 501-532.
- Zheng, D., Clark, M.K., Zhang, P., Zheng, W., and Farley, K.A., 2010, Erosion, fault initiation and topographic growth of the North Qilian Shan (northern Tibetan Plateau), 6*6, p. 937 - 941.
- Hetzel, R., Niedermann, S., Tao, M., Kubik, P.W., and Strecker, M.R., 2006, Climatic versus tectonic control on river incision at the margin of NE Tibet: ¹⁰Be exposure dating of river terraces at the mountain front of the Qilian Shan: Journal of Geophysical Research, v. 111, p. 1-13.

Part 3 (Day 8)

- Zhao, Y., Sun, Y., Diwu, C., Guo, A., Ao, W., and Zhu, T., 2016, The Dunhuang block is a Paleozoic orogenic belt and part of the Central Asian Orogenic Belt (CAOB), NW China: Gondwana Research, v. 30, p. 207-223.