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Tien Shan's Qilitak anticline, a large fold that formed over a blind, or buried, fault. The origins and workings of this type of feature are hotly debated, and formed the core of the field investigations. Minibuses in the foreground give a sense of how enormous it is.

Heavenly Mountains, Down-to-Earth Job

By Elisabeth Nadin

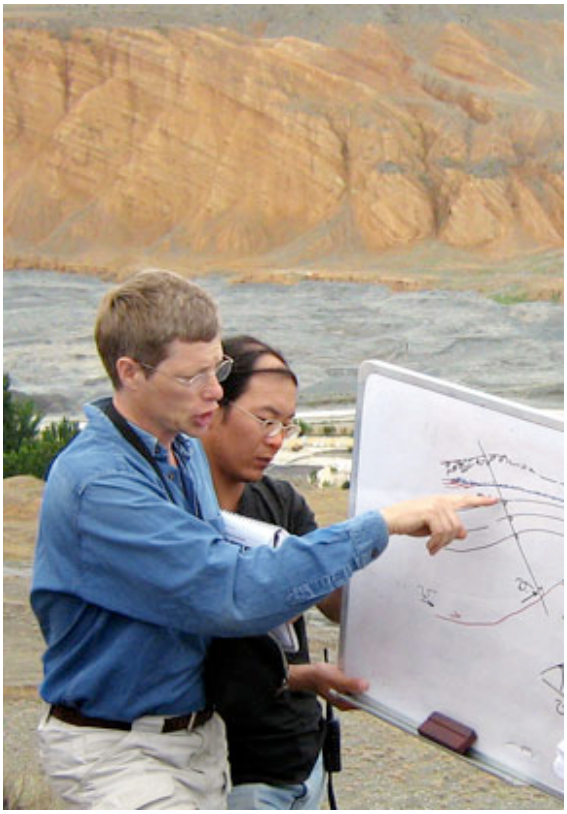
Tien Shan is Chinese for "heavenly mountains"—the name alone reflects how hard it is to get there. In June 2006 a group of 21 Caltech students, postdocs, and professors made the trip to this remote region of northwestern China as participants in a two-week research field trip, sponsored by the Institute's Division of Geological and Planetary Sciences. After landing in Beijing, we flew to Urumqi, capital of the Xinjiang Province—where the range is located—and caught up with the 15 Chinese students and four professors who had traveled 48 hours by train from the east-coast city of Nanjing to join us. A 10-hour drive to the southwest Tien Shan foothills brought us to this arid central Asian landscape of red, yellow, and brown rocks cut by lethargic rivers.

The above map shows the location of the Tien Shan mountain range near Urumqi, the capital of the Uyghur autonomous region, in northwest China.

Although many of the peaks in the Tien Shan rise higher than 16,000 feet (5229 m), we had come here to study geologic activity in the low-lying foothills near the Turpan Depression, the lowest point in central Asia. The Chinese consider this region just as exotic as foreigners do, and few in our group could ever have imagined coming to this place.

The Tien Shan marks the northernmost expression of the Indian subcontinent's northward march into Eurasia, of which the Himalayas form the most conspicuous part. Geologically speaking, the range can be considered both old and young, and its rocks relate a lengthy and dynamic tectonic history. Although the oldest rocks within the range date back 540 million years, geologists come here to study a striking burst of activity that began a mere 25 million years ago and contributed to building some of the highest mountains in the middle of any continent. Geologists know that when India first hit Asia some 60 million years ago, the Himalaya chain rose along the impact front. But it remains unclear why deformation jumped some 2,000 kilometers inland, to build the Tien Shan so much later. We came here to study some of the world's finest and most puzzling active tectonics.

GPS instruments installed across the Tien Shan by German, Russian, and Chinese scientists indicate that the entire range is crumpling horizontally at a rate of about 20 millimeters per year. But these instruments give a regional picture of what's taking place, rather than pinpointing exactly where the action is. Caltech geology professor Jean-Philippe Avouac (director of the Institute's Tectonics Observatory) and his postdoc Mathieu Daëron have set out to show that there is significant and recent motion of rocks along faults in the northern and southern foothills of the range. As rocks are compressed, they break, generating earthquakes and horizontal and vertical shifting of land along faults. Faults that do not break the surface are called "blind faults" (they are common in both the Tien Shan foothills and in Southern California), and they are often associated with such surface features as rocks that are piggy-backed and folded over the fault. By imaging the structure of the disrupted rocks underground and getting their ages, Avouac and Daëron hope to find out when and why these blind thrusts in the foothills quickened their pace of activity.



At right, Caltech geology professor Jean-Philippe Avouac explains the interactions between the tilted rock layers and beveled land surfaces behind him, as Nanjing University geology professor Shengli Wang looks on.

Chinese oil companies have carried out prospecting studies in the Tien Shan foothills, but these were focused on finding potential oil reservoirs at depth, and missed the top half-kilometer of the rock record below the surface, which is precisely the layer that most interests field geologists. So the Caltech team set out to add to the existing data. We sampled rocks and soils for dating back home. We precisely measured surface features with a laser and used Real-Time Kinematic GPS to determine the most accurate locations for these measurements. Finally, we imaged these features at shallow depths, using seismic refraction and reflection studies. All the students' hands were on deck for this project, which involved setting up lines of geophones to record the amount of time it takes seismic signals to reflect from buried rock layers back to the surface. We sent the signals through the ground using a contraption endearingly called the "Betsy" gun (the inventor named it after his wife), which looks like a pogo stick and shoots blanks.

Most of the American and Chinese students had never done experiments like these before, and we were all thrilled at the chance to set off a blast, which involved striking the top of the pogo stick with a rubber mallet, followed immediately by a jolt under our feet and the upward poof of dirt that told us the blast had gone off underground. The resulting seismic images, combined with new age-determinations of the rocks we imaged, will tell us when the tectonic activity that shifted these rocks accelerated.

On the last day of the field trip, the Caltech and Nanjing students toured the Tianchi, or "heavenly lake." Author Nadin is second from left in the back row.

The Caltech and Chinese geology teams came to the Tien Shan out of intellectual curiosity, but the promise of wealth brought oil exploration companies to investigate this region in the 1980s. The oil and natural-gas discoveries along the Tien Shan's blind faults have spurred a building boom in a part of the world once sparsely settled by the formerly nomadic Uyghur people, and created tension between the Chinese and the indigenous populations in this autonomous region. We were led to expect that we might encounter hostility from the locals. But when we did walk around their villages, open staring gave way to tentative smiles and some attempts at communication. Mostly, we enjoyed the juiciest and most delicious peaches, melons, and apricots that we'd ever tasted, sold from wagons in a variety of places. We supplemented our traditional Chinese meals with the lamb kebabs, yogurt drinks, fruits, and bagel-shaped breads sold by Uyghur street vendors. The Nanjing students were concerned at first about potential conflicts but soon found that most locals seemed to care more for their economic well-being than for politics.

We also found the time to visit local historical sites. Near the town of Kuqa, we visited Buddhist caves built and operated along the ancient Silk Road from 200 C.E. to roughly 9,000. The caves are painted with scenes from Buddha's 550 lives, most of which ended in self-sacrifice and reincarnation. In one scene, the Buddha offers himself as dinner to a tiger and her three starving cubs, but they are too weak to eat. So he cuts himself and nourishes them with his blood until they gain enough strength to devour him. The platform from which medieval monks gave sermons more than a millennium ago had been reduced to rubble in the 1800s by an earthquake caused by the same forces we were studying in this region.

As our field work ended, we saw our new Chinese friends off on their two-day train ride back to Nanjing, and treated ourselves to a two-day adventure through bustling Beijing before heading home.

Caltech's two-week expedition to northwestern China was funded by the Robert P. Sharp Ventures Fund and the George W. Housner Student Discovery Fund. More information on geology of the Tien Shan, and on the people, history, and culture of the region, can be found at this website, by Caltech student Ravi Kanda.

Elisabeth Nadin received her PhD in geology from Caltech in June 2006, and has recently joined the staff of Caltech's research magazine, Engineering & Science*.*