INDEPTH-IV Seismic Imaging of Channel Flow Outwards from the Kunlun Mountains Beneath the Qaidam Basin

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The INDEPTH IV active-source seismic experiment illuminated continued growth and deformation of the Tibetan Plateau with a high resolution, 270-km wide-angle refraction profile in Northeast Tibet (Fig. 1*A*). The Kunlun Suture (collinear with the North Kunlun Fault, NKF) is the boundary along which the Songpan-Ganzi (SG) terrane and the Kunlun Mountains (KM) accreted (see, for example, Yin and Harrison, 2000). Our new seismic data suggest that the North Kunlun Thrust system (NKT) bounds an indenting Qaidam crustal wedge, beneath which a lowermost-crustal channel extrudes outwards from the Tibetan Plateau.

The INDEPTH IV refraction profile incorporated 5 large (>1,000 kg) and 105 small (60-100 kg) explosions and more than 2,000 seismometers with 650-m spacing at the profile ends and 50- to 100-m spacing across the central 100-km of the profile. Two off-end earthquakes also provided valuable constraints. First-arrival refraction ray tracing and least-squares inversion yielded a crustal p-wave velocity model for the top 15 km of the crust. Ray tracing of deeper reflections shows considerable differences between the Qaidam Basin (QB) and the SG, including higher crustal velocities beneath the QB and an 18-km deepening of the Moho from 52 km to 70 km located beneath the southern QB (Fig. 1*C*) (see also Chen and others, this vol.). The 18-km offset occurs 30-50 km north of the NKT, farther north than inferred from previous seismic studies (Vergne and others, 2002; Zhu and Helmberger, 1998). A 50-52 km deep reflector beneath the SG and KM may represent an older, shallower Moho. The shallow QB Moho at 52 km depth is underlain by crustal material near the northernmost extent of the deeper Moho.

We tested our seismic velocity model by developing a two-dimensional gravity model. The gravity profile (Fig. 1*B*) roughly follows the Golmud-to-Lhasa highway and was extracted from Bouguer anomaly maps of the Yadong-to-Golmud and Golmud-to-Ejin Qi segments of the Tibet Geoscience transect (Meng and others, 1995). This gravity profile follows the INDEPTH IV profile north of large shot KS3 and then deviates from the INDEPTH IV profile south of KS3 to follow the highway up to 165 km west of the profile. We converted our model velocities (Fig. 1*C*) to densities, simplified the model into density layers, modeled gravity predicted for those densities, and then simplified the model to highlight the main density anomalies (Fig. 1*D*). Our velocity model is consistent with the gravity data and the existence of the Moho step (Fig. 1*B*).

Our preferred tectonic model, which accounts for the main features of the velocity and density model, incorporates a channel of lower-crustal material flowing northward from the Kunlun Mountains (KM) beneath the Qaidam Basin. Surface geologic mapping shows both south- and north-directed thrust faults in the KM (Wu and others, 2009), but we favor a north-vergent NKT based on the south-dipping velocity contrast, and consistent with the topographic step at the north margin of the Tibetan Plateau. The middle and upper QB crust has faster velocities than the KM and SG crust and may form a rigid wedge over which the KM crust is thrust and beneath which the Tibetan lower crust is extruding.

References

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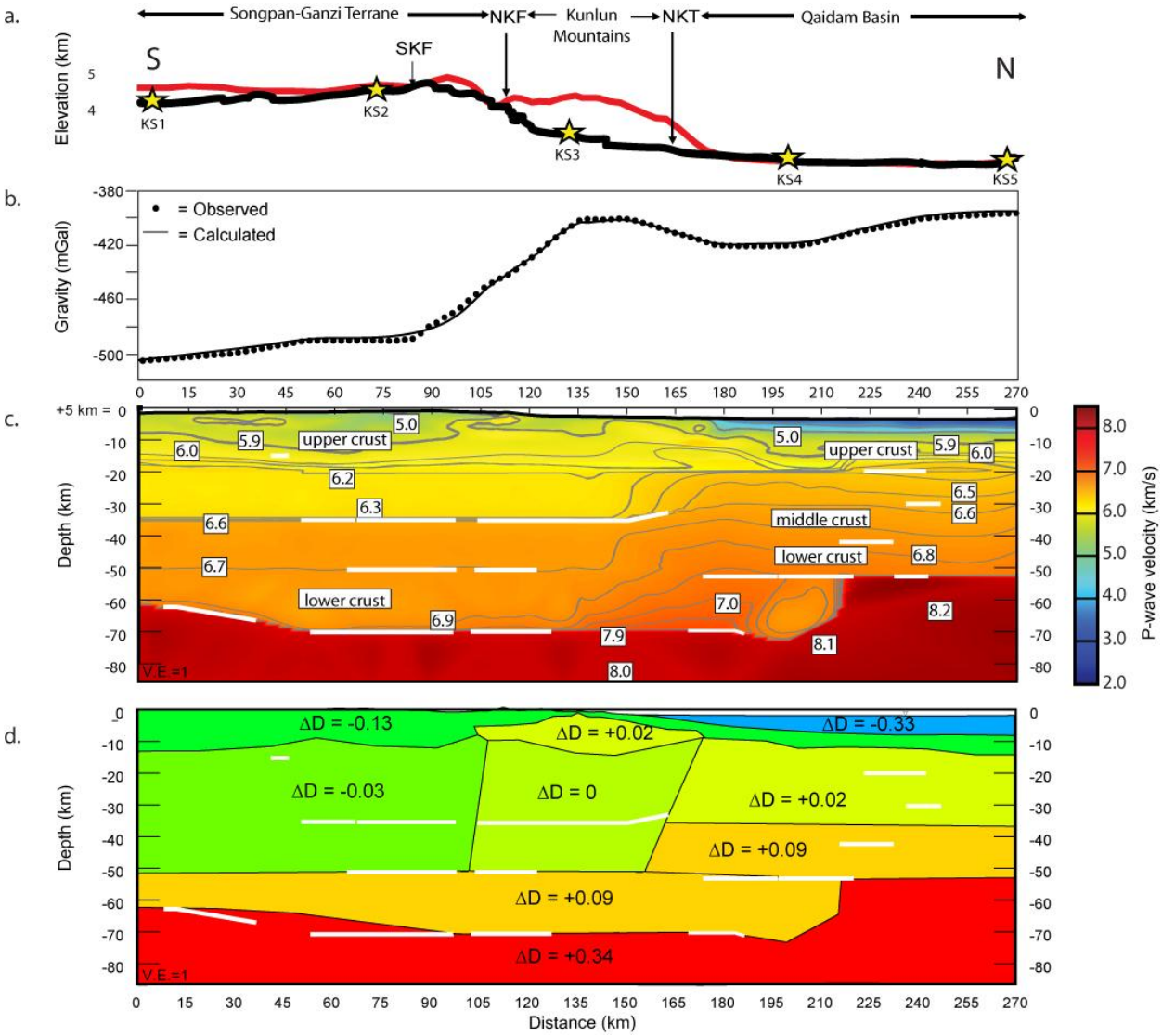

Figure 1. (*A*) Elevation along INDEPTH IV active source profile (black curve) and TOPO1 elevation along the profile averaged over longitudes 94 to 96°E (red curve). South Kunlun Fault (SKF), North Kunlun Fault (NKF), and North Kunlun Thrusts (NKT) are indicated by arrows. Yellow stars show locations of large shots KS1 through KS5. (*B*) Bouguer anomaly data extracted from the gravity map of the Tibet Global Geoscience Transect (Meng and others, 1995) plotted with gravity calculated for the model shown in d. (*C*) Composite shallow and deep crustal velocity model from ray tracing the INDEPTH IV controlled source profile. Major reflectors shown as white lines. (*D*) Simplified density model based on major velocity anomalies shown in c. Density anomalies are given relative to the density of the QB middle crust. Major reflectors shown as white lines. Poor fit of gravity Moho to seismic Moho south of the SKF may be due to the 100 km west-east separation of the gravity and seismic data.

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