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 (Figure 1a). The Kunlun Suture (collinear with the North Kunlun Fault, NKF) is the boundary along which the Songpan-Ganzi (SG) terrane and the Kunlun Mountains accreted (Yin and Harrison, 2000). Our new seismic data suggest the location of the North Kunlun Thrust system (NKT) and a lowermost-crustal channel extruding outwards from the Tibetan Plateau beneath an indenting Qaidam crustal wedge.

The INDEPTH IV refraction profile incorporated 5 large (>1000 kg) and 105 small (60-100 kg) explosions and over 2000 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 (Figure 1c) (see also Chen et al., this vol.). The 18-km offset occurs 30-50 km north of the NKT, farther north than inferred from previous seismic studies (Vergne et al., 2002, Zhu & 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 using regional Bouguer gravity maps. The gravity profile (Fig. 1 b) roughly follows the Golmud-to-Lhasa highway, and was extracted from gridded and contoured Bouguer anomaly data from the Yadong-to-Golmud and Golmud-to-Ejin Qi segments of the Tibet Geoscience transect (Meng et al., 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 165km west of the profile. We converted our model velocities (Figure 1c) 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 (Figure 1d). Our modeling confirms the gravity data are consistent with our velocity model and the existence of the Moho step (Figure 1b).

Our preferred tectonic model to explain 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 et al., 2009), but we favor a north-vergent NKT based on the south-dipping velocity contrast, 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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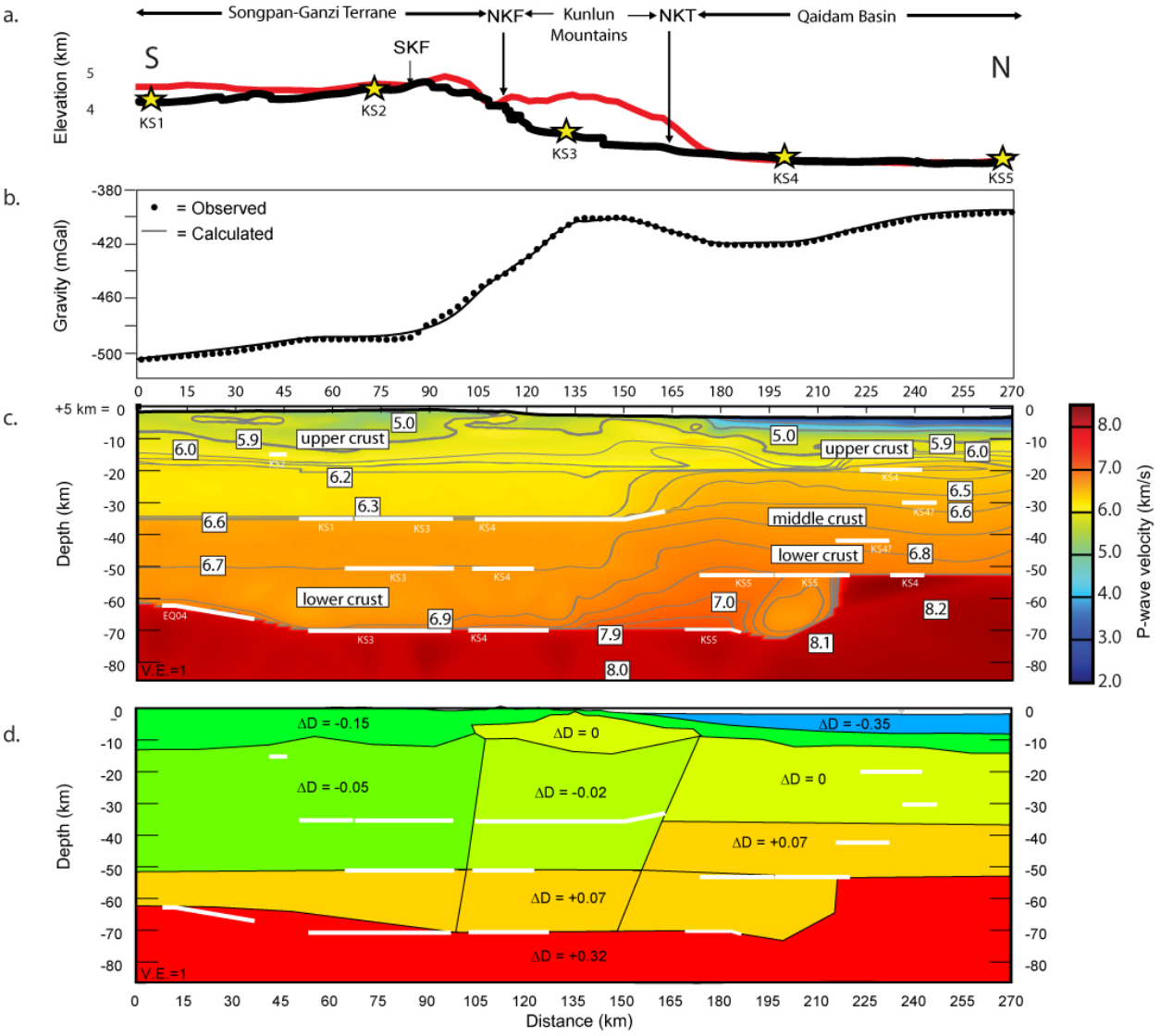

Figure 1. (a) Elevation along INDEPTH IV active source profile (black curve) and TOPO1 elevation along the profile averaged over longitudes 94 to 96°E (red curve). South Kunlun Fault (SKF), North Kunlun Fault (NKF), and North Kunlun Thrusts (NKT) are indicated by arrows. Yellow stars show locations of large shots KS1 through KS5. (b) Bouguer anomaly data extracted from the gravity map of the Tibet Global Geoscience Transect (Meng et al., 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.

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