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High-resolution upper crustal structure from OBH data at the TAG Hydrothermal Field, 26°N on the Mid-Atlantic Ridge

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Summary

We obtained two P-wave velocity models at the TAG hydrothermal field at 26N on the Mid-Atlantic Ridge (MAR) across the detachment fault. TAG area involves strong interpaly of tectonic and volcanic processes. This study aims to search for evidence for the near-surface detachment fault geometry and the fault dip that were poorly constrained because of the confined seafloor exposure of the fault corrugated surface. We also provide new information to the footwall of the detachment by the resolved higher velocities that suggest the uplifted lower crustal gabbroic rocks.

1. TAG hydrothermal field and the Detachment Fault

Aims

-- Constrain the near-surface detachment fault geometry with confined seafloor exposure largely blanked by mass-wasting deposits and the apron composed of unlithified volcanics.

-- Constrain near-surface crustal structure surrounding the detachment fault and explore its relationship with the TAG hydrothermal system.

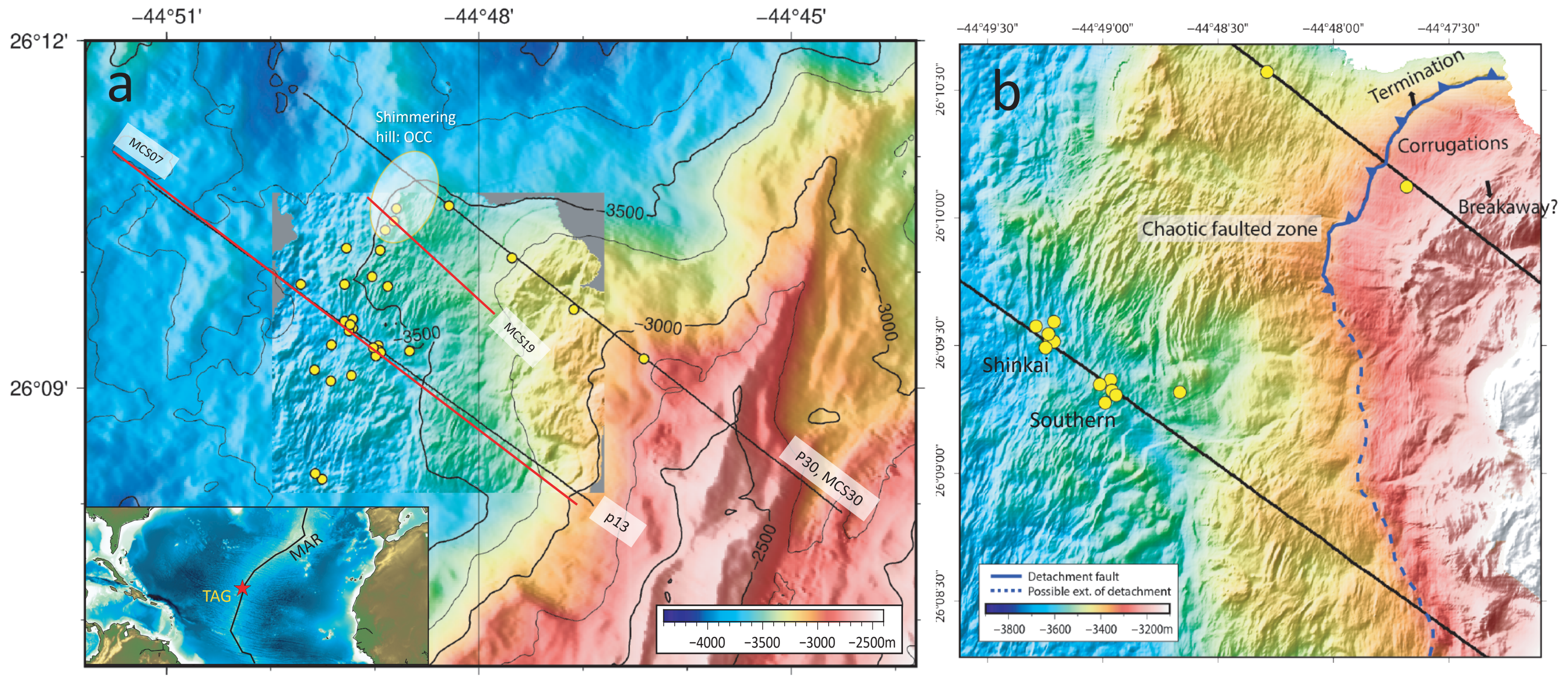


Figure 1. (a) Regional map of the TAG hydrothermal field showing the bathymetry (2 m resolution superimposed on 30 m resolution, M127 R/V Meteor, 2016) and locations of the seismic profile p13 and p30. The yellow dots denote the OBS and OBH locations. Red lines mark the seismic reflection profiles (MCS19, MCS07, MCS30). Black contours show the water depth every 250 m. The shaded circle shows the locations of the recovered lower crustal rocks (Szitkar et al., 2019). (b) Zoom-in of the map showing the detachment features deduced from bathymetry.

2. BlueMining Experiment

We use wide-angle Ocean Bottom Seismometer (OBS) and Ocean Bottom Hydrophone (OBH) data acquired in 2016. Seismic profiles are acquired using a G-gun (two guns of 380 c. in each), with the shot spacing of ~ 20 m (10- 12 s). Profile p13 (9 OBSs) crossing inactive Shinkai and Southern mounds and profile p30 (4 OBHs) across the identified corrugated surface are used in this study (Figure 2).

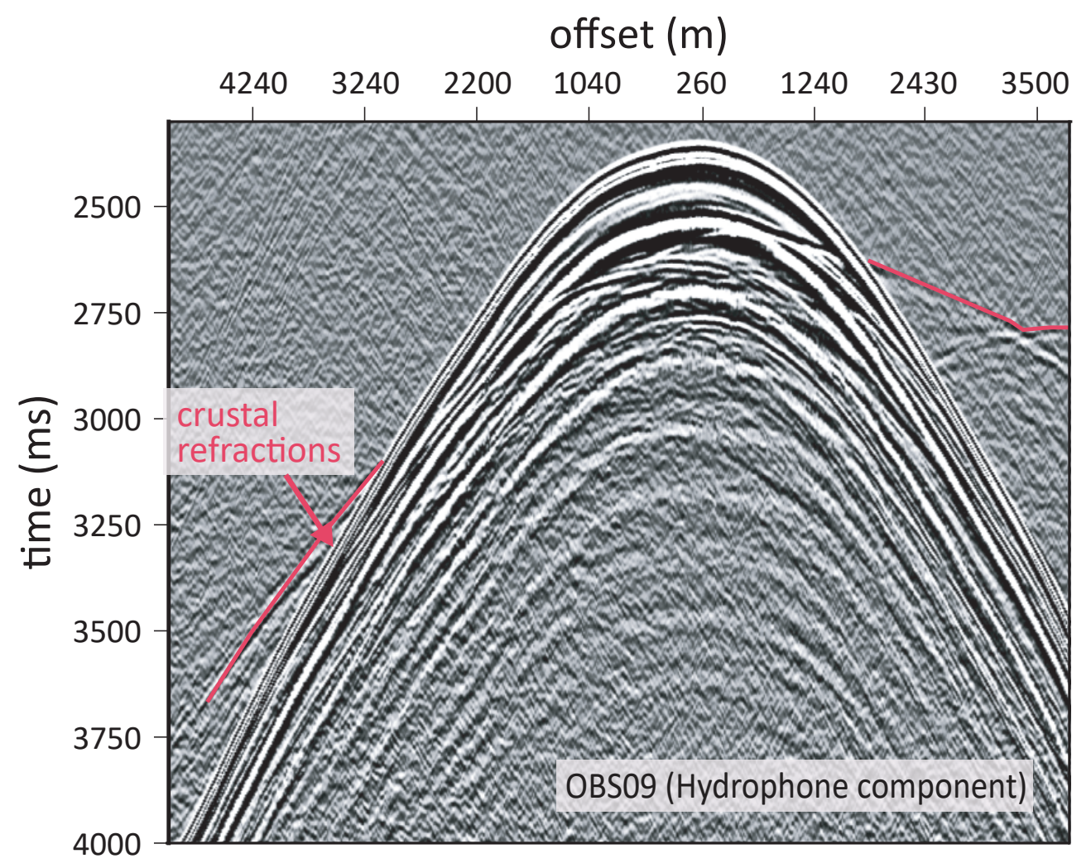


Figure 2. Example of picked phases on the processed OBS gather (OBS location marked by the yellow triangle in Figure 1a).

3. Downward Continuation (DC)

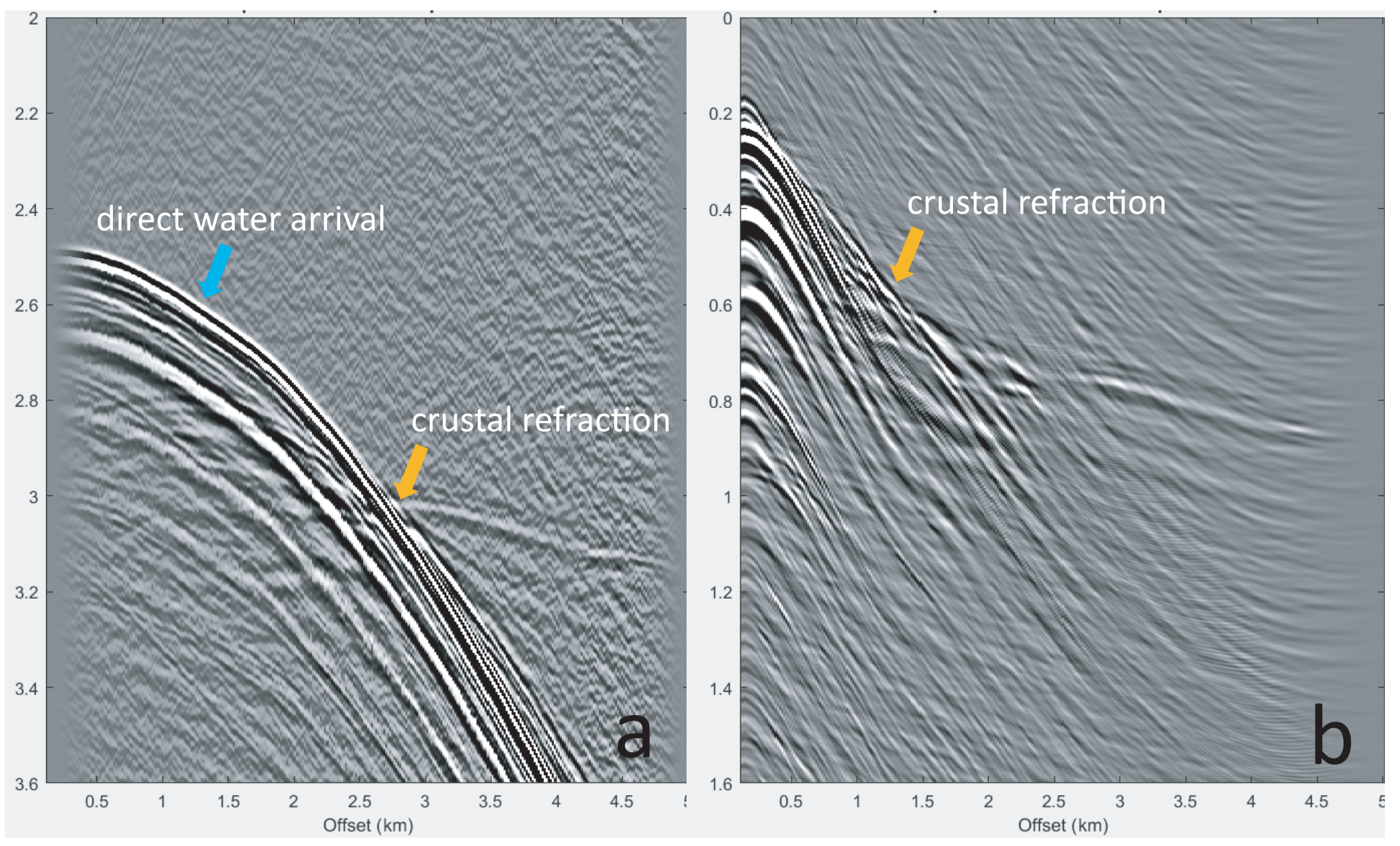


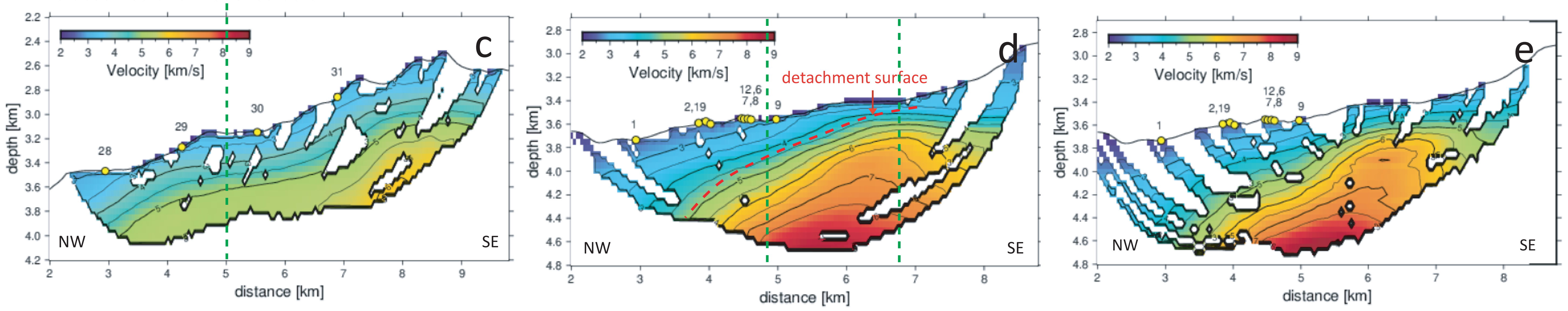
Figure 3. Example receiver gather (OBS02) before (a), and after (b) downward continuation. Crustal refractions identified from the offset of 2.5 km originally are now visible at the near offset from 1 km after DC.

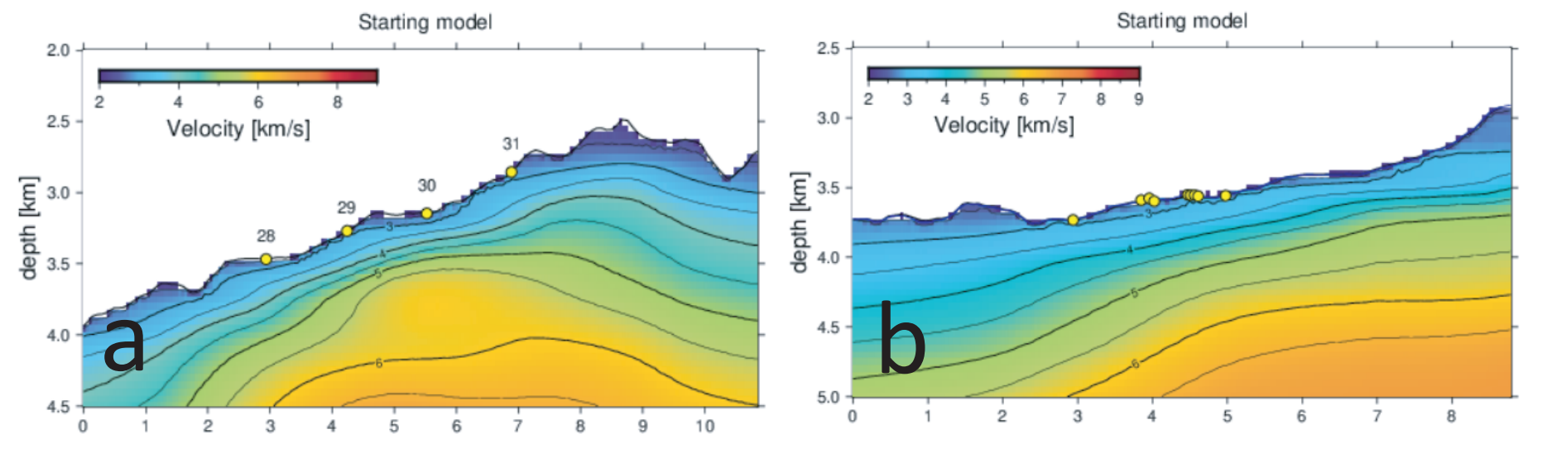
4. First-arrival Traveltime tomography

We use the Tomo2D code (Korenaga et al., 2000) to invert the first arrival time picks, to obtain a P-wave velocity model.

1. Calculate the forward travel time by ray tracing (shortest path [Moser, 1991] and ray bending approaches [Moser et al., 1992])

2. Solve the inverse problem in a least-squares sense by minimising the travel time misfits between the observed and modelled data.





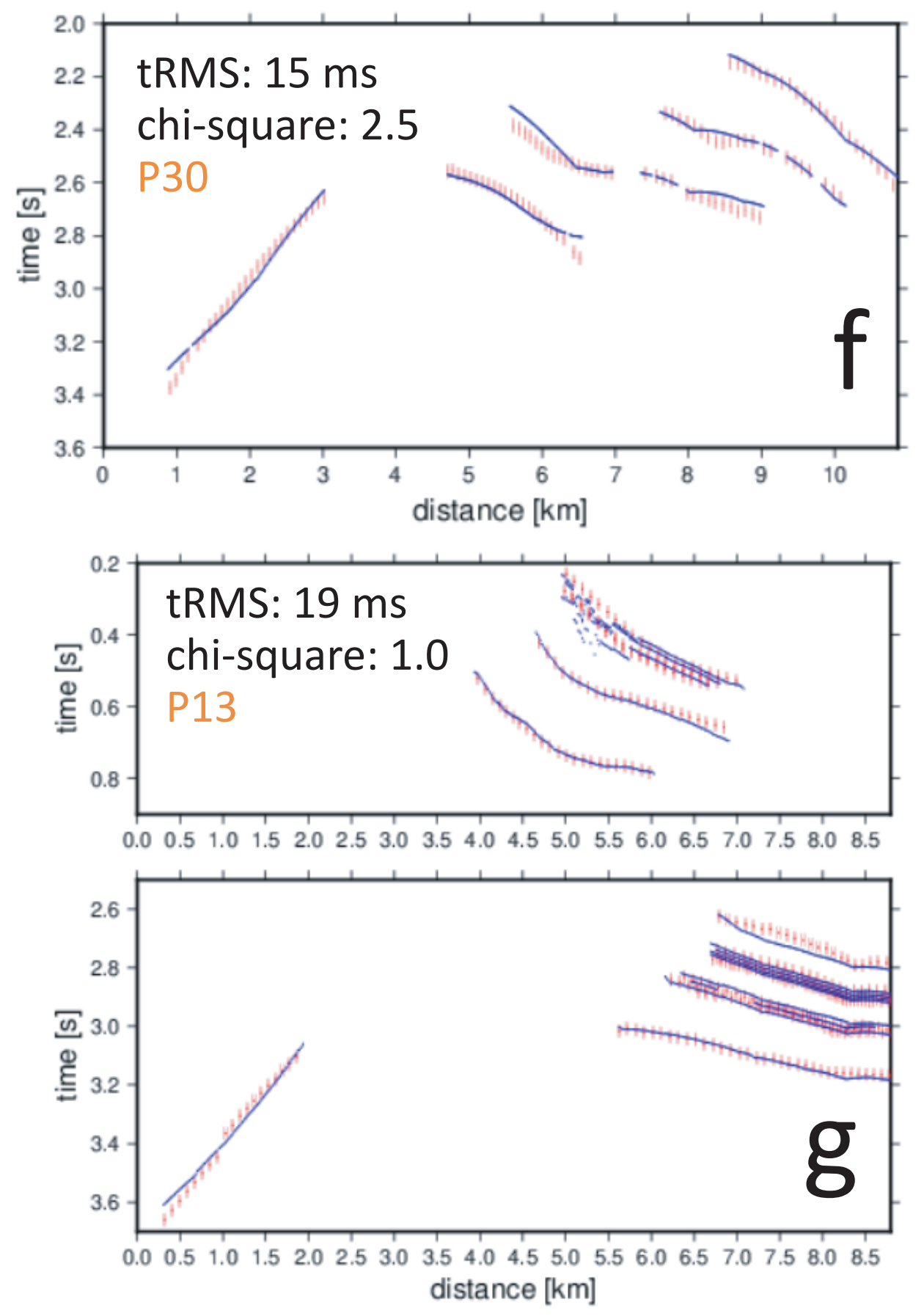
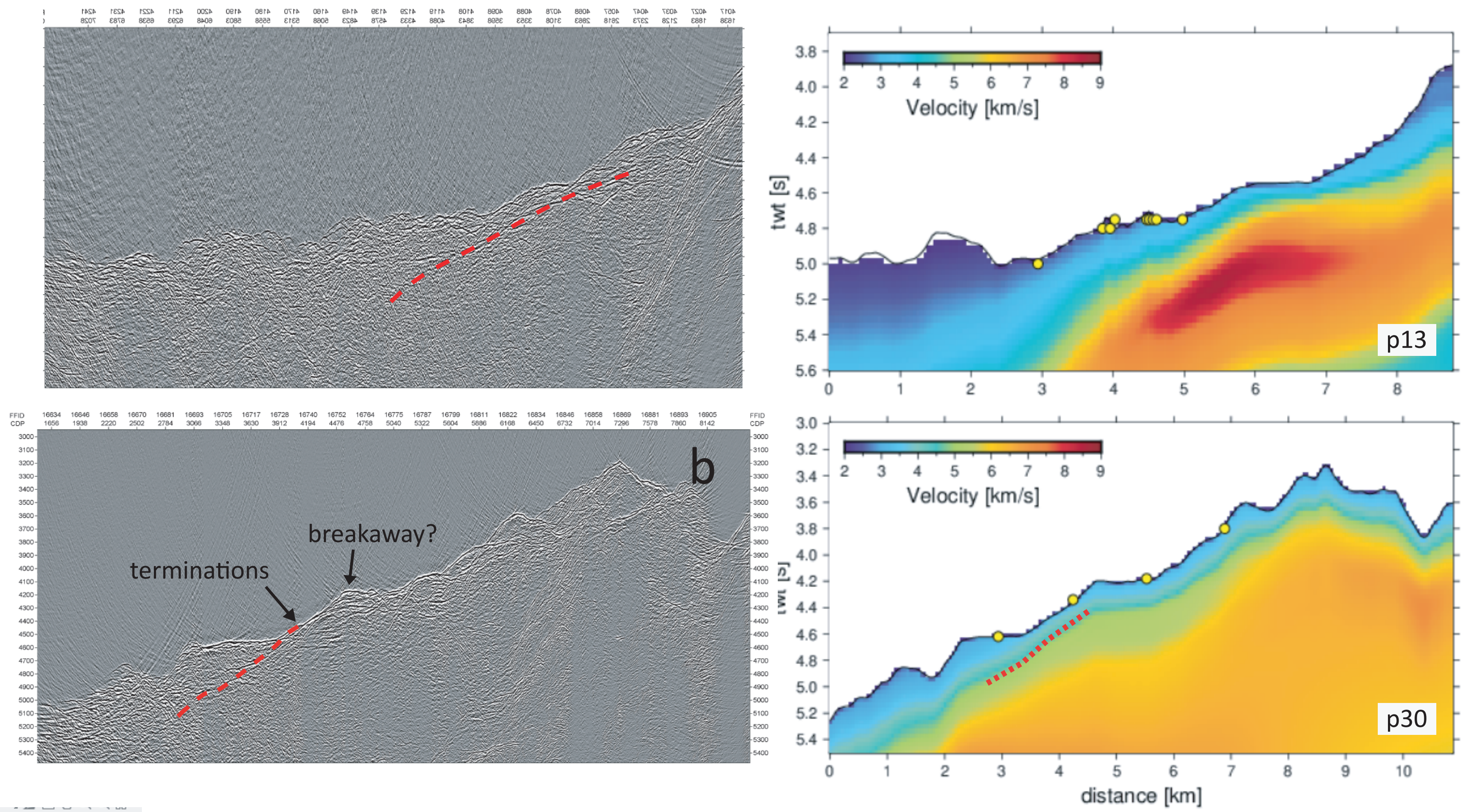


Figure 4. (a,b) The initial models are smoothed 2-D Vp slices extracted along profile p13 and p30 from the first arrival tomographic 3D model of Zhao et al. (2012). The horizontal node spacing is 50 m and the vertical is 25-50 m. The grid follows the seabed that extends down to 3 km below the seabed. (c,d) Final preferred model using both DC and non-DC picks for p13 and p30 (e) Best-fit model for p13 with non-DC traveltime picks. Note the improved ray coverage at the shallow part of the model in d. (f, g) Traveltime plots show the travetime fit.

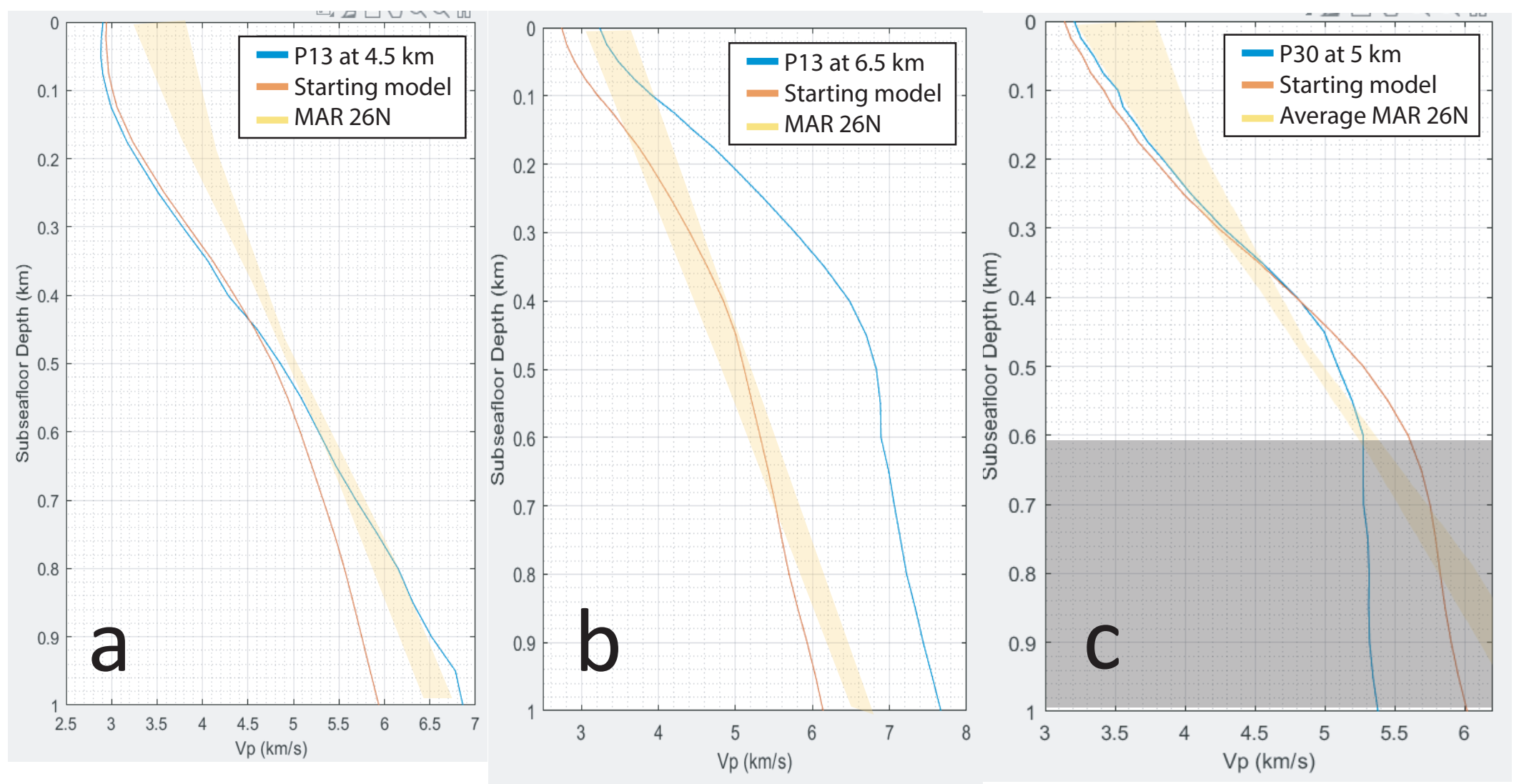
5. Discussion



Detachment surface geometry

We estimate a detachment dip of 13 by comparing the Vp models and the seismic profiles.

Figure 5. Two-way traveltime velocity models compared with MCS07, MCS30 profile. See Fig. 1a for MCS locations.



Upper crustal velocities

-- P13 shows a Vp of 3-5km/s at the hanging wall of the detachment (Fig. 6a), and higher Vp gradient reaching 6.5-7 km/s at footwall at depth, suggesting the uplifted footwall composed of gabbroic rocks

-- P30 shows a Vp of 3-5km/s at depth, in good agreement with average MAR crustal velocities.

Figure 6. P-wave velocity 1D deth profile for p13 and p30, the starting model and the average profile from MAR 26N (Canales et al., 2007). See green dashed line in Figure 4c, 4d for 1D profile locations. Shaded region in p30's 1D function masks the area with low resolution.

6. Conclusions

-- In this study, we obtained two Vp profiles using first arrival travel time tomography to constrain the near-surface detachment fault geometry and estimate a fault dip of 13.

-- Our results shows a higher Vp than Zhao et al., 2012 at the footwall, suggesting the uplifted lower-crustal gabbroic rocks.