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Supporting Information for

Quasi-3D seismic reflection imaging, and wide-angle velocity structure of nearly amagmatic oceanic lithosphere at the ultra-slow spreading Southwest Indian Ridge

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Introduction

We examine common bin supergathers from three inlines to identify some of the events prior to migration. We also compare the time and depth interpretations of three inlines whose locations are shown in Figure 1, and observe the events as they are followed in the 3D box. We further compare the results obtained from the average velocity model realized from the Monte-Carlo analysis and the final model realized without perturbing the starting model. Finally, newly acquired micro-bathymetry data is used to identify seafloor projections of some of the north-dipping reflectors discussed in Section 6.2.

Supergathers and Reflectors

In Figure S1a, we show inline 22, and pre-NMO common bin supergather indicating the events that correspond to the south-dipping reflectors interpreted in Figures 10 and 11a and Figure S2. Another supergather is shown for inline 23 in Figure S1b. In Figure S1c, we show a supergather corresponding to one of the sub-horizontal reflectors. Note the comparably lower moveout of the reflector at 8 s TWT compared to the sea-bottom reflector.

Comparison of Migration with Velocities Derived from Tomography Model and from the reduced Velocity Model

For migration, we tried a velocity model derived from the tomography model, as shown in Figure S2a. We found that the velocities are useful up to ~1 s, with minimum artefacts after the migration. However, the velocity is substantially too high for migration from 1 s TWT, as the event which we interpret as the second part of the detachment fault damage zone is out of focus. To focus this event, it was found that reducing the migration velocity was effective to produce a more geologically-interpretable image.

Time-interpreted and Depth-converted Sections for Three Representative Inlines from the 3D box

In this section, we show the reflectors that are persistent in the 3D box, and extract the line interpretations for inlines 13, 22 and 31 extracted from the eastern, central and western part of the 3D box. Figure S3a shows the time and depth-converted sections of inline 13, and their corresponding interpretation, similar to the scheme used in Figures 10 and 11.

Figure S3b shows the time and depth-converted sections of inline 22 and their corresponding interpretation extracted from the central part of the 3D box. Figure S3c shows the time and depth-converted sections of inline 31 from the western part of the 3D box. From the inlines shown in Figure 10, it is observed that the south-dipping reflectors are persistent in the 3D with decreasing horizontal offset towards the eastern part of the surveyed box. The north-dipping reflectors are also persistent but of slightly varying dips, and appear discontinuous. The shallow sub-horizontal reflectors are visible in the entire 3D box, while the deep sub-horizontal reflectors are observed from the central inline towards the west.

Comparison of Average Model from the Monte-Carlo Analyses and a Final Model realized without Perturbation of the Starting Model.

Here, we compare the final velocity model with the average of the models realized from the Monte-Carlo analysis. In Figure S4a, we show the starting model, same as shown in Figure 7a. In Figure S4b, we show the average of the models from the Monte-Carlo analysis. In Figure S4c, we show the final model (same as Figure 7b). The apparent differences between the average of the models and the final model can be found in the 8 km/ s contour; otherwise the fine details in the velocity models are well replicated.

North-dipping reflectors and Micro-bathymetry Data

Between December 2006 and January 2017, micro-bathymetry data was acquired in our study area (Cannat et al., 2017). This data was acquired with a 50 m grid spacing, hence better resolve seafloor lineaments than the previous bathymetry data. Some of the north-dipping reflectors were projected assuming similar dip to the seafloor. Figure S5a shows the micro-bathymetry data and the location of three inlines and the projections of the reflectors onto the seafloor shown with their inline distances. In Figure S5b, inline 13 from the eastern boundary of the 3D box is shown with the corresponding projections onto the seafloor reflection. Shown in Figure S5c is inline 22 extracted from the central part of the 3D box and the corresponding projections of some of the north-dipping reflectors, while Figure S5d shows inline 31 from the western boundary of the 3D box. In general, the projected reflectors were found to correspond to possible scarps of minor faults (< 200 m-high) on the micro-bathymetry map. The distinctive feature is also observed on one of the north-dipping reflectors at 2.8 km inline distance, which underlies a prominent outcrop of basalts on smooth seafloor (also shown in Figure 1b at 64°36'E and 28°S).

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Figure S1. Selected stacks and common bin supergathers inset. (a) Inline 22. (b) Inline 23. (c) Inline 29.

Figure S2. Comparison of central inline (22) migrated with velocities derived from tomography model, and from constant migration velocity analysis. The tomography-derived velocities seem appropriate for migration ~1 s TWT below the seafloor. The event at 8 s TWT seems out of focus using the tomography velocity.

Figure S3. Selected time and depth-converted sections of the poststack time-migrated data. The left column indicates the uninterpreted images while the right column indicates the interpreted images. (a) Cross-section in time and depth of inline 13 located on the eastern part of the 3D box. (b) Cross-section in time and depth of inline 22 located in the central part of the survey area. (c) Cross-section in time and depth of Inline 31 located on the western part of the 3D box. The interpretation scheme follows similar to those presented in Figures 10 and 11: south-dipping reflectors are annotated in purple, north-dipping reflectors are annotated in green, two sets of sub-horizontal reflectors are annotated in cyan for the shallow set, and orange for the deep set.

Figure S4. (a) An example of a starting velocity model. The rounded circles are the OBSs annotated in Figure 1. (b) A final model realized from the inversion of traveltimes without perturbing the starting models or randomizing the traveltimes. The similarity in the models is apparent especially below the 8 km/ s isovelocity contour. (c) Average velocity model realized from the inversion of the average of 100 perturbations to the starting model. The base of the crust derived from constant density gravity modeling is plotted as a white line (Cannat et al., 2006). The location of the OBS line is shown on the bathymetric map, on the right of Figure 7b.

Figure S5. (a) Bathymetry map (50 m grid spacing) acquired during the Rovsmooth cruise (Cannat et al., 2017). Three selected inlines have been shown as orange lines. The white circles mark the projection of the north-dipping reflectors onto the seafloor. Corresponding inline distances are marked on the respective inlines: (b) Inline 13 from the eastern end of the 3D box, (c) Inline 22 from the central part of the 3D box, and (c) Inline 31 from the western end of the 3D box. The projections of some of the north-dipping reflectors correspond to scarps which are generally < 200 m-high. These were interpreted by Sauter et al. (2013) as minor faults. One of the north-dipping reflectors discussed in the text projects to the seafloor at 2.7-2.8 km inline distance beneath a documented outcrop of basalts.