Structure and composition of large-offset Atlantic transform faults: an extreme example at the Romanche transform from wide-angle refraction data

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Large-offset transform faults (TFs) in the Atlantic juxtapose hot spreading segments against older, colder oceanic lithosphere, leave permanent traces as fracture zones in ageing oceanic crust and represent a significant proportion of the plate boundary along the Mid-Atlantic Ridge (MAR). The manifestation of the thermal contrast and the structure and composition of TFs however, are not well understood. The Romanche TF, situated in the Equatorial Atlantic, offsets the MAR by ~950 km, has a slip of ~1.7 cm/yr, and divides the northern MAR from its equatorial and southern spreading systems. Close to the eastern ridge-transform intersection (RTI), shallowing of the seafloor from north to south across the TF reflects the change from old, cold African lithosphere to the warmer and younger South American plate close to the MAR axis, however the bathymetry and structures across the fault itself are complex. Over 100 km distance, a large northern transverse ridge reaches depths of <1000 m and contains a fossil transform trace, before steeply descending into a 45‑km wide transform valley containing ~7000 m‑deep basins, which is bounded to the south by a further shallow structure reaching ~2500 m‑depth. Previous studies using seafloor sampling, seismic reflection and bathymetry data have suggested these features comprise a mix of uplifted magmatic crustal blocks and serpentinized mantle peridotites. However, these studies cannot effectively determine the sub‑seafloor structure.

The ILAB-SPARC experiment in 2018 obtained an active-source wide-angle refraction profile across the eastern Romanche TF, consisting of twenty-eight ocean-bottom seismometers spaced at ~14 km. We present a P-wave velocity model produced by the inversion of seismic travel time picks which reveals variations in crustal structure from ~40 My lithosphere to the north to ~7 My lithosphere to the south. Within the TF, a ~15 km-wide low‑velocity anomaly extends from the top basement through to >10 km below basement. A lack of Moho reflections suggests no abrupt crust/mantle boundary exists beneath the TF, likely indicating the presence of a deep column of fractured and sheared basalts, breccias and peridotites. Low mantle velocities suggest faulting and water penetration to depths of ~16 km, causing widespread and extensive serpentinization. The crust to the south of Romanche is relatively thin (~5 km thick) compared to north of Romanche (~6 km thick), and contains areas of high velocity indicative of a predominantly gabbroic crust. This may be attributed to the irregularity of the MAR segment as it approaches the RTI, as it jumps to the west in several non-transform discontinuities and exhibits seafloor fabric indicative of
magma-starved, tectonic spreading with exhumation along detachment faults.

These results suggest the shearing and transtensional/transpressional forces present at large-offset transform faults result in mantle exhumation and form deep conduits for fluid circulation. At Romanche, these tectonic forces combined with the thermal contrast and magma-starved ridge axis, stretch and deform magmatic oceanic crust within the TF such that it is thin and patchy. This may suggest that crustal structure within transforms is linked to the fault offset, valley width, and the magma supply at the closest ridge segment.