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Large mantle magma volumes imaged magnetotellurically beneath an active magmatic segment in Afar, Ethiopia

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Though the existence of shallow magma chambers below volcanoes and mid-ocean ridges is well established, there have been no reports of extensive magma reservoirs within the mantle. Indeed the buoyancy of magma relative to the mantle is considered to forbid the presence of magma bodies there. However, a magnetotelluric (MT) survey along a 50 km transect across the Dabbahu magmatic spreading segment in Afar, Ethiopia demonstrates the presence of large quantities of magma well within the mantle. The MT survey reveals the existence of a region of very high electrical conductivity that extends for 30 km across the strike of the segment, and reaches down to about 40 km depth, 20 km into the mantle, for which the only plausible interpretation is a substantial quantity of magma. The MT data are equally well modelled by a single large conductor, or as a series of layered conductors and resistors, i.e. as a single magma chamber or a series of sills. If the magma is contained within sills, it has a very high melt content. Interpretation integrates information from other techniques that have been employed alongside MT, including seismology, GPS, LiDAR, inSAR, structural mapping, and petrology. The conductivity structure suggests melt fractions within the mantle of 20% or more, and a magma volume of at least 3000 cubic km, enough to supply dykes at the current rate of activity for 5000 years, or to build the full thickness of the crust at the current far-field spreading rate for 150000 years. The conductivity structure will be compared with that from a profile across a currently inactive segment, and from sites close to the Dabbahu volcano. Our data provide indications of very substantial magma volumes beneath the Dabbahu volcano.