Figure F1. A. Conceptual sketch of lithospheric accretion and the tectonomagmatic evolution of a heterogeneous lithosphere and denudation of mantle rocks as detachment faulting progresses and OCCs are formed at slow-spreading ridges (from 2010 AGU Chapman Conference Report "Detachments in oceanic lithosphere: deformation, magmatism, fluid flow, and ecosystems," available at **http://2010chapman.blogspot.fr**). B. Example from Atlantis Massif: the southern wall is dominated by variably altered peridotites with gabbroic lenses (modified after Boschi et al., 2006) in contrast to (C) major gabbroic intrusions in the central dome (Grimes et al., 2008; copyright 2008 by the American Geophysical Union).

Figure F2. Location of cored sites (RD2 and MeBo) overlain on multibeam bathymetry acquired during Expedition 357 (multibeam resolution = 50 m). Cored sites from Expedition 304/305 and proposed Expedition 357 sites that were not drilled are also shown.

Figure F3. Field relations in the target area along the Atlantis Massif southern wall. A. Sedimentary cap sequences overlie the detachment fault zone (consisting of variably thick zones of talc-amphibole schists within mylonitic and serpentinized peridotites) (Boschi et al., 2006; Karson et al., 2006). B. These sequences underlie hydrothermal deposits in the vicinity of the LCHF and overlie the detachment shear zone (DSZ) (Karson et al., 2006; copyright 2006 by the American Geophysical Union). C. Above the LCHF, cap sediments are cut by hydrothermal carbonates. D. These carbonates are locally venting diffuse fluids and have microbial filaments. Images captured by the ROV *Hercules* (2005), courtesy of the National Oceanic and Atmospheric Administration (NOAA)'s Office of Ocean Exploration, the University of Washington, and the Institute for Exploration at the University of Rhode Island.

Figure F4. Seabed drills deployed from the *RRS James Cook*, Expedition 357. Top = MeBo, bottom = RD2. Images courtesy of Dave Smith (BGS).

Figure F5. Multibeam image of Atlantis Massif data set acquired at 20 m per pixel resolution acquired during Expedition 357.

Figure F6. Multibeam bathymetry of Atlantis Massif acquired at 50 m per pixel resolution (top left), corresponding slope map (top right), and structural and morphological interpretation (bottom).

Figure F7. 3-D terrain model of Atlantis Massif with (top) a lateral view west of its eastern flank, (center) a lateral view of its southern flank showing extensive mass wasting, and (bottom) a northward view of the detachment fault surface showing striations and cross-cutting tectonic structures. Terrain model resolution = 50 m per pixel (top and center) and 20 m per pixel (bottom). See Figure **F6** for scale on maps of the area, as scaling in 3-D views is variable owing to perspective.

Figure F8. Across-axis profiles over Atlantis Massif and the adjacent rift valley with projected locations of Expedition 357 sites. The southernmost profile (red) runs along the southern sites, the black profile runs over Site M0074, and the blue profile runs close to Hole U1309D, which was drilled to >1500 mbsf.

Figure F9. Lithologic variations, Expedition 357. Pie charts show percentages of dominant lithologies recovered from each drilled site based on integrated core length and are plotted against a bathymetry profile of the Atlantis Massif southern wall.

Figure F10. Recovery and described lithology for all sites, Expedition 357.

Figure F11. Whole-rock major elements (normalized, volatile-free, and in oxides) vs. MgO for (impregnated/metasomatized) serpentinized ultramafic rocks and talc-amphibole-chlorite schists from Atlantis Massif. Data from Mid-Atlantic-Ridge abyssal serpentinized peridotites and talc-altered peridotites are presented for comparison. Global abyssal peridotite field defined by data from PetDB (**http://www.earthchem.org/petdb**, May 2016). Data for talc-altered peridotite field from ODP Leg 209, Hole 1268A (also at PetDB).

Figure F12. Whole-rock major elements (normalized, volatile-free, and in oxides) vs. MgO for gabbroic and chlorite-rich altered mafic rocks from Atlantis Massif. Data for Mid-Atlantic-Ridge volcanic glass and Expedition 304/305 mafic and ultramafic rocks (Godard et al., 2009) are presented for comparison (**http://www.earthchem.org/petdb**, May 2016).

Figure F13. Comparison of Ni concentrations vs. Mg# of Atlantis Massif mafic and ultramafic rocks from Expedition 357 with those recovered at Site U1309 during Expedition 304/305 (Godard et al., 2009).

Figure F14. Comparison of Rb, Sr, U, Ba, Pb, Zr, La, and Yb vs. Nb and enriched mid-ocean-ridge basalt (E-MORB), normal MORB (N-MORB), PM, and CI for Atlantis Massif mafic and ultramafic rocks with basalts from global spreading centers, Expedition 357. Data for basalts from global spreading centers (gray dots) from PetDB (**http://www.earthchem.org/petdb**, May 2016). E-MORB, N-MORB, PM, and CI data) from Sun and McDonough (1989).

Figure F15. Porosity and grain density from all study areas, Expedition 357.

Figure F16. Porosity (from moisture and density analyses) and mean (*x*-, *y*-, and *z*-direction) *P*-wave measurements from all study areas, Expedition 357. Bars = minimum and maximum mean velocities. It was not possible to measure all three orthogonal directions for all samples.

Figure F17. Demagnetized inclinations vs. magnetic susceptibility for 13 discrete samples, Expedition 357. Red lines = expected inclination of ±49°.

Figure F18. Declination and inclination from discrete samples (N = 13) after alternating field demagnetization up to 100 mT, Expedition 357. Solid blue squares = samples with normal polarity NRM (positive inclinations), open red squares = samples with reversed NRM (negative inclinations). Magenta circles = GAD predictions for the highest (inner) and lowest (outer) site latitudes drilled.