Figure F1. A. Atlantis Massif showing main structural features, location of LCHF, Hole U1309D, and Site U1601 (core recovered in Holes U1601A and U1601C). Bathymetry was collected during Expedition 357 (Früh-Green et al., 2018; Escartín et al., 2022). Adapted from Cotterill and Früh-Green (2021). Box = area of Figure F2. B. Full waveform inversion of Seismic Line Meg 4 and locations of Holes U1309D and U1601C, with proposed site numbers. Blue = new core recovered during Expedition 399, pink = core from Expedition 304/305. Modified after Harding et al. (2016).

Figure F2. Location of previous drilling during Expeditions 304/305 and 357 (modified after Früh-Green et al., 2016). MeBo = Meeresboden-Bohrgerät 200 drill, RD2 = RockDrill2 drill. Expedition 399 sites are at Site U1309 (Hole U1309D; labeled U1309A–E) and between Sites M0069 and M0072 (Site U1601).

Figure F3. Conceptual sketches of tectonomagmatic evolution of heterogeneous lithosphere and denudation of mantle rocks as detachment faulting progresses (Früh-Green et al., 2016). A. Generic "detachment mode" seafloor (Escartín and Canales, 2011). B. Southern wall of Atlantis Massif is dominated by variably altered peridotites with gabbroic lenses (Boschi et al., 2006). 100 m thick detachment fault zone containing talc-tremolite-chlorite metasomatic schists is at the summit (Karson et al., 2006). MAR = Mid-Atlantic Ridge. C. In contrast, major gabbroic intrusions dominate the central dome (Grimes et al., 2008).

Figure F4. Lithology, temperature, and resistivity logging results, Expeditions 304/305 and 340T and Hole U1309D (after Blackman et al., 2014). ΔT = difference between observed temperature and extrapolation of conductive gradient at depth to surface. Minor excursions in temperature are interpreted to be zones of fluid flow at 746 mbsf, where temperature gradient changes from convective to conductive, and 1107 mbsf, near a zone of olivine-rich troctolite.

Figure F5. Lithologic summaries from Expedition 357 holes along southern wall of Atlantis Massive (from Früh-Green et al., 2016). Site U1601 is close to Hole M0069A, where metadolerite (metadiabase) intrudes into talc-tremolite-chlorite schists, both of which are brecciated and underlain by subhorizontal brittle fault zone at ~13 mbsf. Below this fault are little-deformed serpentinized harzburgite and dunite. Beneath soft-sediment layer, hole recovery was excellent.

Figure F6. Summary of all DSDP/ODP/IODP holes with >100 m basement penetration (modified after Ildefonse et al., 2014), with Hole U1309D updated to reflect additional penetration during Expedition 399 and Hole U1601C added.

Figure F7. Summary of bulk rock igneous compositions, Hole U1309D (Expedition 304/305; Godard et al., 2009) and Expedition 357 core samples (Früh-Green et al., 2018). Note very primitive compositions of many of the gabbroic rocks compared to diabase (dolerite) dikes, which are similar to MORB at 30°N in Atlantic. Mg# = 100 × Mg/(Mg + Fe). Reprinted from Lithos (v. 323), Früh-Green et al., "Magmatism, serpentinization and life: insights through drilling the Atlantis Massif (IODP Expedition 357)," pages 137–155, Copyright (2018), with permission from Elsevier.

Figure F8. Metabolic potential of microbial communities isolated from subsurface sediments and crust from Atlantis Massif Expedition 357 samples based on metagenomes. Genes associated with autotrophy, including methanogenesis and methanotrophy, and alkane degradation were rare. Identified genes were associated with heterotrophy, aerobic carbon monoxide, and formate cycling. M. Aer oxidase = microaerobic cytochrome oxidase. From Goordial et al. (2021).

Figure F9. Cell counts from interior portions of whole-round cores, Expedition 357. Shaded area = minimum quantification limit (MQL) of 9.8 cells/cm^3. Sediment (Sed) samples from Site M0069 have higher cell counts than other samples from similar depths. Cell counts are generally low; serpentinites at base of Hole M0069A are deepest samples with significant cell counts. From Früh-Green et al. (2018). Reprinted from Lithos (v. 323), Früh-Green et al., "Magmatism, serpentinization and life: insights through drilling the Atlantis Massif (IODP Expedition 357)," pages 137–155, Copyright (2018), with permission from Elsevier.

Figure F10. Recovered lithology, Hole U1309D. A. 1415–1498 mbsf (Expedition 399) B. 0–1415 mbsf (Expedition 304/305).

Figure F11. Downhole variation of percentage of alteration extent of each mineral and percentage of total alteration intensity in gabbroic rocks, Hole U1309D below 1415 mbsf. See Figure F4 for total alteration intensity from 0 to 1415 mbsf (Expedition 304/305). Ol = olivine, Opx = orthopyroxene.

Figure F12. A. Diabase cutting fractured olivine-bearing gabbro (399-U1309D-303R-1, 126–132 cm). Diabase is at 127–128 cm. B. Chilled margin of undeformed diabase against zone of cataclasis in isotropic olivine gabbro (297R-2, 97–100 cm [TS22]; cross-polarized light).

Figure F13. Lithologic percentages of recovered cores, Site U1601. Final lithologic distributions may require updating once thin sections are available. Opx = orthopyroxene.

Figure F14. Running average for harzburgites, dunites (including orthopyroxene-bearing dunites), and gabbroic rocks recovered using 10 m bin size and 2 m step size between each iteration, Hole U1601C. Final lithologic distributions may require updating once thin sections are available.

Figure F15. Orthopyroxene (Opx) grain size distribution in peridotites, Hole U1601C. Note progressive decrease in grain size between harzburgite, orthopyroxene-bearing dunite, and dunite.

Figure F16. Cut surface showing discrete gabbronorite vein in harzburgite, Hole U1601C.

Figure F17. A, B. Intrusion size as function of lithology for gabbroic rocks, Hole U1601C. Note that histograms count size of intrusions in which given lithologies occur, but intrusions do not have to be composed entirely of this lithology to be included (e.g., troctolites and oxide gabbros occur preferentially in larger intrusions but typically only form minor component of them).

Figure F18. Troctolite contacts between coarse-grained gabbros and peridotites, Hole U1601C. A. Troctolite is present along contacts on both sides between gabbro intrusion and peridotite, with one side thicker than the other. Note interstitial habit of olivine in troctolite. B. Relatively thin troctolite contact between gabbro and peridotite, with euhedral plagioclase crystal growing across contact. C. Granular olivine in mixed olivine gabbro to troctolite contact between coarse-grained gabbro and peridotite. D. Thick troctolite with olivine-rich areas at gabbro-peridotite contact.

Figure F19. Mesh interiors and olivine relicts in serpentinized dunite, Hole U1601A (TS6; plane-polarized light). A. Typical serpentine, brucite, and iowaite mesh texture after olivine (ol); mesh rims are composed of magnetite-serpentine veins. Presence of iowaite in sample was confirmed by XRD, location is inferred. B. Enlargement showing olivine relicts containing trails of secondary fluid inclusions. srp = serpentine, mag = magnetite.

Figure F20. Main vein type occurrences in serpentinized peridotites and at serpentinized peridotite/gabbroic rocks contact, Hole U1601C. Scale bars = 1 cm. A. Set of white, fibrous to massive, subparallel horizontal transgranular to locally paragranular chrysotile (Ctl) veins cutting serpentinized harzburgite. B. Hydrothermally overprinted magmatic vein of clinopyroxene (Cpx), amphibole (Amp)?, prehnite (Prh), and secondary plagioclase (2nd Pl) cut by set of green massive picrolite veins. C. Contact between serpentinized peridotite and altered gabbro. Set of talc (Tlc)-carbonate (Cb) veins branches at contact and further continues in gabbro but not in serpentinite. A few picrolite veins cut through serpentinite and grade to prehnite veins when propagating in gabbro. D. Hydrothermally overprinted magmatic vein cut by set of composite chrysotile-picrolite veins. Picrolite vanishes away from magmatic vein.

Figure F21. Diversity of hydrothermally altered magmatic veins intruding into serpentinized peridotite, Hole U1601C. A. Metasomatic reaction zone comprised of amphibole (Amp), chlorite (Chl), clay, and talc (Tlc) formed by mass transfer between ultramafic and mafic lithologies. B. Hydrothermally altered magmatic vein in serpentinite (Srp) cut by picrolite and chrysotile (Ctl) veins. C. Altered magmatic vein of prehnite, secondary prehnite, and chlorite cut by green picrolite veins. D. Highly altered magmatic dike intruding into serpentinized peridotite. E. Thin (2–3 mm wide) vein cutting serpentinized peridotite. Green picrolite veins cut the altered magmatic vein and white, fibrous chrysotile veins cut serpentine + magnetite (mag) mesh texture and bastites. F. Hydrothermally altered magmatic vein of amphibole and chlorite cutting serpentinized peridotite. Altered magmatic vein is cut by green picrolite veins. Plg = plagioclase.

Figure F22. Wet images. A. Gabbroic protomylonite (399-U1601C-176R-1, 81–90 cm). B. Oxide-gabbro protomylonite (159R-3, 8–13 cm). C. Gabbroic mylonite to ultramylonite in contact peridotite (dark brown, bottom right), reverse shear sense; undeformed talc ± carbonate ± prehnite veins cut mylonite (176R-1, 81–90 cm). D. Oxide-gabbro with protomylonitic, mylonitic, and ultramylonitic domains, controlled by variability of protolith grain size and/or lithology (130R-4, 30–45 cm). E. Gabbroic mylonitic to ultramylonite discrete shear zone, normal shear sense (131R-1, 50–72 cm). F. Gabbroic ultramylonite (134R-2, 100–114 cm; unoriented). G. Irregular sheared contacts between mylonitic gabbroic rock (gray) and protomylonitic peridotite (dark brown); alteration veins cut mylonitic fabric (178R-2, 12–27 cm). H. Sheared contact between protomylonitic gabbroic rock (gray) and protomylonitic peridotite (dark brown-gray, top left); green-white talc ± carbonate ± prehnite alteration and veins overprint and cut mylonitic fabric (156R-3, 77–78 cm).