Figure F1. SAT study region. Top: bathymetry (Ryan et al., 2009) of South Atlantic Ocean. Inset shows regional setting. Bottom: magnetic anomalies (Meyer et al., 2017). Solid lines = CREST seismic reflection profiles (Reece et al., 2016; Reece and Estep, 2019), dashed line = WOCE Line A10. MAR = Mid-Atlantic Ridge, RGR = Rio Grande Rise, ERGR = eastern Rio Grande Rise, TdC = Tristan da Cunha.

Figure F2. A. Observed and predicted conductive heat flow. Discrepancy between observed and predicted heat flow (blue area) indicates hydrothermal circulation persists across ridge flanks for ~65 My on average (modified from Stein and Stein, 1994). B. Compilation of all scientific ocean drilling holes prior to SAT that penetrate >100 m into intact upper (basaltic) ocean crust vs. crustal age, excluding holes drilled in seamounts, oceanic plateaus, back-arc basement, hydrothermal mounds, or passive continental margins (after Michibayashi et al., 2019). Colors show crustal spreading rate, and colored proportion of cored interval indicates average core recovery. Dashed lines = two holes that penetrated through entire upper ocean crust into underlying sheeted dikes.

Figure F3. Sediment cover vs. crustal age, Expedition 390 and 393 sites. Solid circles = observed sediment thickness; open circles = expected sediment thickness; diamonds = sediment thicknesses at all scientific ocean drilling holes that cored >100 m into basement in intact ocean crust and tectonically exposed lower crust/upper mantle; solid line = global average sediment thickness vs. age (25 My moving average of median sediment thickness of 5 Ma binned global compilation of sediment thickness vs. lithospheric age of Spinelli et al. [2004]); dashed lines = 25 My moving average of 25th and 75th percentiles of 5 Ma binned data.

Figure F4. Bathymetry of western flank of southern Mid-Atlantic Ridge. Top: exaggerated bathymetric profile (black line; left scale) along SAT superimposed on depth predicted from simple plate cooling model (orange line; Marty and Cazenave, 1899) assuming ridge crest is ~2500 m depth and adjusting age to latitude. Other cooling models (e.g., Korenaga and Korenaga, 2008) yield similar curves, although classic Parsons and Sclater (1977) predicts deeper oceans with age. Green line = age model (right scale) for South Atlantic of Pérez-Díaz and Eagles (2017a), blue line = age model for South Atlantic of Seton et al. (2020). Bottom: SAT drill sites superimposed on regional and limited high-resolution bathymetry (Ryan et al., 2009) including west–east track of CREST site survey cruise (Reece et al., 2016).

Figure F5. Map of South Atlantic Ocean showing conductive heat flow measurements in vicinity of SAT drill sites. Heat flow data from Fuchs et al. (2021). ETOPO1 bathymetry data from Amante and Eakins (2009).

Figure F6. Seismic reflection profiles for SAT sites occupied during Expeditions 390C, 395E, 390, and 393. Site U1557 was relocated from proposed Site SATL-54A, given thicker than expected sediment cover at Site U1556 and consequent reinterpretation of seismic data for this area, to ensure casing could be installed to basement at Site U1557 without exceeding maximum deployable casing string length of ~600 m in that water depth (~5 km).

Figure F7. Ages and spreading rates along CREST transect. Blue line = cubic interpolation of rates calculated from table S3 in Kardell et al. (2019), red circles = estimated values at SAT drill sites.

Figure F8. A. Schematic architecture of MOR flank (not to scale) illustrating parameters that may influence intensity and style of hydrothermal alteration and hypothetical trajectory of 120°C isotherm with crustal age. Arrows = heat (red) and fluid (blue) flow. B. Calculated global hydrothermal heat flow anomaly, which decreases to 0 by 65 Ma on average, and hypothetical variations in fluid flow and chemical exchange and crustal properties that could be measured to investigate intensity and style of ridge flank hydrothermal circulation (e.g., porosity, permeability, and two possible scenarios for alteration intensity). (After Coggon and Teagle, 2011; Expedition 335 Scientists, 2012; and an original figure by K. Nakamura, AIST.)

Figure F9. Left: global distribution of scientific ocean drilling sites. Larger circles = where microbiological samples were taken. Right: microbial cell abundance vs. depth, revealing >5 orders of magnitude variation in biomass-depth trends, depending on geographic origin of samples (after D'Hondt et al., 2019). MQL = minimum quantifiable limit. The South Atlantic represents a crucial gap in knowledge (orange box with question mark), and SAT samples will be used to groundtruth models of biomass density in subsurface sediments and basement predicted from current biomass database. Note that symbol colors between diagrams are not related because they are derived from different sources.

Figure F10. Comparison of predicted range of TOC for SAT study area with other areas where scientific ocean drilling has conducted microbiological investigations (data from Andrén et al., 2015; Shipboard Scientific Party, 2003a; Expedition 329 Scientists, 2011; Expedition 336 Scientists, 2012; Expedition 308 Scientists, 2006; Tobin et al., 2009; Expedition 313 Scientists, 2010; Expedition 325 Scientists, 2011). SAT drill sites have higher TOC than South Pacific Gyre, where oxygen penetrated to basement, and North Pond, where oxygen penetrated tens of meters into the seafloor in Holes U1383D, U1383E, and U1384A, but lower than Nankai Trough, where pore water oxygen was consumed <5 m below seafloor, based on pore water Mn concentrations.

Figure F11. Composite deep-sea benthic foraminiferal $\delta^{13}C$ and $\delta^{18}O$ records show both gradual and abrupt changes in global climate during the Cenozoic; key events are highlighted by vertical bars (modified from Westerhold et al., 2020). Red and blue "climate stripes" = departure from average Cenozoic temperature in 100 ky time bins (red = warmer than average, blue = colder than average). SAT samples record a rich paleoceanographic record of these changes. Bottom bars show present water depths of SAT sites and intervals of Cenozoic climate history they expected to sample. Deepest sites were expected to contain carbonate-rich sediment (blue) in older part, deposited when site was closer to ridge crest and shallower than CCD, transitioning up to poorly preserved carbonate sediment (light blue) or carbonate-poor sediment (brown) in younger part as each site subsided below CCD. Sites on younger ocean crust were expected to recover younger carbonate-rich sediment. Together, these sites represent a megasplice of the last 61 My of Earth's climate history from an understudied region of the ocean.

Figure F12. Composite deep-sea benthic foraminiferal $\delta^{13}C$ and $\delta^{18}O$ records show both gradual and abrupt changes in global climate during the Cenozoic; key events are highlighted by vertical bars (modified from Westerhold et al., 2020). Red and blue "climate stripes" = departure from average Cenozoic temperature in 100 ky time bins (red = warmer than average, blue = colder than average). Bottom bars show present water depth of SAT sites and intervals of Cenozoic climate history they sampled. Deepest sites comprise carbonate-rich sediment (blue) in older part, deposited when site was closer to ridge crest and shallower than CCD, transitioning up to carbonate-poor sediment (brown) in younger part as each site subsided below CCD. Sites on younger ocean crust recovered younger carbonate-rich sediment. Together, these sites represent a megasplice of the last 61 My of Earth's climate history from an understudied region of the ocean.

Figure F13. WOCE (top) temperature, (middle) salinity, and (bottom) phosphorus profiles along (left) south–north Transect A16 through (right) western South Atlantic Basin and west–east Transect A10 at 30°S close to location of SAT (data from WOCE; **http://www.ewoce.org**). Rectangles show approximate coverage of SAT. AAIW = Antarctic Intermediate Water.

Figure F14. Top: carbonate in depth transect recovered during Leg 208 on Walvis Ridge, eastern South Atlantic (Shipboard Scientific Party, 2004). Position of lysocline and CCD were dynamic during Cenozoic related to changing deepwater circulation, productivity, and ocean acidification associated with PETM. Bottom: modeled relative water mass age during mid-Miocene climatic optimum (Coggon et al., 2020). Red oval = correlative changes in carbonate chemistry on Walvis Ridge. Colors represent benthic "age," which is a $\delta^{13}C$-like tracer; red = old water, blue = young water. Left: mode with NCW on. Right: NCW off. The SAT, near 31°S, is expected to capture changes in these two modes of deepwater formation.

Figure F15. A. Engineering and coring operations completed during Expeditions 390C and 395E and planned SAT operations prior to Expedition 390. B. A modified to show operations completed during Expeditions 390C, 395E, and 390 and planned operations for Expedition 393. (Continued on next page.)

Figure F15 (continued). C. Operations completed during SAT Expeditions 390C, 395E, 390, and 393. MM = missed mudline.

Figure F16. Sites U1556, U1557, and U1561 bathymetry (Christeson and Reece, 2020). Seismic reflection profiles were acquired during CREST cruise (Reece et al., 2016).

Figure F17. Stratigraphic summary of representative sediment holes at each Expedition 390 site, Holes U1556C, U1557B, U1561A, and U1559C. For epoch, see Figure F19. a* (red–green) is smoothed with 100 point moving average. cps = counts per second. NGR and magnetic susceptibility (point source) are plotted on CSF-B depth scale.

Figure F18. Summary of calcareous nannoplankton and planktic foraminifera abundance and preservation across the SAT and plotted in 10 m thick bins (except Site U1557 foraminifera, which are binned at 20 m because of sample resolution) and shown above seafloor bathymetry measured during CREST cruise (Reece and Estep, 2019), Expedition 390. Preservation: E = excellent, VG = very good, G = good, M = moderate, P = poor, VP = very poor.

Figure F19. Age-depth plots, Expedition 390. Lighter symbols = all biostratigraphic and magnetostratigraphic datums, darker symbols = datums used to construct age-depth models at each site. Inset to interpret sedimentation rates for the age transect is also shown.

Figure F20. IW chemistry along SAT, Expedition 390. Orange lines = standard seawater values (SO_4^{2-}/Cl = 28 mM/546 mM, Mn = 0.36 µM, Ca/Mg = 10.27 mM/52.7 mM, Li = 25.9 µM) taken from Monterey Bay Aquarium Research Institute (MBARI) Periodic Table of Elements in the Ocean (**https://www.mbari.org/know-your-ocean/periodic-table-of-elements-in-the-ocean**). Sediment depths were normalized to maximum sediment thickness of each hole to compare variations in IW chemical profiles (0 = near mudline, 1 = near basement). Inset on SO_4^{2-}/Cl plot shows depth dependent decrease in ratios in all holes between 0 and 0.15 normalized depth.

Figure F21. Representative samples of uppermost basement rocks, Sites U1556 and U1557. A. Sedimentary breccia from sediment/basement interface: fragments of basaltic lava in micritic limestone matrix. B. Moderately olivine phyric basalt (Stratigraphic Sequence A; upper half of image) in which olivine is highly altered to distinctive orange-brown, intrudes an older, intensely altered pillow basalt (Stratigraphic Sequence B; lower half of image). C. Chilled margins of highly plagioclase-olivine-clinopyroxene phyric basalts (Stratigraphic Sequence C). D. Hyaloclastite breccia with carbonate cement. E. Talus breccia comprising gray, brown, and orange clasts of altered basalt and altered glass cemented by a zeolite ± micritic or microsparry calcite. F. Common alteration types and their typical spatial relationship in sequence from chilled margin (right) to interior of large pillow (left), typically including altered glass, a mottled gray cryptocrystalline to variolitic zone, orange halos paralleling pillow margin and along veins, and orange speckled background interior.

Figure F22. Expedition 390 basement core description summary. Core recovery and igneous stratigraphy are based on Holes U1556B and U1557D. Zr/TiO_2 shows enriched geochemical signatures in Stratigraphic Sequences A and B at Site U1556 (all geochemical data measured during Expedition 390 are shown; vertical dashed line = composition of N-MORB [Sun and McDonough, 1989] for reference). Note that some pXRF data from Holes U1556A and U1557B plot shallower than top of basement in Holes U1556B and U1557D. Total vein density and open macroscale porosity (vertical dashed line = mean as a proportion of all recovered rock, open circles = calculated by section, solid circles = calculated by core, dotted red lines = tie lines indicating differences in *x*-axis scales for the two holes). Summary of relative proportion of alteration types recorded for each igneous unit (thick black lines = boundaries between major stratigraphic sequences).

Figure F23. Stepwise demagnetization OVPs, decay AF plot, and discrete sample locations of representative samples of different alteration classes (ACs) along with (A) ChRM and (B–D) overprint inclinations, Hole U1556B (B: no overprint, C: completely overprinted, D: partially overprinted).

Figure F24. A. DMT CoreScan3 workstation with example of 3-D high-resolution image created using novel methods developed during Expedition 390. B. Foldio workstation with rotating stage and camera positioned to take multiple time-lapsed images of core pieces as it rotates that were taken to preserve information on pieces fragmented for microbiological sampling.

Figure F25. Summary of physical properties in Section 390-U1557B-50X-3, inferred to contain sediments deposited during PETM. Stars = locations of samples taken for nannofossil analyses, 1–14 = locations of closely spaced lithologic descriptions, yellow lines = two intervals for which close-up images are provided on right. Magnetic susceptibility is from point source. Photomicrographs show *Rhomboaster calcitrapa* (top: plane-polarized light, bottom: cross-polarized light).

Figure F26. Site U1558 bathymetry (Christeson and Reece, 2020). Seismic reflection profiles were acquired during CREST cruise (Reece et al., 2016).

Figure F27. Lithostratigraphic summary of sediment units and correlation of full sediment sequences, Holes U1558A and U1558F. Dashed lines = correlation between units. cps = counts per second.

Figure F28. A. Stratigraphic column for igneous basement, Hole U1558D. Unit contact depths and thicknesses are expanded to account for <100% recovery. B. Area abundance of background alteration, alteration halos, fresh and altered glass, and altered sediment. Data are plotted at individual core level. Depths are CSF-A and plotted at top of cored interval. Black trend lines = locally weighted nonparametric regression (LOWESS), gray shading = 2σ of mean.

Figure F29. (A) Boron, (B) lithium, (C) silicon, and (D) potassium, Holes U1558A and U1558F. Significant increases in B, Li, Si, and K relative to mudline in Unit I (nannofossil-rich clay) likely result from dissolution of biogenic silica, weathering of detrital silicates, and/or ion exchange between sediment and pore waters. Second increase in B and Li coincides with higher clay contents and lower $CaCO_3$ at Subunit IIB (nannofossil chalk with clay)/IIC (nannofossil chalk with clay and volcaniclastics) boundary. Although Si decreases with depth in both holes, K virtually does not change in Subunit IIC. Smectite-to-illite transformation and alteration of underlying ocean crust may also affect concentrations of these elements. Seawater (SW) reference values for B, Li, and K correspond to International Association for the Physical Sciences of the Oceans (IAPSO) standard composition; local Si concentration is sourced from Sarmiento et al. (2007).

Figure F30. Zr/Y vs. Zr tectonic discrimination diagram from Pearce and Norry (1979) showing combined pXRF and ICP-AES data for Site U1558 basalts compared to data from Sites U1556, U1557, and U1559. MORB = mid-ocean-ridge basalt.

Figure F31. A. Curves of saturation IRM (SIRM) acquisition up to 1200 mT and backfield IRM truncated at −0.3 T for two representative samples of basement rock, Hole U1558D. B. Coercivity distribution and unmixing of IRM acquisition curves (Maxbauer et al., 2016). C. IRM acquisition: B_{cr} = coercivity of remanence, $S_{0.1}$ = IRM_{100}/SIRM, $S_{0.3}$ = S ratio.

Figure F32. Site U1583 bathymetry (Christeson and Reece, 2020). Seismic reflection profiles were acquired during CREST cruise (Reece et al., 2016).

Figure F33. Lithostratigraphic summary of sediment units and correlation of full sediment sequences, Holes U1583C and U1583E. Dashed lines = correlation between units. cps = counts per second.

Figure F34. A. Stratigraphic column for igneous basement, Hole U1583F. Unit contact depths and thicknesses are expanded to account for <100% recovery. B. Area abundance of background alteration, alteration halos, fresh and altered glass, and altered sediment. Data are plotted at individual core level. Depths are CSF-A and plotted at top of cored interval. Black trend lines = locally weighted nonparametric regression (LOWESS), gray shading = 2σ of mean.

Figure F35. Age-depth model showing biostratigraphic and magnetostratigraphic datums, Hole U1583C. LSRs were averaged for Pleistocene, Pliocene, Miocene, and Oligocene.

Figure F36. Summary of logging data recorded with triple combo logging string, Hole U1583F. Caliper is combination of two upward passes that were made. RLA1, RLA3, and RLA5 = apparent resistivity from Computed Focusing Modes 1, 3, and 5, respectively; RT = true resistivity.

Figure F37. Site U1560 bathymetry (Christeson and Reece, 2020). Seismic reflection profiles were acquired during CREST cruise (Reece et al., 2016).

Figure F38. Lithostratigraphic summary of sediment units and correlation of full sediment sequences, Holes U1560A and U1560C. Dashed lines = correlation between units. cps = counts per second.

Figure F39. A. Stratigraphic column for igneous basement, Hole U1560B. Unit contact depths and thicknesses are expanded to account for <100% recovery. B. Area abundance of background alteration, alteration halos, fresh and altered glass, and altered sediment. Data are plotted at individual core level. Depths are CSF-A and plotted at top of cored interval. Black trend lines = locally weighted nonparametric regression (LOWESS), gray shading = 2σ of mean.

Figure F40. (A) Calcium, (B) magnesium, (C) strontium, and (D) Sr/Ca ratios, Holes U1560A and U1560C. Ca remains close to or above seawater (SW) value (dashed black line) throughout Holes U1560A (10.2–11.4 mM) and U1560C (10.5–11.4 mM), with good agreement between holes. Mg broadly decreases in Hole U1560A (54.3–52.6 mM at 0–116.86 m CSF-A), remaining less than SW throughout sediment column. In Hole U1560C, Mg increases in Subunit IA (53.7–54.5 mM; ~3–27 m CSF-A), decreases in Subunits IB–ID (54.6–53.2 mM; ~27 to ~90 m CSF-A), and increases slightly in Subunit IE (to 53.8 mM at 111.00 m CSF-A). In contrast to small changes observed in Ca and Mg profiles, Sr and Sr/Ca ratios vary significantly in both holes. Sr and Sr/Ca ratios increase in Subunit IA (Sr: ~90–180 µM; Sr/Ca: ~8–17 µM/mM), remain uniform throughout Subunits IB and IC (Sr: ~190 µM; Sr/Ca: ~17 µM/mM), and then decrease toward sediment/basement interface in both holes (Sr: ~110–115 µM; Sr/Ca: ~11 µM/mM). SW reference values correspond to International Association for the Physical Sciences of the Oceans (IAPSO) standard composition. RZ = Rhizon.

Figure F41. Vein types, Hole U1560B. A. Strong green vein, potentially composed of celadonite, on broken rock surface. B. Submillimeter-wide clay vein with brown halo. C. Several crosscutting narrow carbonate veins. D. Branched carbonate veins with crack-seal texture and wider carbonate vein in which brecciated fragment of host rock are floating. E. Carbonate-filled vein and vuggy space. Also note vein filled with metamorphosed sediment.

Figure F42. Summary of logging data recorded with triple combo logging string, Hole U1560B. RLA1, RLA3, and RLA5 = apparent resistivity from Computed Focusing Modes 1, 3, and 5, respectively; RT = true resistivity; MSS = Magnetic Susceptibility Sonde.

Figure F43. Site U1559 bathymetry (Christeson and Reece., 2020). Seismic reflection profiles were acquired during CREST cruise (Reece et al., 2016).

Figure F44. A. Stratigraphic column for igneous basement, Hole U1559B. Unit contact depths and thicknesses are expanded to account for <100% recovery. B. Area abundance of background alteration, alteration halos, fresh and altered glass, and altered sediment. Data are plotted at individual core level. Depths are CSF-A and plotted at top of cored interval. Black trend lines = locally weighted nonparametric regression (LOWESS), gray shading = 2σ of mean.

Figure F45. Comparison of physical properties of discrete samples, Holes U1559B and 896A. Range of data from Hole 896A (red line = mean value of each data type, shaded boxes = ±1σ). V_P shown is maximum velocity measured for each sample. Symbol colors represent alteration degree, black symbols lack alteration degree description.

Figure F46. Comparison of porosity, *P*-wave velocity, and alteration for discrete basalt samples, Site U1556. A. *P*-wave velocity vs. porosity by alteration class. B. Basalt cubes illustrating different alteration classes. Class 1 = least altered, Class 8 = most altered. Class descriptions are directly comparable to core alteration description of Site U1556 basement sequence.

Figure F47. Summary of basement drilling during Expedition 393 across SAT showing examples of basalts, interflow sediments, and breccias. Cr/Ti data were measured directly on split-core surfaces by pXRF.

Figure F48. Geochemistry of igneous rocks from across the SAT. A. Shipboard analyses of Sr vs. TiO_2 concentrations for basalts showing clustering Expedition 393 analyses (Sites U1558–U1560 and U1583) on top of analysis of fresh glasses from modern South Atlantic Ridge MORB in contrast to analyses from Hole U1556B and the Rio Grande Rise (RGR). B. Basalt V/TiO_2 ratios vs. age. Geochemistry of lavas with MORB affinities show irregular progression from compositions with strong influence from Tristan da Cunha plume to V/TiO_2 values similar to lavas on modern southern Mid-Atlantic Ridge.

Figure F49. Bathymetric cross section of western flank of southern Mid-Atlantic Ridge at 31°S showing location of sediment coring during Expedition 393 (red) that completes SAT operations initiated during Expeditions 390C, 395E, and 390 (gray). CCD = modern-day CCD.