Figure F1. Expedition 352 sites at the IBM fore arc. Red circle = Site U1439, yellow circles = other Expedition 352 sites. White lines = multichannel seismic lines (S. Kodaira, pers. comm., 2013).

Figure F2. Location of Site U1439 along multichannel seismic Line IBr11 (S. Kodaira, pers. comm., 2013). Green bar shows the depth of Hole U1439A, blue bar shows the depth of Hole U1439C. CDP = common depth point.

Figure F3. Reentry system.

Figure F4. Lithostratigraphic summary of sediment cores. Very closely spaced ash layers may not always appear individually in the tephra column.

Figure F5. Examples of textures and vesicles of pyroclasts in smear slides of ash layers, Hole U1439A. A. Pumiceous clast with tubular vesicles. B, C. Tubular and elliptical to elongate vesicles in pumiceous clasts. D, E. Dense blocky glass shards, (E) some with round bubbles, together with cuspate glass shards and also pumiceous clasts with elongate and elliptical vesicles. F. Cuspate glass shards formed by fragmentation of "foamy" pyroclasts with predominantly large, rounded, or elliptical bubbles. G. Rounded and elliptical vesicles within blocky and cuspate glass shards. H, I. Dense brownish glass shard containing vesicles, some round and others elliptical.

Figure F6. Pale olive silty mud with grayish brown sand, together with a normally graded pinkish brown ash layer, Hole U1439A. The cemented, finer grained upper part is disturbed by drilling.

Figure F7. Slightly bioturbated light gray/brownish to white, massive, silty calcareous nannofossil ooze with foraminifers, Hole U1439A.

Figure F8. Ash layers in Subunit IB, Hole U1439A. A. Normally graded, pinkish beige ash layer with a sharp, planar, horizontal boundary in contact with pelagic sediment and a gradational bioturbated contact with background sedimentation above. White dashed line = estimated limit of the strongly bioturbated, dispersed ash above the ~10 cm thick primary depositional layer. B. Pinkish gray, normally graded ash layer with a sharp subhorizontal contact with the sediment below but a much sharper transition to the background sedimentation above compared to the ash layer in A.

Figure F9. Dark brown silty mud with sand together with an ash layer (0–3 cm), Hole U1439A.

Figure F10. Thick beds of massive, strongly bioturbated silty sand containing common lithified ash pod alternating with very pale brown nannofossil-bearing sandy silt, Hole U1439A. Pyroclast textures and vesicles vary between the ash layers.

Figure F11. Consolidated, highly bioturbated pink calcareous nannofossil ooze with silt, Hole U1439A. The disrupted primary bedding was caused by drilling disturbance.

Figure F12. Clay, Hole U1439A. A. Massive reddish gray clay with pinkish patches of silt and also black metal-oxide segregations. B. Color-banded clay.

Figure F13. Alternations of dark gray siltstone and highly bioturbated sandstone/siltstone with lithified interbeds of nannofossil ooze, Hole U1439A. 12

Figure F14. Characteristic features of Unit V, Hole U1439A. A. Highly bioturbated sandstone/siltstone with interbeds of lithified nannofossil ooze. B. Dark gray planar-laminated tuffaceous siltstone.

Figure F15. Sediment cover vs. igneous basement, Hole U1439A. A. Contact between the deep-sea sediment cover and the volcanogenic basement, characterized by a manganese crust (<5 cm). Nannofossil carbonate follows directly above this. B. Fragment of lava breccia from the "basement" containing pink pelagic carbonate between volcanic clasts.

Figure F16. A. *Pseudoemiliania lacunosa* (coccosphere) (U1439A-2H-CC). B. *Discoaster brouweri* (3H-CC). C. *Ceratolithus cristatus* demonstrating strong "ornamentation" (3H-CC). D. *Ceratolithus cristatus* var. *telesmus* (2H-CC). E. *Discoaster quinqueramus* (6H-CC). F. *Discoaster berggrenii* with strong distal boss (7H-CC).

Figure F17. A. *Cyclicargolithus floridanus* (U1439A-9H-CC). B. *Sphenolithus heteromorphus* (10H-CC). C. *Discoaster deflandrei* (11X-CC). D. *Triquetrorhabdulus carinatus* (15X-CC).

Figure F18. Age-depth plot with a comparison of calcareous nannofossil ages, Hole U1439A.

Figure F19. Stratigraphic column of sedimentary units with calcareous nannofossil biozonation indicating approximate ages of each unit.

Figure F20. Interstitial water methane, ammonium, phosphate, pH, and alkalinity concentrations, Hole U1439A. Blue arrow = seawater value.

Figure F21. Interstitial water sulfate, sodium, potassium, and bromide concentrations, Hole U1439A. Blue arrows = seawater values.

Figure F22. Interstitial water calcium and magnesium concentrations and Ca/Mg ratios, Hole U1439A. Blue arrows = seawater values.

Figure F23. Stratigraphic summary of basement cores. Hatched red bars adjacent to lithology column represent fault zones. opx = orthopyroxene, cpx = clinopyroxene. The line for smectite-group clays includes mixed-layer clays.

Figure F24. Phase assemblage variations. Hatched red bars adjacent to lithology column represent fault zones.

Figure F25. Variations in chemical compositions. Hatched red bars adjacent to lithology column represent fault zones.

Figure F26. Ovoid texture in boninites in (A) Hole U1439A vs. (B) Hole U1439C, illustrating the correlation of Unit 1 between both holes.

Figure F27. Macroscopic features, Hole U1439C. A. Pyroclastic breccia containing partially welded glass fragments. B. Globular structures in olivine-orthopyroxene-phyric boninite. C. Olivine, orthopyroxene, and augite phenocryst accumulations with globular structure in boninitic pillow lava. D. Diffuse and sharp contacts between clast and host magma. In places, the contact can be cuspate, suggestive of magma mingling. E. Pillow margin developed in boninitic lava.

Figure F28. Microscopic features, Hole U1439C. A. Orthopyroxene-olivine-phyric boninite with acicular augite and orthopyroxene in vitrophyric groundmass (cross-polarized light [XPL]). B. Pyroclastic breccia containing glassy fragments of boninite, in places welded, surrounded by calcite cement (plane-polarized light [PPL]). C. Vesicular olivine-phyric boninite containing skeletal olivine in a glassy matrix (XPL). D. Augite-phyric boninite with a hypohyaline groundmass of augite and plagioclase; pseudomorphed olivine is present in the upper right of the photo (PPL). E. Aphyric basalt with intersertal augite and plagioclase in the groundmass; plagioclase weakly defines a trachytic texture (PPL). F. Dolerite displaying intergranular to subophitic texture defined by augite and plagioclase (PPL).

Figure F29. Alteration features, Hole U1439C. A. Smectite clay pseudomorphs in olivine-phyric boninite. B. Clay, calcite, and Fe oxyhydroxide pseudomorph of olivine in a matrix completely transformed to calcite. C, D. Linear and irregular biogenic tubules from Unit 8 showing (D) crystal remnants of an organism or its waste within biotubes. E. Altered boninite showing complete replacement of glass by zeolite without significant alteration of microcrystals. F. Green smectite-group or mixed-layer clay replacement of groundmass in deeper core sample. G. Groundmass alteration to fibrous zeolites with small oxide needles parallelized to the fibers, Unit 5. H. Pervasive replacement of glass with calcite. I. Vesicular boninites showing vesicles filled with coarse-grained zeolite. J. Secondary saponite within zeolite grown from margin (right). K, L. Geopetals of zeolite and calcite with zeolite filling at the bottom and continuous calcite above.

Figure F30. Main alteration features, Hole U1439C. A. Background alteration of phyric to aphyric pillow rim (48–54 cm). Olivine is completely altered to smectite, whereas the glassy rim remains mainly fresh. B. Highly vesicular boninite showing three types of filling: zeolite (light blue), saponite (deep blue), and calcite (white). C. Brownish Fe oxyhydroxide alteration along veins in the deeper dolerites.

Figure F31. Macroscopic and microscopic vein features, Hole U1439C. A. Highly fracturing calcite vein network with transformation of the original rock into one with calcite cementation. B. Relatively dense network of calcite veins in igneous Unit 7. C. Partly brecciated boninite containing a cataclastic calcite vein network partly connected to the vesicles. D. Zeolite vein showing partial replacement by calcite. E. Zeolite vein with oxidizing halo. F. Zeolite vein crosscut by a clay vein.

Figure F33. CaO, Sr, and Ba analyses in sediment.

Figure F32. LOI vs. CO_2 in sediment, Hole U1439A.

Figure F34. Y, Cu, and MnO analyses in sediment.

Figure F35. MgO, Cr, TiO_2, and Zr analyses in sediment.

Figure F36. Igneous rock H_2O, CO_2, and H_2O/CO_2 vs. LOI, Site U1439.

Figure F37. A. Total alkali concentrations vs. SiO_2 (after Le Bas, 1986) of Site U1439 igneous rocks in comparison to Site U1440 igneous samples. B. MgO vs. SiO_2 of Site U1439 igneous rocks in comparison to Site U1440 fore-arc basalts (Reagan et al., 2010) and MORBs. Dotted line = IUGS field for boninites (Le Bas, 2000).

Figure F38. Major elements vs. MgO, Site U1439.

Figure F39. Cr and Ni vs. Mg#, Site U1439.

Figure F40. Ti vs. V, Y, and Zr, Site U1439. The composition of igneous rocks of Site U1440 and MORB (data from Jenner and O'Neill, 2012, and references within), island arc tholeiites (data from the GEOROC Database, August 2014), and fore-arc basalts (data from Reagan et al., 2010) from the IBM subduction system are shown for comparison.

Figure F42. Drilling-induced drag-down structures caused by downward motion of the coring tool, Hole U1439A (20X-1A, 0–18 cm).

Figure F41. Sr vs. TiO_2 for Site U1439 compared to Site U1440. Arrows = approximate trajectories for variable extents of partial melting and/or magma chamber crystallization. For Sr, variable extents of partial melting or fractional crystallization with little or no plagioclase yield a steep positive array, whereas the crystallization of plagioclase-rich assemblages buffers D_{Sr} at ~1 and leads to a horizontal array. Overall higher Sr/Ti in Site U1439 samples may reflect greater slab-derived fluid inputs, necessary to melt a more depleted, and hence lower Ti, mantle source. The most altered igneous rocks recovered at Site U1439 are not plotted on this figure.

Figure F43. Drilling-induced rotational shear of sedimentary material along the core liner caused by rotary drilling, Hole U1439A (19X-1A, 127–135 cm).

Figure F44. Postretrieval core dilation within a restraining core liner, resulting in contractional deformation (thrust), Hole U1439A (15X-2W, 40–45 cm).

Figure F45. Development of contractional structures in a dilating core restrained at both ends. Although these shear fractures appear as thrusts dynamically forming at the surface of the working half core, in the core reference framework these fractures are normal faults.

Figure F46. Poles to 21 bedding planes in Hole U1439A APC-drilled sections. All stereographic projections are in lower hemisphere, equal area.

Figure F47. Poles to 63 bedding planes in Hole U1439A XCB-drilled sections, measured in the least deformed portions of the core between 0 and 92.30 mbsf. All stereographic projections are in lower hemisphere, equal area. 35

Figure F48. Subvertical dewatering structure, Hole U1439A (18X-5A, 42–51 cm).

Figure F49. Convolute folds in pyroclastic sedimentary material, Hole U1439A (17X-4W, 43–53 cm).

Figure F50. Subvertical normal shear fracture, Hole U1439A (18X-2A, 87–96 cm).

Figure F51. Subvertical extensional fractures, Hole U1439A (18X-4W, 94–104 cm).

Figure F52. Bedding dips as a function of depth. Black circles = bedding planes, red circles = cross-bedding top planes, blue circles = planes marking lateral change in sediment grain size and/or color.

Figure F53. Vein abundance per 10 m length of core as a function of depth, Hole U1439C.

Figure F54. Vein thickness as a function of depth, Hole U1439C.

Figure F55. Frequency distribution of vein dip angles, Hole U1439C.

Figure F56. Subvertical to steeply inclined mineralized veins, Hole U1439C (23R-2W, 14–34 cm).

Figure F57. Subvertical to steeply inclined vein with irregular vein margin and lithic fragments embedded within the vein filling, Hole U1439C (3R-2W, 106–117 cm).

Figure F58. Steeply inclined cataclastic shear zone with fault breccia, Hole U1439C (10R-1A, 49–59 cm). The shear zone is bounded by a steeply inclined slickenside with normal sense of shear.

Figure F59. Cataclastic shear zone at 398 mbsf, close to the bottom of fault Zone 1, Hole U1439C (27R-1A, 100–118 cm). The wall rock adjacent to the shear zone is transected by shear fractures and is highly altered.

Figure F60. Cataclastic shear zone at 398 mbsf, close to the bottom of fault Zone 1, Hole U1439C (27R-1W, 100–104 cm). Subvertical to steeply inclined reverse shear fractures (red), extensional veins (blue), and normal shear fractures (yellow) are marked.

Figure F61. Cataclastic shear zone dip angles as a function of depth, Hole U1439C.

Figure F62. Cataclastic shear zone at 420.4 mbsf at the top boundary of fault Zone 2, Hole U1439C (29R-3A, 64–79 cm). Distinct shear fractures indicate reverse sense of shear.

Figure F63. Slickenside dip angles as a function of depth, Hole U1439C. 1–3 = fault zones (see text).

Figure F64. Twinning and undulose extinction of calcite within a vein, Hole U1439C (31R-3W, 106–109 cm; TS135).

Figure F65. Subgrain boundaries within calcite, Hole U1439C (32R-4W, 82–85 cm; TS140).

Figure F66. WRMSL physical property measurements of sediment cores. Blue points = raw values, red lines = filtered data (mean values in 50 cm range).

Figure F67. SHMSL physical properties data and discrete sample MAD measurements of sediment cores. L*, a*, b*: blue points = raw values, red lines = filtered data (mean values in 50 cm range). MAD and porosity: solid circles = discrete values (blue = dry density, black = bulk density, purple = grain density, red = porosity). Black points in MAD are WRMSL GRA density data shown for comparison.

Figure F68. WRMSL physical property measurements of basement cores. Blue points = raw values, red points = filtered data (maximum values of rock pieces ≥10 cm in length), red lines = trend of maximum value in each core.

Figure F69. SHMSL and discrete sample physical property measurements of basement cores. Discrete samples were used for magnetic susceptibility (green diamonds), *P*-wave caliper (PWC), and MAD measurements. L*, a*, b*: blue points = raw values, red points = filtered data (maximum values of rock pieces ≥10 cm in length), red lines = trend of maximum value in each core.

Figure F70. Thermal conductivity probe measurements of whole-round sediment core (black circles) and discrete igneous rock samples (blue circles) and downhole temperature (DHT) measurements. Solid red line with error bars: mean and standard deviation for the Hole U1439A thermal conductivity measurements, solid red line = least-squares fitted line to the four DHT temperature measurements (blue circles), solid black line = borehole temperature profile calculated with thermal conductivity data as a function of summed thermal resistance. Thermal conductivity is 0.98 ± 0.105 W/(m·K). Temperature gradient (T_{depth}) = 3.11 + 0.022 × depth (m). Heat flow is 25 ± 2.7 mW/m^2. T_{bottom} = 19.7 ± 1.8 (°C).

Figure F71. Sediment core magnetization intensity, Hole U1439A.

Figure F72. Representative discrete sample AF demagnetization results, Hole U1439A. This sample shows a steep downward overprint with the NRM direction, several steps of consistent demagnetization (5–20 mT), and then a gradual skewing of the magnetization by a spurious overprint. A. Equal area stereonet with direction of magnetization vector at different AF steps. B. Orthogonal vector (Zijderveld) plot with magnetization end-points plotted on two orthogonal planes. C. Normalized magnetization strength, *M*, at a given AF field demagnetization, normalized by the maximum magnetization strength, M_{max}.

Figure F73. Representative discrete sample thermal demagnetization results, Hole U1439A. Plot conventions as in Figure **F72**.

Figure F74. APC core magnetic stratigraphy, Hole U1439A. Paleomagnetic inclination measurements after 25 mT AF demagnetization. Horizontal gray zones = normal-polarity (positive inclination) sections. Core: gray shading = gap in recovery. Polarity and GPTS (Gradstein et al., 2012): ? = uncertain, dashed lines = correlations. Chron terminology from Cande and Kent (1995). GAD = geocentric axial dipole.

Figure F75. Selected XCB core magnetic stratigraphy, Hole U1439A. Plot conventions as in Figure **F74**. Core: NM = not measured, NR = not recovered.

Figure F76. High-coercivity sample AF demagnetization results, Hole U1439C. This sample exhibits a "hard" magnetization that is not easily removed with AF demagnetization. Even after 60 mT of applied AF field, the sample retains almost half of its magnetization. On the orthogonal vector plot, vector endpoints remain far from the plot origin. Plot conventions as in Figure **F72**.

Figure F77. AF demagnetization experiment showing univectorial decay affected by spurious ARM, Hole U1439C. Although low AF steps are consistent and show nearly univectorial decay on the orthogonal vector plot, higher AF demagnetization steps are erratic. Plot conventions as in Figure **F72**.

Figure F78. Representative thermal demagnetization results for a sample displaying partial self reversal (Doubrovine and Tarduno, 2004, 2005), Hole U1439C. Between 250° and 350°C, normalized magnetization increases and the vector endpoint moves away from the orthogonal vector plot origin. Plot conventions as in Figure **F72**.

Figure F79. Thermal demagnetization results for a well-behaved sample, Hole U1439C. This sample is characterized by a nearly linear decrease in magnetization with increasing temperature. Plot conventions as in Figure **F72**.

Figure F80. Thermal demagnetization of a sample containing nearly pure magnetite, Hole U1439C. This sample magnetization was resistant to heating until temperatures close to the Curie temperature of magnetite (575°C). Plot conventions as in Figure **F72**.

Figure F81. pARM acquisition of four representative samples from Hole U1439C measured with a sliding window of 10 mT in a direct-current field of 0.2 mT superimposed on an AF maximum field of 100 mT. The field indicated on the *x*-axis corresponds to the higher field in the interval in which ARM was applied (see Jackson et al., 1988). For example, the point at 20 mT is the pARM acquired on the 20–15 mT interval.

Figure F82. IRM acquisition curves for five representative samples, Hole U1439C.

Figure F83. Inclination and lithology comparison, Site U1439. Inclinations derived from PCA calculations from AF and thermal demagnetization. Horizontal dashed lines = faults observed in cores (see **Structural geology**), gray shaded bands = zones of anomalously high absolute value inclinations. TH = thermal demagnetization, SRM = AF-demagnetized archive core pieces.

Figure F84. Discrete sample inclination histograms, Hole U1439C.

Figure F85. Schematic of tool string deployments, Hole U1439C.

Figure F86. Summary of spectral gamma ray downhole logging measurements and corresponding data from recovered core material (gray circles; see **Physical properties** and **Sediment and rock geochemistry**).

Figure F87. Summary of triple combo-MSS logs. R5 = deepest HRLA resistivity reading, R3 = medium resistivity reading, RT = true resistivity (modeled from all depths of investigation), uncal = uncalibrated units. Gray circles = core data.

Figure F88. Summary of FMS-sonic tool string logs. C1 = Caliper 1, C2 = Caliper 2. Gray circles = core data.

Figure F89. Comparison of main logs recorded during subsequent passes of the triple combo-MSS tool string.

Figure F90. Comparison of caliper (hole size) and gamma ray data acquired during subsequent tool string passes and tool string deployments (runs).

Figure F91. Statically processed FMS images, Hole U1439C. A. High-angle conductive features, Unit 7. B. More massive fractured interval, Unit 6. C. Planar feature and vesicles, Unit 5.

Figure F92. Through-pipe gamma ray downhole logging data in Hole U1439C compared to NGR core data in Hole U1439A. Light gray line = approximate position of pipe joints, dark gray line = bit depth.