Figure F1. A. Tectonic setting of the Izu-Bonin-Mariana (IBM) arc (modified from Taylor, 1992; Tamura and Tatsumi, 2002). The IBM arc trench system forms the convergent margin between the Pacific and Philippine Sea plates. Double lines indicate spreading centers active in the Mariana Trough and inactive (relic) in the Shikoku and Parece Vela Basins. The Izu arc, Bonin arc, West Mariana Ridge, and Mariana arc are outlined by the 3 km bathymetric contour, and other basins and ridges are outlined by the 4 km contour. Box shows area of B. B. Map of the 16 Quaternary volcanoes on the Izu arc front (modified from Tamura et al., 2009), showing positions of Expedition 350 sites (Site U1436 in the fore arc and Site U1437 in the rear arc); ODP sites are also shown. Dotted line along arc front indicates locations of 103 ocean-bottom seismometers deployed at ~5 km intervals (Kodaira et al., 2007a, 2007b); for profile see Figure **F3** in the Site U1437 chapter (Tamura et al., 2015b).

Figure F2.Location of Site U1436 (IBM-4GT) and ODP Sites 792, 786, and 787. Site U1436 lies 60 km east of Aogashima, an arc-front mafic volcano that forms a small inhabited island; east of that is the East (Higashi) Aogashima submarine caldera, which also appears on the west end of the line of section shown in Figure **F4**.

Figure F3. Izu arc seismic stratigraphy. *P*-wave velocity after Suyehiro et al. (1996). Expedition 350 drilled two sites: Site U1436 in the fore arc and Site U1437 in the rear arc. Site U1436 is a geotechnical hole for Site IBM-4 (see Figure **F2**) and lies 1.5 km from Site 792. Other ODP sites are projected onto the line of section (black bars). Site U1436 is located 25 km north of the seismic line shown here. BON = boninite, FAB = fore-arc basalt.

Figure F4. A. Time-migrated MCS section IBM4-EW5 along the east–west profile through proposed Site IBM-4 (M. Yamashita, pers. comm., 2014). In order to better image the intracrustal structure and to precisely define the upper/middle crust boundary beneath Site IBM-4, seismic experiments were conducted in 2008 using the Japan Agency for Marine-Earth Science and Technology R/V *Kairei* (KR08-09) to deploy a wide-angle ocean-bottom seismometer array with 1 km intervals. Seismic velocity (V_P) of 5 and 6 km/s are inferred to represent upper crust volcanic rocks and middle crust intermediate pluton, respectively. B. Lithostratigraphic Units I–VI described from Site 792 by Taylor, Fujioka, et al. (1990) and inferred intracrustal structure deeper than 886 mbsf.

Figure F5. Bathymetric features of the eastern Philippine Sea, including the IBM arc system, from Tamura et al. (2010), showing positions of Expedition 350 sites (Site U1436 in fore arc and Site U1437 in rear arc). Black dashed lines = wide-angle seismic profiles: the two approximately north–south seismic profiles (along the present-day arc front and rear arc ~150 km west of the arc front) are presented in the **Site U1437** chapter (Tamura et al., 2015b). The lines of circles = three conspicuous north–south rows of long-wavelength magnetic anomalies, attributed to loci of Eocene–Oligocene magmatic centers by Yamazaki and Yuasa (1998). Site U1436 lies on the eastern row of anomalies, which coincides with a fore-arc high (also referred to as the Shin-Kurose Ridge, see text).

Figure F6. Major element compositions of representative subarc mantle (45.6 wt% SiO_2 and 38.6 wt% MgO; Takazawa et al., 2000), primary (basalt) arc magma in the Mariana arc, which is in equilibrium with the subarc mantle (48.2 wt% SiO_2 and 16.4 wt% MgO; Tamura et al., 2014), and average continental crust, which is andesitic in composition (60.6 wt% SiO_2 and 4.7 wt% MgO; Rudnick and Gao, 2004).

Figure F7. Primitive mantle–normalized trace element patterns of average continental crust (Rudnick and Gao, 2004) and two basalt samples from the Pagan Volcano and Mariana arc, interpreted as primary magma compositions (Tamura et al., 2014).

Figure F8. Volume-weighted histograms of rock types from (A) the Quaternary Izu arc (30.5°–35.0°N) (Tamura and Tatsumi, 2002) and (B) the Kermadec arc (30.0°~36.5°S) (Wright et al., 2006), suggesting bimodal volcanism in the oceanic arcs. Basalt and basaltic andesite (<57 wt% SiO_2) are clearly the predominant eruptive products but dacite and/or rhyolite also form a major mode.

Figure F9. Sr, Nd, and Pb isotopes along the Izu arc front from Oshima to southwest Torishima volcanoes, divided into basalt- and rhyolite-dominated volcanoes (modified from Tamura et al., 2007, 2009, and data sources cited therein, including Taylor and Nesbitt, 1998; Ishizuka et al., 2003; Tamura et al., 2005, 2007). Volcano locations shown on Figure **F1B**. For comparison, lava from active rifts (behind arc front) and from rear-arc volcanoes are shown.

Figure F10. From Tamura et al., 2009. A. Along-arc crustal structure (dotted line; thickness of middle crust with V_P = 6.0–6.8 km/s at depths between 5 and 20 km) and average SiO_2 of volcanic rocks (black squares) sampled and dredged from the 16 Izu arc Quaternary volcanoes (Figure **F1B**). The basalt-dominant island volcanoes produce small volumes of rhyolites referred to as R1 by Tamura et al. (2009). Rhyolite-dominant submarine volcanoes erupt mostly rhyolite that is compositionally distinct from R1, referred to as R2 by Tamura et al. (2009). B. Schematic crustal structure of the Izu arc front from Hachijo to Sumisu volcanoes showing alternating basalt-dominant island volcanoes and rhyolite-dominant submarine volcanoes, which have thick and thin middle crust and erupt R1 and R2 rhyolite, respectively.

Figure F11. Composite core scan (350-U1436A-3H). Inset is a blow-up of 3H-2, 2–86 cm, and a graphic log highlights important features.

Figure F12. Summary lithostratigraphic log, Hole U1436A.

Figure F13. Downhole evolution in the relative proportions of the three main lithofacies in Hole U1436A. Relative abundances are the normalized total thickness of each lithofacies per core. Values are not plotted where recovery is too low or where core disturbance is too severe.

Figure F14. Hole U1436A lithofacies. Top: tuffaceous mud (17X-3A, 11–24 cm [105.21–105.34 mbsf]). Bottom: isolated pumice in tuffaceous mud (4H-1A, 103–108 cm [17.85–17.87 mbsf]).

Figure F15. Hole U1436A lithofacies. Top: mafic ash intercalated with tuffaceous mud (16X-2A, 79–83 cm [95.09–95.13 mbsf]). Bottom: normally graded mafic ash transitioning to tuffaceous mud (3H-2A, 39–50 cm [13.09–13.20 mbsf]).

Figure F16. Hole U1436A lithofacies. Top: scoria clast (1H-1, 126–127 cm; TS01 [1.26–1.27 mbsf]). Bottom: normally graded mafic lapilli-ash with scoria clasts (6H-2A, 34–44 cm [37.14–37.24 mbsf]).

Figure F17. Correlation between all Site U1436 holes from 46.15 mbsf and deeper. Tie lines link evolved ash layers, which form good markers because they are undisturbed due to their thinness, with tuffaceous mud above and below.

Figure F18. Hole U1436A lithofacies. Top: range of mafic ash shard morphologies in black glassy mafic ash (8H-2, 97–99 cm; TS03 [52.55–52.57 mbsf]). Bottom: allochthonous black glassy mafic ash intercalated with tuffaceous mud (8H-3A). The mafic ash layer is the result of mid-core flow-in core disturbance.

Figure F19. Nongraded, nonstratified layer of black glassy mafic ash, Hole U1436D (7F-2A, 0–90 cm [52.82–53.72 mbsf]) bounded by tuffaceous mud at top and bottom. The layer is weakly disturbed by core extension.

Figure F20. Normally graded evolved ash intercalated with tuffaceous mud lithofacies, Hole U1436A (4H-2A, 10–29 cm [18.40–18.59 mbsf]).

Figure F21. Hole U1436A lithofacies. Evolved lapilli-ash with pumice intercalated with tuffaceous mud (1H-2A, 21–29 cm [1.73–1.76 mbsf]). Evolved lapilli-ash with pumice and scoria lapilli (3H-3A, 6–35 cm [14.09–14.35 mbsf]).

Figure F22. Correlation between lithostratigraphy in the upper 3 m of Holes U1436A–U1436C, showing perfect correlation of units. Stratigraphy is much more complicated in the rest of the holes, as shown in Figure **F17**.

Figure F24. Pore water salinity, chloride (titration), chloride (IC), and bromide, Hole U1436A (circles). Squares = Hole 792A data, dashed lines = abundances for standard seawater (IAPSO) (Summerhayes and Thorpe, 1996).

Figure F23. Headspace methane concentrations, Hole U1436A, reported in ppmv of 1 cm^3 of air. Methane is plotted at 0 when below detection.

Figure F25. Pore water alkalinity, pH, ammonium, sulfate, and phosphate, Hole U1436A (circles). Squares = Hole 792A data, dashed lines = IAPSO seawater compositions (Summerhayes and Thorpe, 1996).

Figure F26. Pore water geochemical depth profiles, Hole U1436A (circles). IC results for Na, Ca, and Mg and ICP-AES results for B, Ba, Fe, Li, Mn, Si, and Sr. Squares = Hole 792A data, dashed lines = IAPSO seawater compositions (seawater Si 99 µM is below scale; Summerhayes and Thorpe, 1996).

Figure F27. Major element compositions for ash and lapilli samples measured by ICP-AES, Hole U1436A. The bulk samples of black glassy mafic ash are 8H-1, 92–93 cm (51.3 mbsf), 8H-2, 97–99 cm (52.6 mbsf), and 8H-3, 55–56 cm (53.5 mbsf), and a single elevated K_2O pumice composite (7H-2, 20–75 cm [45 mbsf]) is plotted. Oxides are plotted against SiO_2 (Harker diagrams). Data sources referenced in Tamura et al. (2013). Dashed line separates low-K from medium-K field (after Gill, 1981). (Continued on next page.)

Figure F27 (continued).

Figure F28. Trace element abundances for ash and lapilli samples measured by ICP-AES and volatile (LOI) abundances for volcaniclastics measured by gravimetry, Hole U1436A. Tuffaceous mud (4H-6, 60–62 cm [24.9 mbsf]) is plotted for comparison. Top: Sr vs. SiO_2 (normalized to 100 wt%). Bottom: LOI vs. SiO_2 (not normalized). See Figure **F27** for additional data sources.

Figure F30. GRA bulk density and *P*-wave velocity profiles, Holes U1436A–U1436D.

Figure F31. Bulk density, porosity, and *P*-wave velocity with simplified lithology column, Hole U1436A. GRA bulk density values <1.2 g/cm^3 are not displayed because those values are related to cracks, voids, or slurry and are not realistic for sediment cores.

Figure F33. Magnetic susceptibility and NGR profiles, Holes U1436A–U1436D.

Figure F32. Shear strength measurements with simplified lithology column, Hole U1436A.

Figure F34. Magnetic susceptibility and NGR data with simplified lithology column, Hole U1436A.

Figure F35. Thermal conductivity data with simplified lithology column, Hole U1436A.

Figure F36. Color reflectance profiles, Holes U1436A–U1436D. L* (luminosity), a* (redness), and b* (yellowness).

Figure F37. Color reflectance with simplified lithology column, Hole U1436A. L* (luminosity), a* (redness), and b* (yellowness).

Figure F38. Magnetic susceptibility and NGR for evolved and mafic volcaniclastic layers, Hole U1436A.

Figure F39. GRA bulk density and reflectance L* for evolved and mafic volcaniclastic layers, Hole U1436A.

Figure F40. Magnetic susceptibility, GRA bulk density, NGR, CaO and K_2O from XRF, *P*-wave velocity, and reflectance L* for the black glassy mafic ash layer at ~50–52 mbsf, Hole U1436A.

Figure F41. SRM inclination on archive halves before and after 40 mT AF demagnetization. Normal (blue) and reversed (red) GAD inclinations (±51°) for the site latitude. Movement away from steep positive (>+80°) after demagnetization indicates removal of the drilling overprint. Although some negative inclinations deeper than 56.80 mbsf (the Brunhes/Matuyama boundary) appear to be reversed, much of the scatter in inclination is related to severe core disturbance (shaded areas). Last column indicates magnetic polarity determined after 20 mT demagnetization on discrete samples: solid = normal, open = reversed, gray = indeterminate polarity.

Figure F42. Lithology compared with SRM NRM before demagnetization and SHMSL point magnetic susceptibility.

Figure F43. Inclination before and after demagnetization (Core 350-U1436A-9H). Normal (blue) and reversed (red) GAD inclinations. The upper two sections (to 56.55 mbsf) were heavily disturbed, and their inclination record is unreliable. Section 9H-3 (enlarged at left) comprises undisturbed tuffaceous mud, and a magnetic polarity reversal (indicated by gray band) corresponding to the Brunhes/Matuyama (C1n/C1r.1r) boundary at 56.80 mbsf is preserved.

Figure F44. Stereographic plots of unoriented discrete sample directions before and after 20 mT AF demagnetization. Inner ring = GAD inclination (~50°). Undermagnetized NRM is characterized by steep positive (down) inclinations. After demagnetization both normal (down) and reversed (up) polarities cluster around the GAD inclination.

Figure F45. Stereographic projections, vector demagnetization (Zijderveld) plots, and intensity vs. demagnetization plots for typical normal and reversed discrete samples.

Figure F46. Magnetostratigraphy, Site U1436. Black = normal, white = reversed, gray = undetermined polarity.

Figure F47. Core recovery, shipboard biostratigraphic and magnetostratigraphic (Gradstein et al., 2012) datums and our constructed age-depth model, and LSRs and MARs calculated from age model. T = top, B = bottom, X = crossover.