

Appendix 1. Description of facies and facies associations in the Nirehara Formation.

Appendix 2. Samples and methods.

Fig. A1. Columnar sections of the Nirehara Formation along the forest road between Kiritani and Koinami. See Appendix 1 for facies abbreviations and classification. The location of sample 150730-1 for detrital zircon dating is indicated in columnar section A–A'. The asterisk at the top of columnar section A–A' indicates the same horizon as the asterisk in columnar section A–A' in Fig. A2. The inset shows a map indicating the location of columnar sections A–A' and B–B' (Fig. A1) and C–C' and D–D' (Fig. A2), as well as the location of sample 150730-1. The base map is modified from Kashiwagi (2012). See Fig. A3A for the location of the inset.

Fig. A2. Columnar sections of the uppermost Ashiu Sandstone Member of the Nirehara Formation and the overlying Iwaine Formation along the forest road between Kiritani and Koinami, with correlation of depositional cycles SQa1–SQa7. See Appendix 1 for facies abbreviations and classification in the Ashiu Sandstone Member. Abbreviations: TB = Tuff breccia. The asterisk at the base of columnar section A–A' indicates the same horizon as the asterisk in columnar section A–A' in Fig. A1. See Fig. A1 inset for the location of columnar sections.

Fig. A3. Topographic maps showing sample locations. Topographic data are from 1:25,000 maps “Yatsuo” (A) and “Miyamorishin” (B–F) (Geospatial Information Authority of Japan). The locations of these maps are shown in Fig. 3. The locations of samples for U–Pb and FT dating and volcanic ash analysis are shown in maps A–E. The inset in (A) shows the area of the inset map from Fig. A1. The location of the Wadagawa Road section in Fig. 4 and the Akae River section in Fig. 5 are indicated by ① in (C) and ② in (D), respectively. Map (F) shows the locations of diatom samples in the Otogawa Formation, where “X” indicates the location of a sample that contains no diatoms.

Fig. A4. Analytical data for zircons from A) sample 150730-1 in the Nirehara Formation, B) sample 140520-1 in the Iwaine Formation, C) sample 120901-3 in the Yamadanaka Tuff bed, and D) sample 120901-2 in the Tengu-yama Formation. a) Concordia diagram showing individual zircon data for all samples, constructed using Isoplot 3.6 (Ludwig, 2008). The error ellipses represent  $2\sigma$  uncertainties. b) Grain-age diagram for the youngest age group in a). The error

bars represent  $2\sigma$  uncertainties. The calculated age in each case is the weighted mean age of the youngest age group.

Fig. A5. Analytical data for zircons from A) sample 140519-2 in the OT1 Tuff bed, B) sample 140518-9 in the OT3 Tuff bed, C) sample 120901-4 in the Shimose Tuff bed, and D) sample 140518-5 in the Mita Formation. a) Concordia diagram showing individual zircon data for all samples, constructed using Isoplot 3.6 (Ludwig, 2008). The error ellipses represent  $2\sigma$  uncertainties. b) Grain-age diagram for the youngest age group in a). The error bars represent  $2\sigma$  uncertainties. The calculated age in each case is the weighted mean age of the youngest age group.

Fig. A6. Histograms and radial plots of fission-track ages for primary (or totally reset) zircon grains (open circles) and detrital zircon grains (filled circles). The calculated ages are weighted mean ages of primary (or totally reset) zircon grains, except for the age calculated for sample 150730-1, which is a weighted mean age of all detrital zircon grains.

Fig. A7. Analytical results for volcanic ashes in the middle to upper part of the Mita Formation. Legend: VG =volcanic glass; LM = light mineral; HM = heavy mineral; LTH = lithic; Opx = orthopyroxene; Cpx = clinopyroxene; BHb = blue hornblende; GHb = green hornblende; Opq = opaque; Zr = zircon; Bt = biotite. Ha, Hb, Ca, Cb, Ta, Tb, and It are based on the classification of volcanic glasses reported in Yoshikawa (1976).

Table A1. Instrumental and operational conditions during LA-ICP-MS analysis.

Table A2. LA-ICP-MS U-Pb analysis conditions for each sample.

Table A3. U-Pb dating results.

Table A4. Fission-track (FT) dating results.

Table A5. The occurrence of diatom species in the upper Otogawa Formation