# 分析方法

## 1. 全岩化学組成分析

試料は約100 °Cに設定したオーブンで24時間以上乾燥させた後，ジョークラッシャーで粉砕し，2 mmと850 μmの篩にかけて850 μm～2 mmの破片を純水で超音波洗浄した．洗浄した試料は100 °Cのオーブンで24時間以上かけて乾燥させた．その後，異質岩片を多く含む試料は無作為に二分し，一方からは鏡下でハンドピッキングにより異質岩片を可能な限り除去した．各試料をアルミナミルで10分間微粉砕し，粉末試料を作成した．

波長分散型蛍光X 線分析装置 (WD-XRF) 分析用試料の調製には，粉末試料を磁性るつぼに ≥ 1.5 g測りとり，110 °Cに設定したオーブンで24時間以上加熱し，吸着水を取り除いた後，マッフル炉で焼成した．マッフル炉の焼成プログラムは，約2時間10分で1000 °Cまで昇温し，約3時間10分の間1000 °Cを保った後，自然冷却するものである．焼成試料は瑪瑙乳鉢で再度粉末にし，隅田・齊藤 (2018) にしたがって，融剤としてMerck社製のSpectromelt A12 (LiBO2 : Li2B4O7 = 34 : 66) を試料0.9000 ± 0.0001 gに対して4.5000 ± 0.0005 g，酸化剤として硝酸リチウム (LiNO3) を0.2700 ± 0.0050 g加えて，愛媛大学理学部の高周波溶融装置 (TK-4100, 東京科学社) によりガラスビード化した．

分析には愛媛大学理学部のWD-XRF (ZSX Primus II, リガク) を用いた．分析手順は隅田・齊藤 (2018) に従った．ドリフト補正試料には産業技術総合研究所 (AIST) の地球化学標準物質JB-1a，JG-2，JH-1を使用した．また，United States Geological Survey (USGS) の標準試料GSP-2とAISTの地球化学標準物質JB-2およびJG-2を同時に分析した (Table S1)．それらの推奨値と比較すると，主要元素は推奨値と調和的であった．微量元素は特に微量な場合にやや推奨値との差が大きくなるが，分析試料の値は多くの場合それらの値よりも高いので，議論には影響を与えない．Baは微量でなくても推奨値との差が大きいが，分析値のばらつきは小さいので，定性的な議論は可能だと考えられる．

誘導結合プラズマ質量分析装置 (ICP-MS) による希土類元素組成分析用試料にはWD-XRF分析と同じ粉末試料を使用し，分析用溶液試料の調整から分析までは新潟大学理学部でおこなった．溶液試料の調製にはAlkali fusion after acid digestion法を用いた (Senda et al., 2014)．まず，粉末試料を磁性るつぼに ≥ 0.1 g測りとり，900 °Cに設定したマッフル炉で30分焼成し，吸着水を取り除いた．白金るつぼに焼成試料を0.1000 ± 0.0005 g測りとり，2.5 molに調整した塩酸1000 μL，フッ酸 (ELグレード) を1000 μL滴下し，150 °Cに設定したホットプレート上で約2時間乾固させた．乾固後，炭酸ナトリウムを0.5000 ± 0.0005 g添加し，900 °Cのマッフル炉で10分間焼成した．焼成後マッフル炉から白金るつぼを取り出し，室温で急冷させガラス化した．ガラス試料に硝酸 (EL-UMグレード) 5 mLを滴下し，超純水を10 mL，フッ酸を60 mL滴下し，140 °Cに設定したホットプレート上で20分加熱後，超純水を用いてボトルに回収した．白金るつぼに中の溶け残りを塩酸 (ELグレード) 10 mL，超純水を5 mL，フッ酸を60 mL滴下し140 °Cに設定したホットプレート上で20分加熱後，同様に超純水を用いてボトルに回収するとともに，回収した全溶液が100 mLとなるように超純水を加えた．この溶液試料200 μL，2 wt％硝酸を9.7 mL測りとり，ドリフト補正用の内標準溶液100 μLを滴下することにより，希釈率50000倍の分析用溶液試料を作成した (Senda et al., 2014)．

分析は新潟大学理学部の四重極型ICP-MS (Agilent 7500a, Agilent Technologies) を用いて，Nakamura and Chang (2007) およびSenda et al. (2014) に従っておこなった．標準試料として，USGSのBHVO-2，W-2a，AISTのJB-2を使用し，未知試料と同時に分析を行った．得られた分析値をW-2aの分析値と推奨値をもとに補正し標準試料の値が推奨値と調和的であることを確認した．

## 2. 柘榴石化学組成分析

岩石薄片は鏡面研磨後に炭素蒸着し分析に用いた．岩石試料からの柘榴石の抽出は，国立科学博物館において高電圧パルス選択性粉砕装置 (SELFRAG Lab, SELFRAG AG) による試料粉砕，椀掛けによる軽鉱物除去の後，ハンドピッキングによりおこなった．抽出した柘榴石のうち，自形結晶の多いピンク色の柘榴石はできるだけ自形結晶を，破片の多いオレンジ色～赤色の柘榴石は無作為に選んで樹脂に埋め，スライドガラスに貼り付けた研磨片を作成して鏡面研磨後に炭素蒸着した．

分析は，愛媛大学理学部に設置されているSEM (JSM-6510LV, 日本電子) とEDS (X-MAX 50, Oxford Instruments) を使用し，EDS付属のソフトフェアINCA 4.15でデータを定量した．分析は傷やひび割れのない部分を選んで，主に10 μm × 10 μm程度の面分析を，15 kV，0.8 nAでおこなった．柘榴石の分析前にカリ長石，エンスタタイト，単斜輝石の標準試料を分析し，分析値が推奨値と調和的であることを確認した．

分析で得られた酸化物の重量%から柘榴石の一般化学式X3Y2(SiO4)3に基づきO = 12として各元素のatoms per formula unitを算出した (Table S2)．その際，本研究で得られた分析値はいずれもSi，Alがそれぞれほぼ3.0，2.0となり，cation数もおよそ8.0と電荷バランスもとれていたため，すべてのSiで四面体サイトが，すべてのAlで八面体サイトが占められるとし，鉄はすべてFe2+とした．また，その結果に基づき，十二面体サイトのFe2+，Mg，Mn，Caの割合から，almandine，pyrope，spessartine，grossularの各端成分の割合を算出した．

## 3. ジルコンU–Pb年代測定

年代測定は，ジルコン分離から測定まですべて国立科学博物館においておこなった．ジルコン粒子は，SELFRAG Labによる試料粉砕，椀掛けによる軽鉱物除去，磁石 (NEOMAG 8000) による磁性鉱物除去，ジヨードメタン (3.3 g/cm³) による重液分離の順に処理した試料から，ハンドピッキングにより抽出した．抽出したジルコン粒子から無作為に選んだものと，ジルコン標準試料のTEMORA2 (417 Ma; Black et al., 2004)，FC1 (Paces and Miller, 1993; ただしNMK-M26-1とOMG-MYJ-T1の分析時のみ) 及びOD-3 (Iwano et al., 2013) をエポキシ樹脂で封入し，6 µm，3 µm，および1 µm のダイヤモンドペーストで研磨した．その後，走査型電子顕微鏡 (JSM–6610, JEOL) を使用してジルコン粒子の後方散乱電子像とカソードルミネッセンス像を撮影し，できる限りオシラトリー累帯構造を示し包有物や割れ目のないリム部分を分析スポットとして選定した (Fig. S6)．

年代測定には，レーザー・アブレーション・システム (NWR213, Electro Scientiﬁc Industries; Nd-YAG 発振源; 波長213 nm) と四重極型ICP-MS (Agilent 7700x, Agilent Technology) とをbuffered type スタビライザー (Tunheng and Hirata, 2004) を介して接続したものを用いた．レーザー径は約25 µmとし，レーザーの基本的な条件はTsutsumi et al. (2012) に従った．分析は1粒子につき1スポットずつおこなった．UおよびTh濃度はガラス標準試料SRM610の測定データを用いて29Siを内標準として算出した．206Pb/238U比の補正に関してはTEMORA2を標準試料とし，二次標準試料にはOD-3を用いた．初生鉛の補正は，コンコーディア図作成には208Pb補正 (例えば, Williams, 1998)，年代値計算には207Pb補正をおこなった (Stacey and Kramers, 1975)．コンコーディア図作成には IsoplotR (Vermeesch, 2018) を使用した．凝灰岩の噴出年代を議論するため，小論ではコンコーダントなデータについてのみ扱う．また，年代値は238U–206Pb年代の値を用いる．加重平均年代は95 %信頼区間で算出し，mean squared weighted deviation (MSWD) も同時に算出した．

分析は3回に分けておこなった．試料と同時に分析した二次標準試料OD-3からは，1 回目の分析時 (OMG-MYJ-T1, NMK-M26-1) には加重平均238U–206Pb 年代31.64 ± 0.66 Ma (n = 7, MSWD = 1.01) が，2回目 (NMK-M05-1, M06-2) には32.32 ± 0.36 Ma (n = 18, MSWD = 1.87) が，3回目 (NMK-M12-1, M16-3, M17-1, M31-1) には32.23 ± 0.41 Ma (n = 12, MSWD = 1.58) が得られた．これらの年代値はいずれも誤差の範囲で一致している．OD-3からはIwano et al. (2013) が加重平均238U–206Pb 年代33.0 ± 0.1 Ma (2σ) を，Lukács et al. (2015) は32.853 ± 0.016 Ma (95 %信頼区間) を報告している．本研究で得られたOD-3の各加重平均年代とこれらの値とでは，誤差の範囲を若干超えた差が認められるが，本研究の結果や議論に影響を及ぼすことはない．

# データファイルの引用文献 (図表での引用を含む)

Barrat, J. A., Zanda, B., Moynier, F., Bollinger, C., Liorzou, C. and Bayon, G., 2012, Geochemistry of CI chondrites: Major and trace elements and Cu and Zn isotopes. *Geochim. Cosmochim. Acta*, **83**, 79–92.

Black, L. P., Kamo, S. L., Allen, C. M., Davis, D. W., Aleinikoff, J. N., Valley, J. W.,...Foudoulis, C., 2004, Improved 206Pb/238U microprobe geochronology by the monitoring of a trace-element-related matrix effect; SHRIMP, ID–TIMS, ELA–ICP–MS and oxygen isotope documentation for a series of zircon standards. *Chem. Geol.*, **205**, 115–140.

代 開秋・津末昭生・本間弘次, 1993, 高知県南西部柏島–沖ノ島地域の花崗岩類の岩石学的研究. 岩鉱, **88**, 247–264. [Dai, K., Tsusue, A. and Honma, H., 1993, Petrological study of granitic rocks from the Kashiwajima–Okinoshima district in the southwestern part of Kochi Prefecture. *J. Mineral. Petrol. Econ. Geol.*, **88**, 247–264.]

Hanchar, J. M. and Watson, E. B., 2003, Zircon saturation thermometry. *Rev. Mineral. Geochem.*, **53**, 89–112.

Imai, N., Terashima, S., Itoh, S. and Ando, A., 1995, 1994 compilation values for GSJ reference samples, “Igneous rock series.” *Geochem. J.*, **29**, 91–95.

Iwano, H., Orihashi, Y., Hirata, T., Ogasawara, M., Danhara, T., Horie, K.,...Yamamoto, K., 2013, An inter-laboratory evaluation of OD-3 zircon for use as a secondary U–Pb dating standard. *Isl. Arc*, **22**, 382–394.

Kawabata, H. and Shuto, K., 2005, Magma mixing recorded in intermediate rocks associated with high-Mg andesites from the Setouchi volcanic belt, Japan: implications for Archean TTG formation. *J. Volcanol. Geotherm. Res.*, **140**, 241–271.

Kawabata, H. and Takafuji, N., 2005, Origin of garnet crystals in calc-alkaline volcanic rocks from the Setouchi volcanic belt, Japan. *Mineral. Mag.*, **69**, 951–971.

Lukács, R., Harangi, S., Bachmann, O., Guillong, M., Danišík, M., Buret, Y.,...Szepesi, J., 2015, Zircon geochronology and geochemistry to constrain the youngest eruption events and magma evolution of the mid-Miocene ignimbrite flare-up in the Pannonian Basin, eastern central Europe. *Contrib. Mineral. Petrol.*, **170**, 52, doi:10.1007/s00410-015-1206-8.

室生団体研究グループ・八尾 昭, 2008, 室生火砕流堆積物の給源火山. 地球科学, **62**, 97–108. [The Collaborated Research Group in the Murou Area and Yao, A., 2008, The source volcano for the Murou pyroclastic-flow deposit in the Southwest Japan. *Earth Sci. (Chikyu Kagaku)*, **62**, 97–108.]

Nakamura, K. and Chang, Q., 2007, Precise Determination of ultra-low (sub-ng g-1) level rare earth elements in ultramafic rocks by quadrupole ICP-MS. *Geostand. Geoanal. Res.*, **31**, 185–197.

Paces, J. B. and Miller, J. D., Jr., 1993, Precise U–Pb ages of Duluth Complex and related mafic intrusions, northeastern Minnesota: Geochronological insights to physical, petrogenetic, paleomagnetic, and tectonomagmatic processes associated with the 1.1 Ga Midcontinent Rift system. *J. Geophys. Res.*, **98**, 13997–14013.

R Core Team, 2023, R: *A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. (https://www.R-project.org/).

Rubatto, D., 2017, Zircon: The metamorphic mineral. *Rev. Mineral. Geochem.*, **83**, 261–295.

Senda, R., Kimura, J.-I. and Chang, Q., 2014, Evaluation of a rapid, effective sample digestion method for trace element analysis of granitoid samples containing acid-resistant minerals: Alkali fusion after acid digestion. *Geochem. J.*, **48**, 99–103.

Shimoda, G. and Tatsumi, Y., 1999, Generation of rhyolite magmas by melting of subducting sediments in Shodo-Shima island, Southwest Japan, and its bearing on the origin of high-Mg andesites. *Isl. Arc*, **8**, 383–392.

Shimoda, G., Tatsumi, Y., Nohda, S., Ishizaka, K. and Jahn, B. M., 1998, Setouchi high-Mg andesites revisited: geochemical evidence for melting of subducting sediments. *Earth Planet. Sci. Lett.*, **160**, 479–492.

Shimoda, H., 1996, *Origin of the Setouchi volcanic rocks in SW Japan arc: Constraints from Pb-Nd-Sr isotope geochemistry*. Ph.D. Thesis, Kyoto Univ., 98p.

新正裕尚・折橋裕二・外西奈津美, 2016, 九州東部大野火山岩の全岩化学組成 (補遺). 東京経済大人文自然科学論集, **138**, 91–98. [Shinjoe, H., Orihashi, Y. and Hokanishi, N., 2016, Whole rock composition of the Ohno volcanic rocks in eastern Kyushu (supplement). *J. Humanit. Nat. Sci., Tokyo Keizai Univ.*, **138**, 91–98.]

新正裕尚・折橋裕二・角井朝昭・中井俊一, 2002, 室生火砕流堆積物の全岩化学組成: その給源への手掛り. 岩石鉱物科学, **31**, 307–317. [Shinjoe, H., Orihashi, Y., Sumii, T. and Nakai, S., 2002, Bulk rock chemistry of the Muro pyroclastic flow deposit: a clue to its source region. *Japan. Mag. Mineral. Petrol. Sci.*, **31**, 307–317.]

新正裕尚・折橋裕二・和田穣隆・角井朝昭・中井俊一, 2007, 紀伊半島中新世珪長質火成岩類の全岩組成の広域的変化. 地質雑, **113**, 310–325. [Shinjoe, H., Orihashi, Y., Wada, Y., Sumii, T. and Nakai, S., 2007, Regional variation of whole rock chemistry of the Miocene felsic igneous rocks in the Kii Peninsula, southwest Japan. *J. Geol. Soc. Japan*, **113**, 310–325.]

新正裕尚・下田 玄・福岡孝昭・角井朝昭, 2005, 紀伊半島大峯花こう岩質岩から見いだされたMgに富む火成包有物. 岩石鉱物科学, **34**, 15–23. [Shinjoe, H., Shimoda, G., Fukuoka, T. and Sumii, T., 2005, Magnesian igneous enclave in the Ohmine Granitic Rocks of Kii peninsula. *Japan. Mag. Mineral. Petrol. Sci.*, **34**, 15–23.]

新正裕尚・角井朝昭, 2014, 九州東部大野火山岩の全岩化学組成. 東京経済大人文自然科学論集, **135**, 145–155. [Shinjoe, H. and Sumii, T., 2014, Whole rock composition of the Ohno volcanic rocks in eastern Kyushu. *J. Humanit. Nat. Sci., Tokyo Keizai Univ.*, **135**, 145–155.]

新正裕尚・角井朝昭, 2019, 紀伊半島, 大峯花こう岩の全岩化学組成. 東京経済大人文自然科学論集, **145**, 65–78. [Shinjoe, H. and Sumii, T., 2014, Whole rock composition of the Ohmine Granitic Rocks in the Kii peninsula. *J. Humanit. Nat. Sci., Tokyo Keizai Univ.*, **145**, 65–78.]

新正裕尚・山下啓太・清水健介・角井朝昭, 2009, 紀伊半島中央部, 川迫, 白川八丁花こう岩体の全岩化学組成. 東京経済大人文自然科学論集, **127**, 143–152. [Shinjoe, H., Yamashita, K., Shimizu, K. and Sumii, T., 2009, Whole rock chemistry of the Kose and Shirakawa-haccho plutons in central Kii peninsula. *J. Humanit. Nat. Sci., Tokyo Keizai Univ.*, **127**, 143–152.]

隅田祥光・本吉洋一, 2011, 蛍光X線分析装置を用いた低希釈ガラスビード法による珪酸塩岩中の主要・微量・希土類元素の定量分析. 南極資料, **55**, 93–108. [Suda, Y. and Motoyoshi, Y., 2011, X-ray fluorescence analysis of major, trace, and rare earth elements in silicate rocks using the low-dilution glass bead method. *Antarct. Rec.*, **55**, 93–108.]

隅田祥光・齊藤 哲, 2018, 波長分散型蛍光X線分析装置を用いた低希釈ガラスビードによる珪酸塩岩中の主要・微量元素分析. 愛媛大学理学部紀要, **21**, 1–11. [Suda, Y. and Saito, S., 2018, A method of X-ray fluorescence analysis of major and trace elements in silicate rocks by fused-bead method. *Mem*. *Fac. Sci. Ehime Univ.*, **21**, 1–11.]

Stacey, J. S. and Kramers, J. D., 1975, Approximation of terrestrial lead isotope evolution by a two-stage model. *Earth Planet. Sci. Lett.*, **26**, 207–221.

Tatsumi, Y., Suzuki, T., Kawabata, H., Sato, K., Miyazaki, T., Chang, Q.,...Yoshikawa, M., 2006, The petrology and geochemistry of Oto-Zan composite lava flow on Shodo-Shima Island, SW Japan: Remelting of a solidified high-Mg andesite magma. *J. Petrol.*, **47**, 595–629.

Tsutsumi, Y., Horie, K., Sano, T., Miyawaki, R., Momma, K., Matsubara, S.,...Yokoyama, K., 2012, LA-ICP-MS and SHRIMP ages of zircons in chevkinite and monazite tuffs from the Boso Peninsula, Central Japan. *Bull. Natl. Mus. Nat. Sci., Ser. C*, **38**, 15–32.

Tunheng, A. and Hirata, T., 2004, Development of signal smoothing device for precise elemental analysis using laser ablation-ICP-mass spectrometry. *J. Anal. At. Spectrom.*, **19**, 932–934.

Vermeesch, P., 2018, IsoplotR: A free and open toolbox for geochronology. *Geosci. Front.*, **9**, 1479–1493.

Watson, E. B. and Harrison, T. M., 1983, Zircon saturation revisited: temperature and composition effects in a variety of crustal magma types. *Earth Planet. Sci. Lett.*, **64**, 295–304.

Williams, I. S., 1998, U–Th–Pb geochronology by ion microprobe. *In* McKibben, M. A., Shanks, W. C. P. and Ridley, W. I., eds., *Applications of Microanalytical Techniques to Understanding Mineralizing Processes*, Rev. Econ. Geol., **7**, 1–35.

Wilson, S. A., 1998, *United States Geological Survey certificate analysis: granodiorite, Silver plume, Colorado, GSP-2*.

吉田武義・村田 守・山路 敦, 1993, 石鎚コールドロンの形成と中新世テクトニクス. 地質学論集, **42**, 297–349. [Yoshida, T., Murata, M. and Yamaji, A., 1993, Formation of Ishizuchi cauldron and Miocene tectonics. *Mem. Geol. Soc. Japan*, **42**, 297–349.]

**figure and table captions**

**Fig. S1.** Photographs of outcrops in the study area. Locations and stratigraphic positions are indicated in [Figs. 2 and 3.](https://doi.org/10.5575/geosoc.2024.0031) **(a)** Unconformity between the Sambagawa metamorphic rocks (SMR) and the Furuiwaya Formation (FIY) of the Kuma Group. The hammer for scale (in the ellipse) is ~30 cm long. **(b)** Unconformity (dotted line) between the Sambagawa metamorphic rocks and the Myojin Formation (MYJ) of the Kuma Group. **(c)** Conglomerate of the uppermost part of the Myojin Formation containing granitoid clasts. The riverbed is approximately parallel to bedding. **(d)** Unconformity (dotted line) between the Myojin Formation and basal conglomerate of the Takano Formation (TKN). The same conglomerate unit is shown in Fig. 4a. **(e)** Basal volcaniclastic part of the Takano Formation, showing fine tuff (F-tf) and lapilli tuff (L-tf) overlying sandstone (Sst). **(f)** Lower part of the Takano Formation. Sample NMK-M05-1 was collected from the lower part of this outcrop. The lower arrow indicates a tree trunk that fell from the recess indicated by the upper arrow. The ruler for scale (in the ellipse) is 1 m long. **(g)** Lower part of the Takano Formation. Sample NMK-M06-2 was collected from the lower part of this outcrop. **(h)** Strongly welded horizon from the lower part of the Takano Formation. Sample NMK-M10-1 was collected from the middle part of this outcrop. **(i)** Horizon containing many accidental lithic fragments (Alf) of the lower part of the Takano Formation. Sample NMK-M13-1 was collected from this outcrop. The pen for scale is ~15 cm long. **(j)** Upper part of the Takano Formation. Sample NMK-M18-1 was collected from the lower part of this outcrop. **(k)** Upper part of the Takano Formation. Samples NMK-M18-1-2 and M18-2 were collected near this outcrop. **(l)** Possible contact (dotted line) between the Takano (TKN?) and Kuromoritoge (KMT) formations, though interpretation of the lower tabular-stratified part of this outcrop as belonging to the Takano Formation is questionable (see text). Samples NMK-2b9-TKN and 2b9-KMT were collected from this outcrop. **(m)** Possible contact (dotted line) between the Takano and the Kuromoritoge formations, though the interpretation of the pebbly tuff at the base of this outcrop as belonging to the Takano Formation requires further investigation (see text). **(n)** Epiclastic conglomerate at the basal part of the Kuromoritoge Formation. Sample NMK-M30-1 was collected from this outcrop. **(o)** Lowermost part of the andesitic tuff of the Kuromoritoge Formation. Sample NMK-M31-1 was collected from the lower part of this outcrop. **(p)** Wood fragment (arrow) embedded in the outcrop shown in (o). **(q)** Tuff breccia of the Kuromoritoge Formation. **(r)** Tuffaceous mudstone interbed in the uppermost part of the Myojin Formation in the Omogo area. Sample OMG-MYJ-T1 was collected from this outcrop.

**Fig. S2.** **(a–h)** Polished surfaces of rock samples of the (a–c) lower, (d) transitional, and (e–f) upper parts of the Takano Formation and (g–h) the Kuromoritoge Formation. **(i–x)** Photomicrographs of the (i–j) lower, (k–o) transitional, and (p–w) upper parts of the Takano Formation and (x) the Kuromoritoge Formation taken under plane-polarized light (left) and cross-polarized light (right). **Rock samples:** (a) NMK-M06-2; (b) NMK-M12-1; (c) NMK-M13-2; (d) NMK-M16-3; (e) NMK-M17-1; (f) NMK-M23-1, fine tuff containing accretionary lapilli; and (g, h) NMK-M30-1, (g) volcanic rock and (h) gravel clasts of pebbly tuff in the basal conglomerate. **Thin sections:** (i) NMK-M10-1; (j) NMK-M10-1-2, the garnet labeled is grain 1 (type 1) of the sample in Table S2; (k) NMK-M15-1-2; (l) NMK-M16-1, the garnet labeled is grain 1 (type 1); (m) NMK-M16-1, the garnets labeled are grains 2 (left, type 1) and 3 (right, type 1); (n) NMK-M16-1, the garnet labeled is grain 4 (type 2); (o) NMK-M16-1-2, the garnet labeled is grain 1 (type 1); (p) NMK-M17-1; (q) NMK-M17-1, the garnet labeled is grain 1 (type 2); (r) NMK-M17-1, the garnet labeled is grain 3 (type 2); (s) NMK-M17-1, the garnet labeled is grain 4 (type 1); (t) NMK-M17-1, the garnet labeled is grain 6 (type 1); (u) NMK-M23-1; (v) NMK-M25-1, the garnet labeled is grain 2 (type 2); (w) NMK-M29-1; and (x) NMK-M31-1. Scale bars for rock samples are 1 cm and those for thin sections are 1 mm. All photographs are oriented so that the stratigraphic up direction is toward the top of the image except for (g) and (h). Sampling locations and stratigraphic positions are indicated in Figs. 2 and 3. Abbreviations: Ab, albite; Acl, accretionary lapillus; Afs, alkali feldspar; Alf, accidental lithic fragment; Ap, apatite; Bt, biotite; Grt, garnet; Ilm, ilmenite; Opq, opaque mineral; Pbl, pebble (volcanic clast); Pmm, pseudomorph after a mafic mineral; Pl, plagioclase; Qz, quartz; Vcl, volcanic clast; Wf, whitish fiamma; Wl, whitish lapillus.

**Fig. S3.** Bulk-rock chemical composition showing major and trace elements for samples of the Ishizuchi Group. A/CNK = Al2O3/(CaO + Na2O + K2O) in molar ratio, and Mg# = Mg/(Mg + Fe) × 100 in molar ratio. See Figs. 2 and 3 for sample names and locations, and Figs. 7 and S4 for an explanation of symbols. Analytical data are provided in Table S1.

**Fig. S4.** Harker diagrams of major and trace elements for samples of the Ishizuchi Group and other igneous and volcaniclastic rocks of the Outer Zone felsic rocks (OZFR) and Setouchi volcanic rocks (SVR). A/CNK = Al2O3/(CaO + Na2O + K2O) in molar ratio, Mg# = Mg/(Mg + Fe) × 100 in molar ratio, Eu/Eu\* = EuCN/(SmCN × GdCN)1/2, where CN indicates normalized to CI chondrite (Barrat et al., 2012). Analytical data are provided in Table S1. Data from previous studies are included (Dai et al., 1993; Yoshida et al., 1993; Shimoda, 1996; Shimoda et al., 1998; Shimoda and Tatsumi, 1999; Shinjoe et al., 2002, 2005, 2007, 2009, 2016; Kawabata and Shuto, 2005; Kawabata and Takafuji, 2005; Tatsumi et al., 2006; The Collaborated Research Group in the Murou Area and Yao, 2008; Shinjoe and Sumii, 2014, 2019). Gray arrows show mixing trends between the lower and transitional parts of the Takano Formation and accidental lithic fragments. Abbreviations: ALF, accidental lithic fragments; Br, branch; Cgl, conglomerate; Fm, Formation; Gp, Group; Trans, Transitional.

**Fig. S5.** **(a)** Compositional profiles of garnets from the Takano Formation. Black squares on the backscattered electron composition image of each grain indicate approximate positions and sizes of analyzed points. Scale bars are 100 μm except for those of grain 1 of NMK-M17-1 and grain 2 of NMK-M25-1, which are 500 μm. Analytical data are provided in Table S2. Sampling locations and stratigraphic positions are indicated in Figs. 2 and 3. Abbreviations: Ap, apatite; Ilm, ilmenite; Mnz, monazite; Pl, plagioclase; Py, pyrite; Qz, quartz; Zrn, zircon. **(b)** Dendrogram based on the bulk-rock chemical compositions of the Takano and Kuromoritoge formations analyzed using the hclust function (ward.D method) of the R stats package (version 4.3.1) (R Core Team, 2023). Accidental lithic fragments were removed from samples included in this analysis where necessary. Analytical data are provided in Table S1. Abbreviations: KMT, the Kuromoritoge Formation; TKN-L, lower part of the Takano Formation; TKN-T, transitional part of the Takano Formation; TKN-U, upper part of the Takano Formation. (KMT) denotes the matrix of the basal epiclastic conglomerate of the Kuromoritoge Formation. **(c)** Th/U ratio versus U content of zircons, from which concordant data were obtained, including measurements from zircons collected from the Myojin (OMG-MYJ-T1), Takano (NMK-M05-1, M06-2, M12-1, M16-3, M17-1, M26-1), and Kuromoritoge (NMK-M31-1) formations. The dotted line (Th/U = 0.1) indicates the approximate boundary between typical metamorphic and igneous zircons (Rubatto, 2017). Analytical data are provided in Table S3. Abbreviations: Fm, Formation; Gp, Group; Trans, Transitional.

**Fig. S6.** Backscattered electron (left) and cathodoluminescence (right) images of zircon grains, from which concordant data were obtained, including measurements from zircons collected from the Myojin (OMG-MYJ-T1), Takano (NMK-M05-1, M06-2, M12-1, M16-3, M17-1, M26-1), and Kuromoritoge (NMK-M31-1) formations. 238U–206Pb ages in Ma (207Pb corrected, 1σ error) are obtained from each analyzed spot shown by a circle on the cathodoluminescence image. The scale bar is 100 µm. Sampling locations and stratigraphic positions are indicated in Figs. 2 and 3, and analytical data in Table S3.

**Table S1.** Bulk-rock chemical compositions of samples collected from the Takano and Kuromoritoge formations and Sambagawa metamorphic rocks, analyzed by wavelength dispersive X-ray fluorescence spectrometer (WD-XRF) and inductively coupled plasma–mass spectrometry (ICP–MS). Also shown are zircon saturation temperatures (ZrT; Watson and Harrison, 1983; Hanchar and Watson, 2003) and Eu/Eu\* = EuCN/(SmCN × GdCN)1/2, where CN indicates normalized to CI chondrite (Barrat et al., 2012) values based on analytical data. Dashes (–) indicate values were below the lower detection limit. Sampling locations and stratigraphic positions are indicated in Figs. 2 and 3. Summaries of WD-XRF analytical data (2SD, double standard deviation; n, number of analyses that yielded values above the detection limit; CV%, coefficient of variation in %) from standards (GSP-2, JB-2, and JG-2) measured in this study are included for reference with errors and relative errors (Error%) from recommended values (Rec; Imai et al., 1995; Wilson, 1998 cited by Suda and Motoyoshi, 2011).

**Table S2.** Chemical compositions of garnets from the Takano Formation analyzed by scanning electron microscope and energy dispersive X-ray spectroscopy, showing calculated atoms per formula unit for each element and garnet end-member compositions. All iron was quantified and calculated as divalent (FeOtotal and Fe2+). Dashes (–) and n.q. denote values below the lower detection limit and not quantified (not automatically detected due to low value), respectively. Sampling locations and stratigraphic positions are indicated in Figs. 2 and 3. Data from analyzed points indicated with \* are plotted in Fig. 11.

**Table S3.** U and Th concentrations, U/Th ratios, fractions of common 206Pb in percent (%f207) calculated from measured and common 207Pb/206Pb, U–Pb isotopic ratios (208Pb corrected), and calculated ages (207Pb corrected) of zircons from which concordant data were obtained. Zircons were collected and separated from the Myojin (OMG-MYJ-T1), Takano (NMK-M05-1, M06-2, M12-1, M16-3, M17-1, M26-1), and Kuromoritoge (NMK-M31-1) formations. Sampling locations and stratigraphic positions are indicated in Figs. 2 and 3. Errors on isotopic ratios, %f207, and ages are 1σ. Pb\* indicates the radiogenic portion.