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Transition between the Pacific and African mantle domains beneath southwest Pacific marginal basins

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Abstract

Long-lived subduction during Pangea assembly and along the circum-(paleo-)Pacific girdle preferentially enriched the African mantle domain relative to the Pacific mantle domain, establishing an east-west hemispherical dichotomy. The post-Pangea subduction girdle has thus been regarded as the dividing boundary between these domains, yet its nature and precise spatial-temporal evolution remain poorly constrained. Here, we present Sr-Nd-Pb-Hf isotopes from mid-ocean ridge basalt (MORB) and ocean island basalt (OIB)-like samples from Cretaceous–Paleogene continental marginal basins in the southwest Pacific. The MORB samples consistently show African MORB mantle signatures distinct from the Pacific MORB mantle signatures sampled by post-50 Ma oceanic marginal basins. This contrast suggests that the Zealandia continental subduction zone marked the upper mantle boundary between the two domains. MORB and OIB-like samples associated with the Tasmantid and Lord Howe hotspots trend toward EM-1 compositions, consistent with the subduction-enriched African mantle domain in the deeper mantle. In contrast, samples associated with the Zealandia–Antarctica plume(s) extend toward HIMU signatures, potentially reflecting a Pacific-type deep mantle source. Overall, our results support the long-lived

subduction girdle as a first-order mantle domain boundary, whereas the development of continental and oceanic marginal basins and evolving subduction geometry refine the precise boundary locations.

Introduction

Radiogenic isotopes in oceanic basalts record multi-stage depletion and enrichment of their mantle sources, reflecting the process of plate tectonics and mantle dynamics during supercontinent cycles[1,2]. The Pacific mid-ocean ridge basalts (MORBs) are characterized by lower $^{208}Pb/^{204}Pb$ for a given $^{206}Pb/^{204}Pb$ and higher $^{143}Nd/^{144}Nd$ compared to the Indian and Atlantic MORBs[2,3], defining a hemispheric isotopic contrast between the shallow Pacific and African (including mantle under the Indian and Atlantic oceans) mantle domain[2]. Similar large-scale heterogeneities are also observed in the deep mantle, as reflected by the isotopically distinct ocean island basalts (OIBs) associated with the Pacific and African large low-shear-velocity provinces (LLSVPs) [1,2]. These geochemical and geophysical observations suggest that long-lived circum-Pacific subduction since the beginning of Pangea assembly (ca. 650 Ma) has introduced enriched crustal materials into the mantle beneath the Indian and Atlantic oceans, implying that the circum-Pacific subduction girdle should delineate the first-order boundary between the Pacific and African mantle domains[1,2,4–6]. Despite its significance in understanding global mantle convection and remixing patterns and processes, the precise location and time evolution of this boundary remain poorly constrained.

The marginal basins in the southwest Pacific lie between the Pacific and Indo-Australian plates and sample the transitional mantle across the proposed domain boundary[5,8–12]. MORB-like samples from oceanic marginal basins formed by intra-arc rifting[13] (e.g. the Havre Trough and the South Fiji basin in Fig. 1a) show isotopic affinities with the subducting Pacific MORBs[9,11,14]. Such Pacific-type signatures complicate the simple interpretation that the present-day Pacific subduction zone here might define boundary between the African and Pacific mantle domains. Magni et al.[7]argued that a subduction polarity reversal[15] and retreat since around ca. 55 Ma could have introduced Pacific upper mantle into these young marginal basins. However, we

are yet to know whether the older Cretaceous-Paleogene marginal basins recorded African or Pacific mantle signatures, and thus the time evolution of this global-scale mantle domain boundary and how it extends into the deeper mantle.

The pre-50 Ma marginal basins including the Tasman Sea basin and the Coral Sea basin formed by rifting of the eastern Australia and the Zealandia continents, and are hereby referred to as continental marginal basins[13]. The Santa Cruz basin-South Rennell Trough[16–19] can be regarded as the northern extension of this continental marginal basin group (Fig. 1). In addition, OIB-like Zealandia-Antarctica intraplate volcanism and Tasmantid-Lord Howe hotspot tracks are found in the Tasman Sea Basin and the Santa Cruz Basin-South Rennell Trough (Fig. 1b)[17,20], which can potentially provide constraints on the deeper mantle occurrence of the Pacific-African mantle domain boundary. In this study, we present new Sr-Nd-Pb-Hf isotope data of MORB and OIB-like samples from the Tasman Sea basin, the Coral Sea basin and the Santa Cruz basin-South Rennell Trough[17–19]. In combination with compiled geochemical data and plate reconstruction models, we define the boundary between the African and Pacific mantle domains in both the shallow and deeper mantle.

Results

Geological setting and samples

The southwest Pacific marginal basins and arcs preserve comprehensive records of the subduction of the Pacific plate beneath the Zealandia-Australia margin since the Cretaceous time, sampling transitional mantle between the Pacific and African mantle domains (Fig. 1). The oldest marginal basins formed by continental rifting in the southwest Pacific[17–19,21], including the Tasman Sea basin (84–52 Ma)[16] and the Coral Sea basin (62–56 Ma)[22], with spreading cessation in these two basins occurring contemporaneous with a subduction polarity change further east in SW Pacific at ca. 55–50 Ma[15,19].

The Santa Cruz basin opened at ca. 48 Ma, west of the continental subduction zone along the Zealandia margin[19]. Enriched MORB-like samples from the Santa Cruz basin and the South Rennell Trough display a southward-younging age progression, likely

associated with activity of the Tasmantid and Lord Howe hotspots[18–20].

At ca. 55–50 Ma, a subduction polarity reversal is believed to have occurred along the New Caledonia and the Papua New Guinea sectors[15,19], possibly accompanied by slab retreat and re-initiation of the Pacific plate subduction[23,24]. Subsequently, numerous marginal basins developed through rifting of oceanic arcs, including the Solomon Sea basin (magnetic ages of 41.5–35 Ma)[25], the South Fiji basin (^{40}Ar-^{39}Ar ages of 32–22 Ma)[26], and the Lau basin and the Havre Trough (~5 Ma to present). MORB samples from these oceanic marginal basins (including the early Lau Basin) show low ^{208}Pb/^{204}Pb at a given ^{206}Pb/^{204}Pb and low εHf at a given εNd, typical of Pacific MORB mantle[9,11,23,25,27,28], although those from the modern Lau basin exhibit African MORB mantle signatures possibly associated with complex mantle flow[11,29].

Samples analyzed in this study were obtained from the GNS Science National Petrology Reference Collection[30], including both MORB and OIB-like samples from the continental marginal basins. Tasman Sea Basin samples show Ar-Ar ages of 61–59 Ma[17]. One basalt sample from the Coral Sea Basin has an Ar-Ar age of 55 Ma[18]. Basalt samples from the Santa Cruz Basin and the South Rennell Trough have Ar-Ar ages of 43–29 Ma[18,19].

Geochemical compositions of MORBs and OIB-like samples

The new and compiled major and trace element and Sr-Nd-Pb-Hf isotopic data are listed in Supplementary Table 2. On the diagram of total alkali vs. silica (Supplementary Fig. 1a), most samples from the continental marginal basins (the Tasman Sea basin, the Coral Sea basin, and the Santa Cruz basin-South Rennell Trough) are tholeiitic basalts that plot within the MORB field, with the exception of two alkaline samples from the Tasman Sea basin. These samples generally show negative Pb anomalies and lack negative Nb-Ta anomalies on the plot of primitive mantle normalized trace element patterns, and display variable LREEs (light rare earth elements)/HREEs (heavy rare earth elements) ratios (Supplementary Figs. 1b and 2). The only sample from the Coral Sea basin has trace element contents lower than typical N-MORB[31]. Samples from the Tasman Sea basin and the Santa Cruz basin-South Rennell Trough can be divided into

two groups: the MORB samples show flatten trace element patterns while the OIB-like samples exhibit higher LREE/HREE ratios. On the $(La/Sm)_N$ vs. $(Sm/Yb)_N$ diagram ('N' denotes to primitive mantle normalization), MORB samples from the Tasman Sea basin overlap with those from the Santa Cruz basin-South Rennell Trough, while OIB-like samples from the Tasman Sea basin exhibit lower $(La/Sm)_N$ relative to those from the Santa Cruz basin-South Rennell Trough (Supplementary Fig. 1b).

The MORB and OIB-like samples from these continental marginal basins show a wide range of Sr-Nd-Pb-Hf isotope compositions (Fig. 2). Compared to the Pacific MORB mantle, the MORB sample from the Coral Sea basin has higher $^{208}Pb/^{204}Pb$ at a given $^{206}Pb/^{204}Pb$, lower εNd and higher εHf at a given εNd, typical of African MORB mantle. The depleted MORB samples from the Tasman Sea basin and Santa Cruz basin-South Rennell Trough with high εNd also fall within the African MORB mantle field (i.e., shallow African mantle domain)[1,2]. MORB and OIB-like samples from these marginal basins also exhibit distinct isotopic variations. In the Santa Cruz basin-South Rennell Trough, the MORB and OIB-like samples show decreasing εNd and εHf, and increasing $^{87}Sr/^{86}Sr$ with decreasing $^{206}Pb/^{204}Pb$, trending toward the EM-1 (enriched mantle 1) endmember. In the Tasman Sea basin, the MORB and OIB-like samples show, to a less extent, decreasing Nd-Hf isotope ratios with increasing $^{206}Pb/^{204}Pb$, extending toward the HIMU (high-μ, $^{238}U/^{204}Pb$) endmember (Fig. 2).

Discussion

Boundary between the shallow Pacific and African mantle domains

Determining the mantle domain affinity of marginal basin basalts requires first ruling out direct subduction inputs[9,11,32]. Marginal basin basalts can display a wide range of Nb anomalies ($Nb/Nb^* = Nb_N^{0.5}/(Th_N^{0.5} \times La_N^{0.5})$), ranging from values typical of island arc basalts (Nb/Nb*~0.2) to MORBs (Nb/Nb*>0.8) (Supplementary Fig. 3), reflecting varying degrees of subduction modification. The samples analyzed and compiled in this study have consistently high Nb/Nb* values comparable to normal MORBs, thus should reflect that of the ambient upper mantle at mid-ocean ridge environments, with negligible direct subduction influence.

Long-lived continent-ward subduction along the circum-Pacific girdle has shaped the enriched mantle beneath the Indian and Atlantic oceans, implying that the circum-Pacific subduction zone should delineate the Pacific-African mantle domain boundary[1,2,4]. However, this circum-Pacific subduction girdle has a complex temporal and spatial evolution history, and post-50 Ma MORB samples from oceanic marginal basins (e.g., ophiolite of the Solomon Sea basin, the South Fiji basin, and the Havre Trough etc.) in the southwest Pacific generally show Nd-Hf-Pb isotope compositions overlapping with the Pacific MORB mantle[11,23] (Fig. 2). Such Pacific mantle signatures are also observed in Cretaceous MORBs from the Osbourn basin and the Tonga forearc[14,33], indicating a long-lived Pacific MORB mantle domain across the Tonga subduction zone. These observations demonstrate that the present-day Tonga subduction zone does not represent the boundary between the Pacific and African mantle domains.

By contrast, MORB samples with high εNd from continental marginal basins, including the Tasman Sea, Coral Sea, and Santa Cruz–South Rennell Trough basins, broadly fall within the African MORB mantle field (Fig. 2). These basalts exhibit higher εHf at a given εNd and higher $^{208}Pb/^{204}Pb$ at a given $^{206}Pb/^{204}Pb$ compared to Pacific MORB mantle[2,3,9]. Such African MORB mantle signatures[2] beneath the continental marginal basins are distinct from the Pacific MORB mantle signatures beneath the oceanic marginal basins, indicating a shallow African-Pacific mantle domain boundary between them.

We interpret the distinct mantle domain affinities beneath the continental and oceanic marginal basins to be associated with the complex temporal and spatial evolution history of oceanic subduction in the southwest Pacific. Basalts from the Tasman Sea and Coral Sea basins exhibit isotopic signatures distinct from those of the Osbourn basin and the Tonga fore-arc[14,33] (Fig. 2). Given that these basins formed on the opposite sides of the continental subduction zone along the Zealandia margin, this contrast indicates that the continental subduction zone delineated the shallow Pacific-African mantle domain boundary during the Cretaceous–Paleocene[2,5] (Fig. 1). This continent-ward subduction persisted until ~55–50 Ma, when an ocean-ward subduction

east of the continental subduction zone was proposed by Matthews et al.[15] and Seton et al.[19], possibly accompanied by subduction retreat and initiation of the (paleo-)Pacific plate[15,23,24,34]. Younger oceanic marginal basins east of the Zealandia continental subduction zone recorded Pacific MORB mantle signatures, whereas basalts from the Santa Cruz Basin-South Rennell Trough north of the Tasman Sea (Fig. 1) still show African MORB mantle characters (Fig. 2). Overall, our analysis shows that the continental subduction zone along the Zealandia margin served as a first-order boundary between the shallow Pacific and African mantle domain[2].

Interaction of shallow African mantle with distinct deep-mantle plumes

Although MORB samples with high εNd from the continental marginal basins consistently record African MORB mantle signatures, OIB-like samples from the Santa Cruz basin-South Rennell Trough and the Tasman Sea basin extend differently toward EM-1 and HIMU endmembers, respectively (Figs. 2–4). This observation is consistent with a south-north, EM-1 to HIMU geochemical zonation, as was previously noticed by Mather et al.[35]. Published geodynamic models[12,35,36] for the possible causes of this chemical heterogeneity include (1) oceanic subduction modification, (2) sub-continental lithospheric delamination, and (3) distinct plume sources.

Mather et al.[35] proposed that oceanic subduction from the Pacific Ocean over the past 200 Myr introduced distinct recycled materials into the mantle under the northern Zealandia and southern Zealandia-Antarctica margin. However, subducted oceanic crust and sediments near the Tonga trench generally show isotopic signatures of depleted Pacific-type mantle and EM-2 signatures[14] (Fig. 2), respectively. Addition of such subducted oceanic crust and sediments therefore could explain neither the dominant EM-1 signatures beneath the northern Zealandia margin, nor the HIMU signature in the Tasman Sea basin (Fig. 2b). Recycled carbonatites with high $^{238}U/^{204}Pb$ (μ) in the past 200 Myr might have contributed to the high $^{206}Pb/^{204}Pb$ signatures beneath the southern Zealandia-Antarctica margin[35,37] and possibly also the Tasman Sea basin. However, young carbonated sediments should have high Sr content and $^{87}Sr/^{86}Sr$

of ~0.7060[38], which unlikely accounts for the observed low values ($^{87}Sr/^{86}Sr$ <0.7040) of the HIMU components found in the region (Fig. 2d).

Recycled metasomatized subcontinental lithosphere mantle could have locally generated the contrasting EM-1 and HIMU signatures in the study region[39,40]. However, a shallow lithospheric source containing ancient recycled crustal components does not readily explain the large-scale, south–north zonation of EM-1 and HIMU components[35,36]. Moreover, given the prolonged history of paleo-Pacific and Pacific plate subduction along the Zealandia margin since ca. 650 Ma[41], the metasomatized lithospheric mantle would be expected to predominantly carry EM-1 and EM-2 signatures. Such material may have contributed sporadically to small-volume intraplate magmatism[42], but is unlikely to account for the systematic geochemical zonation.

Here we propose that the north-to-south contrasting EM-1 to HIMU signatures in OIB-like samples in the studied continental marginal seas reflect deep mantle plume processes (Fig. 5). The EM-1 signatures of the OIB-like samples from the Santa Cruz Basin and the South Rennell trough in the north are comparable to those observed from the Tasmantid and Lord Howe hotspots[43,44] (Figs. 2–4). In addition, basalts from the Santa Cruz basin and the South Rennell trough were spatial-temporally associated with activities of Tasmantid and Lord Howe hotspots, supporting their plume origin[19,20] (Figs. 5a–c). The high Ba/Nb and low εNd (Fig. 3) of these basalts suggest a mantle source containing ancient subducted sediments[45,46]. Such ancient sediments with low μ[45] (Supplementary Fig. 4) can evolve toward time-integrated low $^{206}Pb/^{204}Pb$ similar to EM-1 with depositional ages of 600–800 Ma (Supplementary Fig. 5). These EM-1 signatures are consistent with dominant signals of the deep African domain[1,2], possibly reflecting the closeness of this region to the Austro-India plate on the eastern side of the African domain that has experienced long-term enrichment of continental materials since the break-up of the supercontinent Rodinia[1,2,6,47].

In contrast, the HIMU signatures recorded by OIB-like samples in the Tasman Sea basin as well as the Zealandia and Antarctica plumes occur as dispersed intraplate volcanism along the southern Zealandia and Antarctic margin[36] (Figs. 4 and 5). This broad distribution spatially coincides with large-scale low-velocity mantle anomalies

that extend into the Pacific lower mantle[12]. Similar HIMU intraplate magmas can be traced back to the ~99 Ma Hikurangi Plateau, across the paleo-Pacific subduction zone[48] (Fig. 5d). HIMU signatures have been interpreted to originate from subducted oceanic lithosphere[49] with possible involvement of carbonates[50], and requires recycling ages older than 1.0–1.5 Ga[49,50] (Supplementary Fig. 5). These ancient recycled components may therefore represent material from the deep Pacific mantle domain, potentially preserving the imprint of subduction associated with the late Mesoproterozoic–early Neoproterozoic assembly of Rodinia[1,2,47]. Together, these observations likely indicate that plume upwelling transported HIMU-bearing material from the deep Pacific mantle into the shallow mantle beneath the Zealandia–Antarctica margin during and after opening of the Tasman Sea Basin (Fig. 5).

Collectively, the African MORB mantle and EM-1 signatures of MORB and OIB-like samples from the northern end of the continental marginal seas show a consistent African domain affinity, whereas toward the south, the African-domain upper mantle (African MORB mantle signatures) overlays a likely Pacific-domain lower mantle (HIMU signatures), indicating the presence of a complex juxtaposition of the two mantle domains in this southern segment of the broad domain boundary zone (Fig. 6). We propose that at the northern segment where the subduction zone has remained close to the Australia-Zealandia continent and the domain boundary zone is narrower, a sharper and consistent domain boundary exists across the lower and upper mantle (Fig. 6b). Toward the south where subduction retreat has brought the subduction zone into the Pacific interior after ~90 Ma, an African domain upper mantle was likely drawn eastward by the subduction retreat over a Pacific lower mantle (Fig. 6c).

Methods

Sr-Nd-Hf isotope analyses were performed on a Neptune Plus MC–ICP–MS (Thermo Fisher Scientific, Dreieich, Germany) at the Wuhan Sample Solution Analytical Technology Co., Ltd, Hubei, China. Sample powders (200 mesh) were dried at 105 °C for 12 h. Aliquots of 50–200 mg were digested with 1–3 mL each of HNO_3 and HF in Teflon bombs enclosed in stainless-steel pressure jackets at 190 °C for >24

h. After cooling, the solutions were evaporated to near dryness at 140 °C, treated with 1 mL HNO_3, and evaporated to dryness again. The residues were dissolved in 1 mL of 2.5 M HCl. Then the solution was loaded into an ion-exchange column packed with AG50W resin. The Sr fraction was separated by the Sr-specific resin (SR-B50-S), then the Nd fraction was separated by the LN resin. Hf fraction was separated by the LN resin from another solution. $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$, and $^{176}Hf/^{177}Hf$ ratios were normalized to $^{88}Sr/^{86}Sr$=8.3752, $^{146}Nd/^{144}Nd$=0.7219, and $^{179}Hf/^{177}Hf$=0.7325, respectively[51]. The analytical reproducibility and accuracy of Sr–Nd–Hf isotope measurements were monitored by repeated analyses of NBS 987, GSB 04-3258-2015, and an in-house Hf isotope solution, respectively. The measured isotope ratios were consistent with the reported values within analytical uncertainties. Results of reference materials (JA-3 and JB-3) are provided in the Supplementary Table 1 and agree with recommended values.

Pb isotope analyses were conducted by a Nu Instruments Plasma 3 MC–ICP–MS at the Guizhou Tongwei Analytical Technology Company. To minimize post-magmatic alteration, ~200 mg of sample powder was ultrasonically leached in 4 mL of 6 N HCl at 50 °C for 20 min. The detailed analytical procedure is provided in Zhang et al.[52]. For the measurement of Pb isotopic data, thallium with a $^{205}Tl/^{203}Tl$ ratio of 2.3875 was added to each sample to correct for mass fractionation. The instrument drift was monitored using the standard bracketing method using the NIST-981 standard. During the analysis, repeated analyses of NIST-981 yielded average ratios of $^{208}Pb/^{204}Pb$ = 36.7189 ± 17, $^{207}Pb/^{204}Pb$ = 15.4948 ± 7 and $^{206}Pb/^{204}Pb$ = 16.9413 ± 5 (n = 9, 2SD). Lead isotope ratios were presented after recalibration using a NIST-981 value of $^{208}Pb/^{204}Pb$ = 36.7179, $^{207}Pb/^{204}Pb$ = 15.4944 and $^{206}Pb/^{204}Pb$ = 16.9410. Results of reference materials (BCR-2) are listed in the Supplementary Table 1, which are comparable to the recommended values.

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Author contributions:

Conceptualization: FX, ZXL

Investigation: FX, ZXL, GLZ, MS

Visualization: FX

Writing—original draft: FX

Writing—review & editing: FX, ZXL, MS, GLZ

Competing interests: Authors declare that they have no competing interests.

Data and materials availability: The data generated and analyzed in this study are provided in the Supplementary Tables.

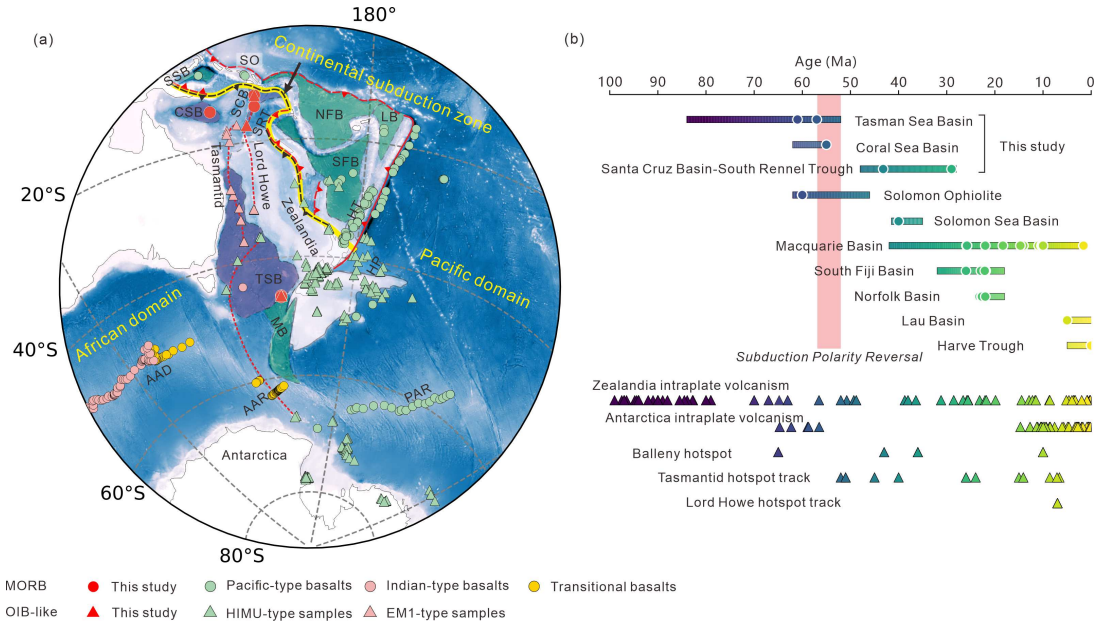


Fig. 1 (a) Bathymetric map and sample locations of the southwest Pacific region. (b) Temporal distribution of marginal basin basalts and intraplate volcanism in the southwest Pacific region. AAD, Australia-Antarctica Discordance; AAR, Australia-Antarctica ridge; CSB, Coral Sea basin; HP, Hikurangi Plateau; HT, Havre trough; LB, Lau Basin; MB, Macquarie basin; NFB, North Fiji basin; PAR, Pacific-Antarctica ridge; SFB, South Fiji basin; SCB, Santa Cruz basin; SO, Solomon ophiolites; SRT, South Rennell Trough; SSB, Solomon Sea basin; TSB, Tasman Sea basin.

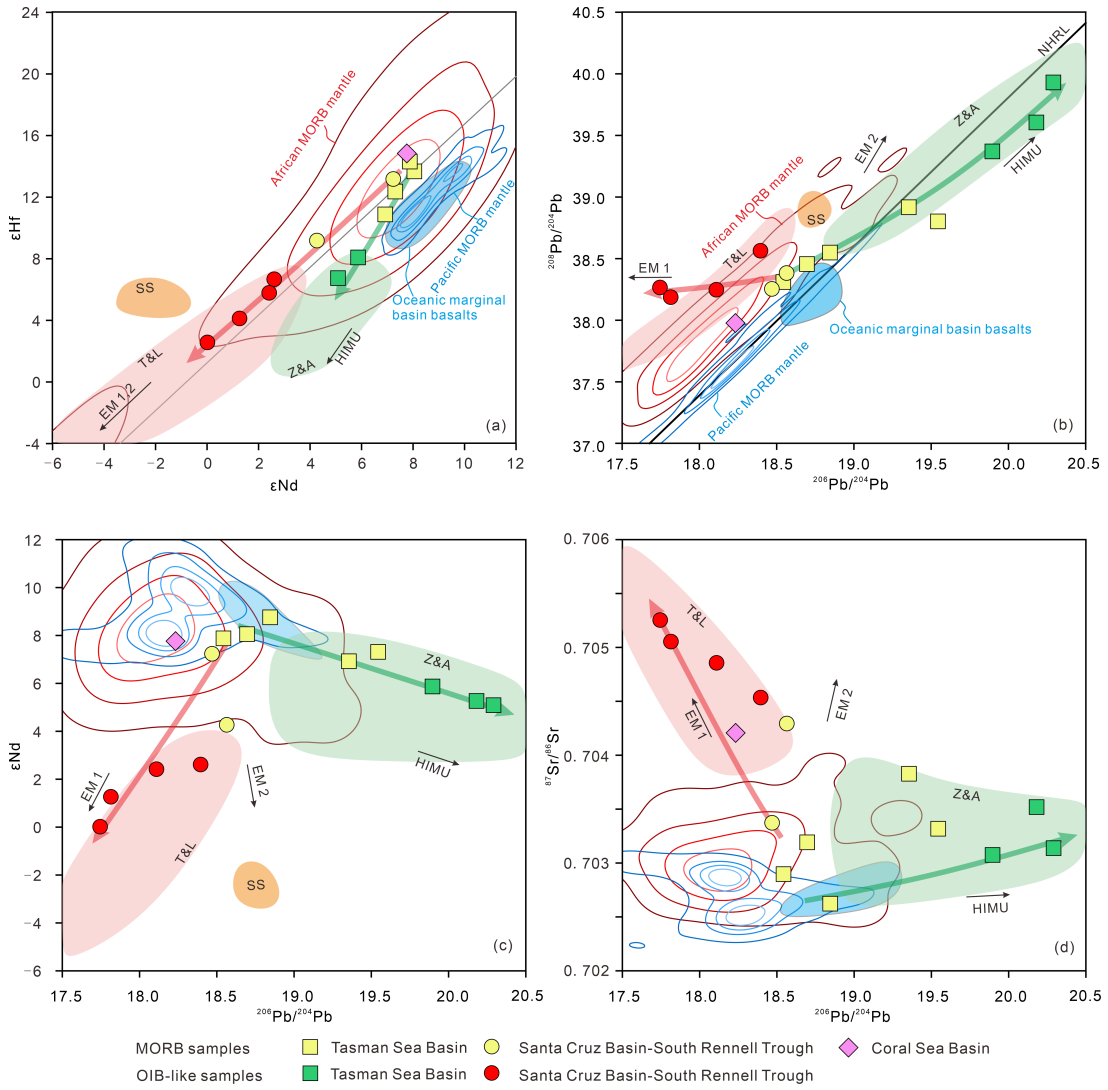


Fig. 2 Sr-Nd-Pb-Hf isotope ratios of the MORB and OIB samples from the southwest Pacific region: (a) εNd vs. εHf; (b) $^{206}Pb/^{204}Pb$ vs. $^{208}Pb/^{204}Pb$; (c) $^{206}Pb/^{204}Pb$ vs. εNd; (d) $^{206}Pb/^{204}Pb$ vs. $^{87}Sr/^{86}Sr$. T&L, field of OIB samples from the Tasmantid and Lord Howe hotspots; Z&A, field of OIB-like samples from plume(s) along the southern Zealandia-Antarctica margin; SS, subducted sediments near the Tonga trench. Blue shades represent isotope compositions of basalts from oceanic marginal basins including the Solomon Ophiolite from the Solomon Sea Basin, South Fiji Basin, early Lau Basin and Havre Trough. Red and blue contour lines represent percentiles of the kernel density estimation for African and Pacific MORB data, respectively. The literature data are listed in Supplementary Table 3.

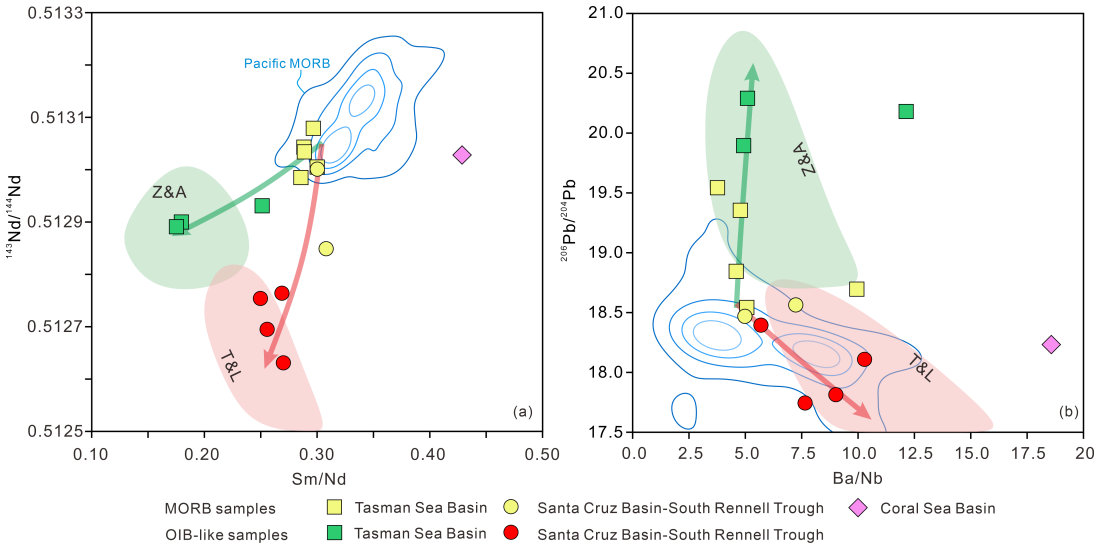


Fig. 3 Trace element ratios vs. isotope ratios of the MORB and OIB-like samples from the southwest Pacific region. T&L, field of OIB samples from the Tasmantid and Lord Howe hotspots; Z&A, field of OIB-like samples from plume(s) along the southern Zealandia-Antarctica margin. Blue contour lines represent percentiles of the kernel density estimation for African MORB data. The literature data are listed in Supplementary Table 3.

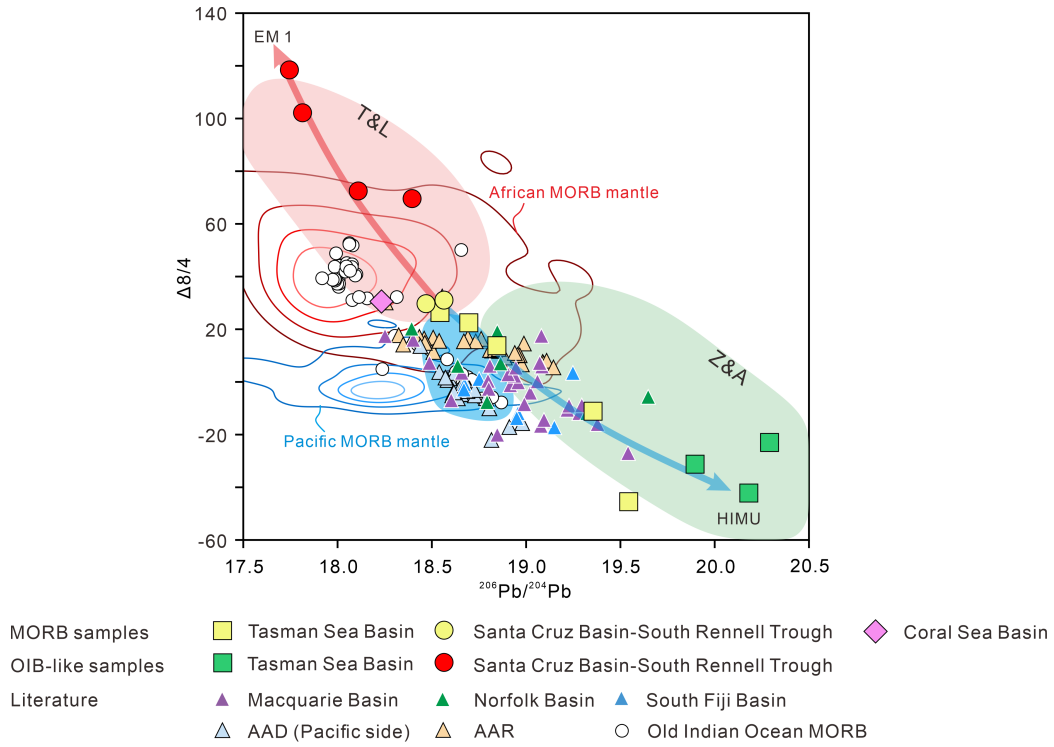


Fig. 4 $^{206}Pb/^{204}Pb$ vs. Δ8/4 of the MORB and OIB-like samples from the southwest Pacific region. T&L, field of OIB samples from the Tasmantid and Lord Howe hotspots; Z&A, field of OIB-like samples from plume(s) along the southern Zealandia-Antarctica margin. Red and blue contour lines represent percentiles of the kernel density estimation for African and Pacific MORB data, respectively. The literature data are listed in Supplementary Table 3.

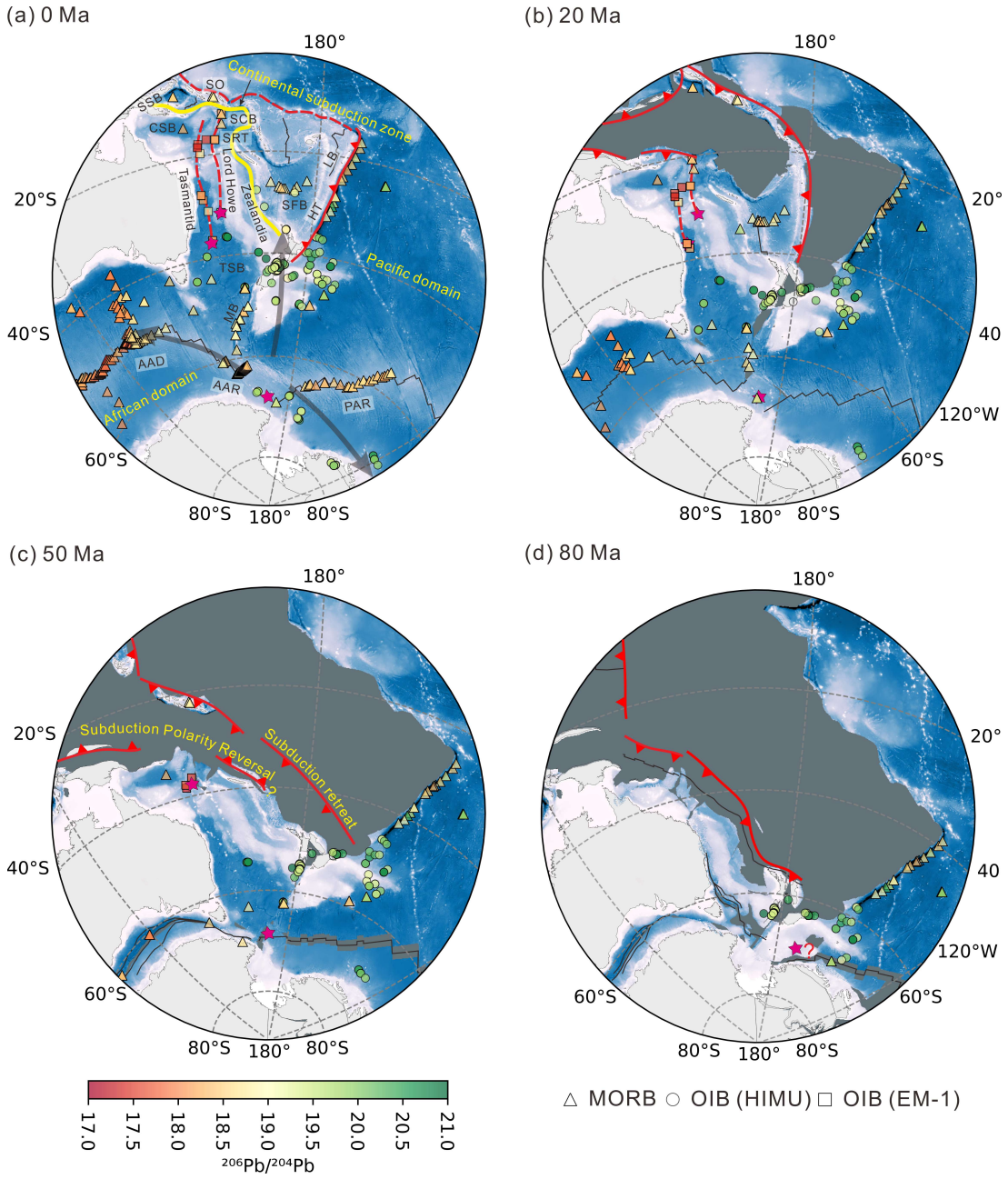


Fig. 5 Plate reconstruction model[53] and Pb isotope compositions of basalts in the southwest Pacific region at (a) 0 Ma, (b) 20 Ma, (c) 50 Ma and (d) 80 Ma, respectively. The assumed plume center at ca. 80 Ma is based on the distribution of the intraplate volcanism at the New Zealand and Hikurangi Plateau. Triangles represent MORBs, while circles and squares represent intraplate volcanism influenced by HIMU and EM-1 components, respectively. AAD, Australia-Antarctica Discordance; AAR, Australia-Antarctica ridge; CSB, Coral Sea basin; HP, Hikurangi Plateau; HT, Havre trough; LB, Lau Basin; MB, Macquarie basin; NFB, North Fiji basin; PAR, Pacific-

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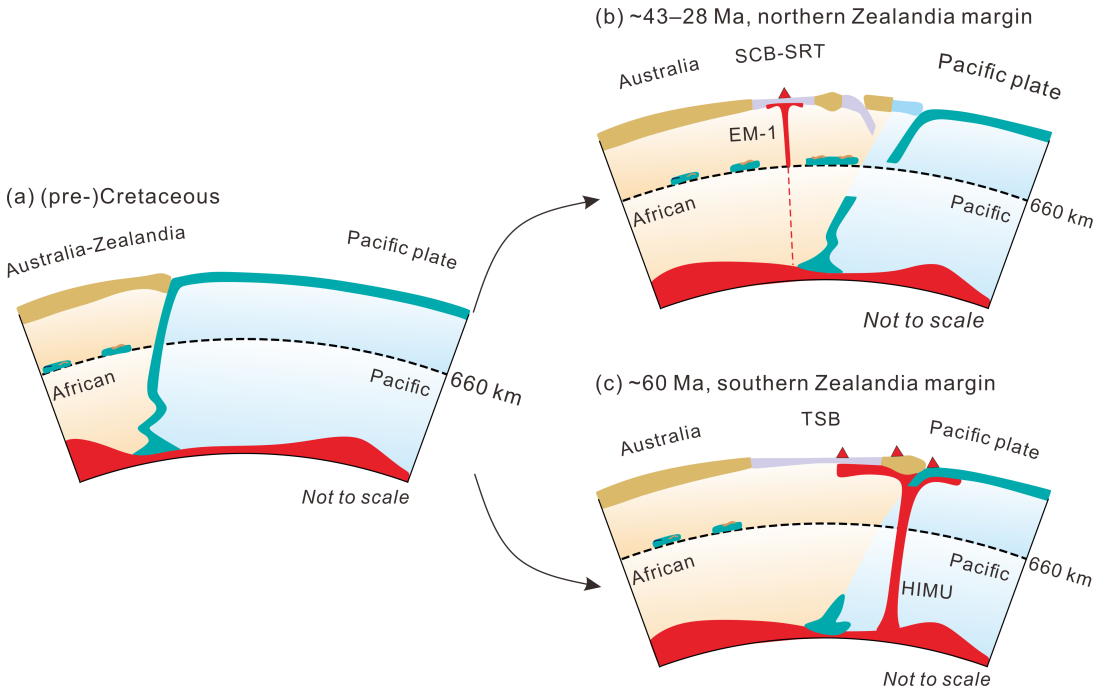
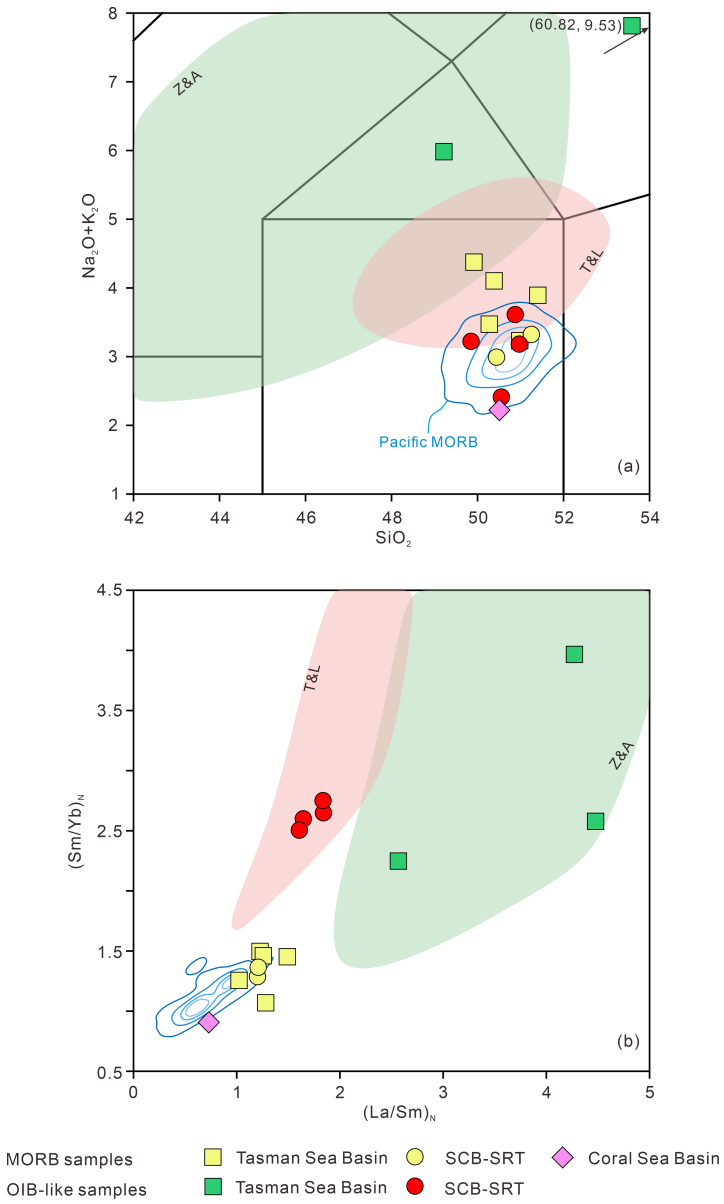
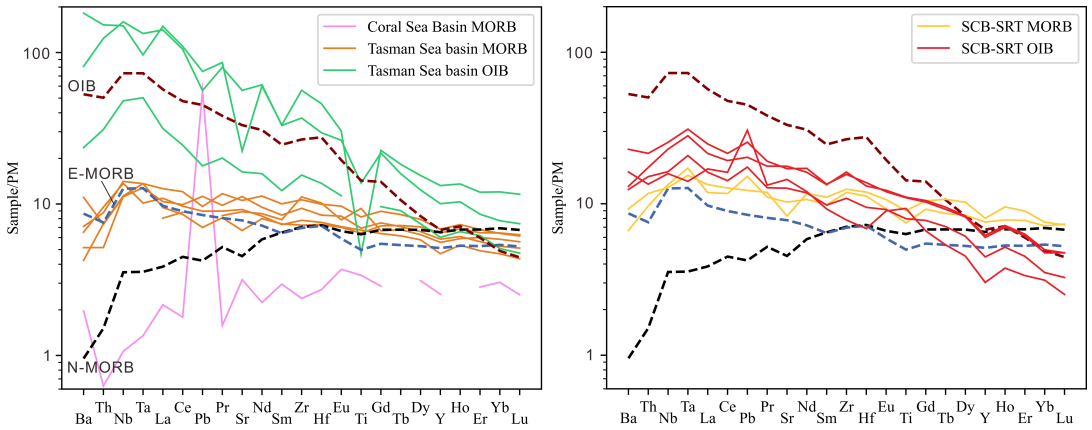


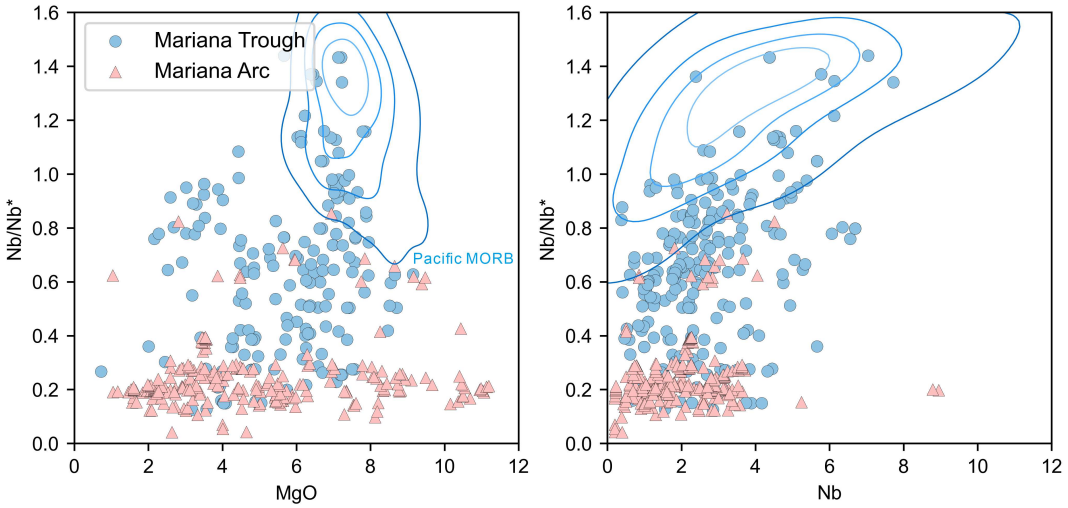
Fig. 6 Cartoon illustrating the Pacific-African mantle domain transition beneath the southwest Pacific margin. (a) During the (pre-)Cretaceous, continental subduction zone along the Zealandia margin defined the boundary between the Pacific-African mantle domains. **(b)** Along the northern Zealandia margin, MORB and OIB-like samples from the Santa Cruz basin–South Rennell Trough (SCB–SRT) from 43–26 Ma show African MORB mantle and EM-1 signatures, whereas MORBs from the oceanic marginal basins show Pacific MORB mantle signatures, suggesting the relic continental subduction zone represents the first-order upper mantle boundary. **(c)** Along the southern Zealandia margin, MORBs and OIB-like samples from the Tasman Sea basin (TSB) at ~60 Ma show African MORB mantle and HIMU signatures, indicating interaction between African MORB mantle and HIMU components derived from the deep Pacific mantle.



Supplementary Fig. 1 (a) SiO_2 vs. Na_2O+K_2O, and (b) $(La/Sm)_N$ vs. $(Sm/Yb)_N$ of basalts from the southwest Pacific marginal basins. T&L, field of OIB samples from the Tasmantid and Lord Howe hotspots; Z&A, field of OIB-like samples from plume(s) along the southern Zealandia-Antarctica margin.



Supplementary Fig. 2 Primitive mantle[54] normalized trace element patterns of basalts from the southwest Pacific marginal basins. N-MORB, E-MORB and OIB are from Sun and McDonough[31].

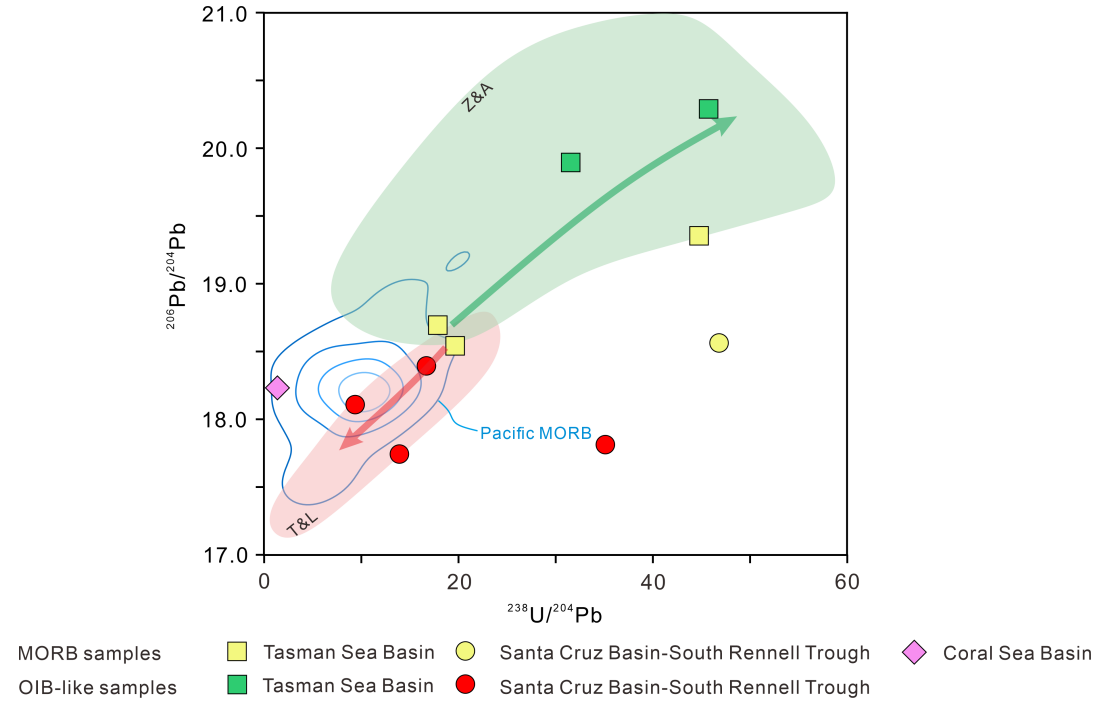


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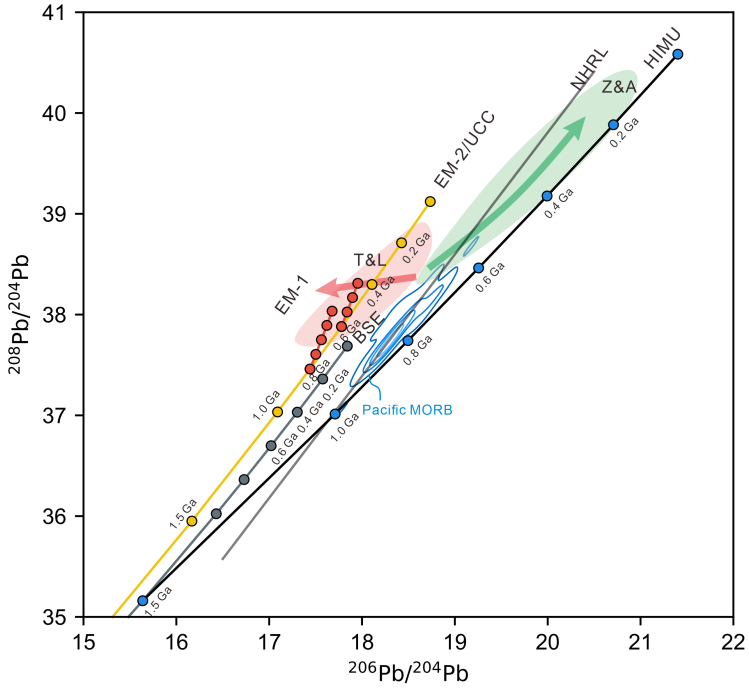
508 **Supplementary Fig. 3 MgO (a) and Nb (b) vs. Nb/Nb* of basalts from the Mariana**

509 **Trough and arc.**

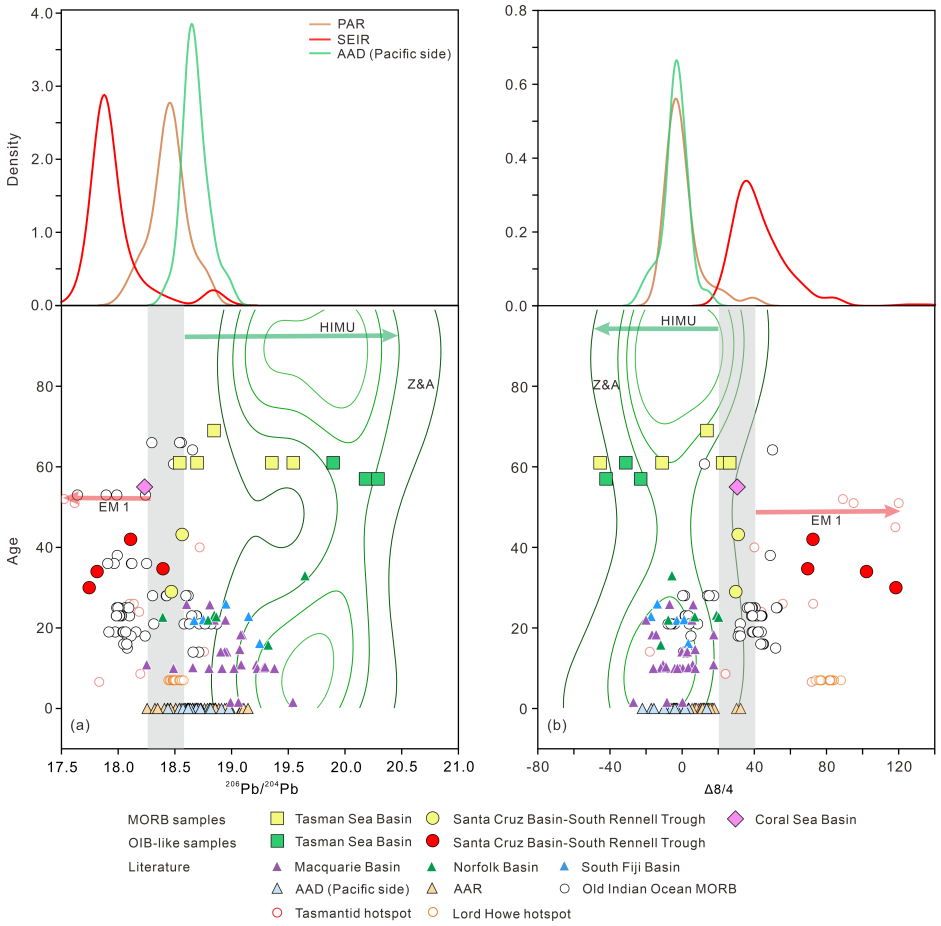
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Supplementary Fig. 4 $^{206}Pb/^{204}Pb$ vs. $^{238}U/^{204}Pb$ of the MORB and OIB samples from the southwest Pacific region. T&L, field of OIB samples from the Tasmantid and Lord Howe hotspots; Z&A, field of OIB-like samples from plume(s) along the southern Zealandia-Antarctica margin.



Supplementary Fig. 5 Pb isotope evolution of the modeled EM-1 and HIMU endmembers. Pb isotope evolution of UCC and BSE is from Doucet et al.[55]. T&L, field of OIB samples from the Tasmantid and Lord Howe hotspots; Z&A, field of OIB-like samples from plume(s) along the southern Zealandia-Antarctica margin.



523

524 **Supplementary Fig. 6 Temporal evolution of Pb isotope compositions for MORB**
525 **and OIB-like samples in the southwest Pacific region.** The literature data are listed
526 in Supplementary Table 3. Z&A, field of OIB-like samples from plume(s) along the
527 southern Zealandia-Antarctica margin.

528

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryTable1.xlsx
- SupplementaryTable2.xlsx
- SupplementaryTable3.xlsx