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Tracing continental contamination along the Sunda-Banda arc transition: geochemical indicators of subduction to collision

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1. Introduction

In subduction zones surface materials are subducted, transferring elements to the mantle (Plank and Langmuir, 1998). This is a key process modifying magma geochemistry.

The Sunda and Banda volcanic arcs in Indonesia record the northward subduction of the Indo-Australian plate beneath the Sunda plate and a progressive tectonic change from subduction to island-arc collision with the Australian continental margin.

Previous studies indicate that collisional volcanics in the Southwest Banda arc carry geochemical signatures of local subducting sediments enriched in Australian continental material (Vroon *et al.*, 1995). Elburg, van Bergen and Foden (2004) propose that elements were transferred to the mantle from partially subducted segments of Australian continental margin. Additionally, helium isotope data suggests continental influence may extend west beneath the active region around the island of Flores (Hilton *et al.,* 1992).

2. Research aims and methodology

Aim: Use secondary data to test whether geochemical and isotopic signatures along the Sunda-Banda arc transition progressively approximate continental values with proximity to the collision zone consistent with increasing contamination by subducted continental material at the mantle source.

Key proxies: Elevated $^{87}Sr/^{86}Sr$, $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$ and depleted $^{143}Nd/^{144}Nd$ ratios and trace-element ratios such as Th/Nb, La/Nb and K_2O/Na_2O serve as proxies for mantle source contamination in this project.

Data collection and grouping: The most primitive whole-rock data with loss on ignition <2 wt.% were extracted from the GEOROC convergent margin dataset (DIGIS Team, 2024 and references therein). Samples grouped by tectonic setting: West Banda (Alor to Romang; collisional inactive sector, 16 samples), East Sunda (Flores and surrounding islets; active sector with continental helium ratios, 18 samples), and Sumbawa (typical active island arc, 19 samples).

Key objectives and method:

- Compare parental magmas and end members by plotting arc samples with mid-ocean ridge basalt, local trench sediments and Australian upper continental crust.
- Use one-way ANOVA or Kruskal-Wallis and post hoc tests to evaluate along-arc geochemical variation or differences between volcanically active and inactive regions.
- Identify the variables driving variation using principal component analyses (PCA) and assess the role of magmatic evolution by including MgO (wt.%).

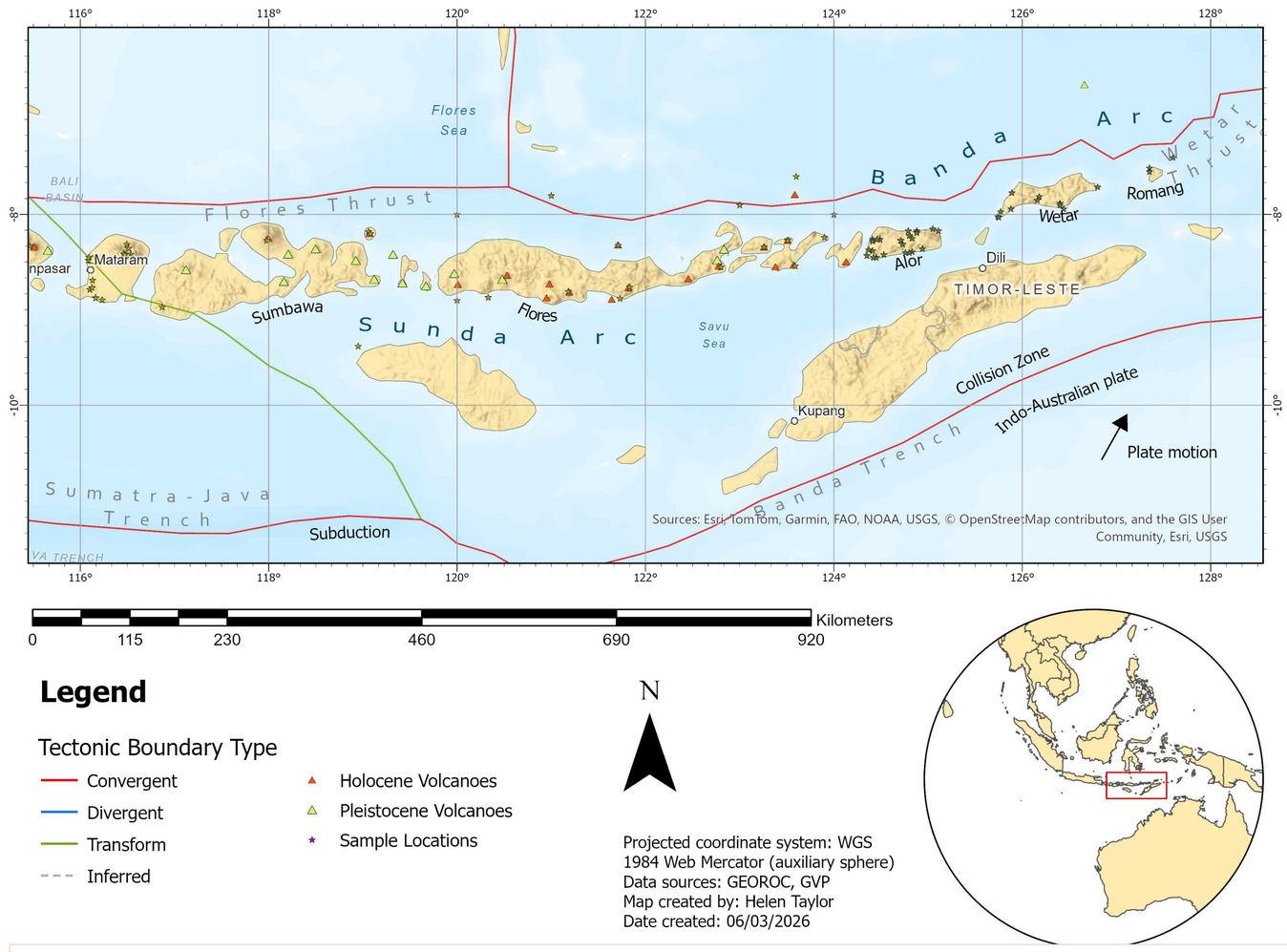
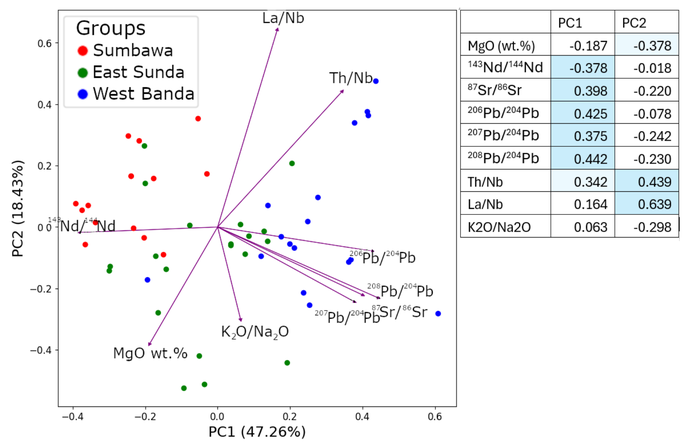


Figure 1: Map created in ArcGIS pro identifying key islands and sample locations (stars) from the Sunda and Banda arcs. Volcanoes with Holocene (Red Triangles) and Pleistocene (Orange) eruptions are shown.

3. Results

Principal components (Figure 2): PC1 and 2 explain 47.26% and 18.43% of total variance. PC1 comprises Pb, Sr and Nd isotope ratios and Th/Nb. PC2 shows highest loadings for La/Nb and Th/Nb. MgO wt.% and K_2O/Na_2O exhibit weak loadings in both PCs.
Statistical differences (Figure 3): Significant differences ($p<0.001$) in Sr, Nd and Pb isotope ratios between two or more regions and most significant between the most geographically separated groups. Th/Nb increases towards West Banda but with lower statistical strength. La/Nb and K_2O/Na_2O ratios did not display along-arc trends and did not yield significant results.

Discrimination plots (Figure 4): All groups plot between I-MORB, trench sediments and Australian continental crust. Sumbawa plots closest to I-MORB, West Banda trends towards marine sediments and continental compositions, East Sunda occupies an intermediate position. One West Banda sample exhibits a $^{208}Pb/^{204}Pb$–$^{206}Pb/^{204}Pb$ ratio that only aligns with North Australian upper continental crust (Figure 4, c., and e.).



	PC1	PC2
MgO (wt.%)	-0.187	-0.378
$^{143}Nd/^{144}Nd$	-0.378	-0.018
$^{87}Sr/^{86}Sr$	0.398	-0.220
$^{206}Pb/^{204}Pb$	0.425	-0.078
$^{207}Pb/^{204}Pb$	0.375	-0.242
$^{208}Pb/^{204}Pb$	0.442	-0.230
Th/Nb	0.342	0.439
La/Nb	0.164	0.639
K2O/Na2O	0.063	-0.298

Figure 2: Principal component analysis (PCA) plot of the contamination proxies. Sample scores are illustrated by points, colours represent West Banda (Blue), East Sunda (Green) and Sumbawa (Red). Raw data obtained from GEOROC (DIGIS Team, 2024, and references therein).

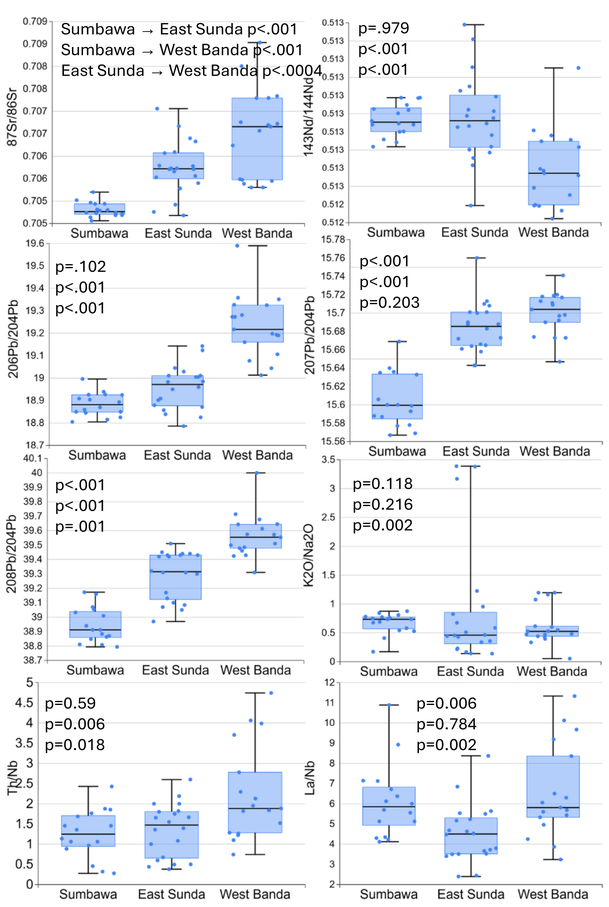


Figure 3: Boxplots illustrate post hoc analyses (Tukey-Kramer and Dunn's) following one-way ANOVA and Kruskal–Wallis tests. Raw data obtained from GEOROC (DIGIS Team, 2024, and references therein).

4. Discussion

- **Isotopic evidence:** Increasing radiogenic Pb and Sr and decreasing Nd towards West Banda are consistent with rising continental contamination supporting the experimental hypothesis.
- Observed trends align with prior work connecting subducted sediments and continental material to the geochemistry of the arc (Vroon *et al.*, 1995; Elburg *et al.*, 2002).

- **Trace element behaviour**: Major and trace elements are less diagnostic than isotopes.
- Th/Nb increases towards West Banda reflecting sensitivity to continental input.
- The absence of spatial trends in La/Nb and K_2O/Na_2O departs from earlier across-arc studies (Elburg *et al.*, 2002) and suggest that continental contamination may be masked by other magmatic processes.

- **End-member mixing:** Sample positions between I-MORB, trench sediments and Australian upper continental crust support a mixing model involving a MORB-like mantle modified by subducted sediments and continental material (Plank and Langmuir, 1998).
- The anomalous West Banda sample may indicate either a higher proportion of continental sediment in the subducted package or direct involvement of the continental margin in the zone of melting (Elburg, van Bergen and Foden, 2004).

- **Limitations:** Sampling bias from uneven spatial coverage, particularly in western Flores. Lack of sample age data or arc front to rear position, complicates separation of spatial and temporal effects.
- Whole-rock data alone limit the ability to separate source contamination from crustal assimilation and magmatic differentiation.

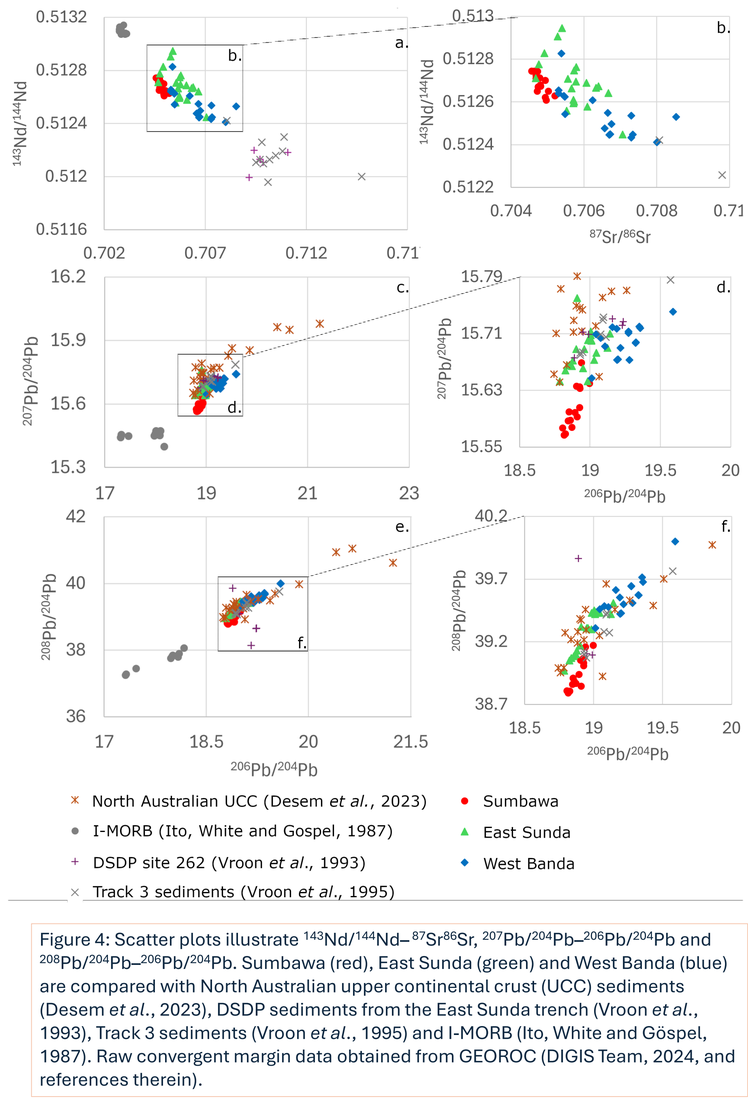


Figure 4: Scatter plots illustrate $^{143}Nd/^{144}Nd$–$^{87}Sr/^{86}Sr$, $^{207}Pb/^{204}Pb$–$^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$–$^{206}Pb/^{204}Pb$. Sumbawa (red), East Sunda (green) and West Banda (blue) are compared with North Australian upper continental crust (UCC) sediments (Desem *et al.*, 2023), DSDP sediments from the East Sunda trench (Vroon *et al.*, 1993), Track 3 sediments (Vroon *et al.*, 1995) and I-MORB (Ito, White and Göspel, 1987). Raw convergent margin data obtained from GEOROC (DIGIS Team, 2024, and references therein).

5. Conclusions and recommendations

Geochemical patterns along the Sunda-Banda arc transition are consistent with progressive mantle source contamination by subducted continental material towards the collision zone. The tectonic change to collision is most apparent within the isotope ratios, comparatively the effect on major and trace element composition is far weaker, with only Th/Nb ratios increasing with statistical significance with proximity to the collision zone.

Interpretation could be enhanced through future research, by extracting sample age and arc front or rear position. Incorporation of mineral-scale isotopic and trace-element analyses and targeted studies of trench sediments and forearc materials could better constrain the nature and transfer mechanisms of continental-derived components into the mantle wedge.

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