Testing induced vs spontaneous subduction initiation mechanisms in the SW Pacific

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Most of this white paper summarizes a 2013 proposal to the Marsden Fund (a New Zealand equivalent of NSF); we also mention related sedimentary basin work that is underway and a planned research cruise. We welcome comment, and invite contributions of additional cross-disciplinary work.

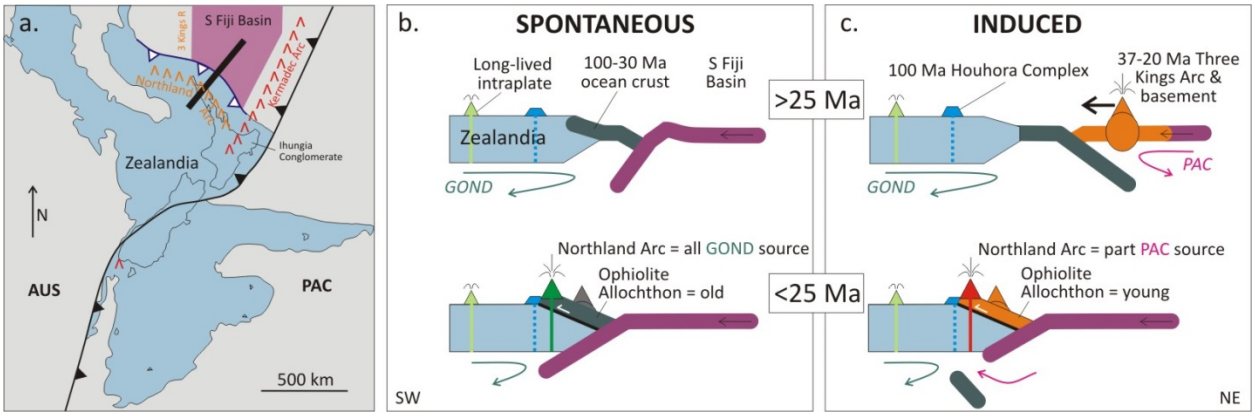

Figure 1. (a) Location map thick black line is cross section line; (b), (c) contrasting options for c. 25 Ma (Early Miocene) subduction initiation in Northland, New Zealand[3]. Green-blue-grey=lavas with Gondwana mantle source, red-orange-purple=Pacific mantle source lavas.

A critical but little-investigated aspect of subduction is how it starts. Conceptual geodynamic models of subduction initiation can be classified as either spontaneous (e.g. subduction triggered by density instabilities) or induced (e.g. arc-continent collision followed by subduction flip)[1,2]. However there are relatively few actual situations in which these models can be empirically tested as subduction initiation is, by definition, a transitory and spatially restricted process. Modern examples are rare and its recognition in the geological record can be controversial and ambiguous (Fig. 1)[3,4].

The Izu-Bonin-Marianas volcanic arc of the western Pacific is often cited in papers on *intra-oceanic* subduction initation. The arc system of the SW Pacific is ideally suited for testing subduction initiation processes at a *continent-ocean boundary* (Fig. 1). This region underwent a convergent to passive margin transition in the Late Cretaceous, with re-establishment of subduction in the Oligocene, eventually evolving into the modern Hikurangi-Kermadec subduction zone. The Miocene Northland volcanic arc (Fig. 1) is known to have erupted through and onto in situ Zealandia continental crust and faulted oceanic ophiolite allochthon in the interval 23-16 Ma [4-6].

When, how and why did SW Pacific subduction initiate adjacent to Northland (white teeth in Fig. 1a)? We propose novel empirical geochemical and geochronological tests of this

longstanding SW Pacific tectonic problem using basalt lava geochemical, Sr, Nd, Pb and Hf isotope and Ar-Ar age data. If subduction was induced spontaneously then all Northland lavas, including those in the Allochthon, will have isotopically distinct Gondwana (a.k.a. Indian) mantle sources (Fig. 1b). However if subduction was induced by subduction flip following collision of an older arc (cf. models of New Caledonia) then some lavas with a Pacific mantle source will be present in the Northland Arc and Allochthon (Fig. 1c). Ar-Ar dating is a critical part of our programme as resolving the disputed Cretaceous (old) vs Oligocene (young) age of parts of the Northland Allochthon will provide a separate but related test of the subduction initiation mode. identifciation and direct dating of compositionally distinct rocks relevant to subduction polarity e.g. boninites, adakites, shoshonites will also be important.

The advantages of investigating continent-ocean subduction initiation models in the Zealandia-SW Pacific area are that (i) established isotopically distinctive end-member Indian and Pacific mantle sources in the region permit our innovative approach[7,8]; (ii) onland geology is well characterised and a long-baseline volcanic record can be sampled[4-6]; (iii) alternative local tectonic models are mature and clearly defined[9-12].

Our results will indicate if continent-ocean subduction initiation off Northland was spontaneous or induced. Induced initiation will demonstrate the applicability of New Caledonia-style collisional models to New Zealand (Fig. 1b) and demand a major overhaul of conventional local tectonic models. Spontaneous initiation will require a new, globally-applicable model of ophiolite emplacement (obduction), unrelated to collision and subduction flip (Fig. 1c).

Related to Oligocene sub duction initiation, but separate from the Marsden Fund proposal, are two other projects:

(1) planned acquisition of samples from the Three-Kings Loyalty Ridge. This is the submarine continuation of the Northland Arc, and is possibly an older feature. The **VESPA** cruise proposal, coordinated by an IFREMER-UBO-GNS group, has been rated P1 (highest) but is not yet scheduled.

(2) CSUN-GNS study of the post-allochthon Ihungia Conglomerate which contains ophiolitic clasts. The sedimentary basin response adjacent to the ophiolite allochthon will help constrain the tectonic geometry of subduction initiation[13,14].

References:

1. Stern, R.J. 2004. Subduction initiation: spontaneous and induced. Earth and Planetary Science Letters 226: 275–292.
2. Gurnis, M., Hall, C. & Lavier, L. 2003. Evolving force balance during incipient subduction. Geochemistry, Geophysics, Geosystems 5: Q07001, doi:10.1029/2003GC000681
3. Wakabayashi, J. & Shervais, J.W. 2012. Initiation and termination of subduction: rock record, geodynamic models, and modern plate boundaries. Lithosphere 4: 467–468.
4. Malpas, J., Sporli, K.B., Black, P.M. & Smith, I.E.M. 1992. Northland ophiolite, New Zealand, and implications for plate-tectonic evolution of the southwest Pacific. Geology 20: 149–152.
5. Booden, M.A., Smith, I.E.M., Black, P.M. & Mauk, J.L. 2011. Geochemistry of the early Miocene volcanic succession of Northland, New Zealand, and implications for the evolution of subduction in the Southwest Pacific. Journal of Volcanology and Geothermal Research 199: 25–37.
6. Mortimer, N., Gans, P.B., Palin, J.M., Meffre, S., Herzer, R.H. & Skinner, D.N.B. 2010. Location and migration of Miocene-Quaternary volcanic arcs in the SW Pacific region. Journal of Volcanology and Geothermal Research 190: 1-10.

7. Crawford, A.J., Briqueu, L., Laporte, C. & Hasenaka, T. 1995. Coexistence of Indian and Pacific oceanic upper mantle reservoirs beneath the central New Hebrides Island Arc. American Geophysical Union Monograph 88: 199–217.
8. Pearce, J. A., Kempton, P.D. & Gill, J.B. 2007. Hf-Nd evidence for the origin and distribution of mantle domains in the SW Pacific, Earth and Planetary Science Letters 260: 98–114.
9.Mortimer, N., Herzer, R.H., Gans, P.B., Laporte-Magoni, C., Calvert, A.T. & Bosch, D. 2007. Oligocene-Miocene tectonic evolution of the South Fiji Basin and Northland Plateau, SW Pacific Ocean: evidence from petrology and dating of dredged rocks. Marine Geology 237: 1–24.
10. Crawford, A.J., Meffre, S. & Symonds, P.A. 2003. 120 to 0 Ma tectonic evolution of the southwest Pacific and analogous geological evolution of the 600 to 220 Ma Tasman Fold Belt System. Geological Society of America Special Paper 372: 383–403.
11.Schellart, W.P., 2007. North-eastward subduction followed by slab detachment to explain ophiolite obduction and Early Miocene volcanism in Northland, New Zealand. Terra Nova 19: 211–218.
12. Whattam, S.A., Malpas, J., Smith, I.E.M. & Ali, J.R. 2006. Link between SSZ ophiolite formation, emplacement and arc inception, Northland, New Zealand : U-Pb SHRIMP constraints: Cenozoic SW Pacific tectonic implications. Earth and Planetary Science Letters 250: 606–632.
13.Marsaglia, KM, Rains, J, Bender, C, Mortimer, N, 2010. Sedimentary signatures and paleogreographic implications of subduction inception: two Pacific margin examples. Geological Society of America Abstracts with Programs, 42, 5, 678.
14.Gurnis, M, 1992. Rapid continental subsidence following the initiation and evolution of subduction. Science, 255, 1556-1558.