Vertically Driven Dynamics and Magmatism of Rapid Subduction Initiation in the Western Pacific

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NERC SCIENCE OF THE ENVIRONMENT

Background

The first continuous, in situ record of subduction initiation was recovered by IODP Expedition 352, in the Izu-Bonin-Marianas (IBM) forearc (Fig. 1A- boreholes in inset).

Magmatic progression: decompression melts (fore-arc basalt or **FAB**) to **boninites** (with a fluid signature) can be explained by a vertically-driven subduction initiation conceptual model (Fig. 1B-D).

Dating of the record reveals that the time-scale for this process is **< 1 Myrs**.

Boreholes closest to trench = FAB dominated; boreholes closer to arc = boninite dominated; FAB has also been recovered behind the original arc (to the west of the Kyushu-Palau Ridge, KPR).

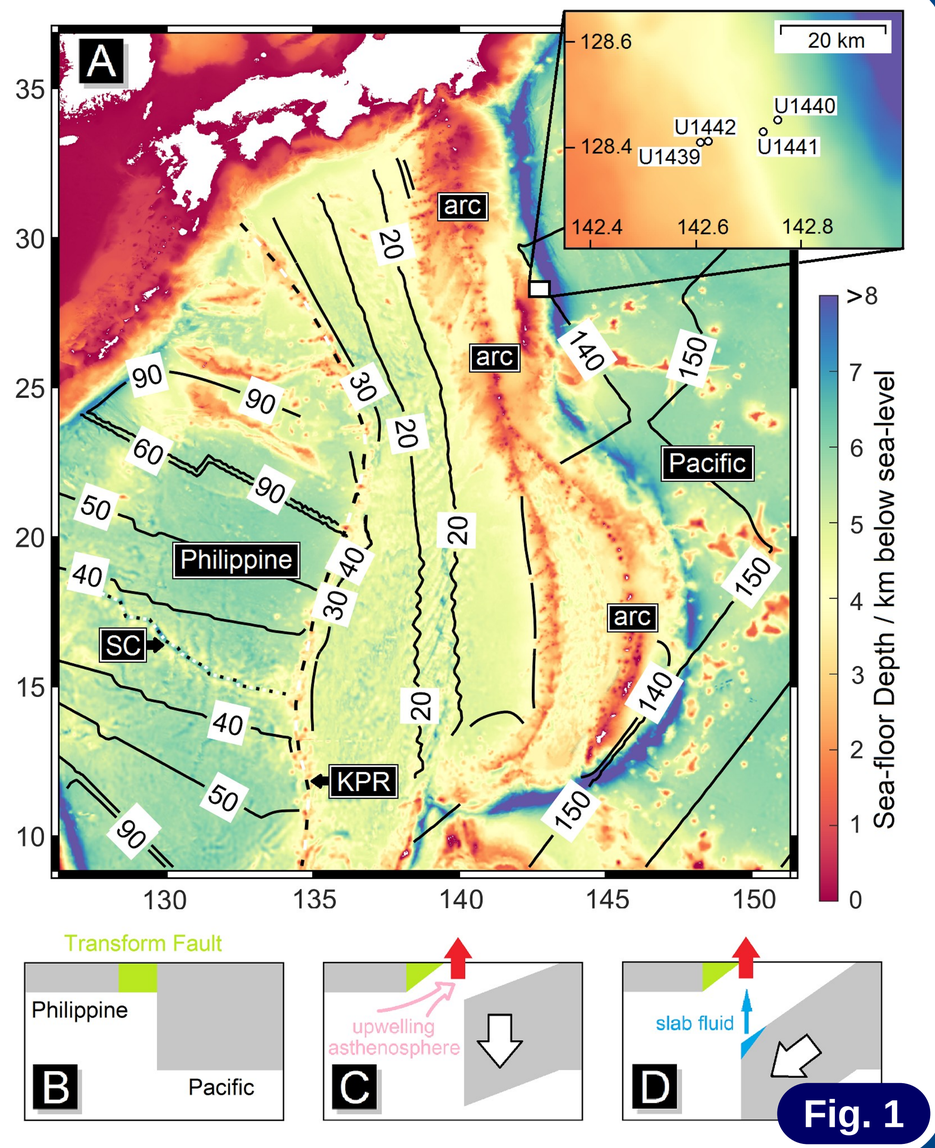

Fig. 1

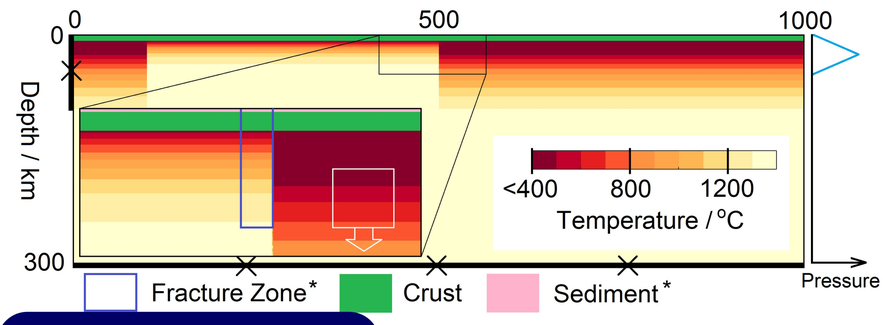

Fig. 2 (Initial Condition)

A free surface allows for the generation of topography and the resulting "ridge push" forces of ~2 TN/m are balanced at the boundaries by an additional pressure. Extra **external push** is applied by increasing this pressure.

An **additional pull** force is applied to the Pacific plate as a proxy for out of plane slab pull (assuming initiation began further south, adjacent to a spreading centre (Fig. 1A: SC)).

Mantle melting is calculated using Katz et al. 2003. The mantle directly above super-solidus crust is assumed to be hydrated by 0.05 wt% (**Fig. 4: green marks areas of slab crust which has crossed its solidus**).

All melt is extracted vertically. Melt production for "initially force balanced" model is plotted above panels A, B and C.
black = dry decompression melt
blue = fluid-fluxed melt

Duration of FAB-only magmatism in this model ~600 kYr. Matches drill core dating.

Magnitudes of horizontal push and vertical pull are varied in a parametric study (Fig. 3). No decompression melting occurs in models that are pushed externally by >2 TN/m **therefore no FAB**

All models that initiate do **transition to fully down-dip subduction.**

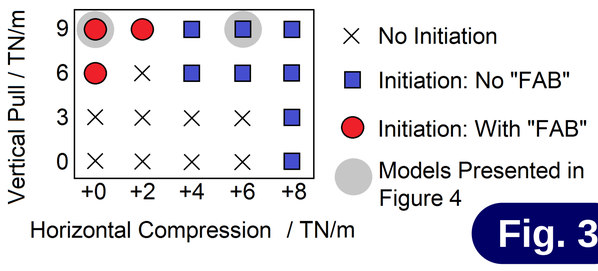

Fig. 3

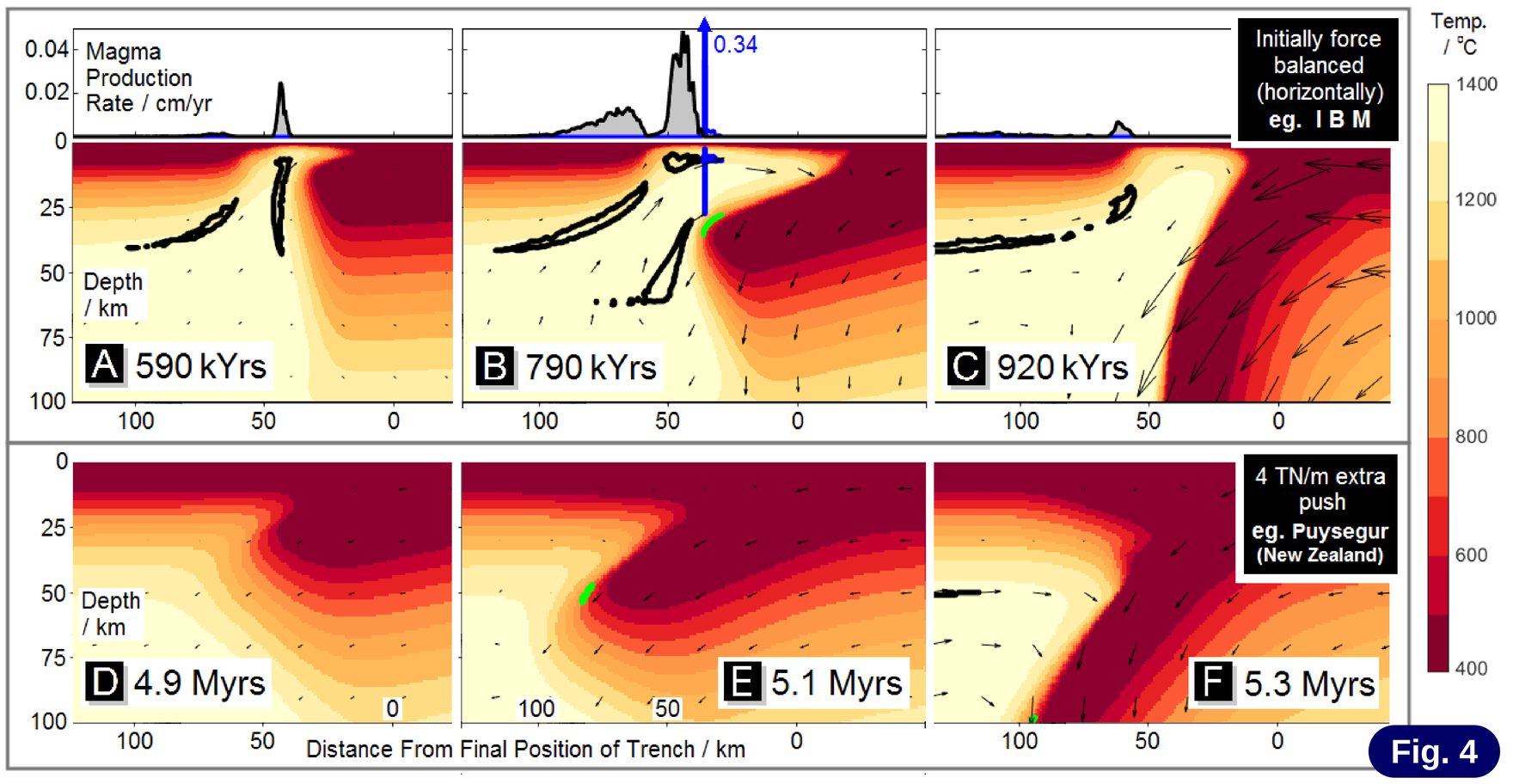

Fig. 4

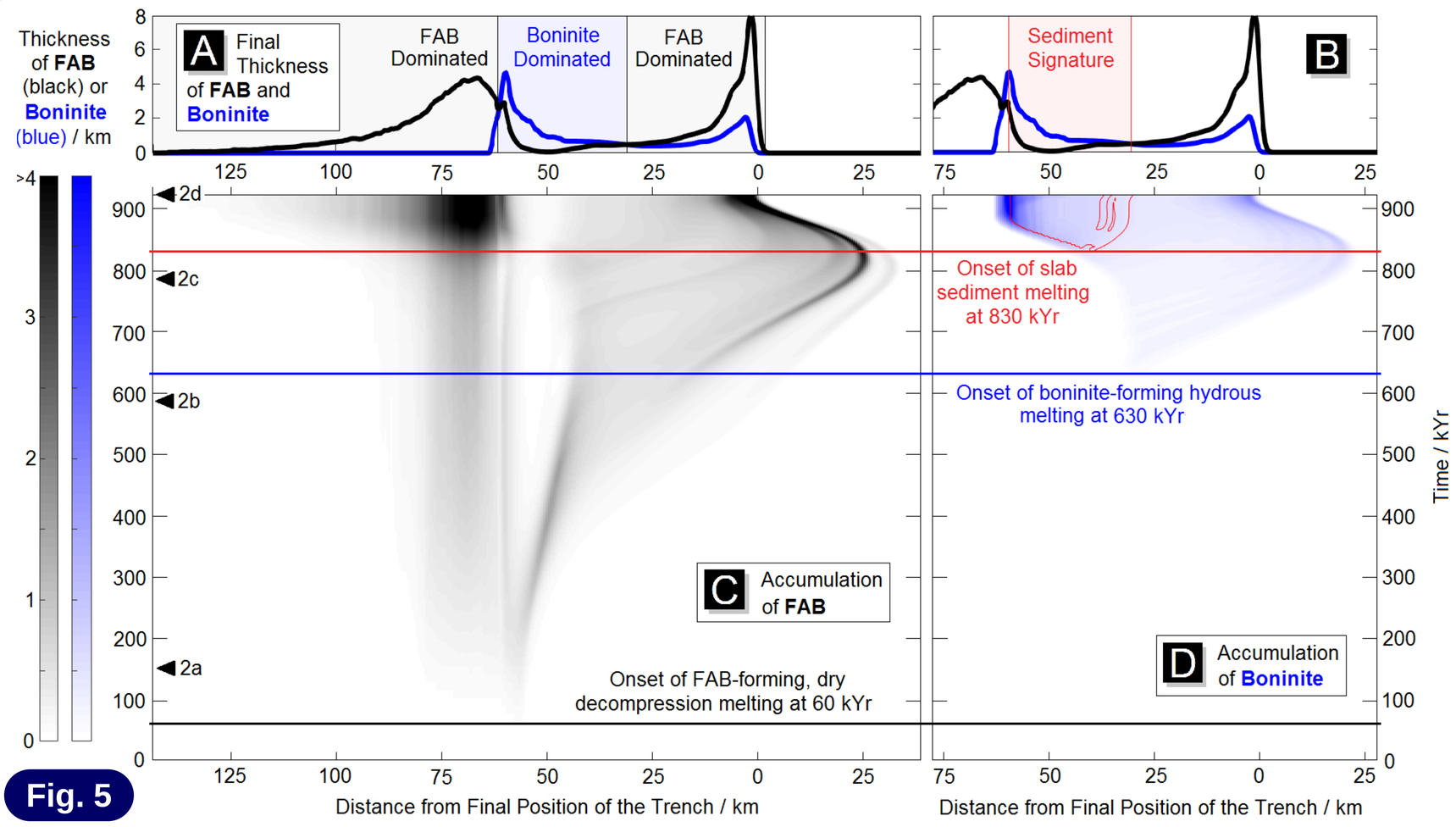

Fig. 5

Magmatic products are advected with the horizontal velocity at the surface. Fig. 5 is a timeline of accumulated dry decompression melts (**FAB**) and fluid-fluxed melts (**boninite**) for the "initially force balanced", or IBM, model.

FAB dominated regions are found nearest the trench and in the back-arc (observed at the IBM).

Red outline marks the region of the surface below which subducted sediment has crossed its solidus. The delay between the onset of boninite and the onset of a sediment melt signature is **also observed in the IBM rock record**.

Conclusions

- A horizontally force-balanced and vertically driven model is able to reproduce the rapid timescale and spatial distribution of magmatic products at the IBM.
- FAB generation in fact **requires** this type of initiation. When horizontally pushed, no FAB is formed.