Subduction Initiation:

Testable Predictions and Emerging Opportunities to Link Geological Observations to Modeling results

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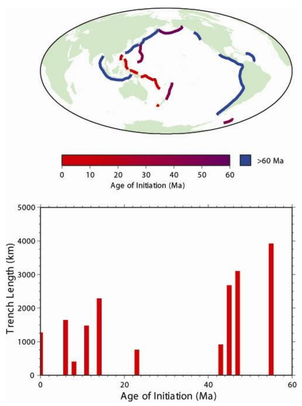
Initiation of Subduction: The Forced Convergence Model. Dynamics and Testable Predictions

Subduction initiation (SI), although only a transient phenomenon, is a vital phase of the plate tectonics cycle. A large proportion of subduction zones are young (Fig. 1) indicating that subduction initiation is a semi-continuous process in which the net force resisting SI is routinely overcome during the normal evolution of plates. It also means that the observational record for subduction initiation is rich (Fig. 2) and well poised for a systematic program of data collection and model development and testing.



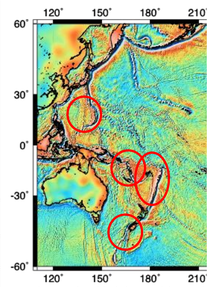
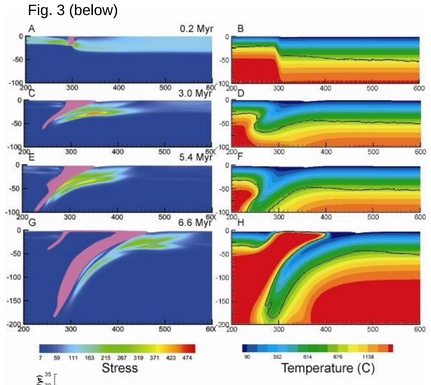


Fig. 2. Sites for Testing Subduction Initiation Hypotheses

•IBM (50-45 Ma; Forced versus Self-Nucleation Hypotheses.
•New Hebrides (~15 Ma) Polarity reversal
•Tonga-Kermadec (50-45 Ma) Forced versus self-nucleation
•Puysegur (~15 Ma): Details of forced Nucleation

Fig. 1. (Left) (a) Position of present-day trenches with age of initiation color coded. Trenches which initiated before the Late Cretaceous are coded with the same color. (b) Length of present-day trenches versus their age of initiation.

Fig. 3 (below)



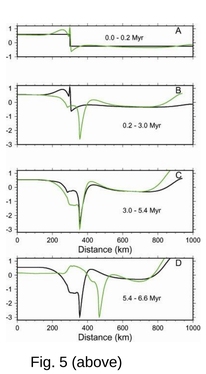
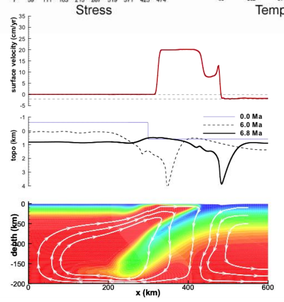


Fig. 5 (above)



Detailed dynamic models of the forced subduction hypothesis:

Fig. 3. Forced convergence across 10-40 Ma Fracture zone with viscoelastic flow. Deformation before and during initiation of a subduction zone at a fracture zone subject to compression.
Fig. 4. Details of the model showing relation between slab structure, topography, and plate kinematics
Fig. 5 Evolution of topography showing the distinctive pattern of uplift and subsidence associated with the initiation of subduction through initial forcing.

Fig. 4 (left)

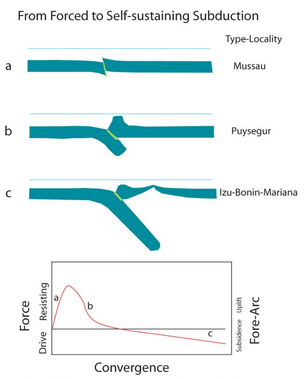


Fig. 6. Three phases in the initiation of subduction shown schematically, with type locality and position on the force versus convergence curve indicated.

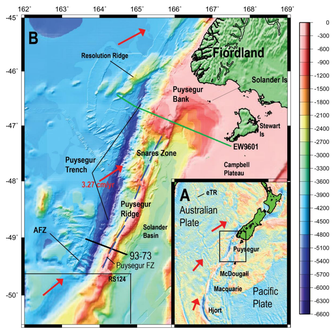


Fig. 7. The Puysegur Subduction zone of New Zealand is an outstanding laboratory to test detailed models for the initiation of subduction.

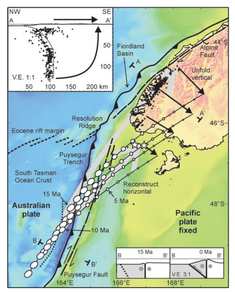


Fig 7. (Right) Regional rock-uplift history associated with subduction initiation beneath Fiordland, New Zealand through the inversion of 410 apatite and zircon fission track and (U-Th)/He ages.

Fig. 8. (Left) Unfolding and reconstructing the Fiordland subduction zone from Sutherland et al. Bold arrows represent the effect of unfolding the subducted plate, restoring it to the Earth's surface with down-dip line length preserved. The trajectory of sequential ellipses is the reconstruction of that point interpolated at 1 m.y. increments using AUS-PAC motion

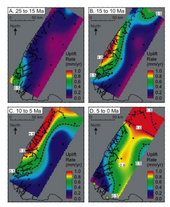


Fig. 7.

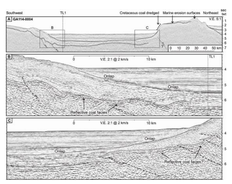


Fig. 9. Seismic-reflection and rock-sample data have been used to propose that the first-order physiography of the New Caledonia Trough and Norfolk Ridge formed in Eocene and Oligocene time, and was associated with the onset of subduction and back-arc spreading at the Australia-Pacific plate boundary

Hall, C., M. Gurnis, M. Sdrolias, L. L. Lavier, and R. D. Müller, Catastrophic initiation of subduction following forced convergence across fracture zones, **Earth and Planetary Sciences Letters, 212**, 15-30, 2003.
Gurnis, M., C. Hall, and L. Lavier, Evolving force balance during incipient subduction, **Geochem., Geophys., Geosys., 5**, 2004.
Sutherland, R., M. Gurnis, P. J. J. Kamp, and M. A. House, Regional exhumation history of brittle crust during subduction initiation, Fiordland, southwest New Zealand, and implications for thermochronologic sampling and analysis strategies, **Geosphere**, **5**, 2009.
Sutherland, R., et al., Lithosphere delamination with foundering of lower crust and mantle caused permanent subsidence of New Caledonia Trough and transient uplift of Lord Howe Rise during Eocene and Oligocene initiation of Tonga-Kermadec subduction, western Pacific **Tectonophysics**, in press, 2010.

Critical questions to be answered by a new generation of geodynamic models for subduction initiation

Question 1 Induced or Spontaneous?

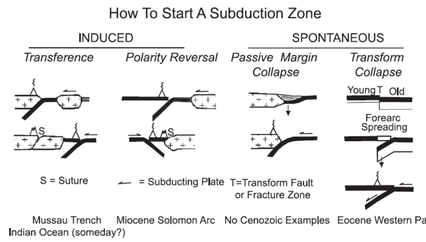


Fig 10 Different subduction initiation scenarios (Stern , 2004);

a) what is the dominate factor for slabs to overcome the tectonic resistance forces?
b) How does the mantle wedge flow field respond to different initiation environments?

Question 2 what can we learn from the magmatic records on the overriding plate?

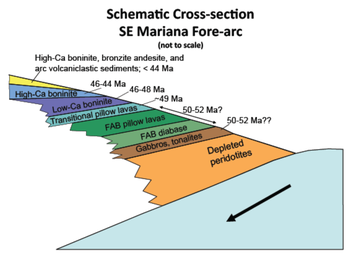


Fig 11. Inferred cross section from petrograhic and geochemical analysis of samples recovered from recent deep sea dives in the Mariana fore-arc near Guam. There is a time span of only several Myr between initial basaltic and boninitic outpourings.

a) During subduction initiation, can the related melting process be models and employed to explain the surface magmatic record?
b) What are the influence of the dehydrated fluid released from the slab?

Question 3 Is the 3-D effects important for subduction initiation?

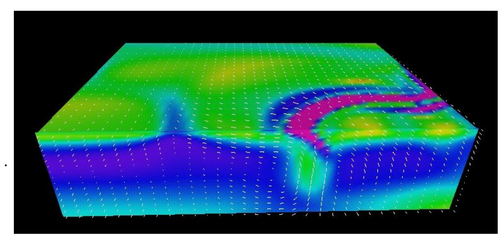


Fig 12. 3-D subdustion (After Tackely 1998)

a) Does subduction initiation start from a point and propagation along a fracture zone?
b) Does the curvature of the trench significantly influence the mantle wedge flow field and melting process?