

PS Pattern and Evolution of the 3-D Subduction-Induced Mantle Flow in the Laboratory: From Generic Models to Case Studies*

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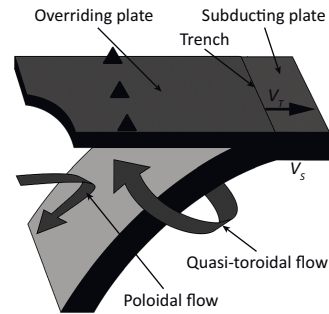
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Abstract

Three-dimensional self-evolving subduction models have been quantitatively analysed in the laboratory by means of a stereoscopic Particle Image Velocimetry (sPIV) technique. The purpose is (1) to provide information on the pattern of the quasi-toroidal mantle flow induced by subduction, particularly focusing on the location and magnitude of upwellings, and (2) to study the evolution of mantle upwellings in terms of location and magnitude. These generic models simulating a narrow subduction zone of ~750 km wide indicate that four types of upwelling are generated by subduction in a Newtonian mantle. One of these upwellings occurs laterally away from the sub-slab domain and is of high magnitude, suggesting that it could potentially trigger decompression melting, and thereby producing intraplate volcanism. Another set of experiments has been performed to investigate how slab width controls the pattern of mantle flow. Crucial points to study are (1) how the lateral extent of the slab controls the position and magnitude of mantle upwellings located laterally away from the sub-slab domain, and (2) what is the relationship between slab width and the extent of the toroidal-component cells. We tested slab widths ranging from narrow (e.g., Calabria) to wider (e.g., Tonga-Kermadec-Hikurangi) subduction zones. The models show that both the magnitude of the upwelling occurring laterally away from the sub-slab domain and the extent of the toroidal-component of mantle flow increase non-linearly with increasing slab width.

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① Introduction

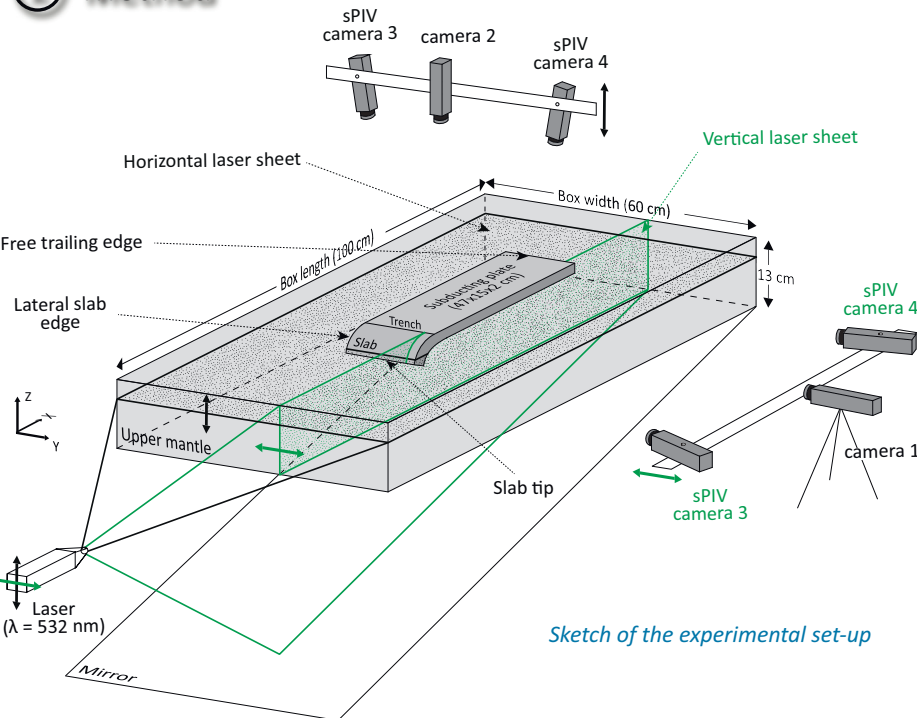


Sketch of subduction-induced mantle flow (modified from Long & Silver, 2008)

The **subduction process** is driven by the negative buoyancy force through the diving of dense oceanic lithosphere into the mantle. The **sinking of slabs** involves motion of subducting plates and **produces mantle flow**. In turn, **subduction-induced mantle flow** deforms the overriding plate and curves the slab leading to trench curvature. Furthermore, laboratory experiments, numerical modelling and anisotropy studies all suggest the occurrence of **quasi-toroidal mantle flow around the lateral slab edges**. This around-edge mantle flow has been proposed to induce strong **upwellings outboard of the subducting plate**. They might result in **decompression melting**, thereby providing a source for **intraplate volcanism** [Schellart et al., 2010]. Examples of intraplate volcanoes that could be explained by this mechanism are **Mount Etna** located near the southern edge of the Calabrian slab and the **Wrangell volcanics** located east of the eastern edge of the Alaska subduction zone.

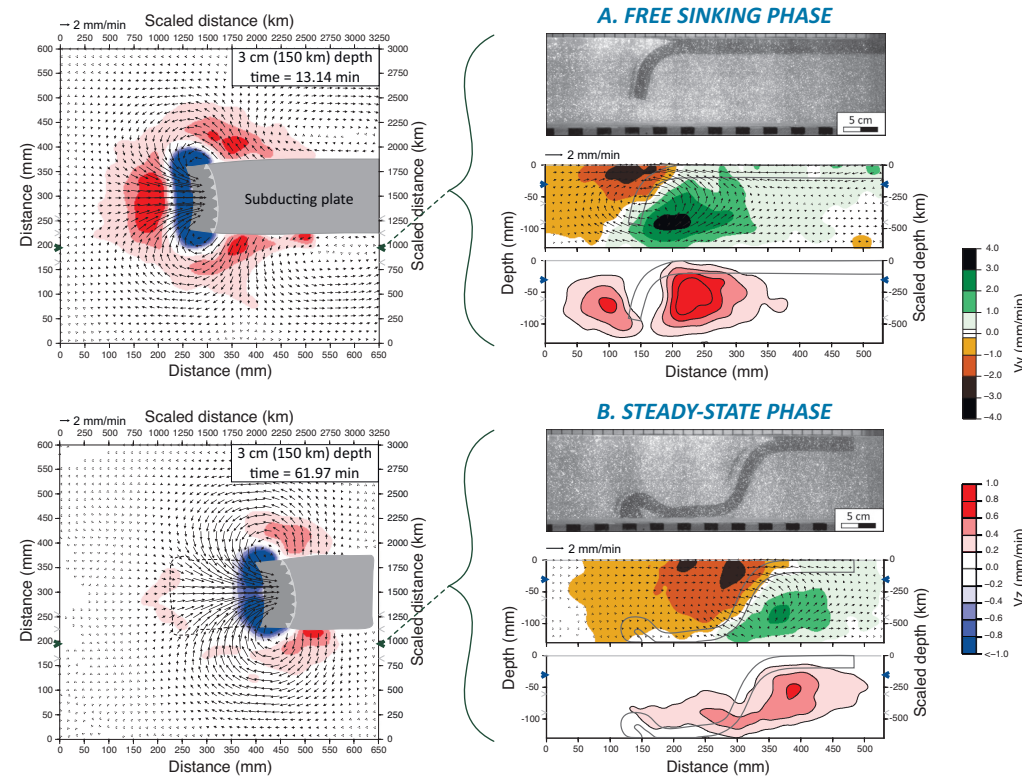
The purpose of our research is to **map the 3 components of the mantle flow velocity field induced by subduction from subduction initiation to maturity**. The main goal is to provide **predictions for the location and magnitude of upwellings** and to track their evolution through time. A second aim is to study the **role of along-trench slab dimension (slab width W) on subduction-induced mantle flow and associated upwellings**.

② Method

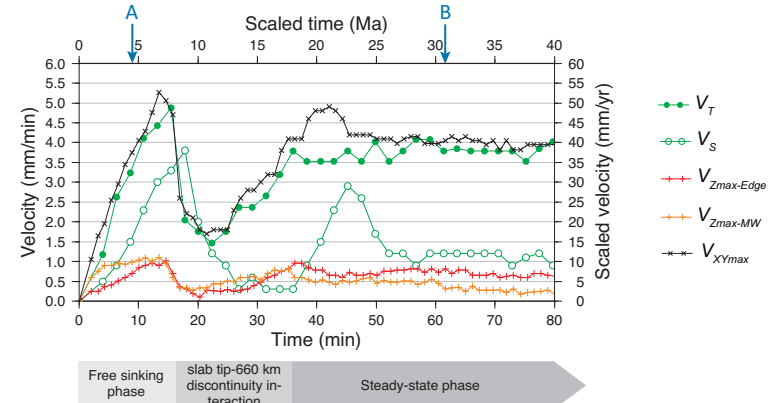


Sketch of the experimental set-up

③ Results of generic narrow-slab (750 km) models

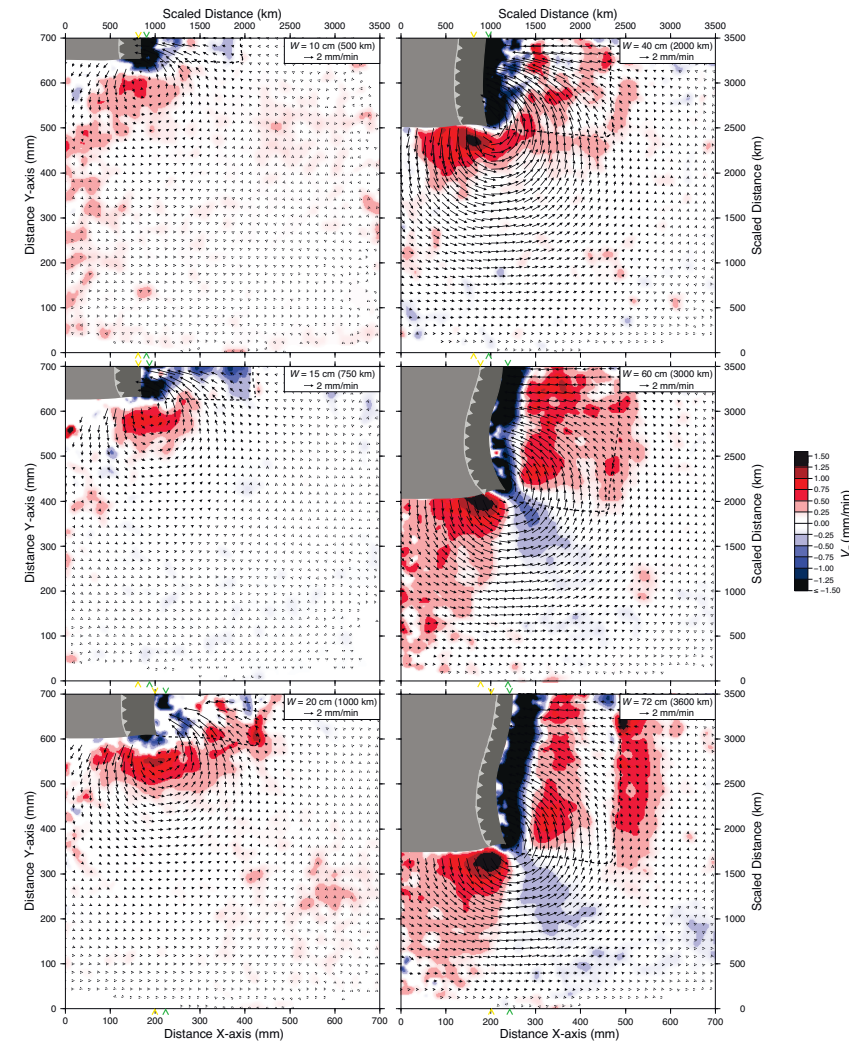


The 3 components of the subduction-induced mantle flow velocity field at (left) 150 km depth and (right) 150 km outboard of the subducting plate for (top) a late stage of the free sinking phase and (bottom) the steady-state phase. 1 mm/min scales to ~1 cm/yr. The two sketches on the right indicate the position of associated upwellings.



Kinematics of the subducting plate and velocity of the induced mantle flow

④ Results of models with different slab widths



The 3 components of the subduction-induced mantle flow velocity field at 275 km depth during the steady-state phase. 1 mm/min scales to ~1 cm/yr.

⑤ Conclusions

- Generic narrow-slab (750 km) subduction models indicate that:**
 - Four types of upwelling are produced, of which one is associated with quasi-toroidal flow around the lateral slab edges.
 - Upwellings associated to each lateral slab edge are present from subduction initiation to maturity.
 - The upwelling occurring in the mantle wedge is strong during the free falling phase and its intensity decreases after.
- Free subduction models with different slab widths W indicate that:**
 - Subduction kinematics and trench curvature are controlled by W .
 - Mantle upwellings are always produced close to the lateral slab edges, irrespective of W .
 - Wide slabs promote focused and fast upwellings close to the lateral slab edges.

References

Long, M.D., and P.G. Silver, 2008. The subduction zone flow field from seismic anisotropy: a global view, *Science*, 319, 315-318.
Schellart, W.P., 2010. Mount Etna-Iblean volcanism caused by rollback-induced upper mantle upwelling around the Ionian slab edge: An alternative to the plume model, *Geology*, 38(8), 691694, doi:10.1130/G31037.1.

Publication

Strak, V., Schellart, W.P., 2014. Evolution of 3-D subduction-induced mantle flow around lateral slab edges in analogue models of free subduction analysed by stereoscopic particle image velocimetry technique, *Earth and Planetary Science Letters*, 403, 368-379.