EGU2020-314: Lubrication Dynamics for Exhumation of high-pressure Rocks in Subduction Zones

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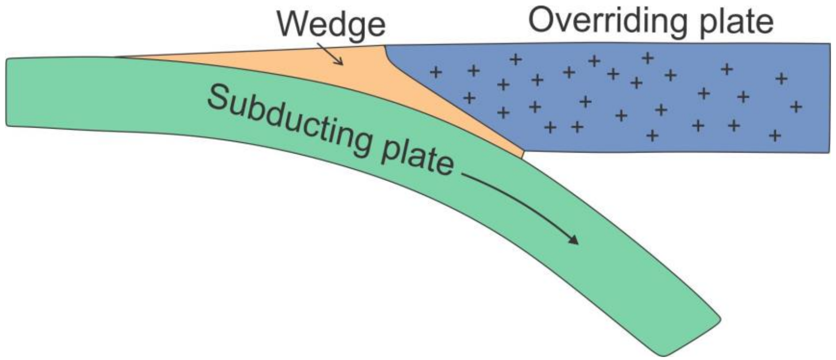
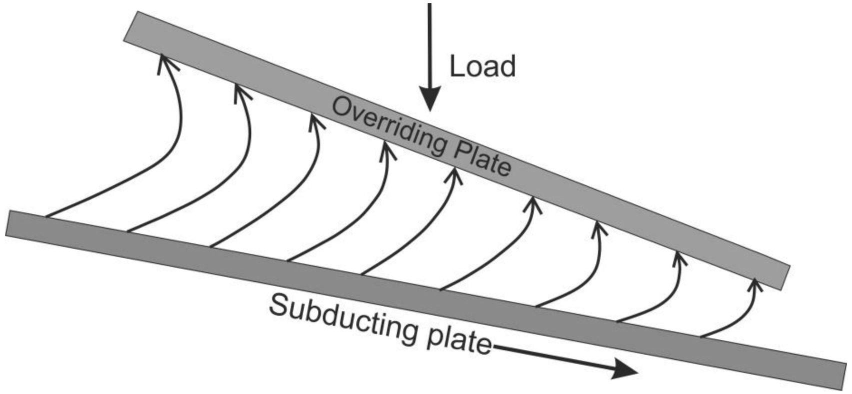
Lab website: http://jugeodynamics.org/

❑ Lubrication Mechanics

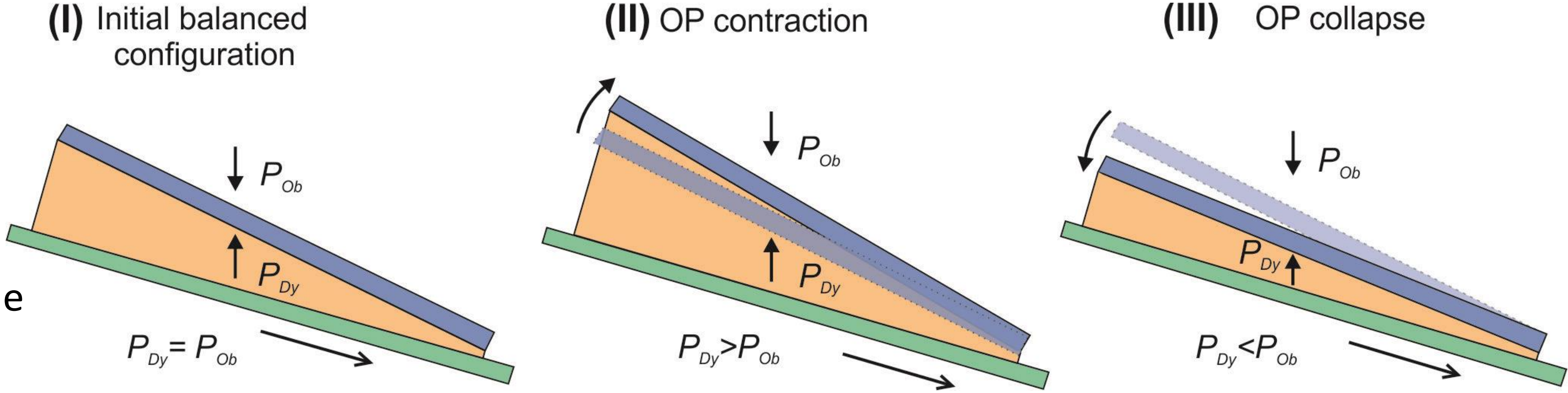
a)



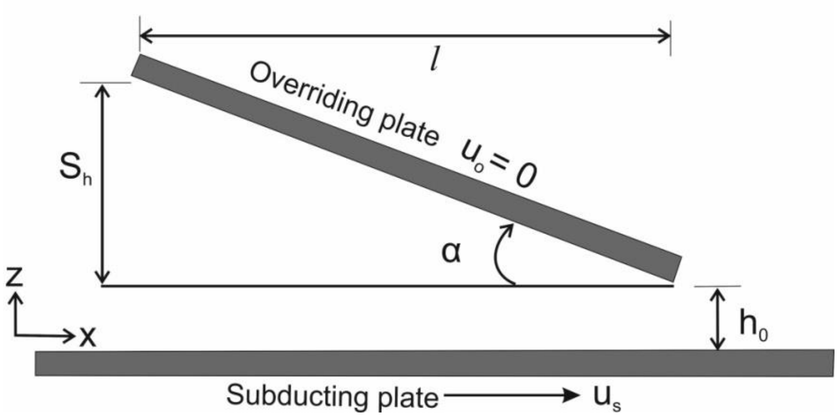
b)



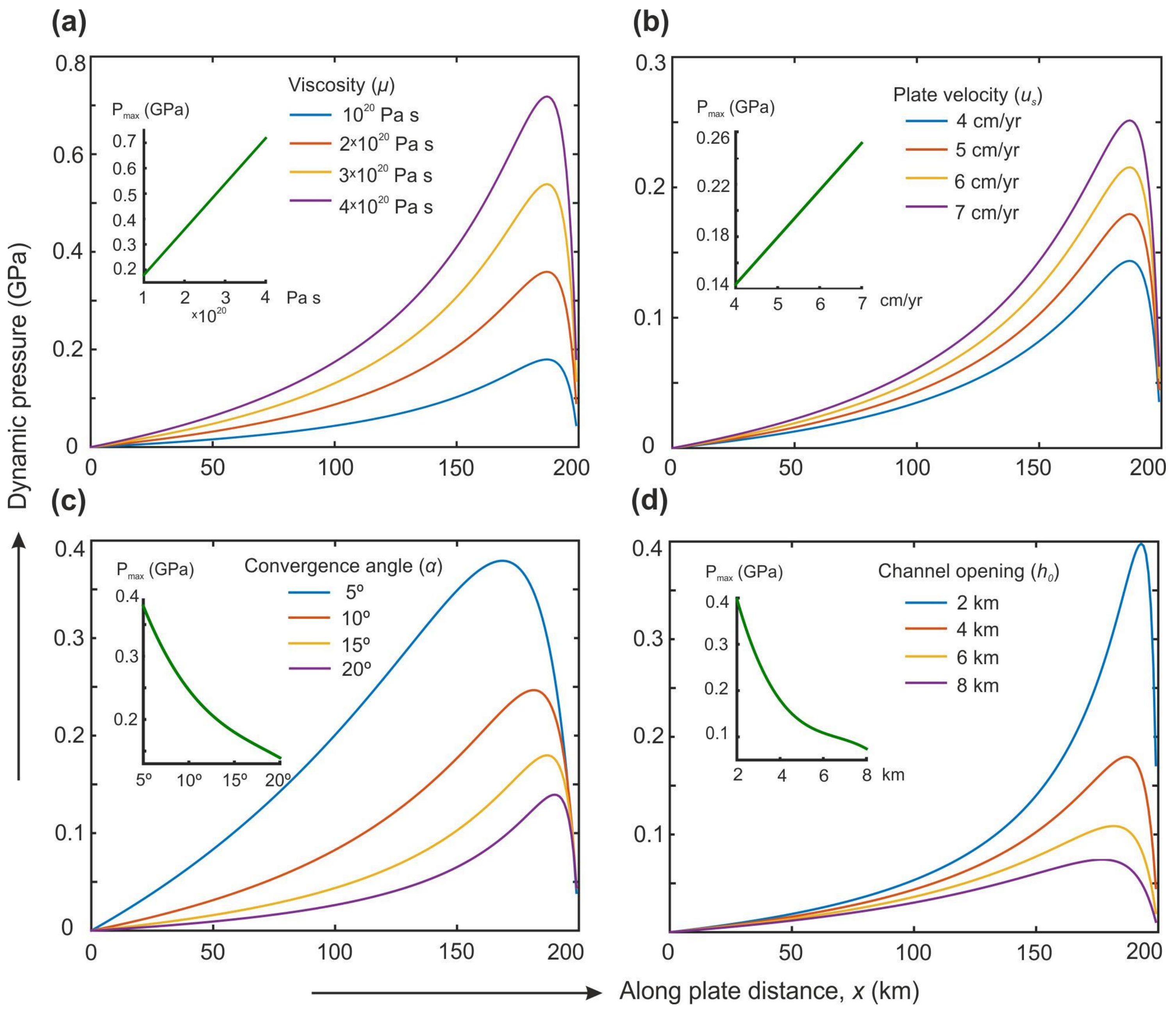
❑ Down-going motion of the subducting plate produces a flow induced dynamic pressure (P_{Dy}) within the wedge. The P_{Dy} interacts with overburden pressure *(P_{Ob})* acting on the Wedge–Overriding plate interface.



Analytical Solution of Lubrication Theory

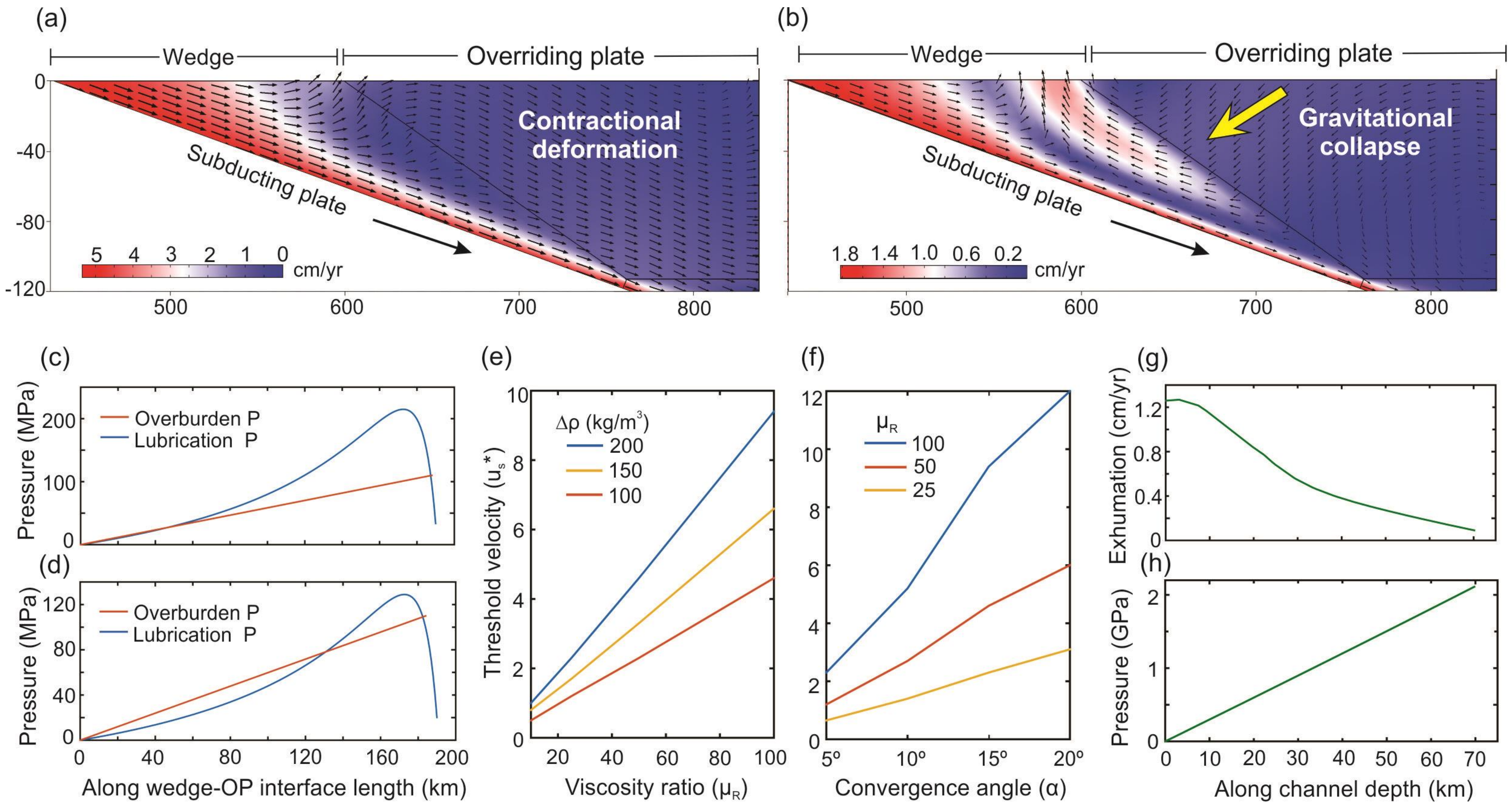


$$P_{Dy} = \frac{6xl(l-x)S_h}{(S_h l + h_0 l - xS_h)^2(S_h + 2h_0)}\,\mu u_s$$



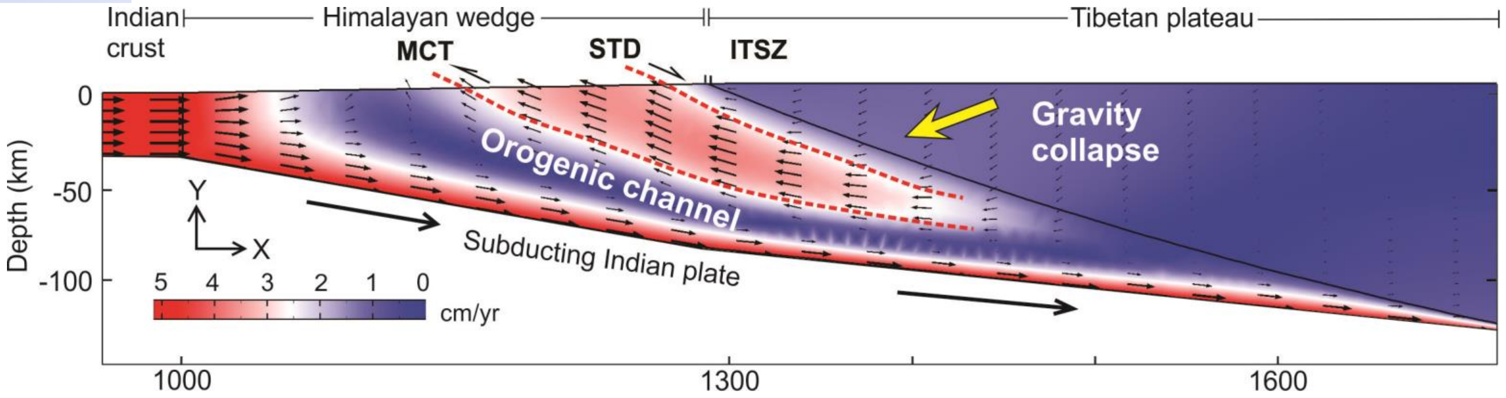
CFD Simulations applying Lubrication Dynamics

Dynamic pressure in subduction wedges remains in equilibrium with the overriding plate load; its drop causes the overriding plate to collapse. Such a collapse forces the deep crustal materials to extrude in the form of channels.

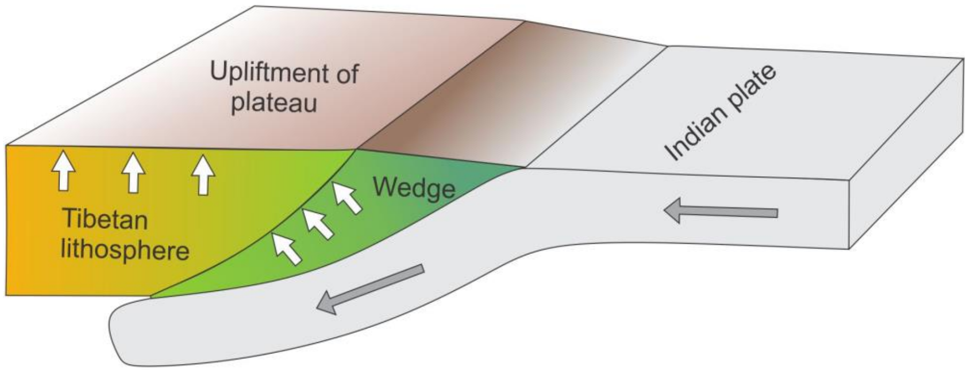


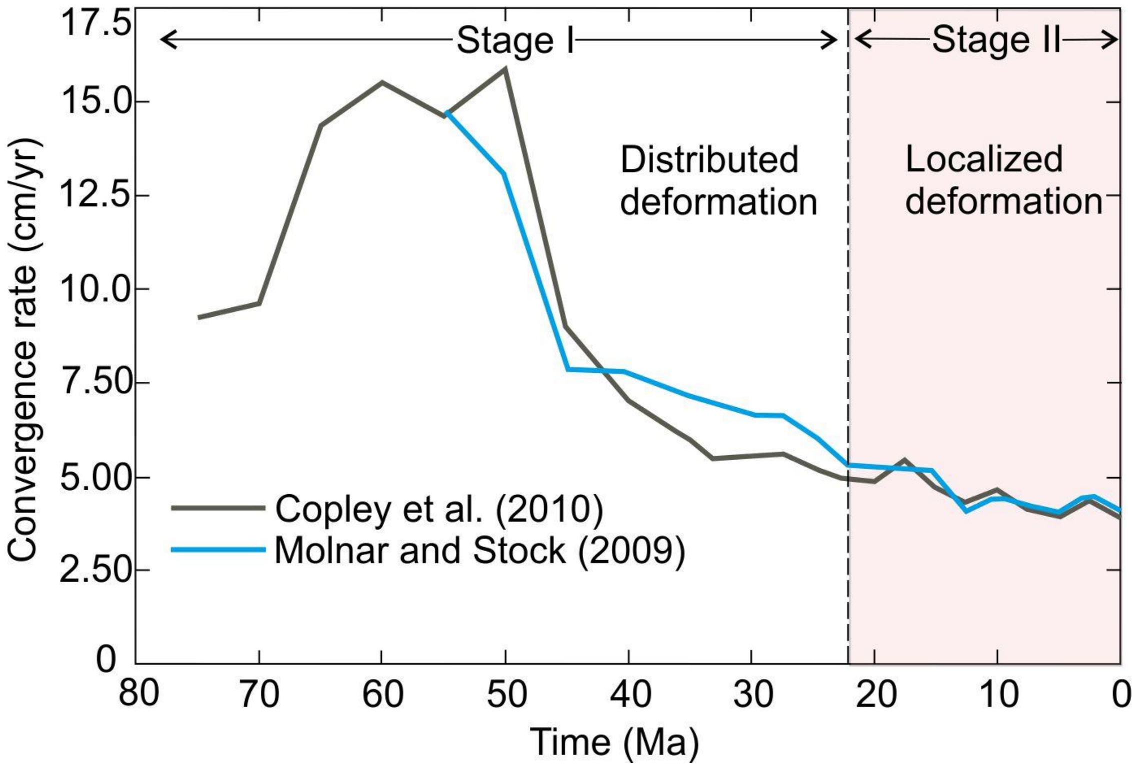
Modified after Maiti and Mandal, 2020

Implication to Himalaya

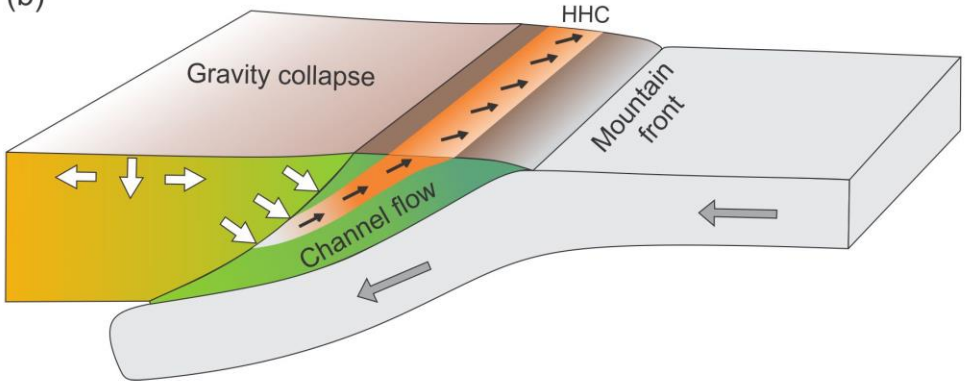


(a)





(b)



Modified after Maiti et al, 2020

Conclusions

1. The Lubrication theory has been applied in understanding exhumation mechanism of high pressure rocks in subduction wedges.

2. Dynamic pressure in subduction wedges remains in equilibrium with the overriding plate load; its drop causes the overriding plate to collapse. Such a collapse forces the deep crustal materials to extrude in the form of channels.

3. Decrease in subduction velocity, wedge viscosity or increase in density contrast between wedge and the overriding plate promote the collapse process.

4. Supports the geological interpretation of a two-stage tectonic evolution in the Tibetan plateau: Stage I (contractional tectonics) and Stage II (extensional tectonics).

5. The stage I to II switch occurred at ~22 Ma when the convergence rate reduced to ~5 cm/yr. At this stage, the Himalaya wedge started to accommodate crustal shortening, and the Himalaya started to gain elevation with the initiation of the Main Central Thrust.

6. The collapse of the overriding Tibetan plate due to reduction in convergence velocity is the key driving mechanism for extrusion-channel formation in the Himalayan wedge at the beginning of stage II at ~22 Ma and N-S to E-W extension.

Thank you for reading!

Further information can be found in published version of this contribution.

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Insights into the dynamics of an orogenic wedge from lubrication theory: Implications for the Himalayan tectonics

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ARTICLE INFO

Keywords:
Collision tectonics
Orogenic wedges
Overriding plate collapse
CFD simulations
Channel flow in the Himalaya

ABSTRACT

Using lubrication theory, we develop a mechanical model to evaluate the dynamic relation between an orogenic wedge and the overriding plate. The model suggests that the subducting plate motion produces a dynamic pressure in the wedge, which supports the gravity load of the overriding plate lying above it (*stable condition*). A drop in the dynamic pressure results in a rotational collapse of the overriding plate (*unstable condition*). We present an analytical solution to provide an estimate of the dynamic pressures in orogenic wedges. The lubrication model is also implemented in computational fluid dynamics (CFD) simulations to perform real scale numerical experiments, considering mainly three variables: 1) plate convergence angle (α), 2) subduction rate (u_s), and 3) viscosity ratio (R) between the overriding plate and wedge. The overriding plates attain mechanical stability when u_s exceeds a threshold value (u_s^*); otherwise, they become unstable as $u_s < u_s^*$. A linear increase of u_s^* with α as well as R widens the unstable fields. We demonstrate that the stable to unstable transition initiates a crustal flow channel in the orogenic wedge, driven by the collapse of the overriding plate. Such a collapse is associated with a kinematic transformation from contraction to extension in the overriding plate. Based on geological proxies, this article finally explains the formation of the orogenic channel in the Himalaya as a consequence of the transition from stable to unstable state in overriding Tibet, lying above the Himalayan wedge, when the Indo-Asia collision rate reduced to ~5 cm/yr at ~22 Ma.

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Short communication

How far does a subduction wedge follow lubrication dynamics?

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ARTICLE INFO

Keywords:
Convergent plate boundaries
Subduction velocity
Wedge taper
Lubrication theory
Dynamic pressure
Extrusion channel

ABSTRACT

Applications of the lubrication dynamics in subduction zones generally assume very small wedge taper angles ($\alpha < 1°$), satisfying the condition of flow within the subduction wedge sub-parallel to the bounding plates. However, many subduction systems have their plate interfaces with α far exceeding 1°. This article aims to address a fundamental question - is the lubrication theory valid for subduction wedges with $\alpha \gg 1°$? We test the validity by comparing its analytical solutions with the results obtained from the numerical solutions of full-form Stokes equations, and constrain α limit ($< 20°$) in applying the lubrication theory with errors $< 5\%$. We also use this theory to evaluate the magnitude of dynamic pressure in subduction wedges as a function of subduction velocity, wedge geometry and its viscosity, and then demonstrate how such dynamic pressure eventually controls the overriding plate deformation and extrusion channel formation in convergent tectonics. Drops in dynamic pressure facilitate gravitational collapse of the overriding plate, which in turn initiates the extrusion channel in a wedge.

1. Maiti, G. & Mandal, N. How far does a subduction wedge follow lubrication dynamics? *Phys. Earth Planet. Inter.* **298**, 106346 (2020). https://doi.org/10.1016/j.pepi.2019.106346

2. Maiti, G., Mandal, N. & Misra, S. Insights into the dynamics of an orogenic wedge from lubrication theory: Implications for the Himalayan tectonics. *Tectonophysics* **776**, 228335 (2020). https://doi.org/10.1016/j.tecto.2020.228335