PETROLOGICAL-THERMOMECHANICAL MODELING OF PRECAMBRIAN CONTINENTAL COLLISION: GEODYNAMICAL EFFECTS OF SUBCONTINENTAL LITHOSPHERIC MANTLE THICKNESS

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Introduction

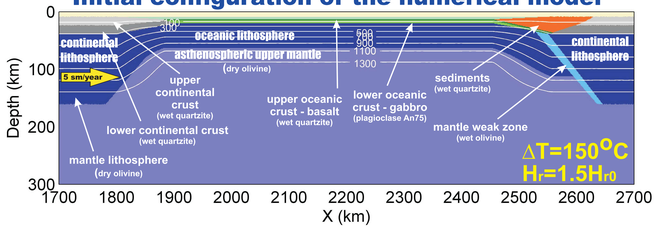
The Precambrian collision and orogeny remain enigmatic and contentious. Different tectonic styles of orogeny in the Precambrian compared to modern Earth are suggested by interpretations of geological, petrological and geochemical observations from Proterozoic and Archean orogenic belts.

Range of possible values of the thickness of the continental lithosphere is very wide (Artemieva, Mooney, 2001; Windley, Devis, 1978). Therefore, it is quite important to investigate the effect of lithosphere thickness on the collision processes in the Precambrian.

We present results of 2D petrological-thermomechanical numerical modeling of continental collision at crustal thickness of 35 km and convergence rate of 5 cm/year with variable thickness of subcontinental lithospheric mantle (SCLM). The numerical experiments cover the range of SCLM thickness from 65 km to 165 km. The model is based on the I2VIS code (Gerya and Yuen, 2003).

In our models the upper mantle temperature exceeded the modern temperature by 150oC, and the radiogenic heat production of continental crust is 1.5 times higher than that at present (Hr=1.5Hr0). Such conditions correspond to the Neoarchean–Paleoproterozoic boundary (Djomani et al., 2001).

Initial configuration of the numerical model



Results

In the case of SCLM thickness of 65 to 125 **(A – D)** the subduction terminates with slab break-off in the transition zone between oceanic and continental lithosphere. This occurred due to a rapid viscosity reduction in this zone that resulted from the deviator stress concentration, deformation, and viscous heating at the transition from subduction to continental collision. The slab break-off was accompanied by mantle upwelling and decompression partial melting, which led to the formation of a large igneous province in between the two continents instead of an orogenic belt.

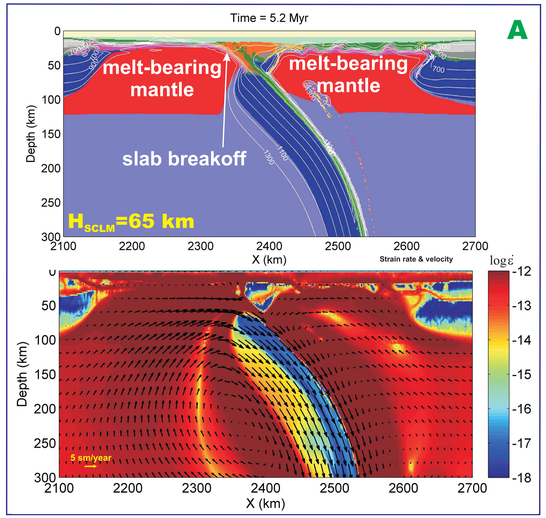
The time and the place of the slab break-off depend on SCLM thickness **(A – D)**. The thinner it was, the earlier the formation of the magmatic province and slab break-off occurred. The dimensions of the igneous province and this parameter are also inversely related.

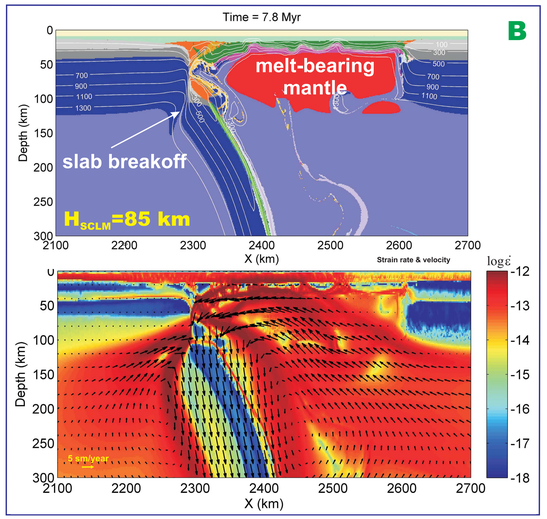
The slab break-off occurred at different depth levels, which decreased with a decrease in the lithosphere thickness.

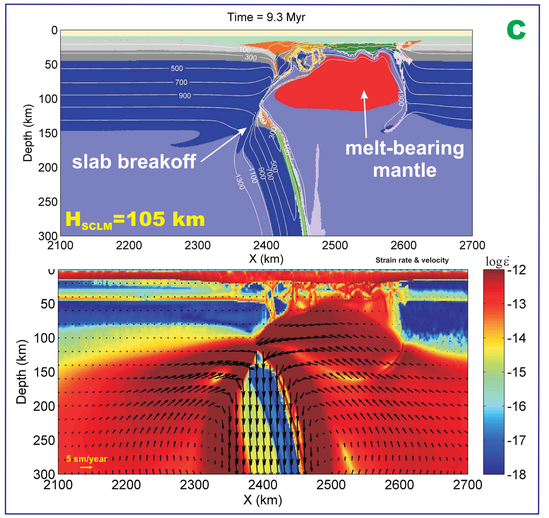
The slab was detached in 10.1 Myr at the depth of 160 km when the model with SCLM of 125 km **(D)**, whereas in the case of a very thin SCLM (65 km) the slab detached in 5.1 Myr almost near the very surface **(A)**.

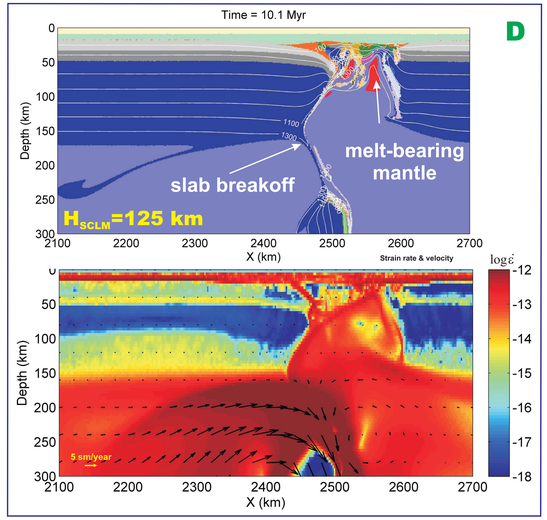
In the case of SCLM of 65 km the magmatic province was very large (>500 km wide) due to development at the both sides of the oceanic slab **(A)**, instead of one side provinces in the other experiments **(B – D)**.

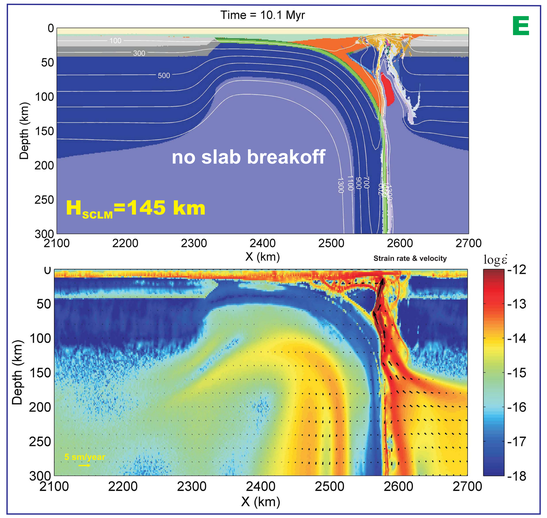
Continental collision with a very thick SCLM (of 145 km and more) proceeded without slab break-off and rather limited volcanism **(E)**. In this case, mantle upwelling occurred locally and it was not accompanied by intensive volcanic activity on the surface.











Summary

Collision process in the “hot” conditions that correspond to the ancient Earth is accompanied by increased heat generation during subduction and largely depends on the lithosphere thickness (Zakharov et al., 2015).

The style of the collision is the same for a SCLM thickness of 65 to 125 km, the subduction terminates with slab break-off followed by the formation of a large igneous province in between the two continents.

Collision of continents with a very thick SCLM did not leads to slab break-ff.

References

Djomani, Y.H.P., O'Reilly, S.Y., Griffin, W.L., Morgan, P., 2001. The density structure of subcontinental lithosphere through time. Earth Plan. Sci. Lett., 184, 605–621.

Artemieva, I.M., and Mooney, W.D., 2001. Thermal thickness and evolution of Precambrian lithosphere; a global study. J. Geophys. Res., 106, 16387–16414.

Gerya, T.V., and Yuen, D.A., 2003. Characteristics-based marker-in-cell method with conservative finite-differences schemes for modeling geological flows with strongly variable transport properties. Phys. Earth Planet. Int., 140, 293–318.

Windley, B.F., and Devis, F.B., 1978. Volcano spacings and lithospheric. Earth and Plan. Sci. Lett., 38, 291–297.

Zakharov, V.S., Perchuk, A.L., Zav'yalov, S.P., Sineva, T.A., and Gerya, T.V., 2015. Supercomputer Simulation of Continental Collisions in Precambrian: The Effect of Lithosphere Thickness. Moscow Univ. Geol. Bull., 70, #2, 77–83.

Acknowledgments

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