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A journey in cratonic mantle: example of Central and Southern Africa

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ABSTRACT

Cratons host the oldest rocks on the Earth, they described as regions with no deformation for a long period of time, cold and thick lithosphere (up to 200 km), depleted lithospheric mantle (higher magnesium number used as proxy) with a dry cratonic root. Recent studies from geochemistry and geophysical observations show that cratonic mantle can experiment modification (metasomatism, delamination) and the evolution of the lithospheric mantle is more complex than we generally think. Here we show recent results from a joint inversion framework using geophysical and geochemical datasets,to constrain the present-day thermochemical structure (temperature and major elements composition) of the mantle across Central and southern Africa. Central and southern Africa is a geologically intriguing region made up of several cratonic blocks (Kalahari, Tanzanian and Congo) surrounding by orogenic belts. More than the simple observations lithospheric thickness versus hot spot tracks and volcanism, our model show that main cratonic domains (Kalahari, Tanzanian and Congo) know different chemical evolutions.

Cratonic domains

Central and southern Africa host 3 larges cratonic domains :

- the Congo craton , one of the largest craton in the world with an inter cratonic sedimentary basin in its center.
- the Tanzanian craton in the East African Rift
- the Kalahari craton composed of the Kapvaal craton in South Africa and the Zimbabwe craton.

If the present-day volcanism is located along the rift zone, central and southern Africa knew intense kimberlitic volcanism in southern Africa and southern Congo. This kind of volcanism is ofter associated with the presence of diamond.

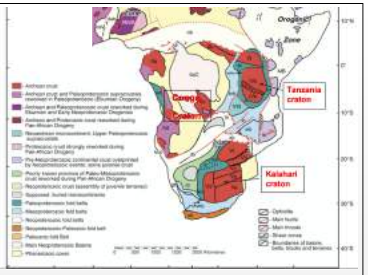
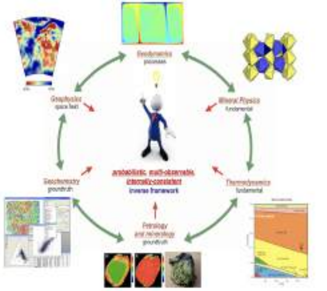


Fig. Simplified geological map of Central and Southern Africa (Begg et al. 2009)

JOINT MODELLING

Joint inversion approach specifically designed to retrieve the physical state (e.g. temperature distribution, compositional structure) of the lithosphere and sublithospheric upper mantle by inverting key data sets with complementary sensitivities to the main fields of interest.



To link geophysical observations and geodynamics, we need to have an idea of the physical properties of mantle minerals.
A full thermodynamic model and an internally-consistent thermodynamic database is used to guaranteeing that our models will not violate fundamental thermodynamic relations.

3 cratons (Congo, Tanzania and Kalahari) were affected at different degree by volcanism in the last 200 Ma.

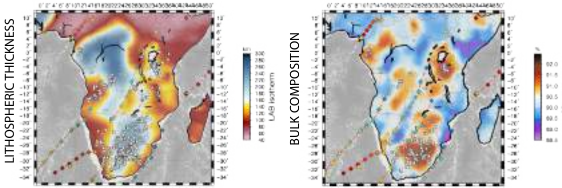


Fig. Comparison between the location of kimberlitic volcanism and lithosphere thickness and and the average Mg# of the lithospheric mantle . Coloured diamonds and red dashes lines are reconstructed hotspot tracks. Coloured circles are kimberlites for which we have eruption ages.

The next step will be the characterization:

- mantle viscosity
- water content

The story continues ...

The thermochemical structure and more precisely the bulk composition suggest that the thermochemical structure can also reflect structural heritage,printed in the lithospheric mantle.

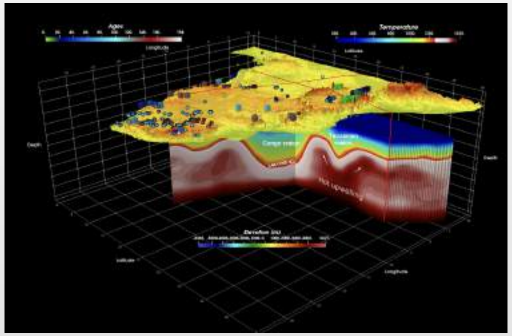


Fig. E-W section of our 3D thermal structure shows two well-defined branches of an asthenospheric upwelling that reach shallow depths

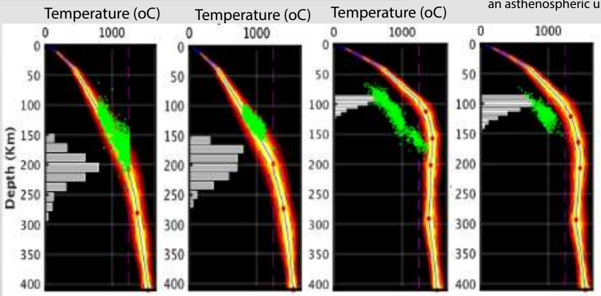
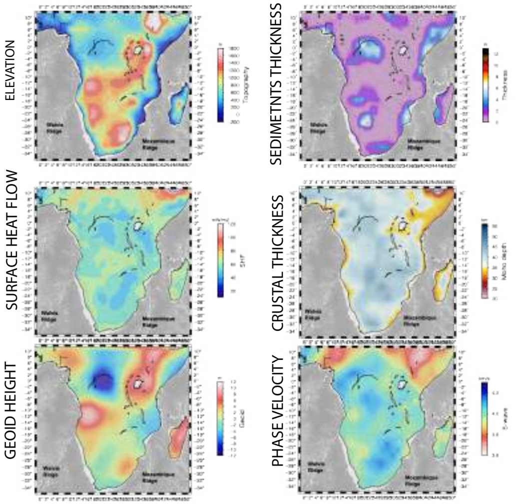


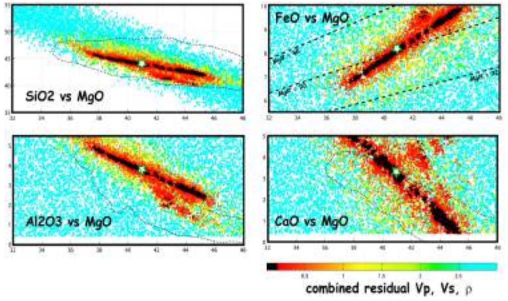
Fig. Comparison between geotherms derived from mantle xenoliths (red dots) and geotherm derived from our thermochemical tomography. Histograms representent the model distributions of lithispheric thickness.

Fig. Mantle xenoliths with macrocrystals with cm scale

The thermal structure affected as suggest the differences between geotherm estimated from mantle xenoltihs and present day thermal structure estimated from geophysical observations.

MULTI-OBSERVABLES





First, surface observable (elevation, surface heat flow, geoid) extract from global models and require to solve 1D isostatic and heat transfer problems. Then seismic observable (crustal models, dispersion curves) extracted from global model .To address the problem of non-uniqueness of compositional space, a datasets of mantle samples used here as prior information. We generally represent the chemical composition of the mantle with 5 major elements representing in term of oxides (SiO_2, Al_2O_3, FeO, CaO, MgO) and we consider here than the mantle is a peridotite.

Afonso et al. (2013). 3-D multiobservable probabilistic inversion for the compositional and thermal structure of the lithosphere and upper mantle. I: a priori petrological information and geophysical observables, JGR, 118, 15,2586-2617.
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Begg et al. (2009). The lithospheric architecture of Africa: Seismic tomography, mantle petrology, and tectonic evolution, Geosphere,5,1,23--50
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