Towards integrated, lithosphere-scale modelling of the thermal structure and evolution of basins

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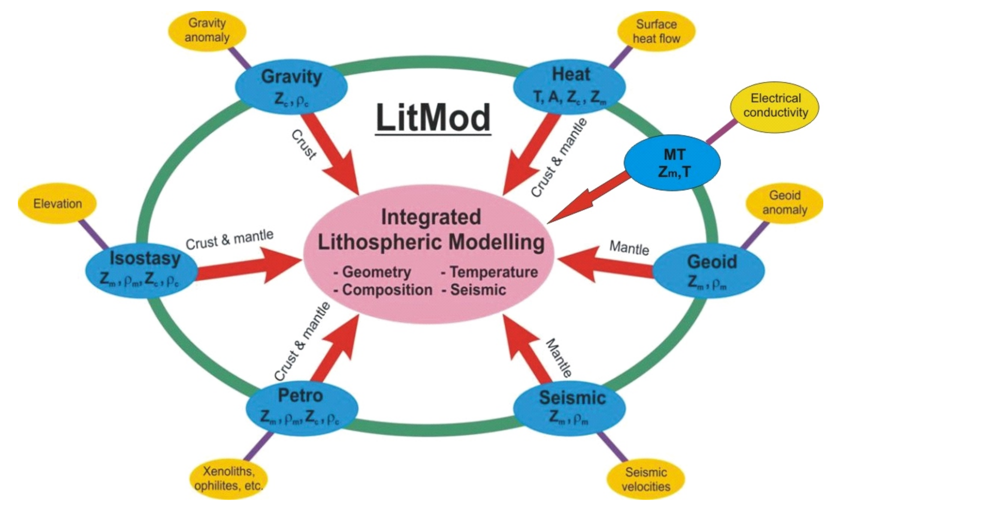
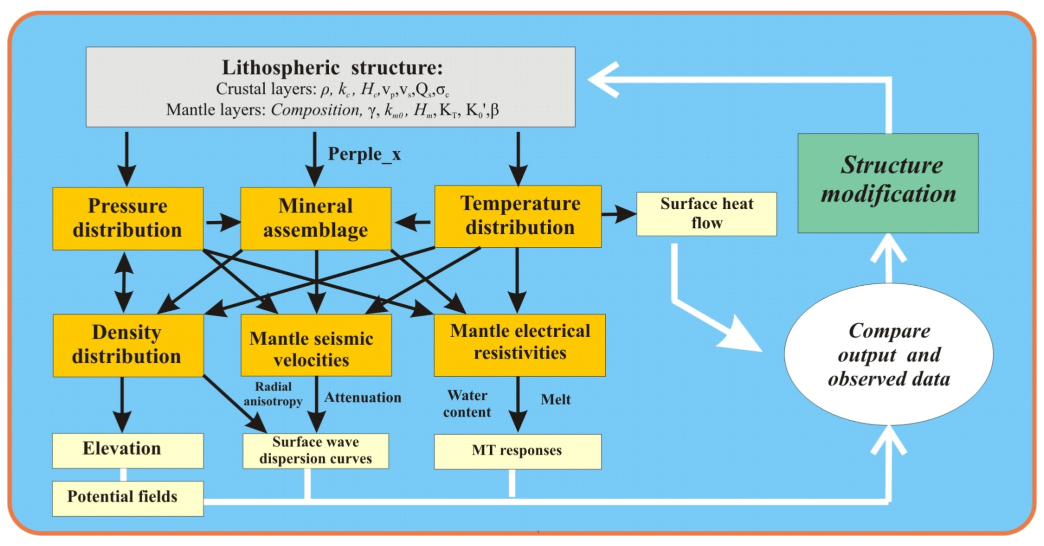
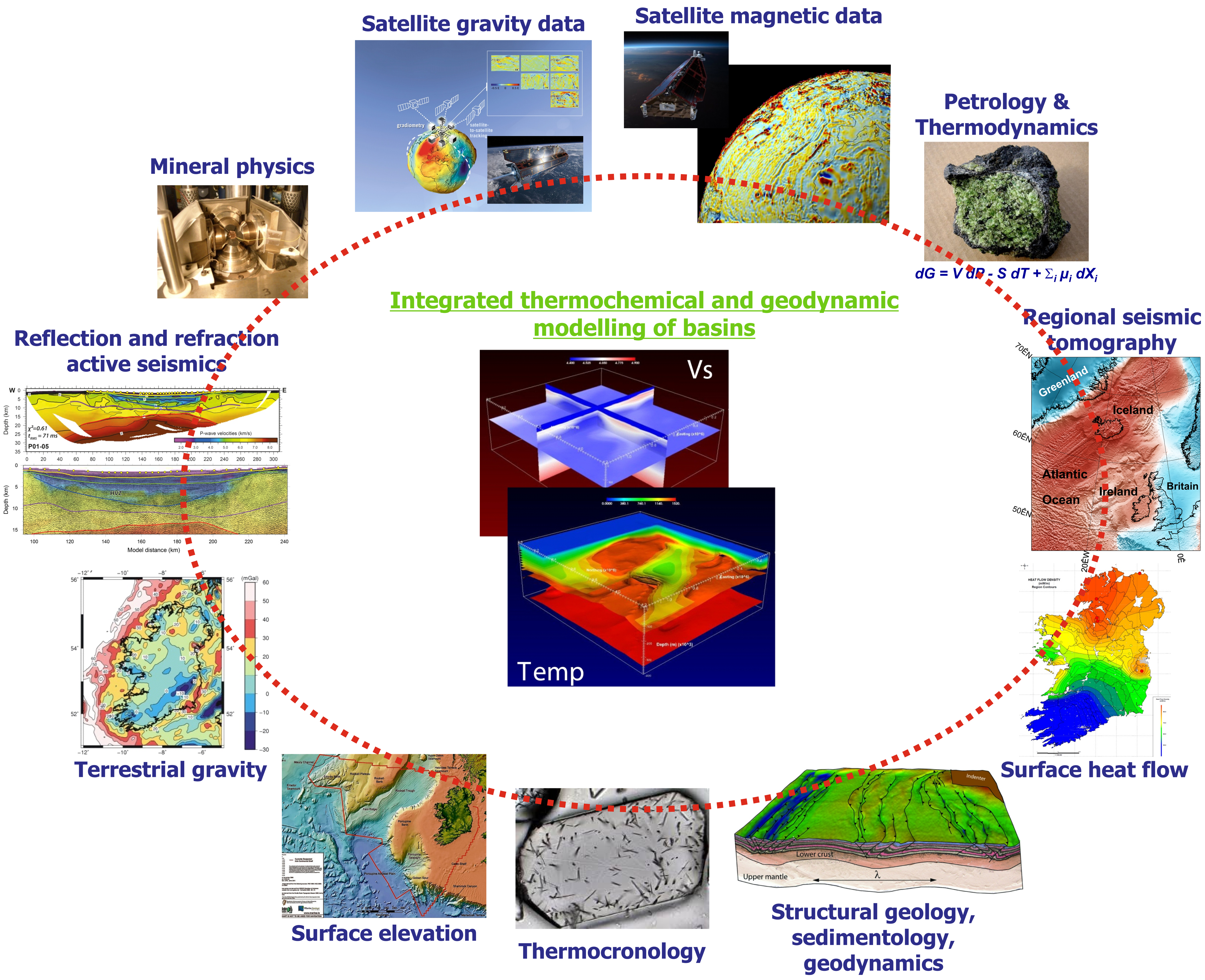
The shape and evolution of the geotherm beneath a basin depends on both crustal and mantle-lithosphere structure beneath it: lithospheric thickness and its changes with time (these determine the supply of heat from the deep Earth), crustal thickness and heat production (the supply of heat from within the crust), and the thickness and thermal conductivity of the sedimentary cover (the insulation). Detailed thermal structure of the basins can be modelled by integrating data on crustal structure and heat production with information from crustal and mantle seismic tomography and with other data (topography and bathymetry, gravity, surface heat flow). New methods of computational petrology provide a framework for self-consistent integrated modelling of basin structure and evolution, using the entirety of relevant data. New tomographic models of the North Atlantic - Arctic crust and upper mantle, constrained by unprecedentedly large waveform datasets, provide increasingly high resolution and accuracy of the imaging. Recent and first of a kind gravity and magnetic satellite data (e.g., GOCE and swarm ESA missions) offer new possibilities to image Earth's structure, from crust to deep mantle, with unprecedented lateral resolution, in particular in. Integrated, lithosphere-scale modelling based on the new terrestrial and satellite data and methods can offer significantly improved models of the thermal structure and evolution of basins.



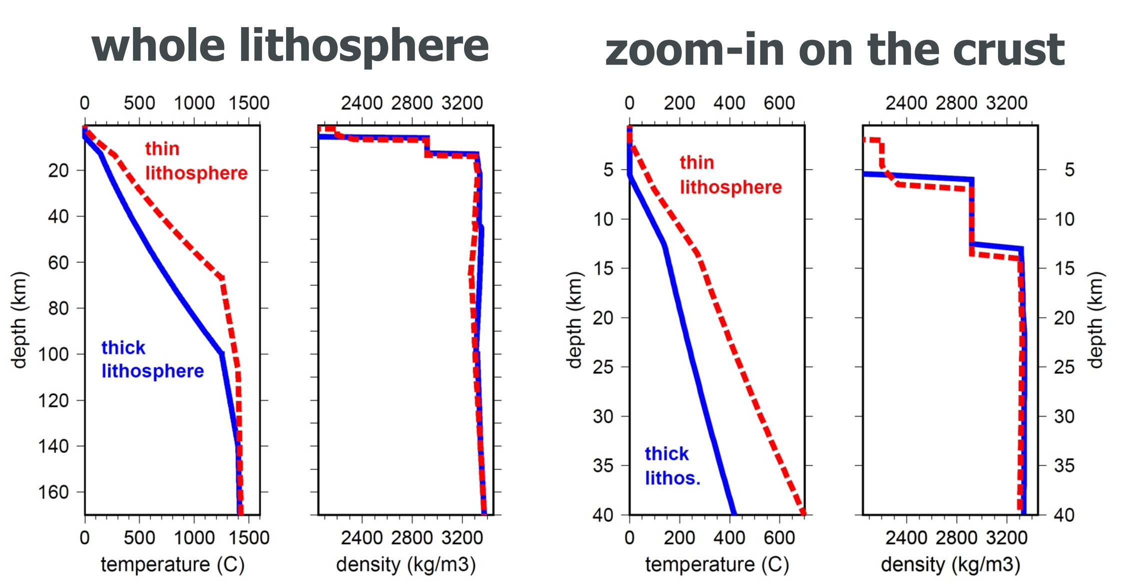


Our modelling approach is built within an integrated geophysical-petrological thermodynamically self-consistent framework including the lithosphere and the sub-lithospheric mantle down to the top of the transition zone at 410 km depth (e.g., Fullea et al., 2009). Essential physical properties in the mantle are determined using computational petrology as a function of the pressure, temperature and bulk composition (Connolly 2005). Modelling several geophysical data-sets simultaneously significantly reduces the uncertainties and inconsistencies related to the modeling of these data-sets separately or in pairs (e.g., Fullea et al. 2012; 2014).



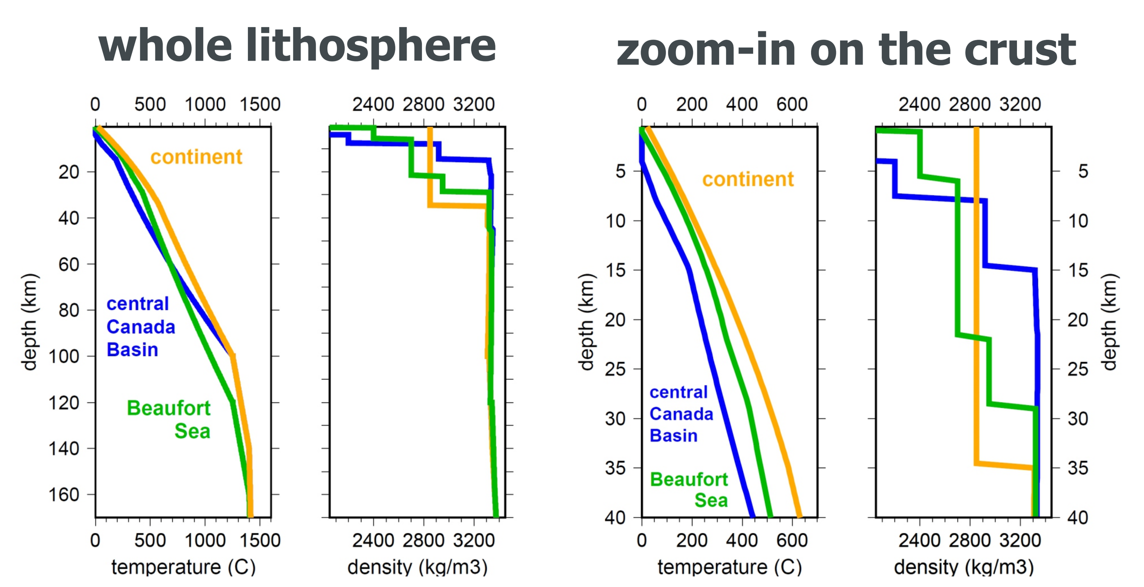
Our approach to understanding the thermal structure and evolution of sedimentary basins is based on integrative, 3D whole-lithosphere modelling of various complementary data sets across Earth Sciences, of both terrestrial and satellite origin. The near surface present day structure of basins (e.g., crystalline basement temperature) and its thermal evolution cannot be understood without knowledge of the lithospheric structure. Our approach uses:

- geophysical (seismic, gravity, magnetic), geological (mineral physics, petrology, deformation) and other data;
- new satellite gravity and magnetic data in areas where terrestrial measurements are scarce;
- thermochemical petrological and thermomechanical modelling of lithospheric-scale basin structure. Geodynamic modelling informed by thermocronology and stratigraphy;
- quantifying the coupling between deposition and thermal evolution of sedimentary layers and the evolution of lithospheric thickness and surface elevation. Isostatic and dynamic topography);



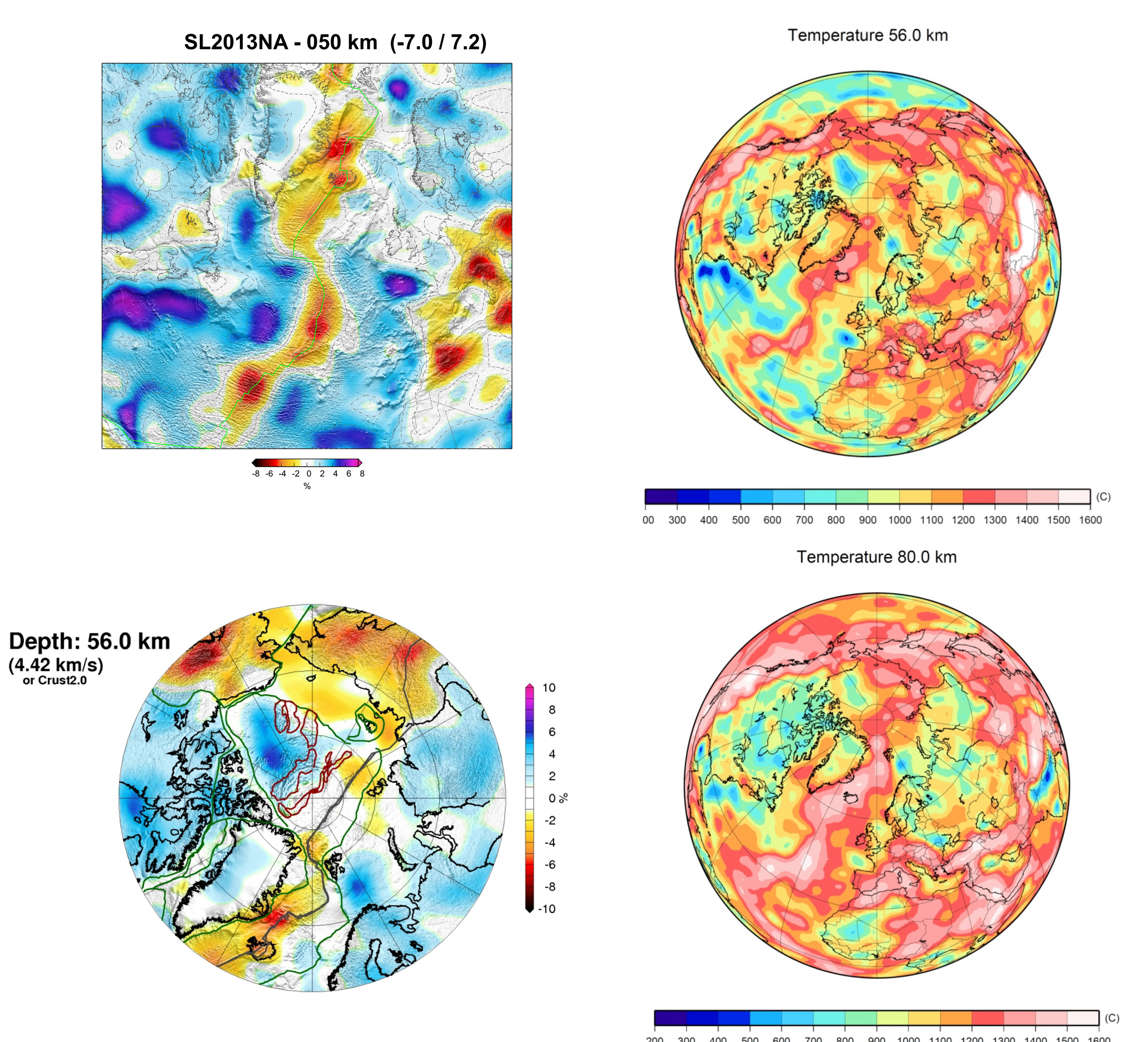
Whole-lithosphere modelling of basins:

- necessary to reconstruct the evolution of geotherms
- deposition and thermal evolution of sedimentary layers are inter-related with the evolution of the lithospheric thickness
- thinning of the lithosphere causes uplift and a steeper geotherm
- continental geotherms warmer than oceanic due to heat production in the thick continental crust
- essential petro-physical properties: thermal conductivity, diffusivity, heat production



Example of the marginal Beaufort Sea Basin:

- 1D model is insufficient, 3D required to explain the physical state of the basin at present
- thick sedimentary layer; warm uppermost mantle; cool deep lithosphere
- probable cooling of the deep lithosphere by the adjacent Mackenzie Craton, causing subsidence



Seismic tomography produces 3D models of seismic velocity distributions within the crust and upper mantle beneath and entire region. Using new methods of computational petrology we can infer temperature within the entire lithosphere from tomographic models (Schaeffer and Lebedev, 2013; 2015; Lebedev et al. 2015).

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