High-resolution subduction modelling of Cenozoic Andean Orogeny

Investigation controls of the foreland deformation patterns

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In Short

- High-resolution 2-D and 3-D geodynamic models of orogen-foreland system
- Investigation factors changing the lithospheric strength and further controlling shortening modes and deformation patterns in the foreland
- Investigation 3-D features of structural deformation changes in Central Andes
- Understanding the formation of Andean Orogeny during the subduction

The Andean Orogeny is the result of the crustal shortening of the upper plate during the Cenozoic Nazca plate subduction beneath South America plate. The second highest plateau Altiplano-Puna Plateau on the earth was formed with a pronounced N-S oriented deformation diversity [1]. In particular, there is a thin-skinned Subandean fold-and-thrust belt in the north Altiplano foreland, whereas the deformation style changes to the thick-skinned structure in the south Santa Barbara and Sierras Pampeanas province. Two questions about why the high plateau has developed only in the Central Andes during the Cenozoic time and how the different deformation patterns in the foreland adjacent to the plateau are formed in Central Andes, remain unclear. The previous 2D numerical studies of the Central Andes [2] demonstrated that the shortening process might be related to the lateral north-to-south variation in the strength of the lithosphere and friction coupling at slab interface. However, the exact nature of the strength reduction was not explored due to the lack of high numerical resolution and 3-D numerical models at that time.

In this project, we use a highly scalable parallel code LaMEM (Lithosphere and Mantle Evolution Model) [3] to develop high-resolution 2-D and 3-D geodynamic models to understand the evolution of foreland deformation. This code is one of the most advanced geodynamic code and have a nearly perfect performance in MPI-based parallelisation computing on HLRN. We first focus on how factors (i.e., lithospheric and crustal structure, friction coefficient) control on the lithospheric strength and further foreland deformation through high-resolution 2-D models of the orogen-foreland system. As a second stage, we employ 3-D numerical models to investigate 3-D aspects of how the lithospheric strength controls shortening modes and deformation styles in the foreland of Central Andes. Furthermore, we are interested to understand the topography evolution and subduction dynamic during the formation of Andean Orogeny by adding the subduction process of the Nazca Plate to the 3-D model.

Model results demonstrate that the difference in crustal thickness between orogen and foreland decides the shortening style. Pure shear shortening occurs when the orogenic crust is not thicker than the foreland crust. In the simple shear compression, which is characterized by foreland underthrusting beneath the orogen, the orogenic crust is thicker than that in foreland. If the lithosphere of both orogen and foreland are thin and weak, the shortening type returns to the pure shear. Regarding the deformation pattern, the fully thick-skinned structure is only formed in pure shear compressing models. The initiation of the thin-skinned thrust in the latter three patterns ensues from the simple shear shortening. The factor of weak foreland sediments is required to promote the extent of the thin-skinned deformation zone. When the orogenic strength is about a third of the foreland strength or less, a fully thin-skinned structure is formed in the foreland weak sedimentary layer. The strength difference can be resulting from lithospheric thinning or crustal thickening in the orogen, or a strengthened foreland achieved by thickening its lithosphere, or both. We apply our high-resolution 2-D and 3-D models to the natural foreland region of Altiplano-Puna Plateau and reproduce the foreland deformation patterns successfully (**Figure 1**).

Since this is a subproject of Project StRATEGy (Surface processes, Tectonics and Georesources: The Andean foreland basin of Argentina), the project is tightly coupled with other projects. The new data collected from field studies planned in other projects will be used to better constrain the model input and to make the model results more robust and realistic. In turn, the modelling results will help to better evaluate geological, geomorphic and geophysical aspects of basin evolution in Andes.

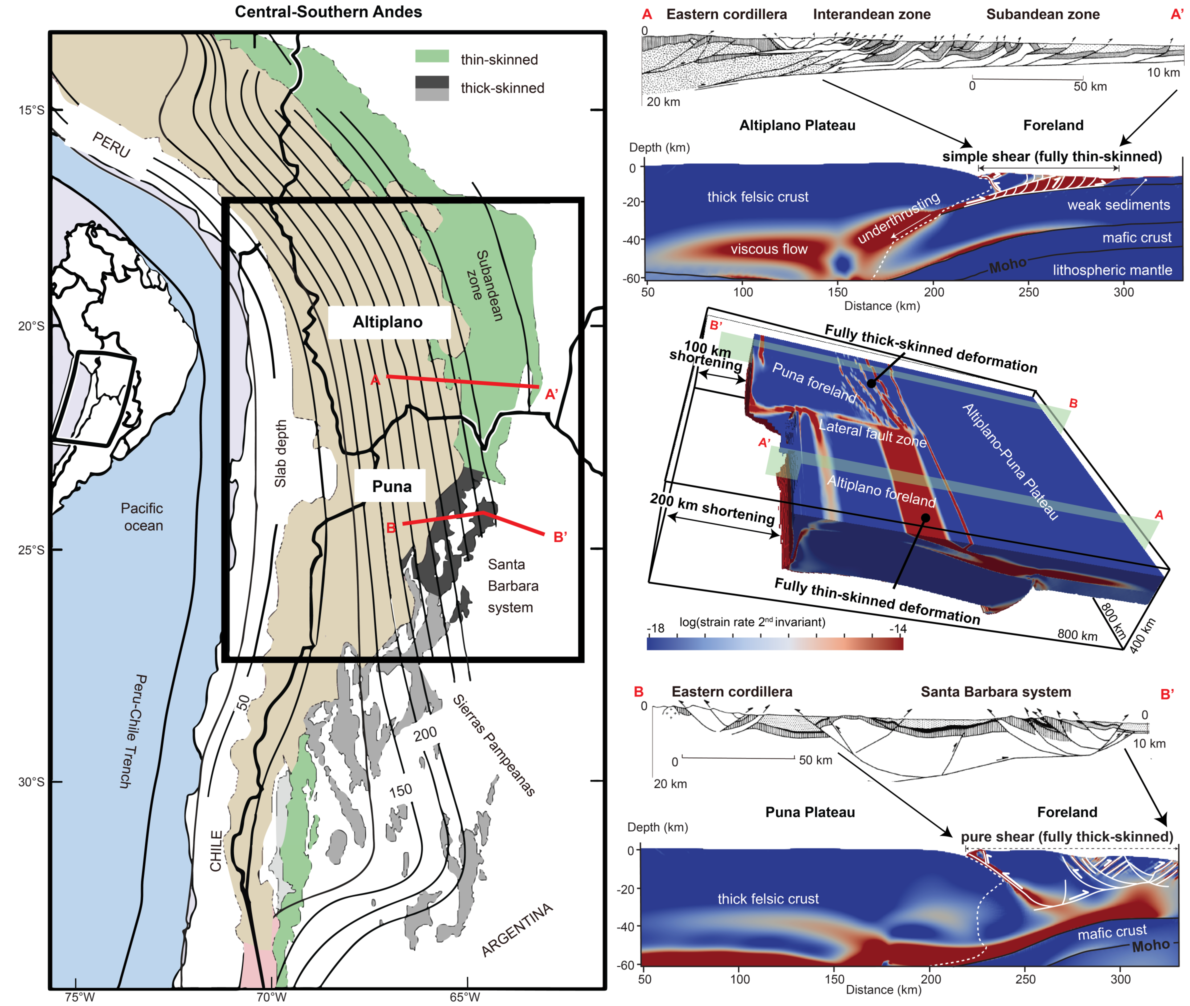

Figure 1: High-resolution models with application to Central Andes. The map is modified from Kay and Coira (2009) [4]. Geological structures of two cross section A-A′ and B-B′ are modified from Kley et al. (1999) [5]. The 2-D and 3-D models reproduce not only the same structure in the foreland but also the reverse fault in front of the foreland.

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More Information

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Project Partners

Other projects in IRTG-StRATEGy

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