



Activity Report 2024 – Task Forces / Coordination Committees

Project Title: Lithospheric evolution and tectonic carbon cycle

Project No.: 2024-TF1

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1. Highlights of recent ILP Task Force work/results

The four following are the main highlights of recent ILP Task Force work/results:

- 1) As is typical of the Tethyan belt's subduction-collision zone, the Western Alps exhibit massive (ultra)high-pressure ((U)HP) rock exhumation. However, the geometry and behavior of subduction-channel and mantle-wedge rocks during exhumation are still poorly constrained by independent geophysical observations. We use a new local earthquake tomography model of the entire fossil subduction zone of the Western Alps based on data collected during the CIFALPS and CIFALPS2 passive seismic experiments, and the first receiver- function profile across the Ligurian Alps, to investigate the styles of subduction-channel and mantle-wedge exhumation. In the northern Western Alps (low upper-plate divergence), a thickened subduction channel can be detected, but no exhumed mantle wedge is found beneath the Gran Paradiso (U)HP dome. In the southern Western Alps (intermediate divergence), an exhumed mantle wedge is detected beneath the Dora-Maira (U)HP dome above a serpentinized subduction channel. In the Ligurian Alps (high divergence), an exhumed mantle wedge and a former subduction channel are detected at much shallower levels beneath the Voltri-Valosio (U)HP dome, and above a shallow-dipping lower-plate Moho.
- 2) According to deep-sea oxygen isotope data, global surface temperatures and $p\text{CO}_2$ level have been steadily increasing since the early Cenozoic, reaching a peak at 53–51 Ma. To explore the dynamic mechanism of Tethyan tectonics' influence on these $p\text{CO}_2$ level variations, geodynamic numerical modeling based

on global plate motion and seafloor age reconstruction is constructed. The findings indicate that, between 60 and 51 Ma, the carbon degassing in the India-Eurasia region is three to six times that of the other regions, including Southeast Asia, the Eastern Pacific, and the Western Pacific. Calculated carbon degassing in the India-Eurasia region and the Cenozoic atmospheric $p\text{CO}_2$ curve are significantly correlated. Thus, we propose that early Cenozoic climate change is greatly influenced by the carbon influx in India-Eurasia, when combined with previous studies on magmatic and geochemical proxies of CO_2 emissions in the Tibetan region.

- 3) The cutting-edge petrological-thermomechanical numerical method has been developed through the efficient integration of chemical and physical processes in the geodynamic simulations. Simulations of tectonic carbon cycle demonstrate that solid-state diapirs formed in the forearc remove substantial amounts of sedimentary carbon and dominate the carbon release from subducting sediments in the ocean-continent subduction zone. These amounts are significantly greater than those removed by subarc diapirs and metamorphic reactions. The massive carbon stored in the overlying lithosphere reservoir is formed via the diagonal transport of forearc diapirs, thus reducing the subduction carbon flux to the subarc depth. These results obtained via the use of the developed geodynamic method provide new insights into the subduction of carbonate sediments.
- 4) The redox state of arc mantle has been considered to be more oxidized and diverse than that of the mid-ocean ridge, but the cause of the variation is debated. We examine the redox state of the Cenozoic global arc mantle by compiling measured/calculated $f\text{O}_2$ of olivine-hosted melt inclusions from arc magma and modeled $f\text{O}_2$ based on V/Sc and Cu/Zr ratios of arc basaltic rocks. The results indicate that the redox state of Cenozoic arc mantle is latitude dependent, with less oxidized arc mantle in the low latitudes, contrasting with a near constant across-latitude trend in the mid-ocean ridges. We propose that such a latitude-dependent pattern in the arc mantle may be controlled by the variation in the redox state of subducted sediment, possibly related to a latitudinal variation in the primary production of phytoplankton, which results in more organic carbon

and sulfide deposited on the low-latitude ocean floor. Our findings provide evidence for the impact of the surface environment on Earth's upper mantle.

2. Presence at international meetings/workshops (this year)

More than 50 peoples have attended European Geoscience Union annual meeting, American Geophysical Union fall meeting, China Geoscience Union annual meeting, DEEP (International symposium on Deep Earth Exploration and Practices, 2024) and ILP Workshop on Interaction Between the Lithosphere and Surface Processes.

3. Important publications of ILP Task Force members (max. five)

- 1) F.Y. Hu*, H.H. Jiang, **B. Wang**, Mihai N. Ducea, L. Gao, F.Y. Wu. Latitude-dependent oxygen fugacity in arc magmas. *Nature Communications*, 2024, 15: 6050. DOI: [10.1038/s41467-024-50337-6](https://doi.org/10.1038/s41467-024-50337-6).
- 2) X.X. Wang, **L. Zhao***, **J.F. Yang**, **Z.T. Guo***. Carbon Storage in the Forearc Produced by Buoyant Diapirs of Subducted Sediment. *Geophysical Research Letters*, 2024, 51: e2023GL107011. DOI: [10.1029/2023GL107011](https://doi.org/10.1029/2023GL107011).
- 3) S. Solarino, **M.G. Malusà***, E. Eva, A. Paul, S. Guillot, S. Pondrelli, S. Salimbeni, **L. Zhao**. Seismic tomography reveals contrasting styles of subduction-channel and mantle-wedge exhumation controlled by upper plate divergent motion. *Gondwana Research*, 2024, 136: 169-182. DOI: [10.1016/j.gr.2024.08.016](https://doi.org/10.1016/j.gr.2024.08.016).
- 4) Z.D. Shi, R.N. Mitchell, Y. Li*, **B. Wan**, **L. Chen**, P. Peng, **L. Zhao**, L.J. Liu, **R.X. Zhu**. Sluggish thermochemical basal mantle structures support their long-lived stability. *Nature Communications*, 2024, 15:10000. DOI:[10.1038/s41467-024-54416-6](https://doi.org/10.1038/s41467-024-54416-6).

4. New contacts (this year)

Prof. Sierd Cloetingh, Utrecht University

Prof. Quanyou Liu, Peking University

Prof. Gregory A. Houseman, University of Leeds

Prof. Barbara Romanowicz, University of California, Berkeley

5. Usage of ILP funding (this year)

4000 Euros has been spent for supporting DEEP meeting and ILP Workshop on Interaction Between the Lithosphere and Surface Processes (Nanjing).

6. Activities planned for 2025

- 1) A session on tectonic carbon cycle at the EGU, Vienna, Austria.
- 2) A session on tectonic carbon cycle at the AGU, tbd, USA
- 3) Holding an international meeting in China