frontiers | Frontiers in Earth Science

TYPE Editorial
PUBLISHED 11 August 2022
DOI 10.3389/feart.2022.989889

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
Michel Grégoire,
UMR5563 Géosciences Environnement Toulouse (GET), France

*CORRESPONDENCE
Yi Chen,
chenyi@mail.iggcas.ac.cn

SPECIALTY SECTION
This article was submitted to Petrology, a section of the journal Frontiers in Earth Science

RECEIVED 09 July 2022
ACCEPTED 13 July 2022
PUBLISHED 11 August 2022

CITATION
Chen Y, Li Q, Zhang G, Tsujimori T and Palin RM (2022), Editorial: Seeing convergent margin processes through metamorphism.
Front. Earth Sci. 10:989889.
doi: 10.3389/feart.2022.989889

Editorial: Seeing convergent margin processes through metamorphism

Yi Chen[1,2]*, Qiuli Li[1,2], Guibin Zhang[3], Tatsuki Tsujimori[4] and Richard M. Palin[5]

[1]State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China, [2]College of Earth and Planetary Sciences, University of Chinese Academy of Sciences, Beijing, China, [3]The Key Laboratory of Orogenic Belts and Crustal Evolution, MOE, School of Earth and Space Sciences, Peking University, Beijing, China, [4]Depertment of Earth Science, Graduate School of Science, Tohoku University, Sendai, Japan, [5]Department of Earth Sciences, University of Oxford, Oxford, United Kingdom

KEYWORDS

convergent plate margin, metamorphism, subduction, collision, carbon cycle, orogenic evolution

Editorial on the Research Topic
Seeing convergent margin processes through metamorphism

Introduction

Plate convergence can induce large-scale metamorphism and magmatism, reshape large parts of continental margins, and subsequently change regional climate and biodiversity. Metamorphic rocks in orogenic belts commonly record different metamorphic evolutions and temporal-spatial distributions at the regional scale, which are strongly influenced by convergent processes through time. In some cases, ultrahigh-pressure (UHP) and ultrahigh-temperature (UHT) metamorphic rocks are observed at both ancient and young convergent plate margins, marking the operation of extreme tectonism in the regime of plate tectonics. This Research Topic aims to understand how regional metamorphism operated at convergent plate margins through the study of field and petrographic observations, geochemical and petrological analysis, high-pressure experiments, and thermodynamic modeling. The scope is to gather new ideas and interpretations on the structure and processes of convergent plate margins.

Contributions in this Topic

This Research Topic assembles ten papers focusing on metamorphic processes in orogenic belts worldwide from the Neoarchean to Cenozoic.

Metamorphic response to tectonic transition in orogenic belts

Tectonic evolution of the early Earth can be seen from multiple metamorphism at Archean cratonic margins. Liu et al. present metamorphic conditions and geochronology for mafic granulites from the east Hebei terrane in the North China Craton. This paper establishes two-episode metamorphism in this region. The late Neoarchean (ca. 2. 5 Ga) UHT metamorphism with an anticlockwise P–T path reflects a vertical sagduction regime. In contrast, the Paleoproterozoic (ca. 1.8 Ga) HP granulite facies metamorphism with a clockwise P–T path corresponds to the continental collision process. Therefore, this study provides valuable information about the Neoarchean-Paleoproterozoic tectonic transition in the northern margin of the North China Craton.

Tectonic transition in orogens can be illustrated by changes in metamorphic thermal structure. Zhang et al. present an example of the tectonic transition from the termination of oceanic subduction to continental collision. This paper investigates two newly found garnet schists from the Ondor Sum Group mélanges (central Inner Mongolia), both of which record clockwise P-T paths but with different peak thermal gradients. The early Paleozoic HP metamorphism with a thermal gradient of ~8°C/km resulted from the terminal subduction of the Paleo-Asian oceanic plate, whereas the Devonian medium-pressure metamorphism with a thermal gradient of ~22°C/km points to the subsequent continental collision process.

How continental collision stems from subduction is a critical but unclear process in subduction zones. Chen et al. yield an eclogite-facies metamorphic age of ca. 31 Ma for the Stak HP massif in the western Himalayan syntaxis. Based on the comparison of peak P–T–t conditions of the Himalayan HP-UHP rocks, the authors find that the HP rocks record higher peak thermal gradients and younger ages than those of UHP rocks. These new data, combined with the regional geological and geophysical evidence, suggest that the Indian continental lithosphere underwent a coherent change in subduction dip angle in the middle Eocene. This study provides critical constraints on the change in subduction geometry responsible for the tectonic transition from continental subduction to collision.

Convergent margin processes trigger intracontinental orogeny

The dynamic mechanism of intracontinental orogens is still controversial. Zhao et al. investigate HP metabasites in the northeastern Cathaysia of the South China Block. Petrological and geochemical data indicate that these rocks originated from the continental crust and experienced eclogite-facies metamorphism during the early Triassic. Based on a comprehensive geological comparison around the South China Block, these high-grade rocks are interpreted to be formed in an intracontinental orogen triggered by far-field stress from margin convergence. This study provides a good case for intracontinental orogeny and constructs its connection with continental margin processes.

Evolution of the continental crust at convergent margins

Convergent margin processes play critical roles in the continental crust reworking. A common way is to investigate the behavior of crustal anatexis in orogens. Yang et al. present isotope geochemistry of Himalayan leucosome produced by partial melting of metasediments. The leucosome shows a broad range of Sr-Nd-Hf isotopes that deviate from the source. This isotopic disequilibrium might be caused by the different consumption (or dissolution) behaviors of muscovite, plagioclase, apatite, monazite, and zircon during crustal melting. This study highlights that isotopic disequilibrium may be common in low-temperature partial melting of metasediments.

Another crustal reworking study, by Gou et al., presents geochronology and metamorphic petrology from the Ramba gneiss dome in the northern Himalaya. The authors obtain a clockwise P–T path for garnet–mica schist in the dome. *In situ* biotite Rb–Sr geochronology yields two metamorphic ages of ca. 37 and 5.0 Ma, corresponding to the timing of retrograde cooling and the cooling age of the latest thermal resetting, respectively. This study provides valuable information on the tectonic evolution of the Ramba gneiss dome, from the Eocene crustal thickening during the India–Asia collision to the later exhumation.

The continental crust reworking can also be illustrated by the thermal structure of the crustal root. Zheng et al. present a large-scale (~10,000 km^2) thermal mapping, based on a Ti-in-quartz thermometer, for the Paleoproterozoic eastern Khondalite Belt, North China Craton. The new results highlight the hottest region in this belt, where UHT metamorphism closely correlates with abundant charnockite. This hottest region may represent the crustal root of a Paleoproterozoic large hot orogen. Further models for the mechanism of large-scale UHT metamorphism need to consider its close relation with charnockite.

Liu et al. present detrital zircon U-Pb geochronology and isotopic geochemistry from the northern Tibetan Plateau, aiming to investigate the continental crust evolution in the South Qilian, North Qaidam, and East Kunlun terranes. The results indicate that these three terranes show affinity to the western Yangtze Block and have undergone multiple Wilson cycles since the Paleoproterozoic. Based on geological comparison in the three terranes, the authors construct a detailed tectonic evolution of the northern Tibetan Plateau from the Neoproterozoic to Early Mesozoic.

Carbon cycle in subduction zones

Subduction zones act as a key region transporting supracrustal carbonates down to the deep mantle. How carbonates evolve at depths is crucial for understanding deep carbon flux and sequestration mechanisms. Gao et al. review prominent progress in the chemistry of carbonates under pressures up to the core-mantle boundary. This review highlights that several new polymorphs of carbonates would be stable at high pressure-temperature conditions, but metamorphic decarbonization and reduction reactions restrict subducting carbonates to the top-mid region of the lower mantle. This study shows more possibilities for carbon behavior in the mantle, which offers a strong handle on Earth's extraordinary history.

Methane (CH_4) is a critical carbon species in subduction zone fluids; however, its flux in subduction zones is still unknown. Using microanalysis techniques, Zhang et al. document the first case to estimate the abiotic CH_4 flux in the western Tianshan based on fluid inclusion compositions in eclogites. The authors estimate that the western Tianshan eclogites at least contain 113–342 Mt CH_4, and propose that cold subduction zones may be a hidden, huge reservoir of CH_4 on Earth. This study highlights that CH_4 flux must be considered further when evaluating carbon flux in global subduction zones.

Author contributions

YC wrote the draft manuscript with input from all authors.

Acknowledgments

We thank all the contributors to this Topic and the referees who spared their time to provide thoughtful and helpful comments.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note