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Editorial: Developments in the lithospheric evolution of the Indo-Pacific region

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Editorial on the Research Topic
Developments in the lithospheric evolution of the Indo-Pacific region

The Indo-Pacific is a biogeographic region between 30°north and south of the equator that stretches from the Polynesian Islands of the Pacific Ocean in the east to the Indian Ocean in the west (Spalding et al., 2007; Hobbs et al., 2009; Crandall et al., 2019). During the Late Paleozoic to Early Mesozoic (300–200 Ma), the geological development of the Indo-Pacific region was a consequence of the dispersal of Gondwanan cratons and terranes, the destruction of the Tethyan and western Panthalassan (Paleo-Pacific) Oceans, and the subsequent creation of the Indian Ocean (Mann and Taira, 2004; Metcalfe, 2013; Metcalfe, 2017; Hutchinson, 2014; Hall, 2017; Ding and Sun, 2020). The lithotectonic evolution of the Indo-Pacific region involved the collision and accretion of ancient cratons and juvenile terranes between Gondwana and Laurasia and the eruption of continental and oceanic flood basalts. The result of this plate reorganization was the development of the Alpine-Himalaya Orogenic Belt, the Indosinian Orogeny, the Taiwan Orogeny, the New Guinea Orogeny, the initiation of west Pacific volcanic-arc magmatism, the development of marginal sea basins (e.g., South China Sea, Andaman Sea, Sulu Sea, Banda Sea, Sulawesi Sea), formation of energy and mineral resources, and the extrusion of Southeast Asia. Although the tectonic processes that formed Asia are understood within the geodynamic paradigm of plate tectonics, the timing and precise nature of the petrological, geophysical, and structural processes involved in its formation are not well constrained.

Four major tectonic plates of Eurasia, Indo-Australia, Philippine Sea, and Pacific are the main components of the Indo-Pacific region (Hall, 2002). The formation of these plates since the breakup of Pangea involved the closure of the Paleo-Pacific, Paleo-, Meso-, and Neo-Tethys, and amalgamation of a collage of continents and microcontinents such as: the North China, South China, Qiangtang, Lhasa, Baoshan, Sibumasu, Sukhothai, Chanthaburi, and Indochina terranes from West to East respectively (Figure 1; Searle et al., 2012; Sone et al., 2008; Ueno, 2003). Paleogeographic reconstructions indicate the Paleo-Tethys between Laurasia and Gondwana started to close from the Late Carboniferous until the Late Permian and was followed by the separation of the ribbon-like Cimmeria micro-continent from the northern boundary of Gondwana and the formation of the Meso-Tethys (Şengör, 1984, 1987; Metcalfe, 2006; Metcalfe, 2011; Metcalfe, 2013; Seton et al., 2012). The Permian-Triassic Tethyan orogeny formed along the southern Eurasian margin as North China, South China,

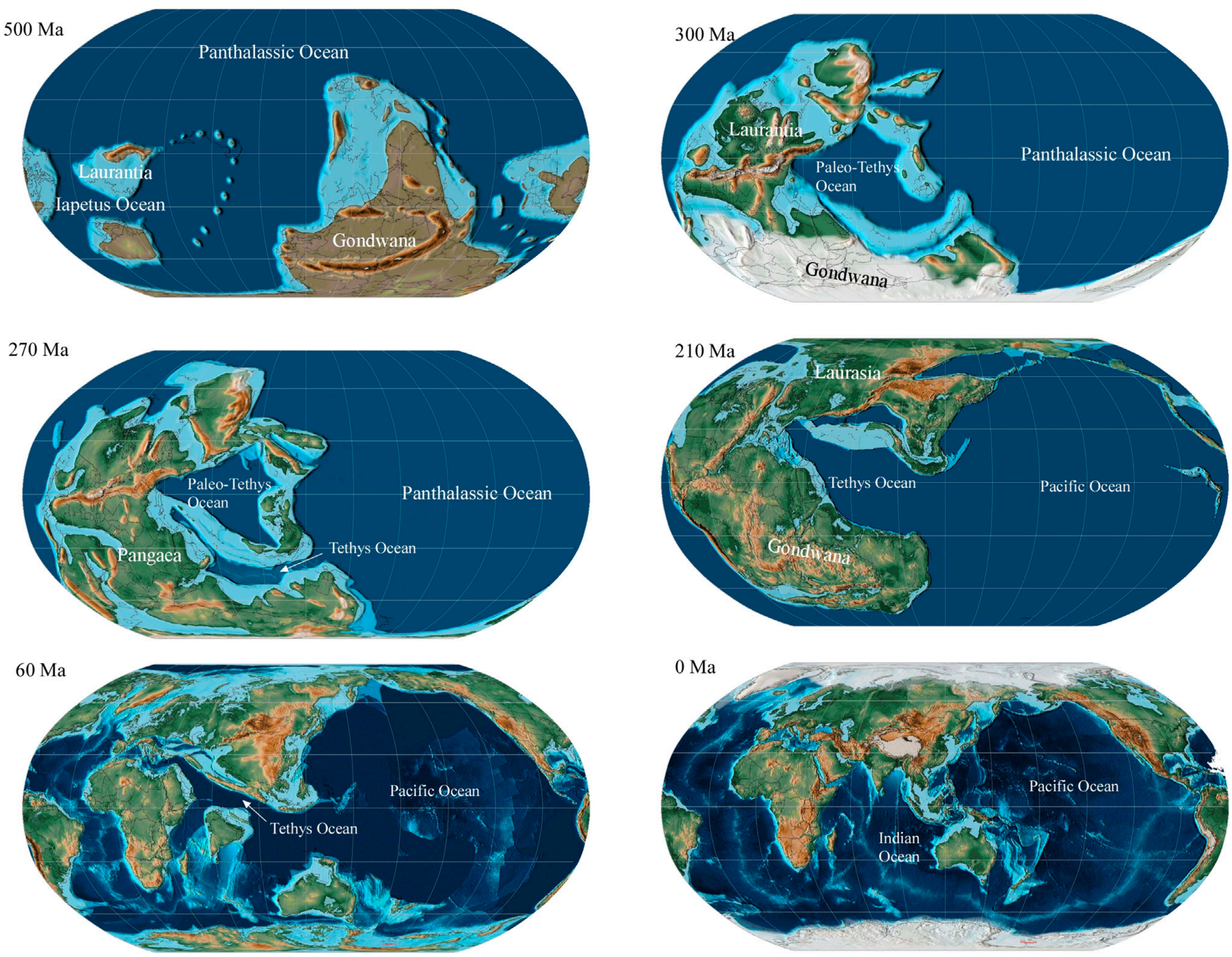

FIGURE 1
Palaeogeographic maps showing the tectonic evolution of Gondwana and Laurasia at 500 Ma, 300 Ma, 270 Ma, 210 Ma, 60 Ma, and present day using GPlates and the base maps of Scotese (2016).

Cathaysia, Indochina, Burma, and Cimmeria terranes amalgamated (Hall, 2002; Metcalfe, 2011; Seton et al., 2012; Metcalfe, 2013; Deng et al., 2014; Hall, 2017; Kapp and Decelles, 2019). The closure of the Meso-Tethys is marked by the Bangong–Nujiang Suture Zone in the central Tibetan Plateau as Qiangtang Terrane and Lhasa Terrane collided together during Cretaceous (Fan et al., 2021). Moreover, the paleo-Pacific continued to subduct under the eastern boundary of the Eurasia plate generating widespread NE-SW trending Cretaceous magmatism. The collision between India and Eurasia marks the closure of Neo-Tethys along the Indus Yarlung Zengbo suture forming the Himalayan orogeny during the Cenozoic time (Mitchell, 1981; Mitchell, 1984; Golognka, et al., 2006; Mitchell et al., 2012).

The Comprehensive Research on East Asia Tectonic Evolution (CREATE) working group was established with a special conference session entitled “Mantle Dynamics and Plate Interactions in East Asia” at the American Geophysical Union Fall Meeting in 1994. The success of the AGU Special Session was the impetus for a formal research initiative that led to a number of seminal papers (i.e., Chung and Jahn, 1995; Lee and Lawver, 1995; Chung et al., 1997; Lo et al., 2002), books (Flower et al., 1998), and journal special issues (Tectonophysics, Journal of Asian Earth Sciences) on the lithotectonic development of East Asia. The goals of the first CREATE project in 1997 were to initiate geoscience research projects with colleagues in China, Hong Kong, and Southeast Asia that related to the Cenozoic collision-extrusion tectonics along the Ailao Shan-Red River fault zone in SE Asia. The Ailao Shan-Red River fault zone is one of the major features responsible for the eastward extrusion of SE Asia after the India-Eurasia collision. Recently, CREATE members have expanded to regions of South Asia, West Asia, and the Indian Ocean and with research interests focusing on the consequences and processes of plate collision, the genesis of juvenile continental crust, and the mechanisms for continental accretion of the well-known Phanerozoic Asian orogenic belts (e.g., Alpine-Himalayan, Indosinian, Yanshanian, Taiwan orogenies).

This Research Topic of Frontiers in Earth Science is a collection of manuscripts focusing on the lithotectonic evolution of cratons, terranes, and marginal ocean basins of the Indo-Pacific region in celebration of the 25th anniversary of CREATE. The authors use novel methods and analytical techniques in seismology, geochronology, structural geology, and geochemistry to offer robust constraints on the principal tectonomagmatic processes that were operating during the amalgamation of the Tethyan terranes of Gondwana with Eurasia. The papers in this volume encompass research topics related to Precambrian mafic dyke swarms, orocline evolution and tectonic extrusion during the India-Eurasia collision, seismic hazards of Vietnam, volcanic-arc and syn-collisional granite magmatism, and tectonics of the Taiwan Orogeny and propose new views on the lithotectonic development of cratonic India, Indochina, the South China Sea, and the India-Eurasia collision. The contents of the Research Topic are summarized below.

Chiu et al. noticed that the curvature from the eastern Himalayan syntaxis through east Burma to west Yunnan exhibits a unique convex shape toward the mantle wedge, which is different from the concave Baluchistan orocline and the Himalayan orocline. The southeastern stretch of the large-scale curvature of the Himalayan orocline, the Gaoligong orocline, exhibit N-S trend in the northern section and NE-SW trend in the southern section. Based on the reconstructed structural evolution models, five distinct deformation events have been identified, which leads to the proposal that the geometry of the Gaoligong orocline does not reflect a "bended orogeny" but rather an "atypical" orocline.

The Singhbhum craton in eastern India records multiple stages of Precambrian dyke emplacements with contrasting petrogenetic models proposed for their formation. Through field observations, petrography, mineral chemistry, whole rock elemental and Sr-Nd isotope geochemistry Manu Prasanth et al. propose that the ubiquitous continental crustal signature of Precambrian dyke swarms of the Singhbhum craton are best explained by a peridotite source with recycled crustal components, probably in the form of pyroxenites. Furthermore, they point out that crustal recycling in the Singhbhum craton was likely an episodic phenomenon rather than a discrete, single-stage process since the Archean.

Shellnutt et al. explore the Early Cretaceous quartz diorites and diorites from the Snoul pluton of eastern Cambodia, which was emplaced during the subduction of the Paleo-Pacific plate beneath the Indochina terrane. The samples are isotopically distinct from the coeval plutonic rocks of Vietnam from the same tectonic setting, suggesting that there could be a litho-tectonic domain boundary within the southern Indochina terrane.

The Taiwan mountain belt was formed by arc-continent collision followed by the subduction of the South China Sea and subsequent closure of the Luzon forearc. Lo et al. report new zircon U-Pb and amphibole $^{40}Ar/^{39}Ar$ ages from the Shihmen Conglomerate within the uplifted South China Sea turbidite sequence from the Hengchun Peninsula. They propose that a piece of early Miocene South China Sea crust was dynamically metamorphosed at ~13 Ma that led to the formation of an isolated high-relief subaerial mountain range along the Chinese continental margin and is best explained by an obduction event due to stress-strain reorganization of the Manila Trench during initial continental subduction.

Silpa et al. reports whole rock Sm-Nd isotopic compositions along with major and trace element geochemistry of meta-dolerite dykes from the western Dharwar craton. The dykes are proposed to be derived from a depleted subcontinental lithospheric mantle (SCLM) source formed during the Mesoarchean to Neoarchean after komatiitic magma extraction. These widespread dyke swarms are interpreted to be the plumbing system of greenstone belt volcanism in the Western Dharwar craton.

The NW-SE striking Day Nui Con Voi (DNCV) metamorphic massif in northern Vietnam is bounded by the Red River Shear Zone (RRSZ) to the south and continues along strike where it meets the South China Sea (SCS). Dinh et al. document new $^{40}Ar/^{39}Ar$ ages combined with microstructural and petrological analyses to constrain the timing of the left-lateral shearing of the RRSZ. New $^{40}Ar/^{39}Ar$ ages from different structural domains of the DNCV metamorphic massif show a rapid exhumation at 26 to 22 Ma. This extrusion tectonism cannot be considered as the cause for the initial opening of the SCS, rather it can be correlated with the southward ridge jump event of the already opened SCS.

Lee et al. studied the Gongga Shan granite, an intrusion along the Xianshuihe fault in easternmost Tibet. The extensive U-Pb zircon ages of the Gongga Shan granite samples provide evidence for the stepwise partial melting of the crust from 56 Ma to 4 Ma. Furthermore, the zircon U-Pb ages significantly extend the onset of crustal melting and timing of granite formation up to 20 Ma earlier than previously recognized.

Nguyen et al. performed a P- and S-wave travel time seismic tomographic inversion of Luzon Island to constrain the regional lithospheric structure and presented a refined slab tearing model. Their tomographic images indicate contrasting velocity structures across the Philippine Fault, which extends up to 60 km and also confirm the presence of slab-tearing regions extended from the fossilized ridges in the northern Luzon region, creating regional kinematic perturbations.

Lin et al. studied the Lan Sang gneisses from the NW-SE trending Mae Ping shear zone (MPSZ) of Thailand. They used zircon U-Pb geochronology and whole-rock major element analysis to evaluate the magmatic history of the area and found that MPSZ is dominated by Triassic-Jurassic and Eocene-Oligocene thermal events. The spatial and temporal distribution of several Eocene-Oligocene intrusions along the Sibumasu terrane indicates that Neo-Tethyan slab shallowing induced the inward migration of magmatism in the overriding plate.

Author contributions

JS: Conceptualization, Writing–original draft, Writing–review and editing. M-WY: Conceptualization, Writing–original draft, Writing–review and editing. MP: Conceptualization, Writing–original draft, Writing–review and editing. V-DN:

Conceptualization, Writing–original draft, Writing–review and editing.

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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.

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