Plate tectonics in the twenty-first century

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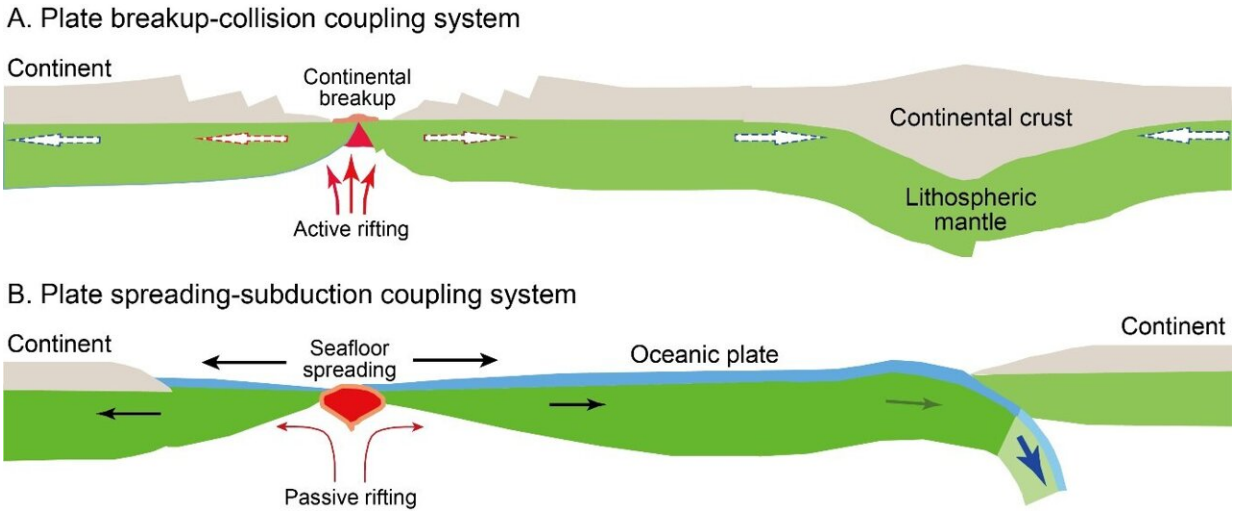

A. The lithospheric breakup-collision coupling system, in which collisional thickening of the continental crust is coupled with lithospheric breakup due to asthenospheric upwelling for active rifting. B. The seafloor spreading-lithospheric subduction coupling system, in which the oceanic slab is subducted to depths of >80–100 km for the gravitational pull, providing far-field stresses for passive rifting. Credit: Science China Press

The emergence of plate tectonics in the late 1960s led to a paradigm shift from fixism to mobilism of global tectonics, providing a unifying context for the previously disparate disciplines of Earth sciences. Although plate tectonics was originally defined by the kinematics of the Earth's outer shell (lithosphere) on the underlying asthenosphere, a number of dynamic interpretations for its operation have developed in

the past five decades.

This has advanced plate tectonics as a holistic theory of kinematics-dynamics for the motion of large and small plates in both horizontal and vertical directions. Because modern plate boundaries occur as a global network of mobile belts on the spherical Earth, the difficulty was encountered in deciphering the operation of ancient plate tectonics in geological history.

A synthetic study presented by Prof. Yong-Fei Zheng at University of Science and Technology of China and published in *Science China Earth Sciences*, focuses on an advanced version of plate tectonics in its basic principles and geological corollaries along active and fossil plate margins. This is achieved by inspection of natural observations and their tectonic interpretations in the fields of geology, geochemistry, geophysics and geodynamics.

The advances are significant and fundamental to our understanding of various phenomena at present and past plate margins, setting general standards to determine the spatiotemporal relationships between material movement, energy transfer, dynamic regime and geothermal gradient along plate margins. Therefore, they provide new insights not only into many first-order problems regarding tectonic occurrences in continental regions but also into the origin of hotspot magmatism in relation to the mantle plume hypothesis.

According to the geometric structure, dynamic regime and thermal state of plate margins, Zheng highlights the importance of plate divergent-convergent coupling systems in the operation of plate tectonics on Earth. These coupling systems are categorized into two types.

One is the lithospheric breakup-collision due to active rifting, with the push effect of lithospheric breakup on collisional thickening and shallow

subduction to smaller depths of 80–100 km. Because plates may be of different sizes since their generation, they may move in different directions to exchange matter and energy not only between lithosphere and asthenosphere but also between the crust and the mantle.

As generalized by Zheng, matter and energy transfers at plate margins proceed in bottom-up and top-down ways, respectively. They correspond to changes of not only their dynamic regime from extension to compression and from compression to extension but also their thermal state from hot to warm and from cold to warm. In the rifting zone, heat is preferentially transferred from the asthenosphere into the crust, resulting in heat loss from the Earth's interior to exterior. In subduction zones, the cold lithosphere sinks into the hotter asthenosphere, leading to cooling of the Earth's interior.

Therefore, both rifting and subduction zones are two basic sites for the matter and energy exchanges between the Earth's spheres. As such, recognition of their geodynamic mechanisms and tectonic effects on the formation and evolution of plate margins is the key to advance plate tectonics.

Although modern plate tectonics is characterized by a global network of mobile belts on the present Earth, its operation on the ancient Earth history can be tested by inspection of plate divergent-convergent coupling systems. This is outlined by Zheng through characterizing two of the fundamental components in plate tectonics. One is the initiation of rifting zones, eventually forming new ocean basins, and the other is the initiation of subduction zones, recycling the crust into the mantle.

Subduction initiation and lithospheric rifting are the two key processes for the onset of plate tectonics. Their operation has great bearing on the structure, processes and geodynamics of plate margins. These elements also fundamentally explain the onset and operation of plate tectonics in

Precambrian time.

More information: Yong-Fei Zheng, Plate tectonics in the twenty-first century, *Science China Earth Sciences* (2022). DOI: 10.1007/s11430-022-1011-9

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