EDITORIAL

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Fifty years of plate tectonics

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What would you put on your list of the great scientific revolutions of the twentieth century? Genetics? General relativity? Something to do with quantum mechanics, perhaps? One discovery that must be on that list is the theory of plate tectonics—the principle of how the rigid outer shell of our Earth (its lithosphere) moves and recycles. It provides a unifying context for the previously disparate disciplines of Earth science and was rapidly accepted across the geological community in the late 1960s. Since then, plate tectonics has arguably become a standard model in Earth science. This theory has experienced further developments over the last 50 years since its advent in 1967–68.

Before the birth of plate tectonics theory, studying geology was essentially an exercise in collecting (apparently disparate) facts and memorizing information. Structural geology was concerned with descriptions and understanding deformation for its own sake. Geochemistry was simply to add information to descriptions of a myriad of different rock types, chiefly igneous. The sites where sedimentary rocks were accumulated were traditionally thought of as geosynclines that formed by mysterious processes. There was no emphasis on stratigraphy, geological time and environmental changes that had influenced the deposition of sedimentary rocks and the records of life they contained.

Plate tectonics is about the outer shell of the Earth being in a constant state of motion, albeit being slow. The old world view had overlooked horizontal motions of lithosphere. The idea that continents might have moved was hardly accepted before the 1960s. But all this had changed once seafloor spreading was confirmed and oceanic crust formation at ridges and destruction through subduction zones were demonstrated. And this is not random, but is geometrically and kinematically organized.

Truly great ideas in science not only seem elegantly simple and intuitive when they come into focus, but also have extraordinary powers to answer many other questions to our scientific understanding of the world. Plate tectonics is a perfect example of this. This theory provides an excellent framework to explain the present-day tectonic and seismic activities near the Earth's surface. However, its application to Earth processes in the geological past (300 million years ago) is not straightforward.

Thanks to courageous attempts and great efforts, the plate tectonics theory has been much advanced in the past 50 years. At its infancy, mantle convection was accepted as the driving force of plate motion. However, further studies indicate that gravitational sinking of the oceanic lithosphere at subarc depths plays a more important role in driving the motion of plates over the convective mantle. At its early time, only oceanic lithosphere was considered subductable whereas continental lithosphere was not because of its lower density. However, findings of coesite and microdiamond as crystal inclusions in metamorphic minerals led to the recognition of continental subduction to mantle depths.

Originally, lithospheric plates were assumed to be rigid in describing plate motion and plate boundary zone processes. Seismic belts are thus zones where differential movements between rigid plates occur. However, the plates may behave as elastic bodies that can accumulate considerable stresses along their boundaries before being relieved by earthquakes. Furthermore, their margins become significantly ductile at high temperatures, leading to mountain building along convergent plate boundaries. This has called for modification of the mechanical behavior of subducting plates at different depths.

In general, plate subduction results in mountain building with lithospheric thickening, giving rise to accretionary and collisional orogens as a result of compression. Afterwards, these thickened orogens were thinned and even destructed in post-subduction stages, which was originally regarded as the result from tectonism independently of plate tectonics. Nevertheless, mountain building also occurs in mid-ocean ridges, making the orogens of extensional style. Such orogens were thinned at first and then had superimposed on the orogens of compressional style with their reactivation for partial melting and lithospheric stretching. These tectonic processes are also the result of plate tectonics and thus collectively termed as rifting orogeny. This extensional tectonism is the herald of supercontinent breakup for the formation of a new ocean basin in a Wilson cycle.

Although many advances due to plate tectonics seem speculative at their beginning, they have been and continue to be verified with the application of advanced technologies to Earth science. This has also benefited from the integrated interpretations of multidisciplinary observations. The results are making an impact on the origin of igneous rocks and their relevant mineralization at ancient plate boundary zones.

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