TKK Science Award in Earth Sciences

Destruction of North China Craton: Unveiling the Violent Side of the Ancient Continent

By SONG Jianlan (Staff Reporter)

CAS Member Prof. ZHU Rixiang, distinguished geologist and geophysicist

The 2020 TKK Science Award in Earth Sciences was conferred on CAS Member Prof. ZHU Rixiang, a researcher working at the CAS Institute of Geology and Geophysics, for his outstanding work on the destruction of the North China Craton (NCC), a complicated issue that has been puzzling geologists for a long time.

As the most ancient continental lithosphere of the Earth, cratons are generally believed to exist as stable shields and platforms where geological activities rarely occur. Challenging this traditional understanding, however, evidence shows that the NCC experienced large-scale geological activities during the Mesozoic period, including magmatic activities and mountain building. What has driven the generation, migration and eruption of massive magmas? What factors have resulted in the instability of the NCC? These scientific issues have perplexed geologists for almost a century. Given that the eastern NCC suffered much stronger destruction than any other cratons in the world, the above questions could bear global significance and help us better understand the formation and evolution of continents on which we inhabit.

To answer the above questions, however, an enormous amount of data is required to reconstruct the temporal and spatial distribution of the destruction of NCC and explore the deep structure of the Earth, including the state and nature of the upper mantle in this region. For this sake, ZHU and colleagues performed long-term interdisciplinary investigations, pooling forces from geological, geophysical, geochemical and paleontological research, to establish linkages between key tectonic events against the global context and eventually probe into the underlying mechanisms of the craton destruction.

Revealing Latent Driver of NCC Destruction

Their sustained dedication has led to a series of important discoveries. In a paper published in 2011 in *Science China · Earth Science*, ZHU and coauthors reported their reconstruction of the destruction's chronology based on the collected data. They determined the temporal and spatial distributions and revealed the source and tectonic setting for the igneous rocks in this region. On top of these, the team identified six stages of tectono-magmatism in Phanerozoic strata. The intensive magmatism occurring in the Early Cretaceous, together with the extensional deformation, gold mineralization, and the significant continental crustal growth, indicated that the peak time of the destruction of the eastern NCC should be during this period. They also found that the destruction mainly occurred in the eastern NCC, leaving the western part merely locally modified. Based on the above discoveries, the authors concluded that the magmatic activities took place mainly during the Mesozoic, peaked at about 125 million years ago, and deformed the NCC strata – which would have otherwise remained stable since it formed around 1.8 billion years ago.

Given that these magmatic activities coincided with globally active plate tectonics and high mantle temperatures during the Cretaceous, the team suspected that these intense activities had resulted from the subduction of a slab called the Paleo-Pacific plate beneath the eastern Asian continent. "Global comparison suggests that most cratons on Earth are still stable," the team explained, "destruction is likely to occur only when the craton has been disturbed by oceanic subduction." The evidence unearthed in their later explorations further strengthened this speculation.

The accumulated evidence indicated that the NCC crust had experienced alternating contraction and extension during the Early Cretaceous. This alternating contraction and extension, as summarized by ZHU in a recent paper published in a special edition for TKK Awards in the *Chinese Science Bulletin*, could have resulted from the changing direction in which the Paleo-Pacific plate could have thrust itself through this part of crust: While the plate subducted into the strata from a low angle, it compressed and hence shortened the strata; and when it pitched down from a high angle, it stretched the strata, instead.

Therefore, the team concluded, the subduction of the Paleo-Pacific plate beneath the eastern Asian continent could have been the primary driver of the destruction. More interestingly, the processes of its repeated thrusts could have even played a more profound role in the destruction of the NCC.

These processes altered the nature of the lithospheric mantle and triggered large-scale magmatism in the crust. The subducted Paleo-Pacific slab destroyed the preexisting equilibrium and disturbed the mantle convection beneath the eastern NCC, fueling geological activities with thermal. This unstable convection even caused the lithospheric delamination and thermal-mechanical-chemical erosion in this region.

The thermal processes in the form of magmatism must have strongly altered the physico-chemical properties of the overlying lithosphere, ZHU concluded. They could have transformed the continental mantle of this region into an oceanic-type one. These changes finally destabilized the lithospheric mantle and further triggered large-scale magmatism and tectonic deformation in the local crust.

The magmatism, deformation and lithospheric thinning, they analyzed, could be just "expressions" of the NCC destruction – the fluidity of the softened upper mantle sat beneath the processes.

This discovery subverted the traditional stereotyped craton stability, shedding new light on studies in intracontinental orogens, as well as theories of plate tectonics and mineralization.

Influence of NCC Destruction on Surface Geology and Ecosystem

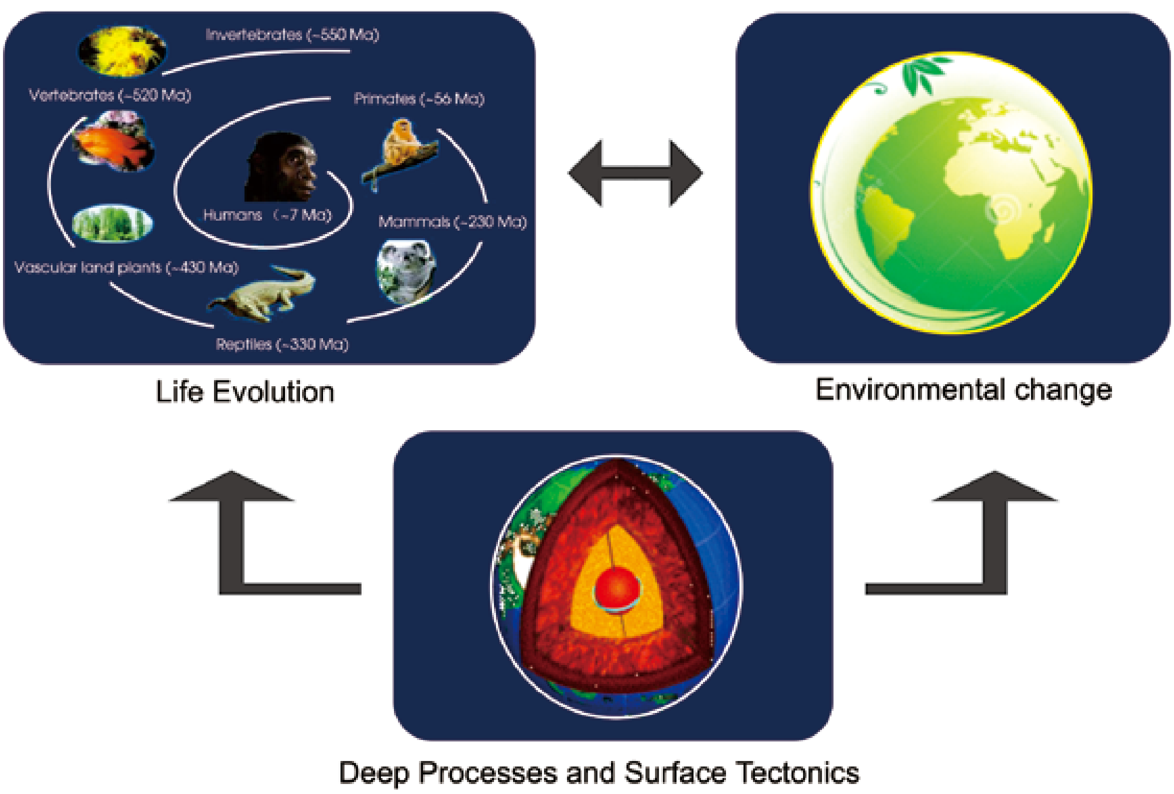
The geodynamics latent in the deeper structure of the continental mantle has not only dominated the destruction of NCC as well as the evolution of surface geological structures but also activated the transitions in local paleo-environments and terrestrial ecosystems, emphasized ZHU and coauthors in their recent review in the special edition of *Chinese Science Bulletin*. Concurrent with the destruction, the emergence and vanishment of two terrestrial ecosystems, namely the Yanliao and Jehol biotas, could be prominent expressions of such dominant influence.

Abundant fossils of the Yanliao and Jehol biotas emerged in the rift basins generated by the destruction of the NCC. Relics, even including soft tissues, of a wide variety of species ranging from insects to vertebrates, are well-preserved in these fossils, offering us a window onto that long-lost prosperity. The biotas evolved respectively during the Middle-Late Jurassic and Early Cretaceous, and the two periods correspond with the initial and peak stages of the NCC destruction. The volcanic activities and sedimentary basins in this region may have led to the thriving and extinction of the species in the biotas. For example, the former might have played some role in the local climates, and the sedentary products from the volcanic ashes could have nourished the biotas. Besides, the volcanic ashes, the magma as well, also helped preserve the refined structure of these organisms in fossils. On the other hand, drastic changes in environments resulting from frequent volcanic activities could also have worked as external stress on the local ecosystems. Such adverse conditions could have sped up their evolutions and even have led to their collapse.

Therefore, ZHU concluded, the geodynamic processes originated from the deep lithosphere may not only have controlled the destruction of NCC and the tectonic evolution of surface structures but also triggered the transition of the paleo-environment and terrestrial ecosystem. In return, life evolution as part of the surface response to the deep-earth dynamic processes, said ZHU, is more than a passive adaptation to the environments. "The organisms are also changing the environments where they inhabit."

Ultimately, however, the coevolution of the concurrent ecosystems and environments, on the whole, has resulted from the underlying dynamic processes, he further explained, though the linkage between terrestrial life and its evolution on the surface, and the underlying tectonic processes remains unclear and deserves further exploration. "Had not for this 'central engine'," he continued, "the Earth would not have been able to foster such a highly sophisticated civilization."

ZHU and colleagues are now paying more



Influence of the deep dynamic processes of the Earth on surface paleogeography and terrestrial ecosystems (Credit: ZHU's group) attention to the interactions between different spheres of the Earth. "The coevolution between the deep-earth geodynamic processes and the biosphere deserves further exploration in the future," remarked ZHU, "and interdisciplinary investigations and comprehensive research can play an important role in this respect."

References

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