

What minerals were present at life's origins?

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Scenarios for life's origins often invoke varied minerals in such roles as catalysts or reactants for molecular synthesis, templates for selection and concentration of potential biomolecules, and protective environments for protolife [1-4]. However, any such model for biogenesis must consider the relatively limited prebiotic mineral diversity. We estimate that prebiotic Earth held no more than ~500 different mineral species, compared to more than 4500 recognized today [5,6]. Modes of mineral paragenesis at 4.0 Ga were severely limited compared to the last 3.0 billion years. Important mineral-forming mechanisms not established at 4 Ga include atmospheric oxidation, emplacement of complex pegmatites, subduction zone volcanism, and the rise of the terrestrial biosphere, which collectively led to as many as 4000 of the known species.

In spite of these constraints, most minerals previously invoked in origins-of-life research are plausible participants in prebiotic reactions. In particular, clay minerals, so often employed in origins studies for their ability to adsorb and template organic molecules, would have been present, though distributions of clay mineral species were significantly different from the modern world. Serpentinization would have produced abundant serpentine and talc, as well as brucite, while anoxic weathering of volcanic deposits may have yielded montmorillonite and kaolinite. This suite of clay minerals contrasts with the modern production, which is dominated by terrestrial clay minerals through oxidic and biological weathering. Most common rock-forming silicates, including Fe-Mg olivine, pyroxene, amphibole, and mica, as well as all major varieties of Na-K-Ca feldspar and feldspathoid would have been present, as well. Though volumetrically much less important, reactive Fe-Ni phases, including metal alloys, sulfides, and the phosphide schreibersite were all available continuously in the near-surface environment in the form of iron meteorites. Similarly, quartz, carbonates, and phosphate minerals, though present, appear to have been volumetrically insignificant, and it is not obvious that any borate minerals were available prior to 3.5 Ga [7].

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Noble gas isotopes in Cenozoic mantle xenoliths from the North China Craton

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Section 17k

The North China Craton (NCC) is one of the oldest cratons on Earth (3.8 Ga) and is also one of the major Archean cratons in eastern Eurasia. However, the craton experienced fundamental lithospheric rejuvenation in late Mesozoic and Cenozoic, resulted in replacement of the old, cold, thick (>180 km), and depleted lithospheric mantle by young, hot, thin (70-80 km), and fertile lithospheric mantle. The NCC can be divided into eastern part (ENCC) and western part (WNCC) by the NS trending Daxing'anling - Taihangshan Gravity Lineament (DTGL) that separates two topographically and tectonically different regions.

The ENCC experienced widespread lithospheric thinning. The preexisting Tan-Lu Fault Zone, main active strike-slip fault zone in eastern China, is believed to have acted as a major channel for the ascending of asthenosphere and played an important role in the Mesozoic-Cenozoic thinning of the North China Craton lithosphere. WNCC, lithospheric removal was possibly relative limited, and the elevation are about 1000m higher than ENCC. The difference of lithospheric thin between ENCC and WNCC is also supported by the contrast of thickness of crust and lithospheric mantle, heat flow and gravity anomaly. Geophysical and geochemical study suggest that the asthenospheric upwelling beneath the ENCC at late Cretaceous and upwelling beneath the WNCC recently.

Noble gas isotopic ratios would provide unique and important constraints for the evolution of the subcontinental mantle and delineate similarities and differences between the MORB reservoir and the subcontinental mantle. We present one-step crushing noble gas isotope data from corundum and co-existed mantle xenoliths and megacrystals from the middle part of the Tan-Lu Fault Zone, ENCC and from Yangyuan, WNCC. The ³He/⁴He ratio is 7.6-8.3 times the atmospheric ratio (Ra) in corundum, indicating contribution of fluid from convective asthenosphere. The olivine and opx in lherzolite show high helium content and homogeneous isotopic helium ratio, 6.9-7.0 Ra for ENCC and 7.6-8.5 Ra for WNCC.

Conclusion

Combined with isotope correlation diagrams, the systematic difference in ⁴He abundance, the ³He/⁴He and ⁴He/⁴⁰Ar* ratios of cpx, opx and olivine in pyroxenite and lherzolite suggest refertilization of lithospheric mantle in the ENCC maybe early than WNCC.