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Alkaline magmatism and the rifting of cratonic lithosphere: behaviour of mantle solidi during sub-rift metasomatism and lithosphere erosion

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The rifting of continental lithosphere to produce oceanic crust and lithosphere is a geodynamically common occurrence associated with the opening of oceans in the plate tectonic cycle. The splitting of Archaean cratons, however, is much rarer due to the thickness of lithospheric mantle (>150km) that has to be parted. Two examples where this has happened during the last 200 Ma are the opening of the Labrador Sea, which divided the North Atlantic craton, and the opening of the Indian Ocean between Antarctica and India. Magmatic rocks from both areas include ultramafic lamprophyres, which have extremely SiO2-poor and carbonate-rich compositions for magmatic rocks. An important role for CO2 in the origin and evolution of alkaline igneous rocks is typical for continental rifts, such as the East African Albertine rift, which contains silica-poor rocks containing kalsilite. The reason for the enrichment in CO2 in these regions and not in others, however, remains enigmatic. High-pressure experimental studies of the melting of peridotites has defined a P-T zone where carbonatitic melts can be produced at 2.0 - 2.9 GPa, and the major element compositions of ultramafic lamprophyres appear to correspond to near-solidus melts at higher pressures. However, the explanation of trace element and isotope compositions requires mixed source rocks, probably in the form of ultramafic veins or dykes cutting peridotite. The mantle solidus at pressures of 4 - 6 GPa may be very sensitive to the oxidation state; this affects the speciation of C-H-O fluid components, which in turn have differing solubilities in melts and effects on their structure. Mantle xenoliths from eastern Antarctica preserve evidence for three progressively hotter geothermal gradients beneath a developing continental rift (the Lambert-Amery rift), and isotope compositions of ultramafic lamprophyres from the same area are consistent with veining

of the mantle with carbonate-rich material less than 200 million years before magma generation. A similar scenario can explain ultramafic lamprophyre magmas on the margins of the Labrador Sea. Increasing oxidation state and heating in the sub-rift mantle results in a drop in solidus temperature by 200-300°C, so that the rift-related carbonate-bearing veins are reactivated at a later stage in the development of the same cratonic rift.