Topics

Komatiites: new information on the type locality (Barberton), and some new ideas

Archean serpentinites in the Komati river valley, South Africa, have distinctive crystal textures and volcanic features which distinguish them from normal coarse-grained serpentinites. They are interpreted to represent peridotite lavas erupted into a deep submarine environment.

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Komatiites have characteristic quench-textured skeletal olivine and pyroxene whose delicate elongate crystals on weathered surfaces superficially resemble a spikey grass from which they get their name (spinifex; Figs 1–3). Such delicate crystals could not have been transported by flowing magma, and must have grown very rapidly *in situ*. These komatiite lavas were emplaced as crystal-free liquids, lacking the traditional volcanic phenocrysts, and have the highest magnesium contents of any terrestrial lavas. This means that they represent the hottest magmas ever to reach the Earth's surface, with temperatures several hundred degrees hotter than normal basaltic magma. Because komatiites are confined in age mostly to the Archean, they are a primary indicator that at that time the Earth may have been hotter.

Similar spinifex-textured komatiites have been found in every major continent with Archean terrain, associated with other metamorphosed volcano-sedimentary sequences called greenstone belts. Some komatiites, such as those in Australia, are associated with economic deposits of nickel. Komatiites are often interlayered with more normal volcanic rocks but do not appear to be restricted to a particular plate-tectonic setting; they are associated with old oceanic plateaus, oceanic ridges and island arcs. Consideration of the petrological phase relations for mantle peridotite requires that komatiites represent high degrees of partial melting, perhaps 30–50%. Continuing debate centres on whether these melts were wet or dry, as this has a large effect on the actual temperature required, and also over what range of possible depths in the mantle they would have remained bouyant. An early explanation for komatiites – that they were produced by impact melting – has recently been revived, but mantle-plume theories for their origins are generally more widely accepted. It is easy to simulate komatiite experimentally by melting of mantle peridotites, but in reality there is no independent evidence constraining the depth as komatiites are xenolith-free. An excellent popular overview of komatiites by R. Renner in (1993) provided a useful short update to the substantial book devoted to komatiites by N. T. Arndt & E. G. Nisbet in (1982).

New field evidence

A paper written by J. C. Cann in 2000 is significant because it re-examines the field evidence of the type locality in great detail, using several coloured digital maps and sections. Cann attempts to quantify the various forms of komatiites within the Komati volcanic formation. This includes a better understanding of the distribution of the classic spinifex textures,

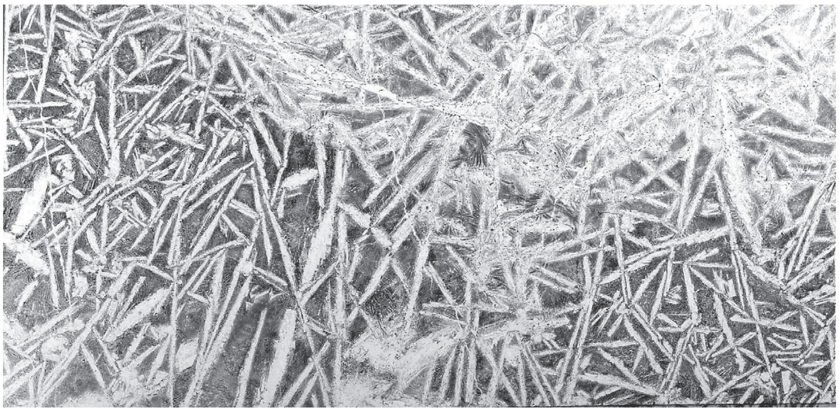

Fig. 1. Photomicrograph of spinifex texture in peridotitic komatiite, from the Komati river, Barberton, South Africa; age = 3480 million years. Length 40 mm, plane polarized light (PPL), specimen BK2093, University College London. This texture is formed by very rapid crystallization of olivine and pyroxene which form characteristic long, slender, branching and skeletal shapes. It is interpreted to have formed from an entirely liquid melt of peridotitic composition, which is quite different from normal volcanic textures where large crystals (phenocrysts) are ubiquitous. Komatiite lavas are thought to represent the hottest magmas to have formed on Earth, perhaps as hot as 1600 °C, and are mostly confined in age to the Archean. Their high temperatures have been interpreted to indicate either a very deep origin, or that the temperature of the ancient Earth's mantle was much hotter than today.

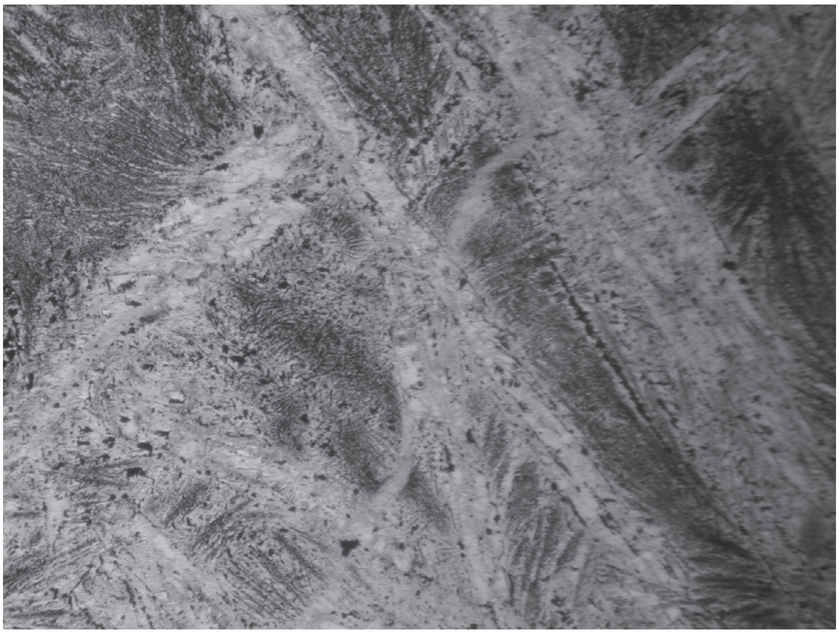

Fig. 2. Photomicrograph: enlargement of Fig. 1 (field of view 0.5 mm) shows several generations of spinifex-textured quench crystals, including radiating fans of pyroxene (now replaced by serpentine) and delicate opaque (black) needles and trains of granular chromite.

which are not always present, in relation to massive flow units, pillow lava horizons, breccias and minor intrusions. He also analyses the overall stratigraphy in terms of its relevance to nearby Barberton spherule beds, where renewed interest in an impact origin has established that these younger units are apparently correlated with an extraterrestrial impact much greater than the renowned 'dinosaur killer' at the K/T boundary.

Cann's renewed geological mapping of the type komatiite occurrence establishes a number of important new criteria for this roughly 5-km-thick sequence of concordant submarine flows cut by intrusions. Komatiites account for about half of the Lower Komati group, the other half being komatiitic basalt and minor tuff with felsic spherules. Here, massive komatiites predominate (60%), interpreted as sheet flows up to 50 m thick and 11 km in extent. Spinifex-textured komatiites occur in five distinct horizons and also as sheet flows up to 8 m thick and 11 km extent, and as smaller lenses. The spinifex textures occur in association with the tops of massive flow units. Some massive komatiites have preserved pockets of seive-textured coarse-grained rock that may be relics of granular olivine-rich protolith. If confirmed, these would represent the first mantle xenoliths discovered in Archean komatiites. The Upper Komati group is characterized by pyroxene spinifex komatiite, in place of olivine. Important sedimentary rocks in the Barberton sequence include volcaniclastic chert with relics of early life.

The sequence is cut by minor intrusions, some of which may have been feeders for some of the komatiite flows, but Cann presents an open verdict on this view. The ultramafic intrusions include dykes and sills of both olivine and pyroxene spinifex-bearing komatiitic magmas and wehrlites.

Cann points out at length that the Komati rocks are well constrained in age (about 3480 million years) and are significantly older than the overlying rocks containing the Barberton spherule beds (Fig Tree group, about 3250 million years), including those now with clear impact signatures. However, in the wider context, Cann's presentation is slightly misleading, because komatiites are not confined to just the Komati Formation. Indeed, komatiites also occur in at least two further overlying formations (the

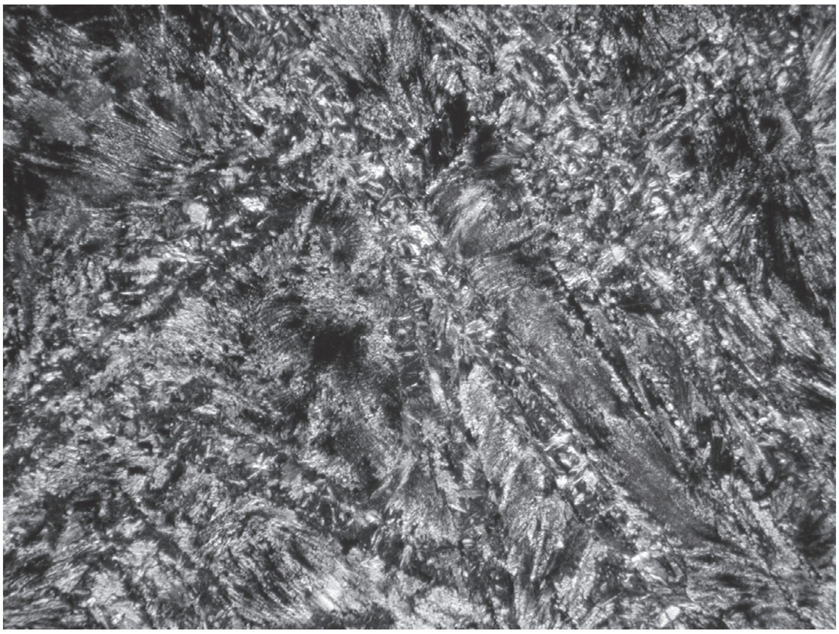

Fig. 3. Photomicrograph as in Fig. 2, but taken in crossed polarized light (XPL).

Hoogenoeg and Kromberg Formations: about 3470–3260 million years). Some komatiites therefore do appear to be similar in age to the impact deposits, although the extent of impact material through the statigraphic column has not been evaluated. It is therefore highly significant in terms of an origin for the komatiites themselves. It surely must be worth reinvestigating the evidence for a palaeometeorite in the Barberton succession, which in 1978 S. A. de Waal claimed to have found, and whose contents do indeed suggest a very high temperature origin. The intensive debate for the Barberton komatiites is unlikely to be settled quickly, but the reader is referred to a reasonably balanced and detailed review presented by W. U. Reimold & others in 2000.

Cann's new field data are an important contribution to the ground truth for any petrogenetic model. Particularly interesting is his suggestion of relic protoliths. Cann does not go so far as to suggest an origin for these relics, but somewhat similar partial melt textures of peridotitic protoliths also characterize breccias associated with the geologically young komatities at Gorgona island. Given the age and thorough alteration of the Barberton komatiites, however, it is most unlikely that any similar glasses will have survived. Until recently, the spinifex-textured komatiites of Cretaceous age in Gorgona Island were the only known Phanerozoic example, but komatiites of Permian–Triassic age have recently been described from north-western Vietnam, where they are associated with Pt-bearing Ni deposits. The widely held view that komatiites are restricted in age to the Precambrian is apparently incorrect. This will need to be considered in the argument for a cooling Earth and will simultaneously require a mechanism for achieving komatiite temperatures in the modern mantle.

One of the attractions of an impact origin for komatiites is that although the physics of melting would strongly prefer an oceanic setting, the melts generated would be constrained by neither plate-tectonic setting nor to 'wet' or 'dry' mantle; they would be indistinguishable from plume-derived melts. It would be ironic, however, if the spinifex textures in komatiites ultimately result from quenching of rapidly formed gigantic impact melts, and have been misinterpreted for so long, as similar quench textures are diagnostic of some crustal impact melts and spinifex komatiite was long ago suggested to be an impact melt in chondritic meteorites (cosmic spherules also feature spinifex olivine). However, the impact theory is just a model, and although there are tantalizing clues in both the impact-derived spherule beds and the palaeometeorite nickel–iron at Barberton, it is probably premature to assign any of the Barberton komatiites to an impact origin before the results of further detailed work are known. Indeed, another extreme view is that komatiites may perhaps have acquired their platinum-group elements and intrinsic heat from that permanently hottest place in the Earth, namely, the Earth's core.

In conclusion, understanding the origin of komatiites and their spectacular spinifex textures is of great significance not only to the early history of the Earth but also perhaps to other planets. They are still the subject of vigorous research, with, for example, some 300 papers published on komatiites in the last two years alone. The original assumption that they are restricted in age to the Archean is incorrect, as two Phanerozoic examples are now known. It is still true, however, that they were far more abundant in the Archean, and their global significance has been widely interpreted. The possible connection between large impacts and komatiite genesis may be testable and needs to be further explored. Lastly, the recent discovery of abundant diamonds in a pyroclastic komatiite from French Guiana was quite unexpected, but implies that at least some komatiites must have a deep origin.

Suggestions for further reading

Arndt, N.T. & Nisbet, E.G. 1982. *Komatiites*, George Allen & Unwin, London, 539pp.

Cann, J.C. 2000. The 3.5 Ga Komati formation, Barberton greenstone belt, South Africa, Part I: new maps and magmatic architecture, *South African Journal of Geology*, v.103, pp.47–68.

Glikson, A.Y. 1999. Oceanic mega-impacts and crustal evolution, *Geology*, v.27, pp.387–391.

Green, D.H. 1972. Archaean greenstone belts may include terrestrial equivalents of Lunar maria? *Earth and Planetary Science Letters*, v.15, pp.263–270.

Jones, A.P., Price, G.D. & Claeys, P. 1999. A petrological model for oceanic impact melting and the origin of komatiites. In: *Second ESF IMPACT meeting, 'Oceanic Impacts', Bremerhaven 15–17 April 1999 (abstract volume)*, pp.39–40.

Reimold, W.U., Koeberl, C., Johnson, S. & McDonald, I. 2000. Early Archaean spherule beds in the Barberton Mountain Land, South Africa: Impact or terrestrial origin? In: *Impacts and the Early Earth* (I. Gilmour & C. Koeberl, eds). Springer, Lecture Notes in the Earth Sciences, v.91, pp.117–180.

Renner, R. 1993. The hottest rocks on Earth, *New Scientist*, 24 July, pp.23–27.