Books

Plates vs Plumes: a Geological Controversy, by Gillian R Foulger, (2010) Wiley-Blackwell. ISBN 978-1-4051-6148-0 (SB), 328 pp. £39.95.

Hugh Rollinson (University of Derby) writes Most text books in the Earth sciences are written to organize and systemize information in order to inform and educate the reader. A smaller number have a different function. These books seek to make a case, to argue a point and to persuade the reader to a particular point of view. *Plates vs Plumes* by Gillian Foulger is one such book. It is written as a polemic, its purpose to persuade the reader that the mantle plume hypothesis is redundant. The sub-title indicates that the reader is being taken into contested territory. What is less clear, until you read the preface, is that the author is one of the principal protagonists against the mantle plume hypothesis. In other words, with her friends, she started the fight. This book is a detailed exposition of her arguments.

What is clear from even a cursory glance at the literature is that the number of 'mantle plume explanations' for geological phenomena has escalated in the past decade. This is particularly true in my field of early Earth history where plumes are used to explain away otherwise difficult-to-explain observations. This is clearly both lazy and wrong and in this sense I heartily agree with a closer scrutiny of the plume hypothesis. However, and here comes the reviewer's prejudice right at the outset, I am not convinced that the time has come to debunk the plume hypothesis in its totality; it is too useful. Having said that, this book is well written and prolifically illustrated. A novel feature is the link to a well-maintained web-site (www.mantleplumes.org) so that the reader can follow up references and subsequent discussion with ease. It would have been better if the book were printed in colour rather than with colour plates inserted into a central section, but I guess this was a marketing/pricing decision on the part of the publisher.

Foulger takes as her starting point an understanding of mantle plumes dating from the mid-2000s, which makes the following predictions:

- A plume will be preceded by domal uplift a few million years before the volcanism commences;
- The arrival of a plume at the Earth's surface is indicated by extensive basaltic volcanism in the form of flood basalts;
- Plume material flows from the core-mantle boundary upwards along a narrow conduit;
- This conduit is fixed relative to the movement of lithospheric plates and so will leave a time-progressive volcanic chain; and
- The lavas associated with plume volcanism are anomalously hot.

The book is therefore structured around these predictions and six substantive chapters discuss in detail the relative merits of plume and plate explanations of these phenomena (there is also a chapter on the geochemical implications of the hypothesis). A final chapter is a synthesis of the preceding discussion and is a useful short cut for the reader who wants to quickly appraise the whole volume.

One of the fundamental features of a mantle plume is that it rises from the core mantle boundary to the surface along a narrow conduit, identifiable as an area of anomalously hot mantle at any given depth. Thus seismology is the tool whereby such images might be observed. This is home territory for Gillian Foulger and she delivers a serious critique of mantle tomography and its limitations in being able to image the deep mantle. 'Tomographic cross section are not geological cross sections and "redium" and "blueium" [the colour coding of tomographic images] are not lithologies'; 'the most intractable problem lies in the geological interpretation of seismic images'. She illustrates how the Iceland plume, the topic of her own research, cannot be imaged below about 650 km and does not demonstrate a narrow conduit down to the core mantle boundary. It is argued that the classic images of mantle plumes showing narrow conduits down to 2800 km published by Montelli and colleagues in *Science*, 2004, are methodologically flawed. But is this so? I note that although on pages 165–168 the Yellowstone plume does not extend below 500 km, newer work published in 2010 shows that it extends down to 1000 km.

My greater concern however turns on the discussion of petrological and geochemical aspects of plume magmatism found in Chapters 6 and 7, for this is my home territory. One of the tenets of plume magmatism is that mantle plumes represent areas of the mantle that are anomalously hot. However some of the methods of establishing mantle temperatures discussed here are not now widely used and other methods currently in use are omitted. I note, for example, that the discussion of komatiites, for which the

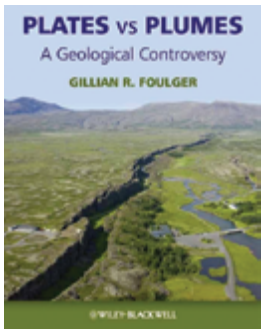

Fig. 1. Plates vs Plumes: a Geological Controversy.

dominant explanation is still that they were derived from abnormally hot, deep mantle and formed in a mantle plume, is relegated to less than a page of text. The argument advanced about ten years ago that komatiites were wet and cool is wheeled out with minimal discussion as the basis for discounting this line of evidence. In contrast recent studies by Herzberg and colleagues using melt temperatures based on melt MgO-content have shown that komatiites are consistently 150 °C hotter than the ambient mantle. This lack of balance in the discussion of komatiites is worrying, given that the tenor of the book is about the close scrutiny of the evidence and intellectual rigor. Further, the complexity of petrological arguments, such as those used in the study of komatiites, does not seem to be fully appreciated by the author. For example, the plea in Chapter 7 to use major element (as well as trace element) chemistry is misunderstood. For the most part the petrological modelling necessary to calculate mantle temperatures is based upon major element compositions.

This lack of understanding of the complexities of the trade also extends to the geochemical arguments used in this book against the existence of mantle plumes. One of the early discoveries in basalt trace element geochemistry was that there is more than one compositional domain in the mantle. Thus began the technique of geochemical fingerprinting of mantle sources using trace elements and isotopes. But there are complex and subtle arguments involved in this process which do not appear to be appreciated in this book. It is true that the technique of isotopic fingerprinting of mantle domains has spawned an entire 'zoo' of possible mantle domains. Nevertheless the basic methodology is robust and there are real differences in mantle chemistry. What these mean, of course, is at the centre-point of the discussion and is the subject of on-going debate. The author points out many inconsistencies in geochemical arguments but it would be simplistic to use this as the basis for discounting the methodology in its entirety.

In my view the flaw in this book is the starting premise. Plumes are defined using the five tenets outlined on pages 12–13, and summarized above. The ensuing discussion shows that these tenets do not exactly hold. I would suggest that this is because the mantle is far more complex than is allowed in this version of the plume hypothesis. The author acknowledges that the mantle contains cold slabs, but it is these that in places may upset the predictions of the plume hypothesis. Sobolev and colleagues in *Nature* (2011) have suggested that some Hawaiian lavas are derived from a 'young' subducted slab which has a memory of seawater alteration. Such a slab will influence the geochemical signature of mantle melts from this region. If, in addition, it is allowed that the mantle contains some subducted sediment and, as now appears to be established from Baffin Island lavas, contains rare primordial domains, we must conclude that the mantle is both physically and chemically complex. Further, as Arndt pointed out in his 2008 book on komatiites, plumes do not choose where they rise, therefore plume–lithosphere interactions have the potential to be both complex and variable. No wonder our current models do not stand up to scrutiny. If further, that part of the mantle processed in the creation of oceanic lithosphere is also variable in composition and structure, then making a distinction between a plate signature and a plume signature will sometimes be difficult. But this does not mean that mantle plumes do not exist.

The anti-plume lobby, if we may use that label, have been around for a number of years and this book is perhaps the most complete statement of their case to date. I guess my final concern is to explore whether anyone is listening to them. Some are. I see a significant paper published in the *Journal of Petrology* in 2011 questioning the plume model for Hawaii. On the other hand, a quick count of papers published in *Nature* over the past year reveals at least five papers making reference to mantle plumes. Whilst but a snapshot it would seem to me that the plume concept is still alive in the geoscience community and its demise is premature.

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