for the strata near the mine of 215 and 211 Ma. The information in this paper has been in part superseded by more recent work, but the data serve to not only set out a general geochronological framework, but the added Pb, Sr, and Nd isotope data on both the footwall and hanging-wall volcanic and related gabbro intrusions, as well as the footwall phyllite and hanging-wall argillite, further constrain both the sources of the mineralizing fluid and the postdepositional metamorphic history of the deposit. The proposed interpretation that the ore-forming fluid has a magmatic origin based on the comparison of the lead isotope data from the rocks compared with that from the ore suggests a magmatic fluid is highly speculative and should be reconsidered in light of new data from studies at Middle Valley and elsewhere.

Chapter 9 provides a comprehensive and well-illustrated study of the mineralogical, textural, and metal residence attributes of primary, remobilized, and recrystallized ores. The preservation of delicate primary-textured parts of the ore is remarkable, considering the structural and metamorphic history of the region. The observations are accompanied by extensive laser-ablation ICP-MS data for many sulfide species. The ore has undergone an extensive history of digenetic and metamorphic recrystallization and remobilization, as reflected in the trace element composition of the various minerals. Because virtually all VMS deposits have undergone significant syndepositional recrystallization, the textural and trace-element variations in Greens Creek are not unexpected, but nevertheless, well documented. One aspect of the deposit that is not treated is the overall zoning present within the entire package of ore zones. Given that most of the sulfides must have formed within the highly permeable conglomerate unit, such zoning might provide useful additional insights into the deposit genesis. Another feature that should be examined is the composition of sphalerite, which can tell much about the precipitation and diagenetic conditions.

The genetic mode presented in the final chapter correctly addresses the enigmatic features of Greens Creek. A typical VMS deposit forms from a single fluid that contains both base metals and sulfur, and that evolved through a combination of adiabatic cooling, phase separation, and mixing with cold seawater. In the case of Greens Creek, the authors suggest, based on the rather compelling S isotope data, metal precipitation was caused by mixing of the ore forming fluid with a fluid containing reduced sulfur that was generated by biogenic reduction of seawater sulfate. This, if correct, would place Greens Creek as a hybrid between the SEDEX and VMS types of deposits. However, without more information about the S isotope composition of the deeper parts of the footwall sequence, a light-sulfur source in the footwall cannot be ruled out. The model for the evolution of the deposit, which involves early phase rifting to form a shallow-water back-arc basin, with sulfide and barite precipitation within a conglomerate wedge that was capped by anoxic sediment, fits well with the observations provided throughout this study. Whereas the genetic model for Greens Creek will be refined with further exploration and research, the evolutionary history outlined in this volume is an excellent starting point.

The Greens Creek volume is a must read for all who either search for or undertake research on both VMS and SEDEX deposits. The organization of the volume is somewhat poor, as the order of the papers could have been better organized, but all the papers are well written and very readable. The data are clearly presented and it's well illustrated. Comprehensive treatments such as this and previous studies on supergiant districts such as Kidd Creek and Bathurst provide an exceptional amount of data that form a baseline for future work. This volume will join those as a legacy of information of lasting value.

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Plates vs. Plumes: A Geological Controversy. Gillian R. Foulger. 2010. Chichester, UK, Wiley-Blackwell. 364 p. ISBN: 978-1-4443-3679-5. Price (hardcover) US$134.95.

In many respects, this book is an outgrowth of the Geological Society of America Special Volume 388, "Plates, Plumes, and Paradigms" (edited by Foulger, G.R., Natland, J.H., Presnall, D.C., and Anderson, D.L, 2005). That volume is notable both for the prevalence of papers that set out to disprove the mantle plume hypothesis, for minimal peer review, and for unreviewed commentaries at the end of many papers by Don Anderson; a few papers, however, were included that reported data endorsing the plume hypothesis for some examples of intraplate magmatism.

In contrast, Foulger's book makes no attempt at a balanced account of plate tectonics and mantle plumes. Rather, it sets out to deconstruct the plume hypothesis, then demonstrate it as inadequate to account for magmatic provinces. There is no room for both plates and plumes; the back cover states this succinctly: "Since the advent of the mantle plume hypothesis in 1971, scientists have been faced with the problem that its predictions are not confirmed by observation. As a result, the multitude of current plume variants now amounts to an unfalsifiable hypothesis." This book is written in a "take-no-prisoners style," reminiscent of Belousov's cold war-written barrage against plate tectonics as a capitalist conspiracy.

An introductory chapter sets the stage by tracing the historical development of plate tectonics and mantle plumes. The original plume hypothesis of Morgan (1971) has been refined by Ian Campbell to synthesize five predictions of the plume hypothesis: (1) domal uplift as a precursor to plume impingement under the lithosphere, (2) flood basalts erupted from the plume head annulus, (3) eruption of material from the hot plume core or tail, (4) time progressive volcanic chains, and (5) temperature anomalies in the mantle expressed as plumes. Foulger devotes six chapters to demonstrate that none of those predictions are consistently present in intraplate magmatic provinces or their mantle sources, finding flaws in all of the canonical body of data from geochronology, geophysics, geochemistry, and petrology that have been used to support the plume hypothesis. Chapter eight summarizes the arguments for plate tectonics and against mantle plumes; this is an exercise in legerdemain—a caricature of complex geological variables flawed by literature citations biased against mantle plumes.

The term "hot spot," as in hotspot volcanic chain, is rejected as an unjustified assumption. Rather, intraplate magmatic provinces, or occurrences, are given the moniker "melting anomalies." Such anomalies are considered to be sourced in relatively shallow asthenospheric mantle, forming as an integral part of plate tectonics where the lithosphere is fractured or in extension, and the volume of magma is related to the fertility of the source and the presence of volatiles, together reflected in magma composition. Seismic modeling of temperature anomalies in the mantle, petrological models, and geochemical models signifying anomalous temperatures in mantle plumes, ancient and modern, are all determined to have limiting assumptions, and komatiites are relegated to convergent margin settings with similarities to boninites. That body of knowledge is dismissed as follows: "The endeavor to use measurements of temperature to study the origins of melting anomalies is plagued by several fundamental problems." However, the author does not accurately cite the petrological modeling of Claude Herzberg and coauthors, where assumptions, constraints, and the errors stemming from them reveal large-scale melt anomalies to have been generated in mantle significantly hotter than the upper mantle source of spreading center basalts. Tellingly, the author does not cite key papers by Derek Wyman discriminating komatiites and boninites. Nor does Foulger address the PGE contents of ultramafic magmas from layered intrusions: high degrees of melting at anomalously elevated temperatures are required both to melt the refractory mantle source, as well as "melt out" PGE from their asthenosphere-hosting phases. In considering the depth of melt formation in the mantle, Foulger notes petrology and geochemistry have essentially no power to determine the ultimate depth of origin of melt sources from deeper then ~100 km (p. 274), or ~200 km (p. 275), then accedes that depths of ~650 km (p. 227) are possible. The first two depths are irreconcilable with inclusions of beta-majorite garnet in kimberlites and with trace element signatures of beta-majorite garnet in Archean komatiites, as was first identified by Qianli Xie in the 1990s.

The hectoring tone of this book is distilled on page 36. "The Plate hypothesis cannot be tested unless there is acceptance that the Plume hypothesis is not proven, and may be falsified at a specified locality…," as if the epistemological purity of plate tectonics requires plumes to be invalidated. And on page 287, the statement appears, that "a theory should be employed where it is useful, but not allowed to control thought." Are advocates of plate tectonics and mantle plumes under thought control?

Foulger compares Hawaii, having a time progressive volcanic chain, and Iceland, which does not, and contrasts the former, having a topographic anomaly only 800 km wide, but a topographic elevation of 8 km above the sea floor, whereas Iceland is on a topographic rise ~3,000 km in diameter, but with an amplitude of ~2 km; these are viewed as fundamental inconsistencies of the plume hypothesis (p. 60). Yet the former is intraplate and the latter is at a spreading ridge. The Samoan plume is given as an example of irregular time progression, but systematic time progression is reported in recent work by Richard Gordon. Foulger considers that plumes should impinge randomly across the Earth's surface, yet finds that ~30 percent of classic hot spots lie on or close to spreading ridges (p. 91). This should come as no surprise; spreading ridges migrate across the upper mantle and, as in the case of Iceland, are captured by plumes. Addressing heat flow at spreading centers, Foulger notes that differences between modeled cooling and observations have been attributed to heat removal by hydrothermal circulation, but this is "problematic to detect" (6.1.1, p. 190). This conclusion is contrary to decades of observations from submersibles for black smoker activity at spreading centers in oceans and back arcs, with attendant base metal sulfide deposits flanked by ferromanganese sediments.

In the context of the philosophy of scientific progress, this book claims that the plume hypothesis has many inconsistencies of predictions and concurrently has so many variants, or exceptions, as to be unfalsifiable. Where does this leave us with subatomic theory? The standard model of physics deals successfully with the "zoo" of subatomic particles, including their microscopic and macroscopic interactions, yet recent discoveries of dark matter and dark energy are entirely beyond the current scope of the standard model. Do we throw the baby out with the bathwater or rather accept that subatomic physics and earth sciences are works in progress?

This book is well produced and structured, with a minimum of typographic errors; a rare exception is no y-axis label on figure 6.5. Fundamentally, however, this book is deeply flawed both in denouncing the plume model whilst at the same time providing no better alternative for the diversity of melt anomalies—specifically, for failing to account for the inconsistency of depleted magmatism from fertile mantle, and in biased literature citation. For example, few papers from the 2003 *Treatise on Geochemistry* or 2008 *Treatise on Geophysics* are referenced.

I cannot recommend this book to any sector of the earth science community, given the flaws. Mary Fowler's treatise on geophysics is an in depth treatment of the subject. Jeff Davies' *Plates and Plumes* presents a balanced view of both geophysical phenomena, and Kent Condie's 2005 book, *The Earth*, weaves together plate tectonics, plumes, Earth evolution, the biosphere, and surface conditions in a rich geologic tapestry of earth-systems science. With a script no less than the Big Bang to Recent volcanism, including plate- and plume-related magmatism, Igor Tolstikin and Jan Kramers' 2008 book is orchestraic in its scope, depth, beauty, and quantitative treatment of major Earth processes; i.e., a bravura performance. For the economic geologist, Franco Pirajno's 2001 book, *Mantle Plumes and Ore Deposits*, has a wealth of hard observations on both, as do review papers in the *Economic Geology 100th Anniversary Volume*. For an up-to-date review of mantle plumes, Bill White's 2010 paper in *Annual Review of Earth and Planetary Sciences* is a masterpiece.

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