**Scientific Debate: The Origin of Melting Anomalies**

Locations on Earth where volcanism occurs away from plate margins (e.g., Hawaii), or where the volume of volcanism is greater than expected at a plate margin (e.g., Iceland), are called hotspots, or more generically melting anomalies. A significant debate exists in the geoscience community about the origin of melting anomalies. In this activity you will jump into this debate, researching one of the arguments and presenting in a debate format with your classmates.

I. What is your understanding of the origin melting anomalies (e.g., Hawaii)? Take five minutes to write a one-paragraph statement.

II. Your professor will present a discussion introducing you to the active debate about the origin of melting anomalies. Some general questions to consider:

A. What are the steps in the scientific method?

B. What is the difference between a hypothesis, theory, and scientific law?

C. Why do rocks melt?

D. What are possible explanations for melting anomalies?

III. Take a side! You (as a small group or individual) will be assigned a side and a topic in the debate of the origin of melting anomalies. Based on which side you are given, you will be assigned two scientific papers to read. One offers a general argument for your side of the debate, and one considers a specific line of evidence or location. Read both papers, taking notes, and coming up with questions to discuss with your professor. Meet with your professor during the week to discuss these questions.

IV. Prepare a short powerpoint presentation explaining the scientific argument put forward in the technical paper you read in the context of the broader debate (your more general paper). Be prepared to concisely present the key points from your readings.

V. Let the debate begin! Your professor will moderate a debate on the origin of melting anomalies. For each topic or location, the groups (or students) on opposite sides will be allotted time to present an initial argument with their powerpoint (5 minutes). Then each side will have a brief period (2 minutes) to rebut the other. After all groups have presented there will be 10 minutes of open floor debate in which students can ask each other questions and make final arguments.

VI. The debate is over. Where do you stand? Now you liberated from the perspective that you selected or were assigned. Weigh in on the debate over the origin of melting anomalies. What side do you find more compelling? What evidence do you find most convincing? Write a paper articulating your perspective in the wake of the in-class debate.**Papers**

**General:** (each student will be assigned one of the following two papers)

*Supporting mantle plumes:* Campbell, I.H., 2007, Testing the plume theory, Chemical Geology, v. 241, p.153-176.

*Against mantle plumes:* Foulger, G.R., 2002, Plumes or plate tectonic processes?, Astronomy and Geophysics, v. 43, p. 19-23.

Alternative set of general papers to set debate:

*Introduction to debate:* Niu, Y., 2005, On the great plume debate, Chinese Science Bulletin, v. Vol. 50, p. 1537-1540.

*Supporting mantle plumes:* Davies, G.H., 2005, A case for mantle plumes, Chinese Science Bulletin, v. Vol. 50, p. 1541-1554.

*Against mantle plumes:* Foulger, G.R., 2005, Mantle plumes: Why the current skepticism?, Chinese Science Bulletin, v. Vol. 50, p. 1555-1560.

\*This series of three articles may seem difficult to access for a U.S. audience, but is available at Yaoling Niu’s web site: http://www.dur.ac.uk/yaoling.niu/MyReprints-pdf/GreatPlulmeDebate-ChineseSciBull2005.pdf

**Topical:** (14 papers total, each student or group will be assigned one)

Temperature of magmas

*Supporting mantle plumes:* Putirka, K.D., Michael Perfit, F.J. Ryerson and Matthew G. Jackson, 2007,Ambient and excess mantle temperatures, olivine thermometry, and active vs. passive upwelling, Chemical Geology, v. 241, p. 177-206.

*Against mantle plumes:* Falloon, T.J., Leonid V. Danyushevsky, Alexei Ariskin, David H. Green and Clifford E. Ford, 2007, The application of olivine geothermometry to infer crystallization temperatures of parental liquids: Implications for the temperature of MORB magmas, Chemical Geology, v. 241, p. 207-233.

Seismic tomography

*Supporting mantle plumes:* Nolet, G., Allen, R., and Zhao, D., 2007, Mantle plume tomography, Chemical Geology, v. 241, p. 248-263.

*Against mantle plumes:* Julian, B.R., 2005, What can seismology say about hotspots?, *in* Foulger, G.R., Natland, J.H., Presnall, D.C., and Anderson, D.L., eds., Plates, Plumes, and Paradigms: Geological Society of America Special Paper 388, p. 155–169.

Flood basalts

*Supporting mantle plumes:* Campbell, I.H., 2005, Large igneous provinces and the mantle plume hypothesis: Elements, 1, 265-270.

*Against mantle plumes:* Anderson, D.L., 2005, Large igneous provinces, delamination, and fertile mantle: Elements, v. 1, p. 271-275.

Helium isotopes

*Supporting mantle plumes:* Graham, D. W., 2002, Noble gas isotope geochemistry of mid-ocean ridge and ocean island basalts; characterization of mantle source reservoirs. *in* Noble Gases in Geochemistry and Cosmochemistry, eds. D. Porcelli, R. Wieler & C. Ballentine, Reviews in Mineralogy and Geochemistry, Mineral. Soc. Amer., Washington, D.C., p. 247-318.

*Against mantle plumes:* Meibom, Anders, Norman H. Sleep, Kevin Zahnle, and Don L. Anderson, 2005, Models for Noble Gases in Mantle Geochemistry: Some Observations and Alternatives, *in* Foulger, G.R., Natland, J.H., Presnall, D.C., and Anderson, D.L., eds., Plates, plumes, and paradigms: Geological Society of America Special Paper 388, p. 347-363.

Meeting plume criteria

*Supporting mantle plumes:* Courtillot, V., Davaille, A., Besse, J., Stock, J., 2003. Three distinct types of hotspots in Earth's mantle. Earth Planet. Sci. Lett. 205, 295–308.

*Against mantle plumes:* Anderson, D.L., 2005, Scoring hotspots: The plume and plate paradigms, *in* Foulger, G.R., Natland, J.H., Presnall, D.C., and Anderson, D.L., eds., Plates, plumes, and paradigms: Geological Society of America Special Paper 388, p. 31-54.

Locations: Yellowstone

*Supporting mantle plumes:* Pierce, K.L., and Morgan, L.A., 2009, Is the track of the Yellowstone hotspot driven by a deep mantle plume? — Review of volcanism, faulting, and uplift in light of new data, Jounal of Volcanology and Geothermal Research, v. 188, p. 1-25.

*Against mantle plumes:* Christiansen, R.L., Foulger, G.R., and Evans, J.R., 2002, Upper mantle origin of the Yellowstone hotspot, Geological Society of America Bulletin, v. 114, p. 1245-1256.

Locations: Iceland

*Supporting mantle plumes (actually somewhat balanced, but in absence of a review article lays out pro-plume perspective):* Bjarnason, I.T., 2009, An Iceland hotspot saga, Jökull, v. 58, p. 3-16.

*Against mantle plumes:* Foulger, G.R., J.H. Natland and D.L. Anderson, 2005, Genesis of the Iceland melt anomaly by plate tectonic processes, *in* Foulger, G.R., Natland, J.H., Presnall, D.C., and Anderson, D.L., eds., Plates, plumes, and paradigms: Geological Society of America Special Paper 388, p. 595-625.

.