HOTSPOT: The Snake River Scientific Drilling Project Tracking the Yellowstone Hotspot Through Space and Time

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Mantle plumes play a crucial role in Earth's thermal and tectonic evolution. Plumes have long been implicated in the breakup and rifting of continents, and plume-derived melts play a significant role in the creation and modification of sub-continental mantle lithosphere. Hotspot volcanism has been the subject of intense recent study in oceanic lithosphere by the *Hawaii Drilling Project*, and studies by IODP will further examine the role of mantle plumes in oceanic settings. These drilling efforts provide base-line information about where mantle plumes originate, how they behave, and the volcanic products of these processes. In contrast, the impacts of hotspot volcanism on continental lithosphere are poorly understood because active continental hotspot systems are limited to surface exposures of volcanic provinces that are too young to be exposed by erosion.

The Snake River Plain volcanic province, which begins under eastern Oregon and ends at the Yellowstone plateau, represents the world's best example of a hotspot track beneath continental crust (figure 1). Basalts of the Snake River Plain are compositionally similar to ocean island basalts and preserve a record of volcanic activity that spans over 12 Ma. The Snake River province is still active today, with flows as young as 6,000 years. Thus, *the Snake River Plain represents the world-class example of active intra-continental plume volcanism*. Further, because it is young and tectonically undisturbed, *the complete record of volcanic activity can only be sampled by drilling*. In addition, the western Snake River Plain preserves an unparalleled deep-water lacustrine archive of paleoclimate evolution in western North America during the late Neogene.

Project *HOTSPOT: Scientific Drilling of the Snake River Plain* held its inaugeral workshop in Twin Falls, Idaho, on May 18-21, 2006. This inter-disciplinary workshop explored the major science issues and logistics central to a comprehensive, intermediate-depth drilling program along the hotspot track. We envisage a series of 4 to 6 drill holes, each 1.5-2.0 km deep, taken along the axis of the SRP that will specifically target the origin and evolution of hotspot-related volcanism in both space and time. Sixty scientists from six countries attended, and additional scientists who could not attend volunteered their interest in pursuing this project.

The first day focused on keynote speakers who highlighted different aspects of the hotspot system, including heat flow, tectonics, basalt geochemistry, and rhyolite geochemistry, as well as paleoclimate and cyclostratigraphic studies on paleolake sediments deposited in basins formed by collapse of the hotspot track. A special guest from the Hawaii Scientific Drilling Project described the both the scientific results of that project and the logistics of a large basalt drilling effort. The day finished with presentations on drilling platforms, downhole logging tools, cyberinfrastructure and the proposal process at ICDP and DOSECC. The highlight of day two was a day-long field trip to potential drill sites that contrasted stratigraphic differences between the basalt-dominated eastern Snake River Plain and the sediment-rich western plain – which is both overlain and underlain by hotspot basalts with distinct origins.

Day three varied between short presentations, break-out sessions, and discussion sessions that featured lively debates on strategies and targets of the drilling campaign. The topical break-out sessions included basalt geochemistry and isotope chemistry, rhyolite geochemistry and volcanology, hydrothermal systems and alteration, sedimentation-paleoclimate-cyclostratigraphy, and geophysics. Participants focused on major questions to be answered in each area and how best to address this questions through a campaign of targeted drilling – keeping in mind the central focus on the *geochemical evolution of continental lithosphere in response to interaction with deep-seated mantle hotspots or plumes*. Day three concluded with a traditional Dutch-oven Bar-B-Que in the Snake River canyon north of Twin Falls – sitting within a high-temperature rhyolite flow, overlain by fluvial and lacustrine sediments, and several hundred feet of basalt lava flows. The workshop ended on Sunday morning with a final wrap-up session that summarized preceding sessions, and laid out the action plan for moving the project towards reality.

The central question addressed by the workshop was: *how do mantle hotspots interact with continental lithosphere, and how does this interaction effect the geochemical evolution of the mantle-derived magmas and the geochemical evolution of the continental lithosphere?* To address this fundamental question, we plan a transect of the continental margin that begins with lavas erupted through Mesozoic accreted terranes of oceanic provenance, and continues through progressively thicker and older lithosphere of Proterozoic to Archean age. The rationale is to examine how basalt chemistry varies through time at different locations along this transect in response to changes in the thickness, age, and composition of the underlying mantle lithosphere. This strategy will allow us to sample extensive sections of basalt at relatively low cost. In addition, the unique potential for resolving unanswered questions about Plio-Pleistocene paleoclimate evolution by drilling paleo-Lake Idaho was discussed.

It was also proposed that one hole should attempt to penetrate the early high-temperature rhyolites, which underlie the basalts, to constrain both the volume of felsic eruptives within the plain and the geologic response to passage of the hotspot. Since most SRP rhyolites represent crustal melts formed in response to the intrusion of mafic magma into the lower and middle crust, the volume of rhyolite allows us to infer the volume of mafic magma trapped in the crust. The nature of pre-rhyolite volcanism and sedimentation reflects crustal response to hotspot passage. It was agreed that the best strategy to achieve this goal is to deepen one of the existing holes at the INL site that already penetrates rhyolite at depth.

The western SRP graben contained a deep lake (Lake Idaho) for much of its history during the late Pliocene-early Pleistocene. Sedimentary deposits formed in Lake Idaho include diatom-rich rhythmites that span the Pliocene-Pleistocene boundary and preserve a detailed record of climate change during this critical transition. These lake deposits will allow us to reconstruct the late Neogene history of North Pacific atmospheric water transport into the Great Basin of western North American craton, resolve linkages between North Pacific atmospheric water transport and the initiation of Northern Hemisphere glaciation, examine the response of the Great Basin hydrological system to the Pliocene climatic optimum, resolve a complete, high-resolution record (nature, timing and character) of the Pliocene-Pleistocene climatic transition in mid-continent North America, and to develop a master reference section for later examination of lacustrine sediments interbedded with basalt and rhyolite in the eastern SRP. Proponents of the Lake Idaho Drilling component will develop the rationale for this scientific effort independently, but complementary with the planned drilling of the volcanic rocks, which underlie the lake sediments.

The great success of the HOTSPOT workshop was its ability to bring together scientists from a wide range of disciplines to address issues related to the central theme of hotspot volcanism, and to forge a work plan that builds on this synergy. In particular, the intersection of hotspot dynamics with paleoclimate records found in sedimentary systems formed in response to these dynamics provides a model for inter-disciplinary science in which the whole is greater the sum of its parts. The use of basalts as geochemical probes of mantle processes will also complement EarthScope investigations of crustal and lithospheric structure by providing mass balance constraints on melt extraction from the mantle and partial melting of the crust. A significant education and outreach component is also planned.

The participants resolved to pursue this project by submitting pre-proposals to ICDP and NSF this coming year that lay out the scientific rationale and logistical background for a HOTSPOT drilling project. This planning effort will require compiling a shared database of existing geologic and geophysical data, coordinating with EarthScope geophysical investigations, establishing a regional geophysical framework based on existing data, and modeling that data to support site selection. We also plan a HOTSPOT session at the American Geophysical Union meeting in December 2006.

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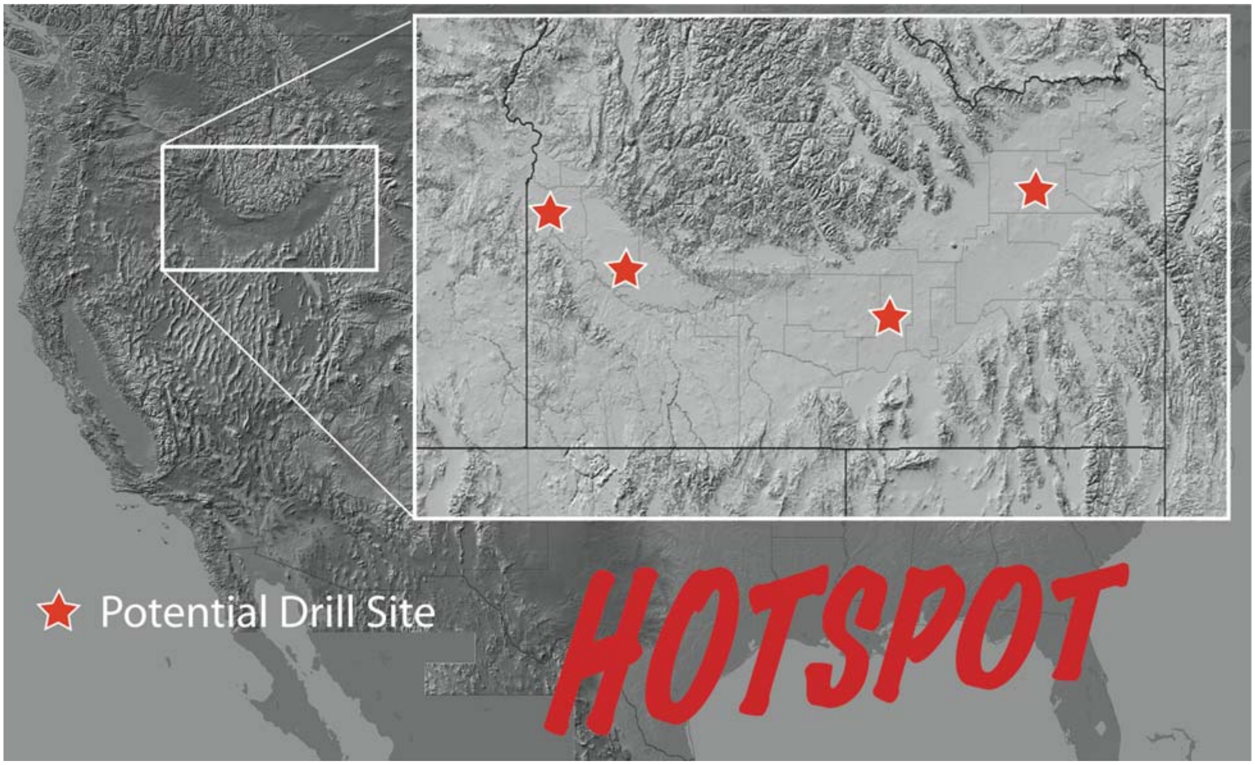

Figure 1. DEM of southern Idaho showing Snake River Plain and its relation to flood basalts of the Columbia Plateau (Washington and Oregon), the basin & range, and the Yellowstone plateau. Potential drill sites shown as yellow stars.

Figure 2. Participants in the ICDP-sponsored workshop HOTSPOT: Scientific Drilling of the Snake River Plain, at Centennial Park, deep inside the Snake River Canyon near Twin Falls, Idaho.