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SUBDUCTION VOLCANISM AND ENVIRONMENTAL CHANGE

Theme: Subduction Factory

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Volcanism links the vast reservoir of greenhouses gases (H_2O, CO_2, sulfur, CH_4) stored in the solid Earth with the cycles of the ocean-atmosphere system. It is well-documented from historical major eruptions of arc volcanoes that the explosive eruption of volatile-rich arc magmas can trigger devastating tsunamis (e.g. Krakatoa 1883) and can influence the global climate with far-reaching consequences for humankind (e.g. global cooling and famine following Tambora 1815).

While the effects of single eruptions are short-lived (a few years), the potential role of arc volcanism as player in the evolution of Cenozoic Earth is a longstanding issue of research. The existence of causal links between arc volcanism and the Earth's Cenozoic surface systems were first postulated by Kennett and Thunell (1975) who observed that variations in the frequency of arc-derived marine fallout tephra layers - and implicate episodic variations of arc volcanism - coincided with the onset of the Quaternary glaciation and potentially an earlier mid-Miocene period of cooling. Several subsequent studies, that built on the improved core recovery of technically more advanced drilling expeditions, confirmed these results (Cambray and Cadet, 1994; Prueher and Rea, 1998; Straub and Schmincke, 1998; Sigurdsson, 2000; Prueher and Rea, 2001). A recent compilation of eruption dates of four circum-Pacific arcs indicates that arc episodicity extends farther back in time, and may be linked to major climate changes of the early Cenozoic (e.g. Eocene-Oligocene cooling, Jicha et al., 2009).

The temporal coincidence between arc volcanism and periods of environmental change has lead to many speculations and models as to cause-and-effect relationships and ensuing feedbacks. An obvious cause of global cooling is the injection of climatically-active gases and aerosols into the atmosphere. Atmospheric cooling may lead to positive feedbacks, such as an increased albedo as snow cover and ice sheets expand, or the biological drawdown of CO_2 driven by the release of nutrients from dissolving ash into the oceans (see Jicha et al. (2009)). Other speculations link arc episodicity to mid-ocean ridge spreading rates (Kennett and Thunell, 1975), and consider sporadic plate tectonic reorganization as driving force of simultaneous arc initiation (e.g. Whittaker et al., 2007). A recent study by Huybers and Langmuir (2009), not limited to arc volcanism, proposed that glacial load of icecaps and glaciers regulate the melt fraction in the upper mantle. Whereas the melt fraction and hence magma production rate increased by mantle decompression during deglaciation, the waxing of the glacial loads reduced the melt fraction and suppressed magmatic activity. Importantly, Huybers and Langmuir (2009) provided a quantitative estimate of the increased contribution of magmatic CO_2 to the increase in worldwide atmospheric CO_2 during the last deglaciation. They estimated amount of ~30-40 ppm of magmatic CO_2

relative to the overall ~100 ppm natural variability during glacial/interglacial periods. This number suggests that magmatism exerts a significant influence on climate evolution together with the mechanisms of the ocean-atmosphere systems.

There is now a critical mass of information and models that warrants a work focus of the MARGINS subduction community towards elucidating causal relationships between arc volcanism and global environmental change. Albeit only a part of global volcanism, subduction volcanism plays a unique role because through the recycling of surface materials it provides a rapid and efficient link between the Earth's exterior and interior processes. Moreover, explosive arc volcanism is famed for leaving a time-precise and temporally highly resolved ash record in marine and lacustrine sediments that cover intermediate (10^3-10^5 yrs) and tectonic ($\geq 10^6$ yrs) time scales. Through composition and temporal distribution, these marine tephras are unique recorders of arc evolution as well of changes in intensity and frequency of arc volcanism (Lee et al., 1995; Bryant et al., 1999; Straub et al., 2009). An extended temporal ash record obtained from suitable sediments may allow for testing the Huybers and Langmuir (2009) hypothesis beyond the last glaciation. The sediment is accessible by drilling, whereby the excellent recovery rates (~100%) of oceanic drilling now allow for an uninterrupted correlation of the ash record with other archives of environmental change (e.g. oxygen stratigraphy, Sigurdsson, 2000).

Exploring links between arc volcanism and the oceanic cycles requires a multi-disciplinary approach. Judicious choice of study areas is needed where a confluence of favorable conditions exists. The influence of glacial loading and unloading is strongest at high latitudes, and thus arc settings like Kamchatka, the Aleutians and the South Sandwich arc should offer the most favorable conditions. Abundant ashes have already been recovered outside Kamchatka and Aleutian trenches. A high background sedimentation rate of non-volcanic datable biogenic sediment will provide a highly-resolved link to other marine climate archives (e.g. Sigurdsson, 2000). Even a temporally incomplete, but longer tephra record may allow for linking arc volcanisms to plate tectonic change (e.g. Straub et al., 2009). Such deep-time studies could further be complemented by studies whether and how the evolution of individual arc volcanoes was related to the glacial/interglaciation cycles.

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