White Paper GeoPRISMS Planning Workshop for the Alaska Primary Site, September 2011, Portland, Oregon

Linking arc volcanic fluxes and growth rates with Pleistocene climate change: Marine tephrostratigraphy of the Aleutian-Alaska volcanic arc

Susanne M. Straub and Gisela Winckler
Lamont Doherty Earth Observatory, Palisades, NY, U.S.A.
(smstraub@ldeo.columbia.edu, winckler@ldeo.columbia.edu)

The long-standing observation that the frequency of arc volcanism changes periodically in intensity has led to many hypotheses and models as to cause-and-effect relationships and feedbacks mechanisms with the global climate (Cambray and Cadet, 1994; Jegen et al., 2010; Jicha et al., 2009; Kennett and Thunell, 1975; Prueher and Rea, 1998; Prueher and Rea, 2001). For example, global cooling has been proposed to follow the enhanced injection of climatically-active gases and aerosols into the atmosphere (Jicha et al., 2009; Kennett and Thunell, 1975; Prueher and Rea, 1998; Prueher and Rea, 2001), that may possibly be followed by positive feedbacks, such as an increased albedo of snow covers and ice sheets, or the biological drawdown of CO_2 driven by the release of nutrients from dissolving ash into the oceans (e.g. Jones and Gislason, 2008). In a recent study, Huybers and Langmuir (2009) proposed that glacially induced volcanism, triggered by the depressurization of the upper mantle increased the frequency of volcanic eruptions worldwide, and thus plays a key role in the atmospheric CO_2 balance and ice-age cycles. A link between arc volcanism and the 41 ka Milankovitch periodicity also emerges from a statistical evaluation of macroscopically visible marine tephra deposits near circum-Pacific arcs (Jegen et al., 2010). On a more immediate scale, Tuffen (2010) concluded that ongoing glacier recession likely will result in intensification of eruptions worldwide, with a corresponding increase in associated hazards.

While these studies suggest causal links between volcanic frequency and climate change, the global approaches remain inconclusive as to magnitude, causes and feedback mechanisms. Testing time-cause relationships between arc volcanism and climate needs an integrated approach where reliable data on the frequency of arc volcanism can be combined with data on volcanic emissions of climatically active volatiles and arc growth rates, and in addition can be directly related to the other parameters of climate change, such as ice volume data, IRD (ice-rafted debris) input, etc.. We propose that the Pleistocene Aleutian-Alaska arc system provides these characteristics and therefore represents an ideal system for addressing a key question of the GeoPRISMS Draft Science Plan (Subduction and Deformation cycles): '*How do surface processes and climate modulate volatile inputs and outputs at subducting margins and vice versa*' (p. 4-15).

Fig. 1 shows the distribution of tephra-bearing ODP/IODP drill cores and piston corers in the proximity of the Aleutian-Alaska arc. ODP Leg 145 drill sites 882, 883 and 887 provide clear evidence for increase in volcanicity at the onset of the Quaternary glaciation (Prueher and Rea, 1998; Prueher and Rea, 2001), despite the incomplete core recovery rate. The recently completed IODP Leg 323 provides an ideal set of sediment drill cores from the Bering Sea. Tephra bed frequency is also high in IODP Leg 323 drill sites in the Bering Sea (drill sites U1340-45) that have a 100% recovery rate (Ravelo et al., 2011). The analyses of drill cores from ODP Leg 145 and IOPD Leg 323 can be complemented by piston cores recently recovered as part of the INOPEX program during the R/V SONNE 202 cruise (INOPEX, 2009) which provide additional information on the Quaternary tephra distribution of the Aleutian-Alaska arc. Clearly, the available marine tephra beds allow for establishing a time-precise and temporally highly resolved record of the Pleistocene Aleutian-Alaska arc volcancity that can be correlated with the marine archives of climate change (Ravelo et al., 2011).

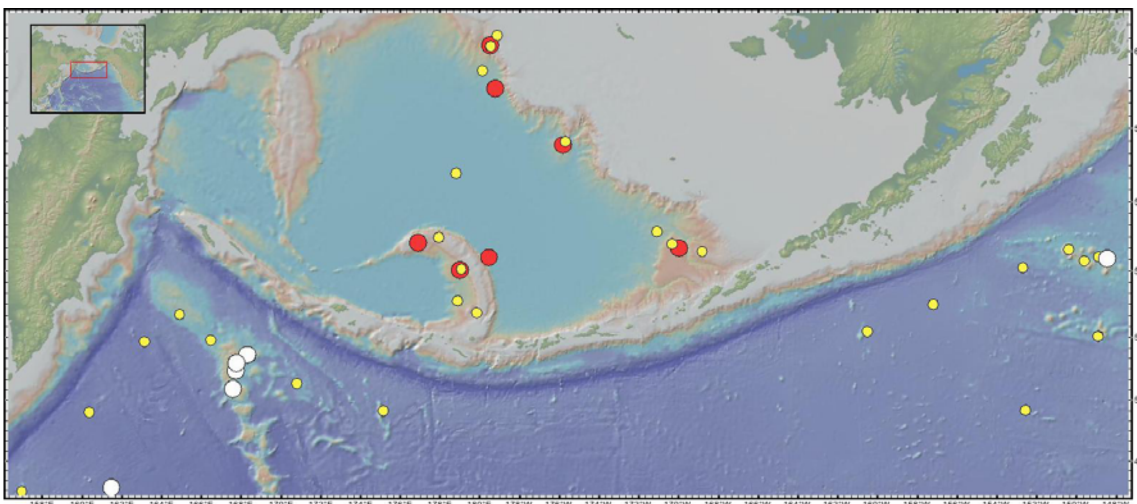

Figure 1: Tephra-bearing drill cores from IOPDP Leg 323 (red), ODO Leg 145 (white) and piston cores from INOPEX-SO202 cruise (yellow) in the Bering Sea and Subarctic North Pacific.

As part of the research of the GeoPRISMS Primary Site 'Alaska/Aleutian Margin', we propose to integrate the information from the marine tephra beds in order to address the following science questions:

(i) Testing the connection between arc volcanic frequency and glaciation as proposed by Huybers and Langmuir (2009) and Jegen et al. (2010).

This connection should be most pronounced at high latitudes, and as northernmost arc on Earth, the Aleutian-Alaska arc is ideally suited for this project. We propose to focus on cores from IODP Leg 323 in the Bering Sea and complement those where needed with piston cores from the INOPEX/SO-202 cruise, south of the arc system. The information on arc volcanic frequency can be obtained from these marine sediment cores whereby the studies must comprise a systematic evaluation of the distribution of both discrete (macroscopic visible) and disperse (tephra camouflaged by non-volcanic sediment) tephra. To reconstruct the climate change signal in these cores, we will combine information from ongoing paleoceanographic studies of the IODP Leg 323 and SO202 cores (Asahi et al., 2011; Schlung et al., 2011) and additional stable isotope and isotope geochemical analyses.

(ii) Connecting the marine tephra record with the volcanic record of the Alaskan-Aleutian arc.

As significant output take the form of tephra far from volcanic sources (Kutterolf et al., 2008b; Kutterolf et al., 2008a; Kutterolf et al., 2008c), the marine tephra record of the Alaskan-Aleutian arc provides important information for characterizing the rate of arc growth (see also pg. 4-17 of GeoPRISMS Draft Science Plan). In addition, the distal tephra may best record high-silica arc volcanism that preferentially erupts explosively and is less well preserved on land. The comprehensive evaluation of composition and volcanic volumes are essential data input for the dedicated GeoPRISMS goal of material transfer through subduction zones (Key Question 3) and arc crustal growth (Key Question 3).

References

Asahi, H. et al., 2011. Foraminiferal oxygen isotope records at the Bering slope (IODP exp. 323 site U1343) provide an orbital scale age model and indicate changes during the mid-Pleistocene transition, AGU Fall Meeting San Francisco, pp. submitted.

Cambray, H., Cadet, J.P., 1994. Testing global synchronism in peri-Pacific arc volcanism. J Volcanol Geotherm Res, 63: 145-164.

Huybers, P., Langmuir, C.H., 2009. Feedback between deglaciation, volcanism, and atmospheric CO2. Earth Planet Sci Lett, 286: 479–491.

Jegen, M.D. et al., 2010. A Detection of Milankovitch Periodocity in Records of Global Arc Volcanism, AGU Fall Meeting, San Francisco, pp. Abstract PP31C-1638.

Jicha, B.R., Scholl, D.W., Rea, D.K., 2009. Circum-Pacific arc flare-ups and global cooling near the Eocene-Oligocene boundary. Geology, 37(4): 303-306; doi:10.1130/G25392A.

Jones, M.T., Gislason, S.R., 2008. Rapid releases of metal salts and nutrients following the deposition of volcanic ash into aqueous environments. Geochim Cosmochim Acta, 72: 3661-3680, doi:10.1016/j.gca.2008.05.030.

Kennett, J.P., Thunell, R.C., 1975. Global increase in Quaternary explosive volcanism. Science, 187: 497-503.

Kutterolf, S., Freundt, A., Perez, W., 2008b. Pacific offshore record of plinian arc volcanism in Central America: 2. Tephra volumes and erupted masses. Geochem Geophys Geosys, 9(2): Q02S02, doi:10.1029/2007GC001791.

Kutterolf, S. et al., 2008a. Pacific offshore record of plinian arc volcanism in CentralAmerica: 1. Along-arc correlations. Geochem Geophys Geosys, 9(2): Q02S01, doi:10.1029/2007GC001631.

Kutterolf, S. et al., 2008c. Pacific offshore record of plinian arc volcanism in Central America: 3. Application to forearc geology. Geochem Geophys Geosys, 9(2): Q02S03, doi:10.1029/2007GC001826.

Prueher, L.M., Rea, D.K., 1998. Rapid onset of glacial conditions in the subarctic North Pacific region at 2.67 Ma: Clues to causality. Geology, 26(11): 1027–1030.

Prueher, L.M., Rea, D.K., 2001. Tephrochronology of the Kamchatka±Kurile and Aleutian arcs: evidence for volcanic episodicity. J Volcanol Geotherm Res, 106: 67-84.

Ravelo, A.C., Takahashi, K., Alvarez-Zarikian, C.A., Party, S.S., 2011. Integrated Ocean Drilling Program Expedition 323 Preliminary Report Bering Sea Paleoceanography Pliocene–Pleistocene paleoceanography and climate history of the Bering Sea. In: IODP-MI (Editor), pp. doi:10.2204/iodp.pr.323.2010.

Schlung, S.A. et al., 2011. Bering Sea Climate Change since 70ka: A high resolution record from Bowers Ridge IODP Site U 1340, AGU Fall Meeting, San Francisco, pp. submitted.

Tuffen, H., 2010. How will melting of ice affect volcanic hazards in the twenty-first century? Philosophical Transactions of the Royal Society, 368: 2535-2558.