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Linkages among tectonism, earthquakes, magma genesis and eruption in volcanic arcs, with a special focus on hazards posed by arc volcanism and great earthquakes

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NON-SUBDUCTION-RELATED ISLAND ARC VOLCANISM: SEDANKINSKY DOL, KAMCHATKA.

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Kamchatka is a mature island arc system; it includes numerous volcanic arcs of different ages that are joined together. The recent volcanic arc is related to subduction of the Pacific Plate (rate ~ 9.5 cm/y). The northern corner of the plate is restricted by its junction with the Aleutian trench and Commander Islands. The northern border line of the subducted plate is usually drawn along a large-scale fracture zone, which is marked by the Kamchatka River valley. Fifteen mln. y.a. the Kamchatka-Aleutian junction was 400 km south (near Shipunskiy Peninsula) of its modern position according to the most recent tectonic reconstructions (Park et al., 2002; Avdeyko et al., 2006). Transition of the junction to the north was a main reason for propagation of the Eastern Volcanic Front of Kamchatka.

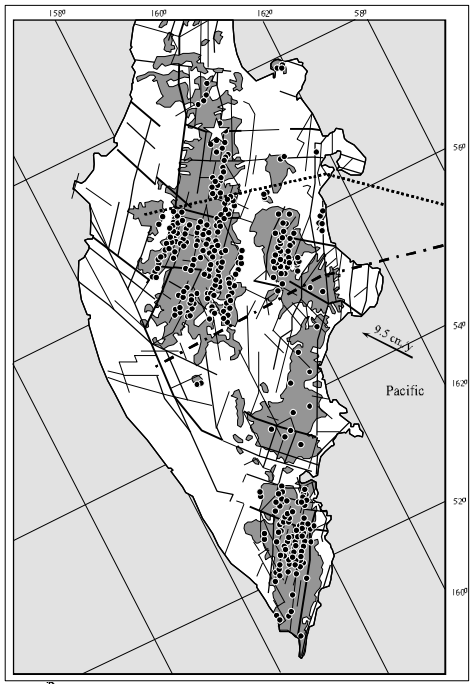

Fig. 1 Schematic map of Holocene-Pleistocene areal volcanoes in Kamchatka. The filled areas represent the areas of quaternary volcanism. The filled dots are areal eruptive centers. The star shows Sedankinsky Dol. Bold dashed lines correspond to the northern edge of the subducted Pacific Plate.

Fig. 1 shows quaternary volcanic areas and hypothetical boundaries of the subducted plate. It is possible that the Holocene-Pleistocene Sredinny Ridge volcanic zone is not related to the modern subduction zone. Meanwhile, more than 120 polygenetic and more than 1000 monogenetic eruptive centers of Holocene-Pleistocene age lie within a 450-km-long longitudinally trending zone with a width of 30-100 km. The scale of Sredinny Ridge basaltic volcanism during the last 40-50 ky significantly exceeds that of other Kamchatka volcanic zones [Bazanova, Pevzner, 2001; Dirksen et al., 2004; Pevzner 2004, 2006].

The Sedankinsky Dol volcanic areal zone is situated far north of any possible boundary of the subducted Pacific plate. Intensive basaltic volcanism appeared here during the late Pleistocene. Two Holocene eruption pulses (9 and 2.5 ky ago) was proved recently [Shur et al., 2009]. All these basalts are enriched in K, Ti, Nd, and LREE compared to "typical island arc" basalts. Basalts often contain skeletal forms of liquidus minerals (olivine up to Fo_{84-86}) and lack evidence of differentiation. Note the absence of high-Mg olivines, which reflects an equilibrium with mantle substrate. We estimated melt composition, H_2O content (~0.3 wt%), temperature (~1210 °C), and pressure (~1.5 kbar) of crystallization of experimentally reheated melt inclusions in most Fo-

rich olivine phenocrysts. Oxygen fugacity was estimated as NNO from Ol-Sp equilibria [Ballhaus et al., 1991].

We hypothesize that an explanation of the specific features of these basalts is the contribution of the non-mantle substrate to the source of melting. A favorable substrate is amphibole-rich pyroxenite. Such pyroxenites are described in the lowest part of the island arc crust of many palaeo-arcs [Kelemen et al., 2003]. Pyroxenites are known as xenoliths in the high-Ti basalts of Sredinny Ridge. These rocks could be involved in magma generation due to delamination or erosion of the lowest parts of the island arc crust by mantle in mature arcs.

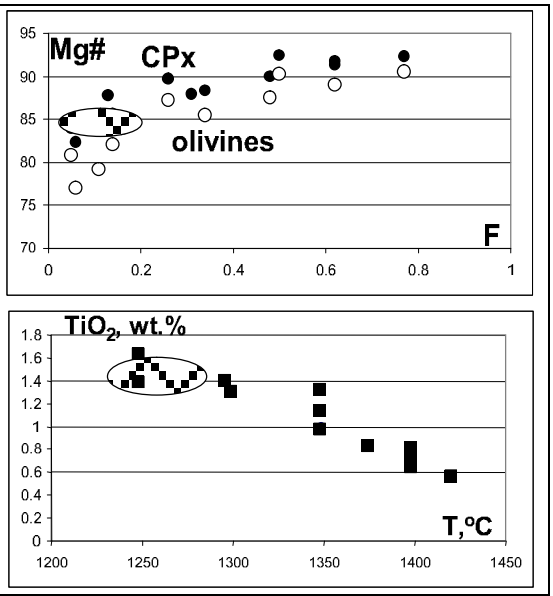

Fig.2 Comparison between Sedankinsky Dol parental melts and experimental data in plots of: a) Mg# vs. melted percentage (F); b) TiO_2 vs temperature (T,°C). Circles reflect experimental data of pyroxenite melting in dry conditions and 8-16 kbar [Kogiso,Hirshmann, 2001]. Empty circles: olivine; filled circles: clinopyroxene; squares: melts. Shaded area shows estimations for parental melts of Sedankinsky Dol basalts.

Tabl.1 Estimated parental melt compositions for Sedankinsky Dol basalts.

Sample	PK-02-32	PK-02-21	PK-02-26	PK-02-20	PK-02-27
SiO_2	48.56	46.89	48.46	47.43	47.79
TiO_2	1.60	1.72	1.65	1.62	1.65
Al_2O_3	18.64	18.28	17.27	19.45	17.26
FeO*	9.94	9.95	9.93	9.95	9.92
MnO	0.32	0.18	0.24	0.17	0.21
MgO	5.54	7.45	7.20	7.40	7.63
CaO	8.60	10.77	10.13	9.68	10.52
Na_2O	4.55	3.51	3.64	4.21	3.39
K_2O	1.21	0.84	0.82	0.93	0.94
P_2O_5	0.77	0.42	0.39	0.18	0.51
Cr_2O_3	0.03	0.03	0.07	0.07	0.06
Fo, %	79.7	84.1	83.3	83.7	83.7
H_2O		0.18	0.29	0.09	
T, °C	1162	1194	1193	1208	1205

Notes: Each column is averaged composition values of glasses from experimentally quenched melt inclusions with correction to olivine-melt equilibrium. Fo: averaged forsterite number for each sample; T: temperature of olivine-melt equilibrium (Ford et al., 1983); Samples PK-02-20, PK-02-21, PK-02-26 from Terpuk lava flows, PK-02-32 from Domashniy-2 cone lava flow, PK-02-27 from Kibeney shield volcano.

[Kogiso&Hirshmann, 2001] showed that pyroxenites could be partially melted at 1250°C and 8-16 kbar (similar to crust-mantle boundary conditions) even in dry conditions. Corrected to 8-16 kbar, temperatures for Sedankinsky Dol parental basalt melts are in the range of 1240-1280°C.

We compared compositions of Sedankinsky Dol basalt melt, olivine, and clinopyroxene with the pyroxenite melting experiments of Kogiso and Hirshmann (2001; Fig.2). Experimental data are in good agreement with natural samples with 5-20% melted at 1230-1280°C.

We can suppose that parental magmas of Sedankinsky Dol (and other Sredinny Ridge magmas of the high-Ti series) could be produced outside of modern supra-subduction zones due to melting of delaminated pyroxenites at a temperature of 1230-1280°C and a pressure of 8-16 kbar, with 5-20% melted. The island arc signature could be partially inherited from pyroxenites, which originated in supra-subduction settings. Elevated concentrations of K, Ti, Nb, and LREE could be explained by low degrees of melting and the hypothetical presence of amphibole in the melt substrate.