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SO249 – BERING – Origin and Evolution of the Bering Sea: An Integrated Geochronological, Volcanological, Petrological and Geochemical Approach

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The R/V SONNE expedition SO-249 is part of the research project BERING, conducted in the framework of the Russian-German Agreement on Marine and Polar Research and in close cooperation with U.S. American colleagues. The overarching goal of BERING is to elucidate the magmatic and tectonic evolution of the Bering Sea and its margins over the past ≥50 m.y. In particular, BERING investigates the physical and chemical conditions that control the development of subduction zones, including subduction initiation, evolution of mature arc systems, and the impact of subduction volcanism on the environment. SO-249 conducted geological, morphological, and biological studies along the Aleutian Volcanic Arc, the Pacific seafloor subducting beneath the Aleutian and northern Kamchatka Arcs, and in the western Bering Sea. Besides extensive multi-beam mapping and sediment echo-sounder profiling, a total of 150 dredge hauls were conducted on the two legs of SO-249. Of these, 91 delivered magmatic and/or metamorphic rocks (not including glacial dropstones), 34 volcaniclastic rocks including breccias containing lava fragments, 64 sedimentary rocks, and 19 Mn-Fe-Oxide crusts and nodules. The on shore work program at Russian, German, and U.S.-American institutions includes geochronological, petrological and geochemical studies on igneous samples obtained during the cruise. Although the analytical work has just begun, we plan to present early results at the meeting. Below we summarize the relevant mapping and sampling pertaining to each of our overarching goals:

Aleutian arc inception and evolution

Dredging of the deep canyons and faults in the fore arc basement, as well as along the lower trench slope, were the prime targets to obtain rocks for reconstructing arc initiation and early arc evolution. While the lower trench slopes mainly delivered semi-consolidated sediments that probably represent accreted sediments, the arc basement was successfully sampled at Adak, Amatignak and Murray canyons and along the southern slope of Attu Island, during leg 1 (USA EEZ). Rocks obtained here range from fairly fresh lava to plutonic rocks confirming that some canyons such as Murray cut deep into presumably older arc crust. During leg 2 (Russian EEZ), we sampled the Komandorsky block, a remnant of the early Aleutian arc crust. Dredging along its NW, NE and SE margins delivered a wide range of volcanic and mafic plutonic rocks that include adakite-like varieties. Abundant solidified sediment was sampled along the lower trench slope of the Komandorsky Block.

Arc Input

In order to characterize the age and composition of the Pacific lithosphere subducting beneath Kamchatka and the Aleutian Arc, dredging operations successfully targeted fracture zones (FZ), bend faults and intraplate seamounts. While fracture zones east of 176°E and those on the Pacific plate subducting beneath Kamchatka delivered variably altered rocks from ocean crust layer 2, the Stalemate FZ provided a full rock suite that represents a cross section through the oceanic lithosphere, including upper mantle ultramafic rocks, a variety of lower crustal gabbroic rocks and upper crustal basalts. Beach sands and pebbles/cobbles consisting of rock fragments, minerals and grains of the aforementioned lithologies were also obtained from the shallowest part of the Stalemate FZ at its northwestern termination just before it enters the Aleutian trench. Therefore the northern end of the Stalemate FZ must have once been subaerially exposed, which indicates that significant vertical uplift must have occurred, either related to collision of the Stalemate FZ with the Aleutian trench or by vertical movements when Stalemate was a transform fault of the Kula spreading system.

Tracing the Pre-Aleutian subduction history

Prior to SO-249, the nature of the Beringian and Chukotka Margins and their junction was unknown. Possible origins included a remnant of the pre-Aleutian (Beringian) arc, passive continental margin or a transform fault scarp. Although numerous seamount structures appeared on the shelf slopes on the predicted bathymetry, extensive mapping and reconnaissance sampling

revealed a thick sediment cover and lack of igneous basement exposures. However, young fault systems were discovered at the Chukotka Margin, which may be related to recent movements at the boundary of the Beringian and North American Plates.

Origin of the Komandorsky and Aleutian marginal basins

Formation of the ocean basins north of the Aleutian Arc is enigmatic. The most prominent models suggest either plate capture at the initiation of the Aleutian arc or back-arc spreading. The very thick sediment cover of the Aleutian basin inhibits direct probing of its basement even by deep sea scientific drilling. Based on seafloor magnetics and NW-SE aligned traces of fracture zones, the Komandorsky basin, however, appears to have formed during a short period of “back-arc” spreading after initiation of the Aleutian arc. Dredging of FZ’s in the Komandorsky basin delivered in-situ lava at only a single location, while semi-consolidated sediments were recovered at all other stations. The N-S trending Shirshov Ridge, separating the Komandorsky from the Aleutian basin, could hold key information on the tectonic evolution of the area. Along its western margin, a series of oval-shaped domes yielded homogeneous dredges of freshly broken ultramafic rocks (harzburgites, pyroxenites and dunites), amphibolite facies basalts, dolerites, and gabbros, as well as greenshist facies metasediments. This rock suite is characteristic of an ophiolite sequence and therefore reflects uplifted, overthrust or accreted ocean crust. In conjunction with Late Cretaceous to Early Paleocene (65-69 Ma) island arc rocks dredged on the Central crest of Shirshov (SO201-2; unpubl. data), several working hypothesis emerge: 1) obduction of Aleutian basin ocean crust, 2) uplift of arc crust and mantle of the Cretaceous Olyutorsky arc (Siberia), which was rifted away from the Siberian margin to form the Komandorsky Basin, or 3) an earlier ophiolite accreted during collision of the Olyutorsky arc with the Siberian margin.

Modern Aleutian arc system:

West of 176°E, plate convergence becomes increasingly oblique leading to absence of young subaerial volcanoes west of Aleutian Buldir Island. An intriguing chain of young submarine cones, located N of the western Aleutian and Komandorsky Islands, however, has been detected by marine surveys. SO-249 filled in sampling gaps at the Western cones north of Attu Island that delivered hornblende-orthopyroxene bearing rhyodacites. The second prime target was Piip volcano and the Volcanologists Massif NE of the Komandorsky block. Together with previous R/V SONNE mapping, the

area is now extensively mapped by EM122 including a high resolution survey of the top region with the EM710 system. In addition, detailed sampling was carried out on Piip volcano and the Volcanologists Massif. Fresh glass bearing lavas were dredged at the tilted crustal block NW of Volcanologists Massif. Preliminary laser ablation ICP-MS analyses suggest that they represent the Komandorsky Basin crust immediately before the Massif formed. No volcanic cones were detected SE of Piip suggesting a large spatial gap of recent volcanic activity between Piip Volcano and the Western cones. The discontinuity of the Aleutian volcanic front and strong compositional contrast between the Western Cones and Volcanologists Massif suggest that the origin of volcanic activity in the Far-Western Aleutian Arc is largely related to upwelling of hot mantle caused by rifting processes in the Komandorsky Basin.

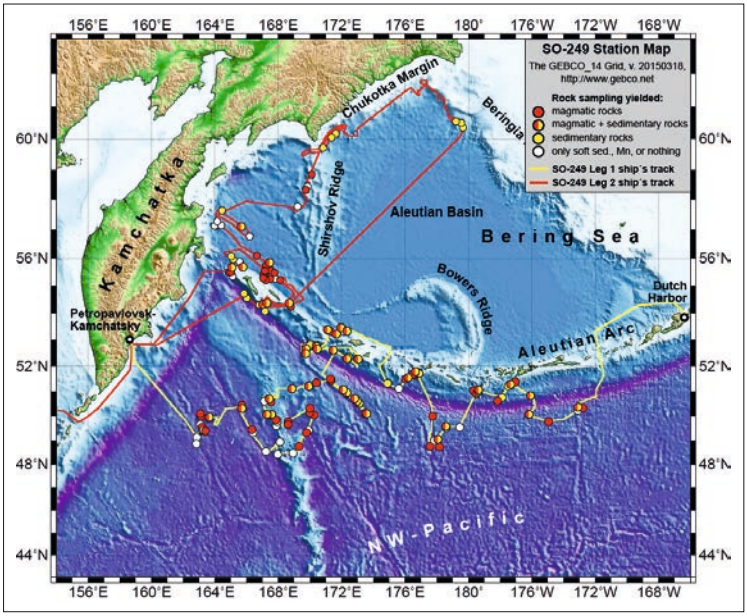

Figure 1: Ship´s tracks and sampling stations (colored dots) of R/V SONNE cruises SO-249 Leg 1 and 2 (data base for bathymetry: The GEBCO_2014 Grid, version 20150318, http://www.gebco.net).