Available online at www.sciencedirect.com
ScienceDirect
Earth and Planetary Science Letters 256 (2007) 617–632
EPSL
www.elsevier.com/locate/epsl

# Trace elements in clinopyroxenes from Aleutian xenoliths: Implications for primitive subduction magmatism in an island arc

G.M. Yogodzinski [a,*], P.B. Kelemen [b,1]

[a] *Department of Geological Sciences, University of South Carolina, 701 Sumter St., EWSC617, Columbia, SC 29208, United States*
[b] *Lamont-Doherty Earth Observatory, Palisades, NY 10964, United States*

Received 1 August 2006; received in revised form 5 February 2007; accepted 5 February 2007
Available online 13 February 2007
Editor: R.W. Carlson

**Abstract**

Trace element abundances in clinopyroxene (cpx) from cumulate xenoliths are used to characterize the nature of primitive magma-forming processes beneath the Aleutian island arc. Clinopyroxenes from deformed mafic and ultramafic xenoliths hosted in a Neogene-age mafic sill from Kanaga Island have widely varying trace element abundances (Sr = 8–32, Y = 2–64, Zr = 2–38, Nd = 0.65–16 ppm) that are generally well correlated with cpx Mg# (Mg/Mg + Fe). Trace element ratios in the Kanaga xenoliths show relatively little variability (Nd/Yb = 1.7–3.5, Sr/Y = 0.20–8.7, Nd/Zr = 0.10–0.43) and trace element patterns are generally parallel to one another, with the most evolved samples showing pronounced negative Eu anomalies (Eu/Eu* = 0.56–0.66). In contrast, cpx from xenoliths hosted in Holocene-age pyroclastic deposits from Mt. Moffett on Adak Island, have more strongly fractionated trace element patterns, with higher and more variable Sr (8–69 ppm), Nd/Yb (3.1–10.5) and Sr/Y (0.5–47) compared to Kanaga xenolith cpx. Clinopyroxene from the amphibole-bearing and igneous-textured Moffett xenoliths also lack substantial negative Eu anomalies (Eu/Eu* = 0.84–1.25). With respect to most trace element characteristics, cpx from the Kanaga xenoliths resemble cpx phenocrysts from Aleutians basalts, and are distinct from Moffett xenolith cpx which resemble phenocrysts from primitive and geochemically enriched, high-Mg# andesites. The strongly contrasting trace element patterns in the two xenolith suites, which are most clearly evident in the most primitive samples (cpx Mg# > 0.86), are present in cpx with broadly similar major element characteristics (XWo = 0.40–0.50, XCaTs = 0.02–0.25, Mg# = 0.65–0.92), and are interpreted to result from differences in the trace element characteristics of the primitive melts that crystallized to produce the xenoliths. Melts that crystallized to produce the Kanaga xenoliths appear to have been similar to modern Aleutian basalts, whereas those that produced the Moffett samples were more hydrous and perhaps more oxidized and had more strongly fractionated trace element patterns, analogous to those observed in the geochemically enriched primitive andesites. If the trace element-enriched signature in the Moffett xenoliths is produced by melting of the subducting plate in the presence of garnet, then these results support recent thermal modeling which suggests that a 50–60 m.y.-old subducting plate, such as that beneath the central Aleutians, may commonly reach at least those temperatures required to produce eclogite melting under water-saturated conditions (~ 850 °C). These results indicate that primitive melts arising from the subduction zone are geochemically diverse and may exert primary control over the nature of the distinctive igneous differentiation series (calc–alkaline versus tholeiitic) which are observed in Aleutian volcanoes.


*Keywords:* subduction; trace elements; xenolith; ion probe; clinopyroxene; mafic; ultramafic; basalt; andesite

* Corresponding author. Tel.: +1 803 777 9524; fax: +1 803 777 4352.
*E-mail addresses:* gyogodzin@geol.sc.edu (G.M. Yogodzinski), peterk@ldeo.columbia.edu (P.B. Kelemen).
[1] Tel.: +1 845 365 8728; fax: +1 845 365 8155.

0012-821X/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsl.2007.02.015

## 1. Introduction

Subduction systems exert first-order controls over the nature of crust–mantle recycling, and play a major role in the evolution of the solid-earth geochemical system [1,2]. To a large degree our understanding of the physical and chemical conditions in subduction zones comes from geochemical studies of island arc lavas, especially lavas that are primitive (relatively Mg/Mg+Fe, or Mg#) and have therefore been little-modified by shallow processes (e.g., [3–5]). Most arc lavas are however, evolved (whole-rock Mg#<0.60), and have been substantially modified by crystal fractionation, mixing and/or assimilation in relatively shallow, crustal-level magma chambers (e.g., [6]). These processes commonly obscure the mantle-level processes that underlie magma genesis in subduction zones.

An alternative approach to understanding subduction magmatism, one that is largely independent of observations of arc lavas, is through the petrologic and geochemical study of mafic and ultramafic xenoliths from modern subduction systems. Such studies are relatively rare because subduction-related xenoliths are rare, however where they exist, mafic and ultramafic xenoliths provide an important source of information on the physical and chemical conditions in subduction zones (e.g., [7–13]).

Here, we present new trace element analyses of clinopyroxene (CPX) from mafic and ultramafic xenoliths from Adak and Kanaga islands in the central Aleutian Island arc (Fig. 1). These data demonstrate that variability of key trace element concentrations and ratios (Sr, Nd, Nd/Yb, Sr/Y) is greatest in Aleutian xenolith CPX with Mg#'s>0.86. The highly variable trace element contents of these primitive CPX converge on relatively uniform, 'normal' compositions in evolved CPX at moderate-to-low Mg-number (<0.80). These observations are consistent with previous studies of CPX phenocrysts in primitive Aleutian lavas [14], and with the idea developed through whole-rock studies, that melts arising from the Aleutian sub-arc mantle are themselves enormously diverse, ranging in composition from arc basalts and picrites with 'normal' subduction-related trace element enrichments compared to MORB, to primitive andesites with highly enriched trace element patterns [3,15–19], now often referred to as 'adakites' [20]. The data presented here are discussed in the context of geochemical source components, with an emphasis on understanding the physical conditions and geochemical processes that have contributed to the genesis of lavas produced in the Aleutian subduction system.

## 2. Xenolith locations, petrography and mineralogy

Xenoliths selected for this study are from Kanaga and Adak islands in the central part of the Aleutian island arc (Fig. 1). At the Kanaga location, the xenoliths are hosted by basaltic sills and dikes, which intrude rocks of probable Neogene age [21–24]. On Adak, the xenoliths occur in Holocene-age pyroclastic deposits from Mt. Moffett [7,10,25]. All samples have been well characterized

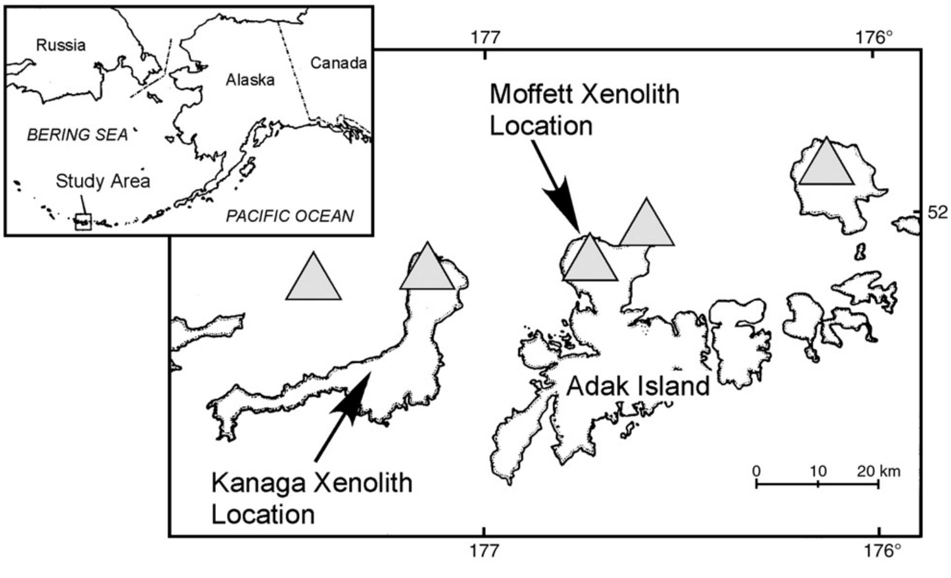


Fig. 1. Location map. Xenoliths discussed in this paper are from Kanaga and Adak Islands in the central Aleutian arc (see inset). Large, gray triangles show the locations of the late Pleistocene and Holocene volcanoes Bobrof, Kanaga, Moffett, Adagdak, and Great Sitkin (west-to-east).