Distinctly different parental magmas for calc-alkaline plutons and tholeiitic lavas in the central and eastern Aleutian arc

Yue Cai, Matthew Rioux, Peter B. Kelemen, Steven L. Goldstein, Louise Bolge, Andrew R.C. Kylander-Clark
11 ± 3 K/Ar Hb
Marlow et al. 1973

27.5
intra-oceanic Aleutians east of Adak
lavas & plutons

polygon: estimates for bulk continental crust

molar Mg#

wt% SiO2
Kelemen & Behn 2014, submitted; Data compilations:
Kelemen et al. 2003 AGU Ch11, Singer et al. 2007,
Yogodzinski et al. WAVE dredging expedition 2005,
Yogodzinski, Hoernle, Portnyagin pers. comm. 2013
central Aleutian lavas?
central Aleutian lavas?
in any case, central Aleutian lavas & plutons are isotopically distinct
central Aleutian plutons have distinctly different sources from central Aleutian lavas

primitive Holocene Aleutian lavas are not representative of bulk arc crust
either the source of central Aleutian magmas changed rapidly after 9 Ma, or there have been two distinct types of magma source throughout Aleutian history
if there have been two different sources throughout Aleutian history: wetter, more SiO$_2$-rich magmas may stall when they degas in the mid-crust
central Aleutian plutons have distinctly different sources from central Aleutian lavas
central Aleutian arc crust is more “calc-alkaline” and more similar to continental crust than central Aleutian primitive lavas
relamination not delamination: continental lower crust forms from arc upper crust

Peter Kelemen & Mark Behn
review article accepted for Nature Geoscience

(also check out Hacker, Kelemen & Behn, Ann. Rev. Earth Planet. Sci. 2015)
Kelemen & Behn 2015, Nature Geoscience
compilations: Kelemen 1995; Rudnick & Gao 2003; Hacker et al. 2015
continental lower crust compositions normalized to bulk continental crust

yellow & grey fields: published estimates for bulk and lower continental crust

Kelemen & Behn 2015, Nature Geoscience
compilations: Rudnick & co-workers 1990-2014; Huang et al. 2013; Hacker et al. 2015
Kelemen & Behn 2015, Nature Geoscience
compilations: Kelemen et al. 2003 AGU Ch11, Singer et al. 2007,
Yogodzinski et al. 2015
Kelemen & Behn 2015, Nature Geoscience;
compilations: Kelemen et al. 2003 AGU Ch11, Singer et al. 2007,
Yogodzinski et al. 2015
too low
Nb  Ta
Kelemen & Behn 2015, Nature Geoscience
compilation Jordan et al., CentAm & IBM Geochem Database, 2012
Aleutian lavas

Kelemen & Behn 2015, Nature Geoscience
compilations: Kelemen et al. 2003 AGU Ch11, Singer et al. 2007, Yogodzinski et al. 2015
Kelemen & Behn 2015, Nature Geoscience
calculated using arc data x lava/(lower crust)
& pluton(lower crust) fr Talkeetna & Kohistan
andesitic lavas & plutons

dense, mafic cumulates

delamination, foundering

74% of Talkeetna & Kohistan lower crust

75% of granulite xenoliths and massifs

Kelemen & Behn 2015, Nature Geoscience; compilations as in previous slides
Kelemen & Behn 2015, Nature Geoscience
compilations as in previous slides

- 83% of Talkeetna & Kohistan lower crust
- 75% of granulite xenoliths and massifs
- 74% of Talkeetna & Kohistan lower crust
- 75% of granulite xenoliths and massifs

Kelemen & Behn 2015, Nature Geoscience
compilations as in previous slides
predominantly felsic upper & middle crust

mafic lower crust

delamination

remaining mafic lower crust

delaminated mafic rocks

relamination

relaminated felsic compositions

subducting mafic compositions

arc crust

delamination

relamination
Aleutian lower crust is definitely mafic with $V_p > 7.3$ in large regions … but what if the Aleutians were gradually subducted via subduction erosion?
Kelemen & Behn 2015, Nature Geoscience
using data compilations as in previous slides
buoyant arc compositions normalized to continental crust

Kelemen & Behn 2015, Nature Geoscience
using data compilations as in previous slides
75% of granulite xenoliths and massifs

74% of Talkeetna & Kohistan lower crust

Kelemen & Behn 2015, Nature Geoscience; compilations as in previous slides
Aleutian & IBM plutons

Aleutian & IBM lavas

continental granulite massifs
continental granulite xenoliths

Kelemen & Behn 2015, Nature Geoscience; compilations as in previous slides
relamination not delamination:

continental lower crust forms from arc upper crust
thank you for your attention and thanks GeoPRISMS!!!
warning: the speaker is about to embark on an entirely different talk
Reevaluating carbon fluxes in subduction zones, what goes down, mostly comes up

Peter B. Kelemen\textsuperscript{a,1} and Craig E. Manning\textsuperscript{b,1}

\textsuperscript{a}Department of Earth & Environmental Sciences, Columbia University, Lamont–Doherty Earth Observatory, Palisades, NY 10964; and \textsuperscript{b}Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, CA 90095

This contribution is part of the special series of Inaugural Articles by members of the National Academy of Sciences elected in 2014.

Contributed by Peter B. Kelemen, April 23, 2015 (sent for review August 7, 2014; reviewed by Jay J. Ague, James Connolly, Rajdeep Dasgupta, and Dimitri Sverjensky)
Kermadec
Chile

X25 subduction geotherms from Syracuse et al. PEPI 2010; solidus from Schmidt et al. EPSL 2004; serp out from Ulmer & Trommsdorff Science 1995
metamorphic decarbonation reactions (Gorman et al. 2006)

4-37 Mt C/yr
Kermadec-Chile subduction geotherms from Syracuse et al. PEPI 2010; solidus from Schmidt et al. EPSL 2004; serp out from Ulmer & Trommsdorff Science 1995
fluids from carbonate-bearing serpentinite at base of crust
dehydration $\leq 10$ wt% aqueous fluid, $3$ wt% total C in fluid
500 m sediment + 500 m carbonated basalt
0.05 m/yr subduction velocity, 50,000 km subduction zones

$\leq 21$ Mt C/yr
Rising diapirs of low density metasediment rise into the overlying mantle wedge
Diapirs Likely

Diapirs Unlikely

Tonga, N Costa Rica, Mariana

Izu

Behn et al., Nature Geoscience 2011
Eggler 1978; Ellis & Wyllie 1980; Falloon & Green 1989; 1990; Wyllie & Huang 1976; Dasgupta & Hirschmann 2006
aqueous melts & fluids from C-bearing melts of subducting material, diapirs, &/or mantle)
The diagram illustrates the carbon cycle in Earth's geodynamic system. The values are in Mt C per year and are from various sources:

- **Arc volcanoes**: 18-43 (18-37) Mt C yr
- **Solid storage**: 0-47 Mt C yr
- **From subducting plate into shallow mantle, crust, ocean, & atmosphere**: 14-66 (18-37) Mt C yr
- **From subducting plate to convecting mantle**: 0.0001 to 52 (24-48) Mt C yr
- **Ridge and ocean island volcanoes**: 8-42 (13-90) Mt C yr
- **Total**: 39-66 (61?-114?) Mt C yr
- **Sediment**: 13-23 (13-17) Mt C yr
- **Crust**: 22-28 (12-61) Mt C yr
- **Mantle**: 4-15 (“36?”) Mt C yr

Values in parentheses are from Dasgupta & Hirschmann EPSL 2010 (DS10). An asterisk indicates values from DS10 used in this paper. "36?" is a direct quote from DS10. Note that Dasgupta RIMG 2013 (D13) used a value of 5 Mt C/yr. (-) indicates that DS10 & D13 did not estimate a value for this flux.
sediment 13-23 (13-17)
crust 22-28 (12-61)
mantle 4-15 ("36?")
from subducting plate into shallow mantle, crust, ocean & atmosphere 14-66 (18-37)
diffuse outgassing 4-15 or more (-)
arc volcanoes 18-43 (18-37)
solid storage 0-47 (-)
from subducting plate to convecting mantle 0.0001-52 (24-48)
ridge and ocean island volcanoes 8-42 (13-90)
total 39-66 (61?-114?)
sediment 13-23 (13-17)
crust 22-28 (12-61)
mantle 4-15 ("36?")
values in Mt C per year
values in parentheses are from Dasgupta & Hirschmann EPSL 2010 (DS10)
asterisk indicates values from DS10 used in this paper
"36?" is a direct quote from DS10;
note Dasgupta RIMG 2013 (D13) used a value of 5 Mt C/yr
(-) indicates that DS10 & D13 did not estimate a value for this flux
values in Mt C per year

values in parentheses are from Dasgupta & Hirschmann EPSL 2010 (DS10)
asterisk indicates values from DS10 used in this paper
“36?” is a direct quote from DS10;
note Dasgupta RIMG 2013 (D13) used a value of 5 Mt C/yr
(-) indicates that DS10 & D13 did not estimate a value for this flux
steadily increasing carbon concentration in the mantle lithosphere + crust + ocean + atmosphere

consistent with $^3$He/CO$_2$ correlation & noble gas data indicative of less-degassed reservoir in the mantle
thank you for your attention
TerraFERMA Examples
New subduction zone models

- Slab geometry from data (here, Alaska Peninsula van Keken et al. 2011)
- Visco-plastic rheology - diffusion creep plus von-mises plasticity
- Similar focusing behavior
carbon fluxes in subduction zones: what goes down, mostly comes up

Peter Kelemen & Craig Manning
TerraFERMA Examples
New subduction zone models

- Slab geometry from data (here, Alaska Peninsula van Keken et al 2011)
- Visco-plastic rheology - diffusion creep plus von-mises plasticity
- Similar focusing behavior
systematically distinct sources for Aleutian plutons and lavas

Merry Cai, Matt Rioux, Peter Kelemen & Steve Goldstein