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Geochemical evidence for delamination from the Jurassic Talkeetna arc crustal section: missing pyroxenites from the Moho

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Earths crust is primarily generated in oceanic settings via divergent and convergent margin processes. In divergent margins, the crust is ultimately recycled back into the mantle, whereas at convergent margins, the resulting island arc crust becomes the buoyant nucleus of new continental crust. If we accept that collision of island arcs with continental margins is a dominant process of post-Archean continental growth, then understanding the processes that modify arc crust, such as delamination, are imperative to understanding the creation of continental crust. The Early to Middle Jurassic Talkeetna Arc section exposed in the Chugach Mountains of south?central Alaska is 5 to 25 km wide and extends for over 150 km. This accreted island arc has been tilted on end to produce exhumed exposures of upper mantle through volcanic upper crust. The rocks that represent the deepest sections of the arc, beneath the paleo-Moho, include residual mantle harzburgite (with lesser proportions of dunite) that grade upward to cumulate pyroxenite and garnet-bearing gabbronorite. The paleo Moho is exposed where pyroxenites grade into plagioclase bearing lithologies (gabbronorite with or without garnet), with some interfingering of the two units along their high temperature contact. Lower crustal gabbronorite (>10 km thick) includes abundant rocks with well-developed modal layering. The mid to upper crust of the arc consists of a heterogeneous assemblage of gabbroic rocks, dioritic to tonalitic rocks, and concentrations of mafic dikes and chilled mafic inclusions. The plutonic rocks are overlain by basaltic to dacitic volcanic rocks. Many of the evolved volcanic compositions are a result of fractional crystallization processes whose cumulate products are directly observable in the lower crustal gabbronorites. For example, Ti and Eu enrichments in lower crustal gabbronorites are mirrored by Ti and Eu depletions in evolved volcanic rocks. In addition, calculated parental liquids from ion microprobe analyses of clinopyroxene in lower crustal gabbronorites indicate that the clinopyroxenes crystallized in equilibrium with liquids whose compositions were the same as those of the volcanic rocks. The compositional variation of the main series of volcanic rocks can be modeled through fractionation of observed phase compositions and phase proportions in lower crustal gabbronorite (i.e. cumulates). Primary, mantle-derived melts in the Talkeetna Arc underwent fractionation of pyroxenite at the base of the crust. However, even the most Mg-rich cumulates currently exposed in the arc were fractionated from liquids that had already themselves been fractionated. In order to bring the most mafic Talkeetna liquid composition in Fe/Mg equilibrium with the mantle, our calculations suggest that a mantle-derived parental basaltic magma must have fractionated ~25 wt % pyroxene (as pyroxenites) at the base of the crust. The discrepancy between the observed proportion of pyroxenites (less than 5% of the arc section) and the proportion required by crystal fractionation modeling (more than 25%) may be best understood as the result of gravitational instability, with dense ultramafic cumulates, probably together with dense garnet granulites, foundering into the underlying mantle during the time when the Talkeetna Arc was magmatically active, or in the initial phases of slow cooling (and sub-solidus garnet growth) immediately after the cessation of arc activity. Given the missing pyroxenites, the Talkeetna arc lower crust was interpreted by Behn and Kelemen (2006) to be an equilibrium configuration that was convectively stable relative to the underlying mantle. The denser, more primitive cumulates may have been removed via foundering into the asthenospheric mantle.

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