Crustal differentiation through magmatic and hydrothermal systems

Two end-members situations are described in the literature regarding crustal growth and differentiation along convergent plate boundaries (Figure 2). Part of the community focuses on the evolution of magmatic arcs based on the idea that mafic magmas are issued from partial melting of an hydrated and enriched mantle, while another part is concerned by magmatism integrated as part of the evolution of collisional belts emphasizing the role of crustal thickening and/or mantle-derived magmatism related to asthenospheric upwelling owing either to slab retreat or removal of the lithospheric root. The magmatic arc model is mainly based on the analysis of petrological-geochemical signatures of plutonic-volcanic rocks and is constrained by a few crustal scale sections, the Kohistan arc exposed in the Himalaya belt and the Talkeetna arc in Alaska (Burg et al., 2011; De Bari et al., 1989; De Bari & Greene, 2011). In this model mantle-derived magmas are considered to pound within the subcontinental lithosphere and/or at the base of the crust (Arndt & Goldstein, 1989; Richards, 2009) or to repeatedly intrude the lower crust forming a deep hot zone (Annen et al., 2006) leading to partial melting, crustal assimilation, magma

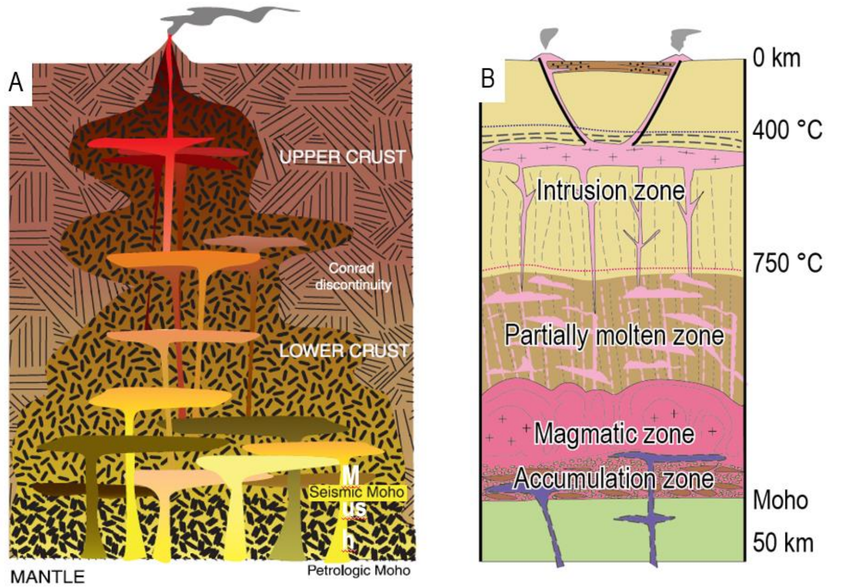

Figure 3: Crustal differentiation in magmatic arcs and hot orogens*.* *A) Model of magma transfer through a crustal-scale column of mush associated with fractional favoring differentiation of the crust in magmatic arcs (modified after Cashman et al., 2017). B) Model of crustal differentiation hot orogens with a lower crust formed of refractory granulites overlain by diatexite and metatexite migmatites, feeding a network of granitic dykes connected to laccolithic plutons emplaced along the ductile/brittle transition and to volcanic deposits at the surface (modified after Vanderhaeghe, 2009).*

mixing followed by fractional crystallization either within intermediate magma chambers (Hildreth, 1988) or on route to the surface through a transcrutal magmatic column (Bachmann et al., 2016; Cashman et al., 2017). In orogenic belts syntectonic migmatites at mid-crustal levels overlye refractory granulites and are structurally linked to plutons through networks of dykes and sills (Brown, 2001; Sawyer, 1994; 2011; Vanderhaeghe and Teysser, 2001, Vanderhaeghe, 2009; Weinberg, 1996). In contrast to the arc model, the orogenic model considers that the crustal distribution of elements according to their degree of incompatibility relative to silicate minerals reflects melt segregation and magma mobility from a migmatitic layer representing a former partially molten zone to form plutons and volcanics enriched in incompatible elements leaving behind a refractory granulitic lower crust (Pin & Vielzeuf, 1983; Sawyer, 1994; Vanderhaeghe, 2009; Vielzeuf et al., 1990). It should be noted that such a model of crustal-scale differentiation remains conceptual and has never been tested at the crustal scale on a single target.

In both cases, structural, petrologic and geochemical data of exposed sections of the deep crust suggest that crustal growth and differentiation are predominantly associated with melt/crystal segregation and magma mobility. The presence of silicate melts at depth is also consistent with geophysical data on currently active arcs and beneath orogenic plateaus, such as the Altiplano in the Andes and the Tibetan plateau, the largest currently active orogenic zones on Earth developed along convergent plate boundaries (Cormeau et al., 2015; Nelson et al., 1996; Schilling and Partsch, 1997; Ward et al., 2014; Figure 3).

Further differentiation of the lithosphere and of the continental crust in particular is achieved by mobilization-transfer-deposit of elements owing to fluid circulations with particular implications for mineral systems and ore deposits (McCuaig & Hronsky, 2014). The nature of the fluids circulating in the crust, the geometry of the reservoirs and the driving forces for fluid circulations are directly controlled by the geodynamic context (Eglinger et al., 2014; Manning & Ingebritsen, 1999; Manning, 2004; Scheffer et al., 2017; Siebenaller et al., 2013), the lithologic composition and the thermal-mechanical evolution of the crust, which in turn control the nature of the deposits (Eglinger et al., 2016; Ingebritsen & Appold, 2012; Turlin et al., 2016; Scheffer et al., 2017; Williams-Jones & Heinrich, 2005). Convergent plate boundaries are dominated by porphyry-type deposits linked to magmatic-hydrothermal systems as well as orogenic-type deposits related to metamorphic evolution of tectonically accreted terranes (Bierlein et al.; 2009; Groves et al., 1998; Sillitoe, 2010).