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An experimental study of the behaviour of cerium/molybdenum ratios during subduction: Implications for tracing the slab component in the Lesser Antilles and Mariana Arc

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Abstract

Arc magmas are very distinct in their geochemical signatures, a consequence of trace element enriched components from the subducting slab that are incorporated into melts of the overlying mantle wedge. However, it is not always straightforward to distinguish such slab components from assimilation of crustal rocks during subsequent differentiation, given that both reservoirs can share similar geochemical characteristics. This has prompted the development of new tools, such as $^{98}Mo/^{95}Mo$ analyses used in combination with Ce/Mo measurements. The diverse range of $\delta^{98/95}Mo$ in the surface environment gives rise to variable isotopic compositions of subducted Mo. Most diagnostic of these is the extremely isotopically heavy Mo in marine black shales, such as those drilled in the vicinity of the Lesser Antilles. However, subducting assemblages are invariably complex and differing melting behaviours and contrasting $\delta^{98/95}Mo$ of various crustal components may counter-balance one another, requiring a more detailed investigation of the behaviour of Mo and Ce in the down-going slab.

This study is dedicated to identifying possible hosts for Mo and Ce in sediments and basalt at sub-arc depths. New melting experiments were performed (3 GPa, 800–900 °C), using synthetic carbon-rich black shale and calcareous sediment compositions from the Lesser Antilles arc. In addition, new analyses of Mo concentrations and Ce/Mo data of previously published partial melting studies on altered oceanic crust and volcaniclastics (Mariana Arc) are presented. Our study suggests that sulfide and to a lesser extent rutile are the major hosts for Mo in eclogites, whereas the presence or absence of monazite (Ca-poor sediments), epidote (Ca-rich sediments) and carbonate ($CaCO_3$-rich sediments) controls Ce concentrations in sediments. Redox conditions are found to be of great importance for the Ce/Mo ratios of slab components derived from these lithologies because of their influence on sulfide and epidote stability. It is further shown that rutile only hosts Mo at suitably reducing conditions, in concordance with previous studies. The combination of measured Ce/Mo with our experimental results thus places important constrains on phase petrology and redox conditions in the subducted slab.

Keywords: Experimental petrology; Subduction; Molybdenum; Sediment melting; Island arcs

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1. INTRODUCTION

1.1. The Lesser Antilles and Mariana Arc systems

Subduction zones magmas acquire their distinctive geochemical signatures either from fluids/melts released from the descending slab (e.g. Gill, 1981) or buoyant portions of the slab itself that rise into the mantle wedge (e.g. Gerya and Yuen, 2003). In either case, slab-derived materials (fluids, melts, diapirs) transfer components that are "exotic" (with respect to the mantle) into the source regions of volcanic arcs (e.g. Lesser Antilles Arc, Fig. 1a; Mariana Arc, Fig. 1b). Although there is a range of tracers available for studying this process (e.g. Gill, 1981; Tera et al., 1986; McCulloch and Gamble, 1991; Hawkesworth et al., 1991; Elliott, 2003), there are many field examples where it is difficult to distinguish a slab component from assimilation of crustal rocks during subsequent differentiation. A prime example is in the Lesser Antilles (Davidson, 1987) (Fig. 1a), where overlying crust and subducted slab share similar isotopic compositions and trace element characters.

The importance of slab addition versus crustal contamination in the Lesser Antilles remains hotly debated (e.g. Thirlwall and Graham, 1984; White and Dupré, 1986; Davidson, 1987; Smith et al., 1996; Turner et al., 1996; Van Soest et al., 2002; Bouvier et al., 2008; Labanieh et al., 2012; Bezard et al., 2015). Prominent along-arc geochemical variations in trace element and isotope ratios correlate with changes in subducting sediment characteristics (south: ≫1000 m thick, dominantly terrigenous sediments; north: <300 m thick, marine and terrigenous sediments) (e.g. Tucholke et al., 1982; White et al., 1985; Westbrook et al., 1988; Plank and Langmuir, 1998). Notably, the lavas in the southern Lesser Antilles exhibit some of the most

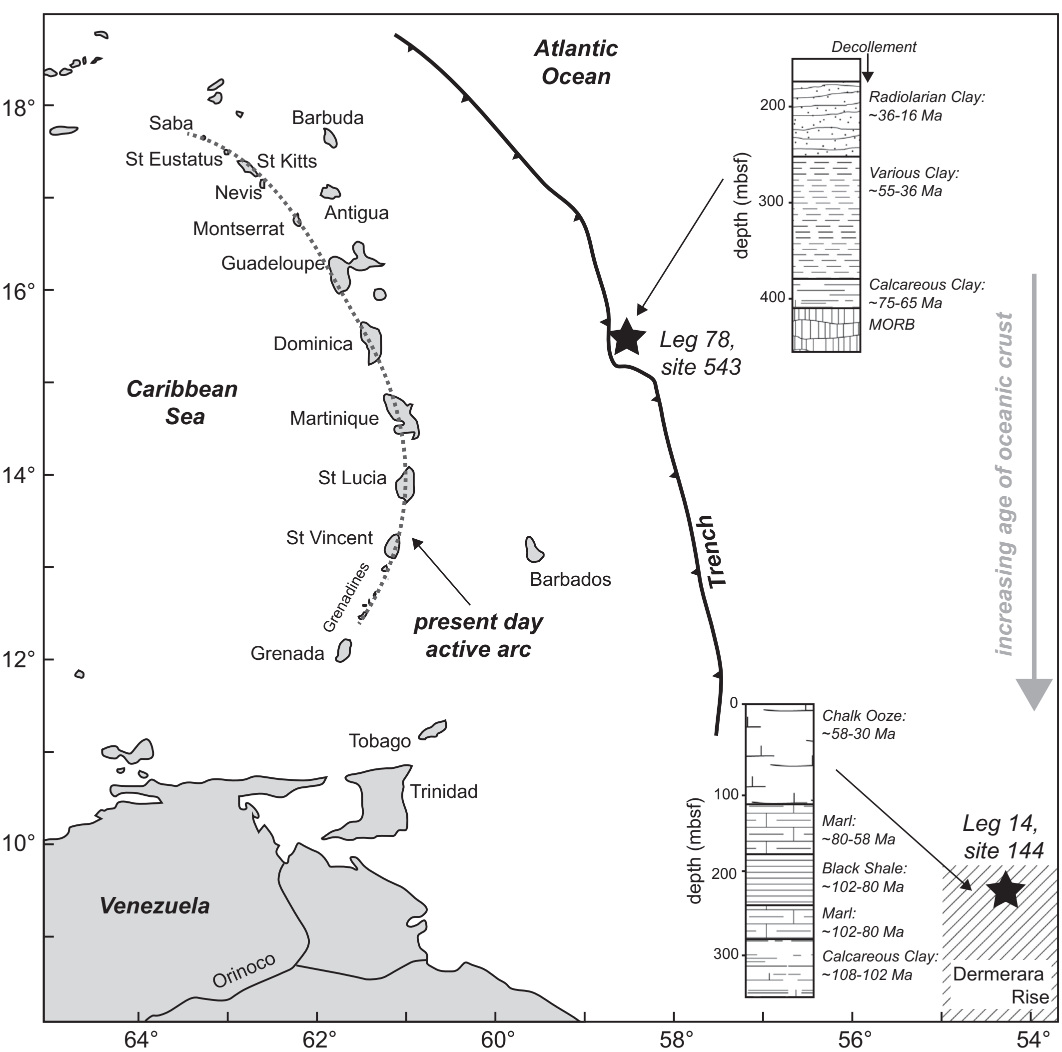

Fig. 1a. Map of the Lesser Antilles showing the locations of the trench and the present-day active volcanic arc, as well as the positions of DSDP Legs 14 Site 144 and Leg 78 Site 543 (mbsf = metres drilled or logged below sea floor). Sediment lithologies and ages are as reported in Carpentier et al. (2009). Note that the age of the underlying basaltic crust increases systematically to the south, implying that older sediments can be found in DSDP leg 14 Site 144 than in DSDP Leg 78 Site 543. The Demerara Rise is a submarine plateau lying in relatively shallow waters off Surinam/French Guyana.