Introduction to Science Theme 2: fluid and mass exchange[1]

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Keywords: OmanDP, Site BT1, Hole BT1B, fluid transport, Samail ophiolite, metamorphic sole, mantle wedge, subduction zone deformation, listvenite, serpentinized peridotite

Chapter contents

Introduction

A close correspondence between 96–95 Ma igneous ages in the crust and the oldest ages of metamorphic rocks along the basal thrust (~95–94 Ma) indicates that thrusting of the Samail ophiolite over adjacent oceanic crust, nearby pelagic sedimentary rocks, and/or an ancient rifted continental margin began during or immediately after initial formation of igneous crust (e.g., Hacker and Gnos, 1997; Hacker and Mosenfelder, 1996; Hacker et al., 1996; Rioux et al., 2012, 2013, 2016; Stanger, 1985, Styles et al., 2006; Tilton et al., 1981; Warren et al., 2005). The "metamorphic sole," emplaced along the basal thrust between overlying peridotite and underlying metasediments of the Hawasina Formation, records hot subduction conditions up to 800°–900°C and pressure as high as 650–900 MPa (Cowan et al., 2014; Ghent and Stout, 1981; Hacker and Gnos, 1997; Searle and Cox, 1999, 2002; Searle et al., 1980; Searle and Malpas, 1980, 1982; Soret et al., 2017). Perhaps at the initiation of subduction, metamorphic rocks are accreted to the base of the mantle wedge, whereas as subduction zones grow colder and develop a steady-state thermal structure, cold dense lithologies in the footwall are subducted rather than accreted to the base of the hanging wall (Agard et al., 2016; Soret et al., 2017). The sole contains alkali basalts, unlike the depleted magmas—"Geotimes" or "V1," very similar to normal mid-ocean-ridge basalts (MORB), though probably hydrous and with a hint of an arc trace element signature (Alabaster et al., 1982; Ernewein et al., 1988; MacLeod et al., 2013; Pearce et al., 1981)—that formed the crust of the Samail ophiolite.

Where the metamorphic sole is preserved, we can infer that the overlying peridotite represents "the leading edge of the mantle wedge" above the subduction zone at the base of the ophiolite that consumed several hundred kilometers of Tethyan basin crust before coming to rest on the Arabian continental margin (Béchennec et al., 1988, 1990; Breton et al., 2004; Searle and Robertson, 1990). We can study these outcrops to access and investigate processes in and above a subduction zone. Of particular interest are (a) the source of footwall fluids, (b) the nature and mechanism of fluid transport along the thrust fault and into the mantle wedge, (c) chemical, mineralogical, and rheological modification of the hanging wall by reaction with footwall fluids, and (d) the mechanisms of subduction zone deformation. Originally, it was envisioned that the Oman Drilling Project (OmanDP) would drill from the overlying mantle, through the basal thrust and the metamorphic sole, and into underlying metasediments of the Haybi and Hawasina Formations. However, funding constraints dictated that we drill at a single site to address the science objectives listed here.

[1]Kelemen, P.B., Matter, J.M., Teagle, D.A.H., Coggon, J.A., and the Oman Drilling Project Science Team, 2020. Introduction to Science Theme 2: fluid and mass exchange. *In* Kelemen, P.B., Matter, J.M., Teagle, D.A.H., Coggon, J.A., and the Oman Drilling Project Science Team, *Proceedings of the Oman Drilling Project*: College Station, TX (International Ocean Discovery Program.
https://doi.org/10.14379/OmanDP.proc.112.2020
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MS OmanDP-112
Published 23 July 2020

In some localities, peridotites at the base of the Samail ophiolite mantle section underwent 100% carbonation at 100°–200°C to form “listvenites” in which all Mg and Ca are in carbonate minerals. These rocks are composed entirely of magnesite and/or dolomite + quartz + Fe oxyhydroxides (hematite, goethite, etc.) + chromite and/or chromian mica (“fuchsite;” Falk and Kelemen, 2015; Nasir et al., 2007; Stanger, 1985; Wilde et al., 2002) (Fig. F1), flanked by 100% serpentinized zones, in turn replacing partially serpentinized peridotites. Other zones of listvenite are found within mélanges within the basal thrust zone (Nasir et al., 2007; Stanger, 1985). This observation, together with an imprecise Rb/Sr isochron (97 ± 29 Ma; Falk and Kelemen, 2015), indicate that the listvenites formed via transfer of CO_2 and other components from subducting material into the overlying mantle wedge during Tethyan subduction and ophiolite emplacement. Potentially similar listvenites are found at and near the basal thrust in other ophiolites worldwide (Akbulut et al., 2006; Borojević Šoštarić et al., 2014; Escayola et al., 2009; Menzel et al., 2018; Quesnel et al., 2013, 2016; Scarsi et al., 2018; Sofiya et al., 2017; Ulrich et al., 2014). If listvenites commonly form in subduction zones, then the leading edge of the mantle wedge—and subduction-modified mantle that has later been incorporated into the continental mantle lithosphere—may be a globally important reservoir for carbon (Foley and Fischer, 2017; Kelemen and Manning, 2015; Li et al., 2017; Scambelluri et al., 2016).

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Figure F1. Mantle outcropping at OmanDP Site BT1B.