From Birth to Death: Fate of The Extremely High-T Subduction Zone of The Oman Ophiolite

*Susumu Umino[1], Yuki Kusano[2], Keitaro Kitamura[3], Kyoko Kanayama[4], Kazuyha Nagaishi[5], Tsuyoshi Ishikawa[6], Ryo Otsuka[1]

1.Department of Earth Sciences, Kanazawa University, 2.Geological Survey of Japan, AIST, 3.Asia Air Survey Co., Ltd., 4.Tottori Prefectural Museum, 5.Marine Works Japan Ltd., 6.Kochi Institute for Core Sample Research, JAMSTEC

The Oman Ophiolite preserves the entire geological records of intra-oceanic subduction zone formation and arc evolution, where 98-96 Ma MORB-like basalt magmatism (V1) was followed by 96-94 Ma arc tholeiitic and low-silica boninitic volcanism (V2) [1,2,3,4]. The remanents of the subducted slab are now preserved as the high-grade metamorphic soles beneath the ophiolite sheets [5]. After a quiescence period, alkali basalt flows (V3) were extruded at about 90 Ma, which has an intermediate geochemical characteristics between OIB and EMORB [6]. The V3 trace element compositions can be reproduced by pooled partial melts in the stability field of garnet and spinel lherzolite.Through the V2 magmatism, the source mantle shows progressive depletion by stepwise melt extraction, as shown by the lower Nb/Ta ratios for the younger volcanic rocks (V2 boninite < V2 tholeiite < V1) [2] with identical εHf(t) values. V2 glasses have higher B, Pb, and LILEs with age, indicating an increasing contribution of slab fluids from earlier arc tholeiite to later boninite. Boninite magma was generated with the supply of high-T hydrous fluid and sedimentary melt liberated from the metamorphic sole as demonstrated by the Sr-Nd isotopic compositions of the amphibolite and metachert in the sole and clinopyroxene separates from boninites [1,2,7]. Therefore, the metamorphic sole beneath the ophiolite sheets are responsible for the generation of V2 arc magmas. Melt inclusions in Cr spinel derived from boninite comprise homogeneous glass of mostly low-Si boninitic [3,4] and slightly differentiated composition, with SiO_2 ranging in 52-62 wt% and MgO up to 16 wt%. The primary boninite magma assumed as the most magnesian melt inclusion can coexist with mantle olivine and orthopyroxene [9] at 0.4-0.6 GPa and 1350°C. This T-P conditions indicate a segregation depth of ~17 km from the mantle with a potential T of 1400°C. Meanwhile, the peak metamorphic conditions for the subducted slab that liberated high-T fluids to form boninite and arc tholeiite magmas are 770–900°C and 1.1-1.3 GPa [1,6,7].
The keys of the Oman subduction zone are 1) the preservation of diapiric structures in the mantle [10], 2) short time interval of the V1 and V2 magmatism <2 m.y., 3) T-P conditions for a primary low-Si boninite (Umino et al., 2014); and 4) extremely high T & low-P metamorphic conditions for the sole that liberated the fluids generating the V2 magmas [1,5]. These lines of evidence are most readily explained by intraoceanic thrusting initiated near the ridge axis that developed into a shallow and hot subduction zone [1,2,8,10].
Forced subduction of such an extremely high-T, buoyant slab suppressed convection in the mantle wedge, resulted in the progressive depletion of the source mantle through the V2 arc magmatism. Numerical modeling suggests that melting of the slab and mantle wedge occurrs only in the early stage and ceases as the mantle wedge cools because of the absence of convection [10]. Consequently, the Oman arc volcanism terminated in only a few million years. After several million years, parts of the subducted slab delaminated and induced upwelling and adiabatic melting of DMM asthenosphere, resulted in the generation of alkalic magmas of V3 extruded onto thick pelagic sediments before colliding onto the Arabian Peninsula.
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Keywords: Oman Ophiolite, boninite, high-T subduction zone, metamorphic sole, subduction initiation, obduction

