New insights into the classification and formation of zeolites hosted by the North Mountain Basalt, Annapolis Valley, southern Nova Scotia

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The Jurassic North Mountain Basalt of southern Nova Scotia constitutes a thick sequence of massive, variably porphyritic [clinopyroxene ($En_{40-50}Wo_{30-40}Fs_{15-40}$, plagioclase ($An_{50-70}$)] and vesicular tholeiites that outcrop along the Bay of Fundy for 100's of km, thus providing excellent exposure. The ubiquity of zeolites in the basalts has been known for ca. 150 years, however, detailed macro- and micro-scale studies of their occurrence remain scarce. Recent field studies and subsequent detailed electron microprobe analysis (EMPA) in conjunction with back scattered electron (BSE) imaging have provided new and insightful information regarding factors controlling zeolite distribution within basalt flows and processes responsible for their formation. Field studies indicate that a 4-part zonation occurs, continuous laterally for 100's m, for zeolite-filled amygdules within individual amygdaloidal flows. From bottom to top these zones are: (1) a basal zone of ca. 1 m containing two types of amygdules, namely (i) oriented (vertical to steeply dipping), cigar-shaped (≤10 cm) amygdules, and (ii) disseminated ≤5%, ≤1-2 cm) amygdules; (2) bubble-train zone of 2-4 m containing vertical, cigar-shaped, amygdule-rich pipes of 10-20 cm diameter; (3) net-textured zone of 1-2 m in which the bubble-train zone coalesces with disseminated amygdules of ≤3 cm; and (4) a disseminated zone (1 m) at the top representing the frothy, oxidized top of the flow with abundant amygdules of highly variable shape and size (≤4-6 cm). The 4 zones are continuous except for a gap of 1-2 m between zones 1 and 2 where massive, non-vesicular basalt occurs. Imaging (BSE) analysis integrated with EMPA indicate the following features: (1) a variety of Ca-Na zeolites occur in filling amygdules along with abundant Fe-, Mg- and Ca-rich micas, minor K-feldspar (Or_{90-98}), and rarely riebeckitic amphibole. The zeolites are relatively late paragenetically compared to other silicates; (2) abundant matrix zeolite occurs, most commonly replacing albitized plagioclase; (3) remnant patches of variably altered and crystallized intergranular glass are common. Field and laboratory data suggest zeolite formation relates to: (1) degassing of volatile-rich flows resulting in a 4 part zonation of vesicles; (2) leaching of elements from intergranular glass via migration of hot (initially ca. 350°C) fluids; and (3) deposition of a variety of silicate phases with zeolites generally late paragenetically.