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Discriminating between different types of ophiolitic basalts and their tectonic significance using a new method based on Th-Nb and Ce-Dy-Yb

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Ophiolites are interpreted to form in a wide variety of plate tectonic settings including oceanic spreading ridges, hot spots, and supra-subduction zone (SSZ) environments, such as intra-oceanic arcs, continental arcs, forearcs, and back-arcs. Hence, different rocks or rock associations found in ophiolitic complexes preserve records of tectono-magmatic events that occurred during distinct phases of oceanic development, from continental rifting to oceanic spreading, subduction, accretion and continental collision. Recognition of the tectonic affinity of ancient ophiolites is therefore a fundamental problem for all scientists working on this topic. To this purpose, tectonic discrimination diagrams based on major and/or trace elements have been a common technique for addressing this problem since the early 70s. In this work, a new discrimination diagram using absolute measures of Th and Nb is proposed and is applied to ancient ophiolites to best discriminate a large number of different ophiolitic basalts. This diagram was obtained using >2000 ophiolitic basalts (spanning in age from Proterozoic to Cenozoic) and was tested using ~560 modern rocks from known tectonic settings. Data consist of ten different basaltic varieties, including two types that have never been considered before, which are: a) medium-Ti basalts (MTB) generated at nascent forearc settings; b) a type of mid-ocean ridge basalts showing garnet signature (G-MORB) that characterizes Alpine-type (i.e., non volcanic) rifted margins and ocean-continent transition zones (OCTZ). In this diagram, basalts generated in subduction-unrelated settings can be distinguished from subduction-related basalts with a misclassification rate <1%. This diagram highlights the chemical variation of oceanic and OCTZ basalts from depleted compositions to progressively more enriched compositions reflecting, in turn, the variance of source composition. Chemical contributions of enriched components (plume-type components) to mantle sources can therefore be identified. Enrichment of Th relative to Nb is effective for highlighting crustal input via subduction or crustal contamination. Basalts formed at continental margin volcanic arcs can be distinguished from those generated in intra-oceanic arcs in supra-subduction zones (SSZ) with a misclassification rate <1%. Within the SSZ group, two sub-settings can be recognized. They are: a) SSZ characterized by chemical contribution from subduction-derived components (forearc and intra-arc) characterized by island arc tholeiitic (IAT) and boninitic basalts; b) SSZ with no contribution from subduction-derived components (nascent forearc) characterized by MTBs and depleted-MORBs. Two additional discrimination diagrams are proposed: a) boninite and IAT basalts can be discriminated with a confidence level >99.5% using a Dy-Yb diagram; b) G-MORBs and N-MORBs can be discriminated using a Ce/Yb-Dy/Yb diagram.