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LIP Printing: Theory and Applications

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Tens of thousands of geochemical analyses have now been published on magmatic rocks from Large Igneous Provinces (LIPs). Processing such a large quantity of data in order to achieve our goal of better understanding the relationships between LIP geochemistry and geological processes is not a trivial task. One approach is through machine learning, but this can have the disadvantage of decoupling the data points from their geological and petrogenetic foundations. Thus, we prefer to focus on specific proxies that enable the characteristics of LIP basalt suites to be represented by a single geochemical projection, or small group of projections, that can both include geological information and be interpreted by geochemical modelling. In Pearce et al. (Lithos, 2021; Paper 106068), we described the use of such projections as 'LIP printing' (the geochemical fingerprinting of LIPs), a term taken (loosely) from forensic science. That publication focused on two immobile trace element ratio proxies which are also near-independent variables: Th/Nb, a crustal input proxy and Ti/Yb, a melting (residual garnet) proxy. In particular, it explored the use of the combined projection (Th/Nb v Ti/Yb) as a 'LIP printing diagram'. On that projection, LIPs derived predominantly from subduction-metasomatized, sub-continental mantle lithosphere (SZLM) and LIPs derived predominantly from a mantle plume form distinct orthogonal arrays, while significant interactions between plume and crust give trends that traverse the two arrays. A subsequent, to date unpublished, extension of this work incorporates an additional immobile fractional crystallization proxy (Ni) and integrates it with the crustal and melting proxies to distinguish between plume-crust and plume-SZLM trends on the LIP printing diagram. In this presentation, we test the various LIP printing methodologies using 60 of the best studied LIPs (12 from each of the Phanerozoic, Neo-Mesoproterozoic, Paleoproterozoic, Neoarchean and Meso-Paleoarchean) to demonstrate that it is extremely rare for two LIP basalt suites to be absolutely identical, so enabling LIP printing to be useful for applications such as cross-correlation of dyke swarms within and between continents, construction of geochemical bar-codes, highlighting parts of LIPs potentially associated with mineralization, and giving a geological context to poorly preserved LIPs in the geologic record.