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Architecture and emplacement mechanisms of the Saint Jean du Doigt bimodal intrusion, Brittany, France

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The St-Jean-du-Doigt (SJDD) pluton emplaced ca. 347 Ma ago (IDTIMS U/Pb on zircon) at a depth of 6-9 km (3.0 $\pm$ 0.6 Kbar, Al-in-hornblende geobarometry) in the Precambrian crust of the Armorican massif, Brittany, France. This intrusion preserves remarkable sill-like emplacement processes of bimodal mafic-felsic magmas. Multiple individual pulses allow us to determine the nature and extend of in situ differentiation and interaction of magmas, while also recording evidence for contrasting sources and pre-emplacement hybridization processes at depth.

The SJDD intrusion was essentially built by injection of multiple, metre-thick sills of basalt, locally connected to vertical feeder dykes of the same composition. These sills often show internal mineral fractionation with a chilled lower margin, a progressive upwards grain-size coarsening associated with an increasing plagioclase/amphibole modal ratio and an upper layer of tonalitic composition, whose thickness varies between 2 to 50 centimetres. Both sill margins are usually sinuous with loadcasts and microdiapir features, which means that magma batches with contrasting densities and viscosities were emplaced among other partially molten units. Some sill boundaries may have been highly unstable with substantial remobilization of the adjacent tonalitic layers; alternatively, other sills quickly solidified without internal differentiation by fractional crystallization.

Apart from the insignificant amounts of tonalites produced by in situ differentiation of the basalt sills, more voluminous felsic rocks were emplaced as metre-thick sills or small laccoliths fed by subvertical dykes. These felsic units consist of various leucogranites (ranging from A-type to sodic granites) and granodiorites, the latter hosting mafic enclaves and xenocrysts attesting to hybridization processes at a deeper level. Preliminary trace-element geochemistry suggests several sources for the felsic rocks, which might include the lower crust and residual melts escaped from crystallizing basalt at depth.

Differentiation processes within individual injection units at the emplacement level suggest that many sills stayed long enough in a magmatic state to allow gravity-driven crystal fractionation, and can therefore be considered as small-scale “magma chambers.” According to the relatively fast cooling rate expected at this depth, magma injection rate had to be high enough to supply the necessary heat to maintain parts of the growing intrusion in a relatively low-viscosity magmatic state or to remobilize crystal-rich mushes. On the other hand, chilled sills document quick cooling in other parts and/or during some periods of the lifespan of the SJDD intrusion, suggesting variations in the overall magma injection rate.

We have collected high-precision IDTIMS U/Pb zircon data from units of various compositions. Single grains of zircon from tonalitic to granitic units show complicated core-rim relationships in cathodoluminescence images and yield dates that span a duration of ca. 2 Ma. Given these dates may represent a mixture of grains crystallized at different periods of magma emplacement, remobilization and mixing, the span of dates can be interpreted as a minimum for the lifespan of the magmatic system as a whole. Because the youngest dates are also likely mixtures of dates, estimating the emplacement time of the felsic units requires more detailed microsampling and dating of single zircon fragments. In contrast, zircon from gabbroic units give single coherent clusters of dates with weighted mean dates as low as ca. $\pm$0.1 Ma, indicating that these dates likely represent emplacement and crystallization of single mafic magma injections.