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Anorthosite-Trondhjemite-Tonalite (ATT) dyke swarms as testimony for the longevity of the Deep Hot Crustal Zone in Beja, Southern Portugal

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The Beja Layered Gabbroic Sequence (LGS) is a large mafic layered intrusion, exposed across the southwestern border of the Ossa-Morena Zone (Iberian Massif), in southern Portugal. Despite its synorogenic character, this intrusion is well-preserved from post-magmatic tectono-metamorphic events. The S-SW border of LGS was intruded by an anorthosite-trondhjemite-tonalite (ATT) suite, locally injected into NW-SE shear zones, which nature and geodynamic significance are here discussed. Dykes forming the ATT suite occur mainly as coalescing, ten-meter-wide stockworks, and are essentially composed of plagioclase (often strongly zoned) and green hornblende, plus accessory quartz, zircon, ilmenite, and magnetite. Gabbroic and amphibolitic xenoliths are frequently included in these rocks presenting evidence of variable chemical digestion. Three main lithological types were recognized: anorthosites displaying mortar texture, anorthosites with hornblende megacrysts, and trondhjemites. Plagioclase cores become less calcic from the former to the latter type (median = An_{48}, An_{46}, An_{30}, respectively), but mortar subgrains are typically more evolved (An_{23-61}). Geochemical features of ATT rocks classify them as diorites or quartzdiorites. In chondrite-normalized REE spidergrams, most samples show strong to moderate positive Eu anomalies ($(Eu/Eu^*)_N$ =1.30–7.22), moderate to strong LREE fractionation ($(La/Sm)_N$ =2.34–8.34) and relatively flat to positive HREE profiles ($(Gd/Yb)_N$ =0.85–2.10), correlating with zircon accumulation (Zr<2314 ppm). More evolved facies display weak negative anomalies ((Eu/Eu*) N =0.60–0.96), plus flat to moderate LREE and HREE profiles ($(La/Sm)_N$ =0.69–3.21; $(Gd/Yb)_N$ =0.60–1.42)). CL images of zircon concentrates reveal well-defined, concentric magmatic oscillatory zoning, as well as scarce diffusive, bright domains near the crystal edges, presumably related to hydrothermal overgrowths. U-Pb SHRIMP zircon dating provided three sets of coherent weighted mean corrected ages: 330.7 ± 1.1 Ma (MSWD=0.0051), 336.5 ± 1.1 Ma (MSWD=0.092); and 348 ± 2 Ma (MSWD=0.0024). Age-corrected Sr and Nd isotopic signatures ($^{87}Sr/^{86}Sr_i$ =0.704597–0.705319; εNd_i = -1.07 to +1.06) suggest the contribution of enriched mantle sources or high amounts of poorly radiogenic crustal components. Values for εHf i in zircon (-1 to +6) are homogeneous and chondritic. Lithogeochemical and isotopic data do not exclude contributions from LGS magmas (εNd 350Ma = -4.21 to +6.75; $^{87}Sr/^{86}Sr$ 350Ma =0.703001–0.707448). Nonetheless, extreme enrichments in Zr+Hf+Th+U imply important contributions from crustal

components, sometimes yielding superchondritic Zr/Hf ratios (38–59). Previous studies have shown that the LGS magmas were underplated at the crust-mantle boundary, triggering the formation of a deep crustal hot zone (DCHZ). Considering the geochemical/isotopic evidence, it is suggested that the ATT suite resulted from a protracted incubation period at the transition between the highly refractory granulitic basement and overlying metasediments. ATT melt generation possibly initiated ~348Ma and proceeded until ~330Ma, implying multiple periods of basaltic melt entrainment and thermal rejuvenation into mush reservoirs at depth, subjected to multi-phased extraction periods. The wide age span of the ATT suite and resetting of LGS amphibolite country rocks (333.9 ± 1.3 Ma, MSWD=0.079; 346.1 ± 1.9 Ma, MSWD=4.7E-06) suggest that the DCHZ in Beja should have persisted for a long period of time.

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