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Implications for the Upper Cycladic Unit: petrological, mineralogical and structural study of intrusive rocks from the Late-Cretaceous volcanic-arc in Anafi Island, Cyclades, Greece

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Anafi Island is located at the southeastern edge of the Attic-Cycladic complex and is one of the few Cycladic islands composed solely by upper plate units, which are now found in the form of scattered relics in the central Aegean. The structure of the island consists of a series of thrust sheets which include from bottom to top: a non-metamorphosed flysch of partly Eocene age; greenschist facies metabasites; massive to plate amphibolites; a sequence of upper amphibolite facies meta-sediments and ophiolitic rocks, intruded by intermediate magmatic rocks; marbles and large bodies of felsic intrusive magmatic rocks. The age of the intrusive rocks within the two uppermost thrust sheets is late Cretaceous, ($\sim$85 Ma[1]).

Mineral chemistry analyses of the intermediate and felsic rocks show that they include quartz, plagioclases (andesines, oligoclases and rarely labradorites), K-feldspars, amphiboles (magnesiohornblendes rarely tremolite), and biotite. The presence of quartz and biotite increases in the most felsic rocks while hornblendes less often appear. These rocks present subophitic textural features, between amphiboles and plagioclases, but also granitic textures in rocks where quartz is in a relatively high modal percentage. Structural observations reveal minor or no ductile deformation (rare undulose extinction in quartz).

Based on CIPW and whole-rock chemistry results intrusive rocks are classified as quartz monzodiorites and granodiorites of calc-alkaline affinity[2]. They present subparallel REE patterns, enriched in LREE [$(La/Yb)_{CN}$=6.1-20.3], with slight to moderate negative Eu anomalies (Eu_{CN}/Eu*=0.75-0.97). Their primitive mantle normalized patterns are also subparallel, enriched in LILE elements, such as Cs, Rb, Ba and K. Their Nb and Ta normalized values are lower than the normalized Th, U, K and La. Positive anomalies are noticed for Pb, negative for Ti and slightly negative to none for Zr. These features, along with their high Th/Yb ratios relative to Nb/Yb ratios, are strong indications for involvement of subduction related processes. All rocks plot in the volcanic-arc granites fields[3]. Compositional variations between the studied rocks are most likely attributed to differentiation processes of a common magma, probably with amphibole and plagioclase fractionation, as indicated from their subparallel normalized patterns, their negative Eu anomalies and by the decrease of MgO, FeO, CaO, TiO_2 and Cr along with increase of SiO_2.

Conclusively, the intrusive rocks of Anafi Island were formed in a volcanic-arc setting during the Late-Cretaceous. The involvement of subduction processes is clearly suggested from the geochemical data and from the presence of hydrous mineral phases, such as magmatic hornblendes and biotite. The fact that both intermediate and felsic intrusives derived from the same magma source, despite being found within different subunits, strongly suggests that these subunits were in close association during the intrusion. Furthermore, this supports the assumption that at least the two upper subunits observed on Anafi Island, are part of the Upper Unit of the Attic-Cycladic complex.

References. [1] Be'eri-Shlevin et al., 2009: Isr J Earth Sci 58, 13-27; [2] Miyashiro 1974: Amer. J. Sci. 274, 321–355; [3] Pearce, Harris, & Tindle: 1984, J. Petrol. 25, 956-983.