THE GENESIS OF PRIMITIVE TONALITES ASSOCIATED WITH AN ACCRETING CRETACEOUS OCEANIC PLATEAU: THE ARUBA BATHOLITH AND THE ARUBA LAVA FORMATION

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INTRODUCTION

Andean batholiths are usually dominated by tonalite, but the nature of the source components and the petrogenetic mechanisms in generating tonalite still need to be resolved. Lower crust, subducted mafic crust or magmatically underplated mafic crust are all possible sources; but each has thermal problems. Some tonalites however appear to be generated entirely within the oceanic environment and so the number of possible sources and the tectonic and thermal regimes under which tonalite may be generated are much reduced. Here we describe the occurrence, relationships and geochemistry of the tonalitic batholith on Aruba, Netherlands Antilles (Figure 1), which appears to have been generated as the thick mafic crust of an ocean plateau was being imbricated, obducted and underplated. The batholith has both the trace element and isotopic characteristics ($^{87}Sr/^{86}Sr_i$ = ~0.7036, Klaver, unpubl. data) that indicate a

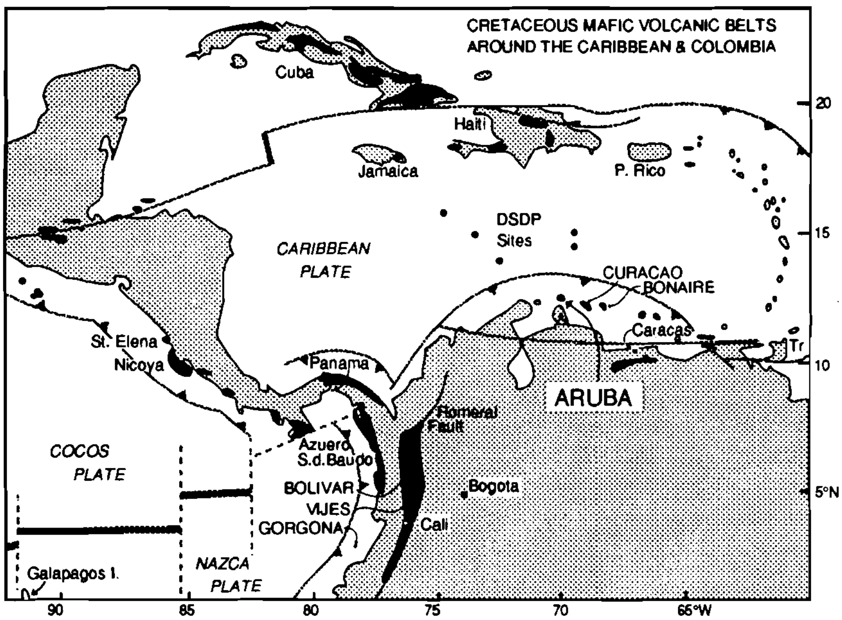

Figure 1: Location map showing the position of Aruba relative to other obducted fragmants of the oceanic plateau sequence of the Caribbean Plateau.

primitive source with short crustal residence time. The results are relevant to the generation of Precambrian tonalites (Martin, 1993).

FIELD RELATIONSHIPS

The Cretaceous batholith that crops out on the island of Aruba comprises dominant tonalite with subordinate trondhjemite, diorite, gabbro and notably melanocratic magma type ("hooibergite") that forms small plugs within the batholith. The batholith is bordered by mafic rocks of the plateau sequence, the Aruba Lava Formation, that comprises pillow basalts, dolerite sills, tuffs and minor sediments, and has chemical affinities with the sequence of pillow basalts and picritic flows exposed on the adjacent island of Curaçao (Klaver, 1987). The Aruba Lavas may represent a stratigraphically higher member of the plateau sequence because of the greater proportion of tuffs exposed, indicating a shallower eruption depth, and the presence of calc-alkaline tuffs but few picrites. The Curaçao and Aruba Lava Formation basalts have a transitional (T-MORB) signature.

Important shear zones, up to 1 km wide, transect the Aruba Lava Formation, and are interpreted as zones where the plateau began to imbricate as it collided with the S. American continental margin subduction zone. Some are high-grade (amphibolite) and must have been exhumed. The plateau, being unusually thick (c. 15km from seismic evidence), and possibly still hot, and would have resisted subduction. One lower-grade shear zone has small tonalitic intrusions within it that have been boudinaged by subsequent shearing, thus dating the tonalite intrusion as syn-deformation. In the high-grade shear zone the amphibolite is net-veined by silicic melts. Examination of small-scale structures reveals that the amphibolite is in fact melting, but there is a considerable volumetric component of melt just "passing through" the amphibolite, with agmatitic textures requiring that this melt was at high magma pressure. These melts are dominantly trondhjemitic, but there are also tonalites and more dioritic rock types cutting the amphibolites that have no chilled margins, and were clearly emplaced into hot rock.

Complex cross-cutting relationships exist between the various rock types of the batholith, and again, chilled margins are very rare, suggesting that the timing between successive episodes of intrusion was not enough for the first magma type to completely cool. Up to five phases of intrusion can be identified in exposures of just $1m^2$, and the order of intrusion is not necessarily the same in different exposures, implying that intrusion of the different magma types occurred in a short time period.

The earliest and latest intrusive phases are the most mafic: gabbro being followed by the dominant tonalite/diorite intrusion, and finishing with the spectacular melanocratic hooibergites. The latter magma was clearly wet enough to crystallise abundant hornblende, but was also hot enough to trigger re-melting of the surrounding tonalites, and acid back-veining of the hooibergite in various rheological states is observed. The hooibergite may represent either melting of the amphibolitic residue remaining after tonalitic and trondhjemitic liquids had been extracted, or melts with a significant mantle component. In either case this requires a later thermal pulse. A late thermal pulse is also indicated by the numerous mafic dykes cross-cutting the batholith, but are chilled against it.

GEOCHEMISTRY

The Aruba Lava Formation, like that on Curaçao, is dominated by mafic rocks that are less-depleted with respect to light REE and other incompatible elements than normal MORB (Kerr et al. 1996), perhaps a consequence of entrainment processes in the ascending plume head. Effectively, this leaves it a more fertile source for tonalite production than normal oceanic crust. The tonalites have many compositional similarities with modern adakites and with Precambrian tonalite-trondhjemite-granodiorite (TTG) suites: low Y, high Sr and Ba, low Rb and with high Sr/Y and K/Rb ratios, but with prominent negative Nb anomalies and small positive Sr and Ba anomalies on multi-element mantle-normalised spidergrams. These characteristics would be compatible with melt generation from a mafic source similar to that of the host amphibolites. The low initial Sr isotopic ratios (0.7036) and positive Nd would be compatible with this.

THE ROLE OF HYDROUS FLUIDS

Water seems to have played an important role in promoting the development of shear zones (greenschist- to amphibolite-facies) within the relatively fresh Aruba Lava Formation, penetration of hydrous fluids being aided by the imbrication of the plateau. With dehydration-melting of amphibolite-facies assemblages, high field strength elements such as Nb and Ta may have been retained in residual titanite or rutile, and Y and the heavy REE in residual garnet or hornblende during tonalite generation. Further melting under higher temperature conditions during the later thermal pulse may have released water (i.e. anhydrous residues) leading to emplacement of the wet melanocratic magmas (hooibergites) that are characterised by extensive sub-solidus hornblende growth, and which promoted hydrous remelting of the tonalites to cause back-veining and production of hornblendic pegmatites.

COMPARISON WITH ARCHAEAN and OTHER TONALITES

There are a number of interesting similarities with Archaean tonalites. The association of tonalites, trondhjemites and granodiorites, with abundant mafic enclaves, is very similar to that of Archaean TTG suites (the melanocratic hooibergite resembles more closely Scottish Caledonian appinites), The correspondence extends to the late stage emplacement of abundant mafic dykes. Greenstone belts have been likened to oceanic plateaus (Storey et al., 1991; Kusky and Kidd, 1992) because of the occurrence of spinifex komatiitic or picritic flows in obducted Cretaceous plateaus (cf. Gorgona: Kerr et al, 1996c). Precambrian greenstone belt mafic sequences are commonly associated with pene-contemporaneous voluminous tonalites (TTG), and hence it is possible these may have formed in exactly the same way as on Aruba.

CONCLUSIONS

The association of a primitive tonalite suite with an accreting oceanic plateau implies that voluminous silicic crustal compositions can be generated during imbrication and thrust stacking of thick mafic volcanic sequences. There are implications for Archaean greenstone belts and for mechanisms of crust generation.

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