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DACITIC VOLCANISM IN THE COURSE OF THE RIO DAS VELHAS (2800-2690 Ma) OROGENY: A BRAZILIAN ARCHEAN ANALOGUE (TTD) TO THE MODERN ADAKITES

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ABSTRACT The evolution of the Rip das Velhas Greenstone Belt followed two main episodes of crustal addition. An initial phase of ocean-floor spreading is associated with tholeiitic to komatiitic magmatism. This early accreted, short-lived oceanic crust underwent rapid subduction, giving rise to widespread arc-related, felsic calc-alkaline volcanism, triggered by the direct melting of the oceanic slab. The felsic rocks comprise lavas and pyroclastic facies, extruded at *ca.* 2775 Ma and rapidly dispersed through syn- and post-eruptive submarine resedimentation processes. The sequence is coeval with a series of granitoids intrusive into the belt margins, characterizing a tonalite-trondhjemite-dacite (TTD) magmatism. The LILE depleted, Na-rich, chemical signature shown by the volcanic rocks fits well with a genetic model which incorporates aspects of the evolution of adakites in the modern Circum-Pacific arcs, and also the ancient FI dacites from the Barberton Greenstone Belt.

Keywords: Rio das Velhas Greenstone Belt, evolution, Archean felsic volcanism, adakites, TTD association.

INTRODUCTION Archean rocks underlie most of the southern part of the basement of the Neoproterozoic São Francisco Craton *(sensu* Almeda 1977) in eastern Minas Gerais State (Fig. 1). The Archean units comprise TTG gneisses and migmatites, high-grade gneisses, tonalitic to granitic plutons, mafic/ultramafic intrusions, and the Neoarchean Rio da Velhas Greenstone Belt (RVGB), a major component of the Quadril&ero Ferrifero ("Iron Quadrangle", Figure 1)

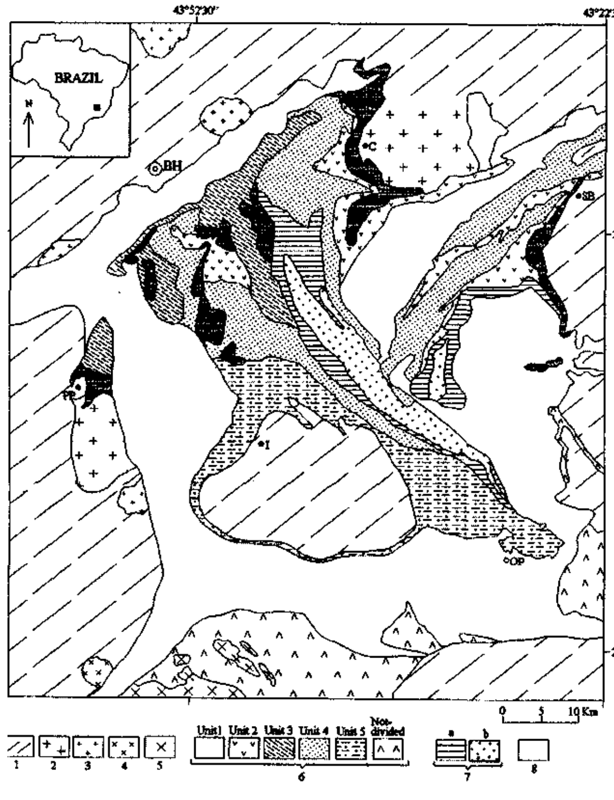
The belt hosts some important world-class gold deposits. On tectonic-stratigraphic grounds the RVGB is referred to as the Rio das Velhas Supergroup, which is subdivided into the lower Nova Lima and the upper Maquiné groups (Door *et al,* 1957, Door 1969). This subdivision has been confirmed in the detailed (1:25,000) geological mapping of the belt, recently carried out by the Geological Survey of Brazil (in: Pinto, 1996). The informal stratigraphy herein adopted (Units 1 to 5, Figure 1) for the Nova Lima Group is based mainly on the tectonic-chemical stratigraphic succession delineated by Silva *et al.* (1995) and Silva (1996). It encompasses a) a basal tholeiitic and minor komatiitic ocean-floor volcanic assemblage with associated volcanogenic-exhalative sedimentary rocks; b) an intraoceanic arc-related, depleted, calc-alkaline dacitic volcanic-sedimentary assemblage; c) volcaniclastic sediments overlain by mixed-source volcaniclastic/terrigenous sediments.

The present study focuses on the chemical/petrographic characterization of the RVGB felsic volcanism within the Unit 2 (Fig. 1) and on the significance of this calc-alkaline accretionary episode in terms of modern and ancient analogues.

PETROGRAPHY OF THE RVGB FELSIC ASSOCIATION (UNIT 2) The felsic dacitic association of Unit 2 (Fig. 1) is assigned to the lower Nova Lima Group and comprises a wide range of volcanogenic members, ranging from an extrusive facies of lavas and minor primary fragmental pyroclastics, to dominantly syn-eruptive, resedimented volcaniclastic rocks. These are interlayered with ocean-floor chemical-exhalative (BIFs) rocks and mafic-ultramafic tholeiitic to komatiitic lavas flows. Notwithstanding the overprinting by greenschist facies metamorphism the prefix "meta" has been omitted from the descriptions of the lithologic assembly of the belt.

Lava facies Extrusive and shallow-level intrusive dacitic lavas are the main, essentially massive component of the felsic association. They consist of holocrystalline seriate, locally porphyritic, quartz-plagioclase phyric and aphyric lavas. Quartz and plagioclase phenocrysts, 1-2 mm in size, are set in a fine-grained, weakly foliated, quartz-plagioclase-sericite matrix. Amphibole altered to sericite is the dominant accessory mineral. Zircon, apatite and magnetite are minor accessory minerals. Planar-flow lamination and flow banding are locally recognized, and trachytic textures, with pseudomorphosed amphibole and plagioclase phenocrysts set in a groundmass of strongly flow-aligned plagioclase laths, are also present. Relict devitrified perlitic fractures filled with sericite and chlorite also occur. The formerly glassy groundmass has recrystallized to quartz-feldspar microliths or has been replaced by phyllosilicates.

Fragmental facies (syn-eruptive, resedimented association) The fragmental facies is also essentially composed of



1. TTG gneiss and migmatile (>2860 Ma); 2. tonalites and granodiorites (2780-2770 Ma); 3. high-K calk-alkaline granites (2720-2700 Ma); 4. granite (2612 Ma); 5. tonalite (2125 Ma); Rio das Velhas Greenstone Belt *(ca.* 2772 Ma): 6. Nova Lima Group (units 1 to 5 see text for description); 7. Maquiné Group (7a. Palmital Formation; 7b. Casa Forte Formation); 8. Paleoproterozoic units. NOVA LIMA GROUP *UNIT 1* - ultramafic and mafic lava flows and sill of tholeiitic composition, with subordinate komatiitic and felsic volcanic; banded iron-formation, chert, and carbonaceous pelites. *UNIT 2* - felsic coherent, fragmental (primary pyroclastics) and proximal, syn-eruptive resedimented volcaniclastics, interlayered and/or tectonically interleaved with chemical-exhalative sediments (banded iron-formations and cherts), with mafic volcanics, carbonaceous pelites and very subordinate komatiites. *UNIT 3* - post-eruptive, resedimented volcanogenic graywackes and pelitic layers. *UNIT 4* - Interlayered petite and sandstone (turbidiles), epiclastic graywackes, carbonaceous pelites and banded iron formation. *UNITS* - epiclastic graywackes, sandstones, conglomerate lenses, pelites, and calc-silicate rocks. MAQUINÉ GROUP/ *Palmital Formation* - pelites, pelitic sandstones and dominatly terrigenous greywackes, conglomerate lenses. *Casa Forte Formation* • sandstones and polimytic conglomerates.Localities: BH = Belo Horizonte; C = Caet6; PP = Piedade do Paraopeba; SB = Santa Barbara; I = Itabirito; OP = Ouro Preto.

Figure 1 - Geological map of the Rio das Velhas Greenstone Belt, Quadrild-tero Ferrifero (modified after Pinto 1996)

plagioclase (albite-oligoclase), K-feldspar and quartz crystals. The plagioclase is euhedral, normally zoned and complexly twinned. Altered amphibole is the main accessory mineral, and apatite, titanite and zircon are minor phases. Preserved volcanic features include corroded and fragmental plagioclase, and bipyramidal quartz crystal clasts, the latter locally displaying corrosion gulfs.

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Coarser rocks with bimodal clast size distribution, including angular and fusiform lithoclasts, are also recorded. Matrix- and clast-supported deposits display the same quartz-plagioclase phyric, dacitic matrix. Clasts are 2-8 mm in size, but may exceptionally reach 20-30 mm. Some lithoclasts with curviplanar outlines seem to have preserved their original shape without post-depositional transport. Fusiform lithoclasts have the same dacitic composition, but are characterized by the presence of devitrified, "mat" textures and spherulitic plagioclase crystallites. Fine-grained, bimodal volcaniclastic rocks have fine-grained (0.01-0.1 mm) matrices with porphyritic components ranging from 0.2 to 1.0 mm in size. The clast/matrix ratios are extremely variable.

Genetic interpretation and classification Owing to the tectonic-metamorphic overprinting, constraining the depositional processes of the volcaniclastic association is not an easy task. In the absence of detailed graphic logging and records of the facies architecture discrimination between primary, syn- and post-eruptive resedimented facies is controversial.

Regionally, the dominantly primary pyroclastic nature of the coarse-grained deposits is clear. They are characterized by well preserved agglomeratic and breccia structures, probably indicating direct proximal (near vent) deposition. However, part of the deposits are represented by layered successions, characterized by: a) the overwhelming dominance of texturally unmodified (cognate) lithoclasts, with preserved curviplanar forms or devitrified perlitic-fractures, amongst other primary features; b) the abundance of sand-sized quartz and feldspar crystal clasts, with preserved volcanic textures such as embayments and corrosion gulfs; c) the unimodal dacitic composition of the lithoclasts; d) the original, Na-rich, LILE-depleted chemical signature preserved in all analyzed samples, including the angular lithoclasts and their sand-sized matrices (Analyses 3 and 4, Table 1); and e) the absence of non-volcanic clasts. Following the criteria of McPhie *et al.* (1993) they represent syn-eruptive, resedimented pyroclasts (volcaniclastic rocks) and are better classified as "resedimented ash-rich mudstones", "resedimented pyroclast-rich lapillistones", and "resedimented pyroclast-rich breccias", rather than tuffs, lapillistones and breccias, respectively. The clasts, as well as the crystal- rich matrix, may be interpreted as syn-eruptive fragmentary rocks derived from primary lava and fragmental volcanogenic layers, deposited during and immediately after the extrusion phase.

Other subaqueous turbiditic deposits occurring especially in Unit 3 (Fig. 1) comprise medium- and fine-grained, layered deposits, locally preserving small-sized (Dm) cross bedding, as well as graded bedding. They may preserve incomplete Bouma sequences (Baltazar & Pedreira 1996) and are interpreted as mass flow and suspension subaqueous deposits, deposited in deep marine/lacustrine environment, by turbiditic currents in a distal position in relation to the eruptive centers. They form greywacke-mudstone couplets and are classified as post-eruptive, resedimented "tuffaceous mudstones" and "tuffaceous sandstones" (McPhie *et al.* 1993).

Table 1 - Chemical data of Archean dacites and modern adakites. Major element oxides in weight %, trace elements in ppm.

	Representative chemical analysis of the RVGB dacites								RVGB TTD dacites average	Modern adakites average @	Fl Barberton dacite #
	1	2	3	4	5	6	7	8	9	10	11
SiO_2	60,10	66,50	68,70	62,20	63,90	66,80	70,80	65,70	65,58	64,21	67,10
TiO_2	0,61	0,44	0,30	0,54	0,44	0,44	0,23	0,52	0,44	0,42	0,28
Al_2O_3	15,00	16,60	13,00	14,20	13,80	15,90	14,40	15,90	14,72	17,53	16,50
Fe_2O_3	4.93	3.8	2.31	5.06	3.27	4.51	2.15	4.83	3.86	3.60	2.06
MnO	0,09	0,08	0,09	0,09	0,07	0,08	0,08	0,08	0,08	0,07	0,04
MgO	1,80	3,00	0,92	3,90	2,20	2,20	0,58	1,40	2,00	1,60	1,60
CaO	4,20	0,79	4,10	3,50	4,00	0,38	2,30	3,80	2,88	4,30	3,90
Na_2O	7,40	4,40	5,70	4,70	5,10	7,10	4,20	5,00	5,45	4,50	5,23
K_2O	1,70	2,50	0,63	0,61	1,40	0,41	2,00	1,10	1,29	2,00	1,72
P_2O_5	0,34	0,10	0,11	0,08	0,08	0,12	0,08	0,13	0,13	0,20	0,10
LOI	0,70	1.98	0,43	2.36	1,08	1,77	1,17	1,31	1,35	1,54	0,65
Total											
Rb	42	42	22	20	39	21	58	32	34,5	36,86	-
Sr	1250	363	870	561	635	474	444	1675	784	1045	500
Ba	1586	360	276	269	362	90	997	653	574,12	644,66	650
Y	17	-	15	20	12	12	7	21	14,85	7,51	12
Zr	180	140	150	140	160	160	150	230	163,75	76,66	160
Nb	5.0	6,0	5,0	5,0	5.0	5,0	5.0	5.0	5,12	6,3	-
Sc	18	10	12	18	9	13	8	16	13	6,64	-
Ni	23	111	21	100	25	33	10	31	44,25	25,83	15
Cr	45	81	42	199	63	59	32	71	74	32,66	70
Co	33	45	20	33	27	33	17	28	29,5	9,5	20
V	99	66	52	107	69	70	23	66	69	57,6	35
La	10,24	-	16,78	-	11,31	10,74	11,22	11,47	11,96	19,96	14,00
Ce	24,46	-	34,79	-	24,78	28,05	26,13	23,42	26,93	36,33	30,00
Nd	12,96	-	17,44	-	13,00	14,65	12,72	11,00	13,62	15,15	14,00
Sm	2,55	-	2,94	-	2,36	2,39	1,64	1,86	2,29		2,40
Eu	0,72	-	0,77	-	0,75	0,55	0,45	0,51	0,62	0,79	0,67
Gd	2,05	-	2,66	-	1,93	1,57	0,89	1,32	1,73		1,70
Dy	1,82	-	1,69	-	1,28	0,96	0,52	1,05	1,22	1,35	0,85
Ho	0,31	-	0,33	-	0,23	0,17	0,09	0,18	0,21		-
Er	0,59	-	0,85	-	0,48	0,37	0,18	0,41	0,48	0,68	0,38
Yb	0,56	-	0,68	-	0,36	0,32	0,17	0,36	0,40	0,54	0,32
Lu	0,07	-	0,11	-	0,08	0,08	0,04	0,05	0,07		0,05

@ = mean of modem adakites analysis, calculated after Maury el al. (1996); # = data from Condie (1981); RVOB * Rio das Velhas Greenstone Belt; TTD = Archean tonalitic-trondhjemitic dacitic association

CHEMISTRY OF THE RVGB FELSIC VOLCANISM Major and trace elements The association has (Table 1) high silica, alumina and Na_2O contents (> 70%, >15% and up to 7.4%, respectively). The Sr contents are high and variable (average 780 ppm). The association also displays a LILE-depleted chemical signature, with low Rb (20-58 ppm), Y (<21 ppm) and HREE contents, and high La contents, high Sr/Y (>40) and La/Y (>20) ratios. The data shown in Table 1 show no important differences of major, trace and REE compositions between volcanic lithoclasts (Analysis 3, Table 1) and their surrounding massive-textured matrix (Analysis 4, Table 1). More importantly, despite the resedimentation processes and the discrete low greenschist facies overprinting, the chemical classification based on the Zr/TiO_2 diagram (Winchester & Floyd 1977) coincides with the microscopically-determined, dominantly dacitic composition (Fig. 2). Similar behavior and chemical classification have also been registered even when the more mobile elements, such as the alkalis, are used (Silva *et al.* 1995).

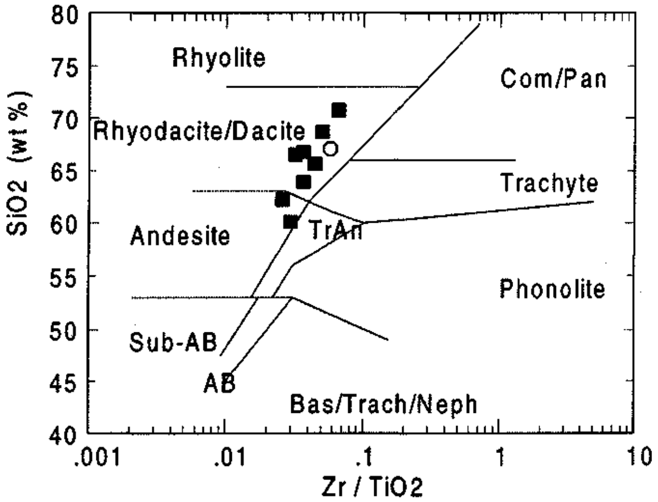

Figure 2 - SiO_2 versus Zr/TiO_2 discrimination diagram (Winchester & Floyd 1977) for the Rio das Velhas felsic association (filled squares), compared to the mean composition of Barberton Fl-type dacites (open circle, data from Condie 1981).

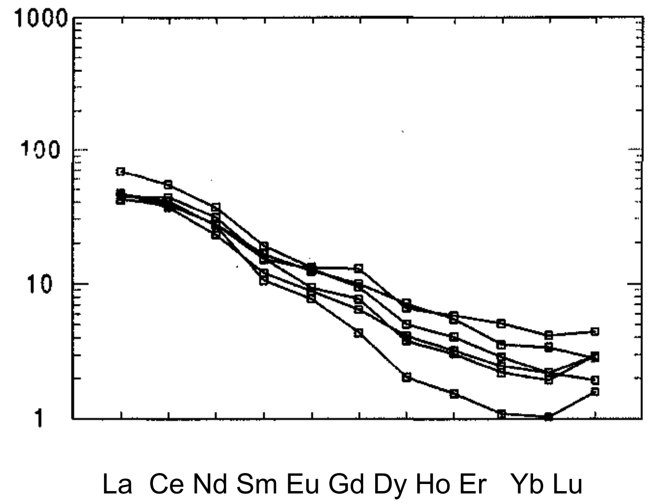

Figure 3 - Chondrite-normalized REE patterns (normalizing values after Evensen et al. 1978) for Rio das Velhas dacitic lavas and pyroclastic rocks.

REE distribution and petrogenesls The chondrite-normalized REE patterns (Evensen *et al.* 1978) are characterized by regular distribution and parallelism of the profiles, strong LREE-HREE fractionation (La_n /Yb_n = 20) with strong depletion of HREE, and upward concavity in the HREE region, and by an absence of negative Eu anomalies (Fig. 3).

The LILE-depleted chemical signature corresponds to the classical signature of Archean plutonic TTG series derived by the subduction and partial melting of tholeiitic oceanic crust. Thie signature has strong K, Rb and HREE depletion. The latter, with its accompanying upward concave-shaped patterns, together with the absence of negative Eu anomalies are suggestive of an origin from sub-crustal melting of a tholeiitic crust leaving a hornblende-garnet-rich and plagioclase-poor residue (e.g. Park & Tamey 1987, Martin 1999). The parallelism and similar REE fractionation in lavas and pyroclastic rocks point to cogenetic and comagmatic origin for both. The immobility of REE during transport, lithification (for the resedimented samples) and metamorphic processes is also deduced from the homogeneous distribution pattern.

Modern analogues: the Tertiary CIrcum-Pacific adakites The recent recognition of the existence of peculiar felsic dacitic volcanic rocks - adakites - associated with the subduction of young (< 20 Ma) and hot, oceanic slabs within the Circum-Pacific arcs opens a window to understand the evolution of their Archean, tonalitic-trondhjemitic-dacitic counterparts, the TTD series (Maury *et al.* 1996, Martin 1999). Adakites are amphibole-biotite bearing, usually dacitic to rhyolitic felsic volcanics (SiO_2 > 56%), which contain titanomagnetite, apatite, zircon and titanite, and very rare pyroxene as minor accessory minerals (Maury *et al.* 1996, Martin 1999). They have high Al_2O_3 (>15%), Na_2O (up to 7.5%) and Sr (>400 ppm) contents. Additionally, they are characterized by low LILE contents (Rb < 40 ppm) and very low HREE (Yb <18), and Y (< 18 ppm), which result in high Sr/Y (>40) and high La/Y (> 20). This chemical composition is typical of magmas produced by direct melting from a mafic source, with associated garnet-rich, plagioclase-poor residue (Martin 1999). Adakites also have high Mg, Ni, and Cr contents compared to normal calc-alkaline arc sequences (Defant & Drummond 1990, Maury *et al.* 1996). When crustal contamination is absent, they have MORB-like Sr- and Nd- isotopic signatures (Mahlburg Kay *et al.* 1993), reflecting partial melting at temperatures of 800°C to 1,000° C and pressures of 1 to 2 GPa (Maury *et al.* 1996) of oceanic slab garnet amphibolite facies metabasalts.

From a petrological and tectonic point of view, adakites are typically related to young (< 20 Ma), Circum-Pacific subducted oceanic slabs (Defant & Drummond 1990, Martin 1999) in a

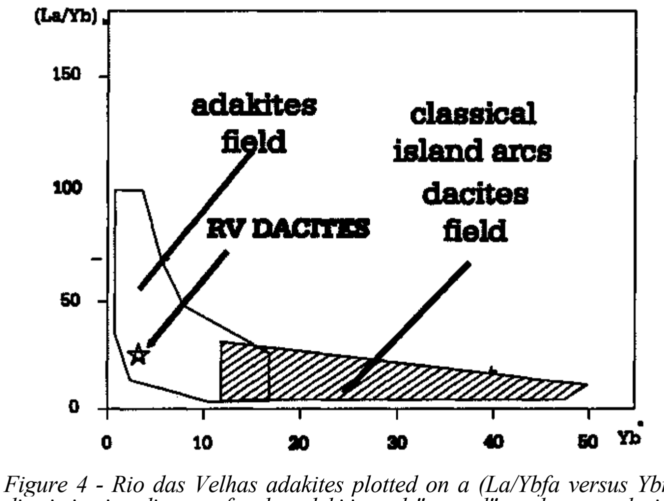

Figure 4 - Rio das Velhas adakites plotted on a (La/Ybfa versus Ybn discrimination diagram for the adakitic and "normal" modern arc dacite fields (after Martin 1999)

proportion of twelve out of nineteen known occurrences. Occurrence of adakites in other modern, subduction-related environments are reported in Maury *et al.* (1996) and Martin (1999).

Comparison between eight analyses representative of the felsic RVGB association and the average chemical composition of modern adakites (Table 1), calculated after the data from Maury *et al.* (1996), shows the two groups to be very similar. This similarity is also evident from the $(La/Yb)_n$ *versus* Yb_n diagram (Martin 1999), which separates the fields of the Yb_n-depleted adakites and the "normal" (undepleted) arc-related dacites (Fig. 4).

Although similar chemical compositions may be taken to infer that petrogenetic evolutions were similar, Archean dacites and their modern analogues must have undergone slightly distinct petrogenesis, as a consequence of the higher Archean thermal gradients (Martin, 1999).

Archean analogues: the F1 dacites from the Barberton Greenstone Belt The chemical compositions of RVGB dacites are extremely similar similarities to those of Barberton FI dacites

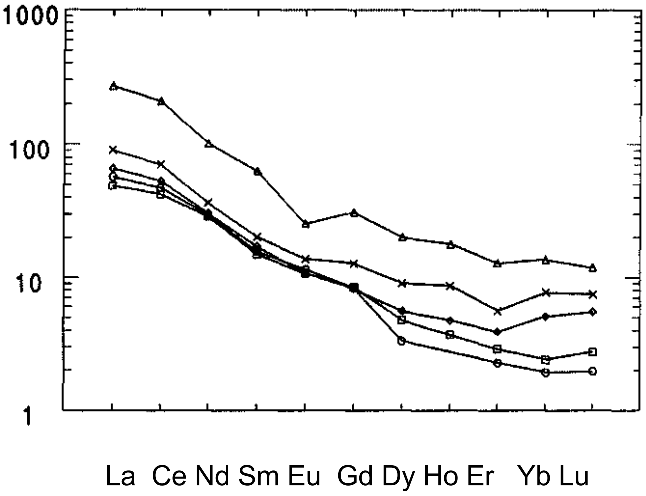

Figure 5 - Mean chondrite-normalized REE pattern for Rio das Velhas dacites (square); Rio das Velhas volcanogenic graywackes (lozenge) compared to the patterns of the FI-type Barberton dacites and Fig Tree (Barberton) graywackes (data from Condie 1981), and the 2780 Ma Samambaia tonalite (triangle, data from Carneiro 1992).

(Condiel980; columns 9 and 11, Table 1). This similarity is also evident in chemical-based classification diagrams, such as the Zr/TiO_2 from Winchester & Floyd (1977), where the unaltered, FI dacitic lavas plot within the same dacitic field of the RVGB (Fig. 2).

Similar behavior is depicted by the chondrite-normalized REE spider-diagram (Figures 5), where the REE profiles of the felsic association from Barberton and from the RVGB are indistinguishable. Both are characterized by regular distribution and parallelism of the curves, high fractionation, and strong HREE depletion associated with upward concavity and absence of negative Eu anomalies.

The similarity between Barberton and the RVGB dacites indicates that the latter, similarly to the former, may represent the volcanic end member of an extended Archean, tonalitic-trondhjemitic-dacitic TTD magmatism. Accordingly, the tonalitic plutons, coeval with the *ca.* 2775 Ma RVGB dacites, intrusive into its basement, are candidates of the plutonic end members of this Archean sodic granitoid "family". In order to test the supposedly comagmatic nature of the dacites and tonalites, the REE analyses of a sample from the *ca.* 2770 Ma Samambaia Tonalite (Fig. 5) is included. The contrasting signature of the latter (triangles, on 'Fig. 5), with a strong negative Eu anomaly and an undepleted HREE profile, indicates strong continental contamination acquired *en route* to its intrusion site within the cratonic foreland.

CONCLUSIONS AND DISCUSSION The chemical characterization and cartographic discrimination of expressive volcanogenic sedimentary (volcaniclastic) deposits, sharing the same chemical signature with the lavas, provides a new dimension to the RVGB evolution and points to a better evaluation of the real extent of the felsic crustal addition within the orogen.

The presently limited cartographic expression of the felsic volcanism relative to the mafic-ultramafic, ocean-floor remnants does not reproduce their original proportions during the build- up of the RVGB volcanic pile. The submarine mafic flows were better preserved during weathering, abrasion and desegregation than the subaerial felsic centers. Estimates based on volcanogenic quartz contents of volcaniclastic graywackes in some Canadian greenstone belts suggest that the original volume of felsic lavas and primary pyroclastic deposits, now residing in the graywackes and volcaniclastic deposits, could have been as much as twice the present volume of volcanogenic metasedimentary rocks (Ayres 1977 in: Ojakangas 1985). We suggest that this could also be the case for the RVGB. The close association of the RVGB volcanism with thick deep marine turbiditic deposits, whose chemically signature is similar to that of the depleted, calc-alkaline original volcanic rocks, suggests that erosion of the felsic subaerial centers, and resedimentation into adjacent marine troughs by turbidity currents occurred quickly. Accordingly, despite the lack of detailed work, it can be inferred that like the Canadian resedimented facies, the RVGB resedimented facies carries important clues, which help to unravel the originally more extensive dacitic arc.

The integration of the present study corroborates previous isotopic data from Machado & Carneiro (1992), Machado *et al* (1992), Noce *et al.* (1998a) and indicates the evolution of the RVGB can be broadly explained in terms of modern tectonic processes, through a three-stages model which gave rise to the ca 2800-2690 Ma Rio das Velhas Cycle (Orogeny):

Stage I: Extenslonal Rifting phase (ca 2800 Ma) Rifting of the ancient (3400-2900 Ma) TTG protocrust at ~ 2900 Ma (Noce *et al.* 1998a) was ocean-floor spreading accompanied by abundant submarine volcanism with tholeiitic, MORB-type and subordinate komatiitic signatures (e.g. Schorscher 1992, Silva *et al.* 1995, Zucchetti 1998). Discrete syn-accretion, chemical-exhalative sedimentation and extensive ocean-floor alteration, driven by connective hydrothermal systems are indicated by the presence of oxide- and sulfide-Algoma-facies BIFs, chert; banded tourmalinites and coticule, anthophyllite-cordierite rocks - ACR (Silva 1996) and carbonaceous shales.

Stage II: Early Compressional (Pre-collisional) phase (2780-2750 Ma) Fast sinking and subduction of the hot oceanic plate under the high Archean thermal gradient led to direct partial melting of the newly-generated oceanic slab. This gives rise to the adakite-like RVGB dacites and coeval plutonic tonalites, characteristic of the main orogenic period of the Rio das Velhas Orogeny (2800 - 27750 Ma). Melting took place at subcrustal levels, out of the plagioclase equilibrium field, as suggested by the absence of negative Eu anomalies in the dacitic liquids, leaving behind a hornblende-garnet rich eclogitic residue (strong HREE depletion in the dacites). Despite the contrasting nature of the two volcanic episodes, they were coeval in certain stages of the evolution, because volcanic rocks dated at 2772±6 Ma (U-Pb, by Machado *et al.* 1992) are interlayered within basaltic piles (e.g. Noce *et al.* 1992). The scarcity of intermediate volcanic rocks implies a bimodal, Archean-style, arc magmatism.

Dating of detrital zircons and monazites from the Nova Lima Group epiclastic sedimentary rocks disclosed the influence of a continental source contribution to the basin infilling. The majority of detrital mineral ages fall into the 3539-2857 Ma range (Machado *et al.* 1996). As a consequence, the intra-oceanic dacitic arc described here was not formed far from an old continental source. The proximity of this mature continental crust also explains the differentiated chemical signature of the contemporaneous plutons, such as the Samambaia Tonalite (Machado & Carneiro 1992), which displays an evolved chemical signature (Fig. 5). The available Nd isotope data also corroborate the derivation of this tonalite through mixing of variable proportions of mantle-derived (dacitic) and older continental crust-derived magmas (Teixeira *et al.* 1996). This overall evolution is compatible with an island-arc/marginal basin (with sea-floor spreading) setting, close to a continental block (see Machado *et al.* 1996), similar to the Aleutian trench/basin from the adakites type-locality and similar Circum-Pacific settings. Syn-volcanic resedimentation and exhumation of the arc gave rise also to shallow marine beach deposits and deep distal, turbiditic volcaniclastic rocks.

Stage III: Late Compresslonal Stage (Collisional) phase (2750-2690 Ma) With the reversal spreading and continuous closure of the Rio das Velhas ocean, contribution of differentiated, K-rich, continental sources grew in importance in the pile. Graywackes displaying adakitic and NASC-type, Eu depleted, REE mixed patterns (Units 3 and 4), evolved to undepleted, NASC-type continental deposits which characterize the Maquine[1] Group (Silva *et al.* 1995). The waning stages of the orogen are characterized by the intrusion of a series of mature, calc-alkaline and even alkaline, late- to post-tectonic granitoids, dated at 2720-2690 Ma (Machado and Carneiro 1992, Noce *etal.* 1998b).

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