OROSIRIAN CALC-ALKALINE VOLCANISM AND THE OROCAIMA EVENT IN THE NORTHERN AMAZÔNIAN CRATON, EASTERN RORAIMA STATE, BRAZIL

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ABSTRACT
In the eastern portion of the Brazilian state of Roraima there are two main volcanic terranes of Paleoproterozoic age: the Surumu Group to the north and the Iricoumé Group to the south. The Central Guayana Belt is located between these groups. Geochemical and geochronological data point to a dissociation with the anorogenic granitoids related to Saracura and Mapuera suites, presently grouped into the Uatumã Supergroup (Uatumã Event, 1.90-1.70 Ga). Chemical characteristics of volcanic rocks are very similar to those observed in the calc-alkaline granitoids such as the Pedra Pintada and Água Branca suites (1.96-1.91 Ga) pointing to a post-collisional setting, related to the end of Trans-Amazônian Orogeny. The Surumu Group is usually metamorphosed in the lower greenschist facies, with steep foliation and open folding. The Surumu - Iricoumé groups represent a series of acidic to intermediate volcanics, metaluminous and calc-alkaline affinities, similar to those observed in modern magmatic arcs. The REE pattern shows two characteristic groups of volcanics, suggesting distinctive magmatic evolution. Both volcanic-plutonic associated Surumu - Pedra Pintada and Iricoumé - Água Branca and previous molassic sedimentary covers show a new geological framework and are postulated to the Orocaima Event (1.98-1.88 Ga), Orosirian Period.

Keywords: Calc-alkaline volcanism, Orocaima Event, Geochemistry, Geochronology, Orosirian, Paleoproterozoic, Guiana Shield, Amazônian Craton, Roraima State, Brazil

INTRODUCTION
The name "Uatumã" was formerly used to designate volcanic rocks from north and south areas of the Amazonas Basin. In the seventies, large Rb-Sr isotope data were used to propose the timing between volcanic and overlying sedimentary rocks and related basic intrusives, within the range of 1.90-1.70 Ga (Basei & Teixeira 1975). Melo et al. (1978) reported the existence of shallow granitic bodies (Saracura Suite) and intruding volcanics, proposing a comagmatic process at their genesis. Other studies (e.g. Costi et al. 1984) have grouped volcanic rocks to the south under the name "Iricoumé", correlating to Surumu Group in the northern part of the state of Roraima (Fig. 1). Gibbs & Barren (1993), despite showing the scarcity of sedimentary intercalations into the sequence, included sedimentary rocks from the Muruwa Formation (Guyana) into the Uatumã Supergroup.

Throughout the Guiana Shield, the Surumu and Iricoumé volcanics correlate with Cuchivero and Pacaraima groups from Venezuela, in Surinam with the Dalbana Formation and in Guyana the Burn-Burro Group (Iwokrama Formation) to the north and the Kuyuwini Group to the south.

Recent studies from Reis & Fraga (1996) and Reis et al. (1999) have demonstrated a comagmatic relation between the Surumu - Iricoumé volcanism and the Pedra Pintada (Fraga et al. 1996) I-type granitoids. A zircon U-Pb age of 1962 ± 42 Ma by Schobbenhaus et al. (1994) from a Surumu sample, reinforces an older chronostratigraphic framework for volcanism more compatible with the chemical characteristics between Surumu volcanics and Pedra Pintada granitoids (Reis & Fraga 1996). Santos (1999) obtained two zircon U-Pb (SHRIMP) ages of 1984 ± 7 Ma and 1977 ± 8 Ma from Surumu volcanics, thus suggesting an age difference between Surumu volcanism and Pedra Pintada granitoids of approximately 25 Ma. The latter indicates a U-Pb (SHRIMP) age of 1958 ± 11 Ma (Santos 1999) and Pb-Pb age of 2005 ± 45 Ma (Almeida et al. 1997). To the south, Santos (1999) obtained a zircon U-Pb (SHRIMP) age of 1896 ± 7 Ma from Iricoumé rocks. In this same region, Almeida et al. (1997) pointed to an Pb-Pb age of 1938 ± 45 Ma.
PETROGRAPHY
Wherever volcanic rocks of Surumu and Iricoumé groups outcrop, they present a small range of effusive and pyroclastic varieties. The most common type is dacite, with a small proportion of andesites and subordinated rhyolites. The felsic nature also prevails in pyroclastic rocks. The volcanics are often foliated, relating to a deformational processes on a ductile - brittle framework associated with the KMuduku Event.

The commonest type of dacite shows a porphyritic texture, with abundant phenocrysts of plagioclase in a matrix of quartz, plagioclase, alkaline feldspar, biotite and hornblende. Opaques, apatite, zircon and titanite are common accessories. Sericite, chlorite, epidote and carbonate are secondary minerals. The rhyolites show porphyritic to glomeroporphyritic texture in relation to dacites, with microcline and quartz phenocrysts over plagioclase. Recrystallized quartz aggregates are common in the matrix, which still shows a minor mafic minerals content (biotite and hornblende), the presence of allanite, but no evidence of carbonate.

The andesite has minor phenocrysts (plagioclase and rare amphibole) in a microcrystalline matrix of plagioclase, amphibole and biotite with abundant secondary sericite and chlorite. Quartz, opaques, apatite and rare titanite are accessories. Late saussuritization and serialization of the plagioclase are always accompanied by replacement of the amphibole with opaque ± chlorite ± epidote. Biotite is always chloritized. Sulphides are locally disseminated.

The mylonites consist largely of andesitic, dacitic and rhyolitic rocks submitted to intense shearing. The groundmass texture is porphyroclastic in a fine matrix characterized by development of a greenschist metamorphic paragenesis through the sericitization of feldspar, saussuritization of plagioclase, recrystallization of quartz, chloritization of biotite and amphibole.

GEOCHEMISTRY
The volcanic rocks show SiO₂ ranging from 54.1% to 72.5%, mg# from 13.40 to 49.93 and Na₂O/K₂O ratios from 0.50 to 1.81 (geochemical results can be obtained from the authors of this article).

In the TAS (silica versus total alkalis) diagram (Le Maitre et al. 1989, Fig. 2a) the metaluminous volcanic rocks plot on rhyolite, dacite, trachydacite, andesite, trachyandesite and a basaltic andesite field. A relative K₂O enrichment in the acid members is related to high-K series (Le Maitre et al. 1989, Fig. 2b). It also shows enrichment in Cr, Ni, Rb, Zr and Ba compared to calc-alkaline types from literature.

Chondrite-normalized REE patterns (Sun 1982) support the distinction of two geochemical groups, both indicating distinctive magmatic evolution. The first one exhibits a relatively fractionated
pattern and a negative Eu anomaly, LREE enrichment and HREE depletion (Fig. 3a). This group is characterized by mafic phase dominated fractionation. The other exhibits moderate negative Eu anomaly, clear LREE fractionation and undifferentiated patterns of MREE and HREE (Fig. 3b). The presence of negative Eu anomalies favors the major or minor presence of plagioclase in order to explain a fractionated or residual phase in the parental magma generation of the volcanic rocks and accompanying mafic phases with added HREE and/or MREE (clinoxyroxene and/or amphibole).

Both Surumu - Iricoumé REE patterns are similar to those observed in the different petrographic groups of Pedra Pintada and Agua Branca suites (Fig. 3c).

According to Brown et al. (1984) (Fig. 4), they also present greater distribution in the calc-alkaline volcanic field than modern magmatic arc, showing similarities with the plot of calc-alkaline granitoids of Pedra Pintada (Fraga et al. 1997b) and Agua Branca suite, in contrast with the anorogenic Saracura and Mapuera suites (Fig. 4).

**DISCUSSION**

Apart from some continents with erogenic episodes within the range 1.95-1.80 Ga, the Trans-Amazônan Cycle constitutes an important event with strong metamorphism, deformation and intrusion in the Amazônan Craton around 2.20 - 2.00 Ga. The end of the cycle was broadly defined by the presence of post-tectonic calc-alkaline plutonism with moderate deformation. In Roraima State the picture is similar, including the Pedra Pintada and Agua Branca suites. Both units show ages within the range 2.00 - 1.91 Ga (Santos & Reis Neto 1982, Jorge João et al. 1985, Almeida et al. 1997, Santos 1999).

Of particular interest to the understanding of the framework of the shield is the transitional timing between the erogenic and cratonic domains, displayed by intense volcanism, plutonism and shield is the transitional timing between the erogenic and cratonic domains, displayed by intense volcanism, plutonism and deformation. In Roraima State, the type-area is defined along the Orocaima Mountains, which point to the occurrence of Pedra Pintada granitoids and Surumu volcanics (about 3°40' and 4°20' N; 60°50' and 61°15' W). This same assemblage is reported somewhere some few kilometers to the northwest from the occurrence of Pedra Pintada and Surumu volcanics (about 3°40' and 4°20' N; 60°50' and 61°15' W). This same assemblage is reported somewhere else south of Roraima including volcanic rocks from Iricoumé Group.

Uatuma, sometimes interdigitated with the first manifestation of volcanism (Gibbs & Barren 1993), but this phenomenon have not yet been reported by the Brazilian counterpart. Some correlated units are known, such as Los Caribes Formation in Venezuela, Muruwa Formation in Guyana and Ston Formation in Suriname, which point to a molasse sedimentation contemporaneous with Paleoproterozoic volcanism and plutonism. They may constitute successor basins (Ingersoll 1988), with limited associated volcanism and moderate deformation, indicating the end of the orogenic activity, forming primarily in intermontane settings, on top of inactive fold-thrust belts or failed rifts.

Santos (1978) took the available geochronological data from the seventies and established the time line between the Lower and Middle Proterozoic, taking into account the initial phase of Uatuma volcanism (1.90Ga) and dissociating the whole magmatism from the Trans-Amazônan Orogenic Cycle. In Suriname, Bosma et al. (1983) noted that the Trans-Amazônan should be regarded as having taken place in two stages, a first one deformational and metamorphic, around 2.0Ga, and the other, essentially magmatic, around 1.87Ga.

The truly terminal phase is represented by more extensive platform cover in previously crateronized orogenic areas, for example, Roraima Supergroup (Pinheiro et al. 1990), whose minimum depositional age was established at 1.77 Ga (Santos 1999) in dykes and sills related to Avanávero Diabase.

The geochronological data also favor a close relationship in space and time between the generation of Surumu magmatism, Pedra Pintada - Agua Branca plutonism and the development of the Central Guiana Belt (CGB). At CGB, the orthogneisses show ages within a 1.96 - 1.91 Ga range (Santos & Olszewski 1988, Gaudette et al. 1996, Fraga et al. 1997a). To the north, outside the CGB, the Surumu and Pedra Pintada rocks show a deformational pattern printed along the shear zones. This feature, especially printed in volcanic rocks, is absent in the Roraima basin. In turn, Gibbs & Barron (1993) report the presence of open folds in volcanic rocks, recording a Post-Trans-Amazônan compressive deformational episode. According to the authors, the sedimentary rocks from Roraima Supergroup rest in unconformity over the previously deformed volcanic rocks.

A chemical relationship toward a camagmatism between Surumu - Iricoumé groups and Pedra Pintada - Agua Branca suites, new geochronological data and structural framework, favor a review of the terminology "Uatuma Supergroup" and "Uatuma Event" in the sense of a volcano-plutonic association with eminent anorogenic character.

Accordingly, the designation "Orocaima Event" is proposed here to demonstrate a major event of calc-alkaline volcano-plutonism, related to the Orosirian Period, of a broad area from Guiana Shield. At Roraima State, the type-area is defined along the Orocaima Mountains, some few kilometers to the northwest from the occurrence of Pedra Pintada granitoids and Surumu volcanics (about 3°40' and 4°20' N; 60°50' and 61°15' W). This same assemblage is reported somewhere else south of Roraima including volcanic rocks from Iricoumé Group.
and granitoids from Água Branca Suite. Emphasized in this paper are the common chemical characteristics and development timing shared by those units, which together provide a new and interesting picture of the evolutionary framework of Orosorio rocks from Guiana Shield.

**FINAL CONSIDERATIONS**

The piononed Orocamia Event represents 4100 Ma volcano-plutonism (1.98-1.88 Ga) as supported from investigations in Surumu - Irirume volcanic rocks and Pedra Pintada - Água Branca granitic rocks from Roraima State, with a similar picture emerging in neighboring countries (Venezuela - VE, Guyana - GU and Suriname - SU). It also includes the sedimentary rocks from Los Carribes (VE), Muruvua (GU) and Ston (SU) formations, which suggest successor basins in intermontane settings.

The available isotopic ages for volcanic rocks suggest younger values toward the southern portion of Amazónian Craton (Iriri Group);

The Central Guiana Belt constitutes a broad area of exposure of Paleoproterozoic (1.96-1.91 Ga) high-grade rocks, in which timing is nearly concordant with that of Orocamia Event to the north and to the south of the belt.

A relatively short time interval between the molassic sedimentation of Los Carribes - Muruvua - Ston basin, calc-alkaline volcano-plutonism and development of the Central Guiana Belt (although of great complexity), points to a temporal association related to the last stages of the Trans-Amazônian Cycle. It follows an anorogenic tectonic environment with plutonism, platform cover and basic magmatism (1.86-1.77 Ga) (e.g., Saracura and Mapuera suite; Roraima Supergroup and Urupi Formation; Avanuveru and Quarenta Illus Dias). REE pattern from volcanics point to two distinctive groups of rocks, suggesting different magmatic evolutions. It shows similarities with different petrogenetic groups from the calc-alkaline Pedra Pintada and Água Branca suite and probably involved mantle derived magma associated with crustal ones.

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