Airborne gamma-ray spectrometry signatures of Ediacaran granitic rocks in the Transversal Zone of Borborema Province – NE/Brazil

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Abstract

High-resolution gamma ray spectrometry was exploited to identify and classify the main granitic intrusions present in Transversal Zone domain, Northeastern Brazil due to the fact that this rock type tend to have relatively high levels of gamma radiation from the decay of potassium, uranium and thorium, elements present in its mineral composition. The granitic suites were grouped according to the data compilation present in literature and the results revealed interesting patterns for the epidote bearing calc-alkalic, high-K calc-alkalic and ultrapotassic peralkalic series. Also, high-K metaluminous and post-orogenic/A-type suites have a distinct gamma-ray signature, even though there are few mapped occurrences in study area. On the other hand, the results for shoshonitic, high-K calc-alkalic and Trondhjemitic-affinity suites are ambiguous, since they do not present gamma-ray signatures that allow their clear differentiation between them.

Introduction

The Transversal Zone domain (TZD), Borborema Province, NE Brazil, is limited by the Patos and Pernambuco shear zones to the north and south, respectively (Figure 1). It features the amalgamation of the Paleoproterozoic Alto Moxotó subdomain, and Neoproterozoic terrains represented by the Piancó-Alto Brígida, Alto Pajeú and Rio Capibaribe subdomains, all displaced westwards through a huge network of EW and NE-SW shear zones. The late Neoproterozoic evolution of the Borborema Province was marked by an abundance of granitic intrusions, most of them associated with NE–SW shear zones (Guimarães et al., 2004).

According to Sial (1986) four groups of granitic rocks have been identified in TZD with syn- to post-orogenic emplacement: 1) calc-alkaline, 2) potassic-calc-alkaline, 3) peralkaline and 4) of trondhjemitic affinities. Rock compositions vary from tonalites, granodiorites, quartz-syenites, syenites to minor granites.

Granitic magmatism in the Transversal Zone Domain of the Borborema Province, northeastern Brazil, occurred in three main time intervals: 650-620 Ma, 590-560 Ma and

Figure 1 – Schematic map of the main granites of Province Borborema, based on Brito Neves et al. (2000), modified

545-520 Ma. The oldest one is characterized by intrusions of magmatic-epidote (mEp) bearing calc-alkalic (some with trondhjemitic affinities) and high-K calc-alkalic plutons, synkinematic to the main regional foliation, under contractional tectonic regime. the 650–620 Ma group of plutons is compatible with partial fusion of subducted oceanic basaltic crust (mEp-bearing calc-alkalic tonalites/granodiorites, equivalent to adakites). Voluminous intrusions in the 590e560 Ma interval are represented by abundant mEp-free high-K calc-alkalic, peralkalic, ultrapotassic,mEp-bearing high-K calc-alkalic, and less abundant shoshonitic magmas (Sial e Ferreira, 2015).

The calc-alkaline suite of rocks is widespread in island arcs and active continental margins, with tholeiitic lavas dominating the volcanic front, and alkaline lavas dominating the backarc regions, although **not exclusively** in this type of geological environment (Sheth et al., 2002). This suite can be classified into low-K, medium-K, high-K and shoshonitic suites, based on their potassium and silica contents.

Based on this information, could the concentrations of K, Th, and U be useful in identifying and distinguishing between the various types of granites in an area?

Method

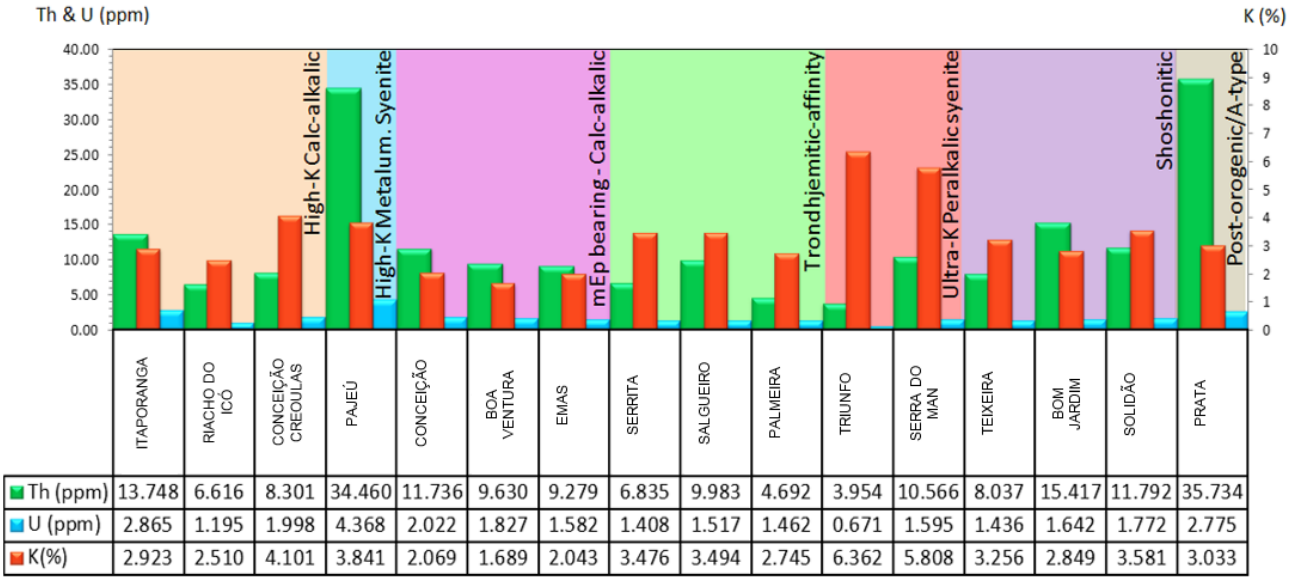
High-resolution airborne gamma-ray data was used to locate, to analyze the concentrations of K, Th and U, and to interpret the boundaries of the main granitic rocks exposed in the region. The airborne geophysical data used are part of the CPRM database, referring to the Pernambuco-Piaui (2006), Borda Leste do Planalto da Borborema (2008), PB/RN/PE/CE (2010) and Centro-Sudoeste do Ceará (2010) projects. The planned flights were spaced 0.5 km between N-S flight lines and 10 km between E-W control lines, respectively, and the average flight height of 100 m over the ground.

On board of all the aircrafts were coupled Exploranium gamma-ray spectrometers, model GR-820, with 256 spectral channels (Figure 2). Each downward-looking detection system consists of three sets of thallium-doped sodium iodid crystals (Nal (TI)), totalizing a volume of 2.560 cubic inches. The upward-looking detector system consists of two cubic 256-inch crystals, totalizing 512 cubic inches, and its function is to monitor the radiation arising from the influence of the radon gas (Rn) present in the atmosphere, captured in the energy band of the uranium channel (1.68 to 1.86 MeV).

Figure 2 - Exploranium gamma-ray spectrometers, model GR-820, coupled to the interior of the aircraft

The TZD granites were individualized and classified according to the data compilation of Sial and Ferreira (2015) and Brito Neves et al. (2013). An analysis of the TZD granite suites was performed with RGB image and according to the average concentrations of K, Th and U of some of their most representative granites

Results



	ITAPORANGA	RIACHO DO ICÓ	CONCEIÇÃO CREOULAS	PAJEÚ	CONCEIÇÃO	BOA VENTURA	EMAS	SERRITA	SALGUEIRO	PALMEIRA	TRIUNFO	SERRA DO MAN	TEIXEIRA	BOM JARDIM	SOLIDÃO	PRATA
Th (ppm)	13.748	6.616	8.301	34.460	11.736	9.630	9.279	6.835	9.983	4.692	3.954	10.566	8.037	15.417	11.792	35.734
U (ppm)	2.865	1.195	1.998	4.368	2.022	1.827	1.582	1.408	1.517	1.462	0.671	1.595	1.436	1.642	1.772	2.775
K(%)	2.923	2.510	4.101	3.841	2.069	1.689	2.043	3.476	3.494	2.745	6.362	5.808	3.256	2.849	3.581	3.033

Figure 4 – Analysis of the gamma-ray signatures for the main granites belonging to the TZD. Classification of granite suites extracted from Sial e Ferreira, 2014, Brito Neves et al., 2003.

Since Northeast Brazil presents a dry climate all year round and most terrains of TZD display large areas with exposed rocks and a thin soil layer, the gamma-ray survey produced excellent results. The Piancó-Alto Brígida, Alto Pajeú, Alto Moxotó and Rio Capibaribe terrains, as well as the Patos and Pernambuco shear zones, have very different gamma-ray signatures, which makes it easy to map the internal division of TZD. An analysis of the TZD granitic suites was performed according to the average concentrations of K, Th and U of some of their most representative granites, in order to verify the existence of patterns in their geophysical signatures that allowed a differentiation between the types of TZD granites with the use of gamma spectrometry (Figure 4).

The set of results shows that these granite types are abundant in TZD, especially in the Alto Pajeú and Piancó-Alto Brígida terrains. In terms of gamma-ray signatures, although they have similar uranium and thorium concentrations, the epidote bearing calc-alkalic and high-

K calc-alkalic suites present in TZD can be differentiated by the potassium content, where the 'high-K' term is translated into concentrations higher than 2.5% of K. The same comparison can be done for the ultrapotassic peralkalic series, in which the K content reaches values of the order of 6%, on average. Even in the lesser amount não entendi!in the TZD, the highest values of K, Th, U define high-K metaluminous and post-orogenic/A-type suites. On the other hand, the results for shoshonitic, high-K calc-alkalic and Trondhjemitic-affinity suites are ambiguous, since they do not present gamma-ray signatures that allow their clear differentiation (Figure 5).

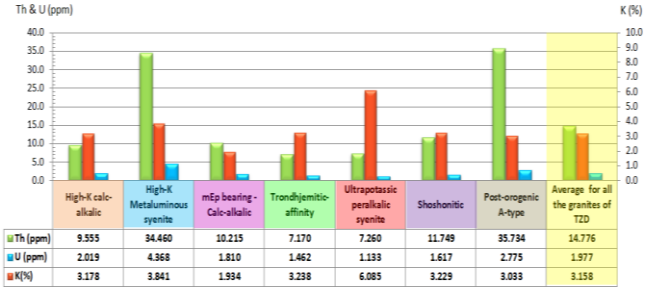


Figure 5- Average K, Th U concentrations for the granitic suites present in the TZD.

Some features related to the granites analyzed in this work are worthy of note. Concentrations of K, Th, and U may vary depending on compositional factors, but also topographic factors.This is the case of granitic stocks intrusive in intermediate-grade metasediments of the Piancó-Alto Brigida subdomain (close to Bodocó eclogite), which has ring structures (Figure 6). Epidote-bearing and biotite-granodiorites are predominant in the core, but the rings of the stocks, composed by aegirine-granites, are located in topographic relief (Neves, 1986), The granitic intrusion core presents an high K signature, but edges are poor in K, presenting high concentrtation of Th and U In comparission with K percentage in that rock. For the purpose of calculating the mean concentrations, only core measurements were taken.

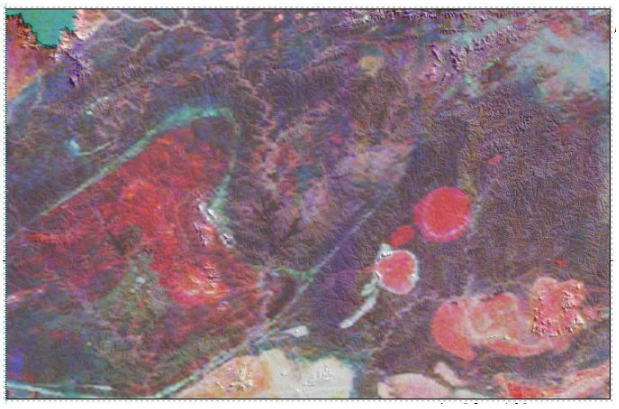


Figure 5- Location of Serrita granite in RGB map. Epidote-bearing and biotite-granodiorites predominare in the cores of the stocks but the rims, usually in topographic relíef, are composed of aegírine-granites.

Conclusions

The results show that are patterns in geophysical signatures for the granitic suites present in Transversal Zone domain. Although all the granites have high values of K, Th and U in comparison to the other rocks, there are important variations in the concentrations of these radioelements among the granites, which can be used as an aid in the analysis and classification. The results indicate interesting patterns for the epidote bearing calc-alkalic, high-K calc-alkalic and ultrapotassic peralkalic series. Also, high-K metaluminous and post-orogenic/A-type suites. However, shoshonitic, high-K calc-alkalic and Trondhjemitic-affinity suites are ambiguous, since they do not present gamma-ray signatures that allow their clear differentiation between

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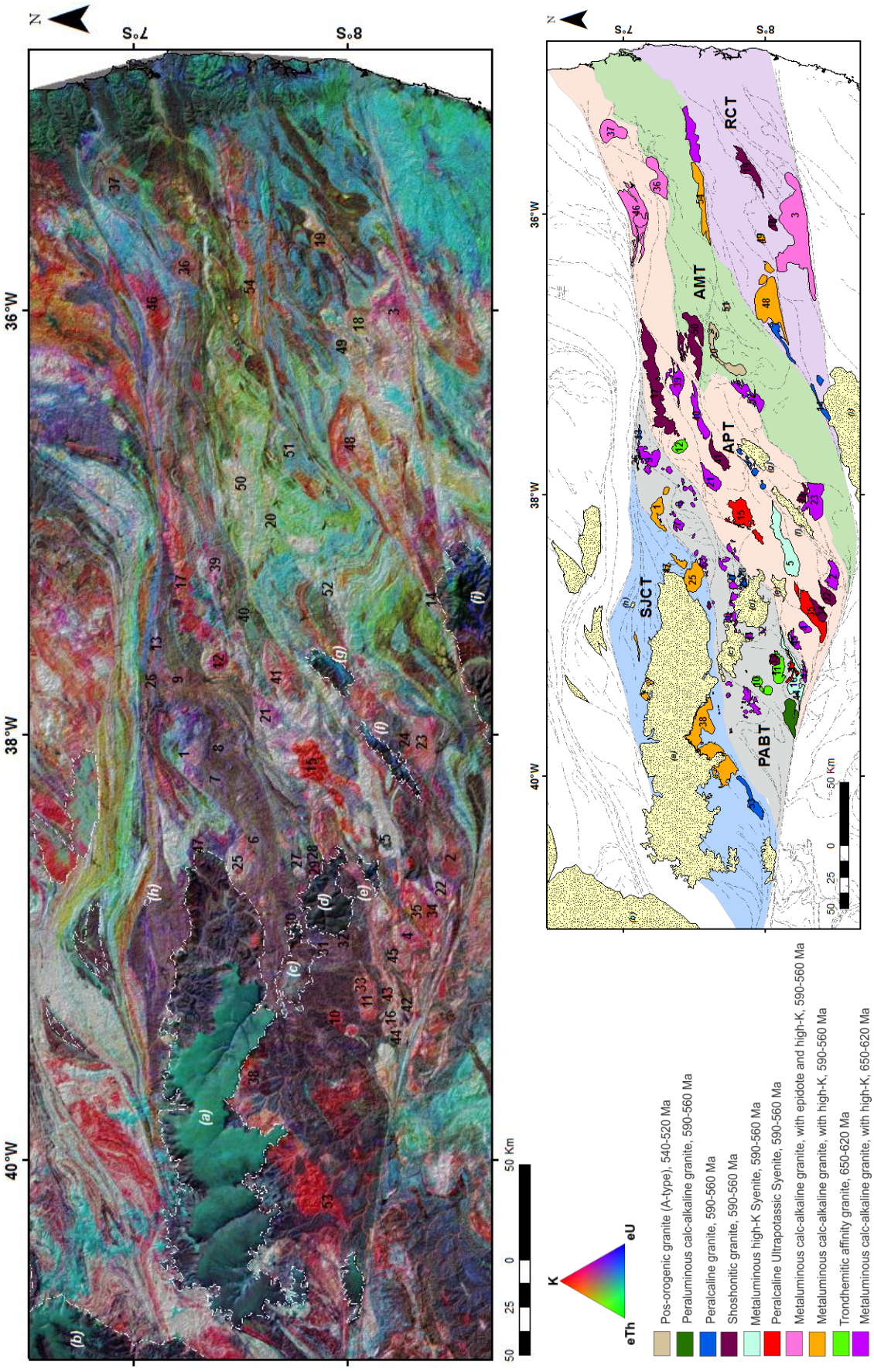

Figure 3- Terranes of the TZD: RCT = Rio Capibaribe Terrain; AMT = Alto Moxoto; APT = Alto Pajeú; PABT = Pianco Alto Brigida; SJCT = São Jose do Caiano. Representative Ediacaran Plutons of the main magma associations of TZD: 1= Itaporanga; 2= Riacho do Ico; 3 = Fazenda Nova; 4 = Conceição das Creoulas; 5= Pajeú; 6 = Conceição; 7 = Boa Ventura; 8 = Pedra Branca; 9 = Emas; 10 = Serrita; 11= Salgueiro; 12 = Palmeira; 13= Catingueira; 14 = Moderna; 15 = Triunfo; 16 = Terra Nova; 17 = Teixeira; 18 = Toritama; 19 = Bom Jardim; 20 = Prata; 21 = Tavares; 22 = Serra do Arapua; 23 = Remedios; 24 = Betania; 25 = Serra da Lagoinha; 26 = Campo Grande; 27 = Cana Brava; 28 = Batinga; 29 = Bernardo Vieira; 30 = Carmo; 31 = Angico Torto; 32 = Verdejante; 33 = Salgueiro Leste; 34 = Serra Grande; 35 = Serra do Man; 36 = Campina Grande; 37 = Lourenço; 38 = Bodocó; 39 = Itapemirim; 40 = Tabira; 41 = Solidão; 42 = Boqueirão; 43 = Livramento; 44 = Caseí; 45 = Caldeirão Encantado; 46 = Esperança; 47 = Serra da Lagoinha; 48 = Sa. da Jararaca; 49 = Sta. Cruz do Capibaribe; 50 = Serra Branca; 51 = Sa. da Engabelada; 52 = Gado Bravo; 53 = Ouricuri. Basins: (a) Araripe; (b) Parnaiba; (c) Carmo; (d) St. Jose Belmonte; (e) Mirandiba; (f) Betânia; (g) Fatima; (h) Iara; (i) Jatobá.