SUBVOLCANIC VENT BRECCIA OF THE CABO FRIO ISLAND, STATE OF RIO DE JANEIRO, BRAZIL

Susanna Eleonora Sichel 1; Akihisa Motoki 2; David Canabarro Savi 3; Heloisa Bauzer Medeiros 4; José Ribeiro Aires 5; Rodrigo Soares 2

Departamento de Geologia, UFF, susanna@igeo.uff.br 1
Departamento de Mineralogia e Petrologia Ígnea/UERJ, vulcaodenovaiguacu@yahoo.com.br 2;
Instituto de Estudo de Mar Almirante Paulo Moreira, david_canabarro@uol.com.br 3
GMA/UFF, medeiros@mat.uff.br 4
ABAST/PETROBRAS, aires@petrobras.com.br 5

Resumo - Na extremidade sudoeste da Ilha do Cabo Frio, RJ, ocorre um corpo piroclástico em uma área aproximada de 800 x 400 m alongada segundo direção NE-SW. As rochas apresentam textura suportada por clasto e matriz, com os clastos de tamanho de lapilli e eventual ocorrência daquele de tamanho de matacão. A textura é heterogênea, não se observando seleção granulométrica e acamamento vulcânico. Os clastos grandes são semi-arredondada e os pequenos são angulosos. Esses são compostos principalmente de trachyte e rocha piroclástica soldada, e subordinadamente de gneiss. A existência dos clastos de rocha piroclástica soldada indica que os vulcanismos explosivos ocorreram repetidamente. Apesar de que a rocha encaixante principal é sienito, esta rocha raramente ocorre nos clastos. Não se observam os fragmentos essenciais vesiculares, tais como escória, bomba e spatter. Certos clastos apresentam notáveis feições de case hardening. A matriz é totalmente consolidada por soldamento. O plano de contato do corpo piroclástico com o corpo encaixante é sub-vertical, intercalando um corpo tabular de trachyte de largura aproximada de 20 m. Essas observações indicam que as rochas piroclásticas da Ilha do Cabo Frio não são constitutíes de fluxos piroclásticos ou tephra de um edifício vulcânico, mas tufo soldado de preenchimento de uma fissura subvulcânica que foi posicionado em uma profundidade quilométrica, ou seja, um conduto de forma tabular que forneceu de materiais piroclásticos.

Palavras-Chave: Ilha de Cabo Frio, Conduto subvulcânico, Brecha vulcânica, Soldamento, Traquito

Abstract - At the south-western end of the Cabo Frio Island, State of Rio de Janeiro, Brazil, a pyroclastic rock body takes place in an area of about 800 x 400 m elongated NE-SW ward. The rocks show clast-matrix supported texture with lapilli-sized clasts and eventual occurrence of bowlder-sized ones. The texture is heterogeneous and no granulometric sorting and volcanic layering are observed. The large clasts are semi-rounded and small ones are angular. They are constituted mainly by trachyte and welded pyroclastic rocks, and secondary by gneiss. The existence of welded pyroclastic clasts indicates repeated explosive volcanism. Although main type of the country rock is syenite, the clasts of this rock are rarely observed. Vesicular essential fragments, such as scoria, bomb and spatter, are not found. Some clasts show notable case hardening fabrics. The matrix is totally consolidated by welding. The contact plane of the pyroclastic body with the host rock body is sub-vertical, intercalating a trachytic tabular body, approximately 20 m wide. These observations indicate that the pyroclastic rocks of the Cabo Frio Island are not constituent of pyroclastic flow deposits or tephra of a volcanic edifice, but of vent-filling welded tuff breccia of a subvolcanic fissure that was emplaced at a kilometric depth, being a wide feeder dyke of pyroclastic materials.

Keywords: Cabo Frio Island, Subvolcanic conduit, Volcanic breccia, Welding, Trachyte
1. Introduction

In the coast region of the State of Rio de Janeiro, a dozen of late Cretaceous to early Tertiary syenitic bodies take place. Some of them, such as Itatiaia, Mendanha, Itaúna and Cabo Frio Island, are associated with volcanic breccia. For geologic mode of emplacement of the pyroclastic rocks, there are two controversial interpretations: 1) Constituents of preserved volcanic edifice; 2) Subvolcanic intrusive rock bodies.

The volcanic breccia of the Mendanha syenitic complex was interpreted by Klein & Vieira (1980), Klein et al. (1984), Klein (1993), Silveira (2005), etc. to be constituent of a volcanic edifice, so-called “Nova Iguaçu Volcano”. However, recent articles published by Motoki & Sichel (2006) and Motoki et al. (2007a; b; c) have revealed inexistence of the crater, the volcanic edifice, the pyroclastic flow deposits, the lava flows, and the volcanic bombs, which were pointed out by the previous works. Therefore, the pyroclastic bodies have been attributed to vent-filling welded tuff breccia. The Itaúna pyroclastic body also was interpreted by Klein et al. (1999) as a volcano. However, recent volcanological works by Motoki et al. (2007d; e) have clarified that they are constituent of a subvolcanic conduit.

The pyroclastic body of the Cabo Frio Island is exposed on the south-western sea-cliff of the island, more than 200 high, in front of the Atlantic Ocean. Therefore, its three-dimensional form is well identified, indicating if this volcanic breccia is surface deposit related to a volcanic edifice or vent-filling welded tuff breccia of a subvolcanic conduit. The present paper introduces the lithology, petrography, and geological mode of occurrence of the pyroclastic rock of the Cabo Frio Island.

2. Regional geology

The Cabo Frio Island is situated approximately at 23°S, 42°W, 126 km to the east of Rio de Janeiro City, and has NE-SW extension of 4.4 km, NW-SE one of 2 km, highest point of 390 m above sea level, and total area of 6.5 km² (Figure 1). The island is indicated entirely as Environmental Protection Area and under administration of Brazilian Navy Force. The geologic basement body of the island is constituted by leucocratic orthogneiss intruded by early Cretaceous tholeiitic mafic dykes. The central and east areas expose nepheline syenite intrusive into the basement and the margin, orthogneiss and pyroclastic body (Lima, 1977; Araújo, 1995; Sichel et al, 2004). All of them are cut by Tertiary dyes made up of lamprophyre, trachyte, and phonolite (Motoki & Sichel, 2008).

3. Pyroclastic rocks

The pyroclastic rocks are distributed in a small area at the south-west end of the Cabo Frio Island, about 800 x 400 m elongated NE-SW ward (Figure 1). The lighthouse is situated on the pyroclastic rocks. The sea-cliff is more than 200 m high, exposing widely the pyroclastic body and its basement. The host rocks are composed of gneiss and syenite. The outcrops and rolling stones of these rocks are observed along the track for accesses to the lighthouse (Loc. 1; Figure 1). Along the north-western contact (Loc. 2), there is a sub-vertical trachytic tabular rock body made up of massive trachyte, about 50 m wide, intercalated between the pyroclastic body and the host body made up of gneiss and syenite.

The pyroclastic rocks contain relatively high amount of clasts, showing clast-matrix supported texture. In general, they are small, of 2 to 4 cm in diameter, classified to be lapilli, however, bolder-sized clasts also eventually take place. In fact, the clast size is highly variable even within an outcrop, from millimetric up to 30 cm (Figure 2B, C). The texture of the pyroclastic rocks is highly heterogeneous and no granulometric sorting and clast layering are observed. The clast form is generally rounded to semi-angular. The larger ones tend to be rounded and smaller ones are angular. On the weathered surface, notable case hardening fabrics is observed in pyroclastic rocks and their clasts.

They are constituted mainly by trachytic (Figure 2B, C) and welded pyroclastic rocks (Figure 2A). Gneissic clasts also are observed (Figure 2D). The existence of welded pyroclastic clasts indicates that explosive volcanisms took place.
place repeatedly. On weathered surface of the large trachytic clasts, case hardening fabrics of notable characteristics is commonly observed. Vesicular essential fragments, such as scoria, bomb and spatter, are not observed. Although main type of the country rock is syenite, the clasts of this rock are rare.

The rock samples of low-grade weathering show that the matrix of the pyroclastic rocks are totally consolidated with the same mechanical firmness of other types of massive igneous rocks. Considering the formation age of these rocks, supposed to be early Tertiary, the consolidation by diagenesis is not suitable. Therefore the hardness of these pyroclastic rocks is attributed to welding.

4. Geologic mode of emplacement

In literature, pyroclastic rocks are frequently interpreted to be constituent of subaerial volcanic deposits, such as pyroclastic flows and tephra. However, not all of the pyroclastic rocks, including welded tuff, are eruptive deposits accumulated on the Earth’s surface. Some of them form subvolcanic intrusive bodies, such as neck, volcanic vent, and fissure (Motoki & Sichel, 2006). The pyroclastic rocks of surface deposits and those of subvolcanic bodies have similar lithologic aspects, and therefore in some cases they are difficult to be distinguished (Motoki, 1997; 1988). The pyroclastic rocks of felsic alkaline intrusive bodies of the Mendanha massif of Nova Iguaçu, the Itaúna massif of São Gonçalo, and the Poços de Caldas massif of Minas Gerais are typical examples (Motoki, 1988; Motoki et al., 2007a; b; c; d; e). Therefore, the geologic emplacement mode must be defined by field observations, especially of contact outcrops, and not deduced by lithologic and petrographic characteristics.
The contact plane is of the pyroclastic body is sub-vertical. The contact is well exposed on the sea-cliff at the south-western end of the Island (Figure 3; Loc. 3), however the access to the sub-vertical outcrops is not easy. The distribution of the pyroclastic rocks indicates that the rock body has tabular form of vertical configuration, about 400 m wide (Figure 1; 3), like a very wide dyke of NE-SW direction filled by welded pyroclastic materials.

As mentioned before, north-western contact of the pyroclastic body intercalates a vertical tabular body of massive trachyte, approximately 50 m wide, between the pyroclastic body and the country rock (Loc. 2, Figure 1). The dyke-like form of the pyroclastic body, the abundance of trachyte clasts in spite of intrusion in syenitic host body, and the intercalation of tabular body of massive trachyte in the contact zone are quite similar to the geological setting of some pyroclastic dykes, that is, subvolcanic pyroclastic fissures of the Mendanha felsic alkaline complex rock body, such as Poço da Queda, Mendanha (Figure 4). However, the size of rock bodies of the Cabo Frio Island is much larger. The above-mentioned geologic and lithologic similarities indicate that the pyroclastic rocks of the Cabo Frio Island also are constituent of a subvolcanic intrusive rock body, and formed by means of similar processes.

These pyroclastic rocks are distributed only in a limited area, without widespread distribution of kilometric extension. No pyroclastic rocks are found at other sites in the island or continental region. Such distribution and sub-vertical contact are similar to the cases of the volcanic breccia of the Mendanha and Itaúna rock bodies. This geologic setting is incompatible with pyroclastic flow or tephra hypothesis, but fits well to vent-filling welded tuff breccia model.

5. Intrusion depth

The pyroclastic rocks of Cabo Frio Island show similar geological and lithological characteristics to the volcanic breccia of the acidic rock body of Sumiyoshigawa, Kobe, Japan, (Motoki, 1979), felsic alkaline complex rock bodies of Poços de Caldas, Minas Gerais (Motoki, 1988), Mendanha, Nova Iguaçu, Rio de Janeiro, (Motoki & Sichel, 2006; Motoki et al., 2007a; b; c) and Itaúna, São Gonçalo, Rio de Janeiro (Motoki et al., 2007d). Therefore, this pyroclastic body also considered to be a subvolcanic body filled by highly welded vent-filling tuff breccia.

The Cabo Frio Island is made up mainly of nepheline syenitic rock body. This intrusive body is considered to be of the same alkaline felsic magma event of the pyroclastic rocks. The present nepheline syenite outcrops show an underground section of subvolcanic magma chamber. A contact plane angle between the syenite and the host gneiss indicate that the present surface corresponds to lower part of the magma chamber (Figure 5; Loc. 4). This situation is similar to the case of Mendanha syenitic intrusive body (Motoki et al., 2007a; 2008).
The above-mentioned observations indicate that the pyroclastic body was emplaced at a relatively deep site of kilometric depth. The fission track datings for apatite extracted from the metamorphic basement of Rio de Janeiro region indicate that there occurred about 3 km’s regional uplift and consequent denudation from the magma intrusion up to the present (Hackspacher et al., 2004; Motoki et al., 2006).

That is, the present outcrops represent subvolcanic structure of the sites about 3 km below the Earth’s surface of the time of the magmatism (Figure 6). It is considered that the eruptions took place on the Japi elevated peneplane (Motoki et al., 2006; 2007a; c), formed about 85 Ma (Almeida & Carneiro, 1988). Because of the deep regional denudation, the volcanic edifice and eruptive deposits were completely eliminated.

6. Conclusions

The field observations of the Cabo Frio Island, with special attention of the pyroclastic rocks, show the following conclusions about its geologic emplacement mode.

1. The pyroclastic rocks are exposed in a small area, about 800 x 400 m elongated NE-SW ward, with at least 200 m of vertical extension.
2. The contact planes with the host rock body are sub-vertical, and the pyroclastic body is of large dyke-like three-dimensional form. The north-western contact intercalates massive trachytic between the volcanic breccia and host rocks.
3. The rocks show clast-matrix supported texture. The clasts in general are few centimetres in diameter, with eventual occurrence of bowlder-sized ones. The small clasts are angular and large ones are semi-rounded.
4. The clast size is highly variable even within the same outcrop and the texture is very heterogeneous. No granulometric sorting and volcanic layering are found. The matrix is totally consolidated by welding.
5. The clasts are constituted mainly by trachytic rocks and welded pyroclastic ones, and secondary by gneissic ones. Syenitic clasts are rare. Vesicular essential fragments, such as bomb, are not observed. Some trachytic clasts show notable case hardening fabrics.
6. The existence of the welded tuff clasts indicates that the explosive volcanism took place repeatedly.
7. These characteristics, especially dyke-like rock body form, indicate that the pyroclastic rocks are not constituent of a volcanic edifice, but of an intrusive rock body emplaced at a kilometric depth, corresponding to subvolcanic conduit. In this sense, the rocks are considered to be vent-filling welded tuff breccia
8. The geologic and lithologic characteristics are quite similar to those of other subvolcanic fissures and conduits of the same event of felsic magmatism of this region, such as Mendanha and Itaúna bodies.

7. Acknowledgement

The authors are grateful to the FAPERJ, Carlos Chagas Filho Foundation, of the Rio de Janeiro State Government, for the financial supports: Category APQ1, “Petrologia, geoquímica e magmageneses dos corpos alcalinos da Ilha de Cabo Frio e Morro de São João e seus aspectos ambientais como patrimônios geológicos”; Category IC, “Geologia e petrografia de corpos subvulcânicos como indicadores de atividades magmáticas subterrâneas e mecanismo de erupções vulcânicas”.

Figure 6. Formation process of trachyte clasts of subvolcanic conduit intrusive into syenitic wall rock by means of lava dome collapse and implosion by fluidization (A, B) and schematic block diagram for geologic emplacement of the Early Tertiary pyroclastic rock body of the State of Rio de Janeiro, Brazil, according to Motoki et al. (2007c).
8. Reference


