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A new type of recent natrocarbonatitic magmatism in Angola: the feeding dykes of the Chiva lagoon maar

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Resumen

En las inmediaciones del graben de Catanda (Angola) se localiza una laguna circular de 900 metros de diámetro conocida como laguna de Chiva. Aunque éste área se encuentra extensamente cubierta por sedimentos lacustres, se ha descrito la presencia de un pequeño grupo de diques de composición carbonatítica que afloran en la orilla SE de la laguna. La intrusión de estos diques carbonatíticos ha sido relacionada con el desarrollo de eventos magmáticos en la zona de la laguna de Chiva, que ha sido interpretada como la localización de los antiguos canales de alimentación de un centro eruptivo que desarrolló una morfología de maar. Los diques carbonatíticos de Chiva presentan una típica textura porfídica formada por fenocristales subhedrales de calcita tabular (60%), apatito (30%) y magnetita (10%) implantados en una matriz de calcita que también contiene otras fases minerales minoritarias como pirocloro, perovskita y kimzeyita. Las características mineralógicas de estos diques es similar a las descritas en las lavas carbonatíticas de la zona del graben de Catanda. Además, texturalmente la calcita es también parecida a la descrita en las lavas traquitoidales de Ipunda, en Catanda, interpretadas como antiguas natrocarbonatitas. Estas similitudes sugieren que el episodio volcánico de Chiva estaría relacionado con una actividad natrocarbonatítica y que sería contemporáneo al producido en el graben de Catanda.

Palabras clave: carbonatitas, natrocarbonatitas, maar, Angola, Catanda, Chiva

Abstract

In the vicinities of the Catanda graben (Angola) is localised a circular lagoon of 900 metres of diameter known as Chiva. Quaternary lacustrine sediments largely cover this area but a few dykes of carbonatitic composition have been found near the SE rim of the lagoon. The intrusion of these carbonatitic dykes have been related to the occurrence of recent magmatic events in this are and can be interpreted as the position of feeding channels of an eruptive centre in Chiva, which created a maar morphology. The Chiva carbonatitic dykes present a finely porphyritic texture formed by phenocrysts of subhedral calcite (60%), apatite (30%) and magnetite (10%) hosted in a calcite-rich groundmass that also contain minor phases such as pyrochlore, perovskite and kimzeyite. The mineralogical features of the Chiva dykes is similar to that described in the carbonatitic lavas from the Catanda graben. In addition, the texture of the Chiva calcite is like to that reported in the trachytoid lavas from Ipunda, in Catanda, those are interpreted as primary natrocarbonatites. These similitudes suggest that the volcanic event of Chiva would be related to a natrocarbonatitic activity contemporaneous to the Catanda graben volcanism.

Keywords: carbonatites, natrocarbonatites, maar, Angola, Catanda, Chiva

1. Introduction

The volcanic area of Catanda (Kwanza Sul, Angola) is formed by a group of small monogenetic volcanic buildings of carbonatitic composition that outcrop in a 50 km^2 graben hosted in Archean granites and delimited by the intersection of three different fault systems (Campeny et al., 2014). Catanda carbonatitic outcrops are largely eroded and covered by Quaternary colluvial and epiclastic sediments, which partly obscure the original morphology of the volcanic edifices. However, seven different eruptive centres were distinguished, associated with tuff ring and maar morphologies (Campeny et al., 2014).

The emplacement of the Catanda volcanic carbonatites is associated with the extensional domain of the Lucapa belt, which is a rift corridor defined by the NE-SW trend fractures of the Quilengues-Andulo fault system (Jelsma et al., 2009). First magmatic activity reported in the Lucapa corridor is from the Palaeoproterozoic (Sykes et al., 1978) but magmatism was also significantly important in the upper Cretaceous associated to the break-up of Gondwana and the corresponding opening of the South Atlantic Ocean (Moulin et al., 2010). Most of the Angolan carbonatites and kimberlites are distributed along Lucapa (Alberti et al., 1999) and emplaced during the Cretaceous magmatic event (Torró et al., 2011; Calvo et al., 2011a; Calvo et al., 2011b; Robles-Cruz et al., 2012). Silva and Pereira (1973) suggested a Cretaceous age for the Catanda carbonatitic volcanism, and Torquato and Amaral (1974) proposed also a Cretaceous age of 92 ±7 Ma based on the dating of a tinguaite dike present in the area. However, it was not clear that these felsic dikes and the carbonatites could be contemporaneous and Campeny et al. (in prep) have finally demonstrated a recent age for this magmatism based in detailed geochronological data.

During the study of satellite images of the Catanda volcanic area we localised a small circular lagoon in the Chiva area, which is located outside from the Catanda graben and slightly far from the main carbonatite outcrops. A field work carried out in the vicinities of this lagoon allowed us to distinguish carbonatitic dykes, thus indicating the possible relation of this area with the occurrence of the carbonatitic volcanism in Catanda (Campeny et al., 2014). The aim of this work is to provide new information about the carbonatitic materials reported in the Chiva eruptive centre and to discern if their formation is related with the carbonatitic volcanism of the Catanda region or it should be considered as an independent volcanic area.

2. Methods

The petrographic study of the carbonatitic rocks from the Chiva volcanic cone, is based in the identification of main rock-forming minerals and the description of textural features, has been carried out by the use of optical microscopy using transmitted and reflected light. Scanning Electron Microscope E-SEM was also used for more detailed analyses of mineralogical relationships and textures, using a Quanta200 FEI XTE 325/D8395BSE with a Genesis EDS microanalysis system from the Scientific and Technical Centres of the University of Barcelona (CCiTUB). The operating conditions of the SEM were 20-25 keV, 1 nA beam current and 10 mm of working distance from the sample to the detector, and detail images of the textural patterns were obtained in mode of back-scattered electrons (BSE).

3. Description of the carbonatite outcrops

The Chiva depressed region is approximately located 5 Km at the NE from the volcanic carbonatitic outcrops of the Catanda area (Fig.1). The Chiva lagoon forms a shallow depression of 900 metres in diameter occupying the centre of a plain, which is surrounded by a smooth relief ring elevated 5 metres in relation to the plain (Fig. 2a). The rounded lagoon of Chiva is considered the source of the N'Dula river.

The smooth reliefs and plains surrounding the lagoon are largely covered by alluvial and colluvial sediments and an intense agriculture is developed, thus totally obscuring the geology of the area. However, in the SE shore is possible to distinguish a few carbonatitic dykes; those form coherent bodies of 1.5 metres thick. The colour of the carbonatitic dykes is brownish in the weathered outcrops, and dark grey in fresh sample (Fig. 2b, 2c). The arrangement of these dykes is radially oriented from the centre of the lagoon.

4. Petrography

Carbonatitic dykes from the Chiva lagoon have a finely porphyritic texture with 20-25% phenocrysts and xenocrysts in a carbonate-rich aphanitic groundmass (Fig. 3a), which also contain a large number of vesicles.

4.1. Phenocrysts

The phenocrysts population is made up by apatite, calcite and magnetite. Apatite crystals are subhedral to euhedral, composed by prism and hexagonal bipyramid; they are shortly prismatic in habit and may achieve up to 0.3 mm in diameter, representing 40-50% modal of the total phenocrysts population. They are slightly zoned, with a rim enriched in the britholite component and, therefore, they are slightly brighter in SEM-BSE image (Fig. 3b). Calcite grains are subhedral, polycrystalline and present a very typical tabular habit being up to 0.25 mm in length. They can represent 30-40% modal of the phenocrysts (Fig. 3c). Magnetite forms euhedral octahedral grains, up to 0.4 mm in diameter and clearly zoned, presenting a pure magnetite rim (Fig. 3b and 3c).

4.2. Xenocrysts

Rounded and corroded olivine grains, up to 0.6 mm, and partly or completely replaced by serpentine minerals are common and may be interpreted as xenocrysts (Fig. 3d). In fact, olivine from the Catanda domain carbonatites has been interpreted as xenocrysts for a long time (Peres et al., 1968).

4.3. Groundmass

The main components of the groundmass are also calcite, apatite and magnetite, and the textural patterns are similar as above, but with a fine grain size (Fig. 4a). In addition, minor proportions of other accessory minerals such as pyrochlore and perovskite are noticeable. The grain size of these minerals is very tiny, less than 5 µm in size (Fig. 4a and 4b), and they are scattered in the groundmass or can appear as inclusions in magnetite. Both minerals develop euhedral to subhedral crystals, and zoning is not evident. Pyrochlore has only low contents in microlite and betafite components, but it is slightly enriched in Zr. It is depleted in Na and F. Nb content in perovskite is below the detection limit of EDS. More rarely, small subhedral grains of kimzeyite garnet, up to 2 µm in diameter, have also been noted.

4.4. Xenoliths

Phenitized xenoliths from the granitic host rocks are extremely rare. By the contrast, small (up to 1 cm in diameter) rounded xenoliths of plutonic carbonatites are more common. These xenoliths are made up by granular calcite grains.

4.5. Vesicular infilling

Vesicular porosity is irregular in size and distribution, but millimetre- to centimetre-sized amygdalae are rather common, and uses to be completely infilled by a supergene sequence of clay minerals, euhedral quartz and a late sparry calcite. Barite is also found in this association as tiny crystals, less than 2 mm in length, commonly included in groundmass calcite.

6. Discussion

Nowadays, the morphology of the Chiva lagoon area, which defines a circular depression, suggests its possible relation to volcanic activity and the occurrence of an old eruptive volcanic centre. However, the lack of good outcrops and systematic geological studies in the area makes difficult to establish the relation between its formation and the occurrence of volcanic events. Even so, we considered that the new find of carbonatitic dykes outcropping in the SE border of the lagoon proofs the development of magmatic events in the Chiva area.

Under our opinion, Chiva carbonatitic dykes are subvolcanic intrusive sheets associated to an old eruptive centre, in a similar relation as described in several volcanic areas of different composition worldwide (Gautneb & Guddmundsson, 1992; Geshi, 2005; Pasquarè & Tibaldi, 2007). These hypabissal intrusive sheets represent the magma path towards the surface (Corazzato et al., 2008) and considering its carbonatitic composition, we can conclude that magmatic events occurred in Chiva area were also carbonatitic and similar to those reported in the near Catanda graben (Campeny et al., 2014).

Textural and mineralogical patterns of the Chiva hypabissal rocks are also very similar to those described in the carbonatitic lavas from Catanda (Campeny et al., 2014; Campeny et al., 2015), agreeing with the fact that both localities are probably related. Comparing the carbonatitic subvolcanic products from Chiva and the carbonatitic lava flows from Catanda graben (Campeny et al., 2015) we conclude that they also present similar porphyritic textures and contain equivalent mineralogy. Calcite, apatite and magnetite are main phenocrysts in Chiva and Catanda lithologies and groundmass mineralogy is also similar, with accessory minerals such as pyrochlore or perovskite; those were also described in the lavas from the Catanda graben (Tab.1).

In addition, the Chiva dykes present trachytoid textures formed by tabular and polycrystalline crystals of calcite. Similar textures have been described in the Ipunda lavas from the Catanda graben, those have been considered as altered natrocarbonatites by Campeny et al. (2015). The tabular morphology of Chiva calcite suggests that these crystals could correspond in origin to nyerereite [$Na_2Ca(CO_3)_2$], an alkaline carbonate described in the recent natrocarbonatite lavas from the Oldoinyo Lengai volcano (Tanzania) (Dawson, 1962; Keller & Zaitsev, 2012). Nyerereite is extremely soluble in meteoric water (Zaitsev & Keller, 2006), and its alteration to calcium carbonates and the corresponding formation of tabular calcite pseudomorphs have been reported worldwide (Zaitsev et al., 2013).

Despite the morphology of the Chiva area is broadly eroded and covered by sediments and vegetation, is possible to distinguish that the old eruptive centre presented a negative relief in comparison to the surrounding area. It is in this part where is nowadays located the Chiva lagoon. From these observations, we consider that the Chiva eruptive centre was related to the occurrence of an old carbonatitic maar, which is a volcanic morphology also described in the Catanda graben (Campeny et al., 2014).

7. Conclusions

The main conclusions of our work can be summarized as follows.

1. Dykes of carbonatitic composition outcrop in the SE border of the Chiva lagoon area. They have been interpreted as hypabissal intrusive sheets related to the occurrence of volcanic activity in the area.

2. The texture and mineralogy of the Chiva dykes are similar to

that reported in the altered natrocarbonatitic lava flows from the Catanda area, suggesting that carbonatitic activity occurred in the Chiva area was also related to the emplacement of natrocarbonatitic melts.

3. Due to the proximity and the similitudes with the Catanda graben carbonatites, the volcanic activity from the Chiva area is considered as formed during the same magmatic event than the Catanda extrusive carbonatites. This fact suggests that the recent carbonatitic volcanic in Angola may have a broader extension than previously supposed.

4. The volcanism in the Chiva area was related to the occurrence of a sole eruptive centre that presented maar morphology, interpreted due to the rounded and depressed topography.

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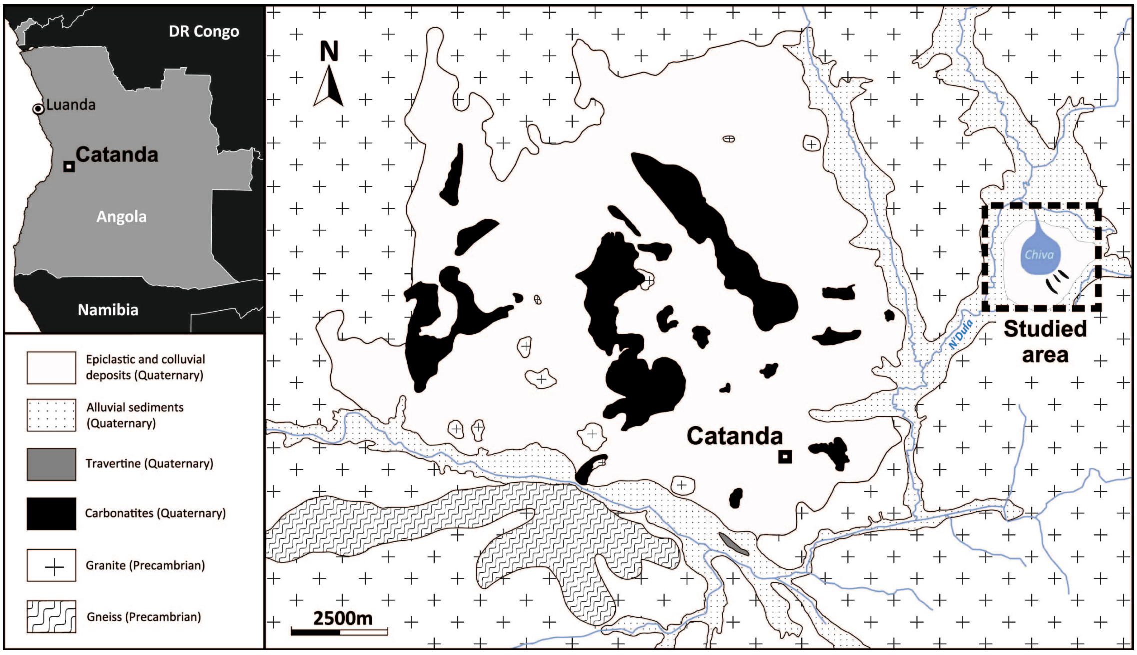

Fig. 1: Geological map of the Catanda graben and the near area of the Chiva lagoon.

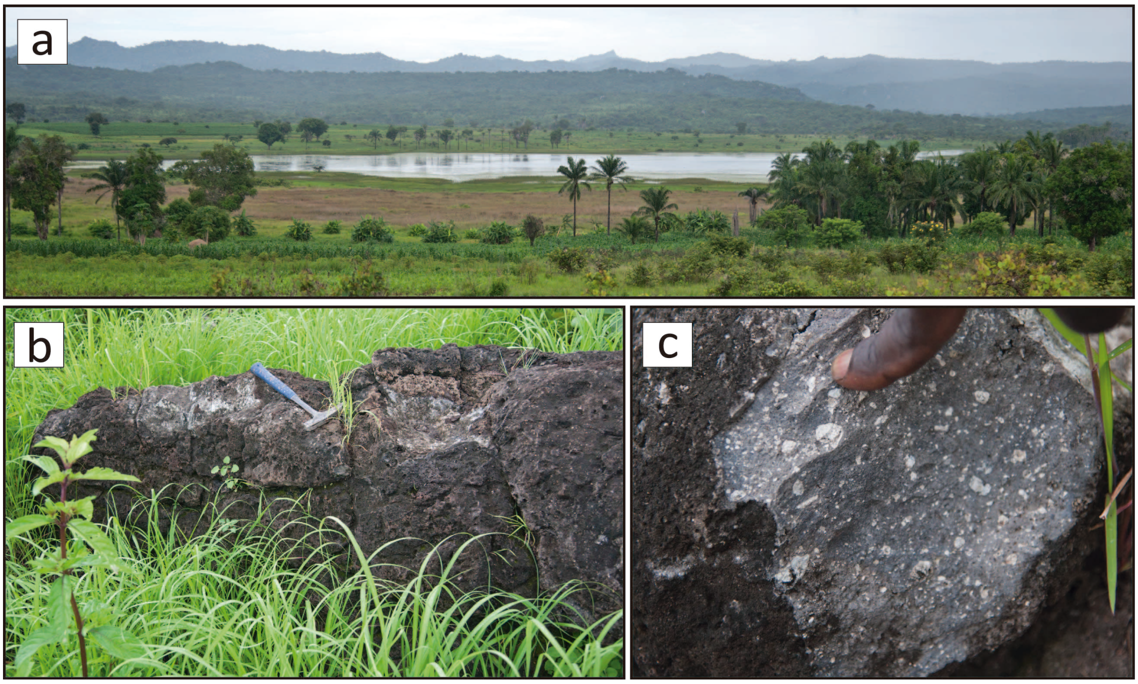

Fig. 2: **a** General view of the Chiva lagoon area. **b** Carbonatitic dyke outcropping in the SE shore of the lagoon. **c** Detail of a carbonatitic dyke in which is possible to distinguish a clear porphyritic texture.

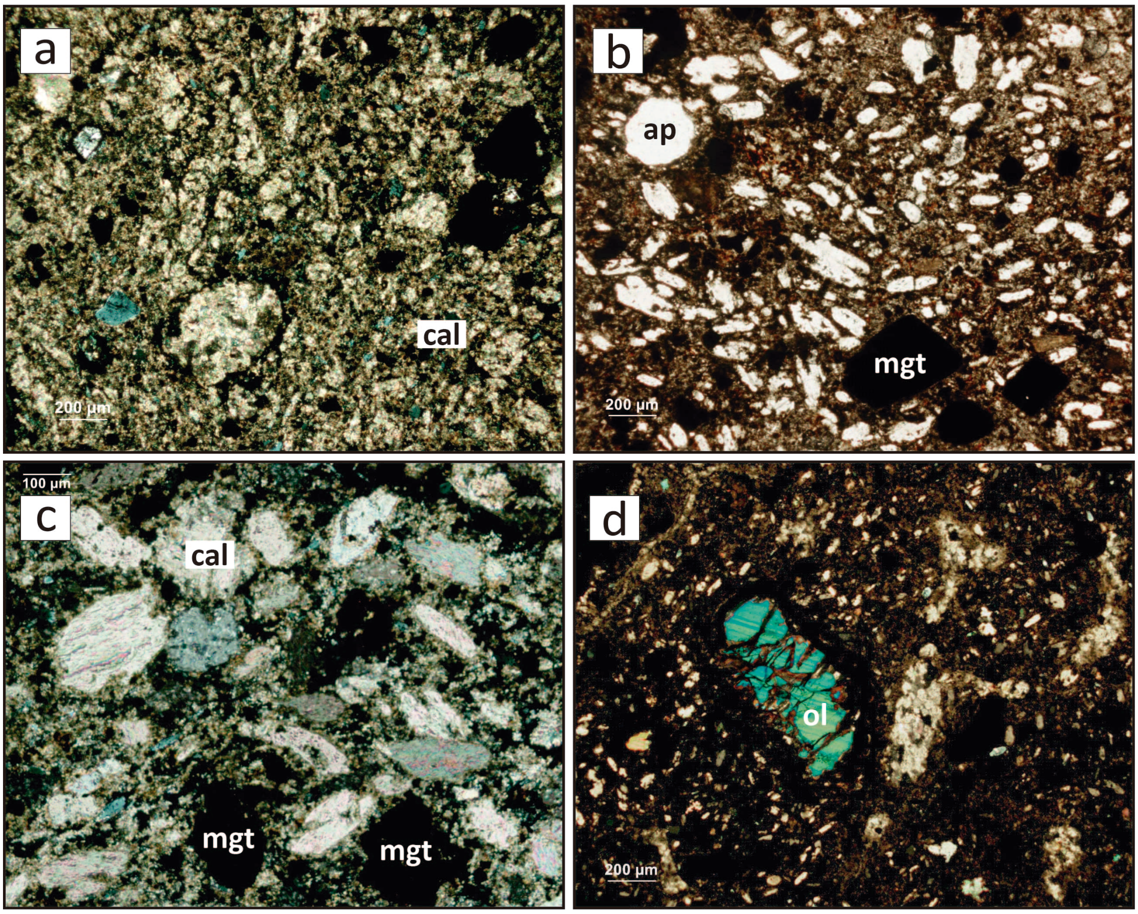

Fig. 3: Plane-polarized light photomicrographs of Chiva carbonatitic dykes. **a** General view of the carbonate-rich groundmass majorly formed by calcite (cal) and magnetite (mgt). **b** Apatite (ap) and magnetite (mgt) phenocrysts hosted in a carbonatite-rich groundmass. **c** Subhedral tabular and polycrystalline phenocrysts of calcite accompanied to magnetite (mgt). **d** Rounded xenocryst of olivine (ol) partially fractured and altered.

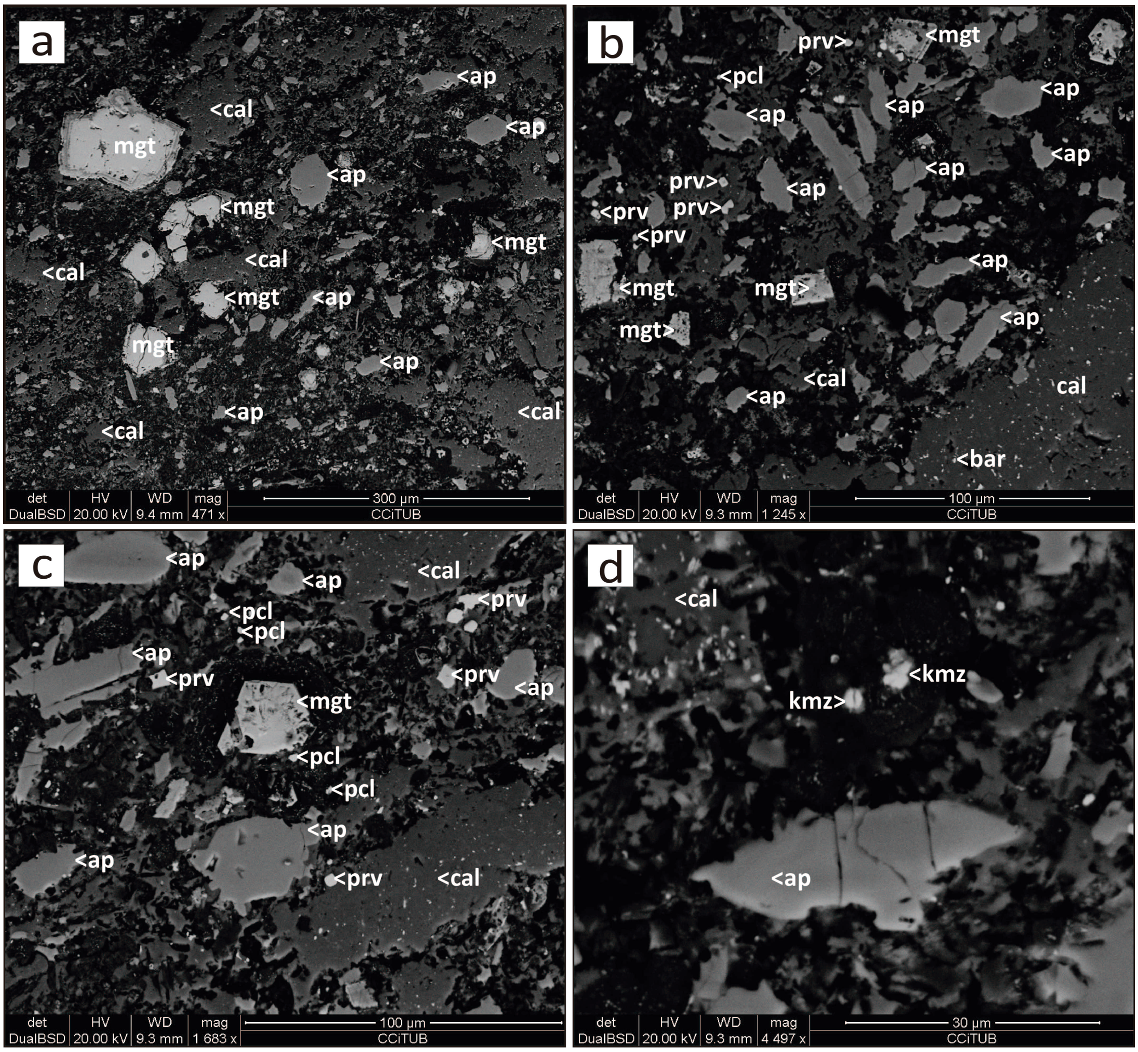

Fig. 4: Backscattered scanning electron microscope (SEM) images of the Chiva carbonatitic dykes samples. **a** General view of typical porphyritic texture with magnetite (mgt) and apatite (ap) microphenocrysts. **b** Apatite (ap) prismatic crystals accompanied by small grains of perovskite (prv) and magnetite (mgt), those are present in a calcite-rich (cal) groundmass, plenty of small inclusions of barite (bar). **c** Detail of the groundmass with pyrochlore (pcl), perovskite (prv) and microphenocrysts of apatite (ap), magnetite (mgt) and calcite (cal). **d** Subhedral grains of kimzeyite (kmz) associated to a calcite groundmass (cal) and a subhedral prismatic grain of apatite (ap).

Location	Texture	Lithology	Composition	Mineralogy
Huilala - Ungongué	Finely porphyritic	Lava	Aillikite	***Microphenocrysts:** fluorapatite (35%), titaniferous magnetite (35%), augite (15%), phlogopite (15%) ***Groundmass:** calcite, fluorapatite, magnetite, pyrochlore, baddeleyite, cuspidine, perovskite, periclase, brucite, zirconolite, spurrite, oldhamite ***Magmatic xenocrysts:** olivine, glimmerite
Jango	Finely porphyritic	Lava	Calciocarbonatite	***Phenocrysts:** fluorapatite (60%), magnetite (25%), phlogopite (10%), augite (5%) ***Groundmass:** calcite, fluorapatite, magnetite, pyrochlore, baddeleyite, monticellite ***Magmatic xenocrysts:** amphibole
Utihohala	Finely porphyritic	Lava	Calciocarbonatite	***Microphenocrysts:** fluorapatite (60%), magnetite (20%), phlogopite (15%), augite (5%) ***Groundmass:** calcite, fluorapatite, magnetite, pyrochlore, alabandite
Ipunda	Trachytoid	Lava	Altered Natrocarbonatite	***Microphenocrysts:** calcite (60%), fluorapatite (15%), magnetite (15%), phlogopite (5%), augite (5%) ***Groundmass:** calcite, fluorapatite, magnetite, pyrochlore, baddeleyite ***Magmatic xenocrysts:** glimmerite
Chiva lagoon	Finely porphyritic	Dyke	Calciocarbonatite	***Microphenocrysts:** calcite (60%), fluorapatite (30%), magnetite (10%) ***Groundmass:** calcite, fluorapatite, magnetite, pyrochlore, perovskite, kimzeyite ***Magmatic xenocrysts:** olivine

Table 1: Mineralogy comparison between the Catanda graben lavas and the carbonatitic dykes from the Chiva lagoon area.