

SHORT COMMUNICATIONS

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Kalsilite in Brazilian kamafugitic rocks

THIS paper describes the first known occurrence of kalsilite in Brazilian lavas and cognate sub-volcanic rocks. The presence of kalsilite in these rocks, chemically and petrographically close to the kamafugitic rocks of Toro-Ankole, SW Uganda, is additional evidence of similarities between the rocks of these two volcanic provinces.

Geological Setting

The general area of this study (nearly 450 km²) is situated in the western part of the state of Minas Gerais (southeastern Brazil), about 340 km from Belo Horizonte city, in the counties of Carmo do Paranaíba, Arapuá and Tiros (Fig. 1). In this area, the Mata da Corda formation consists of ultrabasic alkaline potassic to ultrapotassic lavas and volcanoclastic (mainly epiclastic) rocks. The total thickness of the rock sequence does not exceed 50 m. The lavas were dated by Hasui and Cordani (1968) at 80 Ma (late Cretaceous) by the ⁴⁰K/⁴⁰Ar whole-rock dating method. This formation overlies a non-volcanic sedimentary sequence—the Areado Formation (early Cretaceous), composed of conglomerates, mudstones and sandstones. The two formations constitute the San Franciscan basin, which rests on slightly metamorphosed Proterozoic basement rocks of the Bambuí Group. The lava crops out in the studied area as discontinuous small flows which are commonly highly weathered. Field observations show that this formation is composed largely of massive thin flows (individually not exceeding 0.5 m in thickness), sometimes overlain by, or interbedded with volcanoclastic rocks.

The samples of lavas and associated cumulate rock which were analysed in the present work (Table 1 and Fig. 2*a–d*) come from loose fragments and pebbles collected on the slopes and at the feet of hills where the corresponding altered rocks crop out (Fig. 1).

Petrography and Mineralogy

The lavas and sub-volcanic rocks of the Mata da Corda Formation are aphanitic to fine-grained phaneritic with porphyritic to seriate textures, and grain sizes <2.5 mm (mainly ~0.1 mm). In some rocks phlogopite plates sporadically reach 2.5 cm. Clinopyroxenes, perovskite and Ti-magnetite occur in all rocks. In addition, the following minerals may or may not be present: olivine, phlogopite, leucite, kalsilite, apatite, melilite, and glass. Four rock samples were chosen for the study of kalsilite (Table 1 and Fig. 2*a–d*); kalsilite is only represented by pseudomorphs in two (samples C and D).

Sample A (Fig. 2*a*) shows a porphyritic texture with phenocrysts and microphenocrysts of clinopyroxene, Fe–Ti oxides, apatite, and perovskite set in a very fine-grained groundmass composed of clinopyroxene, pseudomorphs after leucite, perovskite, Ti-magnetite, kalsilite, phlogopite and unidentified oxidized materials (probably originated from alteration of kalsilite or glass). Kalsilite occurs in very small anhedral grains (approximately 0.025 mm in the largest dimension), always fresh and clear, with occasional minute inclusions of Fe–Ti oxides or perovskite.

Sample B (Fig. 2*b*) exhibits an inequigranular (2.5–0.001 mm in size), locally cumulitic texture, with clinopyroxene, kalsilite, Ti-magnetite, perovskite, phlogopite, and apatite. The pyroxenes are oriented and form the main framework of the rock. Phlogopite occurs as large poikilitic flakes (*ca.* 2.5 mm long) with inclusions of all components of the rock (not shown in Fig. 2*b*). Kalsilite occurs as an intercumulus constituent, altered locally to unknown products, with an earthy appearance, displaying an orange brown colour, probably, due to the presence of iron in the mineral.

Sample C (Fig. 2*c*) presents an inequigranular, fine to medium-grained seriate texture with a few large crystals giving the rock a slightly porphyritic appearance. There is an orientation of

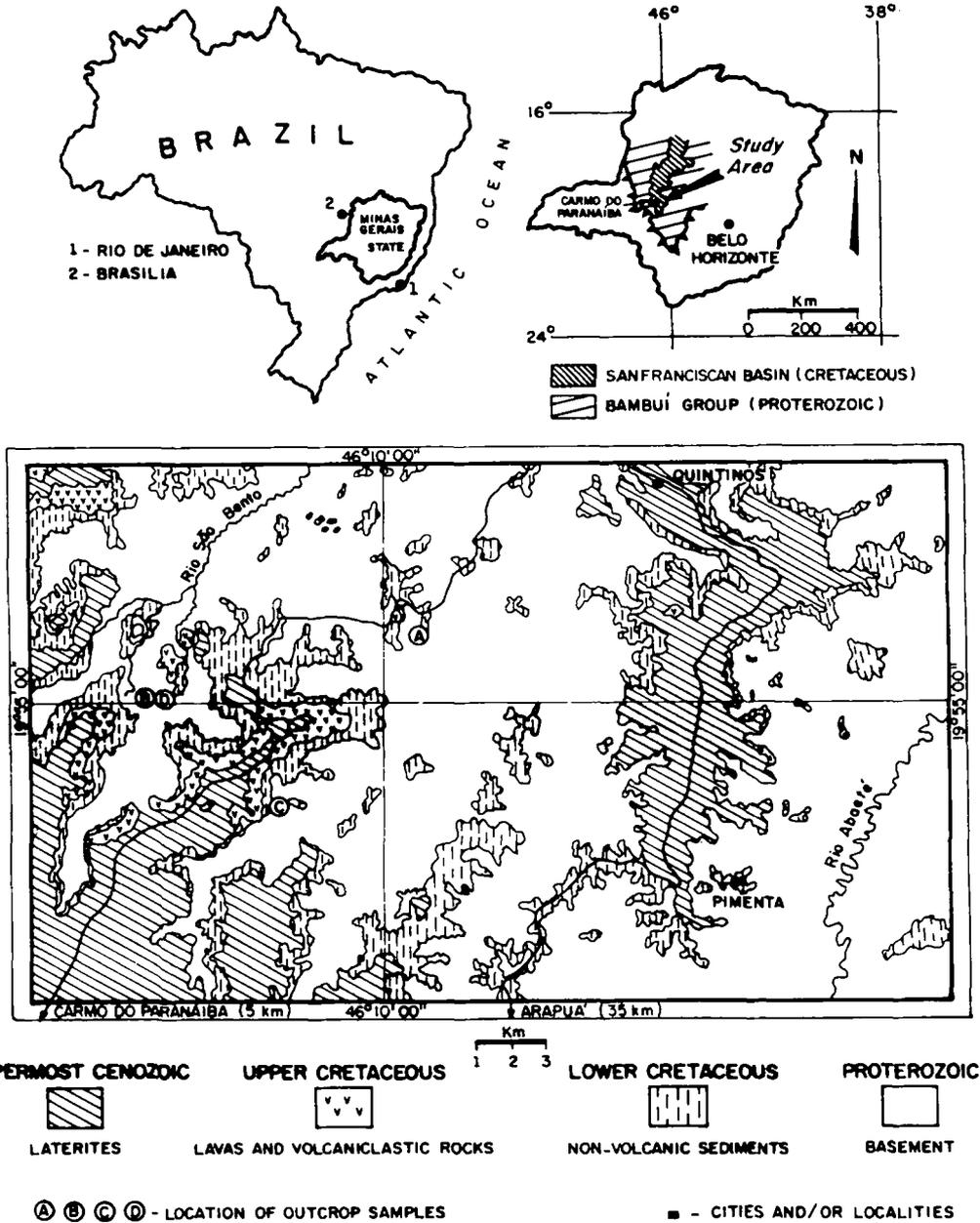


Fig. 1. Geology and locations of studied area and outcrops.

the clinopyroxene prisms defining a flow texture. The minerals included are clinopyroxene, leucite pseudomorphs, kalsilite (?) pseudomorphs, Timagnetite, phlogopite, perovskite, olivine and apatite. Kalsilite (?) occurs as euhedral, square, hexagonal and trapezoidal pseudomorphs, 0.1-

0.35 mm in size, totally replaced by zeolites (harmotome) containing oxidized material of an orange brown colour in the fractures.

A fourth sample (D, Fig. 2d) exhibits a porphyritic seriate texture and is intensely oxidized and altered. This rock is composed of a reddish

Table 1 - Estimated modal composition of kalsilite bearing rocks of Mata da Corda Formation, Minas Gerais, Brazil

	A	A*	B	C
Clinopyroxene	16	42	56	44
Black oxide ores	2	8	11	13
Perovskite	1	11	6	3
Olivine	-	-	-	<1
Phlogopite	1	-	6	4
Apatite	1	-	4	<1
Leucite	-	10 **	-	23 **
Kalsilite	-	8	17	13 **
Groundmass	79	-	-	-
Unidentified material	-	20	-	-

*: groundmass of sample A

**: unidentified pseudomorphous products

brown groundmass with birefringant colourless areas enclosing a large number of phenocrysts and microphenocrysts of clinopyroxene (<5.5 mm in size), kalsilite (?) pseudomorphs (<0.5 mm in size), Ti-magnetite and perovskite. The pseudomorphs are assumed to be kalsilite and not nepheline due to the presence of kalsilite in the rocks, which are predominantly potassic rather than sodic.

Chemistry

The chemical analyses of kalsilite-bearing rocks described above are shown in Table 2. Despite the fact that these rocks come from different places in the area and refer to lava flows (Samples A and C) and subvolcanic pyroxenite (Sample B) they have similar compositions, especially those represented by samples A and B. They are all ultrabasic in character, with high TiO₂, total iron, CaO, P₂O₅, moderate Al₂O₃, MgO, total alkalis, K₂O, and low BaO (samples A and B) and Na₂O. The observed chemical variations in sample C,

are probably due mainly to its higher degree of alteration. Compared to the other rocks, it is much higher in BaO, somewhat higher in SiO₂ and Fe₂O₃, and lower in FeO, CaO, K₂O, and P₂O₅. The microprobe data show that this Ba enrichment is very closely related to the high concentrations (10–20% BaO) of this element found in the products of alteration, which are pseudomorphous after kalsilite (sample C) as well as other minerals.

The chemical analyses of kalsilites found in the rock samples A and B are tabulated in Table 3. For comparison, chemical data on kalsilites from Uganda, Zaire, Italy and Mexico are also given in the same table. The Mata da Corda kalsilites, of both lava (sample A) and cognate subvolcanic pyroxenite (sample B), are very similar. On average, kalsilites of sample B possess somewhat higher SiO₂ and total Fe contents (as Fe₂O₃), and lower Na₂O and BaO contents than those of sample A. The significantly high Fe₂O₃ contents of the Mata da Corda kalsilites are similar to those of the mafurites of south west Uganda (Sahama, 1954) and Colima minettes (Allan and Carmi-

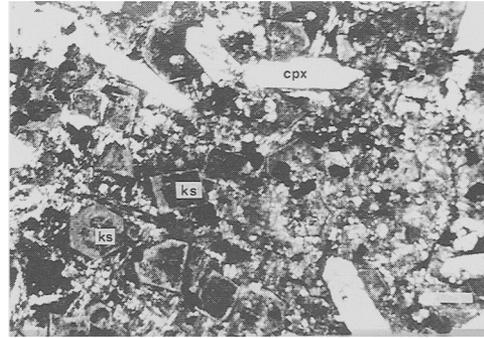
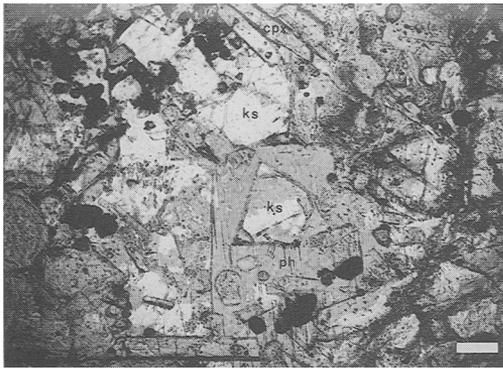
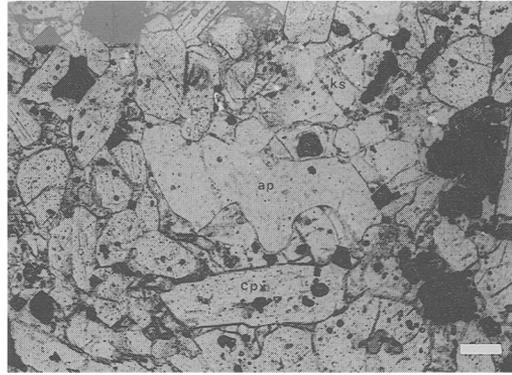
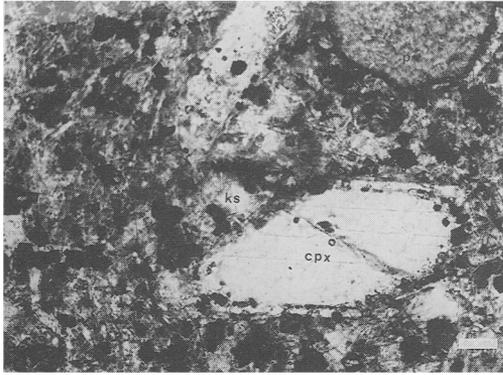


FIG. 2a (Top left) Photomicrograph of lava flow (sample A) from Mata da Corda Formation of Minas Gerais State, Brazil; ks: kalsilite; cpx: clinopyroxene; pv: perovskite. (scale bar 0.05 mm.) Fig. 2b (Top right) Photomicrograph of cognate sub-volcanic pyroxenite (sample B) from Mata da Corda Formation of Minas Gerais State, Brazil; ks: kalsilite; cpx: clinopyroxene; ap: apatite. (Scale bar 0.1 mm.) Fig. 2c (Bottom left) Photomicrograph of lava flow (sample C) from Mata da Corda Formation of Minas Gerais State, Brazil; ks: kalsilite; ph: phlogopite; cpx: clinopyroxene. (Scale bar 0.05 mm.) Fig. 2d. (Bottom right) Photomicrograph of lava flow (sample D) from Mata da Corda Formation of Minas Gerais State, Brazil; ks: kalsilite; cpx: clinopyroxene. (Scale bar 0.2 mm.)

chacl, 1984). The chemical composition does not permit a complete identification of the mineral as kalsilite or kaliophilite. Mineral separation was not made due to the fine grain size and whole-rock X-ray diffraction tests were not conclusive. The mineral is assumed to be kalsilite because it is the more stable form corresponding to the chemical composition.

Summary and conclusions

Kalsilite is reported for the first time in Brazilian rocks of the Mata da Corda Formation. In our study, fresh to totally altered kalsilite (pseudomorphs) is interstitially present as an anhedral mineral in the groundmass of porphyri-

tic lavas and in cumulate sub-volcanic rocks, or as euhedral to subhedral grains in the seriate rocks. These data indicate that in the K-rich Mata da Corda magmas although kalsilite has crystallized mainly as a late phase, the possibility that its formation has initiated as early as those of olivine, clinopyroxene, Ti-magnetite oxides and perovskite cannot be excluded entirely.

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Table 2 - Chemical analyses* of kalsilite bearing rocks
of Mata da Corda Formation, Minas Gerais, Brazil

wt%	A	B	C
SiO ₂	39.5	36.6	41.7
TiO ₂	5.9	6.8	5.5
Al ₂ O ₃	7.1	6.3	7.7
Fe ₂ O ₃	8.1	9.8	10.7
FeO	4.8	5.6	1.5
MnO	0.23	0.20	0.18
MgO	7.8	8.5	8.8
CaO	14.9	17.5	12.4
BaO	0.31	0.58	3.0
Na ₂ O	1.1	0.60	1.5
K ₂ O	3.0	4.6	1.9
P ₂ O ₅	1.3	1.7	0.53
L.O.I.	5.4	1.61	4.14
TOTALS	99.54	100.39	99.55

*: Analyses (X-RF spectroscopy and wet chemistry) by Geosol
Laboratory (Belo Horizonte, Minas Gerais State, Brazil)

A: porphyritic lava;

B: cumulitic cognate sub-volcanic pyroxenite;

C: seriate lava

Table 3 - Chemical analyses of kalsilites from Brazil, Uganda, Congo, Italy and Mexico

	1	2	3	4	5	6	7	8
SiO ₂	38.29	39.93	38.93	38.50	38.48	39.7	39.2	39.22
TiO ₂	0.10	0.10	0.24	0.09	0.05	0.04	0.05	-
Al ₂ O ₃	27.23	27.15	27.72	26.27	31.01	27.9	29.9	25.83
Fe ₂ O ₃	4.75‡	5.56‡	2.99‡	5.07	1.12	-	-	5.37
FeO	-	-	-	0.53	-	-	-	-
FeOt	-	-	-	-	-	2.72	2.24	-
Cr ₂ O ₃	-	0.04	0.06	-	-	-	-	-
MnO	0.01	0.04	0.11	0.02	0.01	-	-	-
MgO	0.52	0.40	0.48	0.87	-	0.70	0.21	-
CaO	0.07	-	0.13	0.44	0.03	0.16	0.08	0.15
Na ₂ O	0.14	0.08	0.54	2.07	0.30	0.09	1.38	1.27
BaO	1.54	1.17	-	-	-	-	-	0.16
K ₂ O	26.77	26.11	28.79	24.85	28.33	27.9	27.3	27.44
H ₂ O ⁺	-	-	-	1.04	-	-	-	-
H ₂ O ⁻	-	-	-	0.05	-	-	-	-
TOTALS	100.42	100.58	99.99	99.80	99.33	99.21	100.36	99.44

1 - Sample A from Mata da Corda Formation (average of 3 analyses)

2 - Sample B from Mata da Corda Formation (average of 2 analyses)

3 - Biotite-mafurite, south west Uganda (Edgar, 1979)

4 - Mafurite, south west Uganda (Sahama, 1954)

5 - Lava of Baruta crater, Nyiragongo area, Congo (Sahama et al., 1956)

6 - Lavas of Cuppaello, Central Italy (Gallo et al., 1984)

7 - Lavas of San Venanzo, Central Italy (Gallo et al., 1984)

8 - Lamprophyric lavas in Colima graben, SW Mexico (Allan and Carmichael, 1984)

‡: Total Fe as Fe₂O₃

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Trevorite in pyroxenite nodules from the Tokinsky Stanovik Mountains (ENE prolongation of Baikal rift zone)

TREVORITE, NiFe_2O_4 , is a well known meteoritic mineral (Schmidt and Keil, 1966). Terrestrially it has been found only in depleted ultrabasic rocks of the ophiolite complex of the Barberton greenstone belt in South Africa, Bon-Accord Fe-Ni deposits (De Waal, 1969, 1972; Tredoux *et al.*, 1989) and in a serpentinite massif in SW China (Houjan *et al.*, 1976). In iron meteorites, trevorite forms by the oxidation of Fe-Ni alloy; the terrestrial origin (Bon-Accord) resulted from the oxidation of spinel and general Ni-enrichment, resulting from heterogeneity of the Lower Mantle as it ascended to the Earth's surface as a result of convective processes.

This paper reports iron oxides with an anomalously high nickel content which were discovered in pyroxenite inclusions in the Quaternary alkaline basalts of the Tokinsky Stanovik Mountains (ENE prolongation of Baikal rift zone, Russia). The concentration of NiO in magnetite of these samples varies from 0.3 to 29.0 wt.%, which

exceeds the upper limit value of 0.2 wt.% given by Medvedev and Almuchamedov, 1990. It has been suggested that Ni-rich magnetites are inhomogeneous and represent a mixture of trevorite and iron oxides. In the microprobe investigation carried out, structural features showing unmixed solid solution structures were recognized (Fig. 1). The composition of the magnetite matrix (dark) and trevorite (light) are listed in Table 1. It is assumed, on account of the chemical composition, that the dark matrix is not solely magnetite, but a mixture of hematite with magnetite or hematite alone. Structural investigations were carried out and confirmed the presence of a member of the spinel group, trevorite ($a = 8.337 \pm 0.001 \text{ \AA}$), and hematite in the magnetic fraction of the pyroxenite sample. The X-ray-diffraction analyses were made with a diffractometer [Dron-3] Co-K α radiation; the results are listed in Table 2. Apparent variation in the nickel content of the magnetites is probably connected with