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Kamafugite volcanism in Brazil

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ABSTRACT. — In the Upper Cretaceous, a tectonic reactivation associated with extensive alkaline-ultramafic volcanism took place in the central-western plateau of Brazil. As a consequence of this diastrophism, the Brasilia Belt, an approximately N-S elongated structure, and two marginal depressions in both sides of the Belt, the southern Sanfranciscana Basin and the NNE border of the Paraná Basin, were formed. This magmatism constitutes the Minas Goiás Alkaline Province, located in Western Minas Gerais and Southern Goiás states. This paper describes the kamafugitic volcanic and volcaniclastic rocks of the province that occur in Mata da Corda and Santo Antônio da Barra areas.

The Cretaceous alkaline rocks of the province occur as lavas, pyroclastic rocks, volcaniclastic deposits, pipes, and plutonic complexes. Pipes and volcanic rocks from both areas are mostly kamafugites. Sr, Nd, Os, and Pb isotopic results indicate a lithospheric mantle derivation and the age data suggest that the magmatism is related to the Trindade plume activity.

The Mata da Corda and Santo Antônio da Barra kamafugites are mafurites and ugandites. The rocks are all feldspar-free, with abundant clinopyroxene and Ti-magnetite in very fine- to medium-grained porphyritic to seriated textures. These Brazilian kamafugites are all undersaturated in SiO_2, with high contents of CaO, FeOt and TiO_2, and relatively low MgO. Regarding the chemical features, a pattern of evolution promoted by fractional crystallization from mafurites toward ugandites is not totally apparent. However, if the possibility of this evolutionary connection is considered, it is most likely that olivine and clinopyroxene would be the major fractionated phases.

The volcaniclastic units occur discontinuously over an extensive area of the Minas Goiás Alkaline Province and are genetically related to a magmatic-tectono-sedimentary cycle that occurred in the region during the Upper Cretaceous.

The pyroclastic deposits of the province can be considered as being of hawaiian/strombolian type, forming small bodies around volcanic vents or diatremes. They are generally chemically altered to a large extent and consist of agglomerates, lapillites and tuffs.

The largest volume of volcaniclastic rocks present in the province consists of intensely altered epiclastic units that reflect continuous severe tropical weathering of the magmatic and pyroclastic units of the Minas Goiás Alkaline Province during the Tertiary and Quaternary periods. The detrital materials were transported and deposited by alluvial fans and torrential streams around the slopes of the region, forming sandstones and conglomerates, with diverse lithological contributions.

RIASSUNTO. — Nel Cretacico superiore una riattivazione tettonica distensiva associata con vulcanismo alcalino-ultrafemico avvenne nella porzione centro occidentale del plateau del Brasile. Come conseguenza di questo diastrofismo si formarono il Brasilia *Belt*, con sviluppo approssimativamente N-S, due depressioni marginali ad entrambi i lati della catena, il bacino di Santafranciscana a sud e il bordo NNE del Bacino del Paraná. Il magmatismo formò la Provincia Alcalina di Minas Goiás, che si trova tra gli stati di Minas Gerais Occidentale e Goiás meridionale. In

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questo contributo vengono descritte le rocce vulcaniche e vulcanoclastiche kamafugitiche di questa provincia che si trovano nelle aree di Mata da Corda e Santo Antônio da Barra.

Le rocce alcaline del Cretacico in questa provincia si rinvengono come lave, rocce piroclastiche, depositi vulcanoclastici, pipes, e complessi plutonici. Pipes e rocce vulcaniche in entrambe le aree sono prevalentemente kamafugiti. Gli isotopi di Sr, Nd, Os e Pb indicano che il magmatismo ha sorgente nel mantello litosferico e l'età è correlabile all'attività del plume di Trinidade.

Le kamafugiti di Mata da Corda e Santo Antônio da Barra sono mafuriti e uganditi. Queste rocce sono prive di feldspati, con abbondante clinopirosseno e Ti-magnetite e hanno granulometria da fine a media e tessitura da porfiritica a seriata. Queste kamafugiti brasiliane sono tutte sottosature in SiO_2, hanno alti contenuti di CaO, FeO_t, TiO_2 e sono povere di MgO. Considerando la loro geochimica, un evoluzione da mafuriti a uganditi non è del tutto evidente. Però se vi è la possibilità di questa connessione evolutiva, è molto probabile che olivina e clinopirosseno siano le fasi maggiormente frazionate.

Le unità vulcanoclastiche si rinvengono con discontinuità su una vasta area della Provincia alcalina di Minas Goiás e sono geneticamente correlate al ciclo tettonico-magmatico-sedimentario che avvenne nel Cretacico in questa regione.

I depositi piroclastici di questa provincia possono essere considerati prodotti da attività hawaiiana/stromboliana, e formano piccoli corpi intorno a bocche vulcaniche o diatremi. Generalmente sono chimicamente molto alterati e consistono di agglomerati, *lapillistones*, e tufi.

Il volume maggiore di rocce vulcanoclastiche in questa provincia è formato da unità epiclastiche fortemente alterate, e testimoniano l'azione del weathering tropicale che ha agito nella provincia alcalina di Minas Goiás durante il Terziario e il Quaternario. I materiali detritici furono trasportati da fiumi e torrenti e depositati lungo i versanti della regione formando sandstones e conglomerati mescolati con differenti tipi litologici.

KEY WORDS: *Upper Cretaceous, Brazilian Kamafugites; Brazilian volcaniclastic rocks; Minas-Goiás Alkaline Province; Potassic magmatism; Diamonds.*

GEOLOGICAL SETTING

The Upper Cretaceous Minas-Goiás Alkaline Province (Sgarbi and Gaspar, 2002) is a voluminous mafic potassic magmatic province, with an area of about 10^5 km^2, positioned between 15° 3' S – 20° 00´' S and 45° 30' W - 52° 00' W, in the central-eastern plateau of Brazil. Its volcanic and intrusive rocks and its related volcaniclastic associations were emplaced into three large tectonic structures, present in the western border of the Sao Francisco Craton: the NNE part of the Lower Cretaceous Paraná Basin; the meridional part of the Sanfranciscana Basin and the Brasília Belt, a Precambrian mobile belt elongated NNW-SSE that forms a cordillera positioned between the two above-mentioned basins (Fig. 1). The more voluminous eruptions of volcanic and pyroclastic rocks in the Minas-Goiás Alkaline Province took place in the southern Sanfranciscana Basin, being related to the Mata da Corda area. In the Santo Antônio da Barra area, NNE border of the Paraná Basin, similar occurrences are also related to the Upper Cretaceous (Fig. 1).

In the Brasília Belt region, Minas Gerais state, the plutonic complexes are carbonatite-bearing, containing additionally ultramafic rocks and phlogopitites. In the Iporá region, Goiás state, carbonatite is absent from the plutonic complexes and the typical rock association include dunites, peridotites, pyroxenites, gabbros, and syenites (Gaspar *et al.* 2000). Pipes and volcanic rocks from both areas are mostly kamafugites. Kimberlite pipes are much less abundant and, when mineralized, they are usually not economic. One exception is the São Roque Diamond Pilot Plant (~ 46°00' W and 20°30' S) near the town of Pium-i, where diamonds were economically recovered from a kimberlite in 1999. Parental magmas, that originated the carbonatite complexes, were also potassium-rich and certainly related to the general potassic magmatism where the complexes occur (Gaspar *et al.* 2000). The Sr, Nd, Os, and Pb isotopic results indicate a lithospheric mantle derivation (Araújo *et al.*, 2001; Bizzi *et al.*, 1995; Carlson *et al.*, 1996; Gibson *et al.*, 1995). The age data suggest that the magmatism is related to the Trindade plume

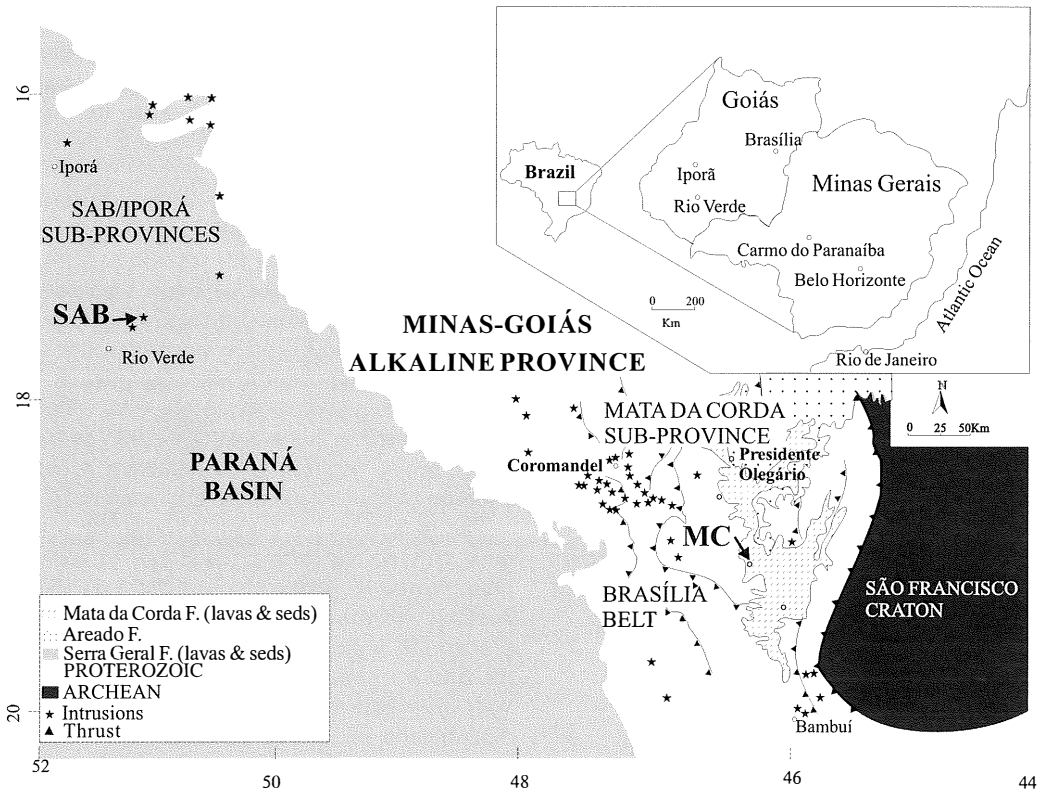

Fig. 1 – Location map of Mata daCorda and Santo Antonio da Barra areas with major geological features (modified from Gibson *et al.*, 1995).

activity (Sgarbi *et al.*, 2000a). However, in the San Fransicana Basin, sedimentological field evidence indicates a genesis related to an aborted intra-continental rifting (Moraes *et al.* 1986, Fleischer 1998, Sgarbi *et al.* 2001). The age of the magmatism of this Province is in the range of 80-90 My (Hasui and Cordani 1968, Gibson *et al.* 1994).

The Mata da Corda Group is constituted by the Patos and Capacete formations (Grossi Sad *et al.*, 1971). The Patos Formation represents the basal portion of the Group, being part of the alkaline-ultramafic volcanism of the Minas-Goiás Alkaline Province, which includes volcanic and sub-volcanic kamafugites (Sgarbi and Valença 1995, Sgarbi *et al.*, 2000b).

The Capacete Formation reaches 130 m of maximum thickness and is formed by volcaniclastic rocks in the sense of Fischer (1961), exhibiting epiclastic, pyroclastic and agglomerate units (Sgarbi *et al.* 1998a, Sgarbi *et al.* 2001).

Normally, the Capacete Formation is modified by weathering, forming a kind of *soapstone*, a soft, reddish ferruginous rock with argillaceous texture. In this case it is common to see relict forms of the original volcanic clasts, rounded as kaolinized white balls. The top of these occurrences is always covered by ferruginous laterites that can reach a thickness of 20 m.

In the Santo Antônio da Barra area, Paraná Basin, the epiclastic rocks belong to the Verdinho Formation. The rocks exhibit the

same lithotypes and show similar depositional systems of those of the Capacete Formation of the Sanfranciscana Basin, the two sequences being chronologically correlated. The Santo Antônio Formation is composed of kamafugitic lavas, breccias, and pipes and rare phonolitic subvolcanic occurrences.

In the Paraná Basin the volcaniclastic rocks overlie the São Bento Group, which comprises interlayered eolian deposits (Botucatu Formation) and flood basalt (Serra Geral Formation). The epiclastic fraction is the more voluminous sequence, being mainly represented by sandstone with rare conglomerate levels, and by mudstone deposited in the alluvial plain of the fluvial meandering system. In the Brasilia Belt region the epiclastic materials were deposited in alluvial fans, as high viscosity mud flows filling depressions in the Precambrian basement.

MAGMATIC DEPOSITS

The Mata da Corda kamafugites (Patos Formation) occur as lavas and pipes associated with minor auto-breccias. The lavas form centimetric to decimetric flows, frequently superposed. The total thickness can exceptionally reach values of up to 40 metres. Generally, the rocks are intensely altered, showing evidences of fluid percolation that give a brecciated aspect to the lava. Auto-breccia levels can be observed, either inter-bedded or superposed to the flows. Locally, these levels, up to 0.5 m thick, show reworked features, such as stratification, probably due to wind action.

The Santo Antônio da Barra kamafugites occur as an alternating sequence of lavas and breccias (Santo Antônio Formation) cut by many kamafugitic and rare phonolitic dikes. Volcaniclastic deposits (Verdinho Formation) are superposed to the Santo Antônio Formation (Sgarbi and Gaspar, 2002).

The Brazilian kamafugites are dominantly mafurites (clinopyroxene + kalsilite) and ugandites (clinopyroxene + leucite). Their classification as mafurites and ugandites is based on the mineral assemblage, following Holmes (1950), although the ugandite described in type-areas of Bufumbira and Toro-Ankole has a much more primitive composition. Besides the abundant clinopyroxene, feldspathoids and Ti-magnetite, Mata da Corda kamafugites contain perovskite, which in Santo Antônio da Barra kamafugites is accessory or absent. Interstitial material is always present and is often intensely altered to zeolites and clay minerals. Kalsilite is the dominant original interstitial phase in Mata da Corda mafurites, but in Santo Antônio da Barra kamafugites, nepheline and analcime occur in addition to kalsilite, as interstitial material.

The mafurites are porphyritic aphanites of dark grey colour with phenocrysts of olivine, clinopyroxene, perovskite (in Mata da Corda rocks), Ti-magnetite, and more rarely, phlogopite, melilite, and apatite. Santo Antônio da Barra ugandites present wide textural variation due to the variable amount and distribution of leucite phenocrysts. Mata da Corda ugandites are fine-grained phanerites and aphanites. The Brazilian ugandites are similar to the mafurites, with the exception that they contain leucite as the major felsic phase. In Santo Antônio da Barra ugandites, most leucite pseudomorphs are constituted by analcime while in Mata da Corda ugandites these pseudomorphs are formed by Ba-feldspar and when more altered, clay minerals. The mafurites are much richer in olivine phenocrysts than the ugandites while the ugandites are much more feldspathoid-rich.

The olivine of the Brazilian kamafugites is forsterite with mg# higher then 83. The pyroxene is diopside (average of 49% Wo; 43% En; 8% Fs) with variable alumina and titanium contents (Sgarbi *et al.*, 2000c). The mica is always phlogopite. Santo Antônio da Barra phlogopites have high BaO content (average of 7 wt.%); in Mata da Corda phlogopites the BaO contents are lower than 2.5 wt.%. Kalsilite and leucite are the main feldspathoids present in mafurites and

ugandites respectively. Kalsilite from Mata da Corda kamafugites (Sgarbi and Valença, 1993) is richer in Fe_2O_3 when compared to Santo Antônio da Barra kalsilite. In Santo Antônio da Barra and Mata da Corda ugandites, leucite is almost totally replaced by secondary minerals, although relicts of unaltered leucite crystals were identified in one of the ugandites studied. The spinels in Santo Antônio da Barra and Mata da Corda kamafugites consist, mainly, of ulvospinel and magnetite end member components. In Santo Antônio da Barra mafurites an important presence of ferro-chromite end member in spinel phenocrysts is noticed, specially in those that form inclusions in olivine (4.0-8.5 wt.% of Cr_2O_3). The perovskites in Brazilian kamafugites are very close to stoichiometric ($CaTiO_3$), with relatively low contents of REE and Na and practically no Sr.

The Brazilian kamafugites have the compositions showed in table 1. The rocks are SiO_2-subsaturated, have high contents of CaO, FeOt and TiO_2, and relatively low MgO, when compared to other ultrabasic rocks.

The rocks are alkaline, although the alkali contents do not represent the primary compositions of the related magma, as leucite and some kalsilite were substituted by secondary phases in Santo Antônio da Barra and Mata da Corda kamafugites.

Kamafugites are characterized by marked enrichment in incompatible and LIL elements together with other typical mafic contents.

The MgO content of mafurites is higher due to the larger amounts of olivine in these rocks. Generally, mafurites are poorer in Al_2O_3 and richer in MgO when compared to ugandites. SiO_2, FeOt and CaO contents are similar in both groups and TiO_2 contents are higher in Mata da Corda kamafugites. In Mata da Corda mafurites olivine fractionation is very clear as MgO in these rocks changes from 10 to 18 wt.%. TiO_2 shows a negative correlation to MgO in Mata da Corda mafurites; whereas Al_2O_3, FeOt and SiO_2 are all unchanged by falling MgO in Mata da Corda and Santo Antônio da Barra mafurites. CaO shows a not very clear negative correlation to MgO in mafurites.

The concentrations of compatible trace elements (Cr, Ni and Co) increase while those of incompatible elements (Zr, Y and Sr, except for Mata da Corda mafurites) decrease, with MgO. In mafurites, Cr follows Mg, as most of Cr-spinel is included in olivine.

Regarding the chemical features discussed above, a pattern of evolution promoted by fractional crystallization from mafurites toward ugandites is not totally apparent. However, if the possibility of this evolutionary connection is considered, it is likely that olivine and clinopyroxene would be the major fractionated phases.

The mineralogical and chemical data for the Brazilian kamafugites indicate that these rocks are well classified. The diagrams proposed by Sahama (1974) to separate kamafugites from lamproites, based uniquely on major chemical features are still up to date and show that the kamafugites (Fig. 2) are more subsaturated in SiO_2 and richer in calcium and iron when compared to lamproites.

It is clear that the Brazilian mafurites are more primitive than ugandites, although it is not possible to be sure that they are cogenetic. More data on these rocks should clear this question in the future.

Up to now, no extrusive carbonatite has been found in association with the Brazilian kamafugites, although this possibility should not be excluded. The carbonatites described in Italy associated to the Italian kamafugites (Stoppa and Woolley, 1997; Stoppa and Cundari, 1998) are largely pyroclastic. The pyroclastic phase of the Brazilian kamafugitic magmatism is, in most cases, intensely altered (Sgarbi *et al.*, 2001) making it difficult to identify its exact nature. Gaspar (1977) described a carbonate-rich lava associated to Santo Antônio da Barra kamafugites, and classified it as carbonatitic lava. This hypothesis was reevaluated years later in a new visit to the outcrop (Sgarbi *et al.*, 1998). The lava is badly altered and was reinterpreted as being a kamafugitic lava rich in amygdules that

TABLE 1

Chemical composition ranges of Brazilian kamafugites

wt.%	SAB mafurites	SAB ugandites	MC mafurites	MC ugandites
SiO_2	39.9 to 43.1	41.90 to 43.20	37.5 to 39.2	44.4 to 44.9
TiO_2	2.80 to 3.70	3.50 to 4.10	4.1 to 7.7	4.7 to 5.6
Al_2O_3	7.40 to 8.50	10.50 to 11.80	4.9 to 6.4	7.0 to 9.4
Fe_2O_3	6.10 to 7.60	7.00 to 8.30	4.2 to 4.4	3.5 to 3.8
FeO	4.20 to 6.30	4.10 to 5.90	8.7 to 9.3	7.3 to 8.0
MnO	0.19 to 0.22	0.22 to 0.24	0.14 to 0.23	0.21 to 0.24
MgO	12.60 to 15.20	5.6 to 8.5	9.7 to 18.0	6.0 to 8.4
CaO	11.50 to 14.90	12.20 to 12.50	10.4 to 16.1	8.0 to 9.8
Na_2O	1.0 to 2.20	2.70 to 4.30	0.4 to 0.9	0,7 to 2.0
K_2O	0.47 to 4.10	1.20 to 2.90	1.2 to 1.7	4.3 to 6.8
P_2O_5	0.45 to 0.62	0.77 to 0.88	0.8 to 1.7	0.6 tp 1.1
LOI	0.69 to 2.90	1.01 to 3.76	4.0 to 6.2	2.2 to 6.2
ppm				
Ba	888 to 1721	1480 to 1590	1791 to 9853	10748 to 19705
Rb	36 to 126	44 to 183	77 to 160	72 to 400
Sr	741 to 949	987 to 1445	1330 to 2900	1570 to 1870
Zr	232 to 283	350 to 430	94 to 900	450 to 1200
Ni	196 to 353	55 to 94	50 to 730	76 to 174
Cr	650 to 1163	109 to 328	80 to 930	38 to 180
Nb	84 to 190	114 to 130	240 to 290	260 to300
Y	14 to 19	23 to 27	62 to 82	66 to 70
Co	40 to 56	22 to 30	56 to 80	44 to 57
La	55 to 103	95 to 113	214 to 340	151 to 226
Ce	130 to 231	198 to 253	375 to 587	270 to 383
Nd	56 to 98	73 to 119	169 to 258	121 to 156
Sm	7 to 12	9 to 15	23 to 37	17 to 23
Eu	2 to 3	2 to 4	5 to 8	4 to 5
Gd	4 to 5	5 to 8	14 to 22	11 to 15
Dy	2 to 3	3 to 8	6 to 10	6 to7
Ho	0 to 1	0 to 1	1 to 2	1
Er	1	1 to 2	3 to 4	3
Yb	0 to 1	0 to 1	1 to 2	1 to2
Lu	0	0	0	0

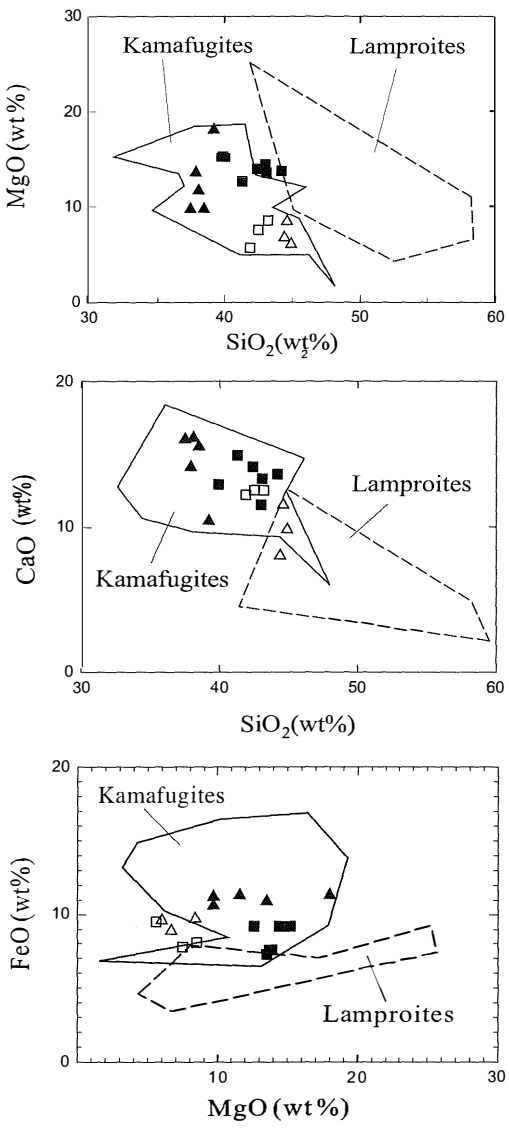

Fig. 2 – Classification diagrams for mafic potassic volcanic rocks proposed by Sahama (1974). Kamafugitic fields include data of Amorinópolis (Danni & Gaspar, 1994), Toro-Ankole (Lloyd *et al.*, 1991,analysis 7-16) and San Venanzo- Cupaello (Gallo *et al.*, 1984; Stoppa & Lavecchia, 1992). Lamproitic fields based on Michel & Bergman (1991) data. Filled symbols = mafurites; open symbols = ugandites. S. Antonio da Barra = squares, Mata da Corda =triangles.

were filled up with secondary carbonate. The Italian carbonatites open new horizons for the carbonate-rich rocks associated to the Brazilian kamafugites and new research should be done with the object of finding new indications of extrusive carbonatite activity in this province.

PYROCLASTIC DEPOSITS

The juvenile components are too altered to permit drawing a conclusion for the genesis of the pyroclastic unit. However, on the basis of their present areal extent and the energy grade of the explosive activities, the pyroclastic deposits of the Minas-Goiás Alkaline Province, can be characterised as hawaiian/strombolian type (Walker 1973). The individual tabular, layers and cone building bodies reach less than 1000 km^2, and the occurrence of fine-grained tuffs is extremely restricted in the province. However, there is a strong possibility that large amounts of pyroclastic rocks - and lavas- have been removed by erosion and incorporated as volcanic detritus in the volumetrically enormous epiclastic unit of the Capacete and Verdinho Formations, during the Tertiary. The pyroclastic deposits can be summarized as follow:

Agglomerates: These occur as small volumes of coarse bodies around some volcanic vents. They can reach 1m of maximum thickness and are monolithologic, massive and generally show a matrix formed by tuff and fine-graded lapillite. Fragments from granule to cobble-size are well-rounded, fluidally shaped and represent the most proximal caldera facies. Because of their low preservation potential, this facies occurs in very restricted areas in the region and is a good indicator of the vertical erosion level of the related volcanic structures.

Lapillistones and Tuffs: The lapillistones are representative of proximal facies of volcanic vents. They are generally clast-supported, poorly sorted and homogeneous in constitution (monolithologic) and form deposits that, exceptionally, can reach a few metres in thickness. Individual flow units can be reversely or normally graded. These deposits do not exhibit any evidence of transportation

by water, and the rounded shape of their clasts is probably related to the mutual friction inside the volcanic conduit during the vertical movement of the materials, and were explosively ejected forming fall deposits. These deposits are generally tilted (20°-30°) and individual levels can show a concentration of the larger clasts at the base at the slopes, moved by gravitational rolling. These occurrences are geometrically very similar to some lapillitic deposits of San Venanzo, Central Italy (Stoppa and Sforna, 1995). In the Presidente Olegário region, Mata da Corda area, the good exposure of the association of volcanic and pyroclastic products has allowed identification of two different facies. The first is related to stratified, sub-horizontal fall deposits of tuffs with intercalated lapillitic layers and small agglomerate levels, reaching 7-10 m in total thickness. The tuff layers are typically 30-60 cm thick and are composed by rounded volcanic fragments 0.5-2 cm in diameter. The second facies is represented by a magmatic hypabyssal intrusion, which cross-cuts vertically the silicoclastic eolian sandstone of the Lower Cretaceous Areado Group and the pyroclastic deposits. Around the main volcanic structure, the layers of the eolian sandstones are inclined to a vertical position and show metric apophyses of the magmatic body between the layers.

The actuation of subaqueous epiclastic processes can re-deposit lapillites and tuffs to form thin layers of turbidite bodies reaching maximum of 20 cm in thickness, deposited in ephemeral lakes near the calderas. The combined influences of pyroclastic and epiclastic processes permit the use of the term tuffite for their products.

EPICLASTIC DEPOSITS

The epiclastic units form the largest volume of volcaniclastic rocks of the Minas-Goiás Alkaline Province and this fact is due to the severe, sub-tropical weathering that affected the magmatic and pyroclastic rocks of the region and their subsequent erosion. The fragments were transported away from the Brasilia Belt, mainly by alluvial fans and torrential streams. They form conglomerates with a clay or lithic sand matrix supporting volcanic clasts or clast supported conglomerates. The boulders present are commonly rounded and this fact is not related to the transport but with the previous spheroidal weathering processes in the source areas, before the transport. Minor amounts of metamorphic and sedimentary clasts from the basement and the host rocks are also found. The matrix has a volcanic origin, always showing low chemical and mineralogical maturity grades. The sandy matrix is rich in volcanic lithics, magnetite, phlogopite and clinopyroxene crystals besides well-rounded quartz and microcline originated from the eolian substrate. The clay matrix is normally ferruginous and/or manganesian, rich in clay minerals such as smectite or kaolinite. Away from the slopes, in the more distal portions of the alluvial deposits, fluvial gravels and sands can occur, deposited by braided rivers.

At the basal portion, the epiclastic occurrences show fresh or low-grade altered black and green volcanic clasts, presenting a metric level of matrix-supported conglomerate with the clasts floating in the volcanic sandy matrix, locally cemented by authigenic Ca-carbonate. Toward the top these rudites show intercalations of lavas, tuffs, and lithic sandstones, besides other volcaniclastic rudite levels, including breccias. The scenario is suggestive of the occurrence of rhythmical volcanism with intercalated periods of erosion, during which the epiclastic products were formed.

The matrix-supported conglomeratic portion that is present occurs predominantly in the base and in the top of the sequence. Its basal levels are generally green and show a sandstone matrix formed also by volcanic, rounded fragments of sand-size locally cemented by Ca-carbonate. The large fragments of the rock framework can reach 30 cm in size and are formed by alkaline rocks, together with minor amounts of metamorphic, acid igneous and

sedimentary rocks of the substrate and of the regional basement. The clast supported conglomerates are locally overlaid by tabular bodies of epiclastic siltstones and sandstones. In the top of the sequence these rudites are commonly altered to iron oxides and the relicts of volcanic clasts appear as white kaolinized balls, covered by a hard crust of ferruginous laterite.

The epiclastic Verdinho sequence is mainly represented by poorly sorted conglomerates with well rounded pebbles and a tuffaceous matrix with carbonate cement. Tuffaceous sandstone levels are interbedded in the conglomerate.

In the Brasília Belt region the epiclastic materials were deposited in alluvial fans as high viscosity mud flows filling depressions in the Precambrian mica-schist and quartzite substrate, along an erosive and angular unconformity or also filling topographic irregularities of the Upper Jurassic-Lower Creta ceous Botucatu Formation sandstones along an erosive discordance.

The end of the Cretaceous was coincident with the end of the volcaniclastic sedimentation in the Minas-Goiás Alkaline Province. In the Tertiary the region was uplifted and nowadays the volcanic and volcaniclastic sequences are located between 950 and 1150 metres above sea level.

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