Chapter 8

The Pântano Intrusion

By

H.O. A. Meyer[1]; *B.L. Garwood*[1] *& D.P. Svisero*[2]

INTRODUCTION

The Pântano ultrabasic alkaline intrusion occurs approximately 43 km east of Coromandel, and 32 km west north-west of Patos, Minas Gerais (18°35'S, 46°50'W)(Fig 1.). It is about 15 ha in size (700 m x 250 m) and has a sigmoidal shape (Fig. 2). The center of the body forms a small knoll about 25 m high relative to the elevation of the margin. All outcrops of fresh rock occur on the eastern half of the intrusion. The dark colored igneous rock which makes up the intrusion was emplaced into green colored schists of the Proterozoic Canastra group. This group plus the Bambui, Ibiá and Araxá groups constitute the Proterozoic supracrustals which together with Archaen rocks, mostly granites and granitic gneisses, form part of the Alto Paranaíba arch. This is a narrow NW-SE trending strip of Precambrian rock which separates the Phanerozoic sediments and basalts of the Paraná basin in the west from those of the São Francisco basin to the east.

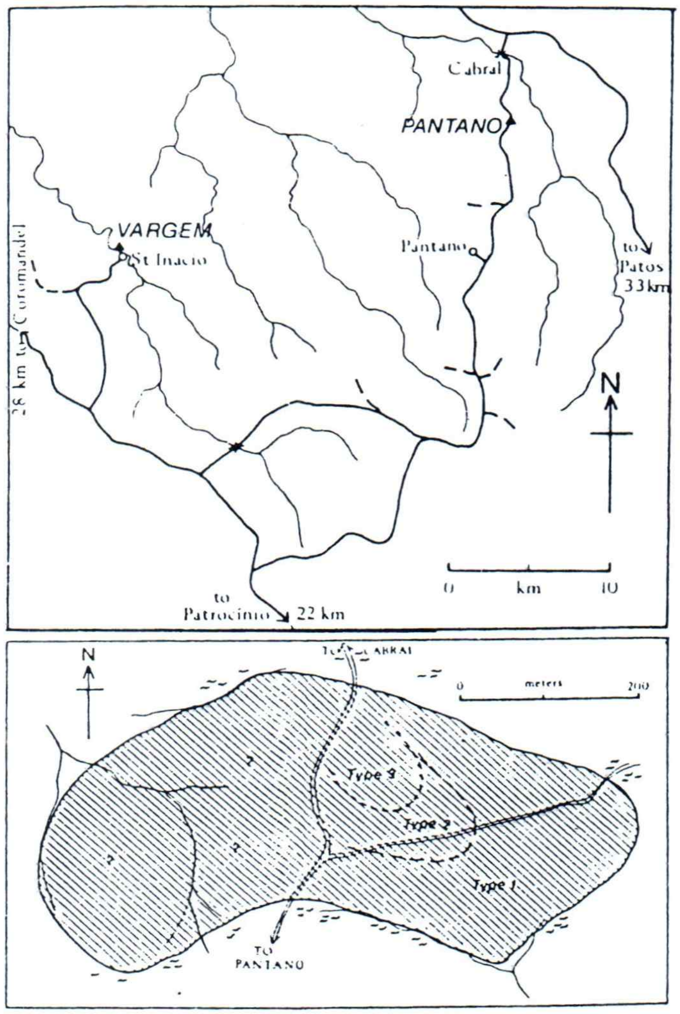

Figure 1

PETROGRAPHY

Texturally the rock is a hypabyssal-facies, macrocrystic to segregationary intrusive rock. It consists of abundant anhedral to euhedral olivine macrocrysts (0.5 - 1.25 mm) and macrocrysts of phlogopite in a fine-grained groundmass of microphenocrystal olivine, phlogopite, monticellite, diopside, perovskite, apatite, spinel and ocelli of altered devitrified glass; serpentine and calcite are also present.

Three distinct petrographic types have been recognized and occur in a somewhat zonal arrangement in the intrusion (Fig. 2):

(1) Dept. Earth and Atmos. Sci., Purdue University, West Lafayette, IN 47907, USA
(2) Instituto de Geociências, Universidade de São Paulo, São Paulo, Brasil

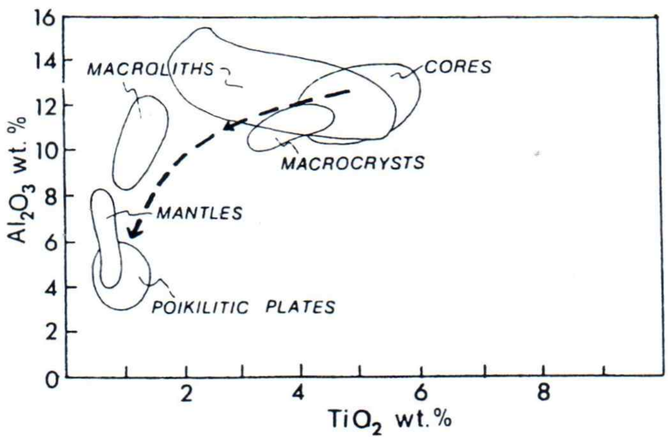

Figure 2

1. The first type is characterized by monticellite being the dominant groundmass phase. Phlogopite occurs either as small (< 0.4 mm) laths with dark cores and colorless mantles, or as small (< 0.01 mm) plates.

2. The second petrographic type is characterized by the presence of plates of mica and abundant globular ocelli.The mica poikilitically encloses the groundmass phases, olivine, monticellite, perovskite and spinel. The ocelli consist of glass with 10 micron size devitrification spherules.

3. In the matrix of the third type, small crystals (< 0.5 mm) of diopside dominate over monticellite, and a fleshy tan colored perovskite is abundant in contrast to a rare orange-brown perovskite which is more plentiful in the other two petrographic types.

Minerals common to the above three petrographic types are olivine macrocrysts and zoned phenocrysts, fleshy tan colored and orange-brown perovskites which display complex twinning and zoning, and zoned spinels consisting of chromite cores with titanomagnetite mantles.

CHEMISTRY

The rock which constitutes the Pântano intrusion is characterized by low SiO_2 (32 wt.%), Al_2O_3 (3 wt.%) and Na_2O (0.3 wt.%), high MgO (20 wt.%), FeO (14 wt.%) and K_2O (2.3 wt.%) and very high TiO_2 (7 wt.%) (Table 1). It is a silica undersaturated, ultrapotassic rock with normative nepheline and leucite. The major element chemistry is controlled by the high modal abundance of olivine, and perovskite, the latter producing the high TiO_2 content. However, if much of the macrocrystal olivine is xenocrystic then the whole rock composition as reported in Table I is not truly representative of the initial magma.

Table 1 – Chemical analyses of three petrographic types of rock forming the Pantano intrusion.

	Type 1	Type 2	Type 3
SiO_2	32.1	31.4	31.7
TiO_2	6.62	5.77	6.80
Al_2O_3	2.76	2.63	2.88
Cr_2O_3	0.08	0.11	0.08
FeO	14.3	12.8	14.0
MnO	0.30	0.30	0.29
MgO	19.8	21.4	19.2
CaO	9.87	11.4	10.3
Na_2O	0.25	0.25	0.29
K_2O	1.86	1.74	2.33
P_2O_5	0.84	0.88	0.17
CO_2	0.30	0.46	0.33

Minor variations in chemistry are apparent between the three petrographic types. Type 2 possesses the highest MgO and CaO contents and lowest SiO_2, TiO_2, Al_2O_3 and FeO, probably due to the presence of the numerous small ocelli.

Ba and Sr values are high, 2100-3300 ppm and 1500-1700 ppm respectively, and are similar to values determined for the Limeira and Indaiá intrusions 65 km to the west, as are the values for Rb. The REE distribution at Pântano is also similar to those recorded for Limeira and Indaiá and shows a high enrichment in LREE (Fig. 3). This pattern is similar to that observed in kimberlite, lamproite and other alkaline rocks. Most of the REE are hosted in the perovskite and possibly apatite.

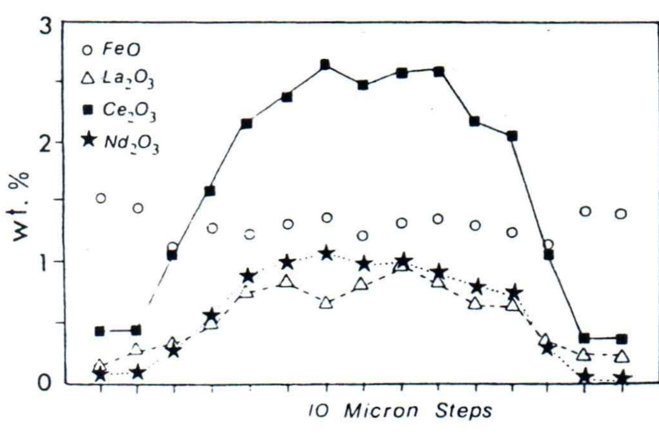

Figure 3

Table 2 – Representative analyses of olivine, diopside monticellite and phlogopite

	Olivine		Diopside	Monticellite	Mica			
					Core	Rim		
	1	2	3	4	5	6	7	8
SiO_2	41.3	40.9	53.9	36.8	37.3	41.2	40.9	43.3
TiO_2	0.02	0.01	1.26	0.06	4.82	0.61	1.38	0.73
Al_2O_3	0.00	0.00	0.11	0.00	12.0	5.10	11.16	4.50
Cr_2O_3	0.05	0.05	0.02	9.59	1.11	0.00	1.10	0.00
FeO	8.29	12.0	4.04	20.9	5.80	7.74	4.50	8.71
MgO	49.9	46.9	16.0	31.5	20.9	25.7	23.7	24.6
CaO	0.07	0.10	23.7	0.44	0.00	0.00	0.00	0.00
MnO	0.10	0.14	0.10	0.02	0.04	0.06	0.00	0.04
NiO	0.38	0.38	0.00		0.19	0.00	0.20	0.00
Na_2O			0.86		0.07	0.92	0.08	0.85
K_2O			0.00		10.8	10.9	10.1	9.98
BaO					0.34	0.53		
Total	100.1	100.5	99.9	99.3	93.4	92.8	93.5	92.7

Analyses:	1	Macrocryst
	2	Microphenocryst
	5,6	Mantled mica
	7	Microlith
	8	Poiquilitic plate

MINERAL CHEMISTRY

Represenative analyses of minerals are presented in Tables 2 and 3.

Olivine

Olivine is the most common phase present at Pântano. It is present up to 35 modal % and is found in all three petrographic types as either macrocrysts between 0.5 and 10 mm in size, or as smaller microphenocrysts, 0.25 mm or less. The size ranges noted above are average; some small olivines (< 0.25mm) are probably fragments of disagregated macrocrysts.

The macrocrysts occur as anhedral fragments and anhedral to euhedral grains in which undulose extinction and kink banding are more evident than in the microphenocrystal olivine. Many large olivines have undergone recrystallization along grain boundaries and fractures and now consist of numerous small neoblasts of olivine. The large olivines may be xenocrysts. The olivine microphenocrysts, especially those that are euhedral, do not show undulose extinction but may contain inclusions of spinel, a phenomenon which is present only in the outer margins of the macrocrysts.

Compositionally olivine shows a bimodal distribution with the macrocrysts having a higher Fo content than the microphenocrysts, 89-92% versus 84-87%. The olivine macrocrysts sometimes have thin margins whose compositional range is similar to that of the microphenocrysts. Minor element contents (TiO_2, Al_2O_3, Cr_2O_3 and NiO) are all low and similar to values observed in most forsteritic olivines. There is a slight enrichment of CaO (0.2-0.3 wt.%) in the rims relative to cores (0.1-0.2 wt.%) of several olivine microphenocrysts. Alteration of olivine to serpentine is common and in some instances to chlorite or clay with fine hair-like needles of millerite.

Table 3 – Representative analyses of perovskite, spinel and glass.

	Spinel		Perovskite		Glass
	Core	Rim	Core	Rim	
SiO_2			0.03	0.18	
TiO_2	6.73	11.1	55.9	56.4	
Al_2O_3	4.94	0.88			
Cr_2O_3	44.1	0.35			
FeO	21.54	27.7	1.26	2.04	
MgO	10.8	7.65			
CaO	0.02	0.02	36.5	39.8	
MnO	0.62	1.11			
NiO					
SrO			0.38	0.55	
La_2O_3			1.11	0.00	
Gd_2O_3			0.24	0.00	
Ce_2O_3			2.89	0.24	
Nd_2O_3			1.13	0.00	
Sm_2O_3			0.00	0.00	
Nb_2O_3			0.40	0.38	
Total	99.7	98.8	99.8	99.6	

Phlogopite

Phlogopite occurs at Pântano in discrete segregations (macroliths) consisting of several large grains of mica, as macrocrysts, as mantled phenocrysts and as poikilitic plates in the groundmass. The poikilitic plates are more common in rocks towards the center of the intrusion.

i. Macroliths: Macroliths, lenticular to ovoid in shape, are up to 1.5 cm in size and composed of >90% mica. Other minerals are olivine, spinel and interstitial glass which is now altered. Alteration of the macroliths varies from a rim of opaque minerals to total replacement by opaques, calcite, barite and serpentine.

The mica is phlogopite but a wide range in element contents of the mica exists between and in the various macroliths analyzed. For example,

	Sample Wt. %	
	88 - 06011*	89 - 07017**
TiO_2	0.9 - 1.6	2.3 - 5.4
Al_2O_3	8.2 - 11.9	11.3 - 15.2
Cr_2O_3	4.3 - 5.4	1.2 - 2.6
FeOT	4.3 - 5.4	5.6 - 7.1
mg#	0.85 - 0.87	0.90

* Mica plates are <0.1mm and contain inclusions of spinel. Olivine is relatively abundant in the macroliths.
** Mica plates are 1mm, undulose extinction common and spinel inclusions abundant; olivine occurs as intergrowth.

ii. Macrocrysts: These range in size between 0.5 and 4 cm. They are generally anhedral and show extensive undulatory extinction with alteration to opaque minerals along grain boundaries. They have a range in composition equivalent to that of mica in the macroliths.

iii. Mantled phenocrysts and groundmass plates: The mantled micas typically possess strongly pleochroic brown to light brown/colorless cores surrounded by overgrowths of colorless mica which exhibits minor pleochroism. The latter is comparable in composition to that of the groundmass plates and also similar to the plates that poikilitically enclose olivine, monticellite, perovskite, spinel and diopside.

The cores of the mantle mica phenocrysts fall in the same compositional range as some of the mica in the macroliths (e.g. TiO_2 3.3-5.5 wt.%, Al_2O_3 10.5-13.5 wt.%, FeO_T 5.5-7.9 wt.%) but the mantles and the groundmass plates are lower in Ti, Al and Cr and higher in Fe (e.g. TiO_2 0.6-1.3 wt.%, Al_2O_3 4.2-8.0, Cr_2O_3 wt.% and FeO_T 5.9-8.8 wt.%). There is no tetrahedral site deficiency in the mica which forms the cores but there is appreciable site deficiency in the mantles and groundmass plates.

There appears to be a general trend of decreasing Ti and Al of the mica in the macroliths, macrocrysts and cores to the mantles and groundmass plates.

Monticellite: Monticellite is a groundmass phase occuring as anhedral gains and euhedral prisms mm in size and is abundant in petrographic rock types 1 and 2. The monticellite contains significant solid solution towards kirschenite ($CaFeSiO_4$: 18 to 25 mol %), and forsterite (Mg_2SiO_4: 1 to 9 mol %).

Diopside: This mineral is a major phase and more abundant than monticellite in the third petrographic rock. It occurs as small (mm) tabular or prismatic grains in the groundmass, and may enclose perovskite, monticellite or spinel. Chemically they have low TiO_2 and Al_2O_3 contents (0.6-1.4 and wt% respectively), and Na_2O of 0.4 to 1.3 wt.%. There is possible Al deficiency in the tetrahedral site. Some larger (0.6 mm) and more TiO_2-rich (max. 3.3 wt.%) diopside is associated with altered glass.

Perovskite: Perovskite at Pântano is ubiquitous and occurs as fragmented, rounded and euhedral grains in the size range 0.01 to 4 mm, but generally between 0.1 and 0.4 mm. They are also found as aggregates with titanomagnetite and as necklaces around olivine. The perovskite occurs in two distinct colors; one is fleshy tan color and the other is orange-brown. Both varieties show strong color zoning from core to margin with the deeper colors in the core. Many of the grains appear to be fragments but this may be a result of sectioning complex polysynthetic twinning which is common to all the perovskite in the rock. Inclusions in the perovskite are titanomagnetite, rare euhedral rutile and olivine.

Perovskite at Pântano is enriched in REE + Nb (max. 8 wt.%) and often shows zoning in which the core contains more LREE, Sr and Fe than the margins. The high contents of LREE and Nb is similar to that observed for perovskite from Limeira and Indaiá intrusions.

Spinel: This phase occurs as anhedral to euhedral grains usually less than 0.2 mm size. Compositionally the spinel ranges from Mg-Ti chromite to titanomagnetite to magnetite. Chromite occurs as in the cores of grains which are mantled by titanomagnetite and magnetite, and as discrete inclusion in olivine. The titanomagnetite may be present as mantles on chromite, as single grains in the groundmass or as inclusions in perovskite, olivine and mica. Magnetite is found in the outer most portion of zoned spinels and as small (0.001 mm) discrete grains in the groundmass.

Ocelli: Ocelli, general circular in shape but with irregular margins and up to 0.2 mm in diameter, occur in the second petrographic type of rock. Thin veins of compositionally similar material are also to be observed. Small plates of phlogopite, diopside and apatite occur inside the ocelli as well as small devitrification spherules. The phlogopite, diopside and apatite heve similar compositions to those phases occuring in the groundmass and both the ocelli and the spherules have similar compositions and are fairly uniform in terms of the major elements Si, Al, Mg, Fe, and K (Table 3).

The ocelli are interpreted to be devitrified glass, although at first glance these ocelli have the appearance of leucite which has been altered. Nevertheless, the composition, the presence of the devitrification spherules and occasional thin veins of the same material mitigates against this identification.

ISOTOPE CHEMISTRY

The radiogenic isotopes of Rb, Sr, Nd and Sm were investigated for the three petrographic rock types. The results were similar to those obtained for the Limeira and Indaia intrusions (i.e. $^{87}Sr/^{86}Sr$ ca. 0.70526 and $^{144}Nd/^{143}Nd$ 0.51228) and are close to the values for the high phosphorous, high titanium (HPT) Paraná basalts which occur in the northern part of the Paraná basin. (See Fig. 4, Meyer and Svisero - this volume).

DISCUSSION AND SUMMARY

Originally, Pântano was described by others as an olivine basalt but this is clearly not the case. The major element chemistry of the rock is somewhat similar to kimberlite, low-Al alnoite and some peridotites. Although several of the mineral phases are similar to those occurring in kimberlite, the petrographic character of the rock is quite dissimilar. However, the minerals in Pântano are similar in type and often compositionally close to minerals which constitute the Limeira, Indaiá and other local intrusions, but the bulk chemistry of the rock is different.

The abundance of olivine and monticellite in the rock suggests the non-genetic name of monticellite peridotite for Pântano. Nevertheless this is not entirely satisfactory as it provides no indication of the possible consanguinity (if one exists) of the rock to other small intrusions in the region.

Based on the almost identical Sr and Nd isotopic signatures of Pântano, Limeira and Indaiá, plus the overall similarity of minerals noted above, it is possible that Pântano was derived from a parental magma that produced a series of mildly alkalic ultrabasic rocks that are related to kamafugites.

ACKNOWLEDGEMENTS.

BLG is grateful for financial support from an award to HOAM from the Harry Winston Research Foundation which enabled field and laboratory work to be accomplished. HOAM gratefully thanks Craig Smith, University of the Witwatersrand, South Africa, for help and guidance in determining Sr and Nd isotopic ratios and for generally introducing him to the wonderful world of geoalchemy.