THE MESOPROTEROZOIC RHYOLITE OCCURRENCES OF FUERTE OLIMPO AND FUERTE SAN CARLOS, NORTHERN PARAGUAY

CELSO DE BARROS GOMES*, PIERO COMIN-CHIARAMONTI & VICTOR FERNANDEZ VELÁZQUEZ ***

Abstract Petrographic and geochemical data make it clear that rocks at the localities pf Fuerte Olimpo and Fuerte San Carlos, which lie on the margins of the Paraguay and Apa rivers, respectively, in northern Paraguay, are rhyolites. However, in the Paraguayan geological literature, these sites nave been associated to alkaline rocks. Isotopic data for the rhyolites indicate a Precambrian age of 1341 Ma (1341 ± 53 Ma and 1343 ± 4 Ma, respectively) and give almost identical values for the initial ratio $^{87}Sr/^{86}Sr$ of 0.71335 ± 0.00126 and 0.71215 ± 0.00008, respectively. On the basis of these results as well as the distribution of minor and trace elements normalized to primitive mantle, they are probably correlated to the Mesoproterozoic acidic rocks of the Rio Branco Suite occurring in the Jauru Terrain at the SW portion of the Amazon Craton.

Resumo Dados petrográficos e geoquímicos demonstram que as rochas aflorando nas localidades de Fuerte Olimpo e Fuerte San Carlos, respectivamente, às margens dos rios Paraguai e Apa, na porção norte do Paraguai, consistem em riólitos. Contudo, na literatura geológica paraguaia, esses lugares têm sido previamente associados à ocorrência de rochas alcalinas. Dados isotópicos indicam para os riólitos uma idade precambriana de 1341 Ma (respectivamente, 1341 ± 53 Ma e 1343 ± 4 Ma, além de valores similares para a razão inicial $^{87}Sr/^{86}Sr$, respectivamente, 0,71335 ± 0,00126 e 0,71215 ± 0,00008). Com base nesses resultados, bem como na distribuição dos elementos menores e traços normalizados para o manto primitivo, eles são provavelmente correlacionados às rochas ácidas mesoproterozóicas da Suíte Rio Branco que ocorrem no Terreno Jauru, na porção SW do Craton Amazônico.

Introduction Alkaline rocks are widespread over the Paraguayan çterritory, the central-eastern region showing the highest conceritration of individual bodies. More recently, Velázquez et al. (1996a, 1998), reviewing the alkaline magmatism in the country, have separated the numerous known occurrences into six distinct provinces: Alto Paraguay and Rio Apa, at the northern sector; Amambay, at the northeastern region; Central and Asunción, lying over the central-eastern área; and Misiones, confined to the southernmost tip. In addition to significam differences in mode of occurrence and rock associations, the listed provinces also display a large span of age from Permian-Triassic to Oligocene. The oldest values (250-240 Ma) relate to the Alto Paraguay rocks; the Rio Apa and Amambay provinces represent an Early Cretaceous (-140 Ma) event, whereas the Central and Misiones provinces are slightly younger (-128 Ma and -120 Ma, respectively). The newest ages (61-39 Ma) are associated to rocks found in the Asunción área.

Information on the Paraguayan alkaline rocks as a whole are not uniform in spite of concentrated studies since the end of last decade by an international cooperative program involving workers of different countries, mainly from Brazil, Italy and Paraguay. However, considerable progress hás already been made, particularly regarding the rock-types from the Alto Paraguay, Central and Asunción provinces. The volume recently edited by Comin-Chiaramonti & Gomes (1996) brings together ali the geochemical data collected in the program. It also provides a general view of the distribution and the main geological and petrographic features of the several alkaline bodies under investigation. More recent sources of information on the Paraguayan alkaline rocks are the papers by Comin-Chiaramonti et al. (1997, 1999).

As a result of the systematic work still in progress, the presence of two occurrences (Fuerte Olimpo and Fuerte San Carlos) in the northern part of the country (Fig. 1), and previously reported in the Paraguayan literature as consisting of alkaline rocks, hás not been confirmed on the basis of petrographic and geochemical data.

General descrlptlon *Fuerte Olimpo* Fuerte Olimpo, a Paraguayan village located along the margins of the Paraguay river at the northern part of the country, is made up by four lava domes, the largest and highest (over 220 m) corresponding to the Cerro Lãs Três Marias. The domes are essentially composed by volcanic rocks, sampled in many places (Fig. 2), and are entirely surrounded by Quaternary alluvial sediments. Médium to coarse-grained rock-types of the Precambriam basement also occur not só far away (Fig. 1).

The volcanic rocks are aphyric to weakly porphyritic in texture, the microphenocrysts mainly consisting of quartz and alkali feldspar and plagioclase in minor proportion. They also contain variable amount of microblasts of epidote-chlorite and of micropatches of calcite ali set in an aphanitic groundmass. The rocks are classified as rhyolites, but can be also described as ignimbrites owing the presence of fiammae fragments. Textural evidences of metamorphic recrystallization (green schists fácies) are recognized in some samples (rheoignimbrites?), and bomb pieces are found included in a few specimens. In earlier studies, they were referfed to as forming a porphyritic dyke by DuGraty (1865) and Carnier (1911). On the basis of these descriptions, Li vieres & Quáde (1987) listed Fuerte Olimpo as one of its 32 Paraguayan alkaline occurrences.

Fuerte San Carlos Fuerte San Carlos rocks form an isolated small plug, 148 m high, at the margins of the Apa river in Paraguayan territory. The volcanics are in direct contact with recent deposits, but Eocambriam sediments (predominantly limestones of the Itapucumí Group, equivalent to the Brazilian Corumbá Group) and Precambriam crystalline rocks are found over the whole área (Fig. 1). The old fort was erected over the volcanic rocks, its ruins lying at short distance from the small village of San Carlos (Fig. 3).

The volcanic rocks are aphanitic and weakly porphyritic in texture, the microphenocryst phase mainly represented by alkali feldspar (sanidine); the mineral forms small laths or radiating fibres. The groundmass is crystalline and essentially composed by alkali feldspar, quartz and widely scattered opaque grains. Secondary minerais include abundant chlorite replacing biotite, epidote and carbonates whereas zircon and apatite are found as accessories. The rocks also show small, irregular to round in shape fragments having quartz and feldspar as principal constituents.

Reference to alkaline rocks in Fuerte San Carlos is due to Wiens (1986), who described the presence of aphanitic and porphyritic rock-types, occasionally with fluidal structure, ranging in composition from trachytes to phonolites.

Geochemístry Major (wt%) and trace (ppm) abundances were determined by X-ray fluorescence on powder pellets and the values are presented in Table l. Sr isotopic data for the Fuerte San Carlos rocks are reported in Table 2 whereas the data for the Fuerte Olimpo samples are taken from Velázquez et al. (1996b). Ali the analyses were performed at the University of Trieste, Italy, using a Philips PW-1400 automated spectrometer.

As shown in Figure 4, the Fuerte Olimpo and Fuerte San Carlos rock-types are basically rhyolitic in composition, which is also confirmed by their high concentrations of Rb, Sr, Zr and Ba. When comparing the both occurrences, the San Carlos volcanics are more enriched in Ti, Fe and Mg in addition to Zr, Y, La, Ce and Nd. Except for Rb, Sr, Nb and Ba, the trace element contents tend to present lesser dispersion in relation to the major ones.

In spite of some small differences, the lithologies from both associations are compositionally similar, as shown by their minor and trace elements (Fig. 5A) forming two practically coincidem distribution curves. This diagram also makes evident the negative anomalies in K, Sr, P and Ti and the positive ones in La-Ce, Nd and Zr. Sr excluded, the rock-types belonging to the Rio Branco Suite are

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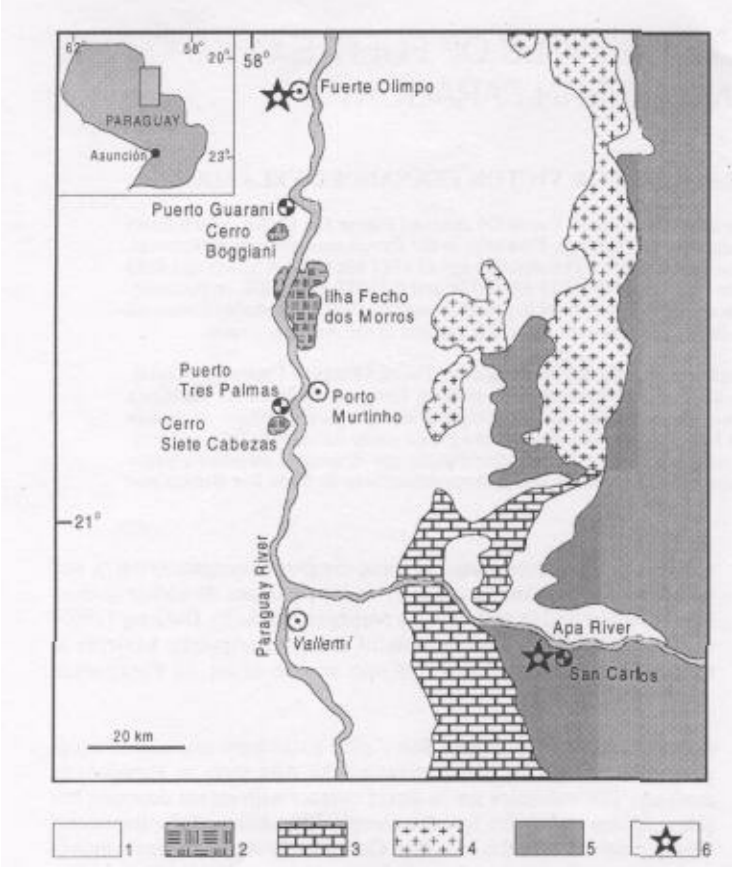

Figure 1 - Geological sketch map of northern Paraguay slwwing the distribution of inain rock-types and the investigated occurrences of Fuerte Olimpo and Fuerte San Carlos. Legends: l. Quaternary alluvium deposits; 2. Permian-Triassic alkaline rocks; 3. Eocambrian carbonate rocks; 4. Precambrian granitic rocks; 5. Precambrian metamorphic-granitoid basement; 6. Studied Occurrences.

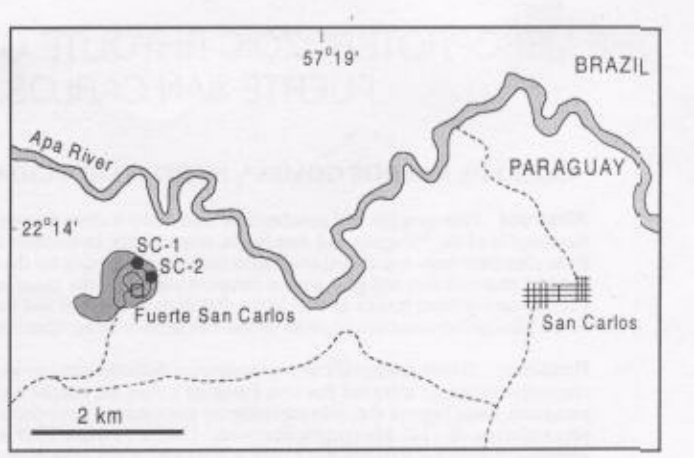

Figure 3 – Location of collected samples in the Fuerte San Carlos area.

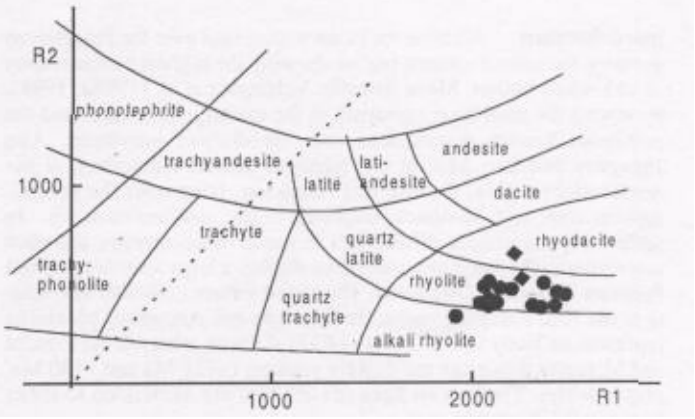

Figure 4 -R1-R2 (De La Roche et al, 1980) classification diagram for the Fuerte Olimpo (full circle) and Fuerte San Carlos (full diamond) volcanic rocks.

Table l - Chemical analysesfor major (wt%) and trace (ppm) elements ofFuerte Olimpo (FO) and Fuerte San Carlos (SC) volcanic rocks. Also shown are the R1 and R2 values (De La Roche et al, 1980).

	FO-23	FO-20	FO-13	FO-10	FO-17	FO-19A	FO-14	FO-15	FO-19B	FO-22	FO-16	FO-12	FO-21	FO-11	FO-18	SC-1	SC-2
SiO_2	74,69	73,31	73,15	72,99	72,84	72,64	72,45	72,31	71,95	71,87	71,85	71,12	70,95	70,89	70,74	68,65	67,65
TiO_2	0,23	0,30	0,23	0,31	0,28	0,34	0,24	0,31	0,23	0,35	0,32	0,23	0,39	0,31	0,35	0,49	0,49
Al_2O_3	13,09	14,40	14,52	14,55	14,27	14,09	14,40	14,10	14,82	14,36	14,64	14,46	14,68	14,06	14,47	13,97	14,21
Fe_2O_3	0,71	0,59	1,02	0,71	0,88	1,12	1,01	0,99	1,04	1,14	1,12	0,88	1,36	0,90	1,08	2,23	2,28
FeO	0,78	0,90	0,75	0,74	0,76	0,81	0,87	0,82	0,32	0,95	0,93	1,01	1,09	1,00	1,26	1,12	1,15
MnO	0,03	0,08	0,08	0,06	0,07	0,09	0,10	0,09	0,02	0,09	0,11	0,08	0,10	0,09	0,10	0,06	0,07
MgO	0,20	0,55	0,55	0,48	0,57	0,58	0,42	0,59	0,04	0,62	0,67	0,65	0,73	0,63	0,82	1,83	1,94
CaO	0,32	0,79	1,21	0,50	0,63	1,40	1,490	0,93	0,75	1,32	0,77	1,31	1,39	0,75	1,46	1,08	1,85
Na_2O	3,79	4,84	4,28	4,72	5,53	5,38	4,30	5,60	3,61	5,11	5,06	3,73	4,90	4,94	5,17	3,24	2,88
K_2O	5,26	3,50	3,45	3,74	2,94	2,65	3,57	2,97	6,45	3,09	3,35	3,80	3,48	3,53	2,95	4,37	4,91
P_2O_5	0,04	0,08	0,07	0,08	0,07	0,09	0,07	0,09	0,05	0,10	0,08	0,07	0,10	0,10	0,10	0,09	0,08
LOI	0,57	0,63	0,63	1,06	1,04	0,7	0,87	1,08	0,66	0,88	0,99	0,90	0,71	0,98	1,46	3,12	2,25
Total	99,71	99,97	99,94	99,94	99,88	99,89	99,79	99,88	99,94	99,88	99,89	98,24	99,88	98,18	99,96	100,25	99,76
Cr	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2
Ni	6	4	7	6	5	7	9	6	5	3	7	6	8	6	4	<1	1
Rb	139	118	128	144	114	94	141	108	154	100	138	178	112	126	96	179	205
Sr	211	192	187	146	188	172	354	206	179	265	133	391	227	199	188	141	190
Zr	133	184	212	208	182	189	208	181	179	194	22	218	198	190	193	285	319
Y	36	34	34	39	34	29	32	32	42	32	36	33	31	32	32	66	49
Nb	17	14	14	15	15	13	15	14	17	14	16	15	14	14	14	16	16
Ba	1716	1300	1003	1229	1136	115	1054	1156	2013	1274	1117	1192	1486	1368	1173	928	1250
La	48	48	39	47	46	46	37	41	52	47	52	44	50	48	46	70	94
Ce	98	101	83	93	98	90	80	95	102	97	107	88	107	96	102	136	169
Nd	49	43	39	46	44	46	40	44	56	45	51	37	49	45	45	61	79
R1	2375	2327	2516	2476	2174	2274	2435	2103	1971	2214	2171	2498	2129	2114	2152	2285	2232
R2	301	394	442	363	376	455	463	406	296	454	403	456	473	387	481	473	573

Table 2 - Isotopic data for the Fuerte Olimpo and Fuerte San Carlos rhyolites. Values for the first occurrence are from Velázquez et al. (1996b).

	Rb	Sr	$^{87}Sr/^{86}Sr$
Fuerte Olimpo			
FO-10	136	141	0.76652 (10)
FO-16	122	134	0.76504 (8)
FO-18	102	198	0.74097 (9)
FO-19	94	238	0.73573 (6)
FO-20	124	208	0.74737 (9)
FO-22	100	265	0.72983 (1)
Fuerte San Carlos			
AP-1	194.9	160.7	0.77064 (2)
AP-2	201.4	158.7	0.77255 (2)
AP-4	198.4	185.8	0.77121 (3)
AP-5	194.1	155.4	0.77191 (2)
AP-6	206.4	190.8	0.76949 (2)
SC-1	179	141	0.78381 (12)
SC-2	205	190	0.77251 (11)
SC-2	408	97	0.95205 (15)

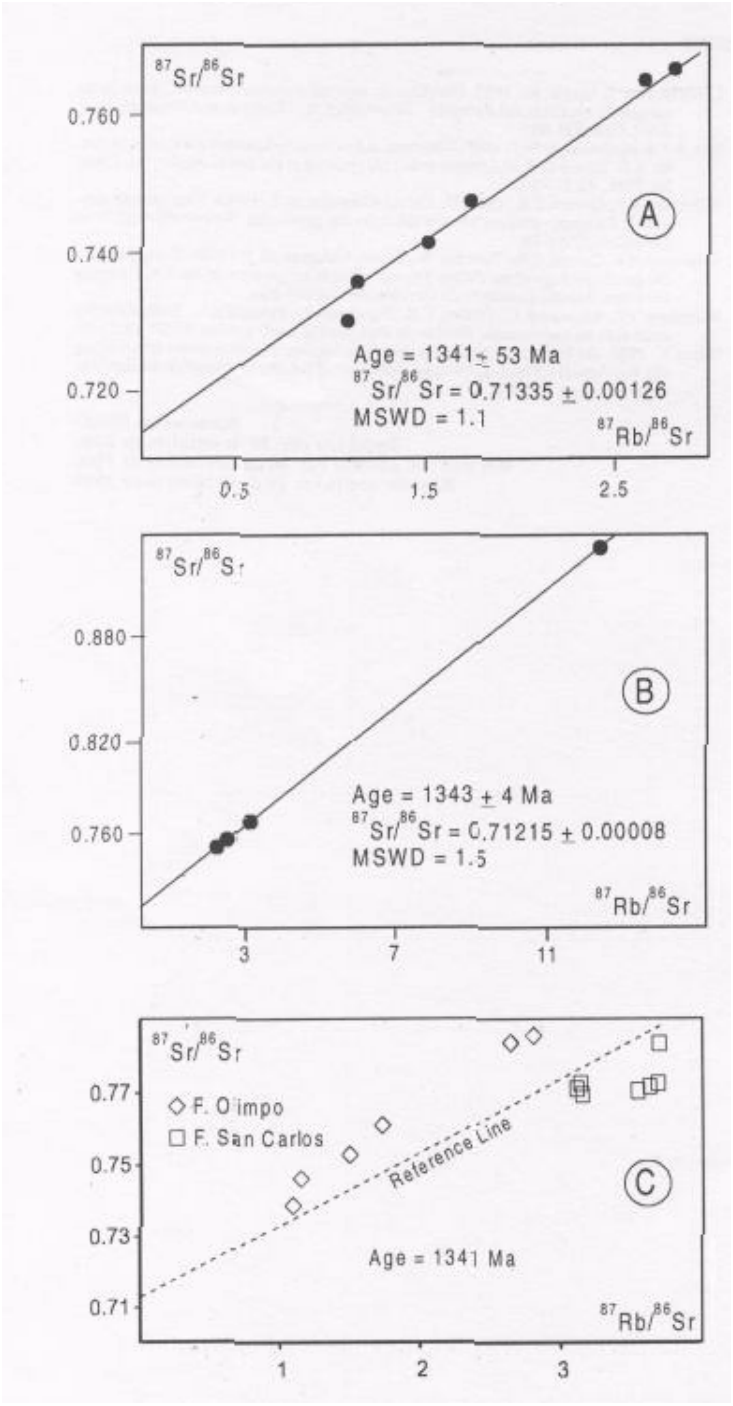

Figure 6 - Isochrons for lhe Fuerte Olimpo (A) and Fuerte San Carlos (B) volcanic rocks, indicating Rb/Sr ages of 1341 ± 53 Ma and 1343 ± 4 Ma, respectively. A reference Une for 1341 Ma is also shown (C).

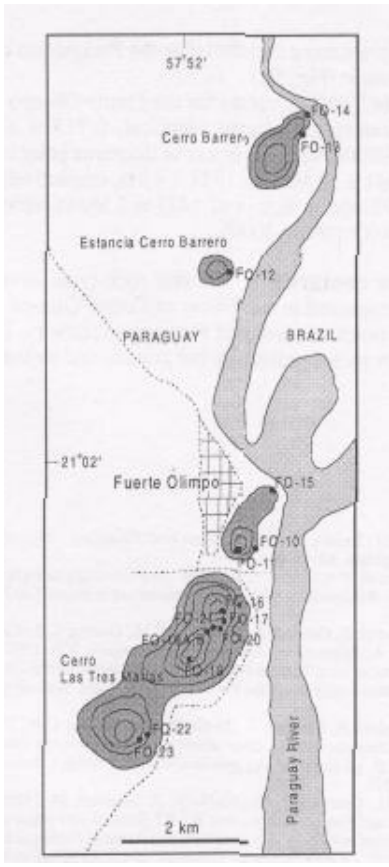

Figure 2 — Location of collected samples in the Fuerte Olimpo área.

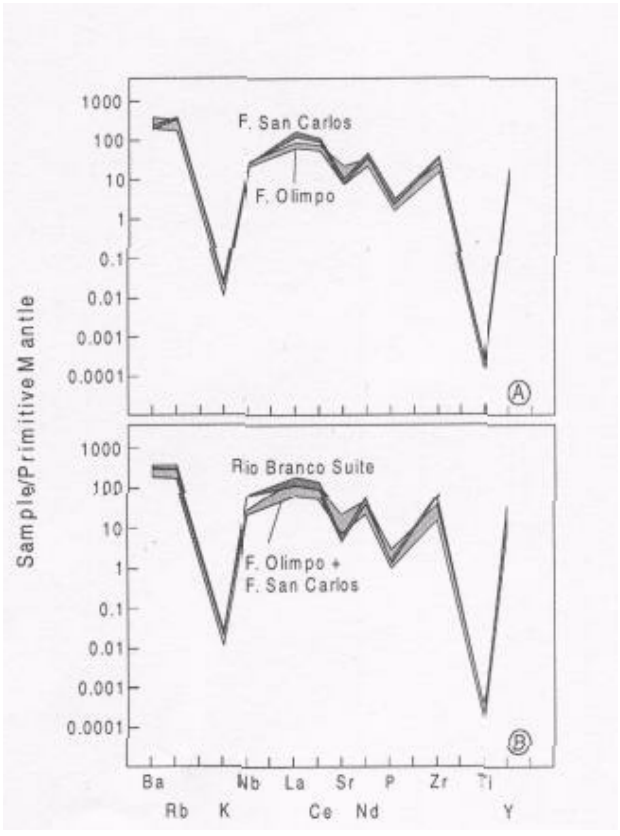

Figure 5 - Primordial mantle-normalized incompaúble elements diagramfor lhe Fuerie Olimpo and Fuerte San Carlos volcanic rocks (A). For comparison, the variation fieldsfor intrusive silicic rocks oj' lhe Rio Branco Suite in lhe Amazon Craton (B). Nonnalizing values arefrom Sun & McDonough (J989).

in general slightly more enriched than the Paraguayan ones, despite the similar behaviour (Fig. 5B).

Initial ratio $^{87}Sr/^{86}Sr$ values for the Fuerte Olimpo and Fuerte San Carlos volcanics are almost identical, 0.71335 ± 0.00126 and 0.71215 ± 0.00008, whereas isochron diagrams point to a Rb/Sr age of 1341 Ma (1341 ± 53 Ma and 1343 ± 4 Ma, respectively). On the other hand, an U/Pb age on zircon of 1423 ± 2 Ma is reported for the Rio Branco Suite (Geraldes, 2000).

Conclusive remarks Volcanic rock-types of rhyolitic composition are recognized in the places of Fuerte Olimpo and Fuerte San Carlos at the northern portion of Paraguayan territory. They are entirely surrounded by recent sediments, but granitic and metamorphic rocks of the crystalline basement are also found over the whole área. Geochemical and isotopic data indicate for the volcanics a Precambrian age (1341 Ma), Sr. values of 0.71215-0.71335 and a similar pattern for incompatible elements compared to the Mesoproterozoic acidic lithologies of the Rio Branco Suite cropping out in the Jauru Terrain at the SW portion of the Amazon Craton.

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