EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol. 13, No.1 (June 2009): 16-29

MESOZOIC MAGMATISM IN EAST URUGUAY: PETROLOGICAL CONSTRAINTS RELATED TO THE SIERRA SAN MIGUEL REGION

Rossana Muzio, Elena Peel, Ethel Morales, Gerardo Veroslavsky, Bruno Conti

Departamento de Evolución de Cuencas, Facultad de Ciencias.
Iguá 4225 C.P. 11400, Montevideo, Uruguay

Corresponding author: Rossana Muzio, rossana@fcien.edu.uy

ABSTRACT

This work presents new results of a detailed geological and structural investigation focusing the easternmost Uruguayan Mesozoic magmatic occurrences related to the south Atlantic opening. Lithological descriptions, their stratigraphic relationships and complimentary lithochemical characterizations carried out in the San Miguel region (East Uruguay) are presented. Three volcanic/sub-volcanic units have been recognized. The felsic volcanic association is composed by rhyolitic - dacitic flows, mainly with porphyritic textures and sub-alkaline nature and related pyroclastic rocks. The felsic sub-volcanic association is characterized by granophyres of about 25 km2 of exposed area, cross- cut by mafic and felsic dykes. Finally, a mafic association has been identified characterized by dykes and a small intrusion of gabbroic composition.

All these units are Mesozoic in age (130 – 127 Ma) and according to their chemical nature they correspond to sub-alkaline to weak peralkaline magmas.

***Key words*:** petrography, geochemistry, Mesozoic, Uruguay.

RESUMEN

Este trabajo presenta nuevos resultados geológico-estructurales y geoquímicos relacionados con el magmatismo Mesozoico del extremo Este de Uruguay (Sierra de San Miguel, Departamento de Rocha), asociados a la apertura del océano Atlántico Sur. Fueron reconocidas para la región estudiada tres unidades volcánicas/subvolcánicas. La asociación volcánica félsica está compuesta por derrames riolíticos – dacíticos, con texturas dominantemente porfiríticas y naturaleza química subalcalina. Asociadas a estas riolitas ocurren

Manuscript receiver: January 12th, 2009.
Accepted for publication: March 30th, 2009.

niveles de rocas piroclásticas. La asociación subvolcánica félsica está compuesta por granófiros con una extensión superficial de aproximadamente 25 km^2, cortados por diques máficos y félsicos. Fue identificada también una asociación básica compuesta por diques y un cuerpo de gabro. Todas estas unidades son de edad Mesozoico (130 – 127 Ma) y de acuerdo a su carácter químico corresponden a magmas de naturaleza subalcalina a débilmente peralcalina.

***Palabras clave*:** petrografía, geoquímica, Mesozoico, Uruguay.

Introduction

The Uruguayan geology is underlain by Precambrian terrains comprising a wide range of metamorphic rocks and granitic intrusions. Five sedimentary basins rest on the cratonic basement, one Palaeozoic and the other four Mesozoic in age.

Mesozoic magmatism tectonically related to the breakup of Gondwana is well represented in the Uruguayan extension of the Paraná Basin and in the rift-type basins of Santa Lucía and Laguna Merin (Fig.1). Recently, in the offshore Punta del Este basin have been also recognized relicts of this magmatic event (Ucha et al., 2003).

The Paraná Magmatic Province (PMP) is one of the largest continental magmatic provinces in the world (Peate, 1997). Although the main outcrop areas are exposed in Brazil, some extensions are well developed in Argentina, Paraguay and Uruguay. Furthermore, Uruguay has a privileged position because of the presence of the southernmost extension of these magmatic exposures.

During the early Cretaceous, a strong volcanic activity made up of basaltic and rhyolitic rocks occurred in south eastern Uruguay along the border of the Paraná basin. Particularly, these exposures are well represented in rift type basins located in the eastern portion of Uruguay (Laguna Merín basin) and comprise from basic to acidic units on which this paper is concerned.

Several petrologic works have been carried out in the south eastern portion of Uruguay, with particular emphasis in the felsic volcanic/sub-volcanic units (Muzio, 2000; Kirstein et al., 2000; Kirstein et al., 2001; Muzio et al., 2002; Lustrino et al. 2003; Lustrino et al. 2005). As main results can be pointed out that the petrologic and isotopic features exhibited by these units differ completely from their temporal correlatives of the Paraná Province (Palmas and Chapecó rhyolites, according to Bellieni et al. 1986).

Recent studies performed by Muzio et al. (2004) and Muzio et al. (2005) in the San Miguel region, allowed the identification of a gabbroic body which

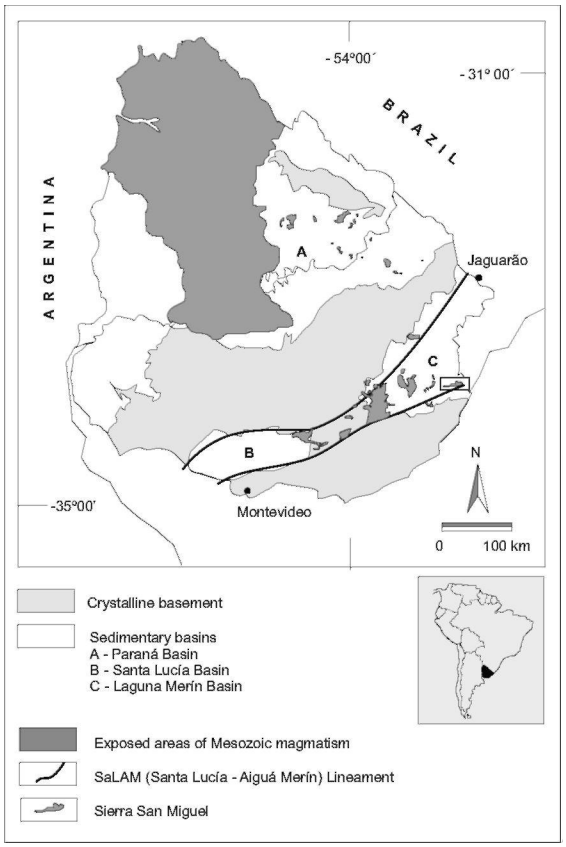

Figure 1. Structural framework and location of the area, modified after Ucha et al. (2003).

has been mapped at semi-detailed scale (Fig. 2). This is the first basic intrusive body that has been recognized out-cropping in the southern portion of the Laguna Merin basin, closed to an important gravimetric anomaly (+90 mGa; Reytmair, 2001). According to Rossello et al. (2000), this gravimetric anomaly results from the development or reactivation of deep parallel fractures, trending N70° to E-W, which affected the crust during Gondwana fragmentation. These fractures, recognized through strong structural, magnetic and gravimetric lineaments, became mantle feeding structures that allowed the emplacement of basic/mafic rocks which caused the excess of gravity in the region (Rossello et al, 2000; Veroslavsky et al., 2002).

The aim of this paper is to present the petrologic and structural characterization of the units exposed in the Sierra San Miguel region, corresponding to the southernmost border of the Laguna Merín Basin (East Uruguay), with particular emphasis in the gabbroic intrusion.

Geologic setting and petrography

The Sierra San Miguel Complex is located in the Department of Rocha (East Uruguay), 340 km eastwards Montevideo, the capital of the country. It represents an important geomorphologic feature, of about 25 km length and regional trend EW within the wetlands and Quaternary sediments of the southern extreme of the Laguna Merin basin (Fig. 2).

The structural framework controlling the development and evolution of the Santa Lucía and Laguna Merin basins is underlain by the SaLAM (Santa Lucia – Aiguá – Merin Lineament, after Rossello et al.; 2000). This structural feature constitutes a transtensive tectonic corridor of the strike-slip faults (*ca*. 450 km), cross-cutting the Río de la Plata craton. As it has been described by Rossello et al. (2001), either two pull-apart depocentres (Santa Lucia and Laguna Merín basins) at its extremes and the emplacement of Mesozoic volcanic/sub-volcanic rocks have been controlled by this structure. According to these authors, the SaLAM compounds two main tectonic phases: (i) a Jurassic to Early Cretaceous extensional stage, represented by intraplate magmatism synchronous with the PMP, and (ii) an Aptian – Albian dextral transtensive stage. In this context, the tectonic development of the Sierra San Miguel Complex is controlled by the Aiguá - India Muerta – Chuy fault, one of the components of the SaLAM lineament that conditioned the opening and extensional development of the Laguna Merín Basin (Rossello et al., 2000).

The pioneer geological works in the Sierra San Miguel correspond to Walther (1927), Caorsi & Goñi (1958) and Bossi & Fernández (1963) and it has been described as a volcanic/sub-volcanic association composed by granophyres and, subordinated rhyolites. These lithologies were later integrated to the Arequita Formation by Bossi (1966). The only available radiometric data by K/Ar systematic (whole rock analyses) yielded ages between 125 – 130 Ma (Bossi, 1969). After recent geological studies developed by Muzio et al. (2004), three petrographic associations have been identified, each-one related to different tectomagmatic stages (Fig.2).

Unit 1 – Felsic sub-volcanic association (FSA)

The FSA is located mainly in the east and central portions of the Sierra San Miguel which occurs as an irregular body along an EW to NE axis. It is composed by strongly fractured granophyric rocks, cross-cut by sub-vertical basic and acidic/felsic dykes with structural trend N65° and EW respectively. The granophyres are progressively covered by rhyolitic lava flows.

The fracture system (sub-horizontal and vertical unfilled fractures) outlining a roughly polyhedral pattern can also be observed. These granophyres are mineralogical and petrographycally homogeneous. The mineral association of these rocks is essentially anhydrous. They are medium to fine grain-sized, with equigranular and occasionally porphyritic hypidiomorphic textures (up to 10% of plagioclase phenocrysts). It can be observed the following mineralogical assemblage: quartz - alkali feldspar intergrowths (micrographic/granophyric texture) and

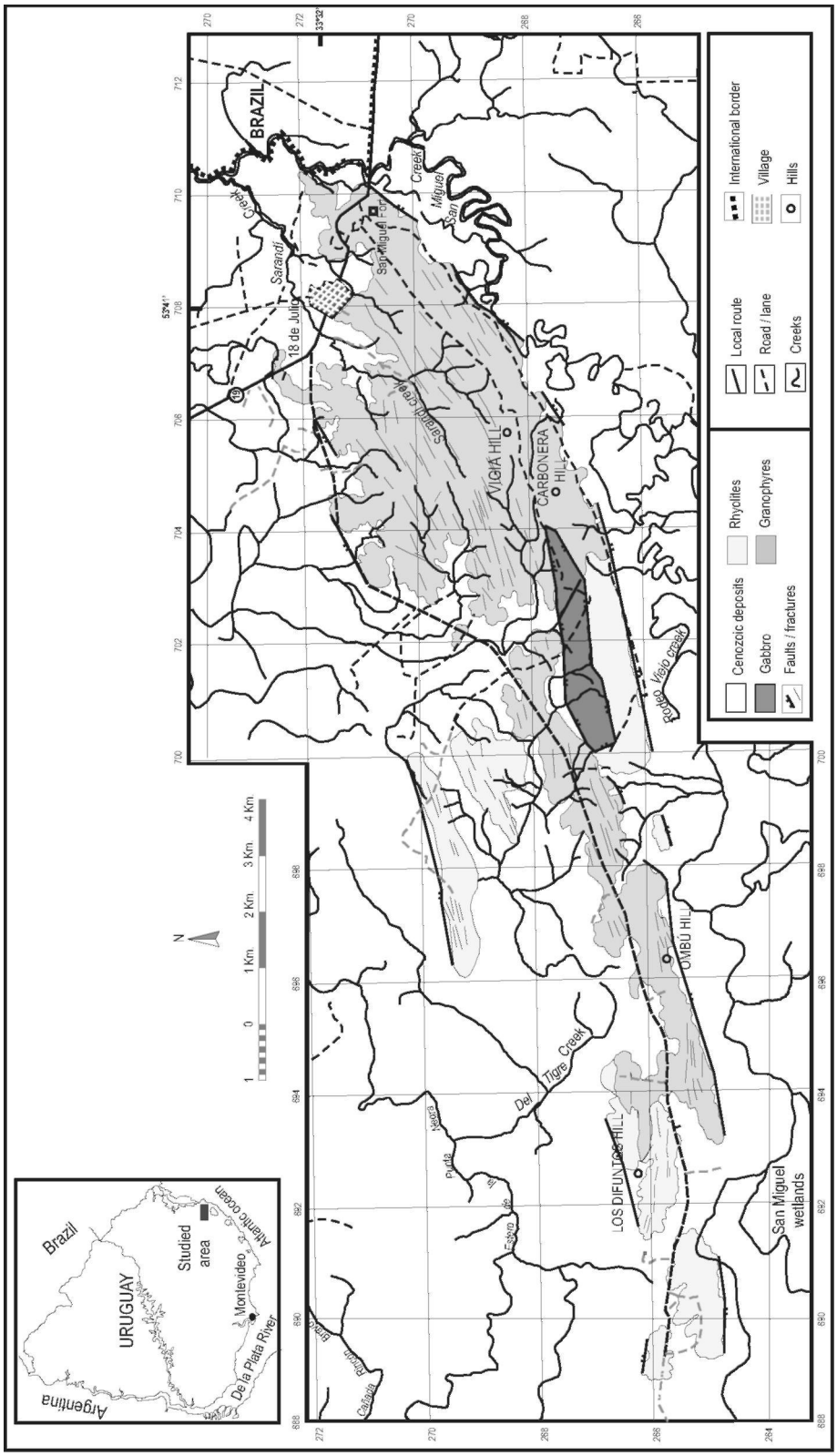

Figure 2. Geological sketch of the Sierra San Miguel region, after Muzio et al. (2004).

partially altered clinopyroxene (augite) often exhibiting uralitization processes. Apatite and opaque minerals are frequent as accessory minerals. In the central-north part of the area, the granophyres are hardly affected by faulting with trends N70°. Also, a synmagmatic foliation N250° - 260° can be observed. This structural trend is coincident with the emplacement of mafic and felsic dykes.

Unit 2 – Mafic association (MA)

Two different types of basic rocks have been recognized, according to their geological setting. The first type corresponds to basic dykes which vertically cross-cut the granophyres. As it was mentioned previously, they are porphyritic basic dykes with structural trend N65-70, 75°. They have porphyritic texture with plagioclase phenocrystals (up to 10 %) in a subophitic to intersertal groundmass. The mineral assemblage is composed by plagioclase, orthopyroxene and clinopyroxene (augite), opaque minerals and apatite.

The second type of basic rocks is represented by an intrusive body – named as San Miguel Gabbro (SMG). The main outcrop area is located around the central-north region of the Sierra San Miguel (S33°43'; W53°38'), and it can be described as a sub-horizontal intrusion cross-cutting the grano- phyric rocks. It is strongly fractured with sub-horizontal and sub-vertical joints. Typical spherical structures due to alteration processes, ranging in diameter from 40 to 80 cm, can be observed.

According to the IUGS classification criteria (Le Maitre, 1989) this intrusive body can be described as a leucocratic gabbro/dolerite with massive structure, with equigranular and subophitic texture, medium to coarse grain sized, composed by plagioclase (An_{55-45}), altered olivine, orthopyroxene, clinopyroxene (augite), opaque minerals and apatite. Occasionally amphibole - as deuteric alteration – is present. Other small gabbroic intrusions appear as wedges or secondary dykes; all injected through the granophyres. Euhedral to subhedral plagioclase crystals surrounded by micrographic/granophyric intergrowths are present. This petrographic feature is also observed as an interstitial granophyric intergrowth, and occurs plagioclase and clinopyroxene crystals with intergranular arrangement, in association with K-feldspar and quartz.

According to Shelley (1992) this kind of texture is consistent with residual crystallization under eutectic conditions and corresponds either with the emplacement of shallow intrusions or with fast degassing processes.

Unit 3 – Felsic Volcanic Association (FVA)

They correspond mainly to pinkish - grey colored rhyolites and compound at least three lava flows softly dipping to the North. They are distributed along the north, northwestern and western region of the Sierra San Miguel. These lithologies are grouped in the Arequita Formation (Bossi, 1966) and can be separated, according to their petrographic and structural features in:

a) Rhyolitic lavas, occasionally with porphyritic textures (approximately 10 to 15% of alkali feldspar and/or quartz phenocrysts), with vesicular levels filled by calcite, zeolite and quartz. Most of these vesicles are stretched according to flow directions such as N170° to EW. Microscopically, spherulitic texture and flow structures formed during the cooling of the rhyolitic lava can be observed. Some of the porphyritic varieties present abundant glass phenocrysts, round shaped and brown to dark black colors. Some volcaniclastic facies in association with the rhyolites have been found and according to McPhie et al. (1993) descriptive criteria they correspond to volcanic lithic breccias and autoclastic breccias (Fig. 3).

b) Rhyolitic dykes with porphyritic texture trending N60-70° and cross-cutting all the lithologies are present in the study area. They present quartz and K-feldspar phenocrysts in an aphyric matrix composed by

Figure 3. Lithic breccias and autoclastic breccias associated with the felsic volcanics in Sierra San Miguel region.

quartz, K-feldspar (orthoclase?) and clinopyroxene. Their stratigraphic relationship with the mafic dykes was not observed.

Lithogeochemistry

Chemical composition of ten samples (one granophyre, three gabbros, one mafic dyke, three felsic dykes and two rhyolites) of the Sierra de San Miguel Complex was analyzed. Major and trace elements were obtained by ICP – AES techniques whereas REE by using ICP – MS, performed at ACME Laboratories Inc., Vancouver, Canada. The analytical data are listed in Table I and illustrated in Fig 3-7. They were plotted in different classification and variation diagrams and they were also compared with similar rocks performed by Kirstein et al. (2001) and Lustrino et al. (2005) in order to evaluate the data for the region.

The SiO_2 variation diagrams (Fig.4) show no extremely high contents in the felsic volcanic samples. However, they present high contents of L.O.I. (>3%). The analyzed samples have SiO_2 ranges from 71.1 to 48.49 wt.%; TiO_2 from 1.48 to 0.58 wt.%; Al_2O_3 from 16.22 to 11.6 wt.%; Fe_2O_3 from 14.2 to 5.01 wt.%; MgO from 9.11 to 0.23 wt.%; CaO from 12.04 to 0.82 wt%; Na_2O from 3.33 to 2.19 wt.% and K_2O from 4.89 to 0.2 wt.%. When plotted against SiO_2, smooth trends are showed. TiO_2, Al_2O_3, Fe_2O_3, MgO and CaO decrease with increasing SiO_2 content. Na_2O does not show a trend at all, while K_2O increases towards the rhyolitic terms. Furthermore, Na_2O and K_2O present an inverse behavior when compared with Lustrino et al. (2005) data.

Trace element contents present a short range when they are compared with published data (Lustrino et al., 2005; Kirstein et al., 2000). Rb varies from 184.4 to 5.4; Zr from 387.1 to 58; Y from 76.6 to 22.2; Nb from 24 to 3.7; Ba from 721.1 to 111 and Sr from 207.8 to 85.4 (Fig. 5, Table I). The ratios between incompatible elements (Fig. 6) vary within narrow ranges (Zr/Nb= 15.03±1.05; Zr/Y=4.11±1.54; Y/Nb= 4.39 ± 1.72). These values are very similar to the Treinta y Tres magma type pointed out by Turner et al. (1999); Kirstein et al. (2000) and Lustrino et al. (2005).

The rock samples have been classified using the R_1-R_2 diagram (De la Roche et al., 1980) and TAS diagrams (Le Maitre et al., 1989) (Fig. 7a and 7b). Two samples of the plutonic rocks plot in the gabbro - norite field of the R_1-R_2 diagram. The volcanic rocks plot mainly in the rhyolitic and dacitic fields and one sample in the basaltic-andesitic field. All samples show a sub-alkaline affinity according to Irvine and Baragar (1971) diagram (Fig. 7c). However, the analyzed data are not enough to establish any petrogenetic link among the samples. The agpaitic index calculated for the samples (A.I. = molar (Na+K)/Al) ranges from 0.24 to 0.74. The rhyolites range from 0.71 to 0.74; dacites present values of 0.66 and andesites around 0.58. The lower values correspond to the gabbro – norite samples. None of the samples show a peralkaline character as described for the Arequita Formation by Muzio et al. (2002). Hence, they have been classified on the basis

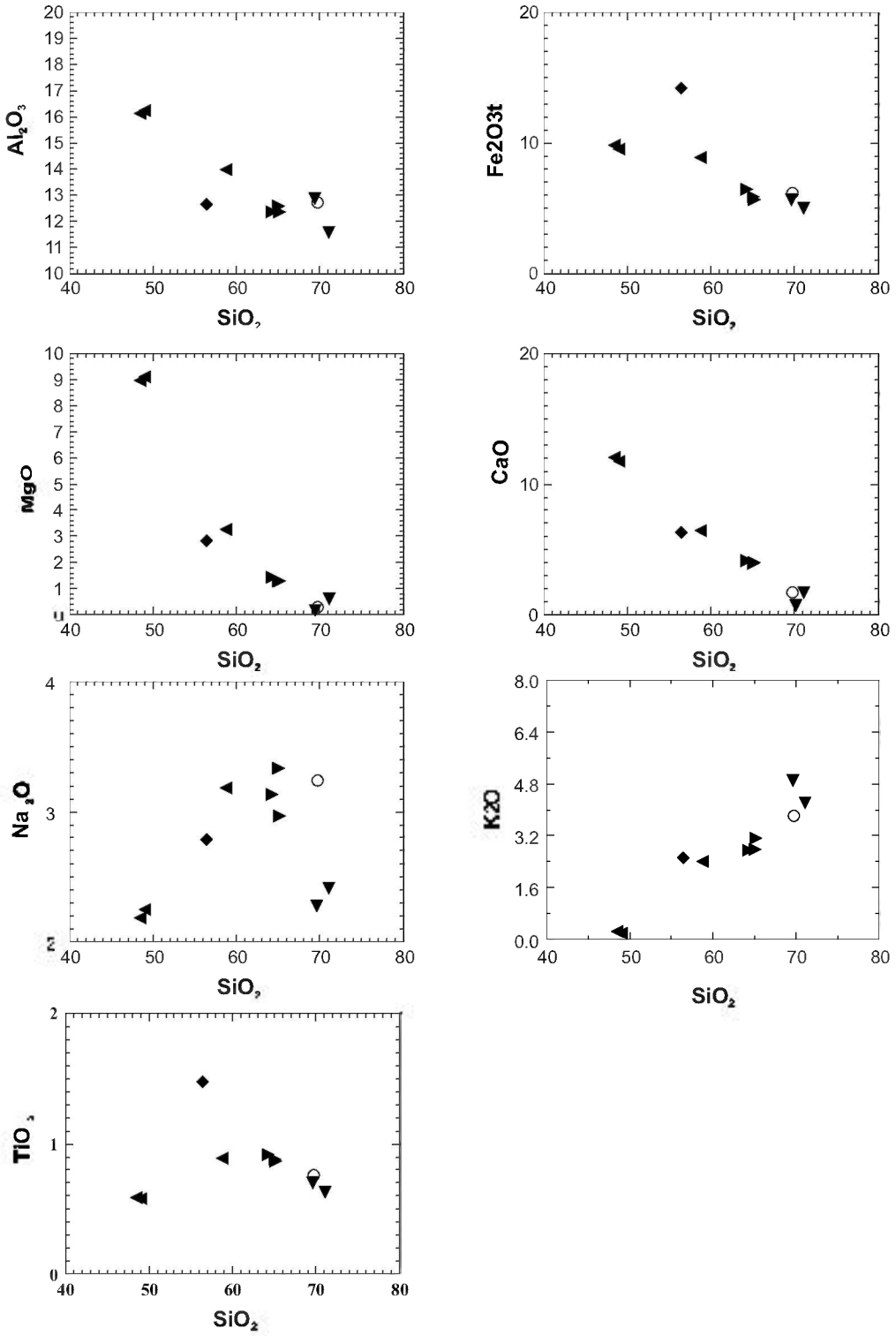

Figure 4. Major and minor element diagrams for samples from the San Miguel region. Symbols: ▸ felsic dykes; ▾ felsic lavas; ◂ gabbros; ♦ basic dyke; ○ granophyre.

Table 1. Geochemical data of selected samples from the Sierra San Miguel region.

Samples	SM50-1	SM50-2	SM50-3	SM008-7	SM008-8	SM008-9	SM51	SM13	SM27	SM29-1
SiO_2 (wt.%)	65,01	64,24	65,1	58,71	48,98	48,49	56,41	69,72	71,1	69,58
TiO_2	0,88	0,92	0,87	0,89	0,58	0,59	1,48	0,76	0,63	0,7
Al_2O_3	12,58	12,38	12,38	13,99	16,22	16,13	12,67	12,74	11,6	12,81
Fe_2O_3	5,87	6,43	5,66	8,89	9,53	9,8	14,2	6,15	5,01	5,66
MnO	0,14	0,14	0,13	0,17	0,15	0,15	0,2	0,11	0,16	0,13
MgO	1,3	1,44	1,28	3,28	9,11	8,95	2,85	0,3	0,67	0,23
CaO	3,95	4,18	3,99	6,44	11,78	12,04	6,28	1,71	1,75	0,82
Na_2O	3,33	3,13	2,97	3,18	2,25	2,19	2,79	3,24	2,42	2,28
K_2O	2,77	2,76	3,12	2,42	0,2	0,25	2,54	3,81	4,22	4,89
P_2O_5	0,26	0,23	0,24	0,28	0,09	0,11	0,19	0,2	0,17	0,16
Cr_2O_3	0,004	0,005	0,015	0,013	0,053	0,068	0,019	0,015	0,041	0,008
LOI %	3,8	3,9	4	1,5	1	1,2	0,3	1,1	2,1	2,6
TOT/C %	0,03	0,02	0,03	0,03	0,03	0,05	0,02	0,05	0,05	0,04
TOT/S %	0,01	<.01	<.01	<.01	0,01	0,06	0,01	0,01	0,01	0,01
SUM %	99,89	99,76	99,76	99,77	99,98	100	99,95	99,86	99,89	99,88
Rb (ppm)	135,8	127,3	142,5	89,9	7,3	5,4	88,8	150,7	158,8	184,5
Ba	625	599,2	583,9	458,1	111	112,6	365,4	721,1	654,6	712,6
Sr	136,8	146,3	146,3	207,8	133,3	139,1	123,1	125,9	92,8	85,4
Zr	301,1	276,4	289,6	237,1	72,2	58	189,4	387,1	293,5	327,9
Y	57,6	56	56,9	56,4	22,2	22,6	50,2	76,6	64,4	58,1
Ga	15,9	16,1	15,8	19,4	14	14,5	19,7	18	15,9	17
Hf	8,6	8,1	8,5	7,2	2,2	1,8	5,7	11	8,7	9,3
Nb	21,6	19,5	20,8	16,6	4,6	3,7	13,4	24	18,7	20,4
Ta	1,4	1,4	1,5	1,2	0,4	0,3	1	1,7	1,4	1,5
Th	16	14,2	15,4	7,4	1,8	1,2	8,1	14,2	14,4	14,7
U	2,5	2,3	2,6	1,4	0,4	0,3	1,3	1,7	2,5	2,7
Ni	29,7	18,8	67,5	31,5	110,5	118,1	65,2	43,9	152,1	39
La	38,8	37,5	40,1	28,7	7,3	7,3	23,1	46,6	42,4	40,7
Ce	96,4	91,8	99,4	68,7	16,9	16,1	54,2	107,2	99,6	102,2
Pr	10,71	10,06	10,77	8,41	2,24	2,18	6,47	13,1	11,38	10,17
Nd	44,3	41,3	43,6	36,8	10,2	9,9	27,3	54,8	45	41

Samples	SM50-1	SM50-2	SM50-3	SM008-7	SM008-8	SM008-9	SM51	SM13	SM27	SM29-1
Sm	9,1	8,9	9	8,5	2,7	2,5	6,1	11,7	10,3	8,6
Eu	1,87	1,86	1,79	2,26	0,77	0,79	1,55	2,35	2,02	1,84
Gd	9,35	9,08	9,41	9,03	3,08	3,24	7,4	11,97	10,31	9,06
Tb	1,8	1,7	1,75	1,78	0,64	0,66	1,41	2,36	2,01	1,81
Dy	9,85	9,57	9,84	9,68	3,58	3,92	8,07	12,87	10,92	10,08
Ho	1,94	1,95	2,05	1,95	0,75	0,81	1,76	2,53	2,16	1,99
Er	6,08	5,95	6,18	5,91	2,32	2,37	5,25	7,59	6,55	6,06
Tm	0,98	0,91	0,92	0,87	0,36	0,36	0,82	1,16	0,96	0,94
Yb	5,86	5,72	5,83	5,69	2,33	2,19	5	7,09	6,17	5,82
Lu	0,87	0,85	0,88	0,85	0,35	0,33	0,75	1,06	0,94	0,84
Zr/Nb	13,94	14,17	13,92	14,28	15,70	15,68	14,13	16,13	15,70	16,07
Zr/Y	5,23	4,94	5,09	4,20	3,25	2,57	3,77	5,05	4,56	5,64
Y/Nb	2,67	0,46	0,49	0,38	0,10	0,09	0,47	0,39	0,54	0,56
(La/Yb)N	4,75	4,70	4,93	3,62	2,25	2,39	3,31	4,71	4,93	5,02
Eu/Eu*	0,20	0,21	0,19	0,26	0,27	0,28	0,23	0,20	0,20	0,21
Rb/Sr	0,99	0,87	0,97	0,43	0,05	0,04	0,72	1,20	1,71	2,16
Agpaitic Index	0,673	0,657	0,667	0,561	0,241	0,24	0,579	0,742	0,736	0,705
A.S.Index	0,82	0,801	0,813	0,728	0,643	0,629	0,684	1,034	1,007	1,239

of the Alumina Saturation Index (A.S.I. = molar Al/(Na+K+Ca)) yielding values from 0.63 to 1.24. Most of the samples present a metaluminous character (A.S.I. <1), and only three of them present a weak peraluminous character (A.S.I.>1).

The samples present moderate light to heavy REE fractionation in chondrite normalized plot [(La/Yb) $_N$ = 5.02 to 2.25]. In one hand, the rhyolites and the acidic to basic dykes have very strong negative Eu anomalies (Eu/Eu* = 0.23 to 0.19), and a flat to slightly concave pattern of HREE. On the other hand, the gabbro – norite samples show a flat pattern when REE normalized against chondrite C1 (La/Yb) $_N$ = 5) and the highest values for Eu/Eu* (from 0.26 to 0.28) yielding less marked negative Eu anomalies (Fig. 8a).

The rocks analyzed do not show typical patterns in the primitive mantle normalized spidergram when compared with the early Cretaceous Santa Lucía type and Aiguá type magmas (Turner et al., 1999; Kirstein et al., 2000). Negative peaks of Ba, Nb, Sr and Pb are present. Only the rhyolitic samples do not show Pb troughs (Fig. 8b). The plutonic rocks show almost a flat pattern in primitive mantle normalized diagram. Enrichment in Ba, Th and U is observed.

Discussion and Conclusions

Field relationships, petrography and geochemistry indicate a bimodal character for San Miguel Complex and reflect the general character of extensional magmatism. This Complex is associated with a regional fault system responsible for the opening and extensional development of the Laguna Merín Basin.

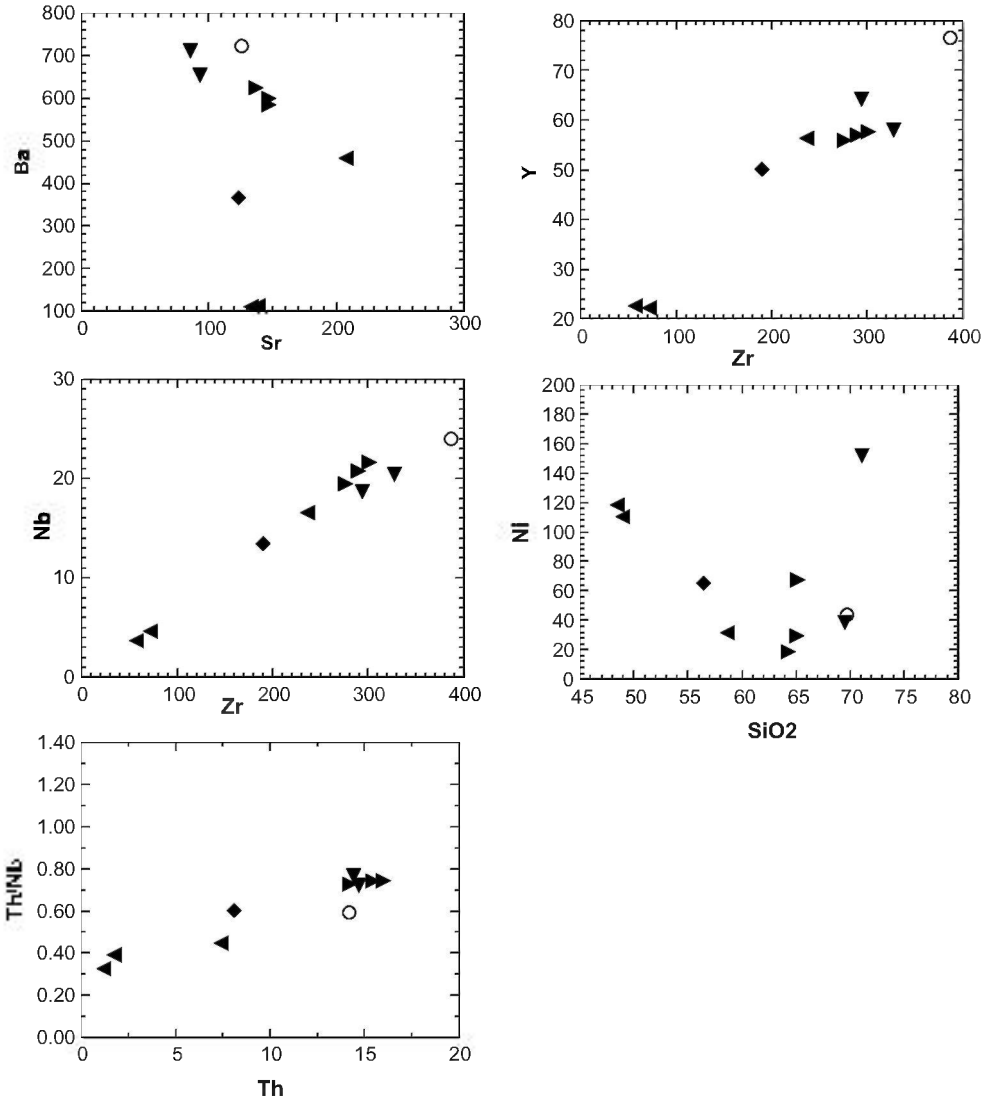

Figure 5. Trace element diagrams for samples from the San Miguel region. Symbols: ▸ felsic dykes; ▾ felsic lavas; ◂ gabbros; ♦ basic dyke; ○ granophyre.

Thus, the Sierra San Miguel morphological feature shows a clear correspondence with the main faults of the basin and the Aiguá – India Muerta – Chuy lineament, trending N60° which is also discordant with other regional structures of the Punta del Este basement.

The studied area shows structural concordance between the conspicuous foliation (N60° – 70°) exposed in the granophyres and the brittle deformation trends (E-W and N70°) affecting all the Mesozoic rocks, including the regional trend of the Sierra San Miguel

The stratigraphic array observed for the sub-volcanic/volcanic lithologies (gabbro, granophyres and rhyolites) shows that the fault system had important vertical components synchronous with the magmatic events in order to formulate a close spatial-temporal relation between these rocks. The San Miguel Gabbro should be linked with the tectomagmatic event responsible of the opening of the Laguna Merín basin

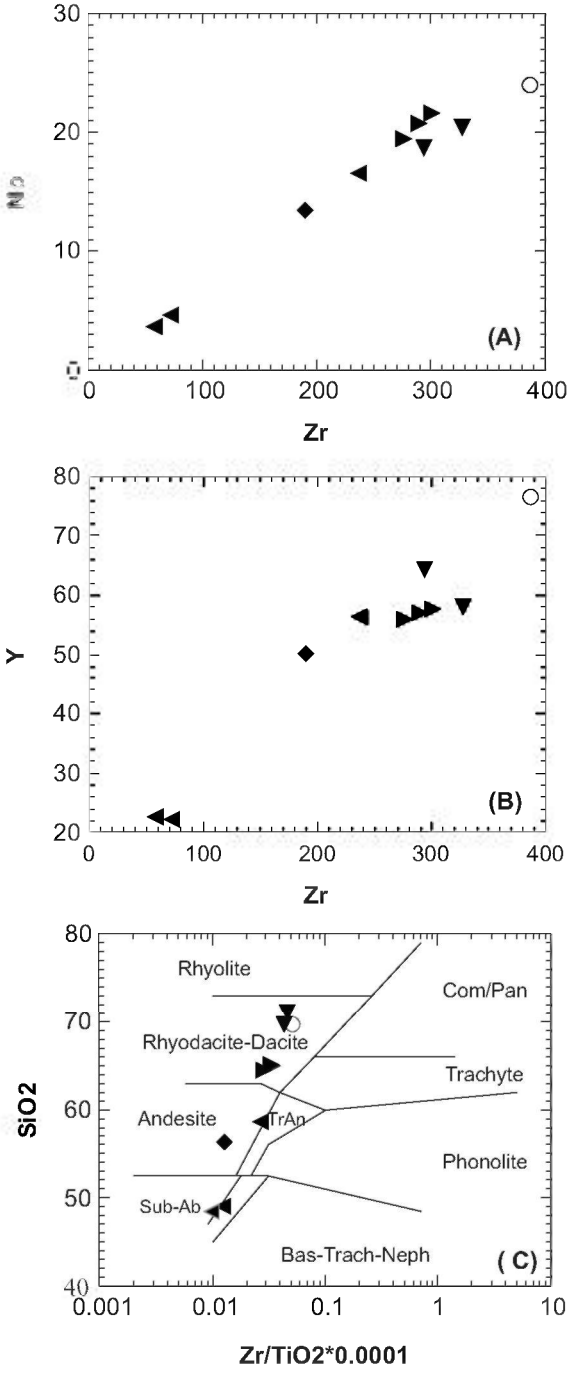

Figure 6. Trace element diagrams and trace element ratio diagram for samples from the San Miguel region. Symbols: ▸ felsic dykes; ▾ felsic lavas; ◂ gabbros; ♦ basic dyke; ○ granophyre.

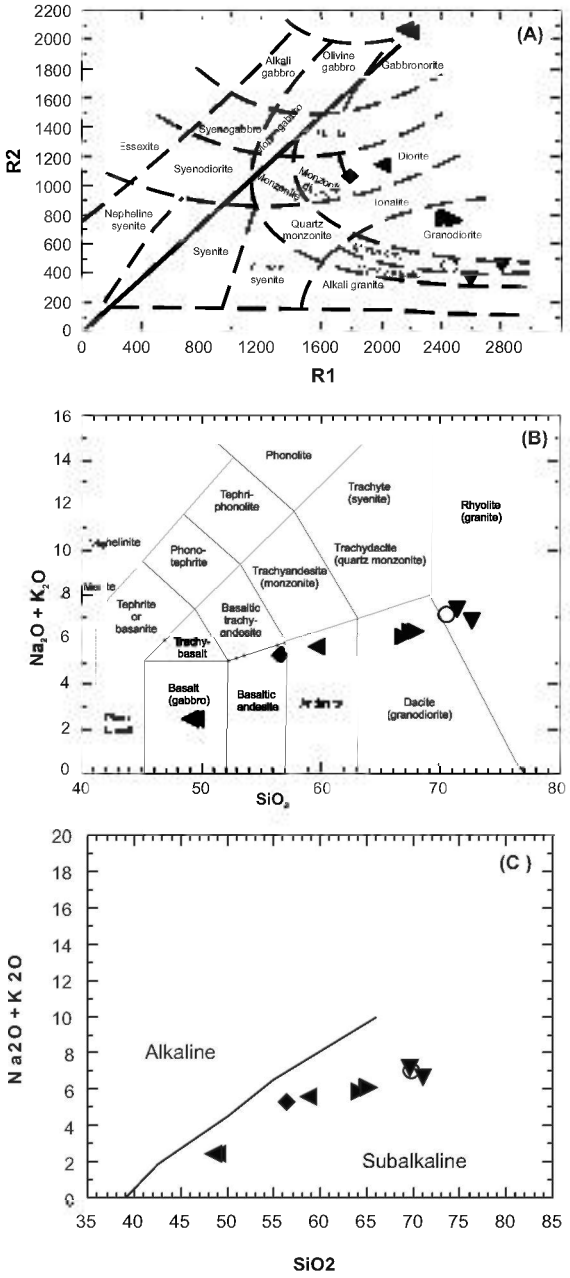

Figure 7. Classification diagrams. (A) Multicationic classification diagram (De la Roche et al. 1980) ; (B) TAS classification diagram (Le Maitre et al. 1989); (C) TAS classification diagram (Irvine and Baragar, 1971). Symbols: ▸ felsic dykes; ▾ felsic lavas; ◂ gabbros; ♦ basic dyke; ○ granophyre.

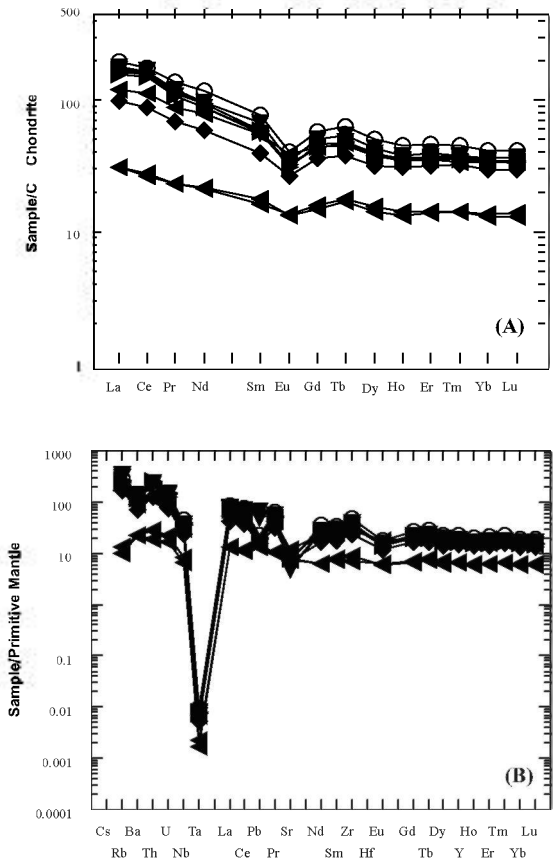

Figure 8. (A) REE patterns for samples from the San Miguel region normalized according to Taylor and Mc Lennan (1985). (B) Spider diagrams normalized according to Sun and Mc Donough (1986). Symbols: ▸ felsic dykes; ▾ felsic lavas; ◂ gabbros; ♦ basic dyke; ○ granophyre.

that also allowed the generation of a great depocentre filled by basic lavas named Puerto Gómez Formation (Bossi, 1966), based on the geological and structural framework.

These evidences allow us to point out a continuous reactivation of the basement which conditioned the faulting and jointing style that affected all the Mesozoic rocks. The structural trends presented by the dykes and the spatial arrange exposed by faults and fractures, most of them concordant with ancient planes of weakness along the basement, remark the presence of dilatants situations in agreement with the dextral sense of displacement proposed for the fault system Cebollatí – Merín and Aiguá – India Muerta – Chuy. This structural framework, according to Rossello et al. (2000) determines the development of the SaLAM lineament and was the main mechanism responsible for the genesis and tectomagmatic evolution of the Laguna Merín basin. The spatial distribution, type and volume of magmatism related to the Laguna Merín basin, allow us to suggest that it represents a magmatic pull-apart type depocentre, sub parallel to the Atlantic margin and developed in a pre-structured cratonic domain.

According to this, the volcanic rocks exposed in the eastern region of Uruguay would represent different magmatic pulses synchronous with the tectonic reactivation of the basement. This would explain the coexistence of intrusive/shallow and effusive terms in a relative short time of emplacement. As a result of the drill campaign performed by private founds near Lascano city (www.ume.com.uy), the rocks described correspond to gabbros/dolerites and granites (granophyres), providing us valuable information close to the Sierra San Miguel region. The Lascano geophysical anomaly has been interpreted as being created by gabbro to granitic (granophyres) intrusive rocks underlying a package of magnetic basalts and felsic volcanic rocks. Whatever be the trigger responsible for the genesis of this gravimetric anomaly, its development can be related to the tectonic evolution of the SaLAM lineament during the early stages of the South Atlantic opening (Rossello et al., 2007).

According to the geological background and field relationships among the different units, the basic and acidic magmatism are considered Mesozoic in age and related with the magmatic events of continental scale predecessors of the opening of the South Atlantic Ocean (Lustrino et al. 2003). Further chemical analyses should be carried out in order to explain petrogenetic correlations between these magmas and the main magma types recognized by other authors.

Acknowledgments

The Authors are grateful to the Comisión Sectorial de Investigación Científica for the financial support to

the Project "Magmatismo Mesozoico de la región sureste de Uruguay", grant 2005 - 2007. Special thanks to Dra. L.Sánchez and to the Editorial Board for the revision and helpful comments.

References

Bellieni, G.; Comin-Chiaramonti, P.; Marques, L.S.; Melfi, A.J.;. Nardy, A.J.R.; Papatrechas, C.; Piccirilo, E.M; Roisemberg, A. and Stolfa, D. (1986). Petrogenetic aspects of acid and basaltic lavas from the Paraná plateau (Brazil): mineralogical and petrochemical relationships. *Journal of Petrology* **27**: 915 – 944.

Bossi, J. (1966). *Geología del Uruguay*. Departamento de Publicaciones de la Universidad de la República, Montevideo, 460 p.

Bossi, J. 1969.

Bossi, J. and Fernández, A. (1963). Evidencias de diferenciación magmática hacia el final del Gondwana uruguayo. *Boletín da Universidade de Paraná*, Geología **Nº 9**, pp. 1 – 20.

Caorsi J. and Goñi, J. (1958). Geología uruguaya. *Boletín del Instituto Geológico del Uruguay* Nº 37, Montevideo, 79 p.

De la Roche; H.; Leterrier,J.; Grandclaude, P. and Marchal, M. (1980). A classification of volcanic and plutonic rocks using R1 – R2 diagram and major element analysis. Its relationship with current nomenclature. *Chemical Geology* **29**: 183 – 210.

Irvine, T. N. and Baragar, W.R. (1971). A guide to the chemical classification of the common igneous rocks. *Canadian Journal of Earth Sciences* **8**: 523 – 546.

Kirstein, L.A.; Hawkesworth, C.J. and Garland, F.G. (2001). Felsic lavas or rheomorphic ignimbrites: is there a chemical distinction? *Contributions to Mineralogy and Petrology* **142**: 309 – 322.

Kirstein, L.A.; Peate, D.W.; Hawkesworth, C.J.; Turner, S.P.; Harris, C. and Mantovani, M.S.M. (2000). Early Cretaceous basaltic and rhyolitic magmatism in southern Uruguay associated with the opening of the south Atlantic. *Journal of Petrology* **41**, pp. 1413 – 1438.

Le Maitre, R.W.; Bateman, P.; Dudek, A. ; Keller, J.; Lameyre, L.; Le Bas, M.J.; Sabine, P.A.; Schmid, R.; Sorensen, H.; Strekeisen, A.; Woolley, A.R. and Zanettin, B. (1989). *A classification of igneous rocks and glossary of terms*. Blackwell – Oxford Eds., 193 p.

Lustrino, M.; Gomes, C.B.; Melluso, L.; Morbidelli, L.; Muzio, R.; Ruberti, E. and Tassinari, C.C. (2003). Early Cretaceous magmatic activity in southeast Uruguay: trace element and Sr-Nd isotopic constraints. *Proc. IV South American Symposium on Isotope Geology*, Salvador, Brazil, pp. 596 – 597.

Lustrino, M.; Melluso, L.; Brotzu, P.; Gomes, C.B.; Morbidelli, L.; Muzio, R.; Ruberti, E. and Tassinari, C.C. (2005). Petrogenesis of the early Cretaceous Valle Chico igneous complex (SE Uruguay): relationships with Paraná – Etendeka magmatism. *Lithos* **82** (3/4): 407 – 434.

McPhie, J.; Doyle, M. and Allen, R. (1993). *Volcanic textures. A guide to the interpretation of textures of volcanic rocks.* Centre for Ore deposit and exploration studies. University of Tasmania, Australia, 198 p.

Muzio, R. (2000). Evolução petrológica e geocronologia do Maciço alcalino Valle Chico, Uruguay. *PhD Thesis,* Instituto de Geociências e Ciências Exâtas – Universidade Estadual Paulista, Rio Claro, Brazil, 171 p.

Muzio, R.; Artur, A.C. and Wernick, E. (2002). Petrological and geochemical evolution of the Valle Chico alkaline massif, southeastern Uruguay. *International Geology Review* **44** (4): 352 – 369.

Muzio, R.; Veroslavsky, G. and Morales, E. (2004). Geología de la Sierra de San Miguel, departamento de Rocha (Uruguay). *Actas IV Congreso Uruguayo de Geología*, Montevideo, versión CD.

Muzio, R.; Veroslavsky, G., Pascale, A.; Cabrera, J. and Furtado, A. (2005). The San Miguel gabbro and its relation with Mesozoic magmatism from southeastern Uruguay. *Anais do III Simpósio de Vulcanismo e Ambientes Asociados*, Cabo Frio, Brazil, pp. 267 – 269.

Peate, D.W. (1997). The Paraná – Etendeka Province. ***In:*** MAHONEY, J.J. & COFFIN, M.F. (Eds.) Large Igneous Provinces, Continental, oceanic and planetary flood volcanism. *Geophysical Monograph* **100**, pp. 217 – 245.

Reitmayr, G. (2001). Una espectacular peculiaridad uruguaya: la anomalía gravimétrica de Laguna Merín. *Actas XI Congreso Latinoamericano de Geología y III Congreso Uruguayo de Geología,* Montevideo, CD.

Rossello, E.; Santa Ana, H. and Veroslavsky, G. (2000). El lineamiento Santa Lucía - Aiguá - Merín (Uruguay): un corredor extensivo y transcurrente dextral preecursor de la apertura Atlántica. *Revista Brasileira de Geociëncias* **30** (4): 749 – 756.

Rossello, E.; Veroslavsky, G. and De Santa Ana, H. (2001). Influencias del lineamiento transtensivo Santa Lucía – Aiguá – Merín sobre el emplazamiento del magmatismo alcalino Cretácico del Cratón del Rio de la Plata (Uruguay): aportes a la prospección diamantífera. *Revista Brasileira de Geociencias* **31** (4): 661 – 662.

Rossello, E.; Veroslavsky, G.; Masquelin, H. and De Santa Ana, H. (2007). El corredor tectónico juro-cretácico Santa Lucía – Aiguá - Merín (Uruguay): evidencias cinemáticas transcurrentes destrales y controles estructurales preexistentes. *Revista de la Asociación Geológica Argentina* **62** (1), 92 – 104.

Shelley, D. (1992). *Igneous and metamorphic rocks under microscope*. Chapman – Hall (Eds.).

Sun, S. and Mc Donough, W.F. (1989). Chemical and isotopic systematics of Oceanic basalts: implications for mantle composition and processes. **In**: *Magmatism in oceanic basins*. Geological Society of London Special Publication **42**, 313 – 345.

Taylor, S.R. and Mc Lennan, S.M. (1985). The continental crust: its composition and evolution. Blackwell, Oxford Eds.

Ucha, N.; De Santa Ana, H. and Veroslavsky, G. (2003). La cuenca Punta del Este: geología y potencial hidrocarburífero. ***In***: *Cuencas sedimentarias del Uruguay: geología, paleontología y recursos naturales. Mesozoico*. Veroslavsky, G.; Ubilla, M. and Martínez, S. (Eds.); DIRAC - Montevideo; p. 171 – 190.

Veroslavsky; G.; Rossello, E. and de Santa Ana, H. (2002). La anomalía gravimétrica de la Laguna Merín (Uruguay): origen y expectativas en la exploración mineral. *Revista Uruguaya de Geología* Vol. **1** (2), Montevideo.

Walter, K. (1927). Contribución al conocimiento de las rocas basálticas de La Formación de Gondwana en la Sud-América. *Boletín del Instituto de Geología y Perforaciones* **Nº 9**, Montevideo, 43 p.

Winchester, J.A. and Floyd, P.A. (1977). Geochemical discrimination of different magma series and their differentiation products using immobile elements. *Chemical Geology* **20**, 325 – 343.

www. ume.com.uy , Uruguay Mineral Explorations Inc. website.