

## FIRST C AND O ISOTOPIC DATA FOR THE PIEDRAS DE AFILAR FORMATION (TANDILIA TERRANE, URUGUAY): THEIR BEARING ON ITS CORRELATION AND AGE

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### INTRODUCTION

The Piedras de Afilar Formation (PAFm) crops out in the Departamento de Canelones, southern Uruguay (Fig. 1). Type area and stratotype were located by Jones (1956) in the Cerros Piedras de Afilar. The unit occurs as an erosional relict preserved only in the newly defined Tandilia Terrane (Bossi et al., 2005; Fig. 1). Its northern boundary has been recognized as the Colonia Shear Zone (Bossi et al., 2005), which separates the Tandilia Terrane from the Piedra Alta Terrane (Bossi et al., 1993). Both terranes are mainly made up of Transamazonian (ca. 2200 to 1900 Ma) supracrustal belts and granite-gneiss areas.

The basement of the PAFm comprises amphibolite-facies metasedimentary rocks of the Montevideo Formation (Pando Belt), as well as the Soca rapakivi Granite (Oyhantçabal et al., 1998). This intrusion yielded an U-Pb SHRIMP zircon age of  $2054 \pm 11$  Ma (Hartmann et al, 2001). The PAFm rests with erosional and angular unconformity on the mentioned basement units.

In this contribution, we report preliminary C and O isotopic analyses performed on limestones at the top of the PAFm, and discuss their bearing on the age and correlations of the unit.

### LITHOSTRATIGRAPHY AND AGE

Piedras de Afilar Formation was erected by Jones (1956) as a siliciclastic, fining and thinning-upward sequence 600m in thickness. The Formation is made of quartzarenite at the base, passing into shales up section. Greenish and gray limestones occur at the top, often interbedded with shales. Diabase sills intrude the succession, especially the pelitic interval. A diabase sill has been observed at the base of the Piedras de Afilar Formation, only 10 m above the contact with the basement.

Coronel et al (1982) describe the sedimentary succession as composed, from base to top, by:

- (a) 350 m of predominantly quartzitic sandstones and shale interbeds. Cross stratification, ripple marks and flute casts were recognized.
- (b) Laminated siltstones 350 m in thickness, which are metamorphosed to hornfels at the contact with diabases.

- (c) Fine-grained, intensively folded limestones with calcitic veins.
- (d) Dolerite sills showing important alteration intrude the succession at many levels.

Coronel et al. (1982) observe two predominant directions of palaeocurrents on asymmetric ripples: N80E and N20E. Very little is known about the age of the Piedras de Afilar Formation. K-Ar datings of shales made by Cingolani et al (1990) yielded ages of  $382 \pm 11$  Ma, which are of difficult geological interpretation (age of dolerites?). Micropalaeontological studies carried out on black, pyritic siltstones of the PAFm by Gaucher (2000) yielded no identifiable fossils.

### ISOTOPIC DATA

We sampled limestone beds exposed at the Heide limestone quarry (Fig. 1), where the following succession is exposed (from base to top, Fig. 2): (a) fine-grained quartzitic sandstones, (b) gray to black, laminated shales, (c) shale-limestone interbeds, (d) gray limestones, and (e) a thick dolerite sill. The succession exposed there clearly represents a fining and thinning-upward succession, typical of the upper Piedras de Afilar Formation.

We sampled dm-thick limestone beds intercalated with laminated shales (Fig. 2), namely: (1) pink limestones at the base, (2) gray limestones in the middle, and (3) green limestones at the top. Stratigraphic distance between the samples is 1 m. Carbon and oxygen isotopic ratios of these limestones are: (1)  $\delta^{13}\text{C} = +5,13$  ‰ V-PDB and  $\delta^{18}\text{O} = -17,80$  ‰ V-PDB; (2)  $\delta^{13}\text{C} = +5,80$  ‰ V-PDB and  $\delta^{18}\text{O} = -18,05$  ‰ V-PDB; (3)  $\delta^{13}\text{C} = +5,05$  ‰ V-PDB and  $\delta^{18}\text{O} = -17,50$  ‰ V-PDB. Therefore,  $\delta^{13}\text{C}$  values consistently vary between +5.05 and +5.80 ‰ V-PDB, which is here considered as a good proxy of seawater carbon isotopic composition at the transition between the shales and carbonates of the PAFm. Regarding oxygen isotopic values obtained, they are very negative and probably reflect thermal overprint of the doleritic intrusion. Although we lack the necessary geochemical data to assess the degree of alteration of  $\delta^{13}\text{C}$  values reported here, we consider that it is negligible in view of the consistently positive values around +5.5 ‰ V-PDB,

and the fact that organic matter has not been affected by the intrusion (no decoloration).

## DISCUSSION

### AGE

$\delta^{13}\text{C}$  values between +5 and +6 ‰ V-PDB are more often encountered in Neoproterozoic carbonate successions, especially in the Cryogenian and Ediacaran (Halverson et al., 2005). Mesoproterozoic carbonates show values mostly between 0 and +3.5 ‰ V-PDB (Kah et al., 1999). Cambrian carbonates, on the other hand, are characterized by  $\delta^{13}\text{C}$  values between -4 and +2.5 ‰ V-PDB (Montañez et al., 2000). Values of +5 ‰ V-PDB occur at the Cambrian-Ordovician boundary (ca. 500-490 Ma), at the Steptoean positive C-isotope excursion (SPICE: Saltzman et al., 1998). However, an age around 500 Ma seems unlikely, because the deformation that affects the PAFm is consistently lower Cambrian in age elsewhere in the Río de la Plata Craton (Bossi & Gaucher, 2004). Although we are well aware that the available data are not enough to solve this issue, we consider a Cryogenian to Ediacaran age as the most likely depositional age of the PAFm.

### CORRELATIONS

Gaucher (2000) considered a correlation of the Piedras de Afilar Formation with the upper Arroyo del Soldado Group (Fig.1, Cerros San Francisco and Cerro Victoria Formations) possible, in view of lithological similarities. Montaña & Sprechmann (1993) and Gaucher (2000), however, pointed out that carbonates of the upper PAFm and the Cerro Victoria Formation exhibit significant differences, which challenged correlation between both units.  $\delta^{13}\text{C}$  obtained for carbonates of the upper PAFm allow to effectively rule out such a correlation. Whereas  $\delta^{13}\text{C}$  at the transition between siliciclastics and carbonates in the PAFm range between +5.05 and +5.80 ‰ V-PDB, carbonates at the transition between the siliciclastic Cerros San Francisco Formation and the dolomitic Cerro Victoria Formation yielded negative  $\delta^{13}\text{C}$  between -3.5 and -1.0 ‰ V-PDB (Gaucher et al., in press; Table 1). Moreover, nowhere in the Cerro Victoria Formation do values in excess of +0.64 ‰ V-PDB occur (Gaucher et al., in press).

If we consider the rest of the Arroyo del Soldado Group,  $\delta^{13}\text{C}$  values as high as in the PAFm only occur in the lower Polanco Formation (Gaucher et al., 2004; Table 1). Values around +5.3 ‰ V-PDB occur stratigraphically 150 m above the transition from the underlying, siliciclastic Yermal Formation (Gaucher et al., 2004). The succession, as in the PAFm, is a deepening-upward sequence (Gaucher, 2000), recording the transition from a siliciclastic shelf into a carbonate ramp. However, facies are completely different in the PAFm compared with those of the upper Yermal and lower Polanco formations. Whereas carbonates of the PAFm are thin and mostly calcitic, those of the lower Polanco Formation are very thick and characterized by limestone-dolostone rhythmites (Gaucher, 2000). No BIF, banded siltstone or

chert occur below carbonates in the PAFm, as recorded in the upper Yermal Formation beneath the basal Polanco Formation (Gaucher et al., 2004). Unless significant facies changes between the PAFm and the Yermal-Polanco formations are accepted, the correlation of these units seems unlikely.

Gaucher et al. (2005) postulate a correlation between the Sierras Bayas Group (Tandilia, Argentina) and the Arroyo del Soldado Group. These authors correlate the Cerro Largo, Loma Negra and Cerro Negro formations (Tandilia) with the Yermal, Polanco and Cerro Espuelitas formations respectively. The Villa Mónica Formation (basal Sierras Bayas Group), however, does not match any unit in Uruguay. It is made up of quartz-arenites at the base, followed by shales and stromatolitic dolostones at the top (Poiré, 1987), thus paralleling the stratigraphy of the PAFm.  $\delta^{13}\text{C}$  values in the dolostone member (Table 1) range between -0.65 and +2.2 ‰ V-PDB (Gómez Peral et al., in press), which are lower than those reported here for the PAFm. In view of the strong lithologic similarity between these units, however, more work is required to decide if they are correlative or not.

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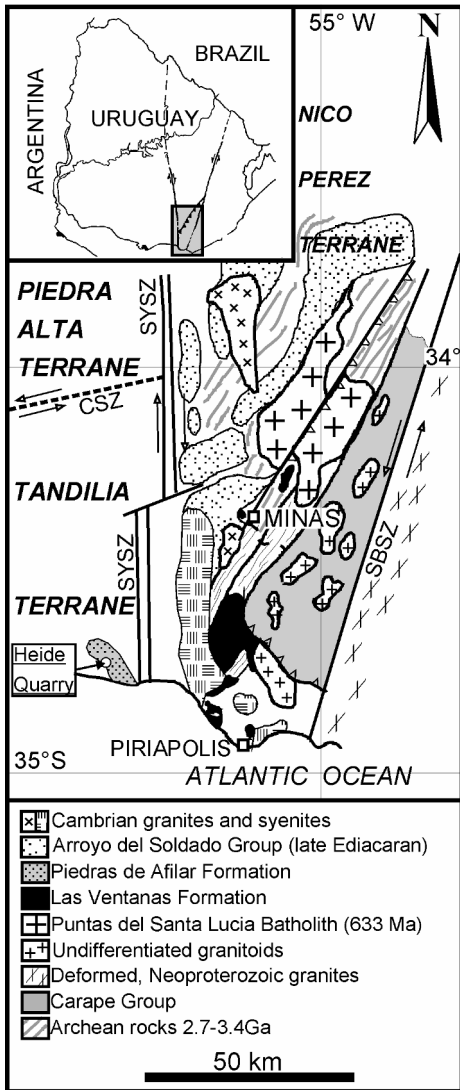
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## RESUMEN

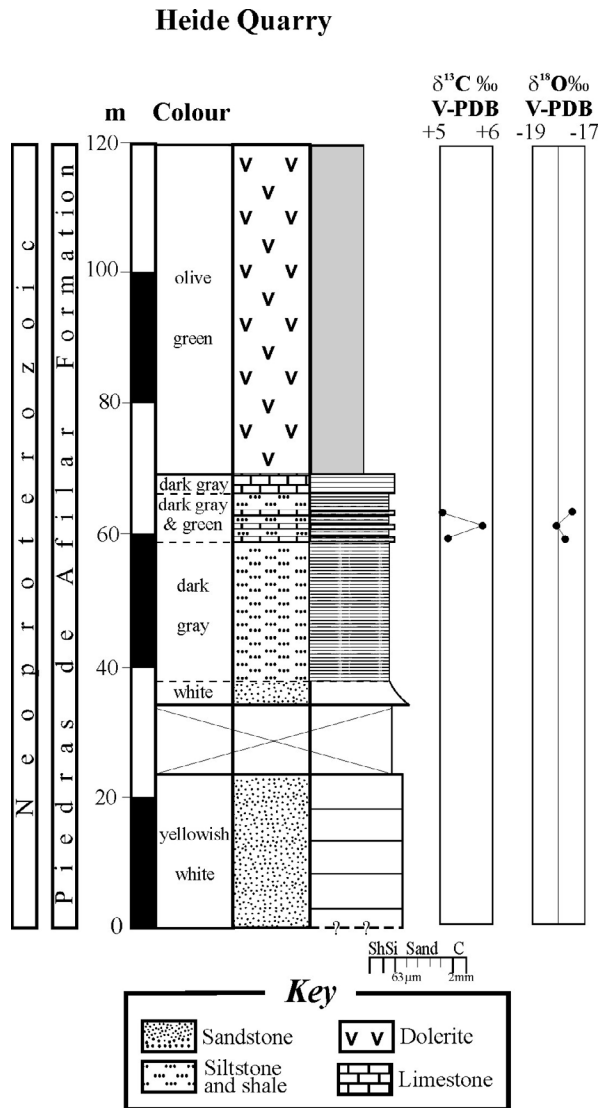
Se presentan los primeros datos isotópicos de oxígeno y carbono para carbonatos del tope de la Formación Piedras de Afilas (FmPA), Uruguay meridional. La sección estudiada en Cantera Heide muestra, de base a tope: (a) areniscas finas cuarzosas, (b) limolitas y arcillitas gris oscuro laminadas, (c) intercalaciones de limolitas gris oscuro con estratos dm de calizas, (d) calizas grises, y (e) filón-capa de dolerita. Las calizas arrojaron valores de  $\delta^{13}\text{C}$  entre +5,05 y +5,80 ‰ V-PDB, y  $\delta^{18}\text{O}$  entre -18,05 y -17,50 ‰ V-PDB. Más datos geoquímicos se requieren para determinar la naturaleza de estos valores de  $\delta^{13}\text{C}$ , pero consideramos que se acercan los valores primarios. Considerando que la deformación que presenta la FmPA no puede ser más moderna que el Cámbrico, y vistos los resultados obtenidos de  $\delta^{13}\text{C}$ , la edad de depositación más probable para la FmPA es Criogénico a Ediacarensis (Neoproterozoico). Los valores de  $\delta^{13}\text{C}$  obtenidos para la FmPA permiten descartar una correlación con el Grupo Arroyo del Soldado superior (formaciones Cerros San Francisco y Cerro Victoria), donde se han reportado valores entre -3.5 y +0.64 ‰ V-PDB. Razones de  $\delta^{13}\text{C}$  de +5.5 ‰ V-PDB se observan en el Grupo Arroyo del Soldado inferior (Formación Polanco), pero las litofacies son bastante diferentes a las de la FmPA. Finalmente, si bien valores de  $\delta^{13}\text{C}$  conocidos para la Formación Villa Mónica son más bajos (-0.65 a +2.2 ‰ V-PDB) que los de la FmPA, el parecido litológico entre ambas unidades requiere que se hagan más estudios para decidir sobre su correlación.

Stratigraphic position	Lithostratigraphic units							
	Villa Mónica Formation <sup>1</sup>		Cerro Victoria Formation <sup>2</sup>		Polanco Formation <sup>3</sup>		Piedras de Afilas Formation <sup>4</sup>	
	$\delta^{13}\text{C}$ ‰V-PDB	$\delta^{18}\text{O}$ ‰V-PDB	$\delta^{13}\text{C}$ ‰V-PDB	$\delta^{18}\text{O}$ ‰V-PDB	$\delta^{13}\text{C}$ ‰V-PDB	$\delta^{18}\text{O}$ ‰V-PDB	$\delta^{13}\text{C}$ ‰V-PDB	$\delta^{18}\text{O}$ ‰V-PDB
Top	+2.2/+1.0	-5.0 / -2.1	0 / -1.0	-6.5 / -12.0	+2.8 / -1.9	-6.0 / -13.0	+5,05/ +5,80	-17,50/ -18,05
Medium	-0.65 / 0	-4.6 / -6.7	0 / +0.64	-5.5 / -8.0	0 / -3.3	-6.1 / -10.5	No carbonates	No carbonates
Base	No carbonates	No carbonates	-3,5 / -1.0	-5.5 / -11.0	+2.6 / +5.3	-6.6 / -9.1	No carbonates	No carbonates

**Table 1:**  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  values for the PAFm and other Neoproterozoic to Cambrian carbonate successions of the Río de la Plata Craton. Sources of data: (1) Gómez Peral et al. (in press), (2) Gaucher et al. (in press), (3) Gaucher et al. (2004), (4) this work.



**Fig. 1:** Location of outcrops and geological framework of the Piedras de Afilar Formation. SYSZ: Sarandí del Yí Shear Zone, CSZ: Colonia Shear Zone (inferred), SBSZ: Sierra Ballena Shear Zone. Modified from Gaucher et al. (2005).



**Fig. 2:** Stratigraphic column of the Piedras de Afilar Formation at Heide Quarry, showing C and O isotopic data.