

OXYGEN AND CARBON STABLE ISOTOPES IN CONTINENTAL AND SHALLOW MARINE DEPOSITS OF THE SALTA BASIN (NEOCOMIAN-EOCENE), NORTHWESTERN ARGENTINA *

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ABSTRACT

Carbon and oxygen stable isotopes were analysed in limestones of the Salta rift (Cretaceous-Paleogene) of northwestern Argentina, taking into account the flooding events – both marine and lacustrine – in the basin. The organic accumulation rate was high during the main flooding events of the synrift stage, and during accumulation of the marine Yacoraite Formation in the initial postrift stage. The Maíz Gordo and Tunal Formations were deposited in lacustrine environments with less organic accumulation. The Güemes and Juramento Members of the Yacoraite Formation and base of the Lecho Formation correspond to sedimentary settings with water mixing (marine-continental). The Las Curtiembres Formation and the transition between the Amblayo and Güemes Members of the Yacoraite Formation show strong meteoric diagenesis influence.

INTRODUCTION

The Salta basin (Cretaceous-Eocene) covered a wide region of northwestern Argentina (Fig. 1). The basin fill consists of synrift deposits of the Pirgua Subgroup and postrift deposits of the Balbuena and Santa Bárbara Subgroups. The strata of the three subgroups together reach a thickness of 5,000 m, composed of redbeds with lacustrine and shallow marine flooding deposits (Salfity and Marquillas, 1994). Two main flooding events occurred during the synrift stage, corresponding to the lacustrine deposits of the Brealito Member (Cenomanian) of La Yesera Formation and the Morales Member (Campanian) of Las Curtiembres Formation (Sabino, 2004). The marine ingression of the Yacoraite Formation (Maastrichtian-Danian), occurred during the initial postrift (Balbuena Subgroup), and a saline lake established subsequently deposited the Tunal Formation (Danian) (Marquillas et al., 2005). The last main flooding recorded was during the late postrift stage (Santa Bárbara Subgroup) when the Maíz Gordo Formation (Paleocene-Eocene) was accumulated in a brackish alkaline lake (del Papa and Salfity, 1999).

In this work, the stable isotopes of the carbonate rocks of different stratigraphic levels of the Salta Group were studied (Fig.1), with emphasis on those which are representative of the flooding events of the basin. We analyzed three units of the Pirgua Subgroup: 1) The lowermost level of the basin, the Brealito Member of La

Yesera Formation in Brealito (Fig. 2), 2) Las Curtiembres Formation in the Pucará Valley, and 3) The Morales Member of Las Curtiembres Formation in Quebrada Las Conchas.

Subgroup	Formation	Member
Santa Bárbara	Lumbrera	
	Maíz Gordo	
	Mealla	
Balbuena	Tunal	
	Yacoraite	Juramento
		Alemania
		Güemes
		Amblayo
Lecho	Siete Hermanos	
Pirgua	Los Blanquitos	
	Las Curtiembres	Morales
	La Yesera	Brealito

Figure 1. Stratigraphic units of the Salta Group. Units studied in bold letters.

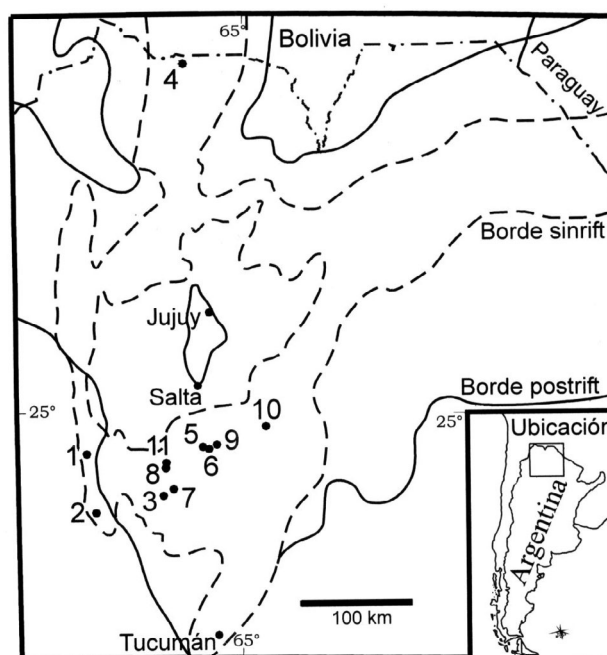


Figure 2. Location map. 1. Brealito, 2. Pucará, 3. Quebrada Las Conchas, 4. Siete Hermanos, 5. Cabra

Corral dam, 6. Quebrada El Chorro, 7. Alemania, 8. La Viña, 9. Peñas Azules, 10. Garabatal, 11. Chuñapampa.

From the Balbuena Subgroup we analyzed: 1) The limestones at the base of the Lecho Formation in the area of Cabra Corral dam, and the limestones of the Siete Hermanos Member, also located at the base of the Formation, in Siete Hermanos, 2) The different Members of Yacoraite Formation, main calcareous level of the Salta Group, in the Cabra Corral dam area and in Quebrada El Chorro (Fig.1), and 3) The Tunal Formation in Quebrada El Chorro, Alemania and La Viña (Fig. 2).

From the Santa Bárbara Subgroup was studied the Maíz Gordo Formation, second calcareous level in importance of the Salta basin. Samples from Peñas Azules, Garabatal and Chuñapampa were selected (Fig. 2).

METHODOLOGY

One hundred and seventy two samples of limestone from the different stratigraphic units of the Salta Group were analysed. These samples were screened after examination in thin sections under a polarising microscope (National University of Salta, Argentina) and analysed by X-ray fluorescence (Federal University of Pernambuco, Brazil).

The analyses were performed on whole-rock samples of micritic, sparry and stromatolite limestones. Semi-quantitative dolomite/calcite ratios were obtained by X-ray diffraction analysis in the LANAIS Laboratory at the National University of Salta, with a maximum error of 2%. The limestones of the Salta Group are often dolomitic to pure dolomites in a variable percentage.

The C and O isotope analyses, employing the conventional digestion method, were performed at the Stable Isotope Laboratory (LABISE), Federal University of Pernambuco, Brazil. Powdered samples were reacted with 100% H_3PO_4 at 25°C for one day to release the CO_2 . An extended reaction period was preferred for the dolomites (three days), rather than increasing the reaction temperature. The $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values were measured on cryogenically cleaned CO_2 in a triple collector SIRA II mass spectrometer. The C and O isotopic data are presented as deviation with reference to PDB. Borborema Skarn Calcite (BSC), calibrated against international standards, was used as the reference gas, and reproducibility of the measurements was generally better than $\pm 0.1\%$. The values obtained for the standard NBS-20 in a separate run against BSC yielded $\delta^{13}\text{C}_{\text{PDB}} = -1.05\%$, and $\delta^{18}\text{O}_{\text{PDB}} = -4.22\%$. These results are in close agreement with the values reported by the US National Bureau of Standards (-1.06‰ and -4.14‰, respectively). The external precision based on multiple standard measurements of NBS-19 was better than 0.1‰ for carbon and oxygen. For XRF analyses, fused beads were prepared using Li fluoride and Li tetraborate, and uncertainties based on the measurement of multiple standard materials by this method were over 5% for Sr and Fe and 10% for Mn.

RESULTS

The carbonate rocks of the Salta Group show wide dispersion in the isotopic values of carbon and oxygen (Fig. 3). However, the values of each stratigraphic unit are grouped in a particular field in the $\delta^{18}\text{O}$ versus $\delta^{13}\text{C}$ diagram (Fig. 3).

Carbonate rocks with positive $\delta^{13}\text{C}$ values are observed in the Brealito Member, in the basal samples of the Morales Member, in the Amblayo Member of the Yacoraite Formation where the more positive values belong to the base of the unit, and in some samples of the Alemania Member of Yacoraite Formation (Fig. 3).

The unit with the most negative $\delta^{13}\text{C}$ values is Tunal Formation, followed in increasing order by Maíz Gordo Formation, the Güemes Member and Lecho Formation. The Juramento Member of Yacoraite Formation shows $\delta^{13}\text{C}$ values close to zero.

The carbonates of Las Curtiembres Formation and those of the transition between the Amblayo and Güemes Members of Yacoraite Formation show a negative tendency towards the top in the $\delta^{13}\text{C}$ values.

Carbonate rocks with $\delta^{18}\text{O}$ positive values correspond to the Amblayo and Alemania Members of Yacoraite Formation, while the other units show negative values. Extreme negative values are observed in the Güemes Member of Yacoraite Formation, in the Tunal Formation and in an isolated sample of Maíz Gordo Formation.

The Las Curtiembres Formation and contact of the Güemes and Amblayo Members show positive correlation between $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$.

DISCUSSION AND CONCLUSIONS

The $\delta^{13}\text{C}$ positive values determined in the carbonates of the first three flooding events in the Salta basin are associated to a high organic accumulation rate. In the first two events, the Brealito and Morales Members were deposited in perennial lakes. These results are accompanied by $\delta^{18}\text{O}$ negative values characteristic of continental waters. In the case of the Amblayo and Alemania Members of Yacoraite Formation, accumulated in a restricted shallow marine environment, the $\delta^{18}\text{O}$ positive values are characteristic of marine dolomitic limestones (Marquillas et al., in press).

The Tunal Formation was accumulated in a saline lake. Here, $\delta^{13}\text{C}$ values are strongly negative, reflecting a low organic sedimentation rate during accumulation of the calcareous beds. The Juramento Member at the top of the Yacoraite Formation represents a transition between marine conditions and the saline lake setting of the Tunal Formation.

Brief flooding occurred during accumulation of the base of the Lecho Formation, especially marked by the Siete Hermanos Member, corresponding to a lacustrine environment with probably marine influence (Quattrocchio et al., 2004). This characteristic is similar to those interpreted for the Güemes Member of Yacoraite Formation, where mixed water conditions prevailed (Marquillas et al., in press).

The correlation found between $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ in Las Curtiembres Formation and in the contact of the Güemes

and Amblayo Members of Yacoraite Formation could be related to meteoric diagenesis. The extreme $\delta^{18}\text{O}$ negative values correspond to sub-aerial exposition surfaces and paleosols, as in the case of the isolated sample of Maíz Gordo Formation.

The Maíz Gordo Formation, related to the last main flooding event of the basin, shows typical lacustrine limestone values, possibly with low organic productivity.

The carbon and oxygen stable isotopes of the Salta Group calcareous rocks generally show a direct relationship of the depositional setting and diagenesis interpreted for each stratigraphic unit. The limestones of each unit can be distinguished in a $\delta^{18}\text{O}$ versus $\delta^{13}\text{C}$ diagram, showing, in some units, continuous variations that reflect modifications in environmental conditions.

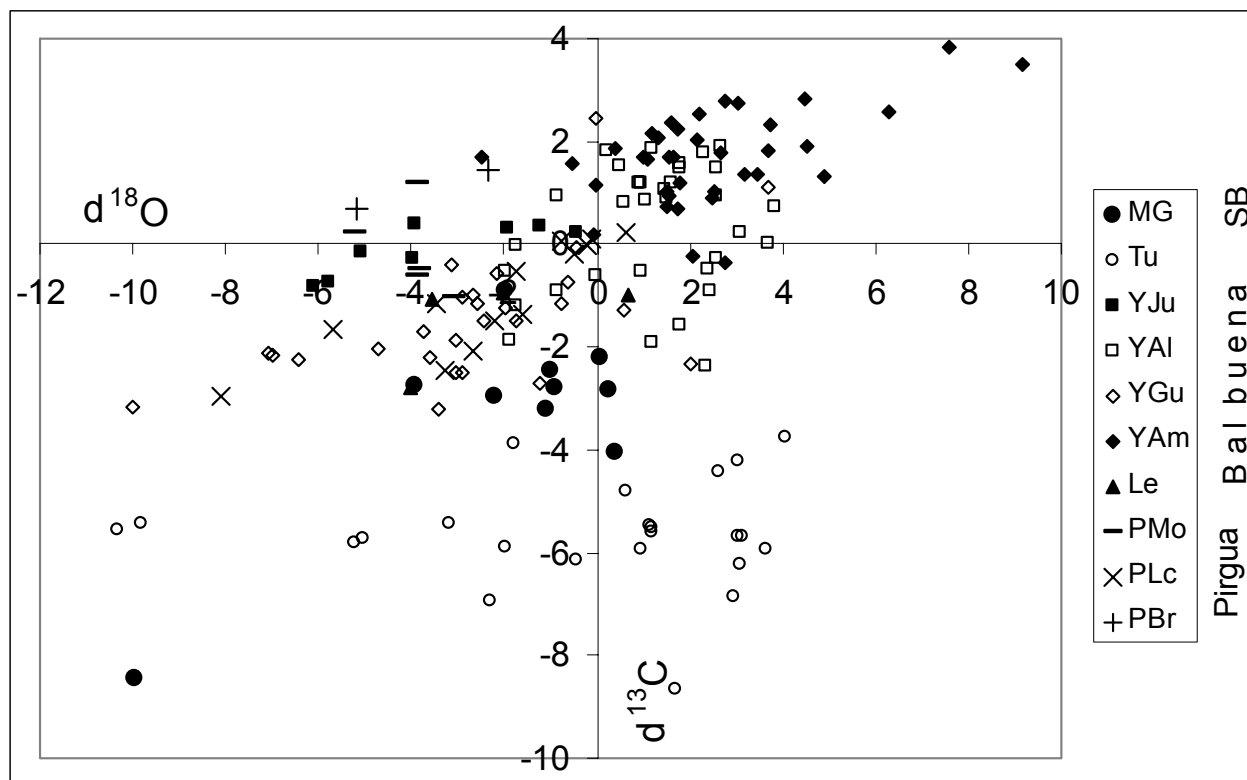


Figure 3. $\delta^{18}\text{O}$ vs. $\delta^{13}\text{C}$ (‰) diagram of carbonate rocks of the Salta Group. Pirgua Subgroup: PBR. Brealito Member, PLc. Las Curtiembres Formation, PMo. Morales Member; Balbuena Subgroup: Le. Lecho Formation, YAm. Amblayo Member, YGu. Güemes Member, YAl. Alemania Member, YJu. Juramento Member, Tu. Tunal Formation; Santa Bárbara Subgroup: MG. Maíz Gordo Formation.

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RESUMEN

Carbon and oxygen stable isotopes were analysed in limestones of the Salta rift (Cretaceous-Paleogene) of northwestern Argentina, taking into account the flooding events – both marine and lacustrine – in the basin. The organic accumulation rate was high during the main flooding events of the synrift stage, and during accumulation of the marine Yacoraite Formation in the initial postrift stage. The Maíz Gordo and Tunal Formations were deposited in lacustrine environments with less organic accumulation. The Güemes and Juramento Members of the Yacoraite Formation and base of the Lecho Formation correspond to sedimentary settings with water mixing (marine-continental). The Las Curtiembres Formation and the transition between the Amblayo and Güemes Members of the Yacoraite Formation show strong meteoric diagenesis influence.