Quebrada de la Sal magnetoestratigraphic section, Los Colorados Formación, Upper Triassic Ischigualasto-Villa Unión basin, Argentina.

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Abstract:

Ischigualasto-Villa Union basin is a continental rift developed in southwestern quarter of Pangea throughout the Triassic. Los Colorados Formation, its youngest stratigraphic unit, is formed by a continuously succession of red beds that host a paleovertebrate assemblage of biostratigraphic importance. In this work are presented the results of the first magnetostratigraphic study applied on Los Colorados Formation with the aim of global correlations. For this, a full section of 600 meters were sampled. The paleomagnetic results show two components, recognized as "A" and "C". Component C has unblocking temperature from 650°C, presents inter-site consistency and was identify as the carrier of the primary remanent magnetization with an SSW-down (reverse polarity) or NNE-up (normal polarity) orientation in different sites. The main magnetic mineral carrier is hematite and only approaches reaches saturation from 2.0 T. The magnetostratigraphic column of Los Colorados presents 16 magnetozones of normal and reverse polarity. In conjunction with published volcanic ash dates, the preferred polarity correlation for Los Colorados Formation magnetostratigraphy is between magnetochrons E7r (227 Ma) and E14n (216-215 Ma) from Newark Basin GPTS, or early to middle Norian. This result is the first step to tune the position of Los Colorados Fm. in Late Triassic Pangea.

Resumen:

El rift continental de Ischigualasto-Villa Union se desarrolló en el cuarto sudoccidental de Pangea durante el Triásico. La Formación Los Colorados (Triásico Superior) está formada por una sucesión continua de estratos rojos con una asociación paleofaunística de importancia bioestratigráfica. Con el fin de hacer correlaciones globales, se presentan los resultados del primer estudio magnetoestratigráfico aplicado en la Formación Los Colorados desarrollado en una sección completa de 600 metros estratigráficos. Los resultados paleomagnéticos muestran dos componentes, "A" y "C". La componente "C" presenta temperatura de desbloqueo desde los 650°C, consistencia intersitio y fue identificada como portadora de la magnetización remanente primaria con una orientación SSO hacia abajo (polaridad reversa) y/o NNE hacia arriba (polaridad normal). El principal mineral portador de la magnetización es hematita que alcanza la saturación desde 2.0 T. La columna magnetoestratigráfica de Los Colorados presenta 16 magnetozonas de polaridad normal y reversa En conjunto con dataciones radiométricas publicadas, la correlación preferente para la magnetoestratigrafía de la Formación Los Colorados se encuentra entre las magnetozonas E7r (227Ma) y E14n (216–215 Ma) de la escala patrón de Newark (Noriano temprano a medio). Este resultado permite ajustar la posición temporal de la Formación Los Colorados en Pangea del Triásico tardío.

Introduction

In the Triassic period the continents were assemblage forming a unique megacontinent called Pangaea. In the southwestern quarter of Pangaea the Ischigualasto-Villa Union basin was developed spanning almost all the Triassic period. This basin possess a quasi-continuously succession of 4000 meters with an exquisite and distinctive vertebrate and plant fossil record that called the interest of the scientific community worldwide (e.g. Romer y Jensen, 1966; Bonaparte, 1971; Benton, 1993; Martinez *et al* 2011). Because of this, many studies related to the tectosedimentary, paleoclimate and geotectonic evolution were developed in the basin in the last 60 years, turning it in a regional example of South American Triassic basins (e. g., Stipanicic y Bonaparate, 1979; Milana & Alcober, 1994, Colombi & Parrish, 2008). Ischigualasto-Villa Union basin (**Fig.1**) is composed by seven stratigraphic units of continental environment that evolve from alluvial fan systems of the Lower Triassic Talampaya and Tarjados Formations to lacustrine and fluvial-deltaic systems Medium to Upper Triassic of Chañares, Ischichuca and Los Rastros Formations and ends up with fluvial systems in the Upper Triassic Ischigualasto and Los Colorados Formations. There are some published dating levels spanning in the base of the basin, although most of the dates are focused in the Ischigualasto Formation.

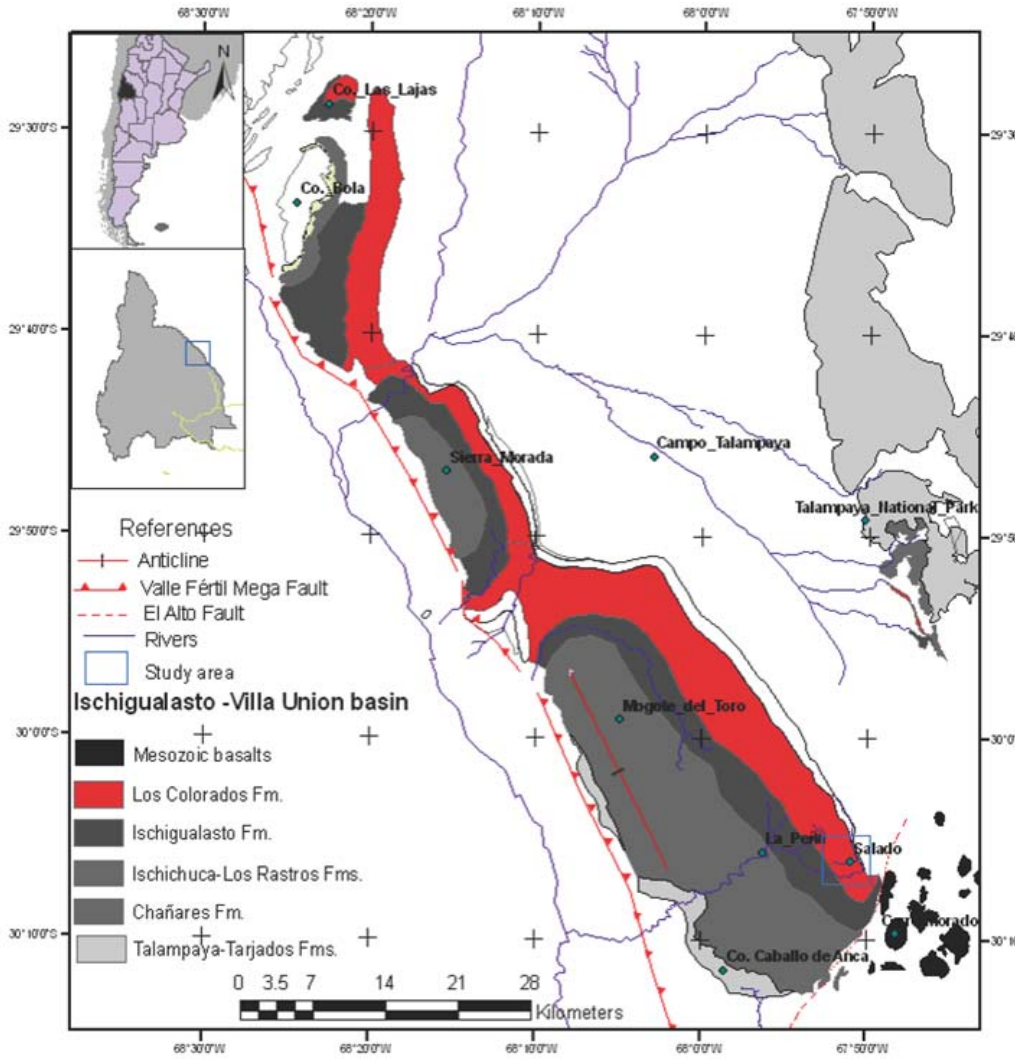


Figure 1: Ischigualasto-Villa Union basin geological map. The light blue square shows the location where this magnetostratigraphic study was accomplished

Los Colorados Formation is formed by a succession of meandering and anastomosing fluvial red beds. Its importance is based on the faunal association in the upper portion of the section, which has been used as biostratigraphic reference for the Upper Triassic assigned as *Coloradense* (Bonaparte, 1973). This faunal association is considered unusual because its variety of taxa where typical Triassic specimens are present with specimens of Jurassic affinities (Arcucci *et al*, 2003; Apaldetti *et al*, 2009; Martinez *et al* 2011). The biostratigraphic correlation of this faunal association with Santa Maria basin from Brazil, and Karoo Basin from South Africa allowed to position Los Colorados Formation as Norian (e.g. Bonaparte, 1971;1973). Nevertheless, some authors questioned this temporal position and propose that Los Colorados faunal association could be younger (Rhaetian or close to the Triassic/Jurassic boundary) (e.g. Lucas, 1998; Martinez, 2002).

The lack of radiometric dates as well as studies of high resolution correlation of Los Colorados have led to the exclusion of this fauna from global compilation and global evolution models, especially for the time that Los Colorados Formation might represent. With the purpose of looking elements for global correlation of high temporal resolution a magnetostratigraphic study has been started in Los Colorados Formation. Magnetostratigraphy was chosen because it shows to be a versatile element very useful in Triassic correlations with the accomplishment of the Geomagnetic Polarity Time Scale for the Upper Triassic - Lower Jurassic in the Newark basin, NE US (GPTS, Kent *et al* 1995; APTS Kent y Olsen, 1999; Kent y Olsen, 2008).

In this work we present a magnetostratigraphic column of Los Colorados Formation in Quebrada de la Sal section, located in the southern margin of the basin. The 600 meters section includes nearly 60 sites were chosen to encompass a complete magnetostratigraphic section, tuned with an ash level dated (Martinez *et al* 2011) located in the top of Ischigualasto Formation. The red beds of Los Colorados have an excellent response to the paleomagnetic analysis offering a complete magnetostratigraphic section. This section was correlated with the pattern section for the Upper Triassic of Newark basin (APTS Kent y Olsen, 1999) obtained a temporal adjustment of this unit. The new temporal approximation of the Los Colorados section sets a new temporal frame for its faunal association and creates new inquiries about Pangea big picture for Upper Triassic.

Sampling and Laboratory procedures:

The chosen section for this study (Quebrada de la Sal) has 600 meters of stratigraphic thickness. The sequence is homoclinal with strike NW-SE and dip to the NE.

The paleomagnetic sampling consists in the extraction of 3 to 5 samples per site, with a total of 60 sites. The section starts in the top of Ischigualasto Formation, in the ash level that was radiometric dated in 225.9 ± 0.9 Ar/Ar (Martinez *et al*, 2011). For the fieldwork a portable battery drill was used whit a diamond drill core of 1 inch and 10 cm length. The cores were oriented in the field with an orientation device which has a Brunton compass embedded.

The laboratory procedures consist on the preparation of specimens, the measurement of its natural remanent magnetism, demagnetization techniques and IRM analysis in a low field environment (<300μT) of a shielded room in the Lamont Doherty Earth Observatory, Columbia University. Thermal demagnetization techniques were selected to look for the characteristic remanent magnetization component. The heating and forced coolness of the specimens in each step was done in a thermal demagnetizer in which local shielding reduces ambient magnetic fields. The components of remanent magnetism were measured in each step in a 3 axis cryogenic magnetometer model 2G 760. The magnetic susceptibility of each specimen was controlled in a Bartington instrument along the procedure to find out

any magneto-chemistry alteration. The routines chosen for thermal treatment were two, one of 11 steps and another one of 13 steps: 0, 100, 200, 300, 400, 500, 550, 600, 625, 650, 660, 670, 675° C, increasing the detail closer to magnetite and hematite Curie temperatures. The evolution of each specimen during the process was visually monitored and all the data analyzed in specific software (e.j. Super IAPD)

Results and analysis

The natural remanent magnetism of Los Colorados Formation (Fig.2) consist of unless two components name A and C. Component A is present in all the samples population and is removed between 200-300°C. This component represents magnetic mineral that has not been identify in the IRM analysis, and because of its random orientation per site no common origin has been assigned to it. Component C is presented in all the samples population and possesses intra and inter-site consistency with an unblocking temperature between 650°C to 675°C which has been interpreted as the carrier of the characteristic remanent magnetization. To establish each specimen components the analysis of principal components was used (PCA, Kirschvink, 1980). Component C was determined selecting the last five steps of thermal demagnetization between 600 and 675°C, anchored to the origin with a MAD tolerance until 15 degrees. The average orientation of component C is SSW-down for reverse polarity and NNE-up for normal polarity orientation in different sites. Reversal test was also applied and it classify as type C (McFadden & McElhinny, 1990) suggesting that the results support the GAD model. Magnetic properties of component C were identified through an IRM analysis (isothermal remanent magnetization analysis) and the Intensity vs T° curve from the thermal cleaning. The IRM shows a stable and high coercitivity element that approaches reaches saturation from 2.0 T and was identify as hematite. The Intensity vs T° curve shows that the intensity of magnetization in general falls to zero from the 650°C supporting the hypothesis of the presence of hematite as the magnetic carrier of component C. Moreover the test of Kruiver *et al* (2001) was applied looking for any other low cohercitivity magnetic mineral but the model with two magnetic minerals shows more residuals than the one with just hematite, confirming the presence of hematite as the only magnetic mineral unless for the medium and upper section of Los Colorados Formation. The results of the study were 16 normal and reverse polarity intervals. The methodology followed to define the magnetozones are based in Kent *et al* (1995) where each magnetozone couplets is defined by two or more successive samples with similar polarity. The nomenclature of each magnetozone was assign with the initials LC + number + “n” or “r” according if it is a normal or reverse polarity interval. Magnetozones couples were designed from the first normal polarity interval as Kent *et al* (1995) in the way of improving the magnetostratigraphic correlation.

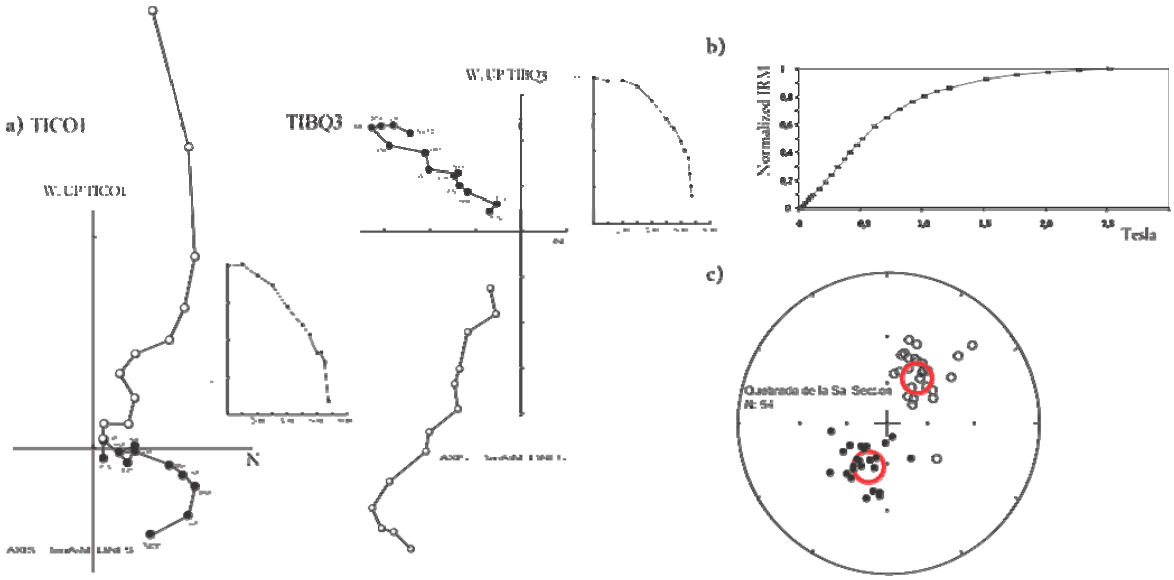


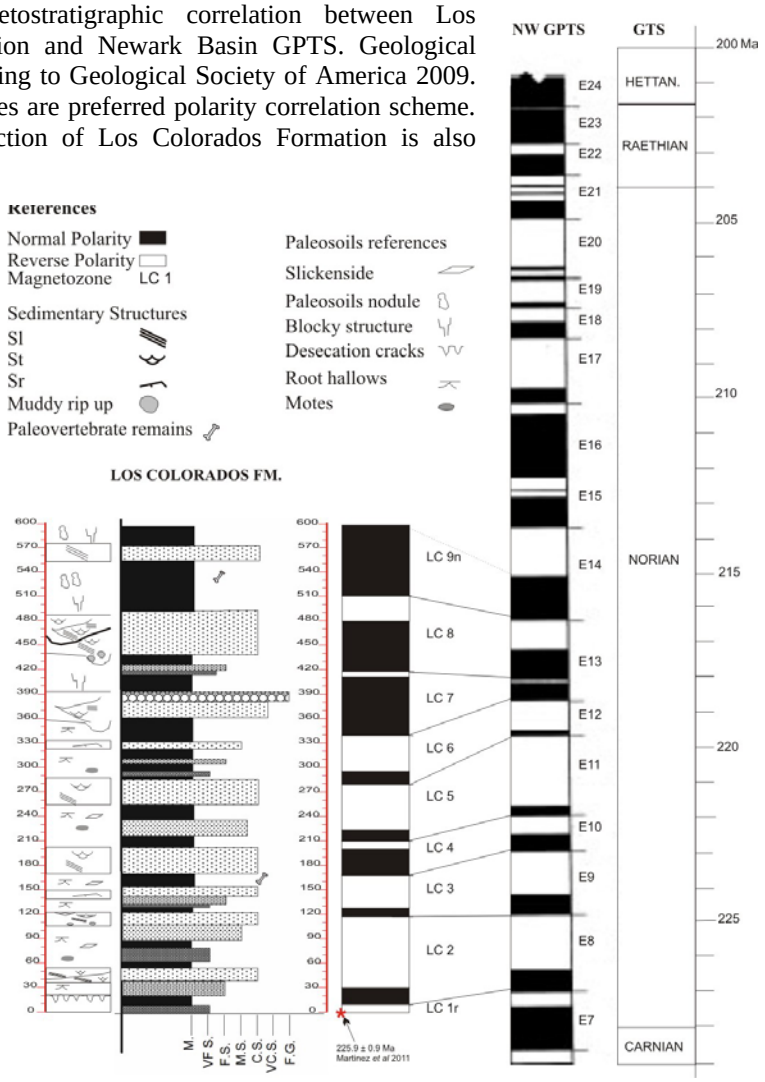
Figure 2: a) Vector end-point demagnetization diagrams of natural remanent magnetization of representative samples from Quebrada de la Sal section, with open and closed symbols plotted on vertical and horizontal axes, respectively, in geographic coordinates, with thermal demagnetization diagram in Celsius Degrees. b) IRM of representative sample, in this case a very fine sandstone c) Equal-area projection of sites with C component in geographic coordinates. The red open circle represents the average orientation of C in normal and reverse sites.

The magnetostratigraphic section was adjusted by radiometric dating published in Martinez *et al* (2011) of 225.9 ± 0.9 Ma located at the base of the section. According to the polarity correlation pattern with the GPTS, Newark section, Los Colorados Formation falls between the magnetozones E7r to E14n from the pattern section (Fig 3). This correlation means that Los Colorados Formation spent 12.5 Ma to be deposited from 227.5 to 215 Ma in the margin of the basin. Using this results it is possible to consider an average sedimentation rate of 0.048 mm/y that match with the rate of sedimentation expected from the geotectonic environment consider for Los Colorados Formation, which is a postrift stage (Milana y Alcober, 1994). In addition, conclusions may be drawn regarding the age of Coloradense fauna that after this study is consider around 215-217 Ma, Middle Norian.

Conclusions

Quebrada de la Sal is a 600 meters section located in the southeastern margin of Ischigualasto-Villa Union basin, where a complete magnetostratigraphic section of Los Colorados Formation was done. The magnetic properties of Los Colorados red beds shows that hematite is the main magnetic carrier of the primary remanent magnetization, observed in all the variety of lithologies. According to the polarity correlation, Los Colorados Formation span from magnetozones E7r to E14n of the GPTS, Newark basin. This means that Los Colorados Formation starts it deposition around 227.5 and ends it earlier than expected, nearly 215 Ma, in Mid Norian. This study also locates Los Colorados faunal association between 217 to 215 Ma far away from the Rhaetian (202 Ma) as it was usually located base on its regional and global faunal association correlations (e.g. Lucas, 1998; Martinez *et al* 2011).

Figure 3: Magnetostratigraphic correlation between Los Colorados Formation and Newark Basin GPTS. Geological Time Scale according to Geological Society of America 2009. The correlation lines are preferred polarity correlation scheme. A sedimentary section of Los Colorados Formation is also shown



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