



## THE PERVASIVE SANRAFAELIC REMAGNETIZATION IN CARBONATES: ROCK MAGNETIC STUDY ON SAMPLES FROM THE LA FLECHA FORMATION (LA RIOJA PROVINCE, ARGENTINE PRECORDILLERA)

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### ABSTRACT

Rock-magnetic experiments, petrographic studies and X-ray diffraction analyses were applied on remagnetized carbonates from the Upper Cambrian La Flecha Formation (Quebrada La Angostura, Precordillera de La Rioja, Argentina) carrying a pre-tectonic Permian secondary magnetization with the aim to extend the knowledge of the widespread Sanrafaelic overprint which affected most of the early Cambrian to mid-Ordovician units of the Argentine Precordillera and the San Rafael Block.

**Keywords:** Sanrafaelic remagnetization, remagnetized carbonates, rock-magnetic properties, magnetic fabrics, Precordillera de La Rioja

### RESUMEN

Experimentos de magnetismo de rocas, estudios petrográficos y análisis de difracción de rayos X fueron aplicados a carbonatos remagnetizados de la Formación La Flecha del Cámbrico Superior (Quebrada La Angostura, Precordillera de La Rioja, Argentina), portadora de una magnetización pérmica secundaria pre-tectónica, con el objetivo de ampliar el conocimiento sobre la remagnetización regional Sanrafaélica, la cual afectó la mayor parte de las unidades del Cámbrico temprano al Ordovícico Medio de la Precordillera Argentina y del Bloque San Rafael.

**Palabras clave:** Remagnetización Sanrafaélica, carbonatos remagnetizados, propiedades magnéticas de rocas, Precordillera de La Rioja

### 1. Introduction

The widespread Sanrafaelic Permian overprint (Rapalini, Tarling, 1993; Truco, Rapalini, 1996; Rapalini *et al.*, 2000; Rapalini, Astini, 2005; Font *et al.*, 2012; Rapalini, 2012) owes its relevance to the extreme difficulty that represents to obtain primary magnetizations from most Early to Middle Paleozoic sedimentary rocks of the Argentine Precordillera and the San Rafael Block, two fragments of the allochthonous Cuyania terrane (Astini *et al.*, 1995; Thomas, Astini, 2003; Ramos, 2004; Rapalini, 2012). The location of the remagnetized geological units and the time of the overprint portray a particular scheme (those in the Western Precordillera were affected during the early Permian while those in the Eastern Precordillera were overprinted during the late Permian) which was interpreted as the result of a temporal-spatial migration of the remagnetizing front caused by an eastward expulsion of fluids from the orogenic area (Rapalini, Astini, 2005). The Sanrafaelic event is characterized by a lithological control. The rocks affected by the Sanrafaelic phenomena belong, in general, to the Cambro-Ordovician carbonate platform but dolomitized grainstones and red siltstones to very fine-grained sandstones of the Cerro Totora Formation (Precordillera of La Rioja; Rapalini, Astini, 1998) and siliciclastic sedimentary rocks of the Pavón Formation (San Rafael Block; Rapalini, Cingolani, 2004) present a primary magnetization.



Though recent rock-magnetic research on remagnetized calcareous units of the Argentine Precordillera and the San Rafael Block have provided new insights into the characterization of the pervasive Sanrafaelic overprint (Fazzito, Rapalini, 2016; Fazzito *et al.*, 2017) further studies to clarify the chemical and physical processes responsible for the event are still required. In this sense, the preliminary results of a rock-magnetic study on remagnetized carbonates from the Upper Cambrian La Flecha Formation (Quebrada La Angostura, Precordillera de La Rioja, Argentina), carrying a pre-tectonic Permian secondary magnetization, are reported.

## 2. Experimental procedures

The research was performed on specimens of limestones and dolostones (9 sites) previously collected by Rapalini and Astini (2005) from the Upper Cambrian La Flecha Formation (Los Sapitos facies, Marjuman-Steptoean) at Quebrada La Angostura (Precordillera de La Rioja). The rock-magnetic studies include several methodologies such as acquisition of isothermal remanent magnetization (IRM), thermal demagnetization of triaxial IRM, magnetization hysteresis, variation of magnetic susceptibility with temperature and frequency and field dependence of magnetic susceptibility. Magnetic fabrics studies were accomplished by low-field anisotropy of magnetic susceptibility (AMS; freq: 976 Hz,  $H_{\text{peak}} = 200 \text{ Am}^{-1}$ ) and anisotropy of anhysteretic magnetic remanence (AARM;  $B_{\text{dc}} = 50 \mu\text{T}$ ,  $B_{\text{ac}} = 90 \text{ mT}$ ). Transmitted and reflected light optical microscopy of thin sections and X-ray diffraction analysis complement our investigation.

## 3. Results

The multiple methodologies suggest that the secondary magnetization is borne by fine-grained titanopoor magnetite. Pyrrhotite, hematite and goethite are present in most samples, though these are in general subordinate carriers of NRM. Hematite and goethite content is confirmed by light optical microscopy, apart from pyrite, which was observed in one site.

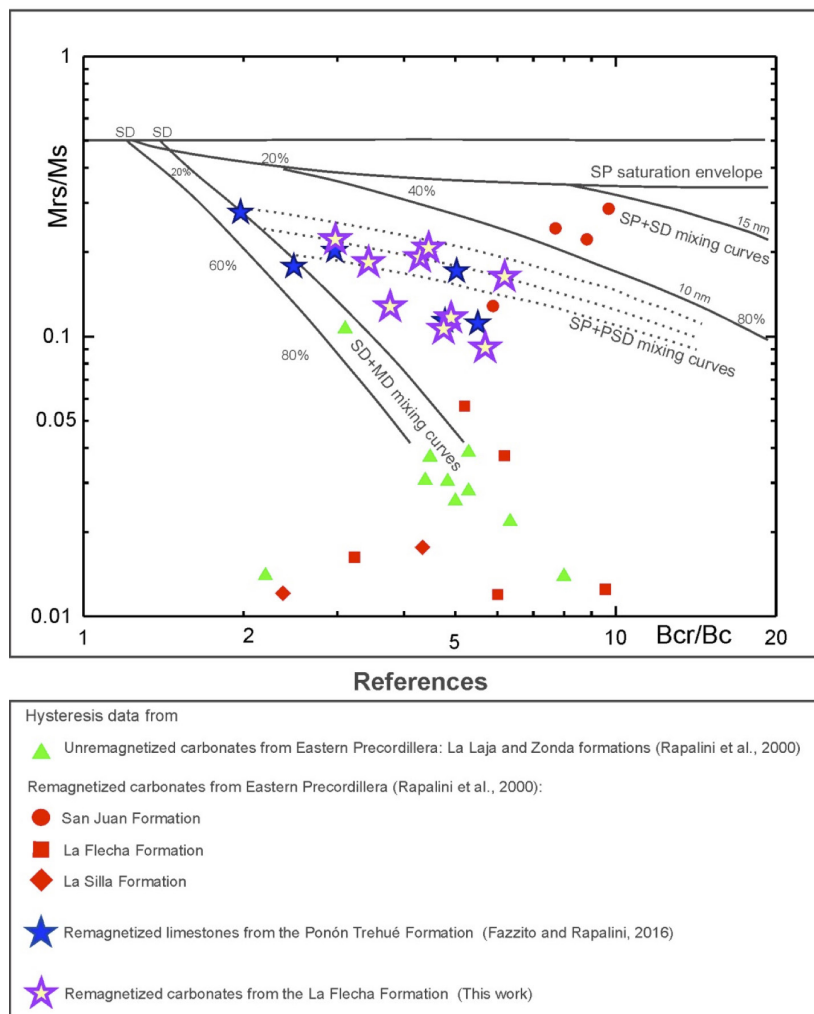
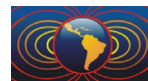
Typical signatures of remagnetized carbonates, as high values of frequency dependence parameter and wasp-waisted hysteresis loops, were identified. The variation of magnetic susceptibility with frequency argues in favour of a significant presence of SP magnetite.

Hysteresis parameters for samples of the La Flecha Formation (Precordillera de la Rioja) plotted on a Day-type diagram are compared with theoretical curves for magnetite (Dunlop 2002), though some influence of high coercivity minerals cannot be discarded. The data are distributed in the area of SP+PSD particle size, between the SD+MD and the 10nm-SP+SD mixing curves, pointing to the existence of ultrafine magnetite (Fig. 1). The set of parameters from the La Flecha Formation (Quebrada La Angostura) are distributed in a similar way as those of the remagnetized limestones from the San Rafael Block (Ponón Trehué Formation, Mendoza province; Fazzito, Rapalini, 2016; Fig. 1) suggesting that some units affected by the Sanrafaelic remagnetization show a magnetic fingerprint.

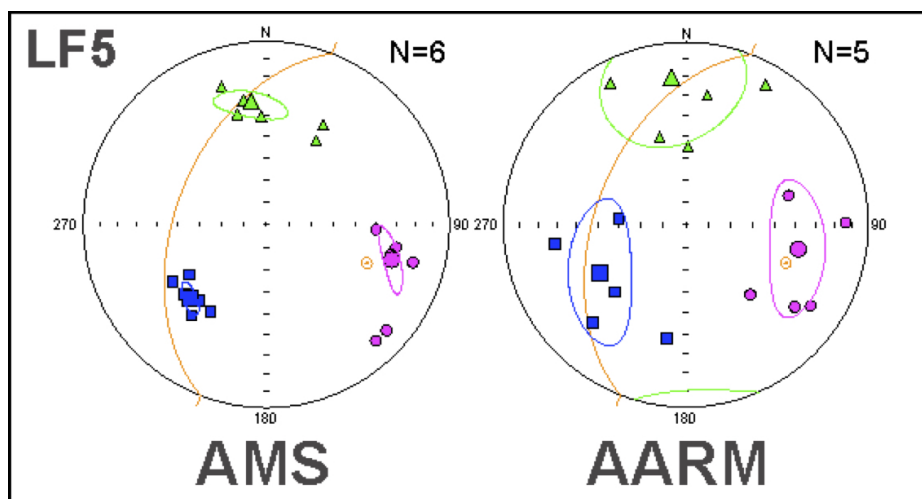
AMS and AARM fabrics are in general normal (e.g. site LF5; Fig. 2). Orientation of anisotropy of magnetic susceptibility and anhysteretic remanence ellipsoids are consistent for several sites which reveals fabrics with overlapping of vertical bedding and horizontal tectonic compaction (e.g. site LF5; Fig. 2). For other sites, the discrepancies between AMS and AARM ellipsoids indicate that the AMS is the result of superimposition of different subfabrics.

Lack of clay content supported by X-ray diffraction (XRD) analyses in one powdered sample per site discards a creation of secondary magnetite originated in the alteration of smectite into illite by chemical alteration during burial diagenesis (Katz *et al.*, 2000).

At the present moment, the detailed rock-magnetic study of samples from the La Flecha Formation (Quebrada La Angostura, Precordillera de La Rioja) is in progress.



**Figure 1.** Hysteresis parameters from Eastern Precordillera samples unaffected (green triangles) and affected (red squares, circles and diamonds) by the Sanrafaelic event (Rapalini *et al.*, 2000), remagnetized limestones from the San Rafael Block (Ponón Trehué Formation, blue stars) and remagnetized carbonates from the La Flecha Formation (violet/yellow stars; this work) on a Day-type plot with theoretical mixing curves for magnetite (Dunlop, 2002).



**Figure 2.** AMS and AARM plots in equal-area projection, lower hemisphere, for site LF5 from the La Flecha Formation (Quebrada La Angostura, Precordillera de La Rioja) in the geographic coordinate system. Maximum, intermediate and minimum principal directions of anisotropy of magnetic susceptibility and anhysteretic remanence are indicated by square, triangle and circle symbols, respectively. Confidence regions (95%) of mean axes (Jelinek, 1978) are indicated by ellipses. The bedding plane is indicated by the yellow arc.



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## References

- Astini, R. A., Benedetto, J.L., Vaccari, N.E., 1995. The early Paleozoic evolution of the Argentine Precordillera as a Laurentian rifted, drifted and collided terrane: a geodynamic model, *Geol. Soc. Am. Bull.* 107 (3), 253-273.
- Dunlop, D.J., 2002. Theory and application of the Day plot (Mrs/M s versus  $H_{cr} / H_c$ ) 1. Theoretical curves and tests using titanomagnetite data. *J. Geophys. Res.* 107 (B3), 2056.
- Fazzito, S.Y., Rapalini, A.E., 2016. Magnetic properties of the remagnetized Middle-Ordovician limestones of the Ponón Trehué Formation (San Rafael Block, central-western Argentina): insights into the Permian widespread Sanrafaelic overprint, *J. South Am. Earth Sci.* 70, 279-297.
- Fazzito, S.Y., Rapalini, A.E., Poiré, D.G., 2017. The Sanrafaelic remagnetization revisited: Magnetic properties and magnetofabrics of Cambrian-Ordovician carbonates of the Eastern Precordillera of San Juan, Argentina, *J. South Am. Earth Sci.* 79, 67-94.
- Font, E., Rapalini, A.E., Tomezzoli, R.N., Trindade, R.I.F., Tohver, E., 2012. Episodic Remagnetizations related to tectonic events and their consequences for the South America Polar Wander Path. In D. Elmore et al. (eds) *Remagnetization and Chemical Alteration of Sedimentary Rocks. Geological Society, Special Publication 371*, 55-87.
- Jelínek, V., 1978. Statistical processing of anisotropy of magnetic susceptibility measured on groups of specimens, *Studia Geoph. Geod.* 22, 50-62.
- Katz, B., Elmore, R.D., Cogoini, M., Engel, M.H., Ferry, S., 2000. Associations between burial diagenesis of smectite, chemical remagnetization, and magnetite authigenesis in the Vocontian trough, SE France. *J. Geophys. Res.* 105, 851-868.
- Ramos, V.A., 2004. Cuyania, an exotic block to Gondwana: Review of a historical success and the present problems, *Gondwana Res.* 7 (4), 1009-1026.
- Rapalini, A.E., 2012. Paleomagnetic evidence for the origin of the Argentine Precordillera, fifteen years later: what is new, what has changed, what is still valid?, *Latinmag Letters*, 2 (1), LL12-0102Rv, 1-20.
- Rapalini, A.E., Astini, R.A., 1998. Paleomagnetic confirmation of the Laurentian origin of the Argentine Precordillera, *Earth Planet. Sci. Lett.* 155, 1-14.
- Rapalini, A.E., Astini, R.A., 2005. La remagnetización sanrafaélica de la Precordillera en el Pérmico: Nuevas evidencias, *Revista de la Asociación Geológica Argentina* 60, 290-300.
- Rapalini, A.E., Cingolani, C.A., 2004. First Late Ordovician Paleomagnetic Pole for the Cuyania (Precordillera) Terrane of Western Argentina: a Microcontinent or a Laurentian Plateau, *Gondwana Res.* 7 (4), 1089-1104.
- Rapalini, A.E., Tarling, D.H., 1993. Multiple magnetizations in the Cambrian-Ordovician carbonate platform of the Argentine Precordillera and their tectonic implications, *Tectonophysics* 227, 49-62.
- Rapalini, A.E., Bordonaro, O., Berquo, T.S., 2000. Paleomagnetic study of Cambrian-Ordovician rocks in the Eastern Precordillera of Argentina: some constraints on the Andean uplift of this block, *Tectonophysics* 326, 173-184.
- Thomas W.A., Astini, R.A., 2003. Ordovician accretion of the Argentine Precordillera terrane to Gondwana: a review, *J. S. Am. Earth Sci.* 16, 67-79.
- Truco, S., Rapalini, A.E., 1996. New evidence of a widespread Permian remagnetizing event in the central andean zone of Argentina, 3rd International Symposium on Andean Geodynamics (ISAG 96), 799-802, Saint-Malo, Francia, 17-19 de septiembre.