CAMBRIAN-ORDOVICIAN REMAGNETIZED CARBONATES OF THE ARGENTINE EASTERN PRECORDILLERA: PRELIMINARY RESULTS ON MAGNETIC PROPERTIES

Sabrina Y. Fazzito[1], Augusto E. Rapalini[1,2]

[1] IGEBA (CONICET-UBA), Buenos Aires, Argentina

[2] Universidad de Buenos Aires, Dpto. Ciencias Geológicas, Buenos Aires, Argentina

ABSTRACT

Palaeomagnetic evidence has suggested that the Lower Palaeozoic carbonatic platform of the Argentine Precordillera was affected by a regional event of remagnetization occurred during the Late Palaeozoic, possibly related to the Sanrafaelic Orogeny. Though detailed magnetic mineralogy research in these carbonates could provide clues to the geologic processes involved in this phenomenon, systematic study is still necessary. The present work presents the preliminary results on the magnetic properties of five Middle Cambrian to Early Ordovician carbonatic formations (limestones to dolomites) exposed in the Eastern Precordillera which carry a post-folding magnetization assigned to a Permian age and associated to the Sanrafaelic remagnetizing event.

Keywords: remagnetized carbonates, magnetic properties, Sanrafaelic remagnetization, San Juan province, Argentine Precordillera

Introduction

Several palaeomagnetic studies carried out on the Cambro-Ordovician carbonatic platform of the Argentine Precordillera and in the Ordovician limestones of the San Rafael Block have not succeeded in finding a primary remanent magnetization (Rapalini, Tarling, 1993; Truco, Rapalini, 1996; Rapalini *et al*., 2000; Rapalini, Astini, 2005). Yet, supported by palaeomagnetic data, a widespread remagnetization Permian event affecting these carbonatic units was suggested and associated to the Sanrafaelic orogenic phase (Rapalini, Tarling, 1993).

Evidence of a secondary magnetization was found for the first time by Rapalini and Tarling (1993) in the Early Ordovician San Juan Formation, which is exposed on the Eastern and Central Precordillera of Argentina (provinces of San Juan, La Rioja and Mendoza). This remagnetizing event has also been interpreted as responsible for the Early Permian syntectonic magnetization of the Carboniferous clastic sediments of Hoyada Verde Formation (Rapalini, Tarling, 1993), the Early Permian syntectonic remagnetization of the Upper Ordovician Alcaparrosa Formation (Vilas, Valencio, 1978), the Early Permian syntectonic magnetization of the limestones of the Middle-Ordovician Ponón Trehué Formation in the San Rafael Block (Truco, Rapalini 1996), the Permian postectonic magnetization of the Early Ordovician San Juan Formation in the Central Precordillera (Rapalini, Tarling, 1993), the Upper Permian pretectonic remagnetization of the Upper Cambrian La Flecha Formation in La Rioja Precordillera (Rapalini, Astini, 2005) and the postectonic magnetization of the Upper Cambrian-Early Ordovician La Flecha, La Silla and San Juan Fm (Rapalini *et al*., 2000). Considering results of polar positions, types of magnetization, polarities and geographical distribution of the remagnetized units, a temporal-spatial migration pattern was proposed by Rapalini and Astini (2005), in which the geological units in the Western Precordillera were remagnetized during Early Permian and the Eastern Precordillera units were remagnetized during Late Permian, as a consequence of fluids expelled from the orogenic area (Rapalini, Astini, 2005).

Though several carbonatic units of the Argentine Precordillera seem to have been affected by the remagnetization process (Rapalini, Astini, 2005), detailed studies of magnetic properties of the lithologies involved are scarce at the moment. In this work, acquisition of isothermal remanent magnetization (IRM) and anisotropy of magnetic susceptibility (AMS) measurements, were performed in order to better constrain the type and size of the carriers of the magnetization and characterize the matrix minerals and their fabric. The units studied were the Middle Cambrian to Early Ordovician carbonates (limestones to dolomites) of the Eastern Precordillera of San Juan province, which belong to La Laja, Zonda, La Flecha, La Silla and San Juan Formations and whose palaeomagnetic properties were studied previously by Rapalini *et al*. (2000, fig. 1 and fig. 2b). In three of these formations (La Laja, La Silla and San Juan), a postectonic high coercitivity component was interpreted as a Permian remagnetization by Rapalini *et al*. (2000), possibly related to the Sanrafaelic orogenic event. A low coercitivity component of Recent magnetization (consistent with the geocentric axial dipole) was found in the five formations.

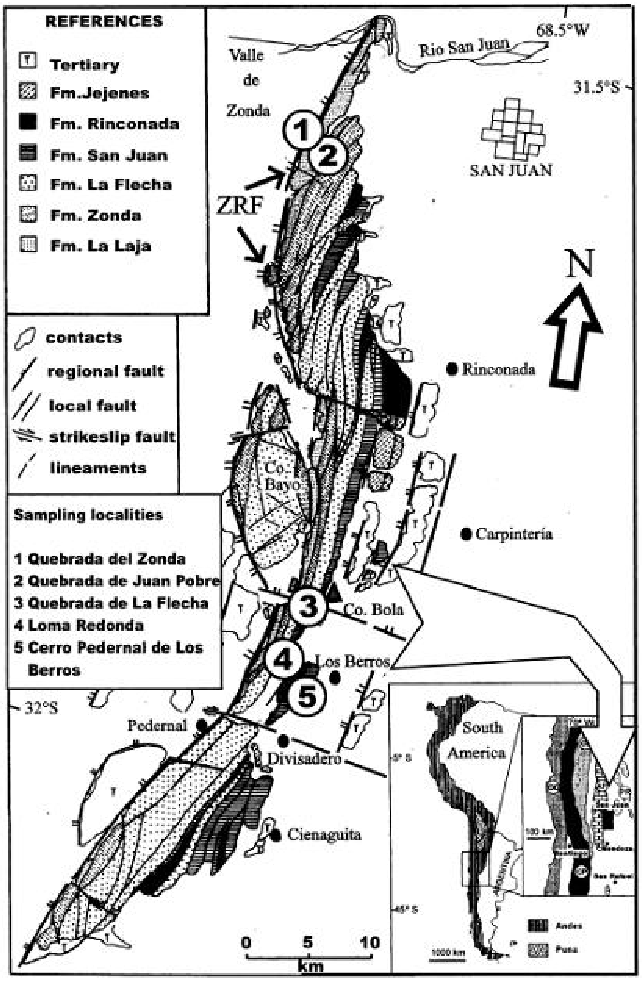

Figure 1. Palaeomagnetic sampling localities (numbers 1 to 5) in geologic map of Sierra Chica de Zonda and Cerro Pedernal (Eastern Precordillera). After Rapalini *et al*. (2000). ZRF: Zonda regional fault.

Methodology

The rock collection under study comprises 151 specimens remaining from the previous palaeomagnetic study developed by Rapalini *et al*. (2000). In Figure 2b it is observed the stratigraphic distribution of the palaeomagnetic sites (La Laja Fm: sites JS1 to JS6; Zonda Fm: sites JS7 to JS10; La Flecha Fm: sites JS11 to JS16; La Silla Fm: sites JS17, JS22 and JS23; San Juan Fm: sites JS18 to JS 21).

Different methods were applied in order to find out the type and size of the magnetic carriers of the magnetization and the minerals that contribute to the magnetic susceptibility. In general, isothermal remanent magnetization (IRM) curves were acquired for one sample per site with an ASC Scientific (IM-10-30) pulse magnetizer, with a maximum field of 2.3 T. A spinner magnetometer AGICO (JR-6) was used for every remanent magnetization measurement. Anisotropy of magnetic susceptibility in low field (Hpeak = 200 Am^{-1}) was measured at the 23 sites with a Kappabridge Susceptibilimetre AGICO (MFK1-FA).

Results and discussion

IRM acquisition curves showed four distinct behaviours (Fig. 3a, b and c). These were compared with acquisition curves compiled by Symons and Cioppa (2000). The first type (T1, Fig. 3a), is represented only by the site JS22 and it is characterized by a rapid acquisition of saturation (SIRM), approximately at 750 mT, which suggests the presence of a ferrimagnetic mineral, as magnetite or pyrrhotite. In the second type of curve (T2, Fig. 3a) a ferrimagnetic mineral is also present, but a lower increment with magnetic field may

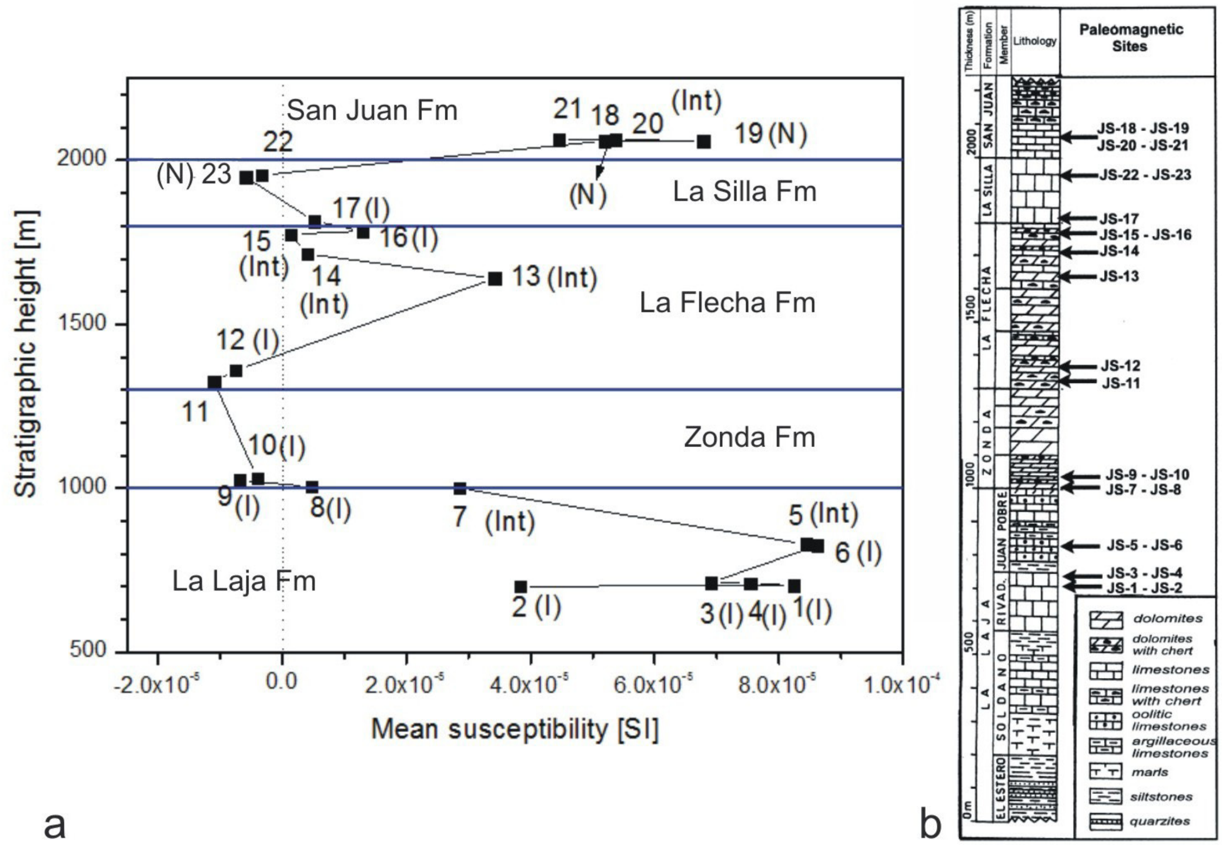

Figure 2. a) Stratigraphic distribution of mean susceptibility (JS sites are indicated by numbers) and fabric type (I: inverse; Int: intermediate; N: normal). b) Stratigraphic distribution of palaeomagnetic sites (after Rapalini *et al*., 2000).

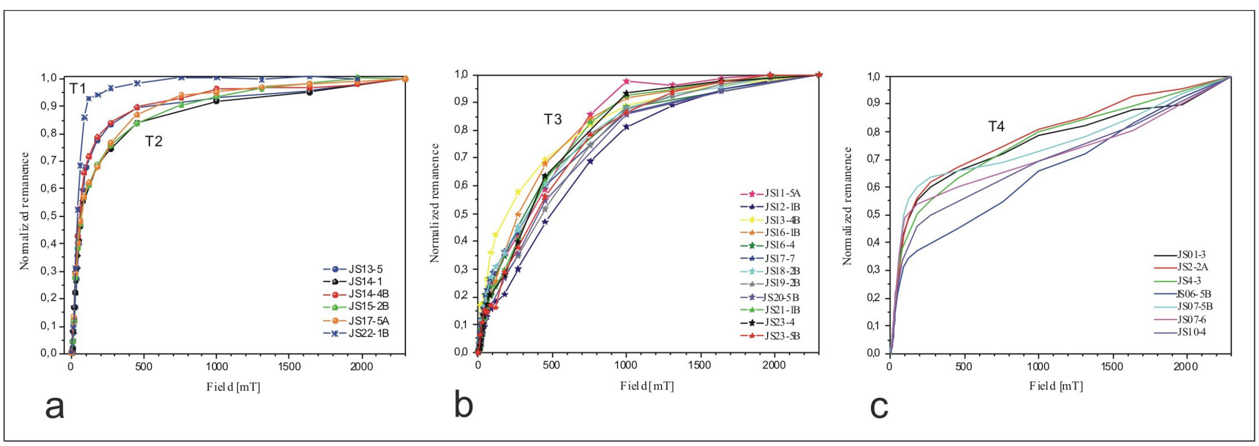

Figure 3. IRM acquisition curves. Four different types of behaviours (T1 to T4) have been distinguished.

indicate dominion of SD particles. The third type of curve (T3, Fig. 3b) presents a ferrimagnetic component at low concentration and an antiferromagnetic component, which may be fine grained haematite. The fourth type (T4, Fig. 3.c) shows a low coercitivity magnetic mineral, probably in a higher concentration than the type T3, and a dominant antiferromagnetic component, maybe coarse grained haematite.

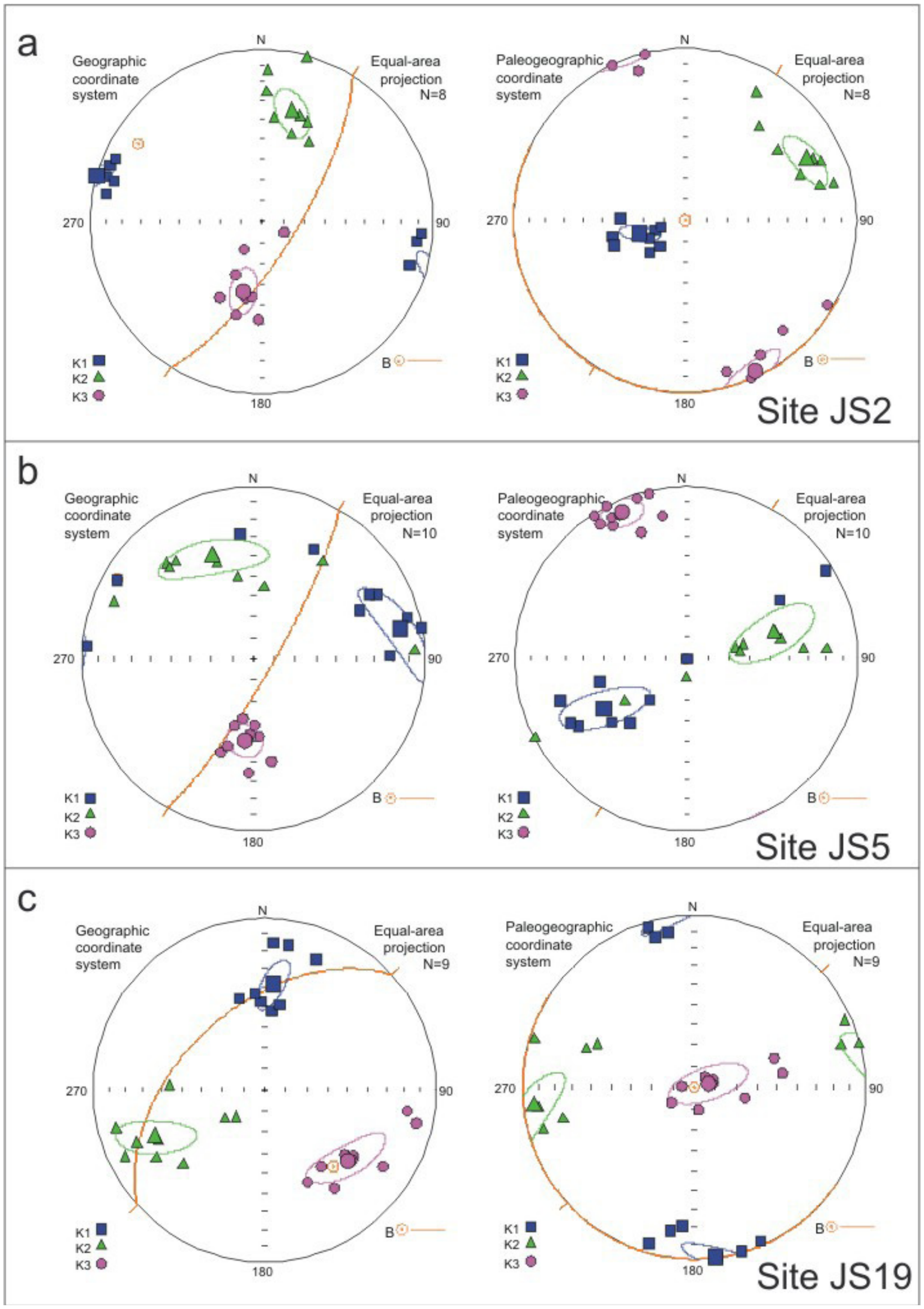

Figure 4. Examples of the three different types of magnetic rock fabric found in the collection of rocks. a) Inverse fabric (site JS2). b) Intermediate fabric (site JS5). c) Normal fabric (site JS19). Left: Geographic coordinate system. Right: Palaeogeographic coordinate system.

It is particularly observed that all the measured samples from La Laja and Zonda Fm. (localities 1 and 2, in the lowest part of the stratigraphic sequence) belong to the T4 type. The samples collected in the following formation, La Flecha (locality 3), are divided between the T2 and T3 type. The next formation, La Silla (localities 3 and 5), has the most variable behaviour. Three samples are T3 type, one sample T2 type, and one sample T1 type. All the samples from San Juan Fm (locality 4, at the top of the stratigraphic sequence) are characterized by T3 curves.

The sites with T4 curves (JS1 to JS10) showed only a low coercitivity component erased at temperatures below 350°C (Rapalini *et al*., 2000). The nine sites that were considered to calculate the Permian palaeopole (JS11, JS13, JS14, JS16, JS17, JS20, JS21, JS22 and JS23; Rapalini *et al*., 2000), whose magnetization was unblocked at temperatures between 350 and 500°C, are characterized by curves T1, T2 or T3. In particular, the natural remanent magnetization was reduced in more than 70% at temperatures around 350°C, which suggests that pyrrhotite or maghemite may be the carrier of the remagnetization.
Values of mean susceptibility (between -7.5 x 10^{-6} and 8.6 x 10^{-5} SI, see Fig. 2.a) indicate that the magnetic fabrics are dominated by diamagnetic and paramagnetic minerals. This property suggests that the magnetic susceptibility is likely dominated by the matrix minerals more than by the carriers of magnetization. Quantitative analysis of anisotropy parameters of sites whose mean susceptibility spans from – 5.0 x 10^{-6} to 5.2 x 10^{-6} (i.e. is almost zero) is obviated as suggested by Hrouda (2004). These sites (JS8, JS10, JS14, JS15, JS17 and JS23) present unusual high anisotropy parameter (P) which would not be connected with the magnetic fabric (Hrouda, 2004). In general, it has been observed that the bedding pole coincides with the k1 or k3 axis of the susceptibility ellipsoid. The orientation of the AMS ellipsoid with respect to the bedding plane permits to define three types of magnetic fabric. Three sites at the top of the section (JS19, JS22 and JS23, in La Silla and San Juan Fm) are characterized by normal fabric (see Fig. 4), i.e. k3 normal to the bedding plane, while eleven sites present inverse fabric (k1 normal to bedding). The latter dominate the lower part of the section, in La Laja, Zonda and La Flecha Fm. In seven sites the magnetic fabric is intermediate. Those sites whose magnetic fabric type is not specified in Figure 2a have not enough number of samples to perform a statistical analysis.
Measurements of magnetic properties have demonstrated that the magnetic fabric for pure calcite (diamagnetic mineral) as for phyllosilicates (paramagnetic minerals) is normal (Rochette, 1988; Rochette *et al*., 1992). An inverse magnetic fabric due to matrix minerals is expected in iron-bearing carbonates, where the paramagnetic anisotropy dominates (Rochette, 1988; Rochette *et al*., 1992). These properties may indicate the presence of iron-bearing carbonates at the lower part of the sequence and a higher content of phylosillicates at the top. An analogue situation has been reported by Winkler *et al.* (1996) in a marly sequence.

Conclusions

The four different behaviours of IRM curves show that there is a stratigraphic control of the carriers of magnetization, where high coercitivity minerals are specially distributed in the lower part of the sequence. Most of the curves are consistent with a bimineralic mixture of a low coercitivity mineral and a high coercitivity mineral. Pyrrhotite could be a possible ferrimagnetic carrier of the remagnetization.
In the lower part of the sequence, where inverse magnetic fabrics are frequent, iron-bearing carbonates may dominate the mineral content, while in the upper part, where normal magnetic fabrics have been observed, a higher concentration of phyllosilicates is expected. Intermediate magnetic fabrics dominate the central part of the sequence. The fabric types have not a direct relation with the values of mean magnetic susceptibility; inverse magnetic fabrics are present in sites with negative mean susceptibility and also in sites with positive mean susceptibility; the higher susceptibility values are both observed at the top and at the bottom of the sequence. This characteristic may also be an indication of stratigraphic (lithological) control.
Further studies on magnetic properties, as back-field demagnetization of SIRM, acquisition of anhysteretic remanent magnetization (ARM), demagnetization of ARM, anisotropy of ARM, thermomagnetic curves for magnetic susceptibility, frequency dependence of magnetic susceptibility and field variation of magnetic susceptibility, are in progress.

Acknowledgements

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