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ANISOTROPY OF MAGNETIC SUSCEPTIBILITY ANALYSIS IN CORES OF TUNAS FORMATION (PERMIAN), CLAROMECÓ BASIN, BUENOS AIRES, ARGENTINA: IT RELATION WITH DEPOSITIONAL CONDITIONS

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ABSTRACT

Claromecó Basin (Buenos Aires Province, Argentina) is composed by carboniferous-permian rocks that lie on a Paleozoic basement. The PANG 0003 well, located in the center of the basin, contains rocks from the Tunas Formation. The succession is composed by sandstone, mudrock, carbonaceous mudrock, coal and tuff. The aim of this work is to analyze the internal structure of cores through anisotropy of magnetic susceptibility (AMS) studies and to relate these parameters with depositional and post-depositional conditions. Additionally, the aim is to compare the results with previous outcrop data of the Tunas Formation. Standard AMS study was carried out from the base to the top of the well. AMS parameters vary with depth. Magnetic susceptibility (K_{mean}) presents an average of 209 x10^{-6} SI, consistent with the presence of paramagnetic minerals. Anisotropy degree (P_j) values increase with depth due to overburden. The shape parameter (T) mainly range from 0 < T < 1 indicating oblate fabric. As the cores are not oriented, K_{max} axis lie distributed in the Equatorial plane, near the horizontal, while K_{min} axis position are near the vertical, perpendicular to the bedding plane, with horizontal attitude indicating a triaxial to sedimentary fabric. These results are consistent with those obtained from the outcrops that indicate efforts attenuating upwards of the sequence and toward the foreland basin located to the east. This kind of study allows increasing the knowledge about the basins as Claromecó, currently considered as frontier basin.

Keywords: AMS parameters, frontier basin, Tunas Formation, Claromecó Basin, Gondwana, Paleozoic.

RESUMEN

La cuenca del Claromecó (provincia de Buenos Aires, Argentina) está compuesta por rocas carboníferas-pérmicas del basamento paleozoico. El pozo PANG 0003, ubicado en el centro de la cuenca, contiene rocas que pertenecen a la Formación Tunas. La sucesión está compuesta por areniscas, fangolitas, fangolitas calcáreas, carbón y tobas. El objetivo de este trabajo es analizar la estructura interna de testigos a través de estudios de anisotropía de susceptibilidad magnética (AMS) y relacionar estos parámetros con las condiciones deposicionales y post-deposicionales. Además, el objetivo es comparar los resultados con datos de afloramientos previos de la Formación Tunas. El estudio estándar de AMS se realizó desde la base hasta la parte superior del pozo. Los parámetros de AMS varían con la profundidad. La susceptibilidad magnética (K_{mean}) presenta un promedio de 209 x10^{-6} SI, consistente con la presencia de minerales paramagnéticos. El grado de anisotropía (Pj) aumenta con la profundidad debido a la sobrecarga. El parámetro de forma (T) varía principalmente de 0 < T <1 que indica fábricas oblatas. Como los núcleos no están orientados, el eje K_{max} se encuentra distribuido en el plano ecuatorial, cerca de la horizontal, mientras que la posición del eje K_{min} está cerca de la vertical, perpendicular al plano de la estratificación, con una actitud horizontal que indica una fábrica triaxial a sedimentaria. Estos resultados son consistentes con los obtenidos de los afloramientos que indican esfuerzos que se atenúan hacia arriba de la secuencia y hacia la cuenca de antepaís ubicada al este. Este tipo de estudio permite aumentar el conocimiento sobre las cuencas como Claromecó,

actualmente considerado como cuenca frontier.

Palabras claves: Parametros de AMS, Cuenca Frontier, Formación Tunas, Cuenca Claromecó, Gondwana, Paleozoico.

1. Introduction

Claromecó Basin (Carboniferous-Permian), is located at the south of Buenos Aires province, Argentina, it belongs to the southwest part of the Late Paleozoic Gondwana supercontinent. The basin is composed of Carboniferous-Permian rocks that lie horizontal on a Paleozoic basement. According to Ramos (1984) and Rosello and Lopez Gamundi (1992) it is considered a foreland basin. It has economic potential based on coal beds and associated methane gas, recorded underground (Lesta and Sylwan 2005; Arzadún 2015; Arzadún *et al.,* 2017; Febbo *et al.,* 2018). The PANG 0003 well (S37° 34.0' 44.24', W61° 22.0' 12.56'') is located in the basin center, at the northeast of Sierras Australes, Buenos Aires, Argentina (Fig. 1). Based on its lithological and fossiliferous content, these rocks are assigned to Tunas Formation (Harrington 1947). Their sequences are represented by medium to fine sandstone, mudrock, carbonaceous mudrock, coal seams and tuff (Arzadún *et al.,* 2016, 2018). Tunas Formation outcrops are at the eastern portion of the Sierras Australes, from the north of "Sierras de las Tunas" to the south of "Sierra de Pillahuincó", small outcrops are near Gonzalez Chavez and Mariano Roldán (Monteverde 1937; Furque 1965; Llambías, Prozzi 1975; Tomezzoli y Vilas, 1997, Febbo *et al.,* 2018). Outcrops are integrated by medium to fine green sandstone, interbedded with siltstone and claystone, and thin pyroclastic levels (Harrington 1947, Andreis *et al.,* 1979, López Gamundi 1996). Presence of *Glossopteris* flora (Archangelsky, Cúneo 1984) and radiometric isotopic dating suggest a Permian age (Alessandreti *et al.,* 2013; López Gamundi *et al.,* 2013, Arzadún *et al.,* 2018). Considering the deformation in the Sierras Australes, the south-west sector include belts with higher deformation sequences than those in the northeastern region, which belongs to the center of the basin with low grade of deformation. AMS and compaction studies in the Tunas Formation shows a decrease in the magnitude of deformation during the Permian toward the foreland region (Arzadún *et al.,* 2016). Based on AMS and paleomagnetic studies, some authors assume that tectonism began during the Late Devonian - Carboniferous and continue until Late Permian as a result of microplates collision with Gondwana (Tomezzoli 2012, Arzadún *et al.,* 2016; Tomezzoli *et al.,* 2018).

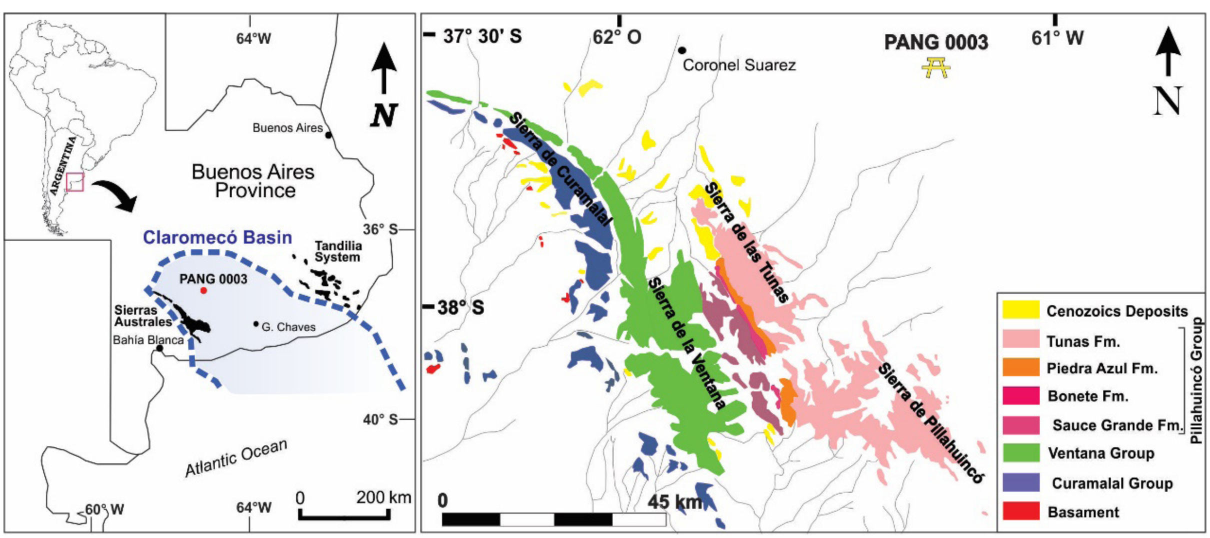

Figure 1. Location of Claromecó Basin and PANG 0003 well.

The aim of this work is to analyze the internal structure in cores through anisotropy of magnetic susceptibility (AMS) studies and to relate these parameters with depositional and post-depositional (diagenesis) conditions. Additionally, we compare these results with previous outcrop data of the Tunas Formation from the Sierras Australes area.

2. Samples and methods

AMS is a useful tool to study rock petrofabric from preferred orientation of magnetic minerals into a rock or unconsolidated sediments (Hrouda 1982; Tarling, Hrouda 1993). Rocks typically reflects the preferred crystallographic orientation, and the shape and distribution of magnetic minerals, hence AMS results depend on mineralogy, lithology and grain size, compaction and tectonic efforts acting during overburden. Standard AMS study was carried out from the base to the top of the PANG 0003 well (901 meters below wellhead, mbw) with 432 specimens measured. Samples were not oriented. Measurements of AMS were accomplished using a MFK1-FA Kappabridge at "Daniel Valencio" Paleomagnetic laboratory at the Universidad de Buenos Aires, IGEBA-CONICET. The obtained parameters were mean susceptibility (K_{mean}), corrected anisotropy degree (P_j; Jelínek, 1978), shape parameter (T), foliation (F) and lineation (L). Shape parameter describes the shape of the ellipsoid; positive/negative values of T indicate oblate/prolate fabrics respectively (Jelínek, 1978).

3. AMS results

The stratigraphic record of PANG 0003 well consists of sedimentary rocks belonging to the Tunas Formation (Fig. 2). The sequence is integrated by carbonaceous mudrock and coal beds interbedded with medium to fine sandstone at the base, and fine sandstone interbedded with green mudrock, thin tuff levels and coal seams to the top. Measured AMS parameters are variable with depth. Mean magnetic susceptibility (K_{mean}) ranges from 20 x 10^{-6} SI to 540 x10^{-6} SI with an average of 209 x10^{-6} SI. Sandy facies exhibit a weak susceptibility due to the presence of diamagnetic minerals as inherited particles (clasts) or authigenic minerals precipitated during diagenesis (carbonate cement and clay minerals). Fine facies (mudrock, coal and tuff) shows higher magnetic susceptibility due to the presence of paramagnetic minerals (iron phyllosilicates such as biotite, muscovite, chlorite and illite). Low values of susceptibility in mudrock are related to high content of organic matter in carbonaceous mudrock and coal, where Total Organic Content (TOC%) reach values around 1-51%. Ferromagnetic minerals are magnetite and pyrrhotite, which is frequently formed in anoxic sedimentary environments.

Anisotropy degree (P_j) ranges from 1.00 to 1.20 with an average of 1.057 (Fig. 3a). This parameter increases with depth, consistent with the increment of burial. Thereby, the higher values are observed at the base (P_j: 1.10 – 1.30) and correspond to mudrock and coal. The shape parameter (T) is variable from −1.0 to +1.0 with an average of 0.55 (Fig. 3a), values are mainly from $0 < T < 1$ indicating oblate fabric. From 500 mbw to the top of the sequence values show variation between $-0.5 < T < 0.8$ that represent prolate to oblate fabrics. Directional AMS data show that K_{max} axis lie near the horizontal while K_{min} axis are near the vertical, perpendicular to the bedding plane with horizontal attitude, indicating triaxial fabric to sedimentary fabric. However, at the base of the sequence from 900 to 800 mbw, there are small intervals that show the K_{min} axis moving to horizontal positions (Fig. 3b). Foliation (F) values range from 1 to 1.15 with an average of 1.042.

4. Petrofabric analysis and correlation

Sedimentary fabrics are characterized by oblate ellipsoids ($0 < T < 1$) with vertical K_{min} axes (Borradaile, Henry, 1997; Tarling, Hrouda 1993). Analyzed AMS parameters are consistent with sedimentary magnetic fabric with oblate ellipsoids (T values mainly positives) and shortening direction (K_{min}) in the vertical, perpendicular to bedding planes. Samples belong to cores that were not orientated, hence correlation with azimuthal values of K_{max} and K_{min} previously obtained in Tunas Formation from outcrops of Claromecó Basin (Arzadún *et. al.,* 2016) cannot be possible. Nevertheless, based on scalar parameters, sedimentary magnetic fabric is similar in subsurface and in outcrops in the basin center.

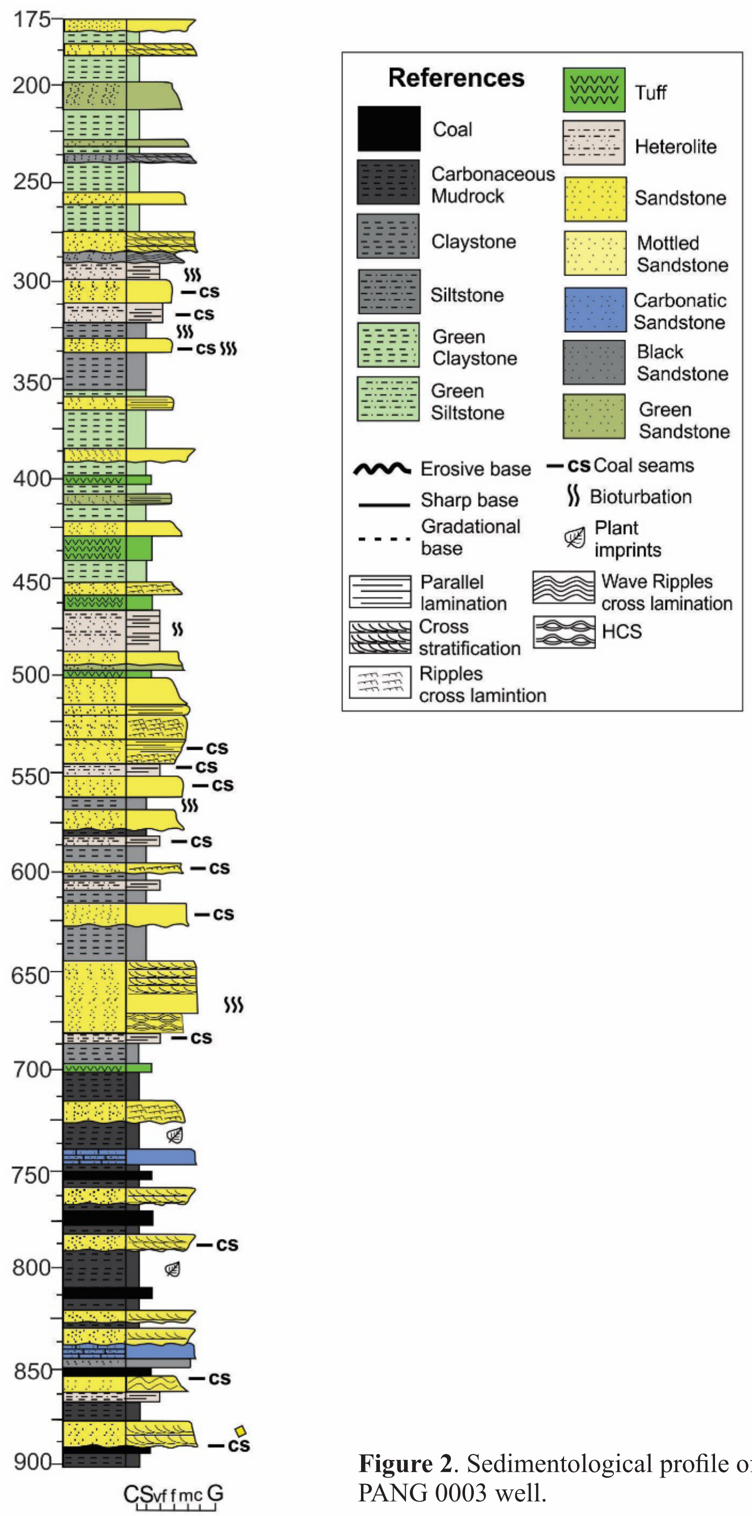

Figure 2. Sedimentological profile of PANG 0003 well.

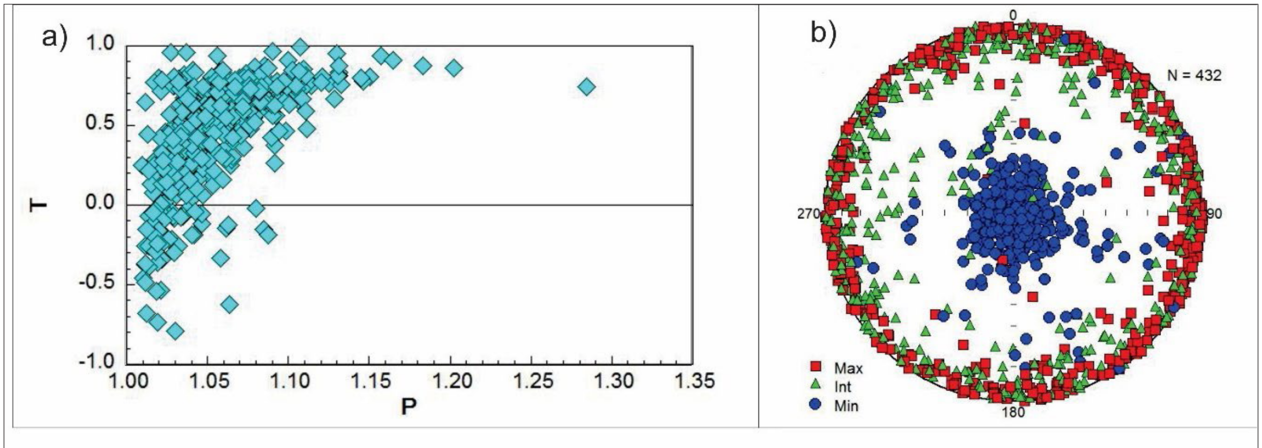

Figure 3. a) Anisotropy degree (P) vs. shape parameter (T). b) Stereographic projections of the principal susceptibility axes (K_{max}, K_{int}, K_{min}).

5. Conclusions

The variation of magnetic susceptibility observed in cores from the Tunas Formation would correspond to changes in sedimentary and chemical conditions during deposition; then, low susceptibility values indicate absence or minor quantity of magnetic minerals under anoxic conditions, meanwhile high susceptibility values reflect presence of magnetic minerals under sub-oxic/oxic conditions. These variations additionally reflect changes in environment energy (sand or mud grain size) and as well the influence of diagenesis (precipitation of authigenic minerals) during deeping.

Tunas Formation predominantly shows a sedimentary magnetic fabric with K_{min} in the vertical, perpendicular to bedding plane. There are two main intervals at the base of the well that show a fabric more clearly related to tectonic influence ($-0.5 < T < 0$), K_{min} axis shifting to horizontal positions and with high foliation values (increasing in the P_j values). At these depths, bedding planes could be not disposed horizontal. These differences may correspond to the diagenetic degree and overburden conditions.

Magnetic sedimentary fabric of the Tunas Formation in subsurface is consistent with outcrops observations of the Tunas Formation in Claromecó Basin, confirming that tectonic deformation had been attenuated to the east, toward the foreland basin. The study of rock petrofabric in cores is an important tool to increase knowledge about Claromecó Basin, currently considered as a frontier basin.

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