Latinmag Letters, Volume 1, Special Issue (2011), D32, 1-6. Proceedings Tandil, Argentina

DISCRIMINATION OF HYDROCARBON-RELATED CONDITIONS BASED ON A STATISTICAL ANALYSIS OF MAGNETIC PARAMETERS

Milagrosa Aldana*, Vincenzo Costanzo-Alvarez, Oswaldo Guzmán

Universidad Simón Bolívar, Dpto. Ciencias de la Tierra, Caracas, Venezuela

Abstract

In this work we try to discriminate hydrocarbon-related conditions that produce near-surface magnetic contrasts using magnetic parameters only. We present preliminary results for an oil field located at the Maturin sub-basin. Cross-plots that combine hysteresis data (Mrs/Ms and Hcr/Hc), Magnetic Susceptibility (MS) and S-ratio were analysed searching for patterns associated with different type of MS anomalies (related (A-type) and not-related (B-type) to hydrocarbon migration, with different reducing conditions (associated or not with the presence of organic matter) and/or with distinct chief magnetic mineralogies at these MS anomalous levels (i.e. Fe-oxides or Fe-sulphides). A Hierarchical Cluster Analysis was applied and the possibility of pattern recognition, combining more than two magnetic variables, was examined. The results obtained seem to indicate that it is possible to discriminate between anomalies associated with different chief magnetic mineralogies. Nevertheless, the statistical analysis of the parameters applied here does not discriminate between anomalies related to hydrocarbon microseepage and those reflecting just lithological contrasts, or between anomalies associated with different reducing conditions.

Resumen

En el presente trabajo se busca discriminar entre diferentes condiciones asociadas con la migración de hidrocarburos, responsables de la presencia de contrastes magnéticos en niveles cercanos a la superficie, usando sólo parámetros magnéticos. Se presentan resultados preliminares para un campo localizado en la sub-cuenca de Maturín. Gráficos cruzados entre datos de histéresis (Mrs/Ms y Hcr/Hc), Susceptibilidad Magnética (MS) y cociente S, fueron analizados tratando de identificar patrones asociados con diferentes tipos de anomalías de MS relacionadas o no con la migración de hidrocarburos(anomalías tipo A y B, respectivamente), con diferentes condiciones reductoras (asociadas o no con la presencia de materia orgánica) y/o con distintas mineralogías magnéticas en estos niveles anómalos de MS (i.e. óxidos o sulfuros de Fe). Se utilizó, además, un Análisis de Agrupamiento Jerárquico y se estudió la posibilidad de reconocer patrones combinando más de dos variables magnéticas. Los resultados obtenidos sugieren que es posible discriminar entre anomalías asociadas con diferentes mineralogías magnéticas principales. Sin embargo, el análisis estadístico de estos parámetros, utilizado en este estudio, no permite discriminar entre anomalías relacionadas con la migración de hidrocarburos y aquellas que corresponden a contrastes litológicos, o entre anomalías a.sociadas a procesos reductores distintos.

Introduction

In previous studies, we have used magnetic susceptibility (MS) measurements in drill cuttings (Aldana et al., 1999, 2003; Costanzo-Álvarez et al., 2000, 2006; Díaz et al., 2000), taken at shallow levels from producer and non-producer wells, trying to detect anomalous magnetizations associated with hydrocarbons microseepage. The basic foundation of the method is that these magnetic contrasts, caused by enhanced concentrations of authigenic magnetite and/or Fe-sulphides in shallow layers, are the by-product of redox condition induced by the seepage of H_2S up from the reservoir (e.g. Foote, 1996; Saunders et al., 1999).

The studies we have performed in fields from south-western Venezuela (Aldana et al., 1999; Aldana et al., 2003; Costanzo-Álvarez et al., 2000) allowed us to identify two types of MS anomalies in drill cuttings from different oil wells (i.e. A and B-like). This identification was achieved integrating magnetic measurements (i.e. MS, IRM curves, S-ratio, low and high temperature susceptibility data), with Organic Matter Free Radical Concentration (OMFRC) derived from Electronic Paramagnetic Resonance (EPR) analyses, Extractable Organic Matter data (EOM), EDX and SEM analyses. A-like anomalies appear mostly in producer wells and are probably related to hydrocarbon microseepage. Samples from A-like anomalous levels reveal the restrictive presence of authigenic magnetic framboids, observed by SEM analyses. Depending on the reducing conditions, the main magnetic mineral could be magnetite or Fe-sulphides, as greigite (Guzman et al., 2011). On the other hand, B-like anomalies, found in both producer and non producer wells, probably reflect lithological contrasts that are not related to the reservoirs. B-like anomalies do not show magnetic framboids either. In this case, magnetite has been identified as the main magnetic mineral.

In this work we present preliminary results trying to discriminate, qualitatively and quantitatively, A and B-like MS anomalies using only magnetic properties measured at room temperature. Cross-plots between different magnetic properties and a Hierarchical Cluster Analysis are applied for qualitative and quantitative discrimination, respectively.

Samples and Methodology

We have analysed drill cuttings (unconsolidated rock samples), taken at intervals of about 15 m from the first 1200 m, in six wells located at the north-eastern lobe of the Maturín sub-Basin which lies south of a structural complex (Santa Bárbara - Carito - El Furrial - Boquerón) and north of the southern limit of a major deformation front (Figure 1).

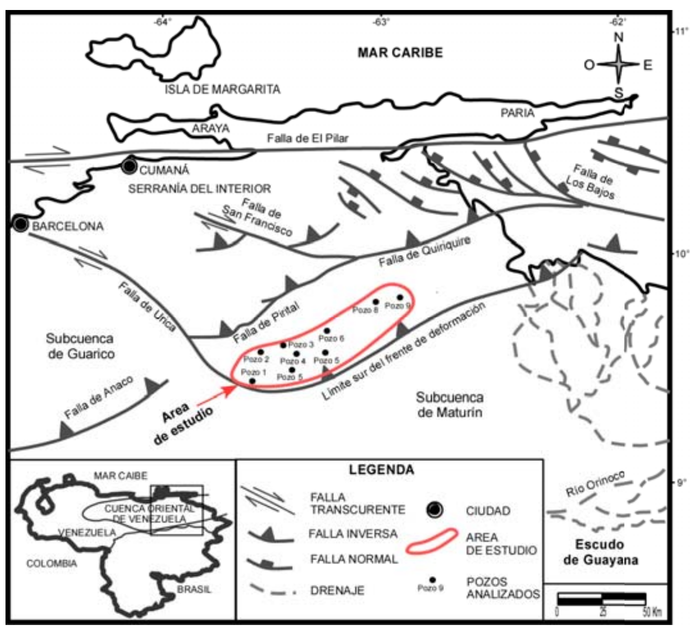

Figure 1.- Studied area (from Guzmán et al., 2009)

Magnetic Susceptibility (MS), S-ratios, saturation remanence - magnetization ratios (Mrs/Ms) and coercivity of remanence - coercive force ratios (Hcr/Hc) values from anomalous MS samples were used in this study. These values were previously obtained by Guzmán et al. (2009) and Guzmán et al. (2011). The MS measurements were carried out at room temperature in a Bartington magnetic susceptibility system. *S*-ratios (*IRM*-0.3T/*SIRM*+2T) were determined using an ASC high field pulse magnetizer. The saturation remanence - saturation magnetization ratio (Mrs/Ms) and coercivity of remanence - coercive force ratio (Hcr/Hc) were obtained from the hysteresis loops measured, at room temperature, between -700 and 700 mT using a Molspin Vibrating Sample Magnetometer VSM Nuvo MK 2 with a noise level of about 0.04 mAm^2.

Anomalous MS levels were previously identified and classified by Guzmán (2010) and Guzman et al. (2011) as related to either a reducing environment caused by the underlying reservoir (Type A), or to primary lithological contrasts (Type B). This identification was made by integrating magnetic results with Scanning Electron Microscopy (SEM), Electronic Paramagnetic Resonance (EPR) and Extractable Organic Matter analysis. The main magnetic mineralogies observed at these levels, as well as the influence of organic matter in the reducing conditions, were also recognised. These results are summarized in Table 1.

Well	Anomalous Level Depth (m)	Type of Anomaly*	Chief Magnetic Mineralogy	Organic Matter related process
POZO-1	374.7	B	Magnetite	-------
POZO-1	487.5	B	Magnetite	-------
POZO-1	548.4	B	Magnetite	-------
POZO -3	481.4	A	Magnetite	Yes
POZO -3	566.7	A	Magnetite	Yes
POZO -4	780.0	A	Magnetite	No
POZO -4	844.0	A	Magnetite	No
POZO -4	889.6	A (?)	Magnetite	No
POZO -4	917.1	A (?)	Magnetite	No
POZO -5	417.4	A	Magnetite	Yes
POZO -5	438.7	A	Magnetite	Yes
POZO -5	551.5	A	Magnetite	Yes
POZO -5	964.3	A	Magnetite	Yes
POZO -8	694.6	A (?)	Magnetite	Yes
POZO -8	746.4	A (?)	Magnetite	Yes
POZO -8	822.6	A (?)	Magnetite	Yes
POZO -8	1005.4	A (?)	Magnetite	Yes
POZO -9	665.7	A	Magnetite, Fe-Sulphides	Yes
POZO -9	688.6	A	Magnetite, Fe-Sulphides	Yes
POZO -9	725.1	A	Magnetite, Fe-Sulphides	Yes

Table 1. Classification of the observed MS anomalies at wells from the Maturínn Sub-basin. The chief magnetic mineralogies and the reduced process associated is also indicated (after Guzmán, 2008 and Guzmán et al., 2011)

Cross-plots and statistical analysis

Cross-plots are a qualitative graphical technique widely used to identify patterns in different type of data (e.g. rock physics parameters, Mukerji et al., 2001**)**. Peters and Thompson (1998) have previously used them, together with a discriminant analysis, combining magnetic parameters in order to emphasize the properties of minerals (selected natural iron oxides and sulphides) and domain states. Also Urbat et al. (1999) have used fuzzy c-means cluster analyses to isolate diagenetic groups in marine sediments.

In the present work, we have used biplots of hysteresis data (MR/MS and HCR/HC), Magnetic Susceptibility (MS) and S-ratio searching for patterns associated with different type of MS anomalies (related and not related to hydrocarbon migration) and different reducing conditions (associated or not with the presence of organic matter). A Hierarchical Cluster Analysis was also applied for pattern recognition of the studied magnetic variables. This procedure tries to identify relatively homogeneous groups using an algorithm that starts with each case in a separate cluster and combines clusters until only one is left. We have used a between-groups linkage and a nearest neighbour method. The distance or similarity measure used was the squared Euclidean distance. Combinations of two and three magnetic variables were tried for these analyses.

Results and Discussion

Figure 2 shows the more significant cross-plots obtained combining the magnetic properties used here. As can be observed, the biplots of hysteresis properties and those of one of these parameters combined with S-ratio, clearly cluster apart the data of POZO-9 (dots in magenta). For all the studied wells, the presence of magnetite was identified at the anomalous MS levels. Nevertheless, only for the anomalous MS levels of POZO-9 also Fe-sulphides were detected. Hence these biplots seem to discriminate between the main magnetic phases present, i.e. magnetite or a combination of magnetite and Fe-sulphides. Peters and Thomson (1998) have attempted to identify iron oxides and iron sulphides (magnetite, hematite, pyrrhotite and greigite) using magnetic susceptibility, remanent magnetizations and hysteresis loops measurements taken at room temperature. Their results indicated that it is possible to discriminate between these minerals using susceptibility and remanence ratios. Nevertheless, in our case, MS measurements combined with any of the other parameters do not allow to identify different magnetic minerals.

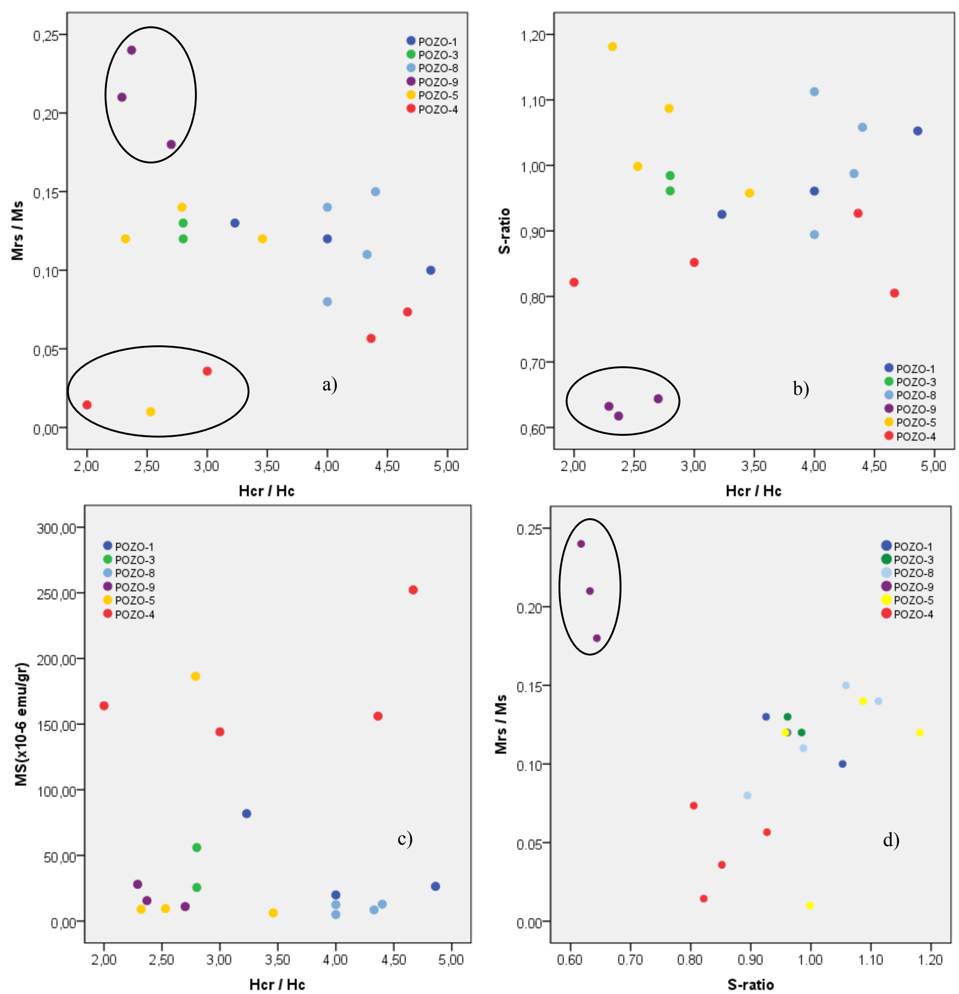

Figure 2.- Biplots of magnetic properties: a) MR/MS vs HCR/HC; b) S-ratio vs HCR/HC; c) MS vs HCR/HC; d) MR/MS vs S-ratio

The results obtained after the Hierarchical Cluster Analysis using the methods previously indicated, are presented in figures 3 and 4. Different number of variables and clusters were tested trying to obtain additional information that is not evident from the qualitative analysis of biplots. The results for two and three magnetic parameters, selected from (Mrs/Ms), (Hcr/Hc) and S-ratios, and 4 clusters are shown. Again, the quantitative analysis shows a clear clustering apart between Fe-oxides and the combination of Fe-oxides and Fe-sulphides. Nevertheless, the other clusters identified in all the cases do not seem to be related with the other properties studied in this work and presented in Table 1. According to these results, the proper identification of MS anomalies related to hydrocarbon migration and/or the type of reducing process necessarily require the integration of EPR and EOM analysis.

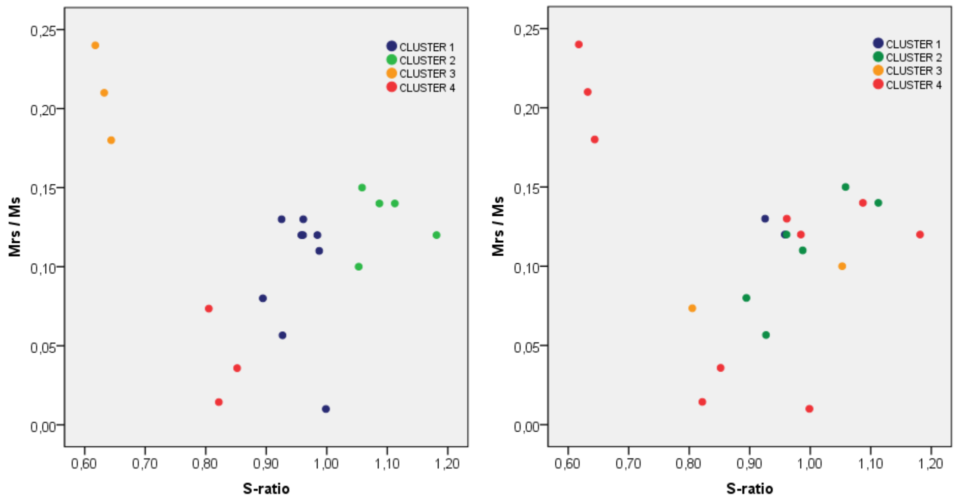

Figure 3.- Hierarchical Cluster Analysis using a between-groups linkage, four clusters and: a) Mrs/Ms and S-ratio data and four clusters; b) Mrs/Ms, S-ratio and Hcr/Hc data.

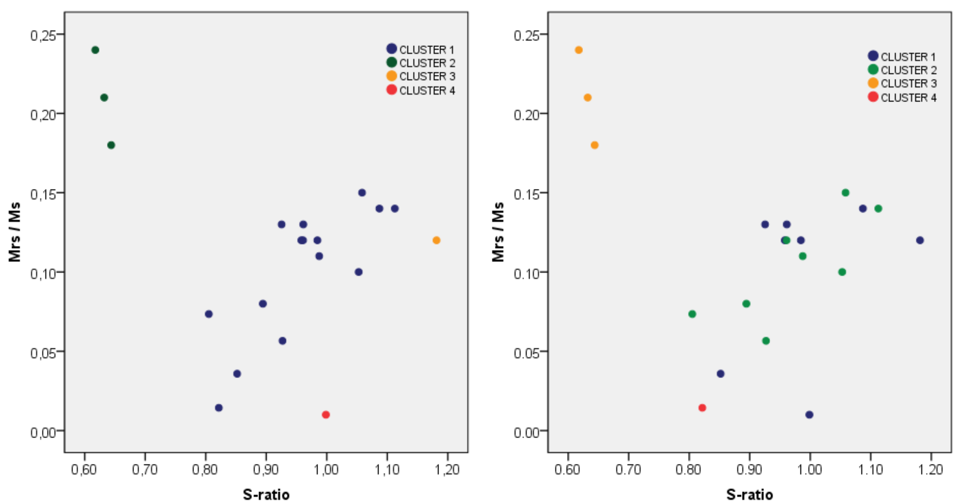

Figure 4.- Hierarchical Cluster Analysis using a nearest neighbour method, four clusters and: a) Mrs/Ms and S-ratio data and four clusters; b) Mrs/Ms, S-ratio and Hcr/Hc data.

Conclusions

In this work, we have presented preliminary results trying to identify patterns in MS-anomalous A and B levels that could discriminate between both types of anomalies or even between reducing processes using only magnetic parameters. The qualitative and quantitative methods applied here show a clear distinction between anomalies associated with different main magnetic mineralogies when a combination of Mrs/Ms, S-ratio and Hcr/Hc values is used. However, biplots or the statistical analysis of these parameters used here, do not discriminates between anomalies related to hydrocarbon microseepage and those reflecting just lithological contrasts, or between anomalies associated with different reducing conditions.

References

Aldana M., Costanzo-Álvarez V., Vitiello D., Comenares L. and Gómez G., 1999, Framboidal magnetic minerals and their possible association to hydrocarbons: La Victoria oil field (SW, Venezuela). Geofis. Int., Vol 38, 137-152.

Aldana M., Costanzo-Álvarez V. and Díaz M., 2003, Magnetic and mineralogical studies to characterize oil reservoirs in Venezuela, The Leading Edge, Vol. 22, 526-528.

Constanzo-Álvarez V., Aldana M., Aristigueta O., Marcano M.C. and Aconcha E., 2000, Study of magnetic contrast in the Guafita Oil Field (southwestern Venezuela), Phys. Chem. Earth, Vol. 25, N. 5, 437-445.

Costanzo-Álvarez V., Aldana M., Díaz M., Bayona G. and Ayala C., 2006, Hydrocarbon-induced magnetic contrasts in some Venezuelan and Colombian oil wells. Earth Planets Space, Vol. 58, 1401−1410.

Díaz, M., Aldana, M., Costanzo-Alvarez, V., Silva, P. and Perez, A., 2000, EPR and magnetic susceptibility studies in well samples from some Venezuelan oil fields, Phys. Chem. Earth, Vol. 25, N. 5, 447-453

Díaz, M., Aldana, M., S.M. Jiménez, P.Sequera, V. Costanzo-Álvarez, 2003, Revista Mexicana de Física, Vol. S52, pp. 63-65

Foote R.S., 1996, Relationship of near-surface magnetic anomalies to oil-and gas-producing area. In: Schumacher D. and Abrams M. (Eds.), Hydrocarbon Migration and Its Near-Surface Expression. AAPG Memoir, Vol. 66, 111−126.

Guzmán, O., 2008, Estudio de Anomalías Magnéticas aplicado a la exploración de Hidrocarburos en la Subcuenca de Maturín, M.Sc. Thesis, Simón Bolívar University.

Guzmán O., Costanzo-Álvarez V., Aldana M. and Díaz M., 2009, Estudio de contrastes magnéticos aplicado a la exploración de hidrocarburos, Resúmenes en extenso, 1ra Bienal Latinmag, Margarita, Venezuela, 1-4

Guzmán O., Costanzo-Álvarez V., Aldana M. and Díaz M., 2011, Study of Magnetic Contrasts Applied to Hydrocarbon Exploration in the Maturín Sub-Basin (Eastern Venezuela). Stud. Geophys. Geod., Vol. 55, 359-376.

Mukerji, T., Avseth, P., Mavko, G., Takahashi, I., and González, E., 2001, Statistical rock physics: Combining rock physics, information theory, and geostatistics to reduce uncertainty in seismic reservoir characterization, The Leading Edge, Vol. 20, 313-319

Peters, C. and Thomson, R., 1998, Magnetic identification of selected natural iron oxides and sulphides, Journal of Magetism and Magnetic Materials, Vol. 183, 365-374

Saunders D.F., Burson K.R. and Thompson C.K., 1999, Model for hydrocarbon microseepage and related near-surface alterations, AAPG Bull., Vol. 83, 170−185.

Urbat M., Dekkers M.J. and Vriend S.P., 1999. The isolation of diagenetic groups in marine sediments using fuzzy c-means cluster analyses. In: Tarling D.H. and Turner P. (Eds.), Palaeomagnetism and Diagenesis in Sediments. Geol. Soc. London Spec. Publl., 151, 85-93.