Notas Geológicas

Las notas geológicas tienen como objetivo el presentar síntesis de trabajos realizados en México y en diferentes partes del mundo por jóvenes profesionales y prestigiosos geocientíficos. Son notas escencialmente de divulgación, con resultados y conocimientos nuevos, en beneficio de nuestra comunidad de geociencias. Estas notas no están sujetas a arbitraje.

Quantitative petrographic analysis in thin section images using supervised classification machine learning

Caja[1], M.A., Tritlla[2], J.

1. Repsol Technology Lab. Agustin de Betancourt, s/n. 28935 Móstoles, Madrid, Spain. miguelangel.caja@repsol.com
2. Gemix / Independent Consultant, 17490 Llançà, Girona, Catalonia (Spain) jtritlla@gmail.com

Key words:

Petrography, classification, quantification, thin section images, machine learning, pre-salt carbonates

Petrographic analysis of thin sections in oil and gas exploration wells represents a crucial source of geological knowledge from subsurface. Petrographic analysis provides qualitative observations on mineralogy, texture, diagenetic features, porosity origin and evolution, etc. However, quantitative analysis is commonly limited to mineral percentages assessment using comparison charts for visual estimation, and manual point-counting, using expensive mechanical stages, in very few cases. Point-counting is subjected to petrographer´s experience, results can be biased and it is very time-consuming. Since recently, fast automatic mineral quantification, including textural and grain-size information, was only possible using expensive electronic microscopy equipment (QEMSCAN, f.i.). For these reasons, this study explores the use of machine learning supervised classification techniques applied to thin section images in order to perform fast quantitative petrographic analysis at low cost and no time-consuming (Caja et al, 2019). To achieve this goal, we used a series of high-quality thin sections obtained from a South-Atlantic exploration well drilled in pre-salt carbonate reservoirs (Tritlla et al, 2018).

A total of 134 Side Wall Core rock samples (1 inch in diameter) were cut, impregnated with blue dyed epoxy resin and prepared for petrographic thin sections with final high-quality (metallographic grade) polishing. Automatic high-resolution thin section scans were performed with a Zeiss Axio Scan.Z1 whole slide image scanner under plane polarized light illumination and 10X magnification. The obtained whole thin section images were gigapixel images (i.e. multi resolution image pyramids) with a maximum resolution of 0.44 microns per pixel.

The petrographic study of the thin sections allowed the definition of five main categories (Figure 1):

1) *Depositional carbonates*, corresponding mainly to "in-situ growths" and reworked microbial shrubs and spheruliths including large shrubs, small shrubs, bands or layers of spheruliths.

2) *Clays*, mainly identified as fine-grained talc-stevensite-kerolite, silty, argillaceous and carbonate mud.

3) *Carbonate and silica cements*; "Carbonate cement" corresponds to calcite and dolomite. "Silica cement" presents different textures and generations, mainly opal, chalcedony and megaquartz, being all of them grouped under a unique category.

4) *Bitumen*, present-day solid hydrocarbons impregnating the rock.

5) *Porosity*, is manly interparticle, intraparticle, vuggy and intercrystalline.

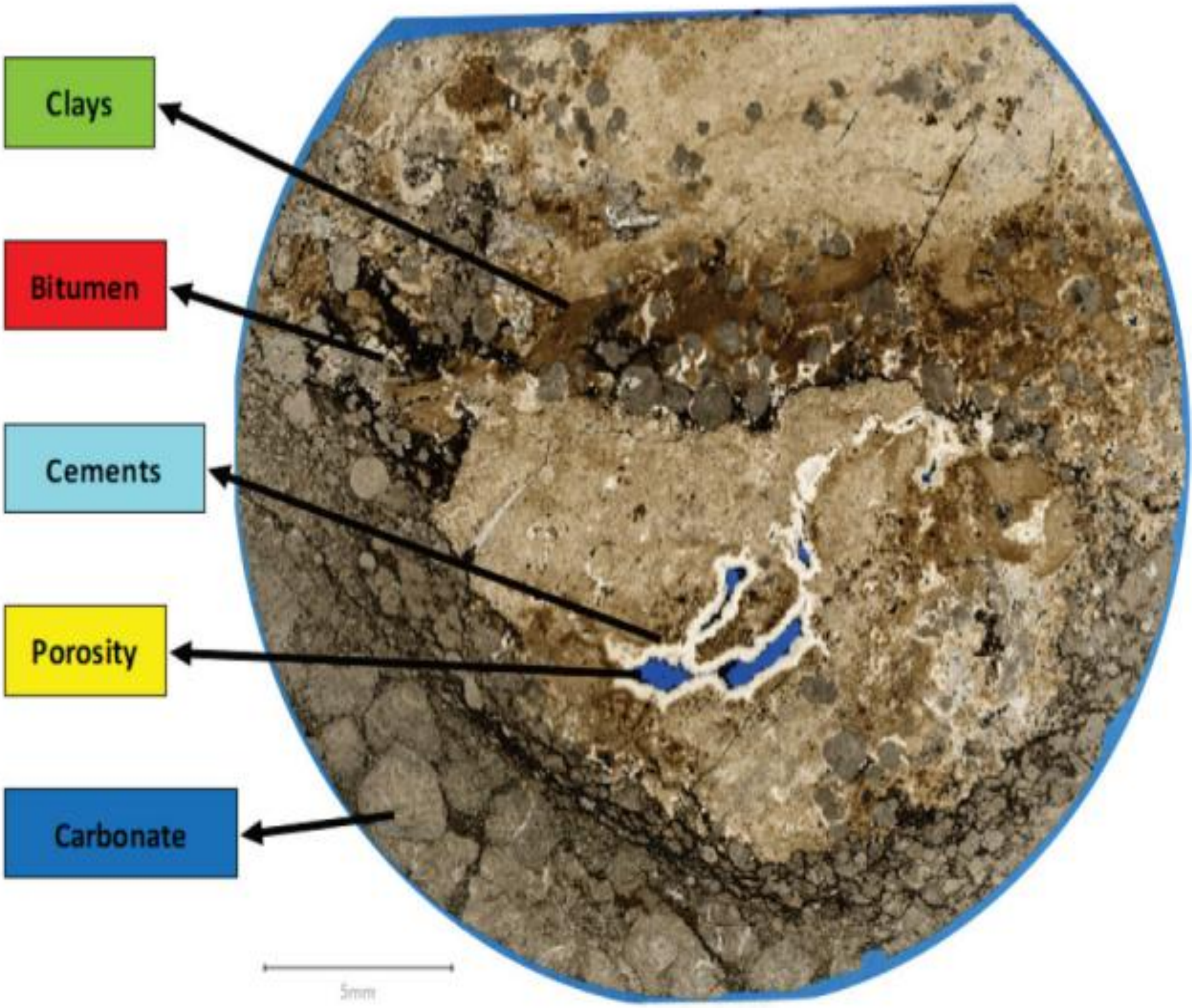
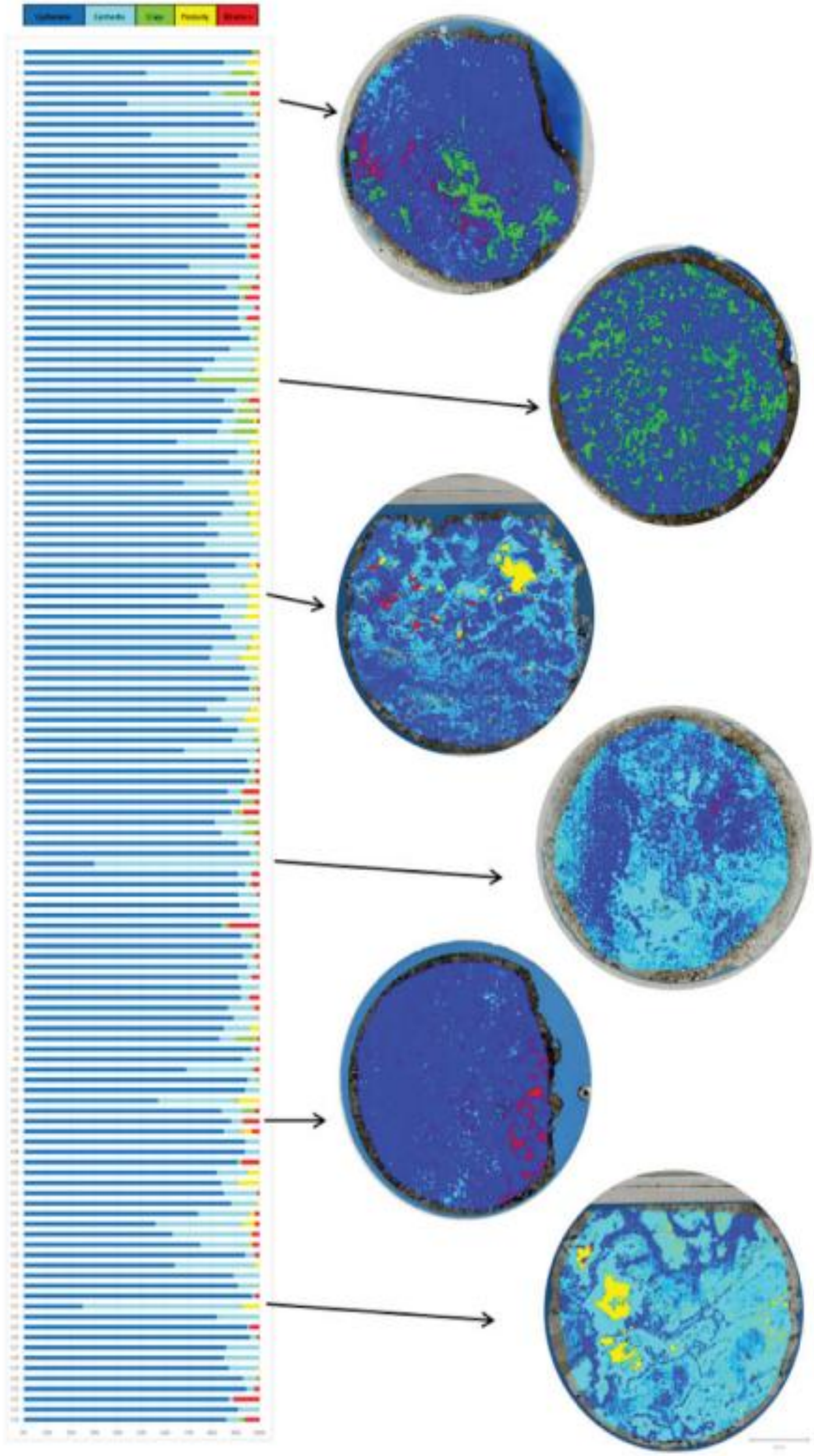


Figure 1. Example of one scanned whole thin sections from the studied well, prepared from one inch diameter Side Wall Core rock, with identification of the five categories differentiated.

An open-source software (ORBIT Image Analysis; Stritt et al, 2020) was carefully selected to perform a whole thin section image analysis using machine learning based classification through multi-resolution image pyramids. A Support Vector Machine (SVM) based classifier was used for pixel classification based on multivariate intensity and structural input parameters. Training data was generated by manually drawing several representative annotations per defined category after careful petrographic examination. The classification step then worked automatically: the features for each pixel of each category were computed and the SVM outputs the corresponding category class.

The obtained results (Figure 2) show the classification and quantification of the five categories selected: depositional carbonates, clays, porosity, carbonate and silica cements, and bitumen. One direct conclusion is the general abundance of cements and the presence of scattered highly cemented samples as well. The porosity trend is also fully captured as the samples with relatively highest porosities are easily identified and its relationship with bitumen abundances is also revealed. Finally, clays abundance is exposed, being more abundant in the shallower part of the well.



The obtained classifications were visually evaluated for each thin section image (Figure 3). One of the main misclassifications detected is silica cement, occasionally overestimated, so we decided to include both cements in a single category. The overall quantification results for the defined categories are representative for each sample.

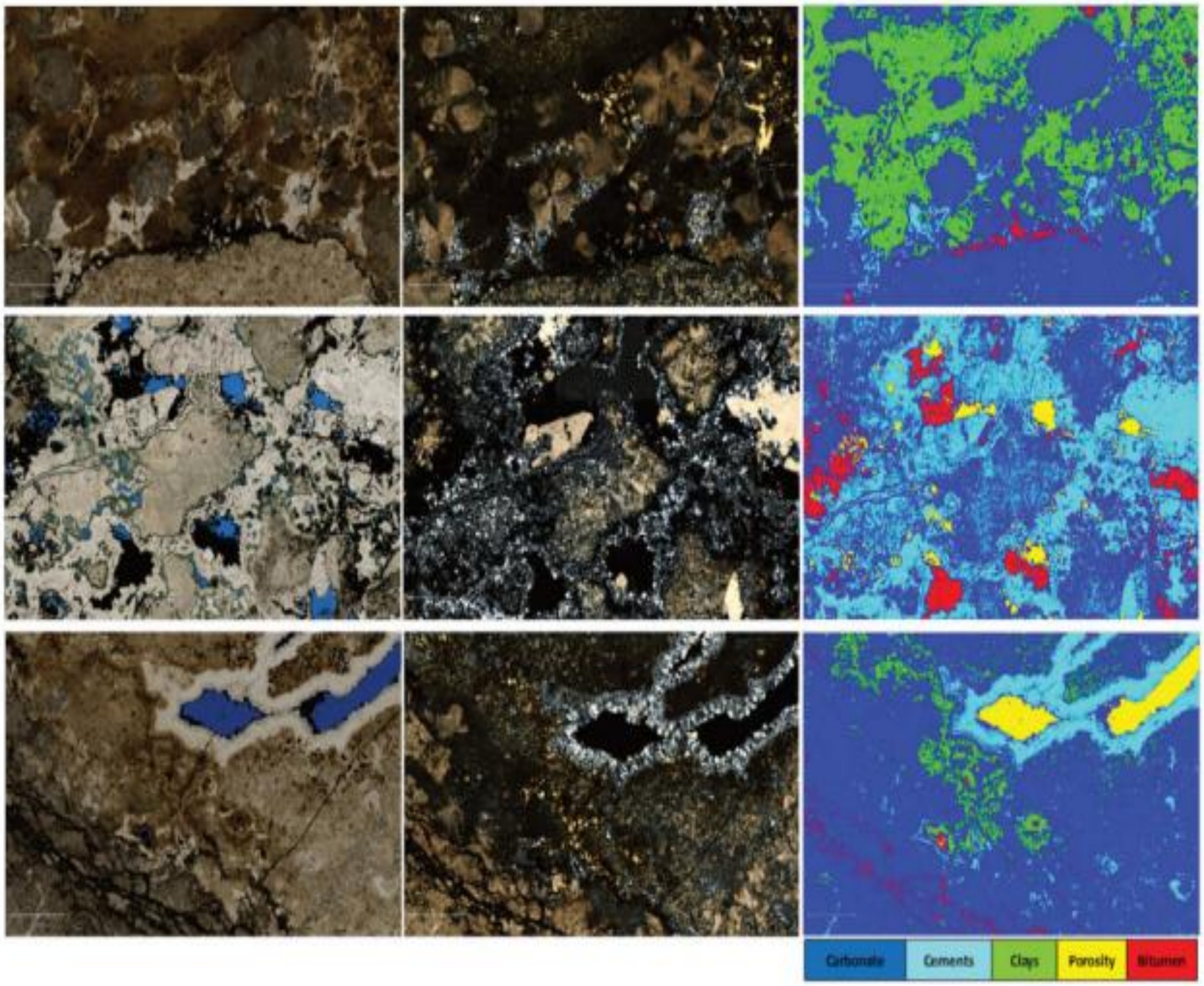


Figure 3. Selected examples of the visual comparison of the obtained classifications using the supervised machine learning algorithm: left column correspond to plane-polarized Light images, middle column to cross-polarized light and right column to the obtained classification (distribution map).

Conclusions

In conclusion, the generated machine learning model was applied to a set of 134 thin section images performing a supervised classification of five defined petrographical categories. This allowed to obtain quantitative petrographic data in a very reduced time (overnight process) for a relatively large set of thin sections without introducing petrographer´s experience bias. The next step consists to validate the performed visual evaluation with quantitative results obtained using other independent techniques (e.g. point-counting, QEMSCAN).

Future work must be focused in the scalability of the generated machine learning model to other wells in the same geological context to prove if categories can be classified and quantified correctly or if the model need re-training with samples from new wells.

References

Caja, M. A., Peña, A. C., Campos, J. R., García Diego, L., Tritlla, J., Bover-Arnal, T., & Martín-Martín, J. D. (2019): Image Processing and Machine Learning Applied to Lithology Identification, Classification and Quantification of Thin Section Cutting Samples. In SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers, 8pp.

Stritt M, Stalder AK, Vezzali E (2020): Orbit Image Analysis: An open-source whole slide image analysis tool. PLoS Comput Biol 16(2):e1007313

Tritlla, J.; Esteban, M.; Loma, R.; Mattos, A.; Sánchez, V.; Boix, C.; Vieria Da Luca, P.H.; Carballo, J.; Levresse, G. (2018): Carbonates That Are No More: Silicified Pre-Salt Oil Reservoirs in Campos Basin (Brazil). AAPG ACE 2018, Salt Lake City, Utah, USA. AAPG Datapages/Search and Discovery Article #90323.

Miguel Ángel Caja Rodríguez (Ph.D.)
Senior Geologist - E&P Technology Product Leader, Repsol Technology
Madrid, Spain

Miguel Ángel Caja received his Ph.D. in petrology and diagenesis from Complutense University of Madrid and postdoctoral fellowship from Barcelona University. He is a geoscientist and researcher with +15 years of experience in the field of clastic and carbonate diagenesis linked to reservoir quality evolution.

At Repsol he has spent the last several years setting up and implementing laboratories supporting E&P analytical needs (petrology, diagenesis, inorganic geochemistry, rock physics,...) with special focus in adding value.

Recently, he started to lead E&P Repsol Technology Products development following agile methodologies, using the latest technical advances supporting the new challenges of O&G industry and shortening the E&P cycle.

Linkedin: www.linkedin.com/in/miguelangelcaja

Research Gate: www.researchgate.net/profile/Miguel-Angel-Caja

Jordi Tritlla Cambra (Ph.D.) is a senior geology and geochemistry consultant, with 35 years of experience.

Dr. Tritlla obtained his Ph.D. in 1994 at the Autonomous University of Barcelona (UAB, Spain) and a MsC on hydrogeology (Curso Internacional de Hidrología Subterránea) at the UPC-FCIHS (1998). His working experience include Senior Consultant at Repsol Exploration (Madrid, Spain); Research Scientist at Instituto de Geología / Centro de Geociencias (UNAM, México); Invited Professor at Université Henry Poincarè (now Université de Lorraine, Nancy, France); Research Fellow at the School of Earth and Environment (Leeds University, UK) and Assistant Professor at the University of Barcelona (Spain).

He has a broad experience in the study of ore deposits (MVT, SEDEX, VMS, IOCG, Skarns, Hg-Sb, ophiolites) and geofluids (oil, gas, brines), including paleofluid PVTx reconstruction (compressional and extensional settings); geothermal systems; and origin an occurrence of native hydrogen. During the last 11 years he has been mostly focused to study the pre-salt microbial carbonates off-shore Brazil and Angola, and their possible analogs worldwide.

Email: gemix.earth@gmail.com

Webpage: https://bit.ly/gemix-earth