PSVaca Muerta Formation - Discontinuities Analysis Related to Fissility: A New Methodology Proposed to Assess the Degree of Fissility of a Fine-Grained Rock*

Martín Lucía Ines[1], Marchal Denis[2], Naides Claudio[2], Silvia Barredo[1]

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[1]Petroleum Department, Technologic Institute of Buenos Aires, Buenos Aires, Argentina (lucia.i.martin@gmail.com)
[2]Shale Division, Pampa Energía S.A., Buenos Aires, Argentina

Abstract

The fissility is the tendency of the volume of rock to split into weakness planes densely spaced and generally roughly parallel to stratification. This property is observed mostly in fine-grained rocks and particularly express in outcrops, when the rocks are submitted to weathering and environmental temperature and pressure conditions for long time. Most of the authors associate the fissility to the planar minerals and their textural orientations. Mechanically, fissility express through weakness planes at different scales which can promote the loss of integrity of a volume of rocks through natural or induced fracturing. Consequently, this mechanical property should influence the efficiency of hydraulic fracture in shale-gas completion. The present study aims to identify the main controls of fissility processes at macroscopic scale analysing the evolution through time of the weakness planes in a 120 meters long core extracted in the Vaca Muerta Formation. The weakness planes are classified into natural fractures and induced fractures. These induced fractures correspond to those weakness planes that develop because of change of stress conditions during the core extraction and due to the stress relaxation along time at environmental conditions for four years. We analyse the evolution through time of weakness plane densities of three different states of physical integrity of the core, allowing us to recognize rock intervals which tend to break with variable intensity over time and core intervals where the rock tend to remain unbroken. In the other hand, we observed that small discontinuities within the pieces of intact core revealed by differential evaporation of sprayed alcohol. A 4-class index was built to estimate these discontinuities density as a proxy for fissility tendency. We integrate these results with geological (such as mineralogy), petrophysical (Shale rock class) and geomechanical data in order to characterize the fissility mechanisms.

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VACA MUERTA FORMATION - DISCONTINUITIES ANALYSIS RELATED TO FISSILITY

AAPG ICE 2019 International Conference & Exhibition. 27-30 August, Buenos Aires, Argentina

A new methodology proposed to assses the degree of fissility of a fine-grained rock

MARTÍN LUCÍA INÉS[1], MARCHAL DENIS[1], NAIDES CLAUDIO[2] & BARREDO, SILVIA[1]

[1]Petroleum Department, Technologic Institute of Buenos Aires (ITBA) [2]Shale division, Pampa Energía S.A.

Introduction

When fine-grained rocks, i. e. those that contain 50% or more of particles less than 63 microns in size (Wilkins, 2014), are exposed in outcrops they can develop a property named fissility, as a response to weathering processes together with temperature and pressure conditions being very different from those of their genesis (Ingram, 1953; Weaver, 1989, among many others).

In general terms, this property is defined as the ability of the rock to break easily into thin layers parallel to the bedding (Pettijohn, 1975). Mechanically, fissility express through weakness planes at different scales which can promote the loss of integrity of a volume of rocks through natural or induced fracturing. Consequently, this property should influence the efficiency of hydraulic fracture in shale-gas completion.

There are several approaches in the bibliography to estimate the degree in which the fissility is developed (Spears, 1976; Shakoor & Brook, 1987; Ho et al., 1999; Carpentier et al., 2003). All of those correspond to studies applied to rocks exposed in outcrops. Here, a new methodology which is under development is presented, to estimate this property in rocks sampled in subsurface.

Figure 1. Vaca Muerta Formation outcrop showing the general aspect of the rock when exhibit fissility.

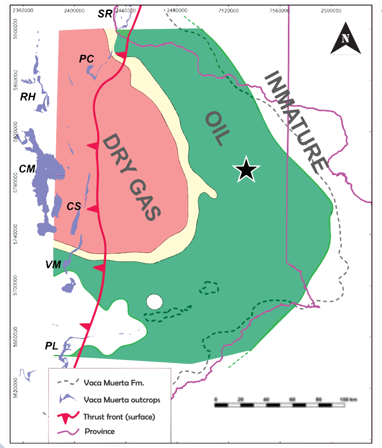
Objetives

The present work is part of a PhD thesis focused on the study of Vaca Muerta Formation in terms of its fissility and how this property can influence its completion performance.

The objectives of this work are:

- To provide a method to estimate the degree of potential fissility on fine-grained rock cores.
- To shed light on the main factors that control the development of this property.

Location



The Vaca Muerta Formation in this location is in the oil window and their facies varies from external ramp to basin.

Figure 2. The studied core belongs to a well located (black star) in the morphostructural area of the embayment.

Generalized workflow

As fissility is a property that shows up at outcrops, it is mandatory to examine it by means of superficial information (mainly maps and sedimentological profiles plus a set of laboratory studies). Nevertheless, we want to translate this property underground where Vaca Muerta Formation is producing as an unconventional play. Thus, it is equaly important to consider sub-surface information and integrate all this data sets (Figure 2).

The input for this study is a core of roughly 120 meters long extracted from the Vaca Muerta Formation which has been analysed together with a wide set of well logs and a microresistivity image log.

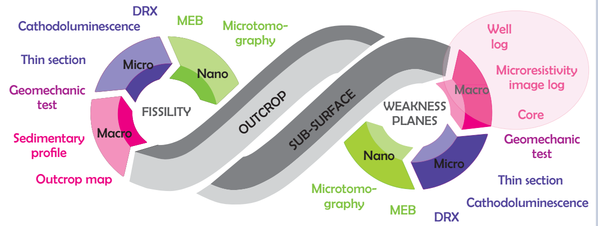


Figure 2. Generalized information input for the whole proyect. In this study, we will focused on the integration between the core, image log and well log information (pink circle).

DSA Index definition

It has been observed that the slabbed cores show discontinuities when sprayed whith alcohol. Those discontinuities present variable density at different core intervals and represent weakness planes that can behave as fissility planes at core surface. In order to stablish a semicuantification of this density, a set of photos were taken allowing to claisffify rock intervals into 4 classes to define the DSA (in spanish: '*Discontinuidades al Secado de Alcohol*', i. e. Drying Alcohol Discontinuities) index as an indicator of discontinuities density where the first class corresponds to the maximun density and the last one to the least dense.

- 262 photos
- all taken from the same high (30 cm) and after the same time (15'') of being sprayed with alcohol

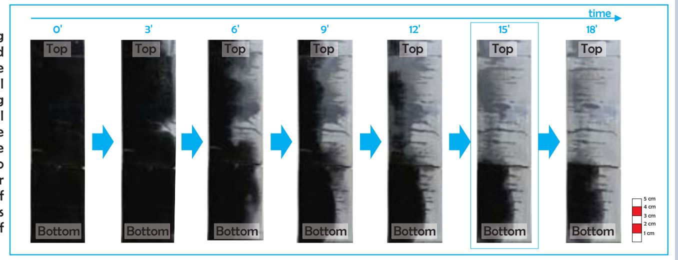


Figure 3. Drying secuence in a slabbed and pulled core showing several discontinuities along time. After several tests, we arrived to the conclusion that the optimum time to estimate the higher density of discontinuities whas after 15 seconds of spraying.

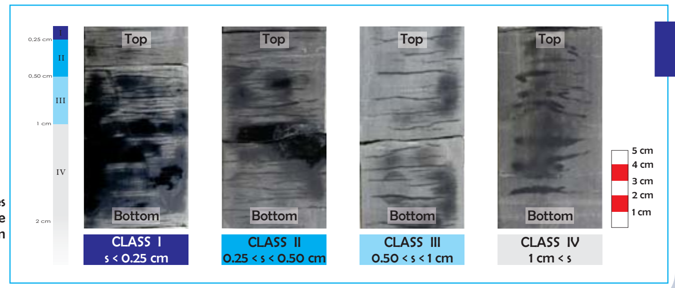


Figure 4. DSA classes defined by the spacement between the discontinuities.

Fractures and DSA mapping

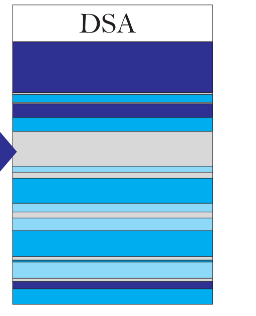
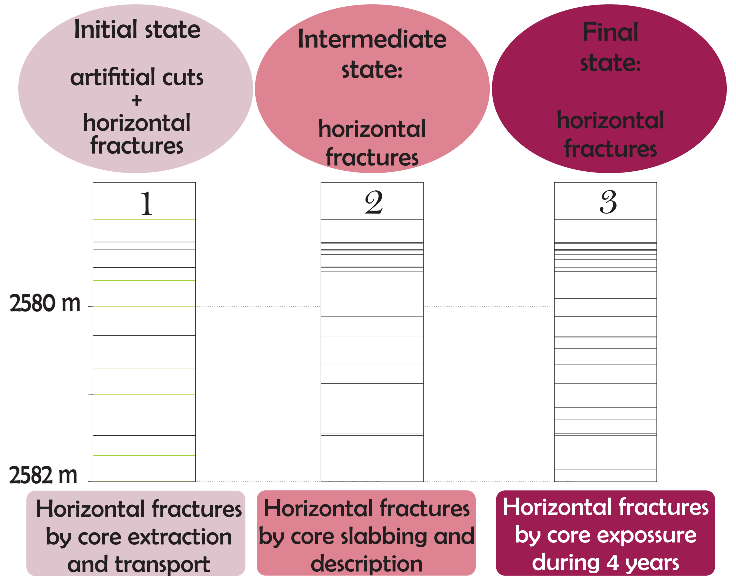


Figure 5. Comparision between the DSA index and the evolution of the horizontal fractures along time.



Among the different fractures that are found at the core, they can be divided between natural fractures, distinguished by their seal; and fractures that were created during extraction and/or decompression of the core, which are generally horizontal. These horizontal fractures correspond to those weakness planes that develop as a consequence of change of stress conditions during the core manipulation (extraction, trasportation and slabbing) and due to the stress relaxation along time at environmental conditions during 4 years.

Those horizontal fractures can be classified into two categories:

- First order horizontal fractures, which are associated with major interphases:
  - Strong lithologic changes (mainly ash beds)
  - Beefs
  - Concretions
- Second order horizontal fractures, associated with minor heterogeneities, such as:
  - Fossils
  - Laminations

Artificial cut
Weakness plane

Data analysis

Calibration & QC

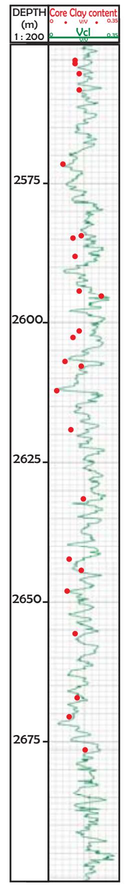


Figure 6. Vcl estimated from GR log compared to the DRX meassurements.

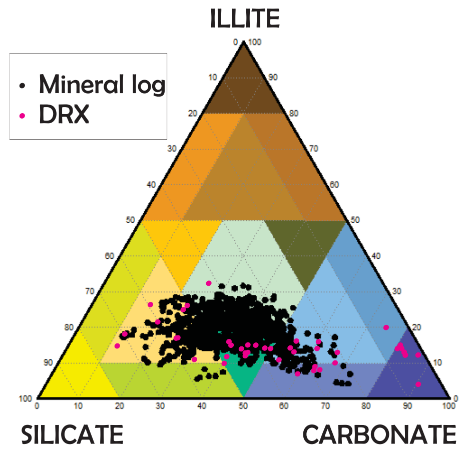


Figure 7. Composition calibration with DRX measurements

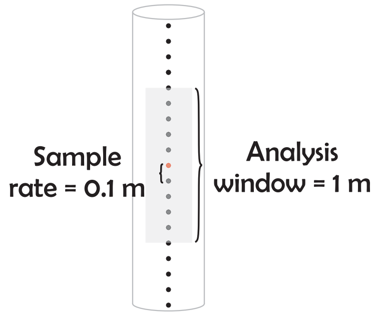
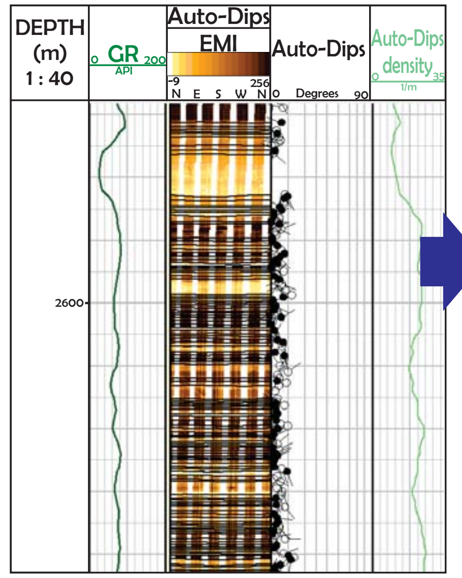


Figure 8. Two parameters that affect the density estimation of induced fractures and Auto-Dips are the sample rate and the windows analysis.

Image analysis

Figure 9. Processed microrresistivity image log showing the Auto-Dips with their angle of dipping and density. Black dots corresponds to Auto-Dips mapped with high certainty whereas the white ones are less reliable.



After processing the microresistivity image log, it was used to estimate two parameters:

1. The autodips density, which was obtained by the automatic dip picking and after a density estimation by using a sample rate of 0.1 m and a widow analysis of 1 m.

2. A porosity estimation from the mean resistivity obtained from the average of all the pads. This curve has a good correlation with other porosity logs but has higher resolution.

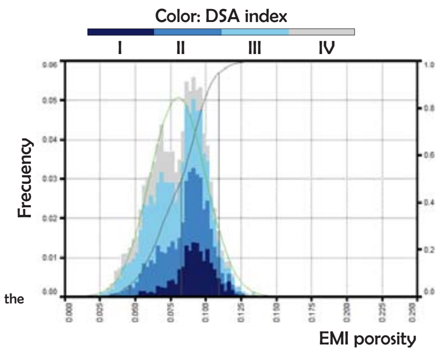


Figure 10. Porosity estimated from the microresistivity image.

Data integration

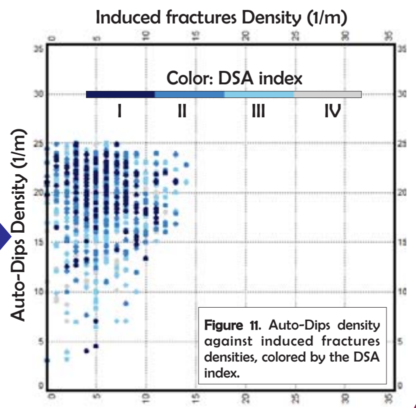
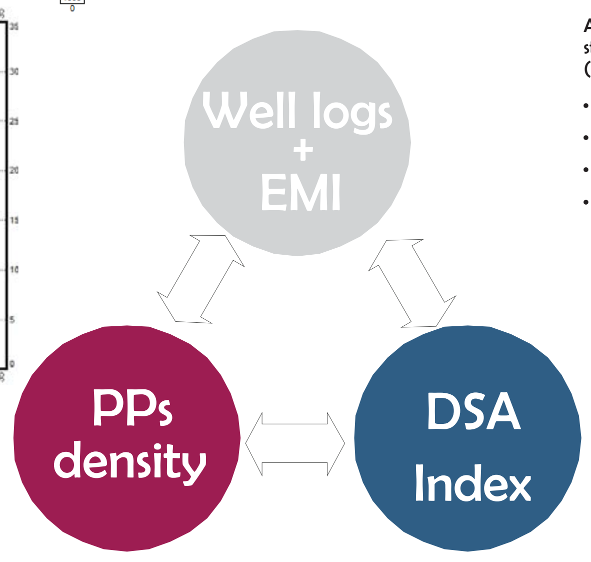


Figure 11. Auto-Dips density against induced fractures densities, colored by the DSA index.

The Auto-Dips can be interpreted as a lamination intensity proxy, as they represents resistivity contrasts along the well.
Figure 11 shows how the higher Auto-Dips density tends to concentrate the first DSA class, which represents the core intervals with higher density of potential fissility planes.



SUPERVISED CLASSIFICATION

A supervised classification was performed to reproduce the DSA index by using standard well logs. The model used is Multi-Resolution Graph-Based Clustering (MRGC).

- GR } COMPOSITION
- PEF }
- RT10 → TEXTURE
- DT → MECHANIC PROPERTY PROXY

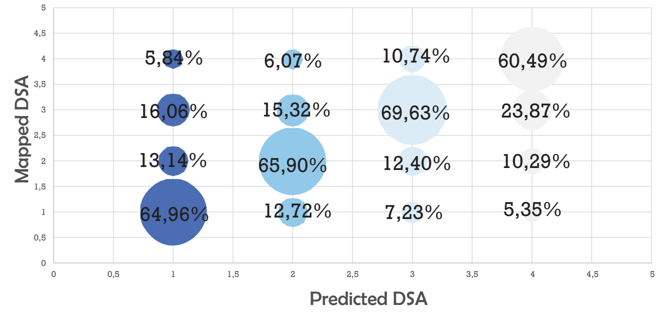


Figure 12. Percentage of correlation between the original DSA index and the DSA index predicted by the model.

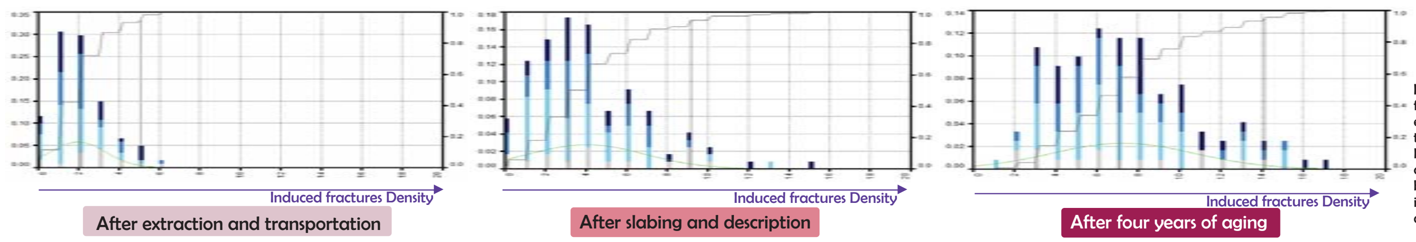


Figure 14. Induced fractures density evolution. Along time, the DSA index I and II tend to concentrate between the higher induced fractures densities.

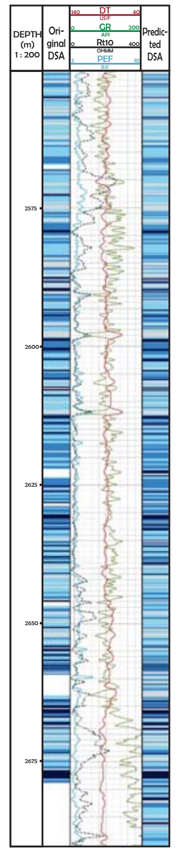


Figure 13. Comparision between the DSA index predicted by the model and the original one.

Preliminary conclusions & forward steps

1. Porosity values are higher for the clases I and II, which represent interval rocks with higher discontinuities density.
2. There is a proportional relationship between the degree of potential fissility and the lamination (autodips).
3. DSA classes can be predicted by generating electrofacies using standar well log information.
4. Complementary studies have to be performed to estimate the fissility degree at each DSA class.

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