

Evaluation of the black shales of the Los Monos Formation (Devonian) as an unconventional shale oil and shales gas reservoir, Balapuca, southern Bolivia

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The object of this study is the evaluation of the black shales of the Los Monos Formation as an unconventional shale oil and shale gas reservoir. To this end, the sedimentology and mineralogy of Los Monos Formation at Balapuca (22°31'00"S, 64°26'00"W), in southern Bolivia immediately north of the limit with Argentina is studied. A sedimentological profile was taken from this unit (140 m) and a total of 48 samples were analyzed by X-ray diffraction on total rock and clays fraction.

Los Monos Formation (late Eifellian-early Frasnian) is the typical mother rock of the north Argentine and south Bolivian Andean environment. Disalvo and Villar (1998) postulated the division of this unit according to its geochemical characteristics. They determined a lower section with a greater content of badly preserved amorphous kerogene (type III/IV), a probable gas generator, and an upper section with predominance of type II/III kerogenes of mixed marine-continental origin generating gas and oil. However, other studies (Cerqueira and Schulz, 1998; di Pascuo, 2007) indicate different distributions. Furthermore, the kerogene dilution in the rock (1% total organic carbon TOC, Disalvo and Villar, 1998) and its fair quality (average original S2 pyrolysis peaks estimated at no greater than 400mg HC/g TOC) would indicate that expulsion and migration have not been efficient. Therefore, there are still important volumes of generated hydrocarbons dispersed within the shales, a phenomenon also evinced by super pressure and manifestations during perforation. The poor quality of mother rock generation is compensated by the potent subsoil (700-1000 m) and broad area distribution (Disalvo and Villar, 1998).

In the area of interest, Los Monos Formation is characterized by decimetric to centimetric intercalations of laminated, micaceous black shales and fine to medium grained grayish psammites in small waves and HCS (hummocky cross stratification), in tabular and lenticular banks. There are also thin layers of brown limolite intercalation. Abundant vegetable fragments, bioturbations and badly preserved plants are visible in both shales and psammites. On the basis of sedimentological characteristics, these would correspond to distal platform facies (Disalvo and Villar 1998).

It is possible to observe, through X-ray diffraction mineralogical analysis, that Los Monos Formation presents average total rock mineralogy (Figure 1) principally composed of quartz (70%), plagioclase (10%) and clays (20%) and traces of calcite, dolomite, siderite, clinoptilolite and pyrite. Mineralogy of the clays is characterized by the average presence of illite (45%), illite/smectite (20%), chlorite (25%) and kaolinite (10%). All the samples analyzed present illite/smectite (IS) stratifications of very poor crystallinity which hinders quantification of its expansive layers, except in three cases with better crystallinity showing 20% of expansive layers for the upper section of Los Monos Formation. These values would indicate the diagenesis of a deeply buried window of gas generation (telodiagenesis) (Fóscolos, 1976).

In the profile taken at Balapuca, Los Monos Formation presents marked vertical lithological and mineralogical variability. Unrelated to whether they are psammites or shales, at least six stretches (3 m) of low clay content (10%) are present along the whole length of the column; some of these are kaolinite enriched (45%) and illite/smectite enriched (30%) to the detriment of illite, and three (5 m) contain intermediate clay percentages (20%); while in the mid to upper section there are two levels (5 m) with 40% clay content.

According to TAI (thermal alteration index) studies carried out on pollinic remains of the Formation at the same location, these 40% clay levels would be in a window of oil generation (di Pascuo, 2007). It is interesting to note that the TAI shows diagenesis figures which are slightly lower than those provided by the method of expansive layer measurement in IS interstratificates. This non concordance between both methods will be the subject of further study. Likewise, the layers carrying abundant clay (40%) and pyrite enriched (3%) suggest that these could be concentrated levels with above average organic matter percentages. Both work hypotheses could collaborate in determining whether these concentrated layers are the principal elements responsible for the great volumes of hydrocarbons generated in the sub Andean Paleozoic environment of northern Argentina and southern Bolivia.

Thus, on the basis of precedent information and the data obtained from the present study, it is considered that Los Monos Formation has some of the attributes necessary to be considered an unconventional hydrocarbon reservoir (shale oil – shale gas) which should be complemented by geomechanics and petrophysics properties to complete characterize the real potential as shale source potential.

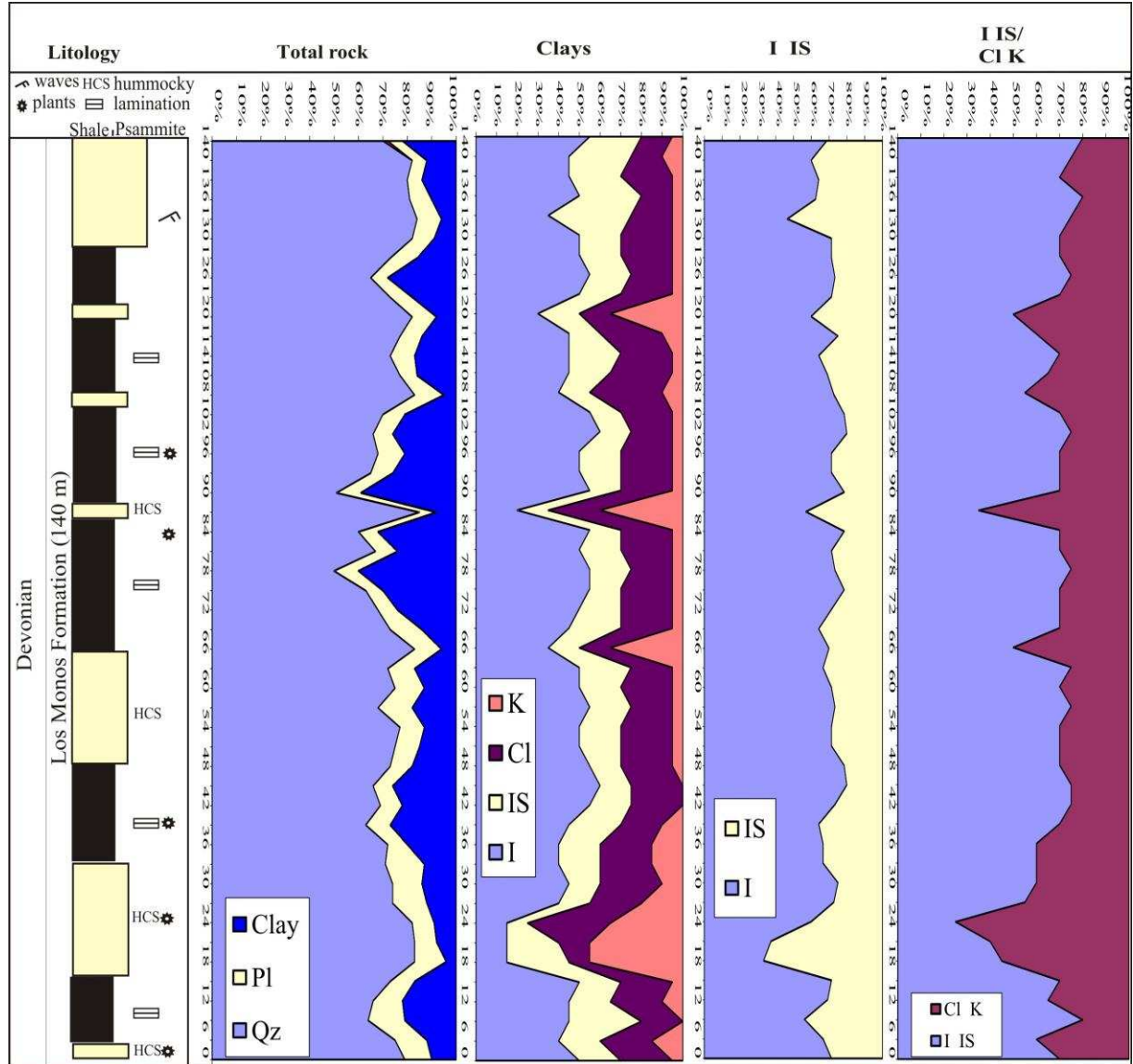


Figure 1. Lithology and mineralogy of Los Monos Formation, Balapuca, southern Bolivia, by total rock and clay fraction XRD (Pl, plagioclase; Qz, quartz; K, kaolinite; Cl, chlorite; IS, illite/smectite; I, illite)

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