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Multidisciplinary Approach and its Role in Hydraulic Unit Characterization

Abstract

In mature fields presenting multiples stacking oil sands, the trinomial “production / injection / pressure” may sometimes not behave as a coherent data set. In such cases, the first approach is to search for possible communication between sands. The understanding of the different communication processes is a key for the field exploitation optimization.

In many cases, analysis of the communication is not evident, mainly when (1) the communication presents severe restrictions or (2) is induced, partly or totally, by the exploitation (mechanical induced communication in wells or fault seal breaking driven by differential pressures).

In Mata field, a detailed geological analysis shows the possible communication amid the L sand package and amid the S sand package either by sand coalescence (erosion processes) or/and by the juxtaposition of the sands through faults.

Nonexistent at the beginning of the field production, the communication between the L package and S package becomes evident after having produced about 20% of OOIP. Systematic material balance studies and analysis of the production history and of the volumes of current mapped gas cap, strongly suggest induced communication between the originally isolated sand packages making coherent the entire history. Although not totally understood, the induced communication process is analyzed and all the hypothesis commented.

For L & S sand packages, communication justifies the field history when sands are analyzed under a grouped sand criteria (Hydraulic Units). As a result of this work the commingled exploitation of these sands was authorized and is being implemented in Mata field.

Introduction

Although the Mata field historically produce ruled by the concept that every sands is hydraulically isolated from the others, analysis of the production, injection and pressure of all sands of L and S packages show evidences of communication between the reservoirs.

Pressure measurements in the last few years indicate common pressures for the sands at a same datum, although presenting distinct recovery factors.

Beside the anomalous behavior of the production and pressure of the field, material balances shows evidences of mass flux amid the sands (of the same units or between the L and S sand packages).

In order to understand the communication between the sands, several geological factors have been considered. Structural juxtaposition of porous sections from the different reservoirs across fault planes and mechanical failures in wells (with more than 50 years of lifetime) are proposed as the main ways of communication.

Exhaustive material balances and production analysis was made to understand the communication, estimate the amount of mass exchanged between the sands and evaluate its impact in the whole field potential.

1. Geology

Field Location and Regional Geology

The Mata Field is located in the Greater Oficina Trend in the southern flank of Maturin sub-basin representing the oriental part of the Eastern Venezuelan Basin (Figure 1). This foreland basin was formed starting from the oblique convergence, in a dextral movement, between the Caribbean and the South American plates (Lugo and Mann, 1995). The Greater Oficina trend is characterized by extensional tectonics with regional dips trending N to NE.



Figure 1: Mata field location

Specific objectives of the geological characterization

The geological characterization, as part of the reservoir characterization, was focused in the necessity of understanding the communication mechanisms amid distinct sands. To complete the current geological model, a 3D geological model was built in order to:

1. Determine the role of the geological factors in the communication between the reservoirs (stratigraphical characteristics, structural features, etc).
2. Characterize in detail the sand-sand communication zones through the fault planes:
 - Practical evaluation of the spatial distribution of the permeable zones juxtaposition through secondary fault planes, allowing possible communication pathways.
 - Dynamic characterization of the L-S sand packages, allowing the integrated simulation of all sands of the L-S packages.
 - Geology-engineer analyses for a new development plan and reserves reevaluation.

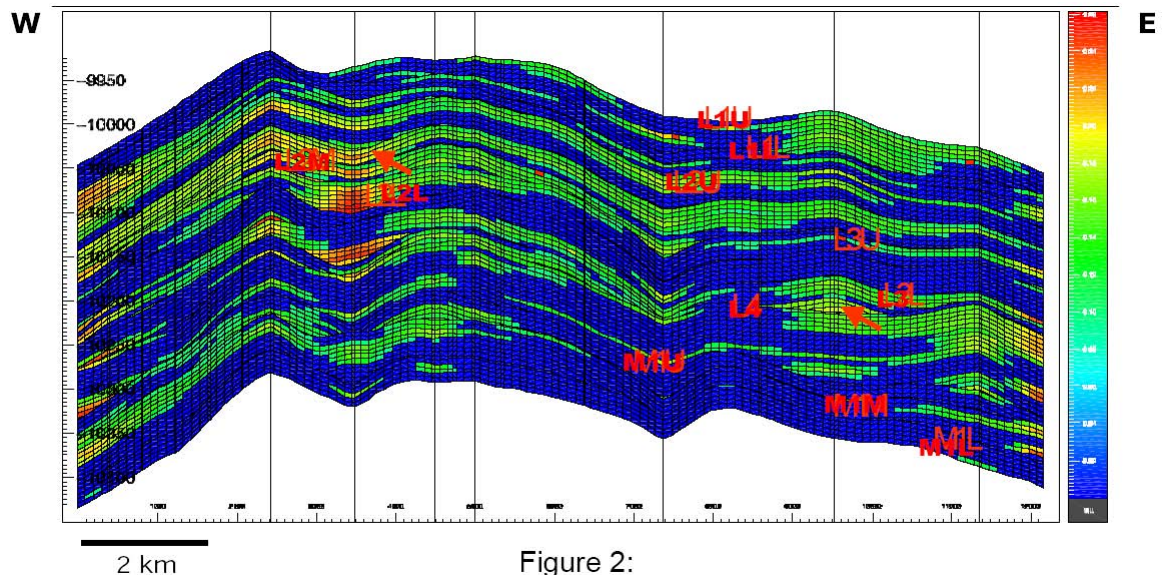


Figure 2:

Stratigraphical characterization

The sequence stratigraphy, mainly based on well logs and core analysis, was made from the basin scale to a sand-reservoir scale. The system tracts were defined and classified (low stand, transgressive and high stand). (Picarelli et al., 2001). The L-S sands are associated to incise valley fillings in canalized deposits in a low standing system tract. The incise valleys, generated by sea level lowering, can produce contact amid sands whenever the sealing horizon is thin. Such kind of sand communication has been identified in the L and S (Figure 2).

Structural characterization

The structure is characterized by normal faults system. Fault displacements induce the juxtaposition of distinct reservoirs through the fault plane (Badley et al, 1991). Based on the 3D geologic model, 3D juxtaposition maps was made ("Allan Maps") over the entire fault planes to analyze the spatial distribution of the fault displacements and of the sands porosity. Assuming that the fault plane itself do not act as a seal, the potential communication zones (leakage zones) were identified with the simultaneous analysis of (i) the juxtapositions among sequences and inside the sequences, for each individual sand, through the fault planes; and of (ii) the spatial (geostatistical) distribution of the porosity on the same fault plane (Figure 3). These zones of potential communication possess lengthened form and they are distributed in an irregular way on the fault planes.

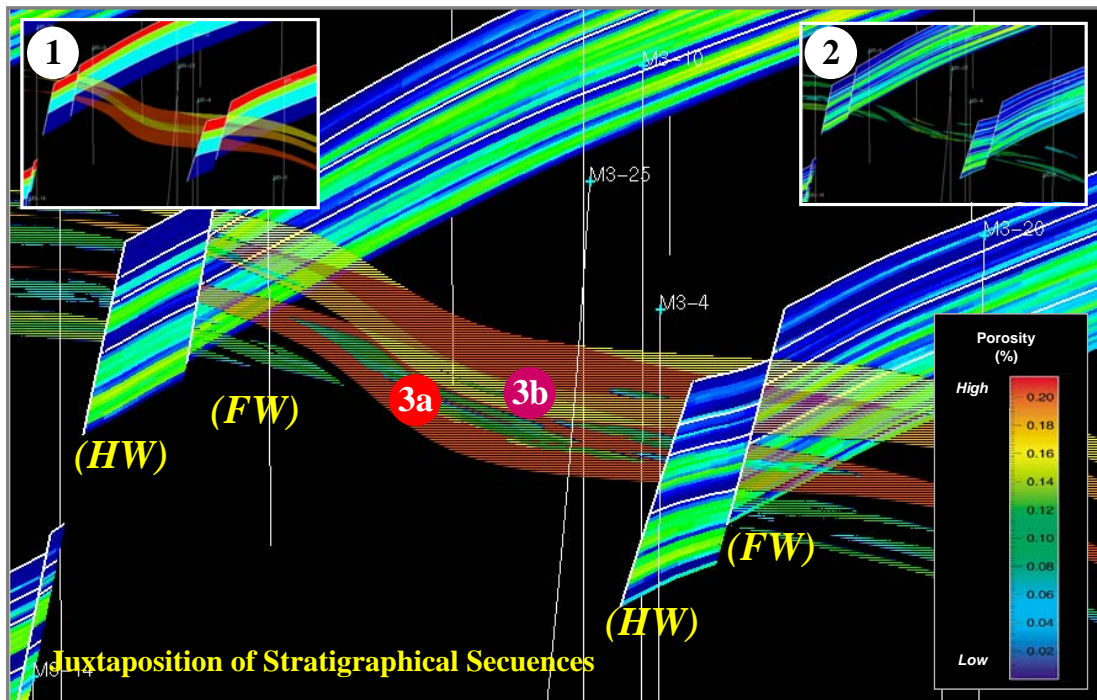


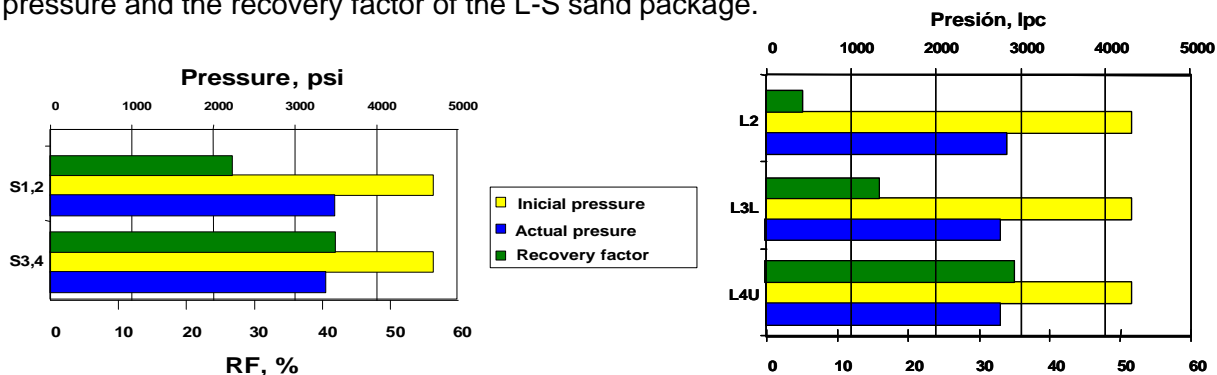
Figure 3: Composite 3D Allan Map showing the possible communication pathways inside the L sand package. (1) 3D juxtaposition of sedimentological sequences. (2) 3D juxtaposition of sand with porosity > 8%. (3a) Communication pathways between immediately superposed sequences (sands + shales). (3b) Communication pathways between sequences separated by, at least another sequence. HW: hanging wall. FW: Footwall.

This geologic study demonstrates that, besides the erosive events that can constitute communication mechanisms among sands, the displacements caused by the secondary faults may also induce communications among the sands in the field.

2. Production

2.1. Introduction, motivation and technique

In the Mata field there are nine main reservoirs with a total OOIP of 200 MMSTB and an oil cumulative of 48 MMSTB. The following figures show the initial pressure, the current pressure and the recovery factor of the L-S sand package.



The figures show that with different recovery factors the actual pressure is almost the same for all sands, even though some sands have secondary recovery and others do not.

Due to the communication between the L-S sand package, the traditional material balance technique was not able to fit the field history; therefore the material balance equation was adjusted to identify the influx/outflux (source term : M) necessary to adjust the history

$$(M = F - N * (E_o + m * E_g + E_{fw}))$$

Another technique implemented was to identify “the total gas available to be produced”, which is as follows: **The solution gas produced with the produced oil + the original gas cap + the injected gas + the gas that comes out of solution (due to the depressurization of the reservoir) - the gas trapped by the critical saturation.** The idea is that the total available gas minus the produced gas is equal to the actual free gas.

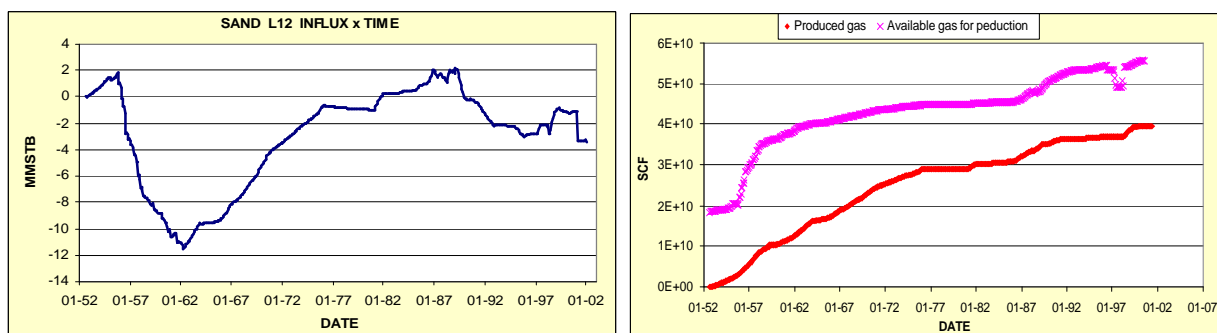
A comparison of this volume with the volume of the actual gas cap, volumetrically calculated with the actual gas/oil contact, possibly indicates gas flux into or out of the sand package.

2.2. Material balances description

In order to apply the material balance, the L-S sand package was divided in four groups, named L12, L34, S12 and S34.

Follow figures and comments of the necessary influx/outflux calculated to fit the sand group history and the produced gas with the available gas for production for 2 sand packages (L12 and L34).

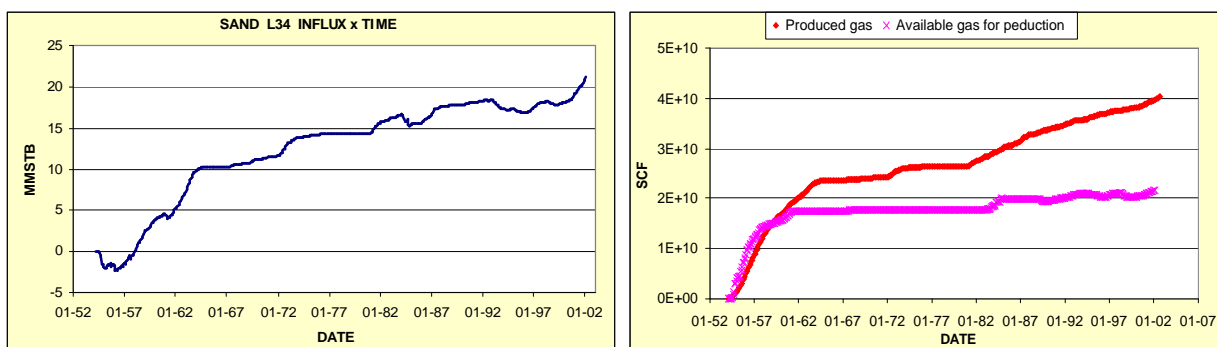
2.2.1. Sand package L12



In the beginning there is a loss of mass from L12 sand package, between 1962 and 1975 the sand receive mass and stay more or less stable after that. At the end of 2002 the sand has lost around 3 MMBbl (reservoir condition).

The actual produced gas is 40 MMMSCF and the actual available gas is 53 MMMSCF, therefore there ought to be around 13 MMMSCF of free gas in the sand. The actual mapped gas cap size shows 18 MMMSCF of free gas, with a difference of -5 MMMSCF.

2.2.2. Sand package L34



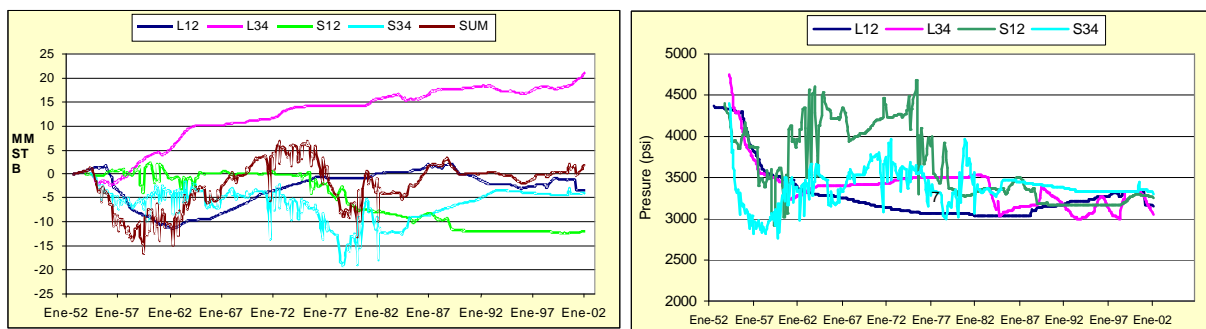
Through all the production time the sand package receives an influx, having received until today around 21 MMBbl (reservoir condition).

The total gas available to be produced is 21 MMMSCF and the sand produced 40 MMMSCF. In other words, the sand produced 19 MMMSCF more than it would be possible if it were an isolated sand. This excess of gas certainly came from others sands. There is no identified gas cap in the sand nowadays.

The two others sand packages were analyzed the same way. The source term (M) of all four sand packages is shown on the figure below. A table of the actual gas cap volume, the produced gas and the available gas to be produced is shown in a following table.

2.3. Material balance and gas balance conclusion

The assumption that the L-S sand package is a hydraulic unit implies that it is a closed system and consequently the entire package should not loss or gain mass. Therefore, if inside the package one sand loses mass is due to the fact that another one is gaining it. Base on this concept, the summation of all influx should be zero. The graphics of the influxes (with the summation) and the pressure history are shown below.



In conclusion, at the beginning the L sands were in communication and the S sands were not. After 1977 all the sands became communicated, as seen in both plots, where all the

pressures are similar, at a common datum, and the summation of the influx in all sands tends to be zero.

SAND	AVAILABLE GAS (MMM scf)	PRODUCED GAS (MMM scf)	BALANCE FREE GAS (MMM scf)	GAS CAP VOLUME (volumetric) (MMM scf)	GAS VOLUME ERROR (MMM scf)
L12	53	40	13	18	-5
L34	21	40	-19	0	-19
S12	37	15	22	9	13
S34	94	65	29	16	13
TOTAL	205	160	45	43	2

Although there is a huge error in the gas volumes calculated by the gas balance when analyzed in a sand by sand criteria, its clear that the total error is small. It means that there was a strong gas movement from the lower sand package S to the upper sand package L. This fact leads to a hypothesis that the communication occurred at the top of the structure.

3. CONSOLIDATION

In the beginning only the L sands behaved as a hydraulic unit, the geological model easily explains this fact. In 1977 almost all sands in the L-S sand package started to behave as a hydraulic unit. The geological model cannot explain this fact and, although some models have been studied, there is no proved reason for this.

Based on the theory that the communication occurred on the top of the structure, among the hypothesis handled the two most accepted are the breaking seal of the main fault or mechanical failures in wells.

4. CONCLUSIONS

In Mata field a multidisciplinary approach was the key to understand the communication between sands historically exploited as individuals reservoirs. This approach was the support for achieving legal authorization to exploit all L-S sand packages as a hydraulic unit.

5. ACKNOWLEDGEMENT

We thank Petrobras Energía de Venezuela for allowing us to publish the results of this work.

6. REFERENCES

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