Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis*

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Abstract

An analysis of historical results on Colombian hydrocarbon exploration activity highlights a pattern with respect to the sequence of reserve discoveries. This pattern is identified by plotting the cumulative reserves of each discovery versus the number of historically drilled wells. This chart illustrates that greater discoveries are made at the beginning of exploratory activity and eventually exploration tends to find smaller reserves. This curve was described by Meisner and Demirmen (1981) as the Creaming Curve and is used as an indicator of the maturity of a petroleum basin. By using numerical methods it is possible to associate the resulting curve with a tangent, which can be projected from historical data to estimate potential undiscovered reserves.

Using public historical data (IHS: 1907–2013) and applying the Creaming Curve method, it is possible to describe hydrocarbon potential in the Colombian productive basins. The results of this analysis facilitate the evaluation of investment alternatives for future exploration focusing the activity into areas that still have remaining potential. Plotting the reserves depicts that great discoveries (>400 MBbls) were achieved after extensive exploration activity. It identifies two periods of significant discoveries, during the 20's with fields like Infantas and the 80's with fields like Caño Limon, Cusiana, Rubiales, and Apiay. Each new period generates a new Creaming Curve and a new projection of potential resources.

Through the implementation of the Creaming Curve method, it is found that the potential of remaining reserves for Colombia are more than 1,624 MBbls and 457 wells are required to be drilled to achieve this potential. The most attractive hydrocarbon areas are Llanos and VMM with 74% of the total oil potential reserves. The results evaluated from an economical and a statistical standpoint suggest onshore potential prospective resources to be discovered and materialized in the short and medium term, without discarding the potential of unevaluated basins to be developed offshore and unconventional exploration discoveries.

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis

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AAPG European Conference & Exhibition

Barcelona, Spain

May 14 2014

The Creaming Curve Method

Outline

- **Introduction:** The Creaming Curve history, past exploration trend, applications of the method

- **Basin Maturity:** Decline field size, from immature to mature stage

- **New Play Introduction:** New exploration cycle, new technology-regulation

- **Future Exploration Performance:** Future discoveries potential, Statistical performance analysis
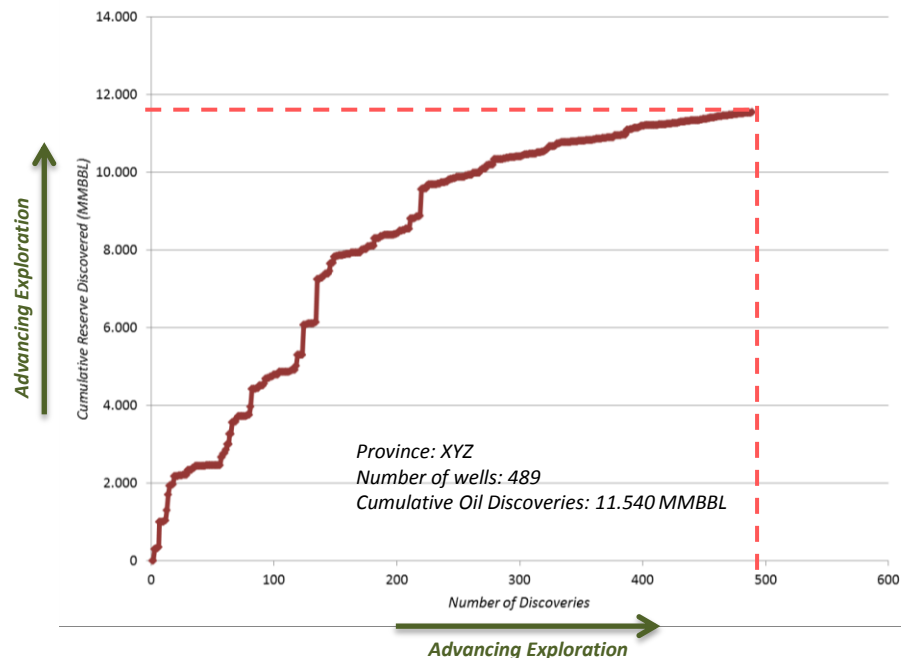
- **Conclusions**

The Creaming Curve Method: *Introduction*

- Introduced in 1981 by J. Meisner and F. Demirmen after finding an empirical relationship in exploration data.

- The method describes the relationship between the cumulative volume of reserves discovered in a single basin and the sequence of the exploration wells drilled.

- It is a simple statistical procedure used to analyze past exploration trends and to forecast oil and gas resources potential.

- Plotting the two variables into a graph shows the past exploration trend of the basin.

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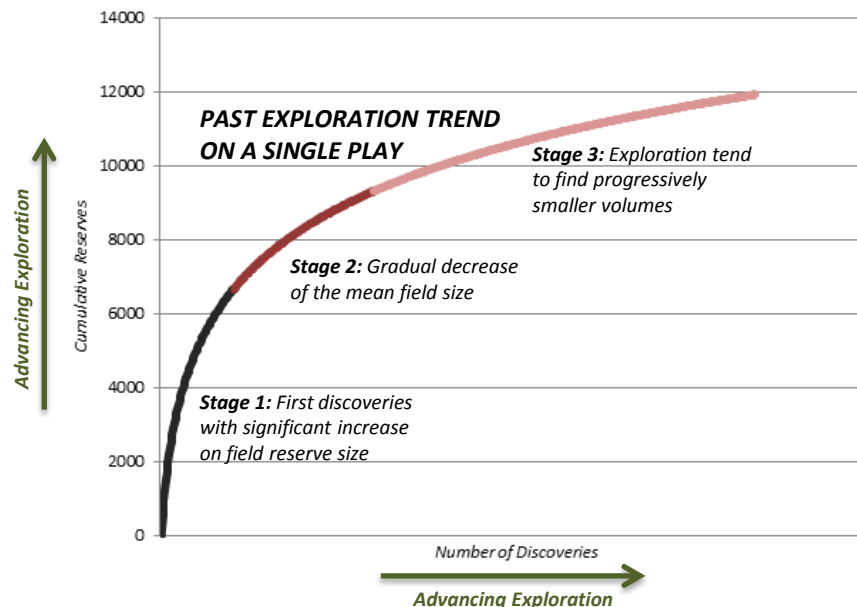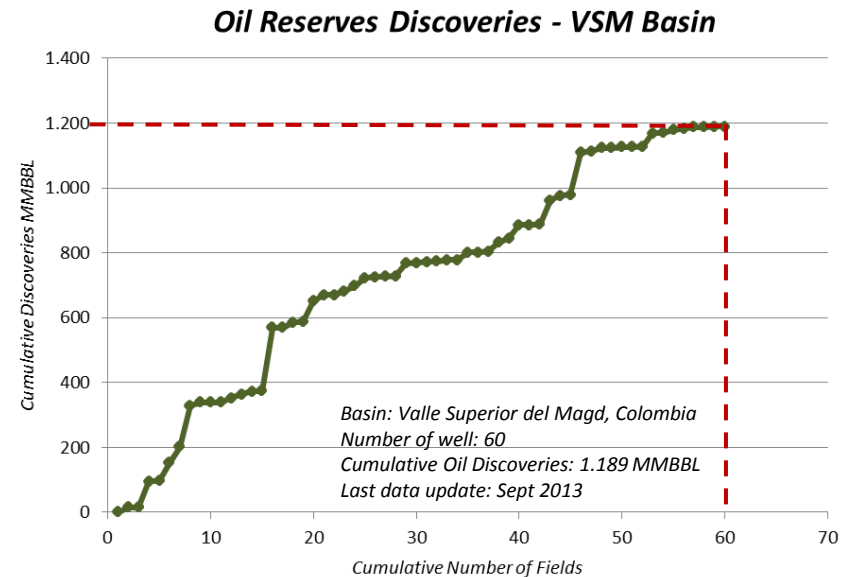
The Creaming Curve Method: *Introduction*

- This method is applicable to any mature basin or basins in a transitional stage (from immature to mature). It may reflect the changes introduced by new plays, technologies or regulatory framework.

- As a statistical method the most important requirement is to have a complete historical data of the discoveries of the basin under analysis.

- Although this method can be used to analyze hydrocarbon discoveries, is recommended to keep separate the study of oil discoveries from gas.

Province: XYZ
Number of wells: 489
Cumulative Oil Discoveries: 11.540 MMBBL

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis

The Creaming Curve Method: *Basin Maturity*

- The method recognized that the discovery success rate and the field size declined as exploration advanced (Creaming Phenomenon).

- This phenomenon is so common that it can be seen in all mature basins and denotes the past exploration trend.

- In the following Colombian basins we examine the size distribution of the oil fields, their order of discovery and the success rate of the historical exploration.

Oil Reserves Discoveries - Llanos Basin

Basin: Llanos, Colombia
Number of well: 253
Cumulative Oil Discoveries: 5.979 MMBBL
Last data update: Sept 2013

Oil Reserves Discoveries - VSM Basin

Basin: Valle Superior del Magd, Colombia
Number of well: 60
Cumulative Oil Discoveries: 1.189 MMBBL
Last data update: Sept 2013

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis
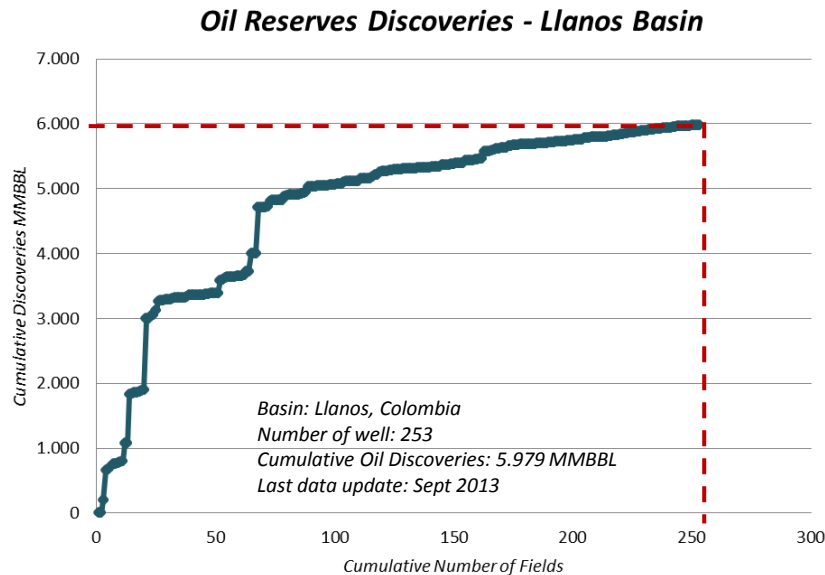
The Creaming Curve Method: *Basin Maturity*

- The declining trends are consistent with the well-known observation that the large fields generally are discovered early during exploration and over time discoveries tend to be of a smaller size.

- When new information is available the evaluation of the method is updated.

Decline field size with advancing exploration (Llanos Basin)

Immature Stage

Transitional Stage

Mature Stage

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis
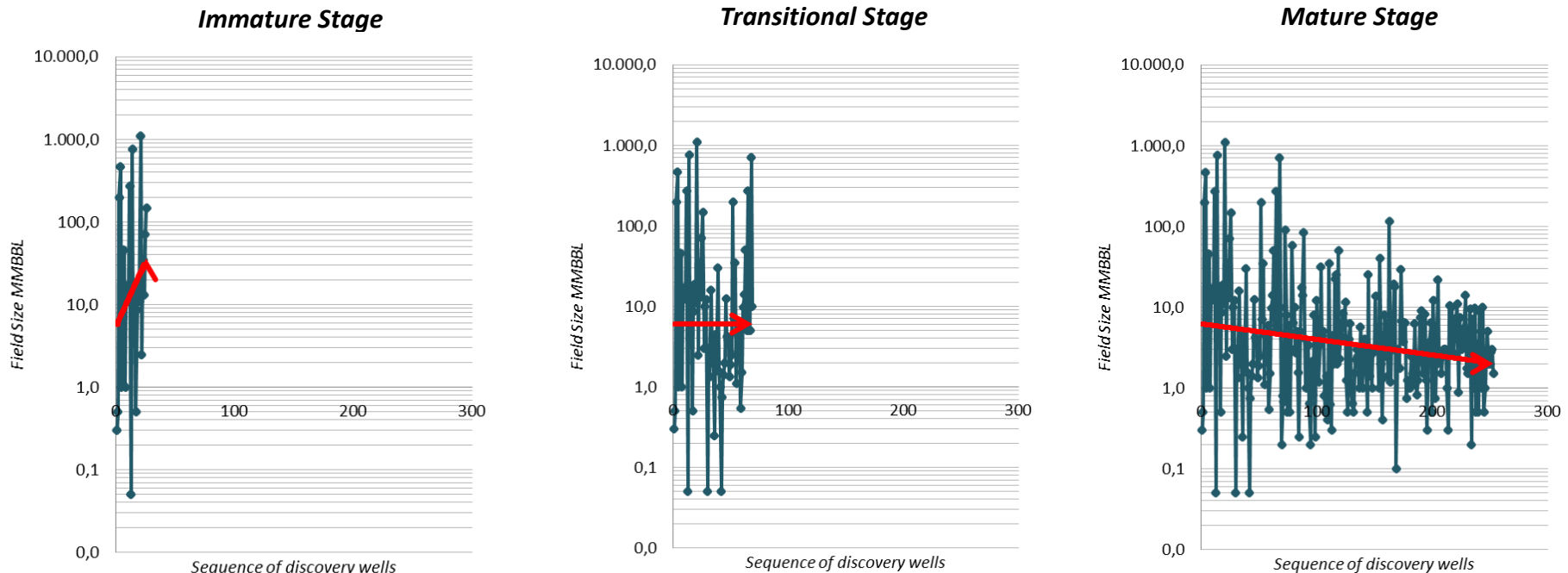
The Creaming Curve Method: *New Play Introduction*

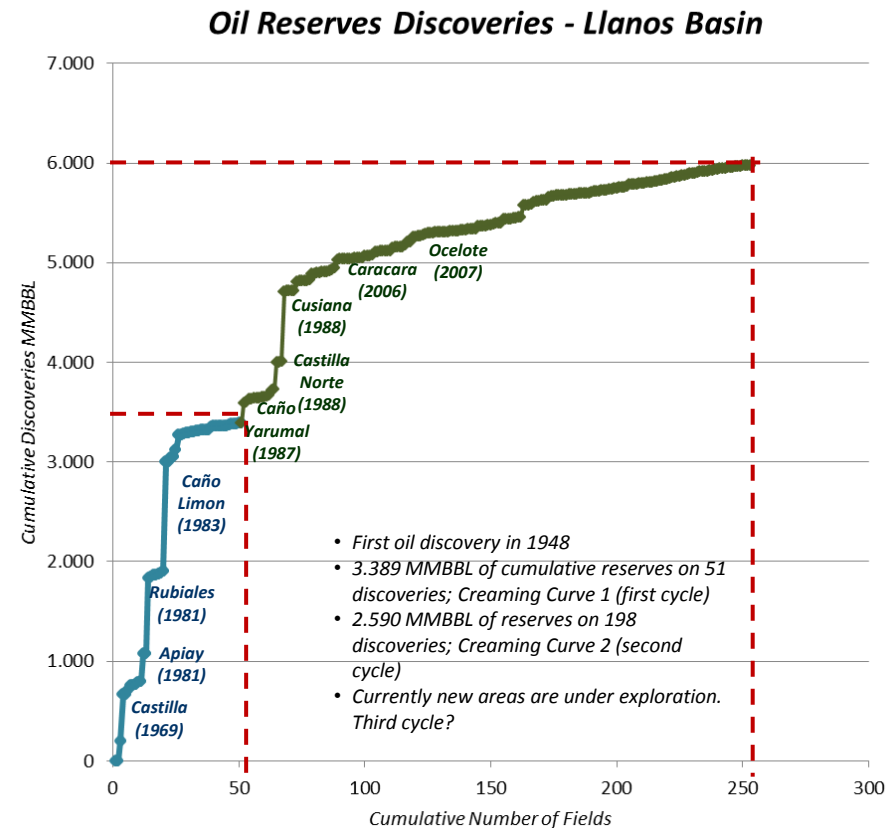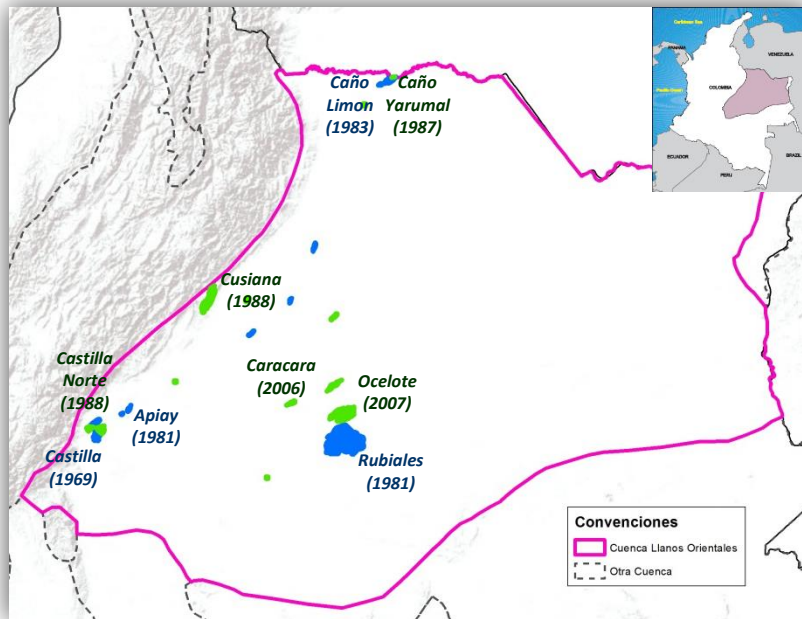- The first major discovery defines the play and generally subsequent discoveries are associated with high reserve volume. If only one play is discovered in the basin, then the total reserves discovered over time will approach to a single Creaming Curve *(Assuming no major policy-regulatory changes)*.

- If a second play is discovered the reserves will increase again starting a new cycle.

- The discrete Creaming Curves describe the evolution of plays over time and give a measure of their contribution to the basin as a whole.

Hypothetical Creaming Curves for new plays discovered within a basin

Cumulative Discoveries

- Total reserves after play 2 was discovered
- **Play 2 Discovered**
- Reserves if only play 1 was discovered
- **Play 1 Discovered**

Number of Fields

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis
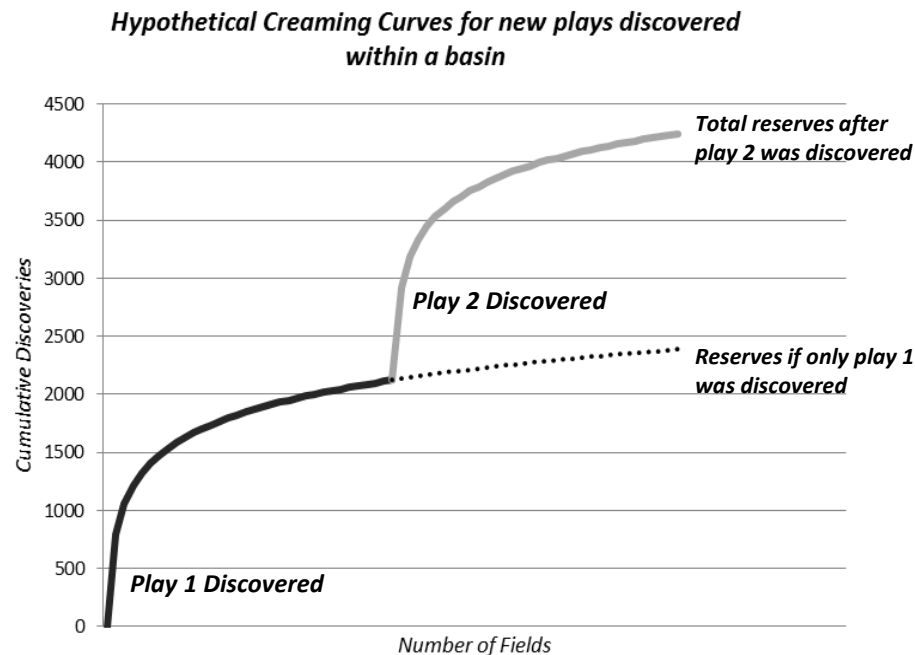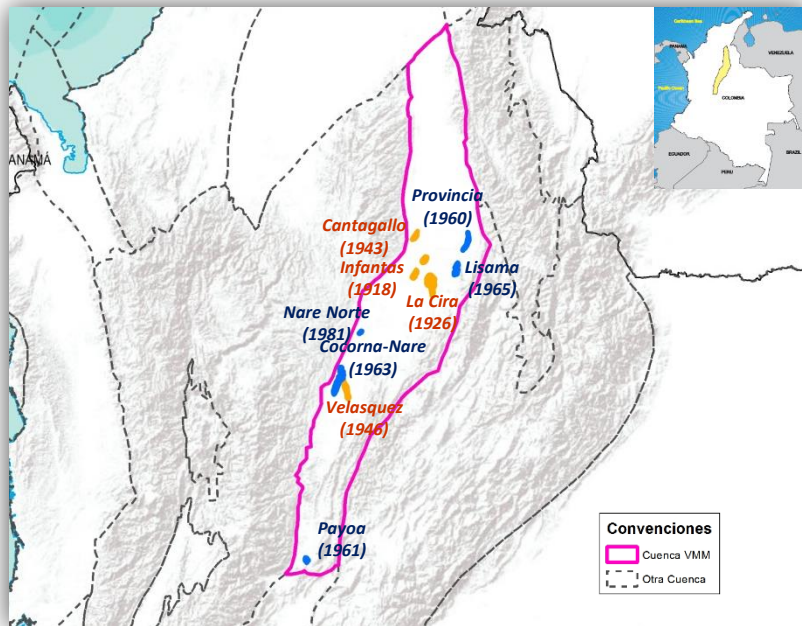
The Creaming Curve Method: *New Play Introduction*

- In the Llanos basin the Creaming Curve could be modeled with two hyperbolas (cycles).

- High exploration efficiency implies that the largest fields have already been found and that a new play type or an introduction of new technology *(i.e. HP/HT drilling for deeper targets)* is needed to find additional large fields.

Oil Reserves Discoveries - Llanos Basin

- First oil discovery in 1948
- 3.389 MMBBL of cumulative reserves on 51 discoveries; Creaming Curve 1 (first cycle)
- 2.590 MMBBL of reserves on 198 discoveries; Creaming Curve 2 (second cycle)
- Currently new areas are under exploration. Third cycle?

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis
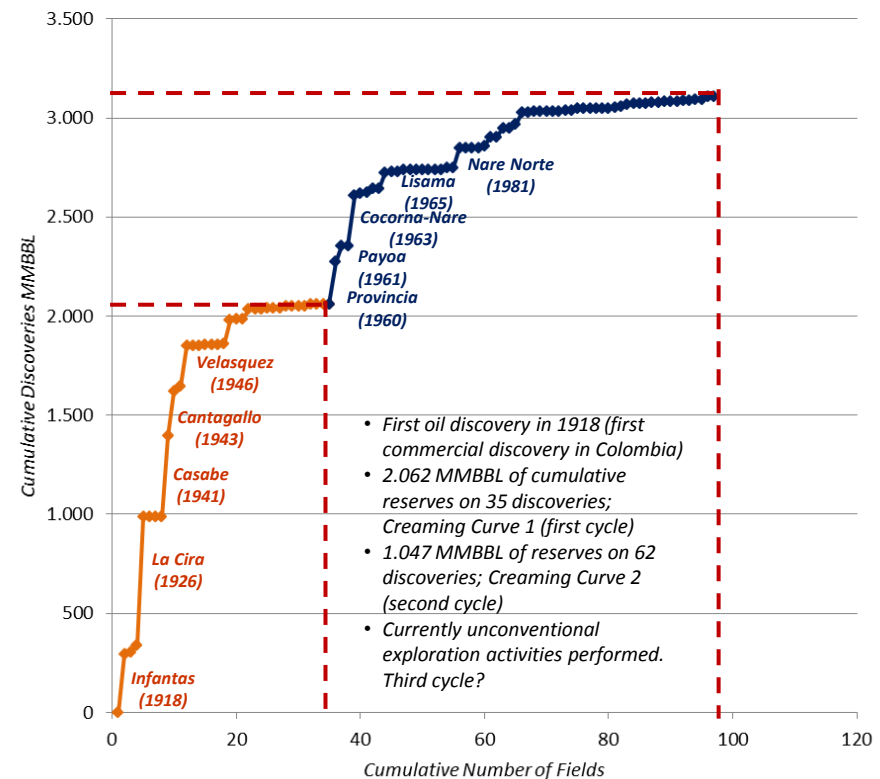
The Creaming Curve Method: *New Play Introduction*

- In the VMM basin two cycles are presented which represent the introduction of abundant resources in the discovery of a new play.

- A new cycle with the introduction of unconventional resources (currently under exploration stage) can be expected in the upcoming years.

Oil Reserves Discoveries - VMM Basin

- First oil discovery in 1918 (first commercial discovery in Colombia)
- 2.062 MMBBL of cumulative reserves on 35 discoveries; Creaming Curve 1 (first cycle)
- 1.047 MMBBL of reserves on 62 discoveries; Creaming Curve 2 (second cycle)
- Currently unconventional exploration activities performed. Third cycle?

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis
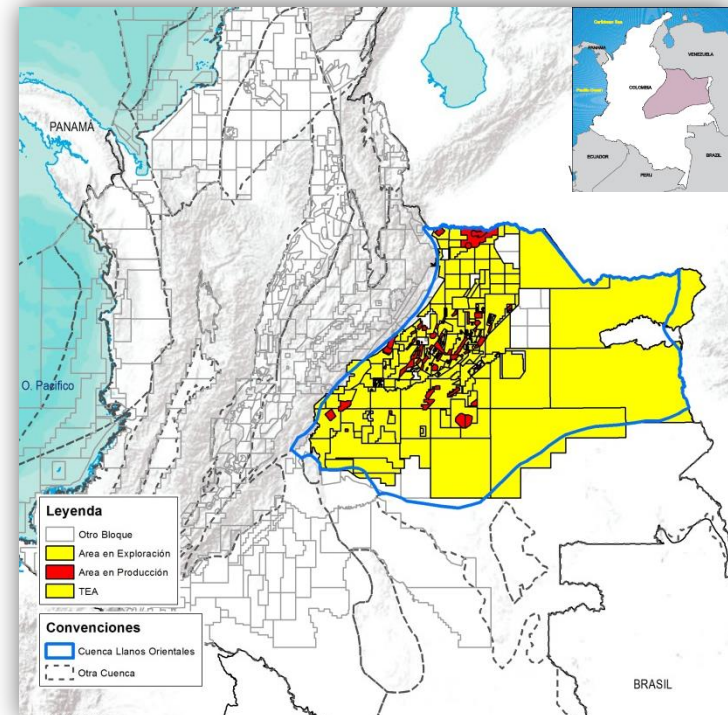
The Creaming Curve Method: *Future Discovery Performance*

- An analysis of past exploration discovery performance in a specific basin provides the information to make the prediction of the future exploration trend.

- The ultimate oil or gas recovery information should be listed in historical sequence distinguishing discoveries from dry holes.

- The field size can be adequately approximated by a lognormal probability distribution.

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis
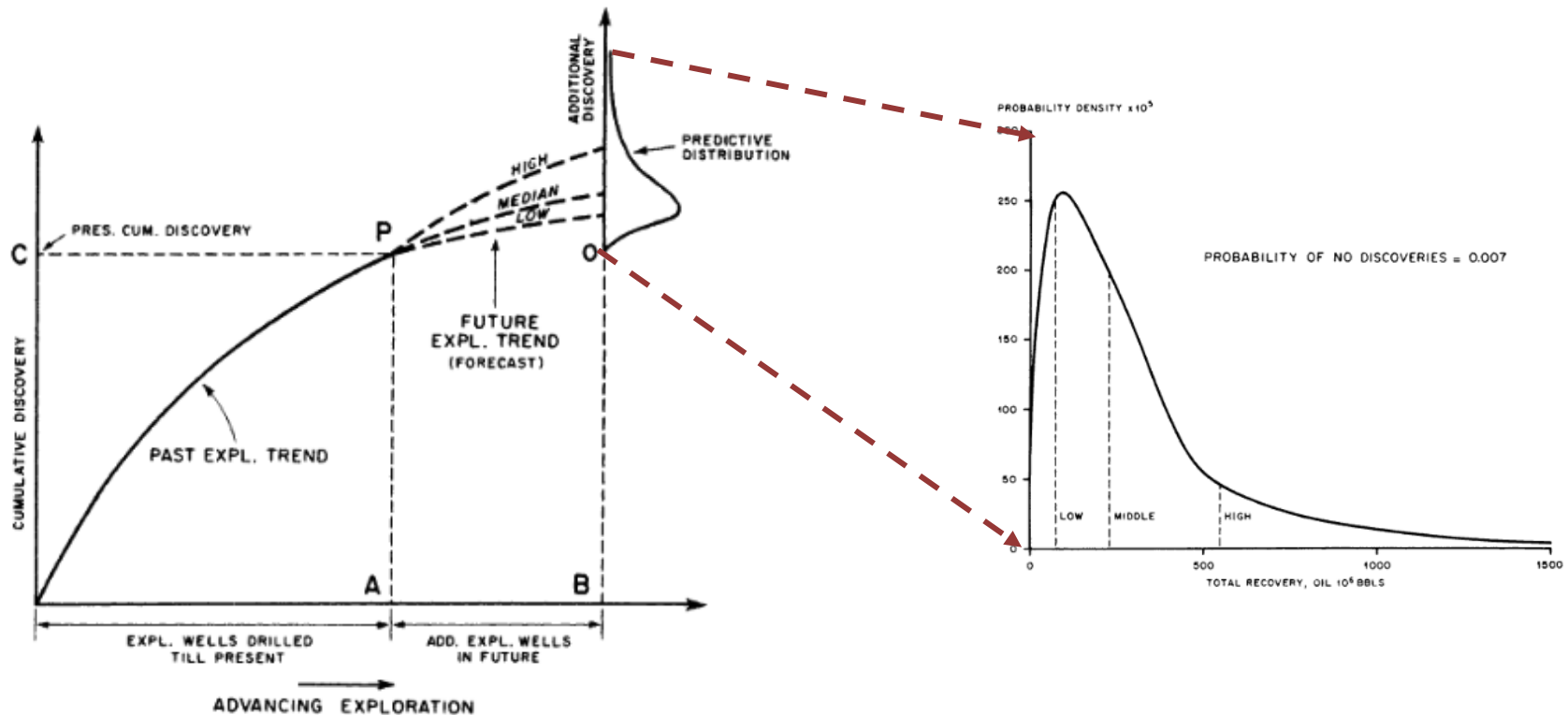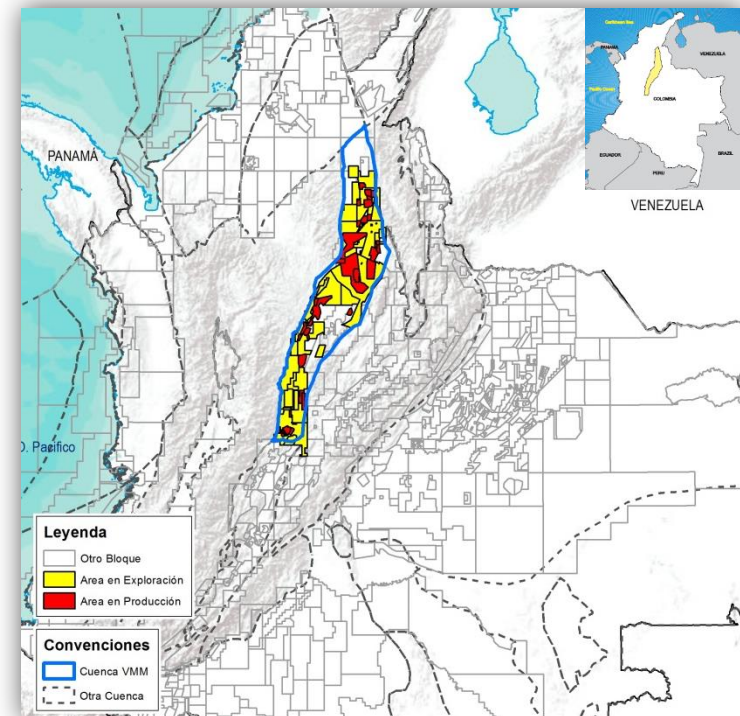
The Creaming Curve Method: *Future Discovery Performance*

- An example of future exploration trend in a **mature basin** in Colombia.

- The Creaming Phenomenon in these mature basins occurs in two cycles with the introduction of new plays associated with new contract awards and exploration activity.

- According to the historical success rate of the basin, the cost of finding potential resources can be estimated *(total number of wells needed to drill to achieve the potential).*

Basin: Llanos, Colombia
Cumulative Oil Discoveries: 5.979 MMBBL
Number of Discoveries: 254
Success Factor: 41,34%

Estimated Resources Potential: 754,9 MMBBL
Number of Exploration Wells to Drill: 597
Number of Exploration Discoveries: 247

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis
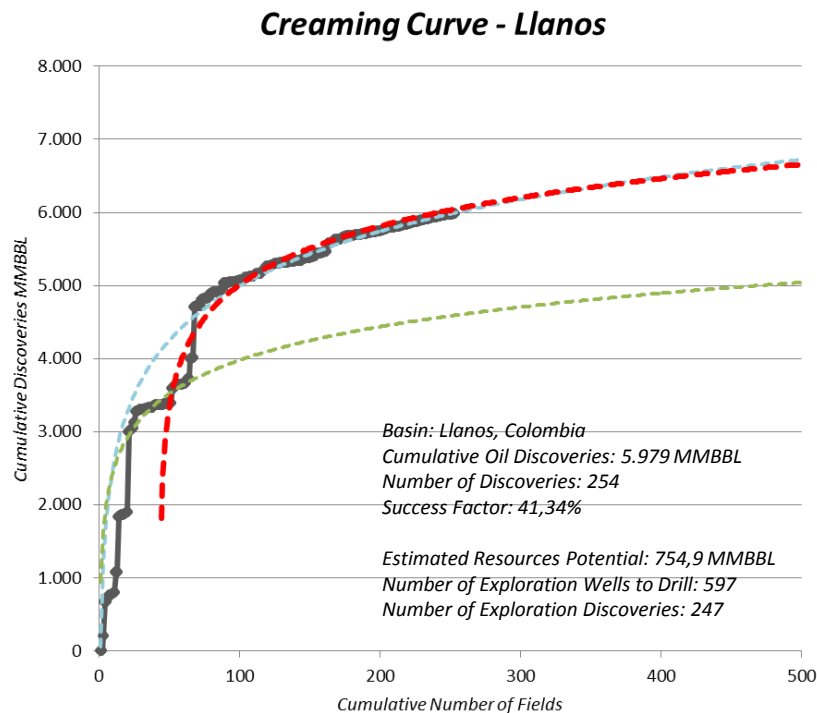
The Creaming Curve Method: *Future Discovery Performance*

- Analyzing the future exploration trend in the VMM **mature basin**, two cycles related to oil discoveries can be distinguished.

- The only uncertainty of this analysis is to predict the potential of a new cycle, and it depends on the geologists prediction to when a new cycle may occur, i.e. unconventional resources?

Creaming Curve - VMM

Basin: VMM, Colombia
Cumulative Oil Discoveries: 3.109 MMBBL
Number of Discoveries: 96
Success Factor: 34,62%

Estimated Resources Potential: 456,7 MMBBL
Number of Exploration Wells to Drill: 288
Number of Exploration Discoveries: 104

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis
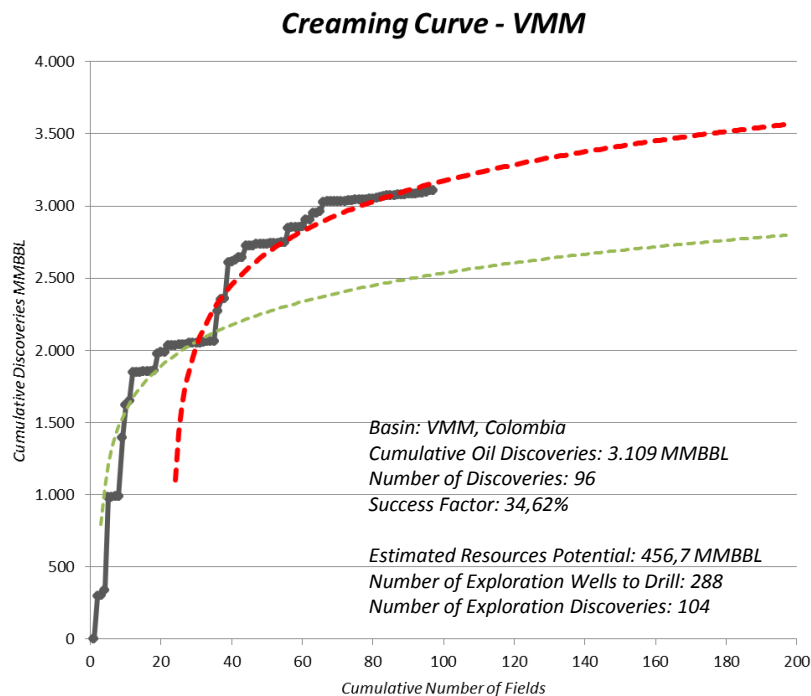
The Creaming Curve Method: *Future Discovery Performance*

- A case for evaluating the reserve potential in a **transitional basin** in Colombia.

- The discoveries show a constant rising trend (from immature to mature) and as result it is more difficult to identify the Creaming Curve.
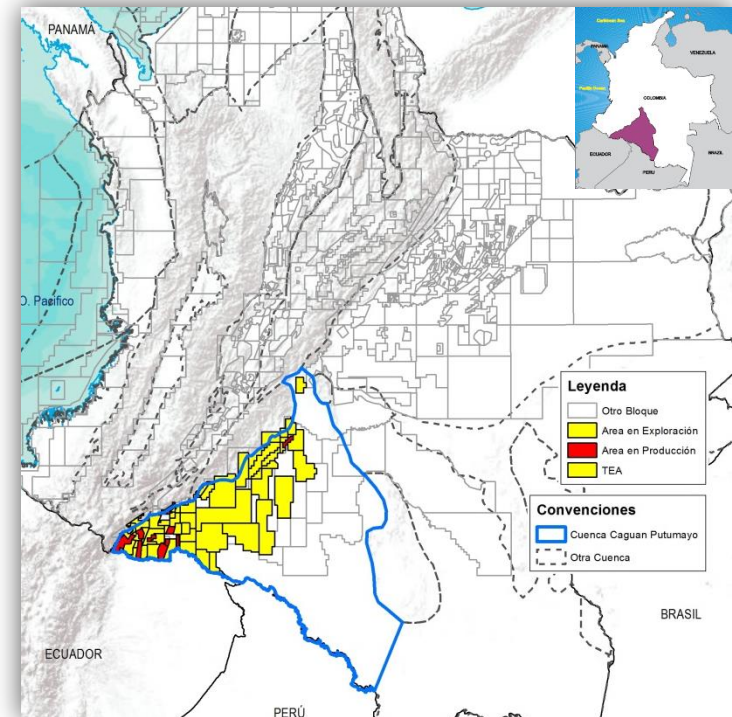
- Experience shows that field size plays a greater role than the success rate when defining the trend.

Creaming Curve - VSM

Basin: VSM, Colombia
Cumulative Oil Discoveries: 1.189 MMBBL
Number of Discoveries: 61
Success Factor: 28,32%

Estimated Resources Potential: 253,9 MMBBL
Number of Exploration Wells to Drill: 212
Number of Exploration Discoveries: 59

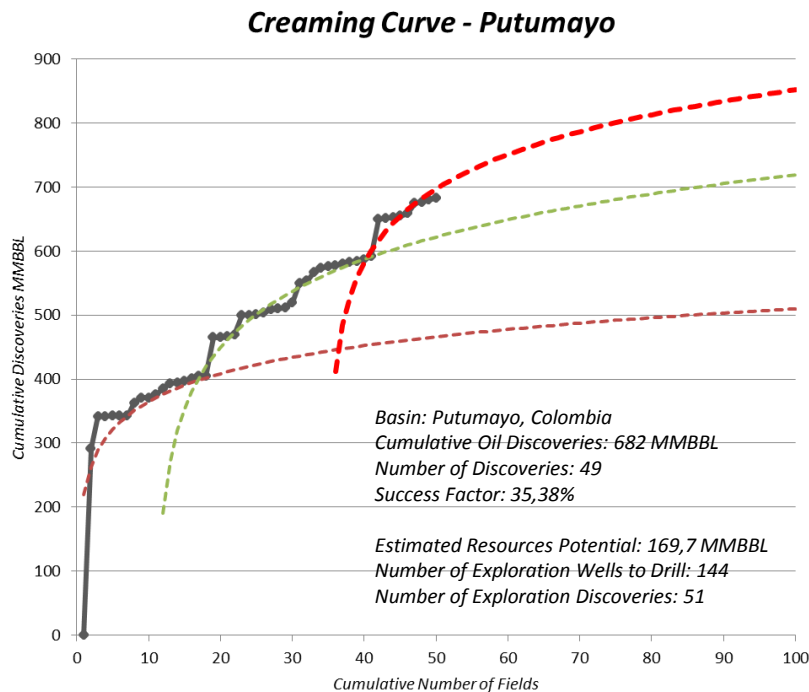Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis
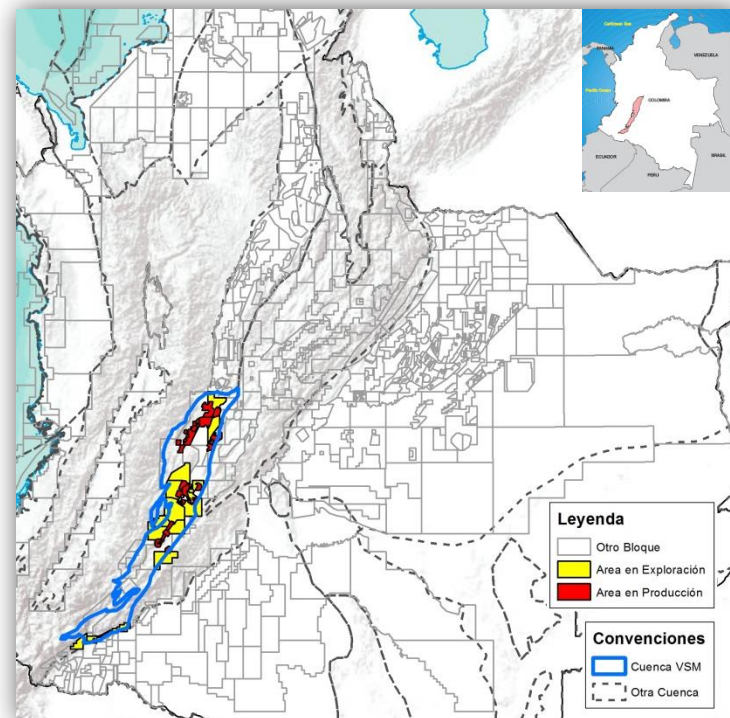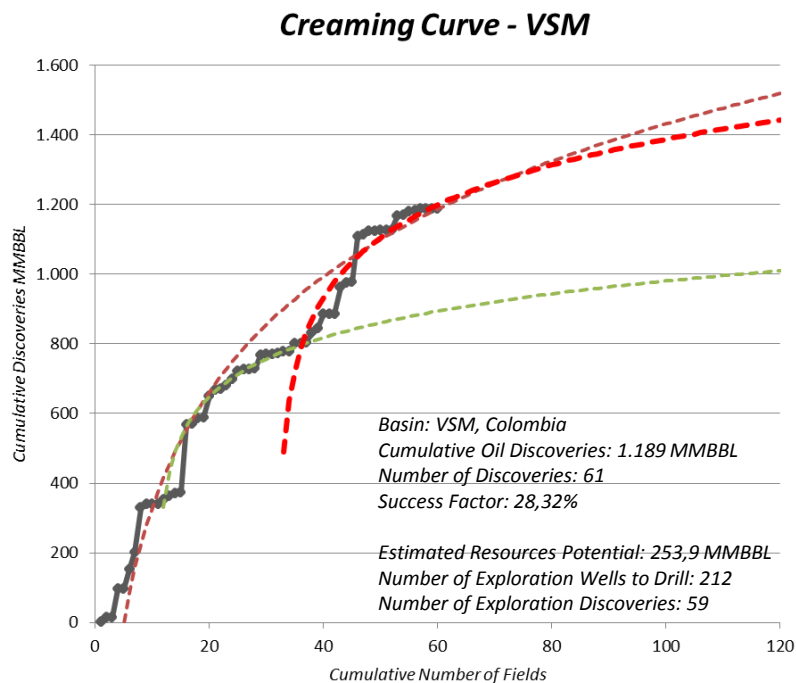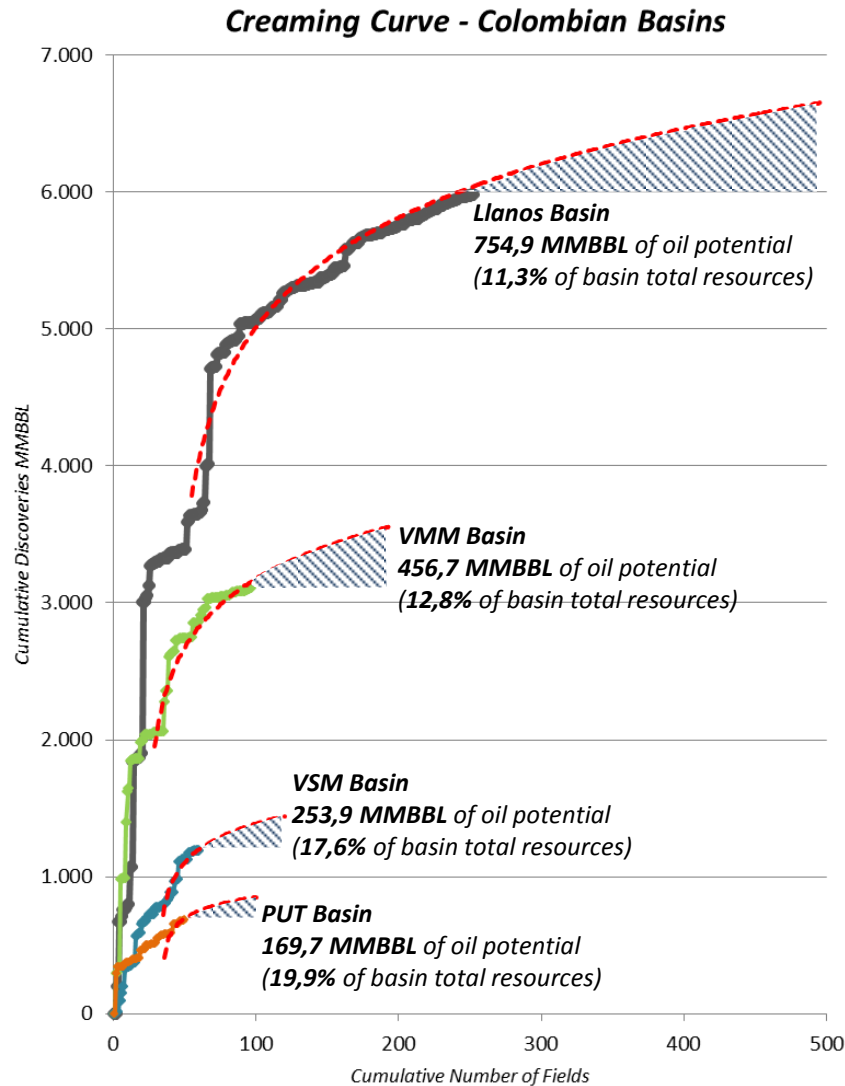
The Creaming Curve Method: *Future Discovery Performance*

- Evaluating the reserve potential in the Putumayo **transitional basin** shows a constant growing trend after its first oil discovery.

- The reserves to be found in a basin with a constant rising trend depends on the ability to define the stage of gradual decrease of the mean field size.

Creaming Curve - Putumayo

Basin: Putumayo, Colombia
Cumulative Oil Discoveries: 682 MMBBL
Number of Discoveries: 49
Success Factor: 35,38%

Estimated Resources Potential: 169,7 MMBBL
Number of Exploration Wells to Drill: 144
Number of Exploration Discoveries: 51

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis

The Creaming Curve Method: *Future Discovery Performance*

Creaming Curve - Colombian Basins

Llanos Basin
754,9 MMBBL *of oil potential*
(**11,3%** *of basin total resources*)

VMM Basin
456,7 MMBBL *of oil potential*
(**12,8%** *of basin total resources*)

VSM Basin
253,9 MMBBL *of oil potential*
(**17,6%** *of basin total resources*)

PUT Basin
169,7 MMBBL *of oil potential*
(**19,9%** *of basin total resources*)

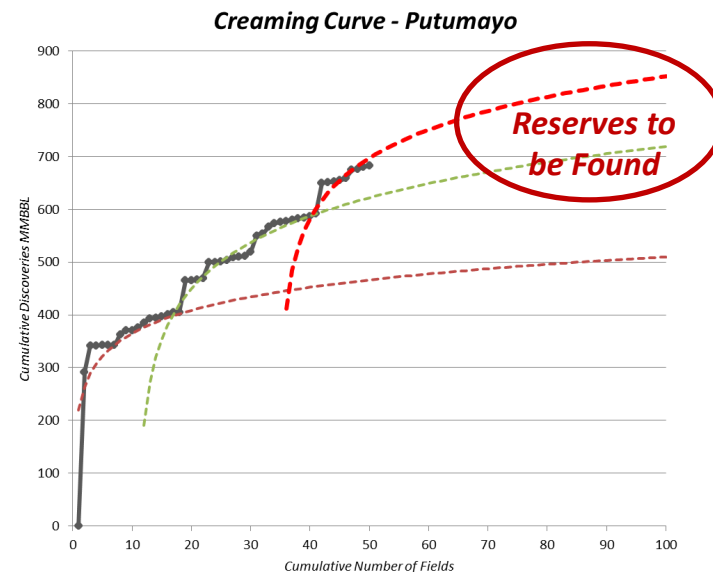*Cumulative Discoveries MMBBL*

Cumulative Number of Fields

- A summary of the future resources potential make evident that for mature basins most of the resources (%) are already found.

- In Llanos basin 88,7% of the resources were already discovered and is missing to find 11,3% of the total potential of the basin.

- In Putumayo basin from the total potential is missing to find the 20% of the resources.

- For mature basins the potential resources to find are higher in volume but lower in % of the total potential of the basin.

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis

The Creaming Curve Method: *Future Discovery Performance*

- In this study the **Yet To Find** analysis was not considered.

- The **YTF** analysis can be performed as a complementary study to distinguish the minimum field size, to consider a field as a potential discovery.

- According to the potential field size, companies like the Majors may decide to leave the basin for future exploration activities.

- A reduced field size potential would be an alternative just for small cap companies.

- The sum of several small potential fields would not create enough value as a large potential field.

- The future reserves potential measured by the Creaming Curve method would give the reserves to be found.

Creaming Curve - Putumayo

Reserves to be Found

Cumulative Discoveries MMBBL

Cumulative Number of Fields

Hydrocarbon Discovery Potential in Colombian Basins: Creaming Curve Analysis

Conclusions

- The Creaming Curve is a helpful tool to predict the remaining exploration potential of a basin and can be implemented in any region where the complete historical information of the discoveries is available.

- Using the historical data allows the analysis of reserve discoveries trends of any mature or transitional basin.

- This method identifies that large deposits of reserves are discovered at the beginning of the exploratory activity and over time volumes tend to be of a smaller size.

- This method is also an indicator of the maturity of a basin where exploration success gradually decreases.

- To consider the cost of finding the hydrocarbon resources potential, it is necessary to know the technical success factors in order to identify the number of wells needed to drill.

- In mature basins the potential resources to be found are higher in volume but lower in % of the total potential of the basin. The opposite happens in the transitional basins where the potential resources are higher in % but lower in volume.

Thank you / Questions