# The Potential for New Discoveries of Oil and Gas in the Shallow Waters of the Campos Basin, Brazil*

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## Abstract

The objective of any exploratory campaign in a geologic province with known accumulations of oil and gas is to determine where to drill, given the expected number and size of the accumulations present. Modern tools for modeling the exploratory process are complex software that make use of the available information about past exploratory history of the play being studied, while also applying the acquired geologic knowledge about specific parameters of the play, in order to provide estimates of the statistical distribution of the number and size of accumulations which remain to be found (yet-to-find-oil). A further refinement to this methodology is the incorporation of the concept of area exhausted by past exploratory efforts, as an adjustment to the estimation process carried out by exploratory process modeling tools.

The discovery of significant new plays in the Campos Basin has displaced, since the 1970s, the focus of exploratory activities from shallower to deeper waters. This trend also resulted in exploratory activities farther offshore, involving higher costs and initial investments. Following a recent broad review of the potential for new discoveries of oil and gas in the general region of shallow waters (under 400 meters water depth) of the Campos Basin, utilizing both exploratory process modeling tools and an adjustment for area exhausted by prior exploratory efforts, a study was made of a specific geologic play, identified by the USGS as Assessment Unit 60350102 - Cretaceous Carbonates, part of the Lagoa Feia-Carapebus Total Petroleum System, as described in their World Energy Assessment 2000 (WE2000--Schenk, 2000).

The results of the present assessment, utilizing extensive historical data from the region of shallow waters of the Campos Basin, suggest that the geologic play known as Cretaceous Carbonates cannot yet be considered a mature exploratory play. Furthermore, the results suggest that this area has the potential for discovery of significant additional total accumulations of oil and gas, as well as individual accumulations of significant size. This potential could be of interest, if not to major players of the oil industry, at least to other companies who could benefit from the relative lower level of investment and technological requirements necessary to carry out exploratory and production activities in this area, in expectation of more modest results than the thresholds required by major players.

## Introduction

Since the 1970s, the discovery of significant new plays in the Campos Basin has displaced much of the focus of exploratory activities from shallower to deeper waters. Exploratory activities moved farther offshore and involved higher initial investments and operating costs. The redirection of exploratory efforts raises the concern that important remaining accumulations in shallow waters may have been ignored during the recent past, possibly passing up opportunities for extracting oil wealth from areas which involve lower capital and operating expenses, and thus lower financial risks. In order to determine if this is indeed the case, the potential for new discoveries of oil and gas fields in shallow waters was investigated through the use of exploratory process modeling tools.

Today, the Campos Basin represents approximately 88% of Brazilian oil reserves and production, but exploration and production (E&P) efforts are concentrated in deep and ultra-deep waters. The trend towards E&P activities in deeper, farther offshore areas (Figure 1) involves technical and economic issues, because E&P activities in shallower waters may present more modest cash outlays (investment) over the full lifecycle of the project, as well as benefits from the presence of an already installed production infrastructure in much of the area. The recent discoveries in deep and ultra-deep waters (Tupi, Guará, Carioca, etc.) demonstrate that the technological solutions for effective monetization of discovered accumulations are not yet 100% resolved, and even then, gigantic investments will be required.

Furthermore, the shallow waters of the Campos Basin present features and technical aspects which suggest a favorable geologic potential (Figure 2). Thus, alternatives for extracting oil wealth from accumulations with a more modest project profile would be welcome, if they were to be shown to be likely to exist. Efforts to carry out such assessments in the Campos Basin date from 1984 (Chaves et al, 1984).

## Methods

The objective of any exploratory campaign in a geologic province with known accumulations of oil and gas is to determine where to drill, given the expected number and size of the accumulations present. Modern tools for modeling the exploratory process are complex software that make use of the available information about past exploratory history of the play being studied, while also applying the acquired geologic knowledge about specific parameters of the play, in order to provide estimates of the statistical distribution of the number and size of accumulations which remain to be found (yet-to-find-oil). In the present case the exploratory modeling tool, GeoX®, from GeoKnowledge, was used to assess yet-to-find-oil probabilities.

The information used to feed data into the modeling tool was obtained from the database of wells drilled in Brazil, maintained by Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP), called BDEP (Banco de Dados de Exploração e Produção da ANP). A spreadsheet was set up with information from each discovery well and its associated field and this information was used to specify input parameters for discoveries (Figure 3).

The modeling tool uses a Monte Carlo approach in estimating accumulation size and total accumulations yet to be discovered. This involves establishing probability distribution curves for each parameter used for calculating the variables representing accumulation size and total accumulations. Past exploratory results help determine the probability distributions for number and size of undiscovered fields, according to the concept of exploratory experience and field-size distribution. Then numerous random samplings of each parameter are made, and the results obtained for those variables (accumulation size and total accumulations) are plotted as probability distributions of values, from which we extracted pertinent points, such as those representing the P10 (level expected with 10% certainty) and P90 (level expected with 90% certainty). This iteration process is described in Figure 4, which represents a similar approach carried out by the US Geological Survey (USGS) in its World Petroleum Assessment 2000 (WA2000--Charpentier and Klett, 2002).

A further refinement to this methodology is the incorporation of the concept of area exhausted by past exploratory efforts, as an adjustment to the estimation process carried out by exploratory process modeling tools. In an exploratory play, the area exhausted is the total (less overlaps) of the area of influence of each well, defined as the area in which no further accumulations can be expected to be discovered, given the average expected size of fields in the play. Given all the wells drilled in the investigation area, and their estimated area of influence, the area of the shallow-water play (33,884 $km^2$) was adjusted downwards by the area exhausted, using geographic information tools (ArcGIS®). Exploratory process modeling was carried out over this adjusted area (Figure 5).

The concept of Discovery Sequence (the order of discovery of accumulations) is important for explorationists because the way in which cumulative discoveries evolves, as new exploratory efforts are carried out (new wells drilled), indicates the degree of success, or exploratory efficiency, of the exploratory campaign (Drew et al., 1980). Besides, the exhaustion curve defines the limit towards 100% exhaustion of discoveries. As the plotted discoveries approach the asymptotic limit of the curve, the play is deemed to be a mature exploratory play. Given this curve, at any point one could determine the expected new discoveries to be found for a given level of new wells (Figure 6). It is thus crucial to be able to build the exploratory experience curve from past experience.

Discoveries in a sedimentary basin represent a sampling of existing accumulations, although that sampling is skewed towards the discovery of larger ones first. Thus, the distribution of the sizes of discoveries must follow that of existing accumulations, including those which are undiscovered. That distribution is the field size distribution (FSD).

The joint use of probabilistic modeling of the historical discovery size and sequence (FSD and Discovery Sequence), and of the geology of the basin, implicitly incorporates geological, technological, and economic aspects associated with the exploration of the play. This allows one to use the past discovery sequence to predict the future sequence of new discoveries (Kontorovich, Dyomin, and Livshits, 2001). The two main geological uncertainties are related to the distribution of the size of accumulations and to the number of accumulations (Divi, 2004).

Thus, the assessment of an individual play consists of three main processes: the determination of the distribution of the sizes of accumulations (FSD), the estimation of the number of possible accumulations, and the quantification of the exploratory risk.

When the play is relatively well explored, as are the shallow waters of the Campos Basin, a good way to build the FSD curve is through curve fitting, where the distribution of the frequency of occurrence of accumulations of a given size is modeled so as to best fit observed discoveries (Divi, 2004). The FSD will generally follow a log-normal distribution. When prospects are defined probabilistically, within a multiplicative model for the value of total accumulation (product of area, thickness, porosity, and saturation), a Monte Carlo simulation can provide random estimates for those values, resulting in a probability distribution curve of values. Then, values at pertinent points can be found, such as the P10 (level expected with 10% certainty) and P90 (level expected with 90% certainty) points on the curve.

## Results

First, using only the discoveries for which full information was available, in order to build a discovery sequence curve, it is apparent that the shallow waters of the Campos Basin cannot be considered a mature exploratory play, since the curve is not close to reaching an asymptotic limit. If anything, it seems to show evidence of several new exploratory stages (generally due to exploratory innovation developments, such as new geologic knowledge or technical capabilities), which tend to start new upward slopes on the curve (Figure 7).

The modeling tool also offered estimates for the number and size of accumulations and for the total of those accumulations, as probabilistic distributions of those variables (Table 1). As can be seen, these results suggest that there are significant yet-to-find-oil accumulations in the shallow waters of the Campos Basin, distributed among individual accumulations of a size which may be attractive as exploratory prospects for many oil industry players, even if not for the majors of the industry, which have generally established very large minimum thresholds for potential discoveries to be of interest to them. The individual results for the size variables (total accumulations and size of accumulations), are shown as probability distribution curves for each variable, as seen in Figure 8 and Figure 9.

The exploration modeling tool also produces a screen showing a size-by-rank graph, which gives an idea of the fields that could still be discovered, in relation to those already discovered, and their sequence (Figure 10). Evidently, there are still many slots to be filled as a result of future exploratory efforts.

The results of this study must still take into consideration the fact that the assessment carried out may be overly optimistic.  Many of the more recent known discoveries in the shallow waters of the Campos Basin were not considered which might have made the analysis less optimistic and might have shown the play to be a more exploratory mature one.

While the results presented seem surprisingly optimistic, the known additional discoveries which have been made in this area, but which were not included in this study because of incomplete information about them, could fit perfectly well into the projections made--as realized discoveries taking the place of the empty slots shown on the FSD curve. This observation tends to support the results of the assessment of the potential for new discoveries in the shallow waters of the Campos Basin.

Given that the industry seems reluctant to dedicate more exploratory efforts towards certain areas that have been relatively well explored in the past, but which may still contain attractive accumulations, this type of study may help bring attention to the potential for new discoveries in those regions and stimulate new exploratory efforts. The potential for new discoveries in areas considered mature is of significant strategic importance, because it represents the potential for efficient monetization of accumulations currently ignored, as may be the case in the shallow waters of the Campos Basin. Here E&P activities could benefit from lower costs and lower levels of sophistication for their exploitation.

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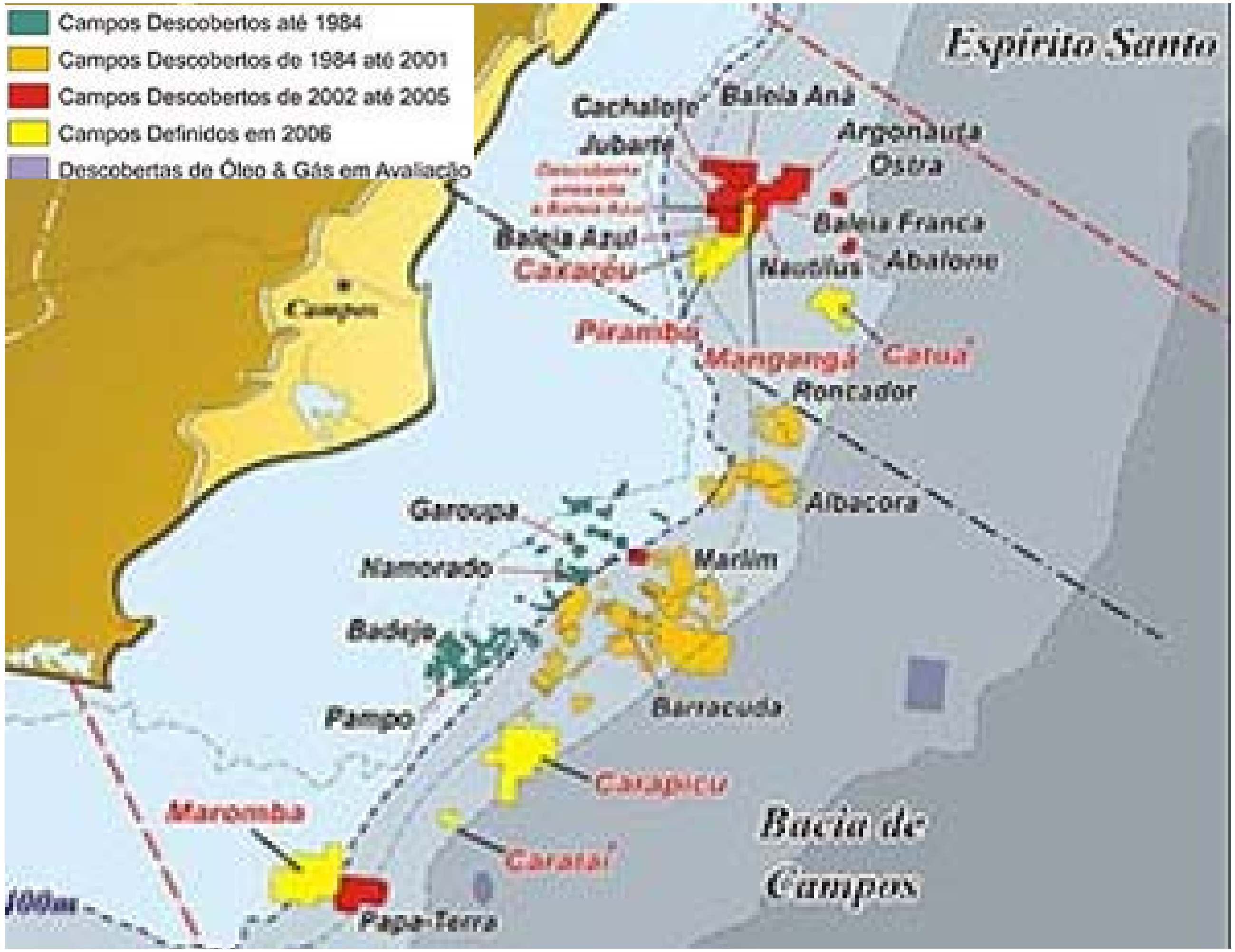


Figure 1. The trend of E&P activities over the years, towards deeper, farther offshore areas in the Campos Basin (Petrobras, Plano de Negócios 2006-2010).

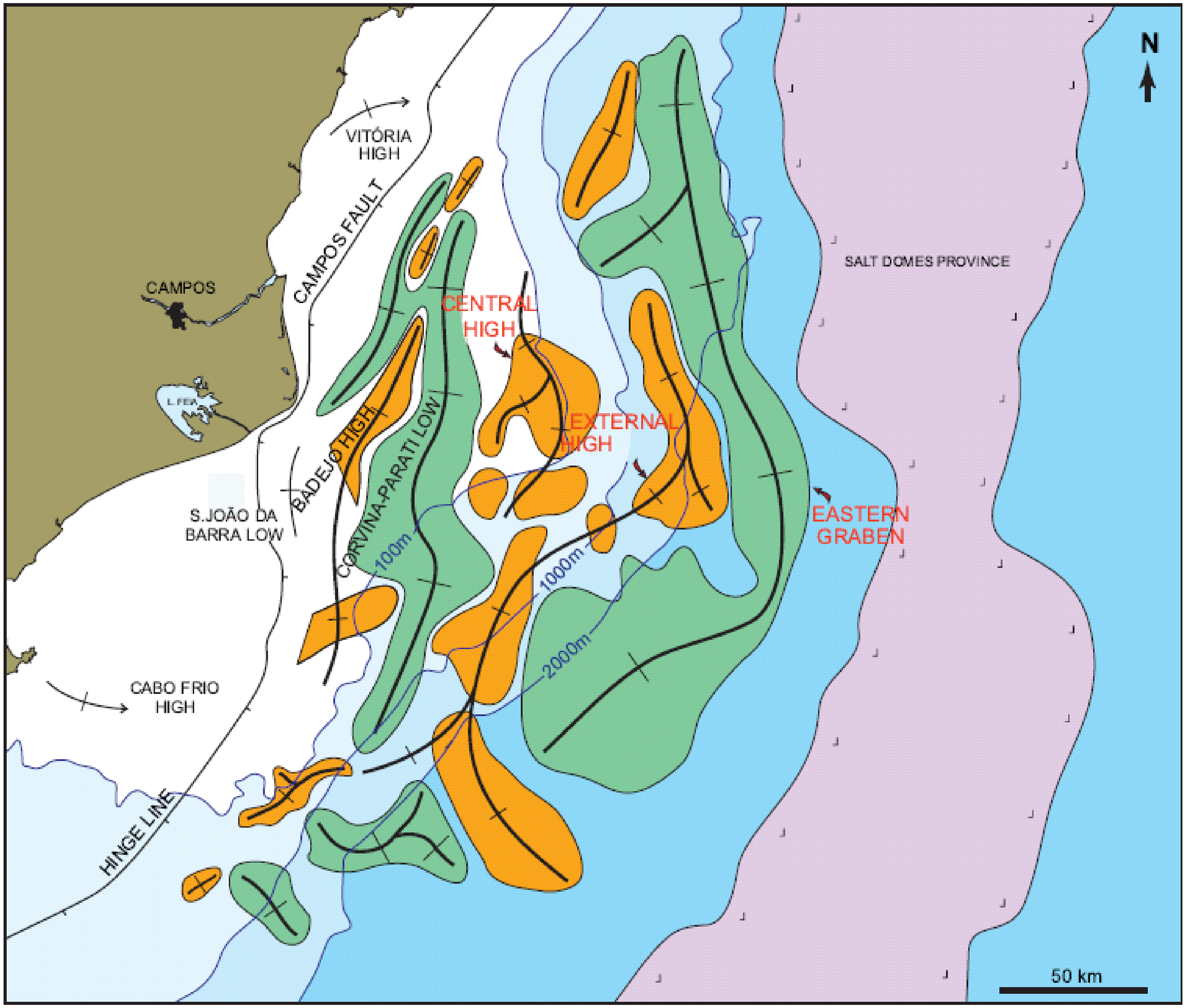


Figure 2. Map of significant geological structures of the Campos Basin (Guardado et al., 2000).

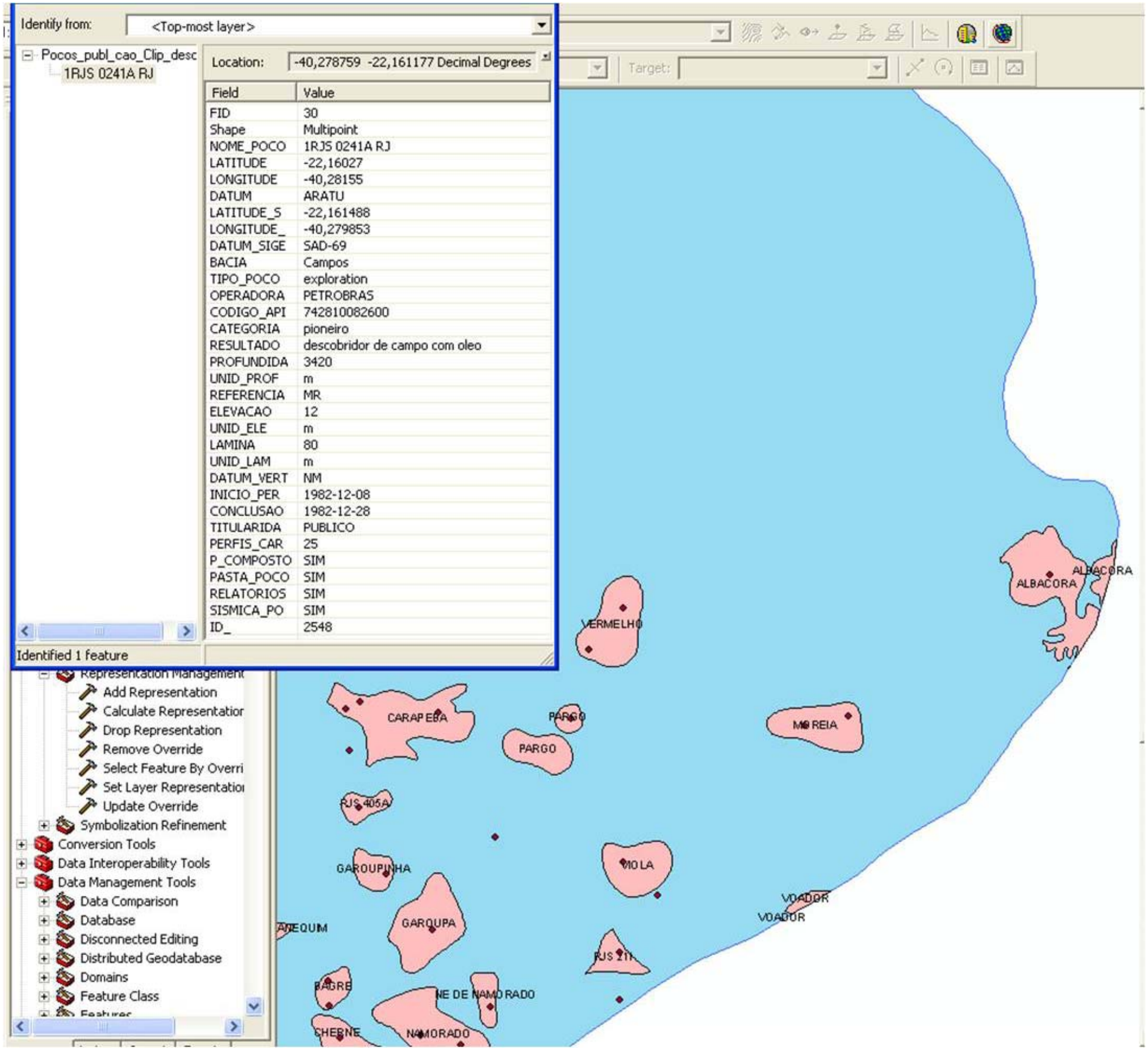


Figure 3. Discovered fields, with associated information, obtained from BDEP, used to specify input parameters of the modeling tool.

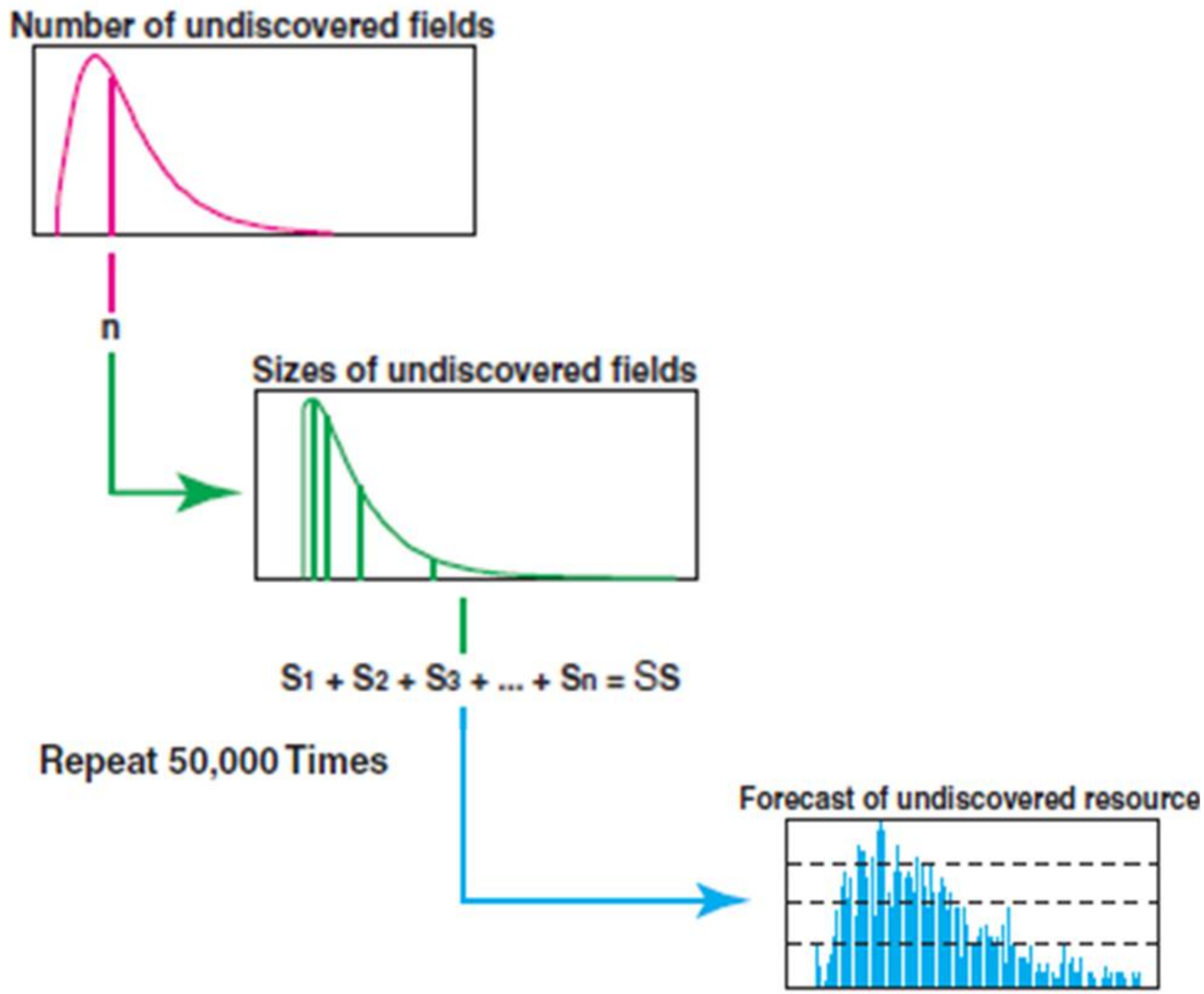


Figure 4. Description of the steps of the Monte Carlo simulation utilized by the WA2000, similar to that utilized by the modeling tool used in this study (Charpentier and Klett, 2002).

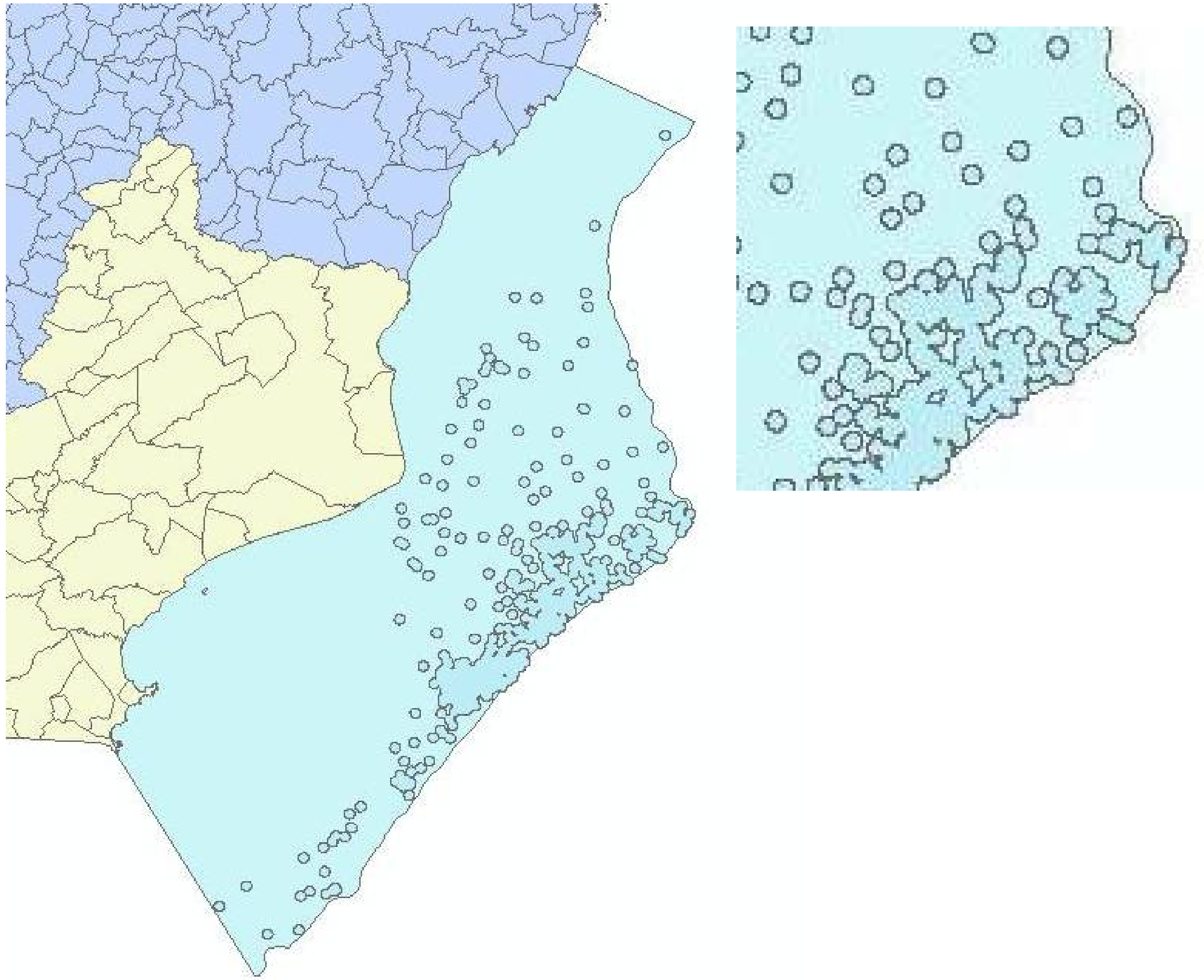

Figure 5. Area exhausted, considering the area of influence of each well at the probability level of P10 (largest area, with least probability), totaling about 10% of the area investigated, with consolidation of individual areas, especially in the east.

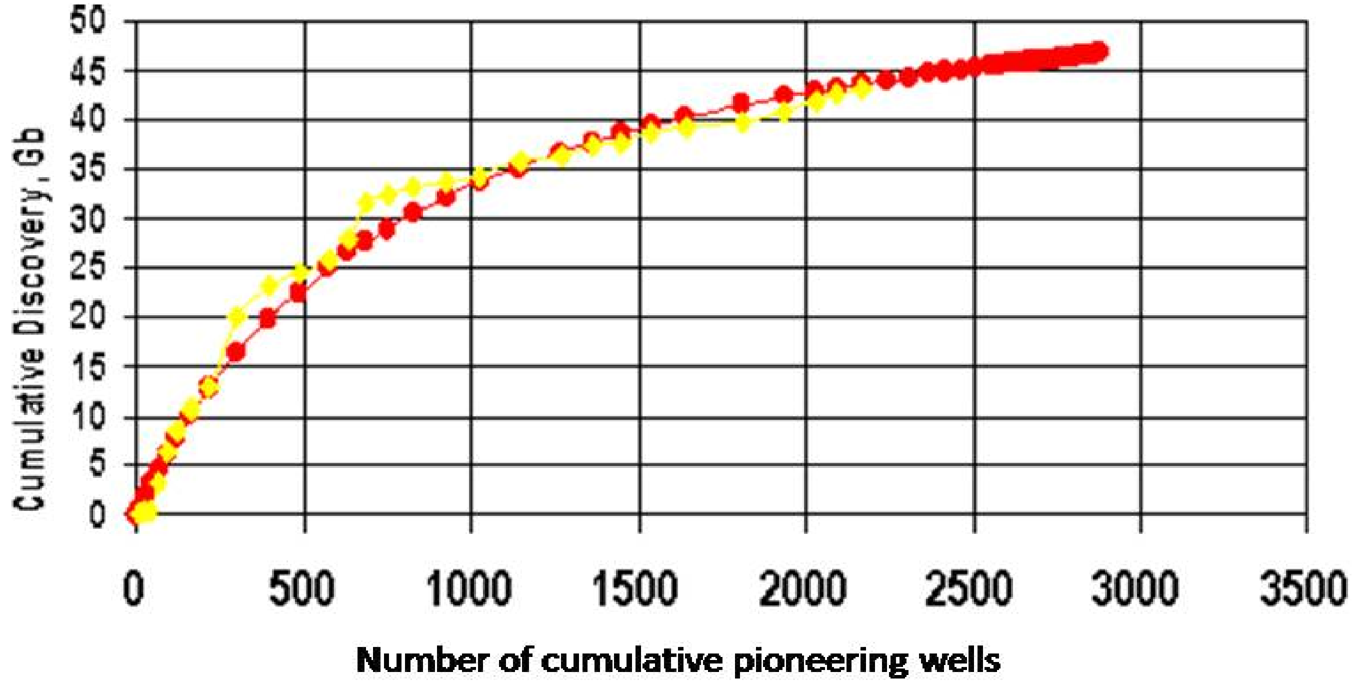


Figure 6. Example of a Discovery Sequence curve (Campbell, 2002).

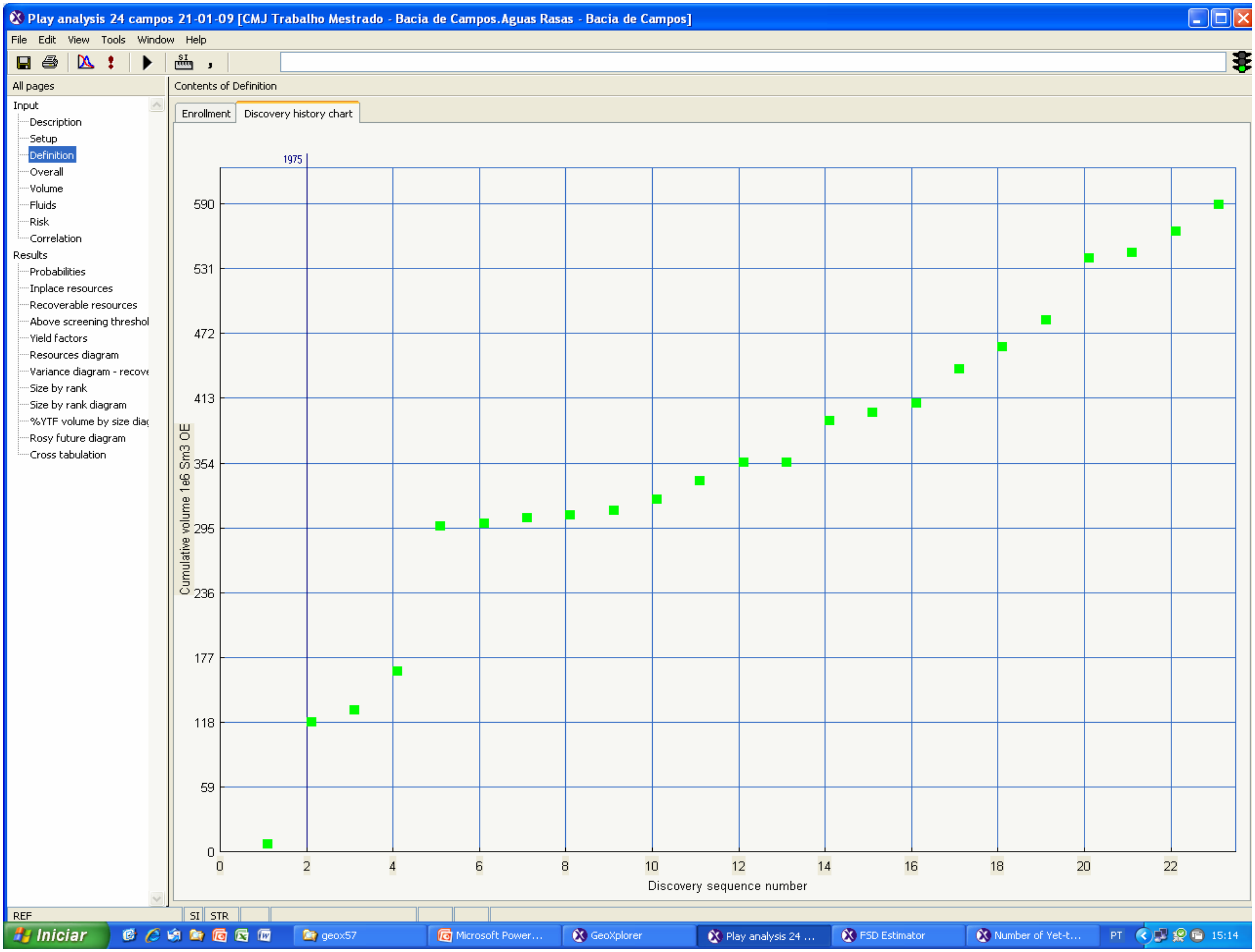

Figure 7. Result screen of the modeling tool, showing the Discovery Sequence curve for the area of study, considering only the discoveries for which full information was available; there is still no horizontal tendency apparent.

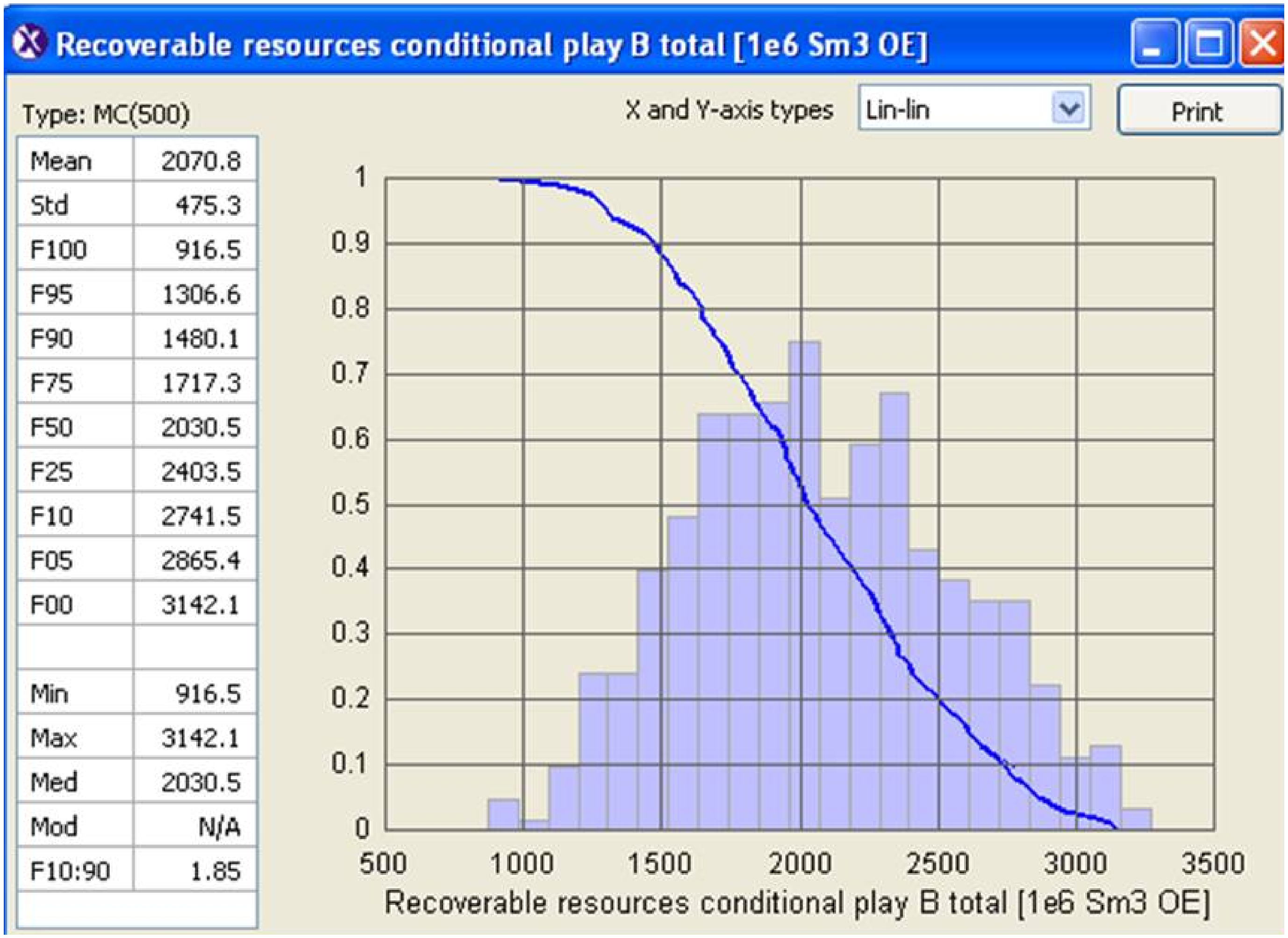


Figure 8. Result screen of the modeling tool--for total accumulations.

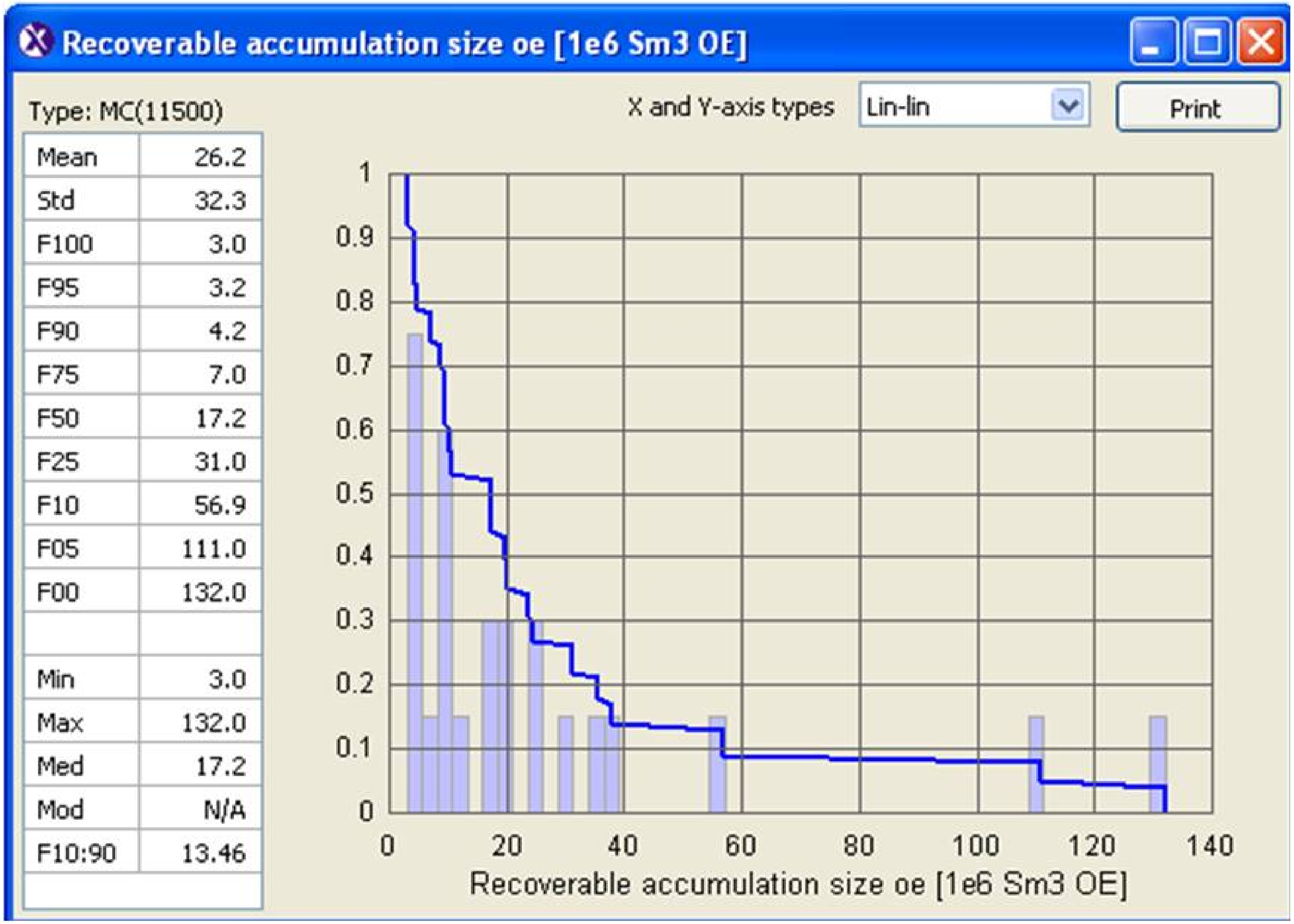


Figure 9. Result screen of the modeling tool-- for size of individual accumulations.

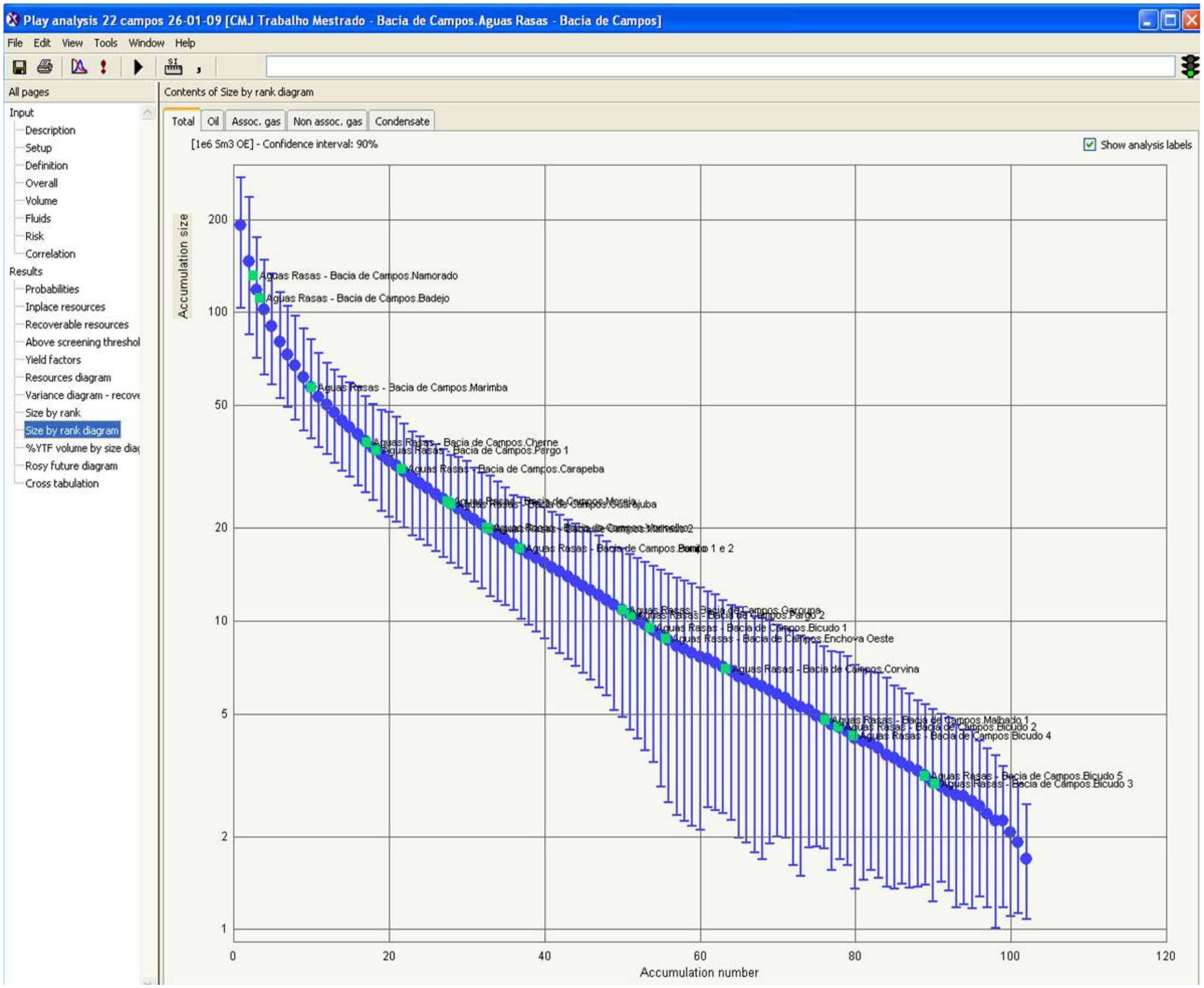


Figure 10. Size-by-rank graph, showing slots representing possible discoveries, and their size range, plotted on a modified FSD curve.

| **RESULTS** | **P90 (90% probability of values shown)** | **P10 (10% probability of values shown)** |
|---|---|---|
| **Total Accumulations** | 1.48 billion m3 | 2.74 billion m3 |
| **Number of Accumulations** | 81.5 121 | |
| **Size of Accumulations** | 4.2 million m3 | 56.9 million m3 |

Table 1. Results from the modeling tool--for play variables of number and size of accumulations and for the total of those accumulations.