Constraining Uncertainty in Static Reservoir Modeling: A Case Study from Namorado Field, Brazil*

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Abstract

The understanding of uncertainties involved in reservoir modeling is an essential tool to support decisions in the petroleum industry. This study focused on the reservoir-modeling case of Namorado, an oil field located in offshore Brazil, the workflow, tolls and benefits of a 3D integrated study with uncertainties. A geological uncertainty study was initiated to identify and quantify the input parameters of greatest impact in the reservoir model. In order to rank reservoir uncertainties, a series of static models were built, a method to quantify the uncertainty associated with geological parameters was proposed, and all combinations of these parameters were tested.

The proposed workflow comprises the following steps: (1) construction of the structural model - using depositional sequences and major faults found in 3D seismic data and depth markers measured along the 55 wells; (2) construction of the geological model - facies were defined by using the weighed k-nearest neighbors algorithm; then facies model was built with Sequential Indicator Simulation; (3) populate the geological model with petrophysical parameters - Sequential Gaussian Simulation was used to populate grid cells with porosity and water-saturation models; and (4) uncertainty analysis. After the stages described above, 100 realizations of complete model were generated by varying seed number alone. In this first iteration parameters were ranked by STOIIP and P90, P50 and P10 cases picked as low-, base- and high-case for structural, grid, facies, porosity, water saturation and net-to-gross models. In the second iteration, addressing uncertainties associated with parameters was used. In this step, the parameters that are actually influent on the production response were identified and 243 realizations of the workflow were run. In the third iteration, the highest parameters ranked in the second iteration were used for addressing uncertainty in the high-, base- and low-case models, and 81 realizations of this workflow were run with the three levels full factorial algorithm.

The identified highest ranked contributors to uncertainty were: oil-water contact in the field; range of variogram used for porosity simulation; and water saturation. The workflow used in this study successfully integrated geophysical and geological data, and all geological uncertainty scenarios. A modeling workflow has been established to handle both multiple scenarios, and multiple realizations of a given scenario.

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Introduction

Field description

Workflow

Results

Conclusions

Uncertainty analisys

- The importance of uncertainties studies
- Sources of uncertainties
  - the static model, upscaling, fluid flow modeling, production data integration, production scheme development, and economic evaluation
- Uncertainties in geology
- This work focuses on the uncertainties associated with stochastic static reservoir modeling of the Namorado Field, offshore Brazil

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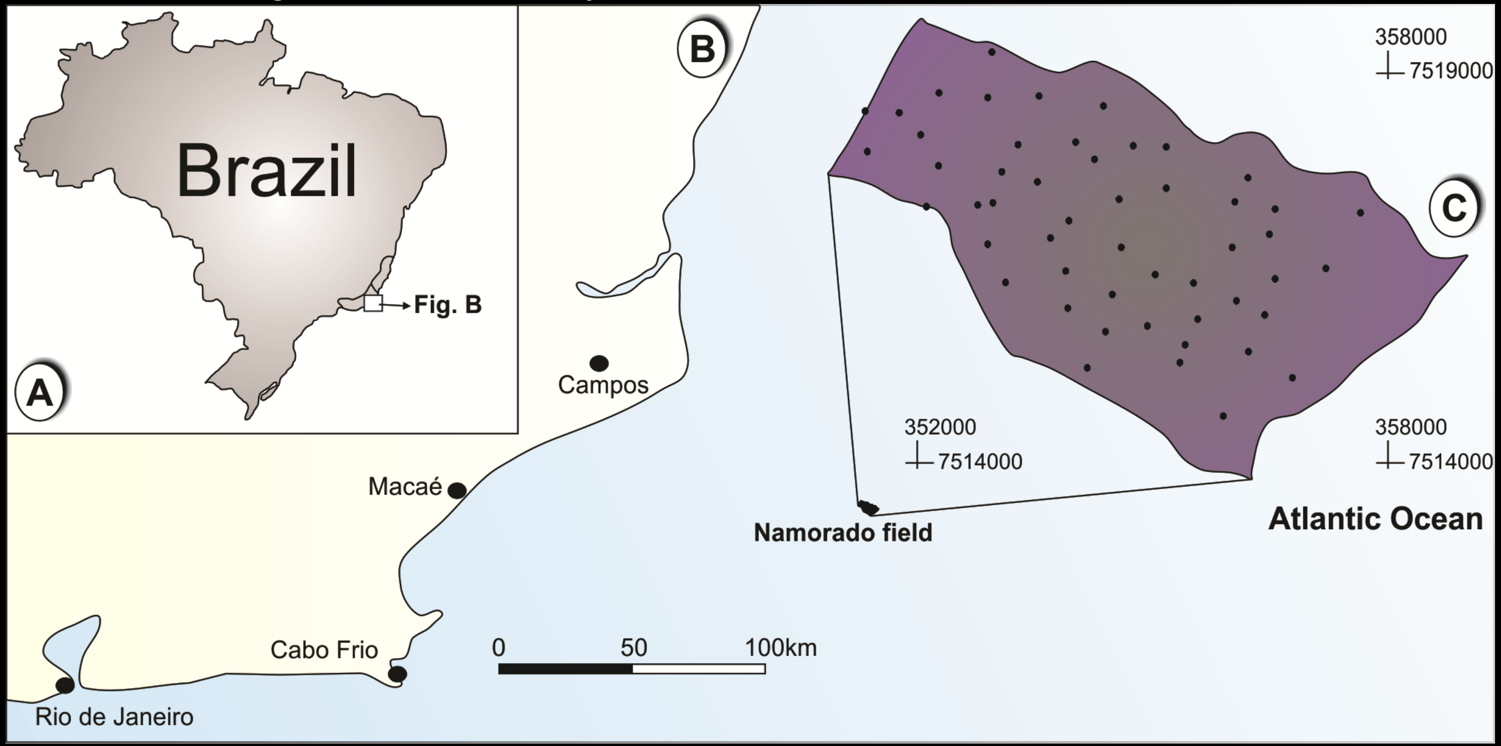
Namorado Field, Brazil

- Located in the central part of Campos Basin in the Brazilian continental platform
  - Composed by turbidite sands and intercalated with shale and carbonates
  - Sandstones have porosity between 20 to 30% and permeability higher than 1 darcy



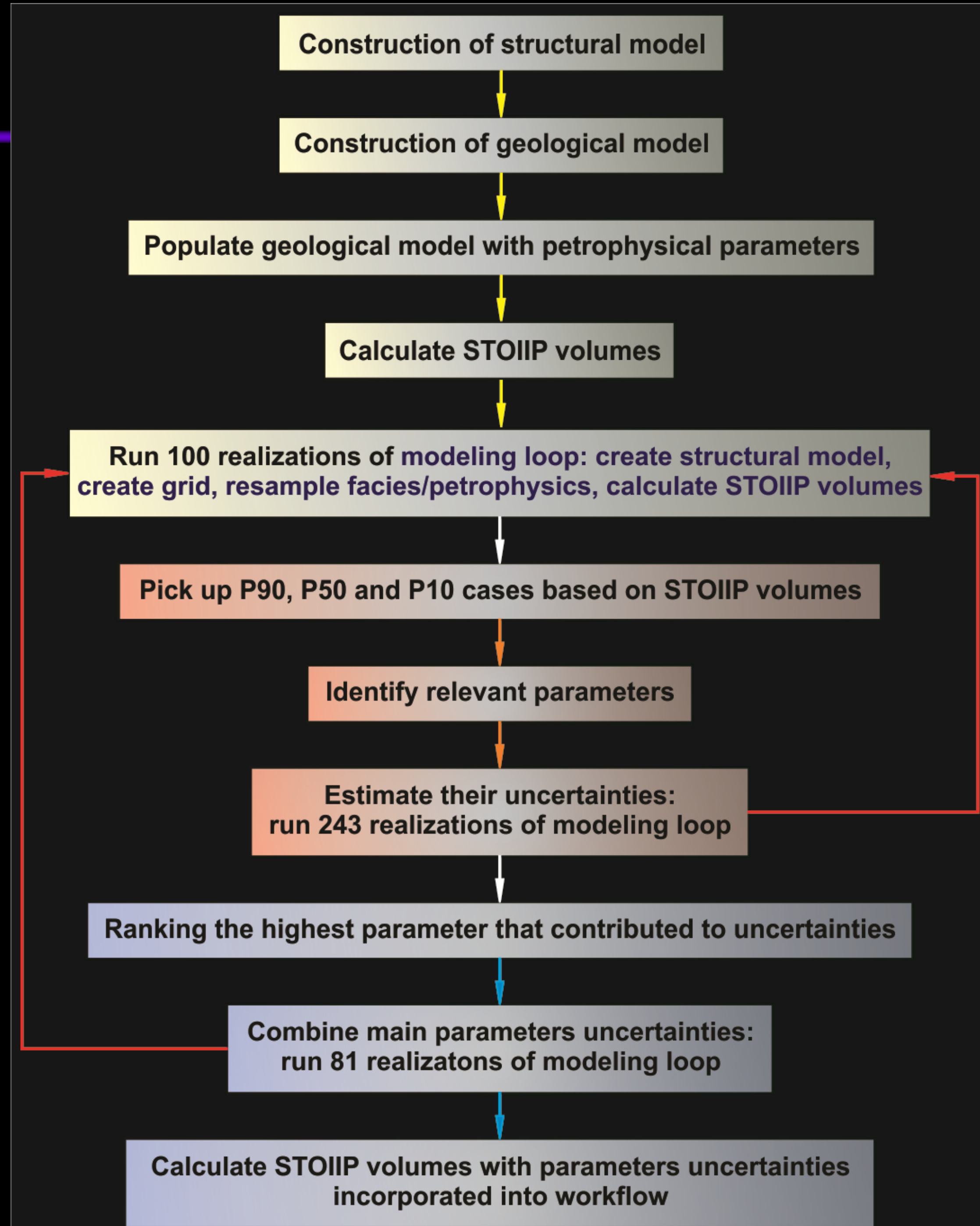
Database

- Namorado Field is covered by a 3D seismic survey
- 55 wells drilled and logged
- The well logs presented in the dataset are: density (RHOB), gamma-ray (GR), resistivity (ILD), neutron porosity (NPHI) and sonic (DT)
- Eight wells were cored and qualitative petrographic description is available
- The dataset is currently available by the Brazilian National Agency of Petroleum (ANP)

General

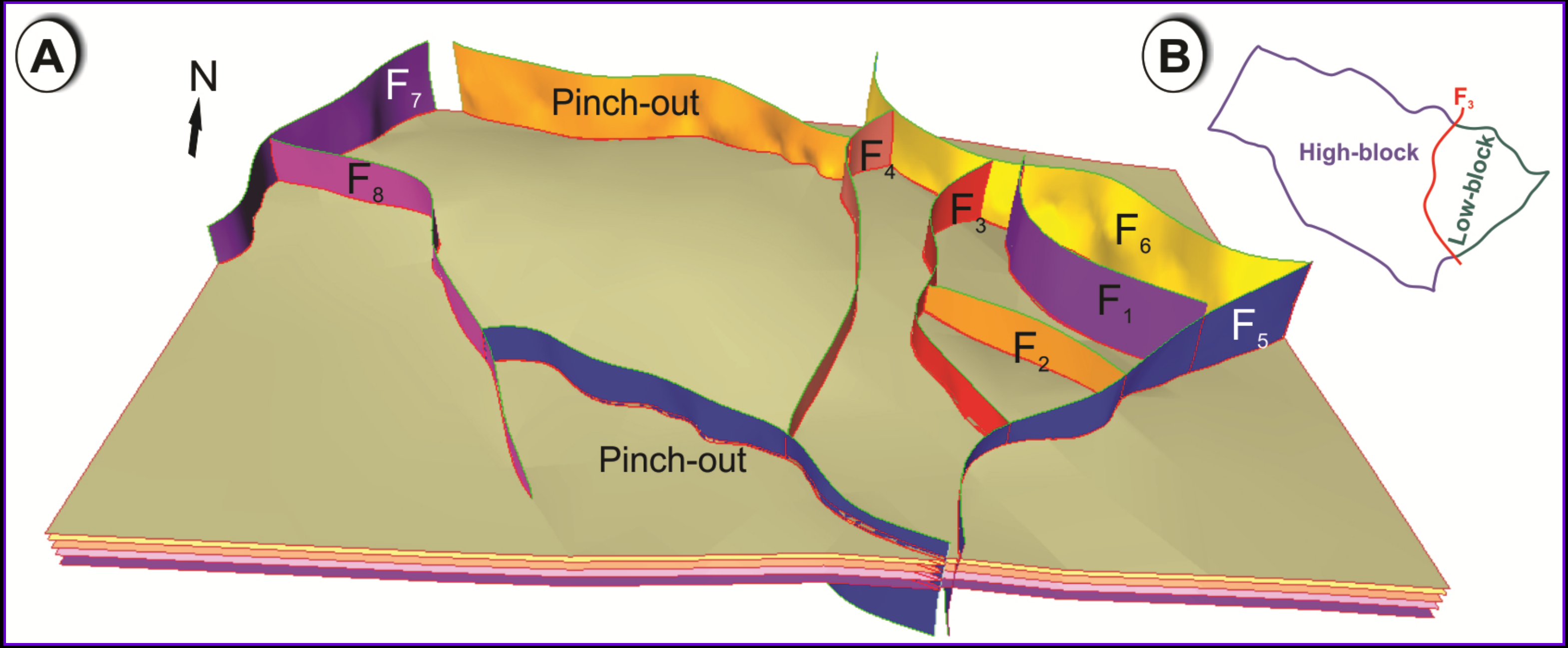
- Workflow set up is a scenario-based, conducted in the Roxar Irap-RMS software
- Three levels full factorial experimental set-up
- Workflow comprises the following steps:
  - construction of the structural model
  - construction of the geological model
  - Population of the geological model with petrophysical parameters
  - uncertainty analysis
- Three iterations of the workflow

General


Construction of structural model
Construction of geological model
Populate geological model with petrophysical parameters
Calculate STOIIP volumes
Run 100 realizations of modeling loop: create structural model, create grid, resample facies/petrophysics, calculate STOIIP volumes
Pick up P90, P50 and P10 cases based on STOIIP volumes
Identify relevant parameters
Estimate their uncertainties: run 243 realizations of modeling loop
Ranking the highest parameter that contributed to uncertainties
Combine main parameters uncertainties: run 81 realizatons of modeling loop
Calculate STOIIP volumes with parameters uncertainties incorporated into workflow

Stage 1: Construction of the structural model

- Three depositional sequences
- Eight major faults in the field were used
  - F_3 divides the field into two blocks



Stage 2: Construction of the geological model

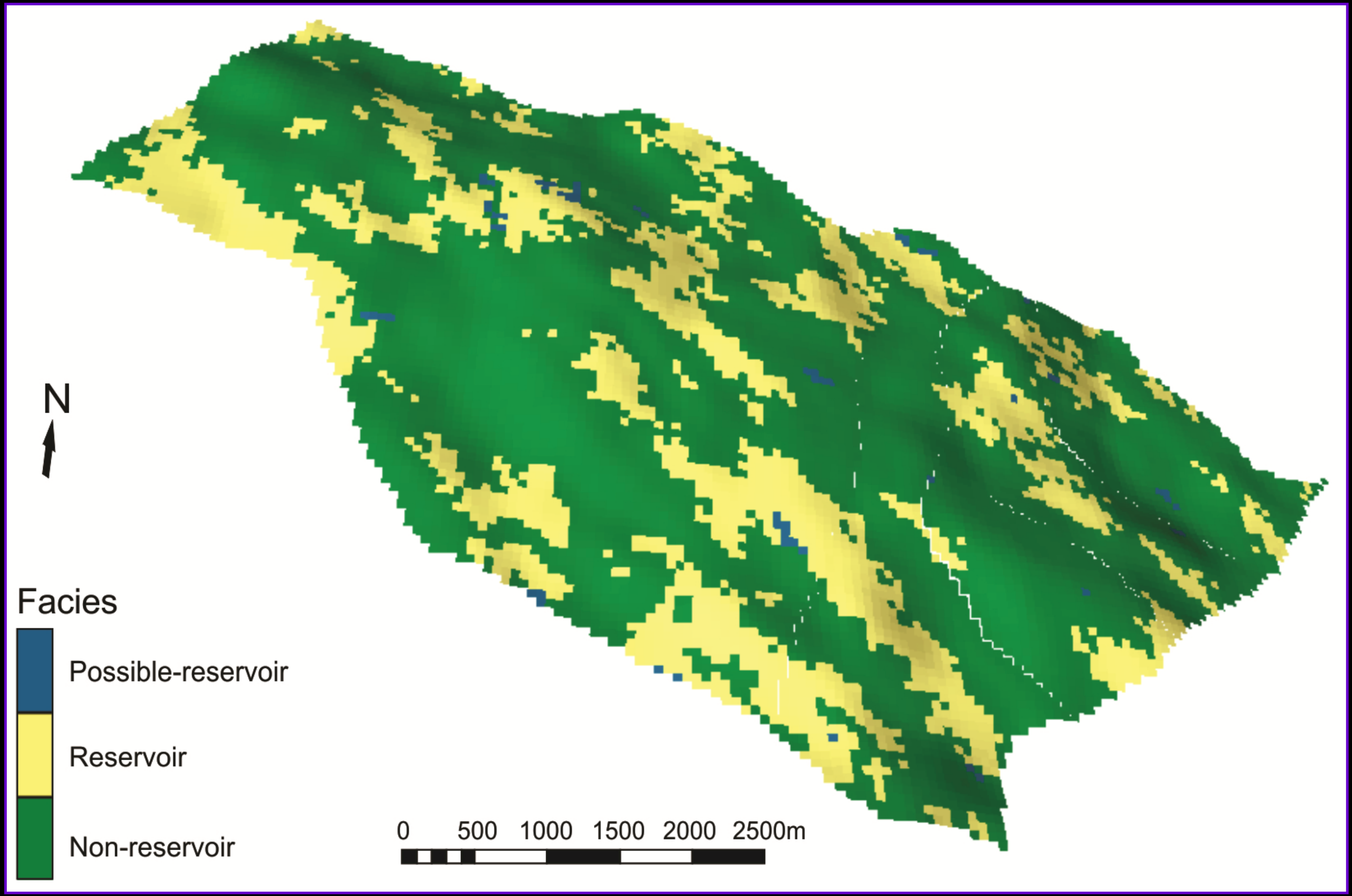
- Facies were defined with the weighed k-nearest neighbors (wk-NN) algorithm

- Core samples identified twenty nine lithofacies: grouped into tree major lithotypes: coarse-medium sand (reservoir), shale and mixed lithotypes (non-reservoir) and shaly sands (possible-reservoir)

- Grid cell resolution was defined as 50x50x1 m

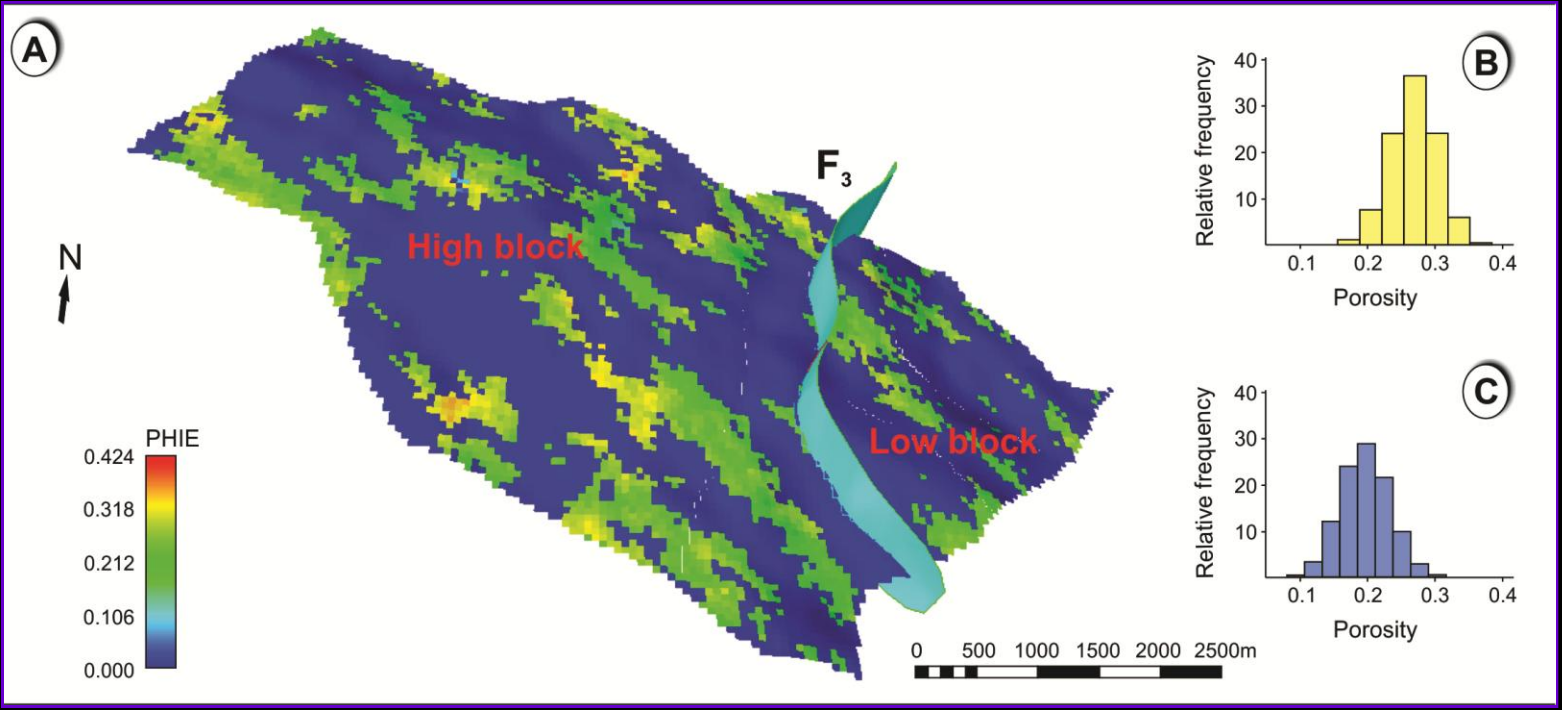
Stage 2: Construction of the geological model

- Sequential Indicator Simulation (SIS)
  - Vertical proportion curves
  - Variogram model



Stage 3: Population of the geological model

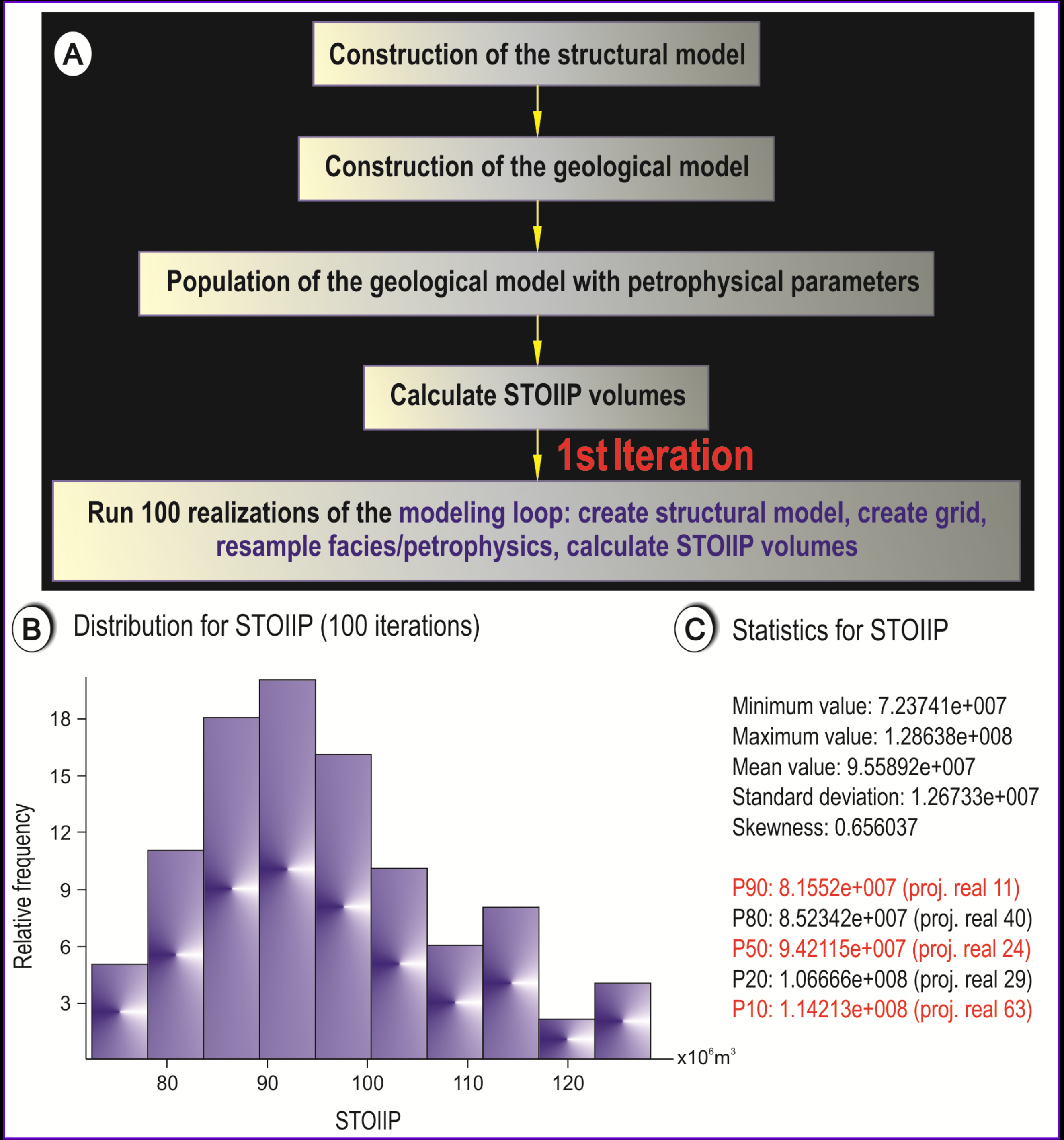
- Porosity and water saturation simulated with Sequential Gaussian Simulation (SGS)
- Two oil-water contacts: -3100m in the high block and -3155 in the low block
- Porosity cut-off > 20% was used to calculate NTG



Iteration 1

- Variation in seed number only

Workflow



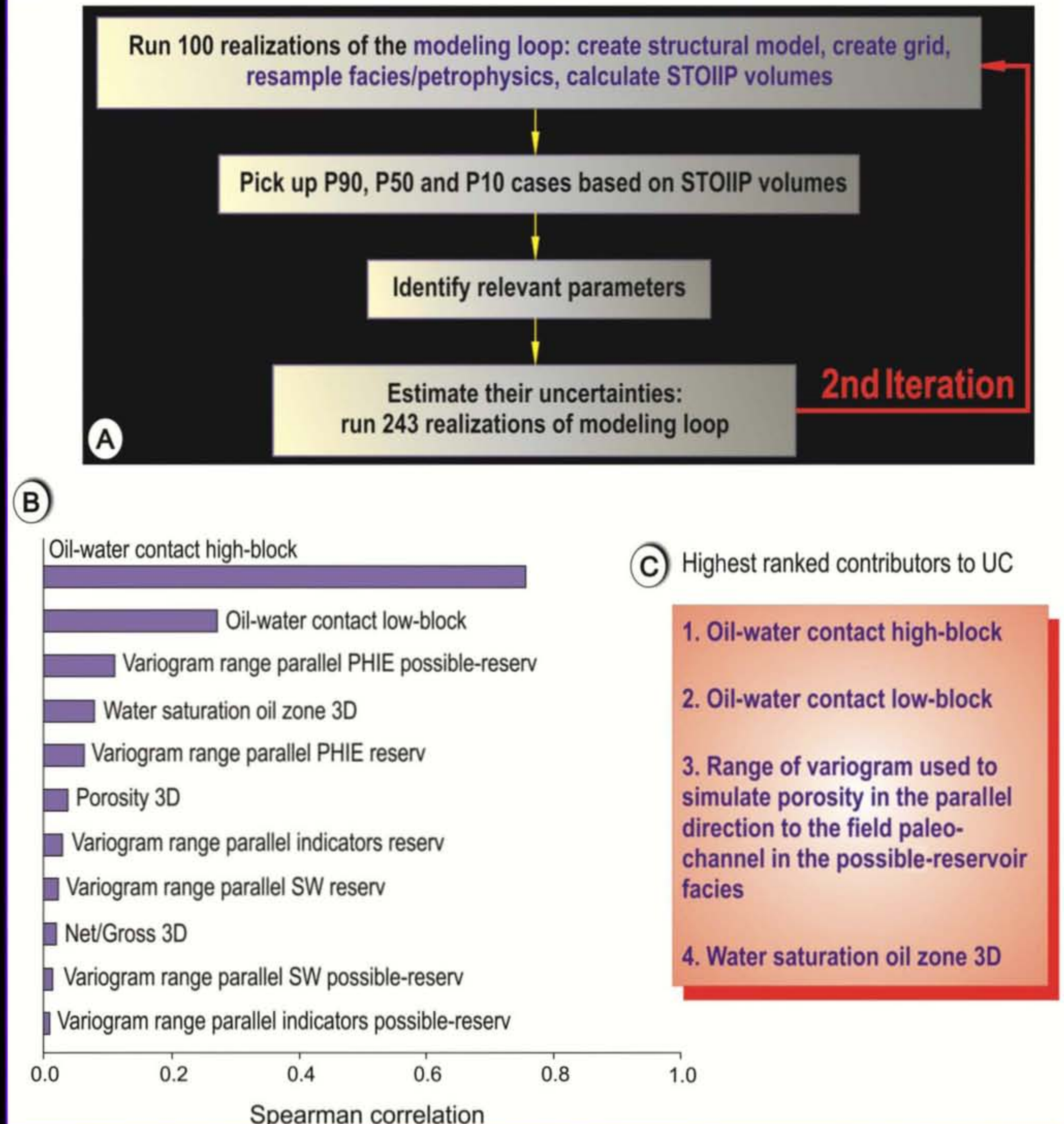
Iteration 2

- Normal distribution for uncertainties in variographic parameters

Workflow

- Low-, base-, high-case models: 3D parameters

- Sampling method: Latin hypercube

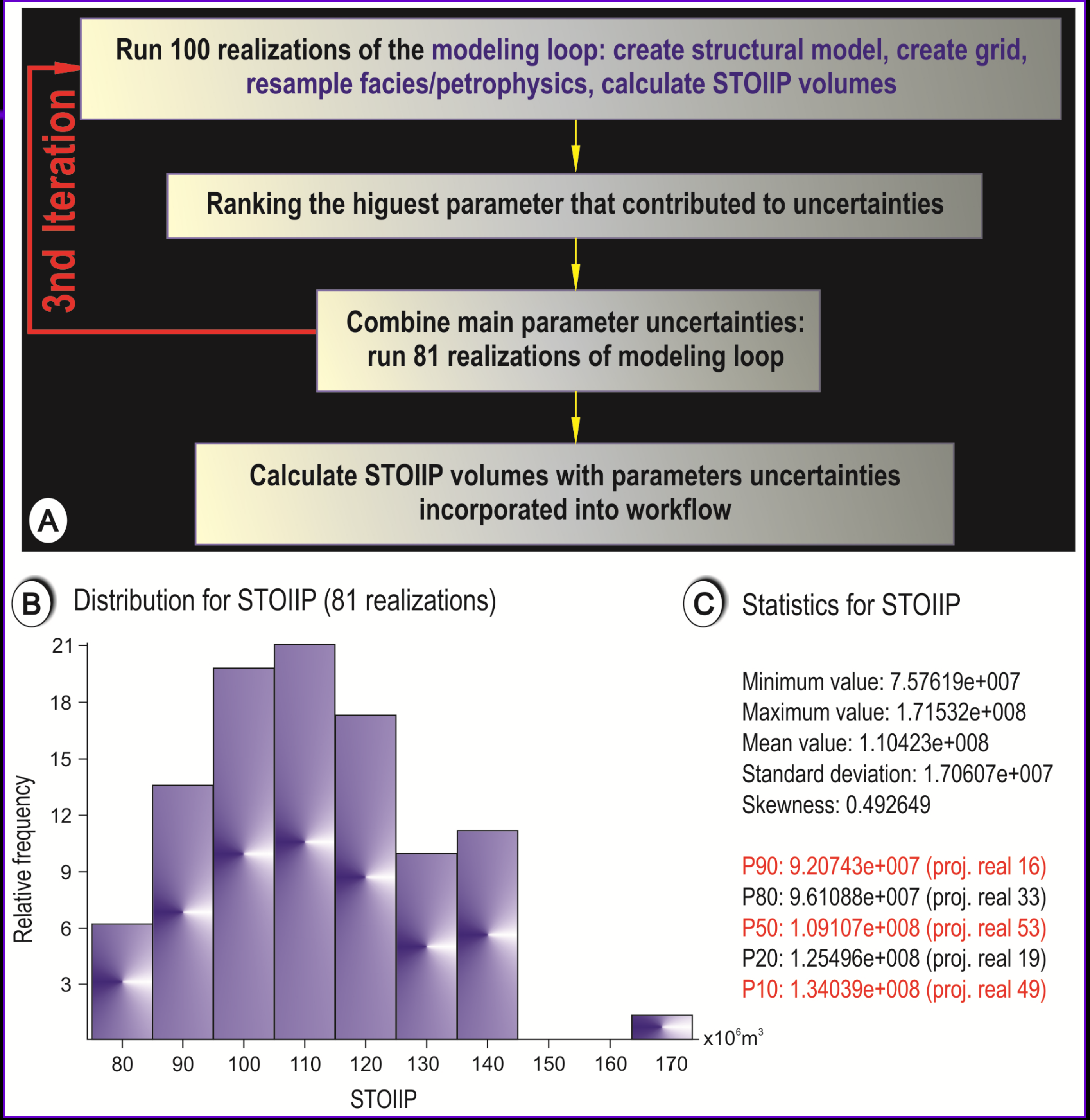


Iteration 3

- Low-, base-, high-case models

Workflow

- Three-levels full factorial algorithm
- Number of combinations: 3^k



Highest contributors to uncertainties in STOIIP

- STOIIP: 92.07 x 10^6 m^3 for P90, 109.11 x 10^6 m^3 for P50 and 134.04 x 10^6 m^3 for P10 scenarios
- Two largest ranked contributors: oil-water contacts
  - OWC = FWL
- Third major contributor: range of variogram used to simulate porosity in the parallel direction to the field paleo-channel in the possible reservoir facies
- Fourth main parameter that affected the volumetric calculation was the 3D water saturation

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Conclusions

- The workflow used in this study successfully integrated all the geological uncertainty scenarios
- The 'top 4' contributors to the total uncertainty range in STOIIP were identified
- The value obtained for STOIIP at P50 was 109.11 x 10^6 m^3, which is very close to the deterministic value of 106 x 10^6 m^3 presented in the literature
- The limitation of the proposed workflow is that structural modeling is restricted because the fault model was not incorporated into the simulation

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- Thank you for your attention