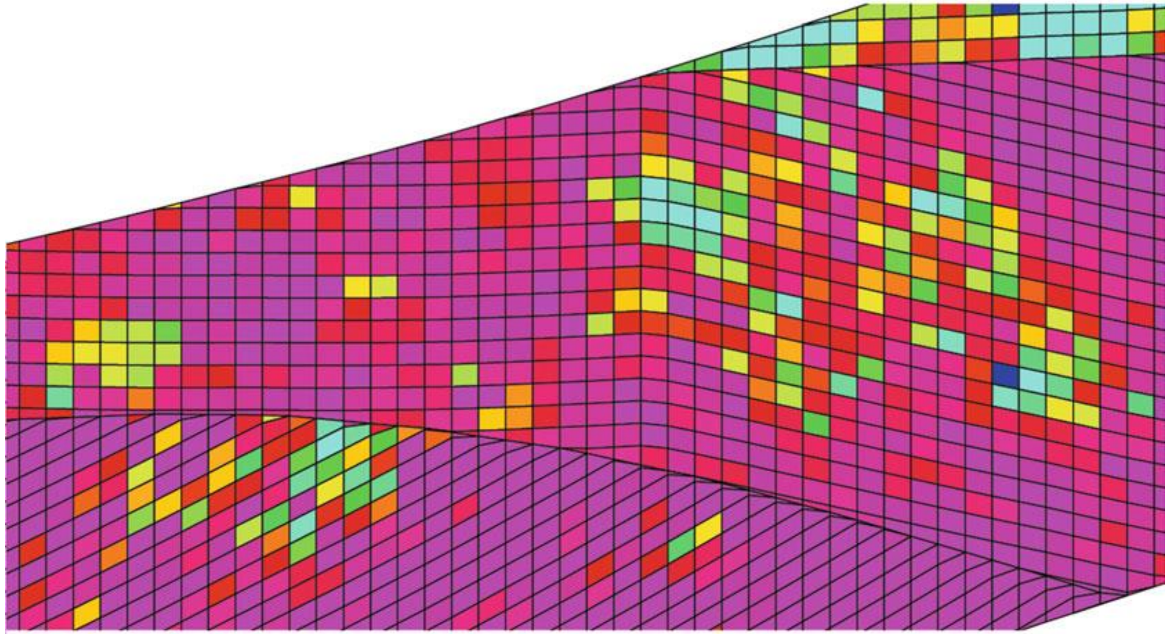
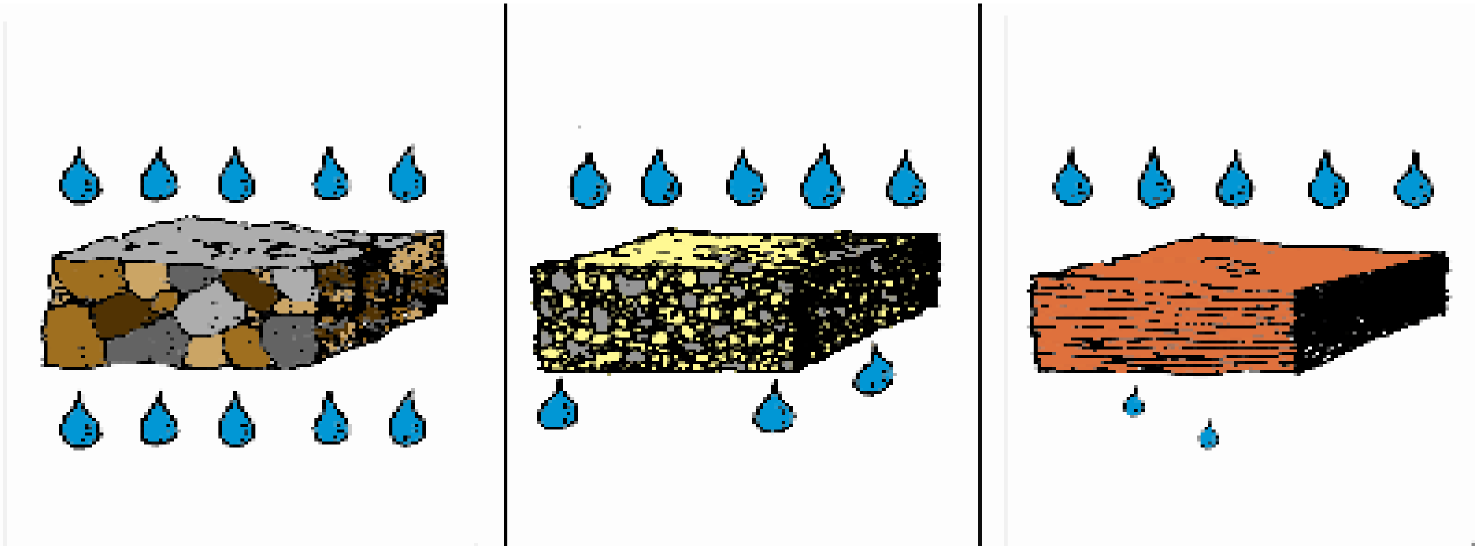
Lecture#3 Permeability Modeling

- Reservoir Modeling
- Porosity Modeling
- Permeability Modeling



Introduction

- Permeability is defined as the ability of a rock formation to conduct fluids. Beyond any doubt, it is the most important petrophysical property of a reservoir.
- permeability is also the most difficult parameter to describe in a reservoir study.



Introduction

- **Geologists and petrophysicists** often plead with management about the necessity of acquiring more information to be able to accurately describe the reservoir **flow units** and they usually devote a lot of technical effort to this modelling issue.
- **Reservoir engineers** often do not hesitate to sacrifice the results of such description in the simulation phase, for the sake of **history matching** the reservoir performance.
- From these points of view, **permeability estimation** is one of the **critical tasks** in the framework of an integrated reservoir study, since in many cases a synergistic approach allows for the definition of accurate and robust permeability models.

Introduction

Permeability Modeling Process

Data gathering and Petrophysical evaluation to get **Vertical profile**

Distribution of permeability data overall reservoir model

Source of permeability data

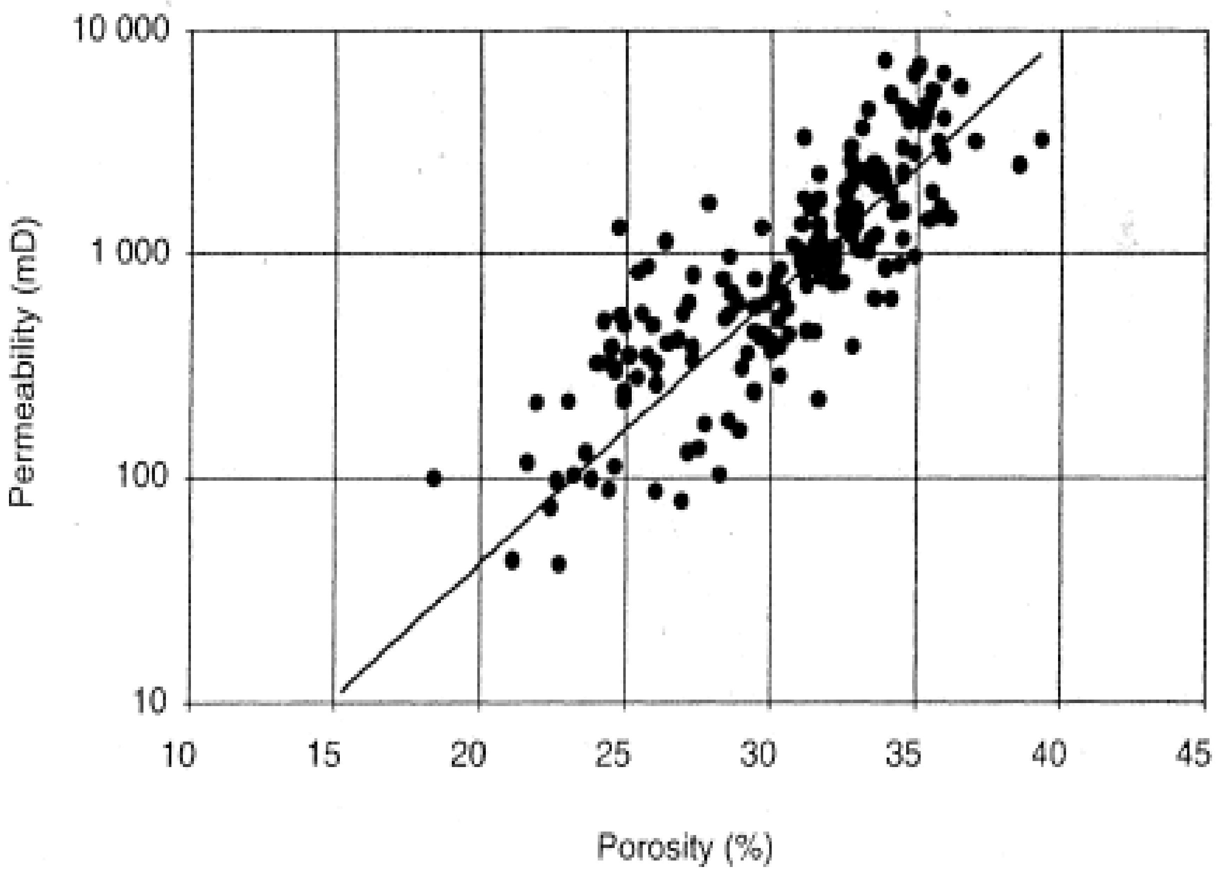
- Core analysis.
- Wireline measurement.
- Well testing.
- Empirical correlation.

Empirical correlation

- The most common way to estimate permeability profiles in **uncored wells** is through some permeability predictor, typically in the form of an **empirical equation**.
- This normally requires a calibration data set that is represented by one or more **key wells** where comprehensive information is available in terms of core and log data.
- This calibration data set is used three types of permeability predictors will be reviewed, namely **porosity-permeability relationships**, **multiple linear regressions** and **existing empirical equations** to build the predictor and to test the reliability of the results.

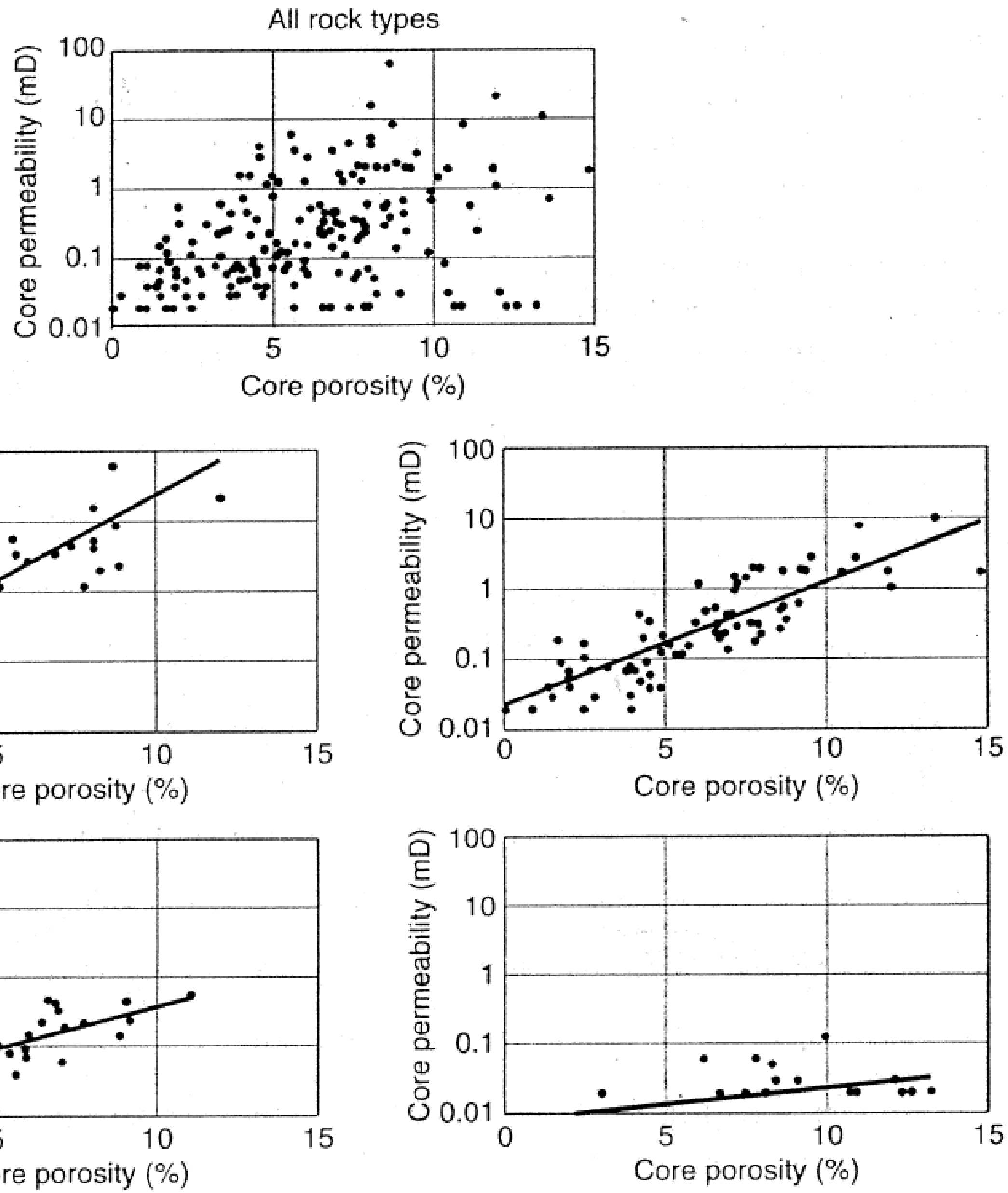
Porosity-permeability relationships

By far the most used permeability predictor is the porosity-permeability relationship. It has long been recognized that most reservoir rocks show a reasonably linear relationship between these parameters in a semilog scale, which allows for the estimation of permeability when a porosity profile is available. The resulting equation shows a correlation coefficient of 0.81.



Porosity-permeability relationships

- If the data are scatter, a good practice in estimating permeability from these kinds of plots is to split the whole data set into **subsets**, which show a more homogeneous behavior.
- The simplest way is of course to use different *K-PHI* plots for different **layers** or areas of the field.
- Much better results can be obtained when a **facies** analysis has been performed on the reservoir under study, since the facies classification criteria are often related to petrophysical properties.

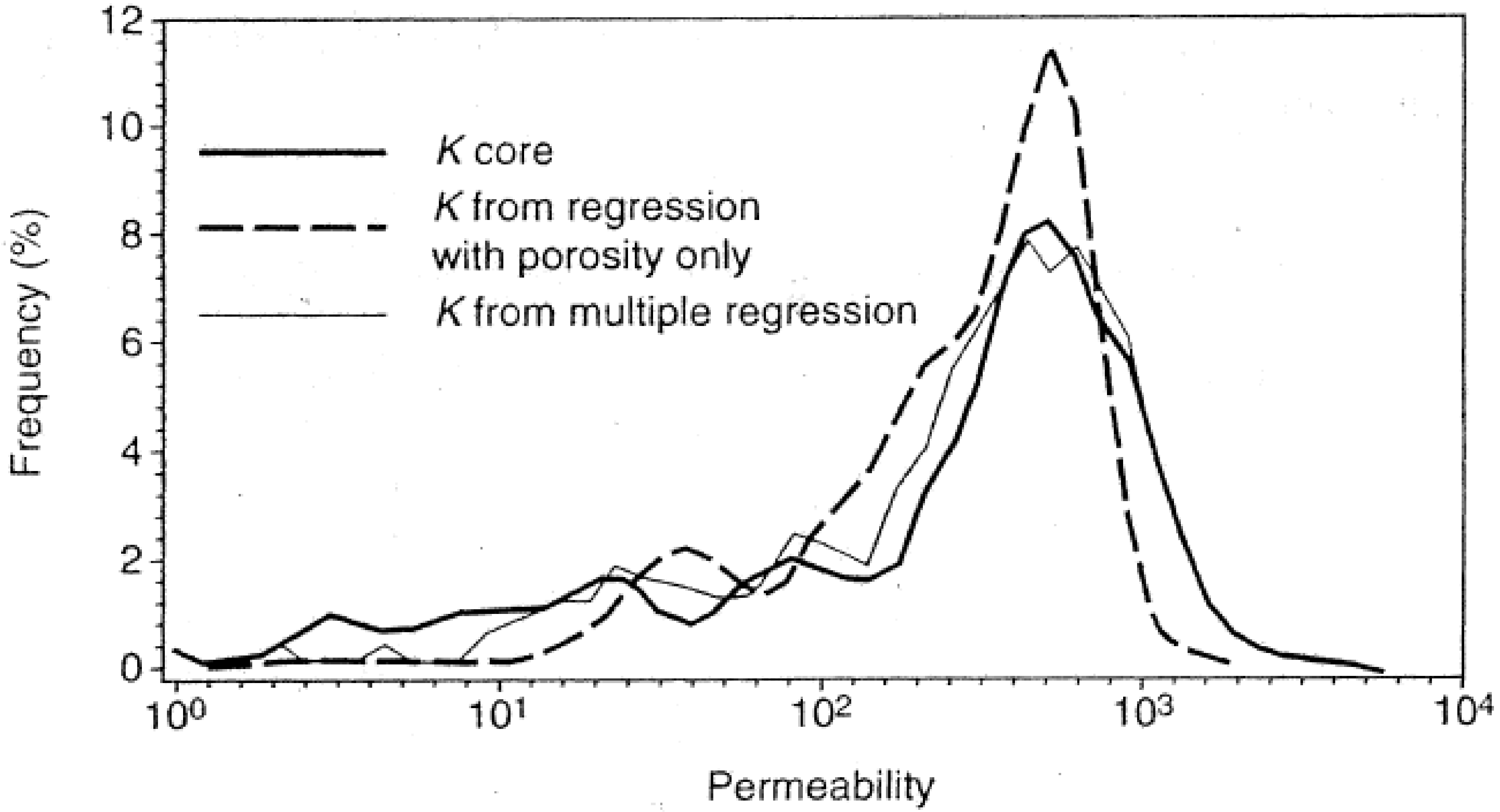


All rock types
Core permeability (mD)
100
10
1
0.1
0.01
0
5
10
15
Core porosity (%)
Core permeability (mD)
Core porosity (%)
Core permeability (mD)
Core porosity (%)
Core permeability (mD)
Core porosity (%)
Core permeability (mD)
Core porosity (%)

Multiple linear regressions

- Multiple linear regression represents a more complex estimation technique with respect to the simple *K-PHI* plots and usually allows for a fast and reliable permeability estimation in most reservoirs
- In many cases, the Porosity-permeability relationship appears too scattered to allow for a reliable regression. This normally happens when the petrological variables (cementation, grain size distribution, diagenetic alteration. etc.) play an important role in the porous structure of the rock.
- In these cases a more sophisticated approach is required that can take into account the influence of other parameters in addition to porosity. The methodology is based on estimating the coefficients *c* of a predictive equation of the type:

$$\mathrm{Log}\, K = c_0 + c_1 x_1 + c_2 x_2 + \ldots + c_n x_n$$



12
10
8
6
4
2
0
Frequency (%)
K core
K from regression
with porosity only
K from multiple regression
10^0
10^1
10^2
10^3
10^4
Permeability

Existing empirical equations

- A number of authors have been proposing empirical correlations to predict permeability. In general, these equations make use of more readily available information, like porosity or water saturation, to derive a permeability profile at the well locations.
- In most cases, these equations can only provide rough estimates of permeability. The main problem of this approach is that, while permeability is dependent on the size and distribution of pore *spaces* within the rock framework, this parameter is always unknown therefore, alternative reservoir characteristics must be used.
- The application of these empirical equations has to be made with caution, since they have been derived applying theoretical considerations to particular sets of samples
- The choice of a particular one of these equations will depend on the reservoir under study and the available data. Also, whenever possible, it is highly recommended to test the reliability of the results against core permeability measurements.

Neural Network

- Neural networks provide an alternative to the traditional techniques of estimating permeability.
- The method has been introduced in the last years, following the widespread availability of powerful computing resources and has rapidly found a number of applications.
- Neural networks can be programmed to recognize patterns, to store and retrieve database entries, to solve optimization problems, to filter noise from experimental data and **to estimate sampled function when the analytical form of the function is unknown**. The last feature is the one relevant to the problem of estimating permeability.

Permeability distribution

- First of all, it is important to note that a single. Recommended methodology for permeability distribution modelling cannot be defined.
- Distribution of permeability is one of the main issues of an integrated reservoir study, since the characteristics of **the fluid flow in the reservoir simulator** depends on the spatial structure attributed to permeability.
- Starting from a **number of vertical permeability** profiles at the well locations, a 3D distribution can be generated by deterministic interpolation stochastic using standard geocellular modelling packages.

- عن الحقل
- جمع البيانات
- تحليل البيانات وايجاد علاقة ربط النفاذية مع المسامية
- تطبيق هذه العلاقة للابار التي لا يوجد فيها بيانات لباب وهي تحتوي على مسامية من اللوك
- هنا تم اكمال خطوة التقييم البتروفيزيائي ليتم البدء بالتوزيع لجميع خلايا الموديل