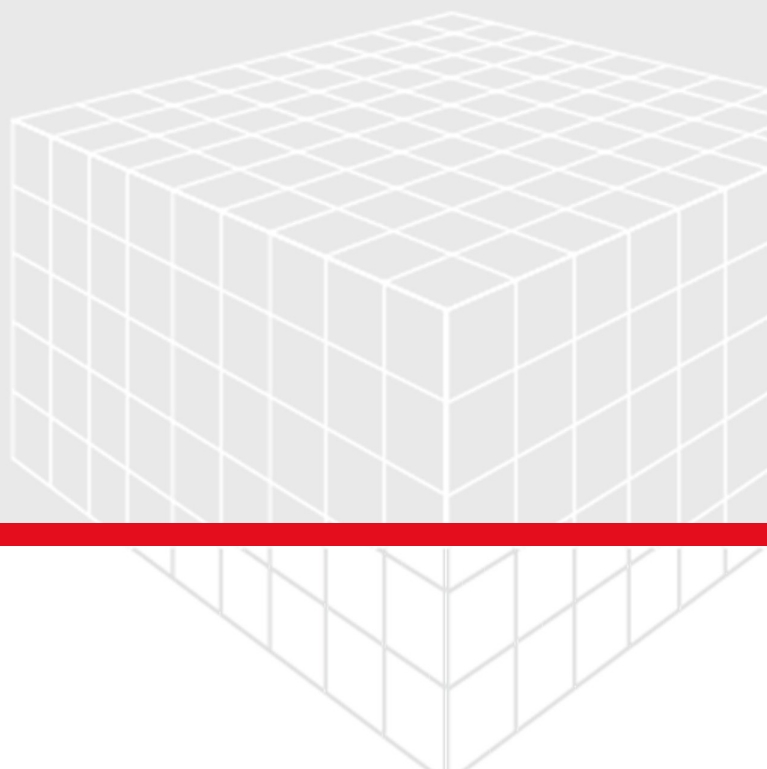


MatDict

User Guide

GEODICT Release 2026

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GEO DICT

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MatDict

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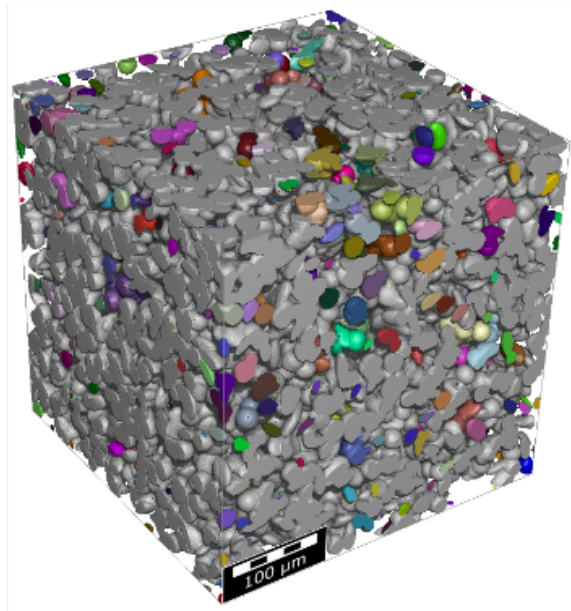
1 MatDict

MatDict is the GeoDict module for analyzing the solid phase of three-dimensional porous-media structures obtained either from tomography images or from digitally (with the GeoDict structure generators) generated models. While PoroDict focuses on the characterization of the pore space, MatDict is dedicated to the analysis of the material structure itself.

The module provides a wide range of tools for computing [statistical](#)^[6] and [geometrical](#)^[35] properties of the solid material. In addition, MatDict includes specialized analysis methods for [analytic data](#)^[110] and offers access to individual [algorithms](#)^[131] for advanced structure characterization.

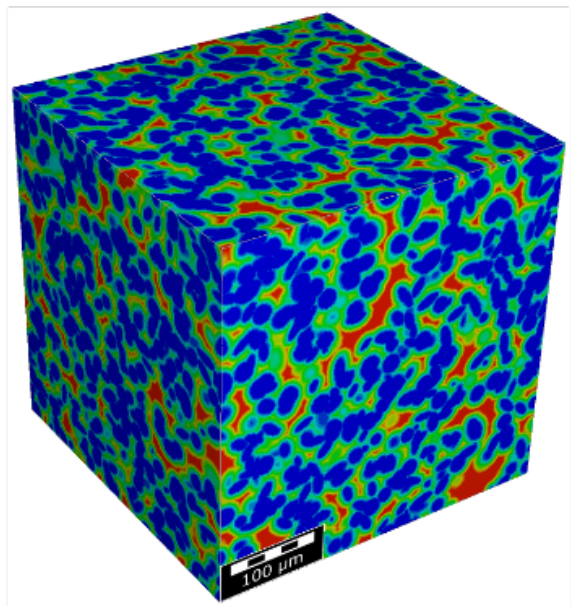
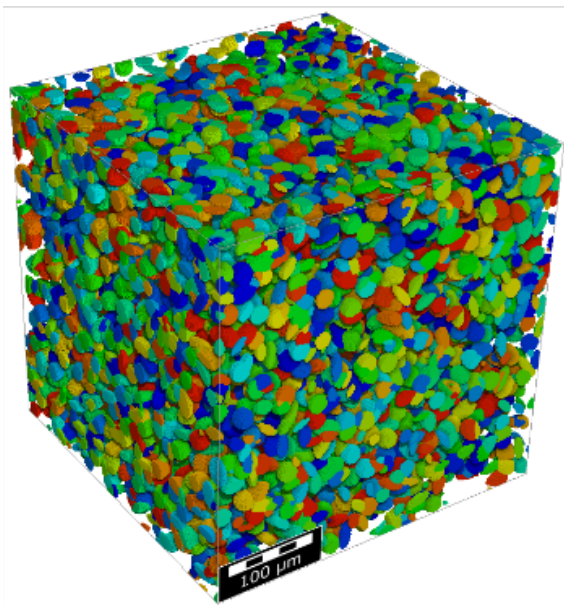
Below, the results of some MatDict commands applied to the same grain structure are visualized.

Voxel length	1e-06 m
Size	400 x 400 x 400 Voxel
Porosity	0.649994
Solid volume fraction	0.350006
Number of GAD-objects	8864
Solid density	700.013 kg/m³
	0.700013 g/cm³
Solid mass	4.48008e-08 kg
Fluid density	0.782592 kg/m³
	0.000782592 g/cm³
Fluid mass	5.00859e-11 kg
Bulk (total) density	700.795 kg/m³
	0.700795 g/cm³
Bulk (total) mass	4.48509e-08 kg



**Material Statistics -
Structure Information**

**Material Characterization -
Connected Components**



**GAD Object Analysis -
GAD Orientation**

**Algorithms -
Euclidean Distance Transform**



New in GeoDict 2026

- New command [Lineal Path Length Distribution](#)^[94] to determine the probability that a straight line segment consists of only one Material ID dependig on the length of the line.
- Additional options are available for the [2-Point correlation](#)^[105] command and the resulting plots have been revised.

Learn to use MatDict

- [Material Statistics](#)⁶
Get information about the structure and compute statistical values.
- [Material Characterization](#)³⁵
Compute geometric properties.
- [GAD Objects Analysis](#)¹¹⁰
Compute properties of objects in analytic data format.
- [Algorithms](#)¹³¹
Apply further algorithms to characterize the structure.
- [Material Analysis GeoApps](#)¹⁴¹
Use the pre-installed GeoApps for specific applications.
- [References](#)¹⁴³
Publications cited in this chapter.



Join the conversation

Visit the Community on [GeoDict Forum](#) to be inspired and get answers to top questions.

Find illustrative application examples on the [website](#).

Our tutorials and seminar videos give you a first hands-on experience. They are collected in the [Learning Center](#).

Send your [Support Request](#) to our technical Support.

1.1 Material Statistics

Select one of the **Material Statistics** commands from the second pull-down menu and click **Edit...** to enter the parameters for the analysis.

Commands of Material Statistics:

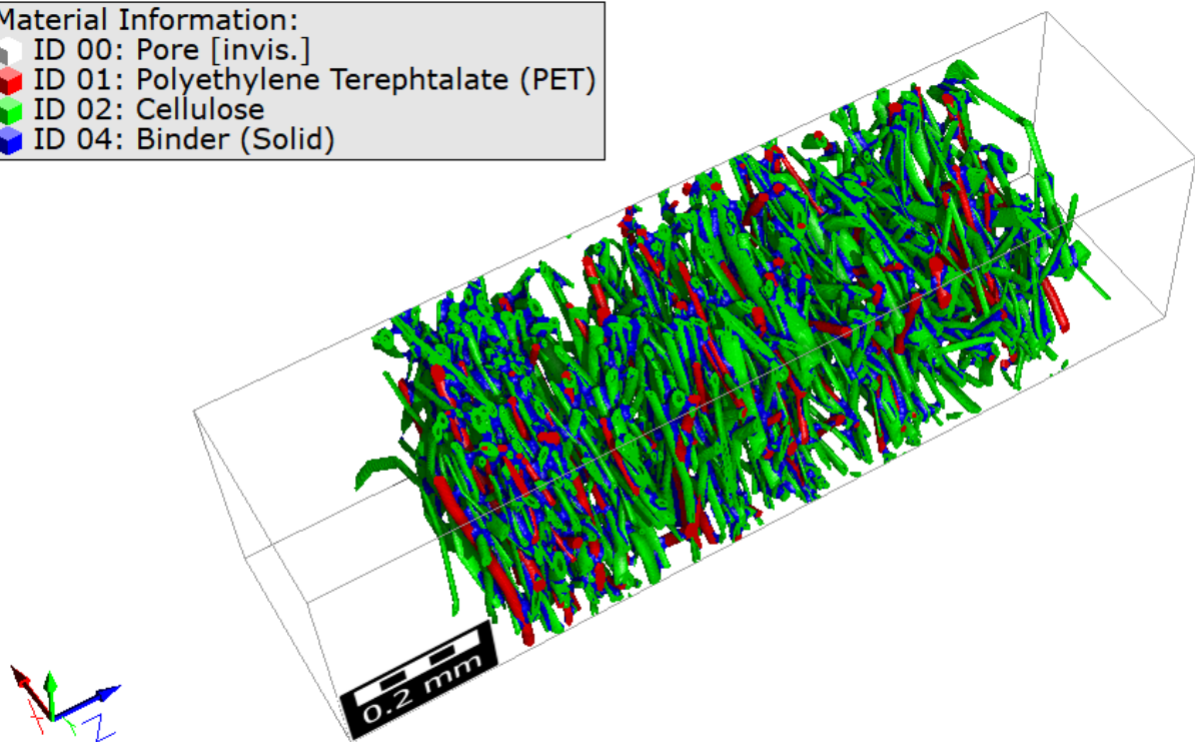
- [Structure Information](#)  ⁶
Collect basic structure information, such as porosity, density, and solid volume fraction of all materials.
- [Thickness Estimation](#)  ¹²
Measure the solid volume fraction of the material in different spatial directions.
- [2D Density Map](#)  ²³
Calculate the distribution of grammage, solid volume fraction, or number of objects in the direction of interest.
- [3D Inhomogeneity](#)  ²⁸
Compute the solid volume fraction, solid density distribution, or porosity with sub-volumes of specified size.

1.1.1 Structure Information

The **Structure Information** command determines porosity, solid volume fraction (SVF), number of GAD objects, density, mass, and grammage in all three spatial directions for the volume inside the bounding box. For these calculations, the algorithm requires the density of all solid materials as input data. Additionally, the individual solid volume fraction of all materials is given as well.

To illustrate the command the structure shown below is used.

Material Information:	
	ID 00: Pore [invis.]
	ID 01: Polyethylene Terephthalate (PET)
	ID 02: Cellulose
	ID 04: Binder (Solid)

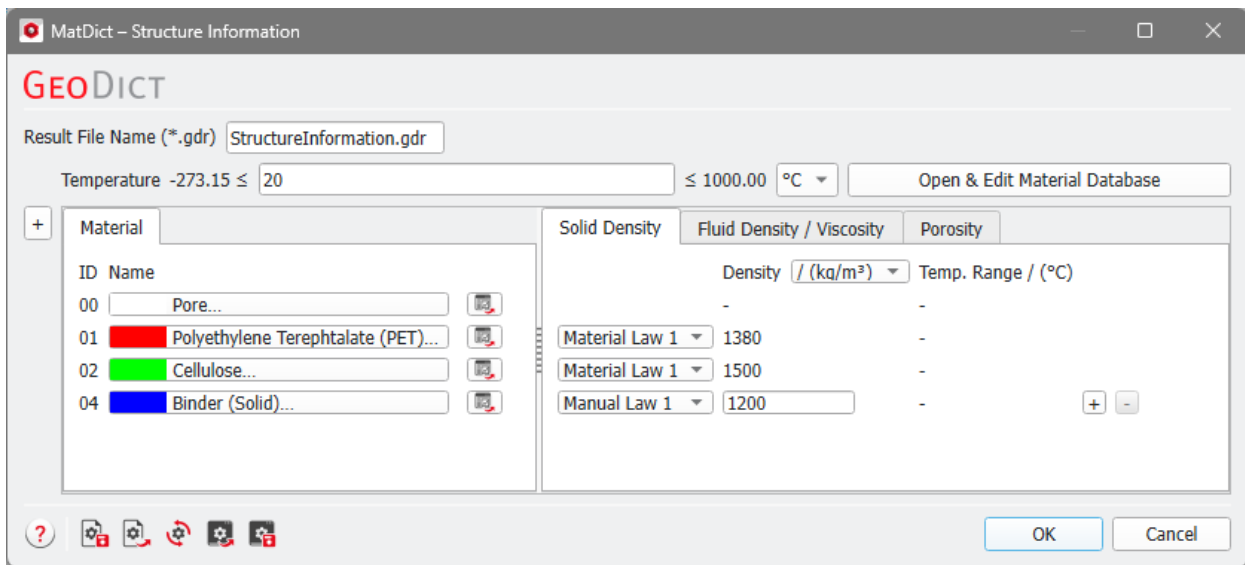


The Structure Information command:

- [Options](#)⁷
Set the parameters for the analysis.
- [Results](#)¹⁰
View the computed results.

Options

After clicking the **Edit...** button, the **Structure Information** dialog opens. At the top of the dialog, you can change the default **Result File Name** by a name according to your current project. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).



The given **Temperature** value and the **Temp. Range** are only of importance if the solid density is defined as a temperature-dependent quantity in the GeoDict Material Database. You can get direct access to the Material Database by clicking the **Open & Edit Material Database** button. For example, if Aluminum would be chosen as material, the solid density would be temperature dependent. In the above example, the densities of the PET and cellulose fibers are not temperature dependent.

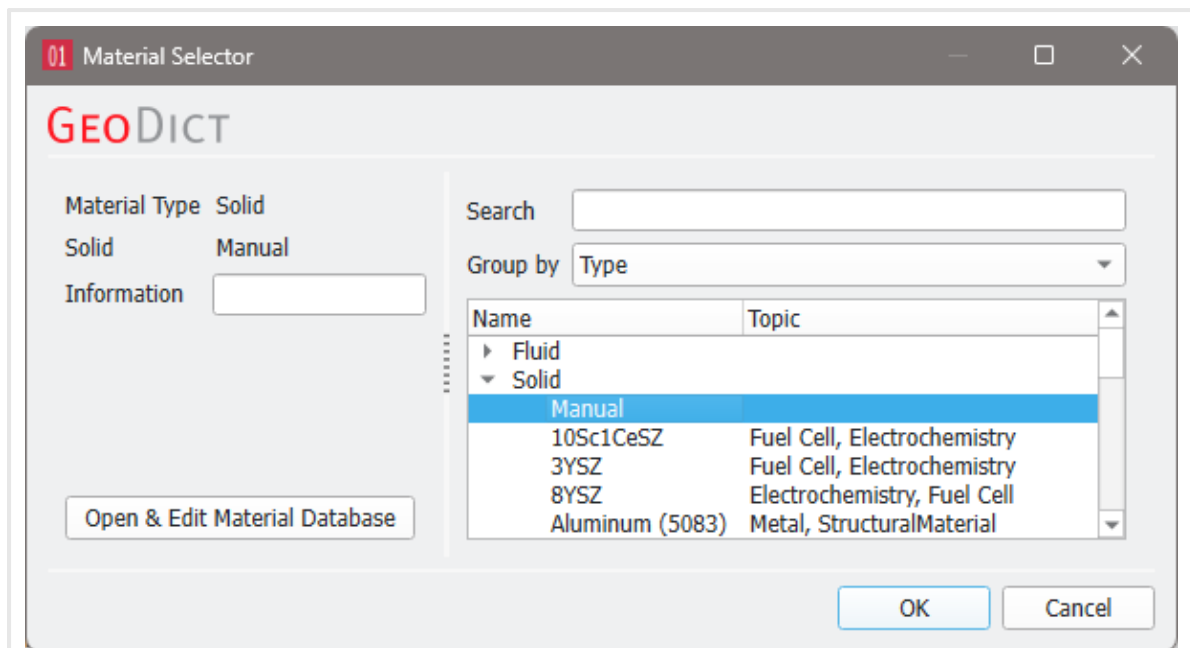
ID	Name	Density / (kg/m³)	Temp. Range / (°C)
00	Pore...	-	-
01	Aluminum...	Material Law 1 2700.09	-253.15 , 659.85

Underneath, on the left side, the **Material** panel contains the Material IDs of the constituent materials present in the current structure. By default, Material IDs that are not present in the structure are not displayed under the **Material** tab, but they can be displayed by clicking on the "+" symbol to the left of the **Material** tab.

✓ How to change the constituent materials

Click on the name of a material to change the material of the corresponding Material ID in the **Material Selector**.

The pull-down menu gives access to selecting the desired material from the GeoDict **Material Database**. When none of the materials available in the database fit the preferred specifications, **Manual** should be chosen. Alternatively, a new material with the desired specifications can be added to the **Material Database** (see the Material Database chapter).



To match realistic material colors for visualization in a certain application, the default material colors can be changed through the **Color & Visibility** tab of the GUI sidebar. For more visualization options, see the Visualization chapter.

You can also set the **Density** properties of this material in the Material Database.

On the right, the **Solid Density** tab contains the density information of the materials for each of the present Material IDs. The density can be given in kg/m^3 or g/cm^3 . For materials that are defined in the Material Database, the density of the material is directly shown under **Density** in the row for that Material ID. If multiple **Material Laws** are defined for a material, select which law you want to use for the computation.

If a material is set to **Manual**, the Material Law changes to **Manual Law** and more laws can be added or deleted by on the right of the corresponding row. You can enter the density for manual materials directly in the **Solid Density** tab. In the example above, the binder material of Material ID 04 is a manual material.

If fluid materials are present in the structure, you can define the density of them in the **Fluid Density / Viscosity** tab in the same way as for solid materials.

Material		Solid Density	Fluid Density / Viscosity	Porosity
ID	Name	Density / (kg/m^3)	Dyn. Viscosity / (kg/(m s))	Temp. Range / ($^{\circ}\text{C}$)
00	Pore...	Not Defined		-
01	Water in Porous...	Pressure = 1.01325 bar (1 atm) 998.206	0.00100161	0.1 , 99.9

If manual porous materials are present, you can define how much of the material are pores in the **Porosity** tab, for other porous materials you have to change it in the Material Database.

Material		Solid Density	Fluid Density / Viscosity	Porosity
ID	Name	Porosity / %		
00	Pore...	100		
01	Water in Porous...	50		

Results

After the **Structure Information** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains four tabs. The computational results are shown under the **Results** tab. The other three tabs (**Input Map**, **Log Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

Be aware, that the reported Solid Grammage values are only meaningful if the whole thickness of the media is included in the domain. In the example this is only true for the value in Z-direction.

Domain Size: 512 x 512 x 2000 Voxel Length: 750 nm Load Structure

Input Map Log Map Results Metadata

Report Map

Voxel length	7.5e-07 m
Size	512 x 512 x 2000 Voxel
Porosity	0.895601
Solid volume fraction	0.104399
Number of GAD-objects	0
Solid density	147.356 kg/m ³
	0.147356 g/cm ³
Solid mass	3.25928e-08 kg
Fluid density	0 kg/m ³
	0 g/cm ³
Fluid mass	0 kg
Bulk (total) density	147.356 kg/m ³
	0.147356 g/cm ³
Bulk (total) mass	3.25928e-08 kg

Solid grammage:

X-Direction: 56.5848 g/m²

Y-Direction: 56.5848 g/m²

Z-Direction: 221.034 g/m²

Specific solid volume:

X-Direction: 40089.3 mm³/m²

Y-Direction: 40089.3 mm³/m²

Z-Direction: 156599 mm³/m²

Specific pore volume:

X-Direction: 0.343911 L/m²

Y-Direction: 0.343911 L/m²

Z-Direction: 1.3434 L/m²

Constituent materials:

Pore, Polyethylene Terephthalate (PET), Cellulose, Manual 1

Volume fraction:

Material Pore: 0.895601

Material Polyethylene Terephthalate (PET): 0.0149915

Material Cellulose: 0.0645953

Material Manual 1: 0.0248125

MaterialID 0: 0.895601

MaterialID 1: 0.0149915

MaterialID 2: 0.0645953

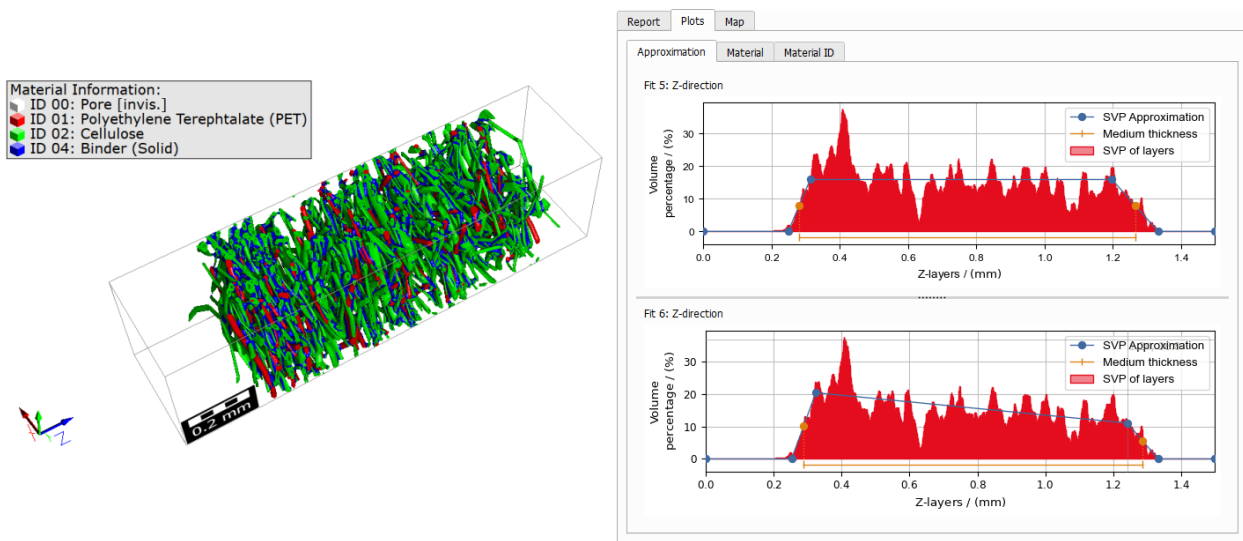
MaterialID 4: 0.0248125

1.1.2 Thickness Estimation

The **Thickness Estimation** command calculates the **solid volume percentage (SVP)** of the material in the different spatial directions and measures the material thickness. The SVP is computed in the plane normal to the direction of interest and the average value for each of those planes is reported.

You can select up to 6 fitting functions, Fit 1 to Fit 6, consisting of piecewise linear segments that best describe the type of porous media. For each selected fitting type, GeoDict solves an optimization problem to identify the best-fitting function. The thickness of the solid medium, of the inlet/outlet, and of the medium's surfaces is then derived from this function.

Furthermore, the SVP of these regions is computed.



The Thickness Estimation command:

- [Options](#)¹²
Set the parameters for the analysis.
- [Results](#)¹⁵
View the computed results.

Options

After clicking the **Edit...** button, the **Thickness Estimation** dialog opens. At the top of the dialog, you can enter the **Result File Name**. The result file with the given name is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar). The parameters are organized into the **Fitting Options** and **Minimizer Options** tabs.

Fitting Options

MatDict – Thickness Estimation

GEODICT

Result File Name (*.gdr)

Fitting Options | **Minimizer Options** | **Equations & References**

Background Mode: (Pore/Fluid Material IDs: 00)

Direction: ☐ X ☐ Y ☒ Z

Questionnaire

Does the medium have inlet and outlet? ☐ Y ☒ ? ☐ N

Is the transition from inlet and outlet to the inner medium smooth? ☐ Y ☒ ? ☐ N

Does the (inner) medium have a gradient? ☐ Y ☒ ? ☐ N

Fit Selection

☒ Fit 1 (Whole, Uniform) ☒ Fit 3 (Sharp, Uniform) ☒ Fit 5 (Smooth, Uniform)

☒ Fit 2 (Whole, Gradient) ☒ Fit 4 (Sharp, Gradient) ☒ Fit 6 (Smooth, Gradient)

Thickness SVP Threshold / (%) ☐ Write Inlet and Outlet to a .gdt file. ☐ Write Cropped Geometry to a .gdt file.

In the **Background Mode** pull-down menu, choose **Pore** to assign the Material ID corresponding to pore space (“background”) and exclude it from the calculations. The Material IDs that are recognized by GeoDict as background are given below as **Pore/Fluid Material IDs**. Alternatively, choose **GivenID** to assign one or multiple Material IDs to the pore space (only for the calculations within **Thickness Estimation**) and select the Material IDs from the **Background Material ID** pull-down menu.

Background Mode: (Pore/Fluid Material IDs: 00)

Background Material ID:

☒	00	Pore
☐	01	Polyethylene Terephthalate (PET)
☐	02	Cellulose
☐	04	Solid

In the **Direction** panel, one or more through directions for the thickness estimation can be chosen from the three principal directions **X**, **Y**, and **Z**.

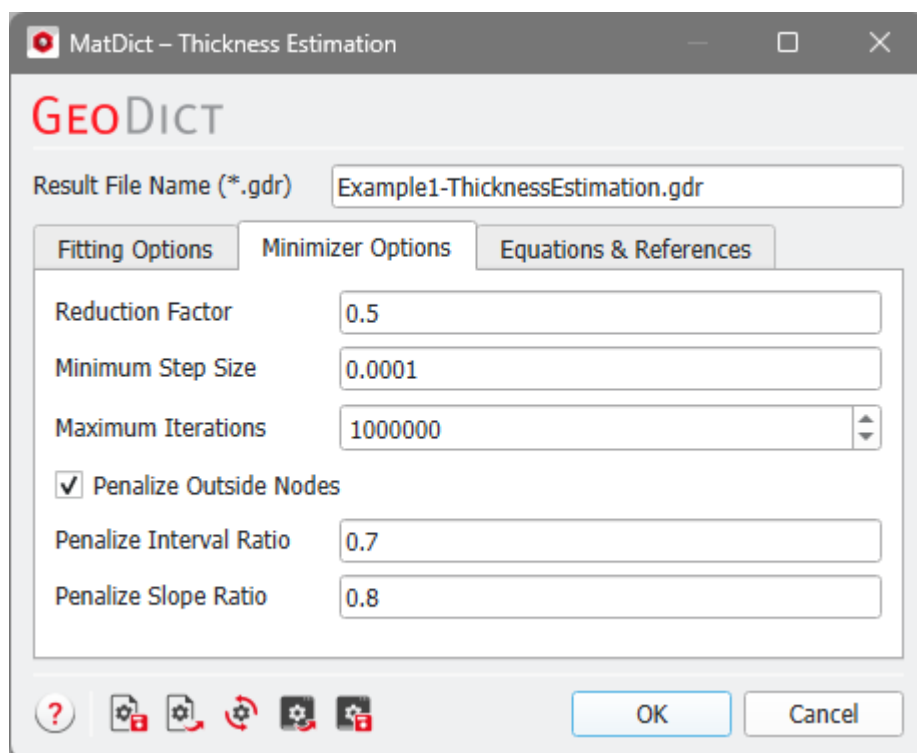
In the **Fit Selection** panel, one or multiple fitting types (Fit 1 to Fit 6) can be selected. In the **Result Viewer**, the selection can be changed for post-processing calculations. This feature is particularly useful for comparing results across various fitting types. Additionally, to facilitate an easier selection, you can employ the **Questionnaire**, which automatically chooses fitting types based on the provided responses.

More precisely, a distinction is made between media with a homogeneous density distribution (**Uniform**) and media with a density gradient (**Gradient**). Furthermore, either the absence (**Whole**) or presence of an inlet area and outlet area is considered. In the latter case, these areas can be non-empty, allowing for solids such as fibers to stick out of the medium. The transition between inlet and medium (and medium and outlet) can be approximated either by a sharp transition zone (**Sharp**) or by a smooth transition zone, which results in a non-zero surface length (**Smooth**).

Fits 3 to 6 take an inlet/outlet area into consideration. If **Write Inlet and Outlet to a .gdt file** is checked, the structure of the detected inlet and outlet is written to a .gdt file in the project folder and can be loaded in the [Data Visualization](#)²² tab of the Result Viewer. Check **Write Cropped Geometry to a .gdt file** to save the structure without inlet and outlet as .gdt file. This file can also be loaded from the [Data Visualization](#)²¹ tab.

Fits 5 and 6 assume that the medium begins at the center of the inlet area and ends at the center of the outlet area. This definition is modified by adjusting the **Thickness SVP Threshold** value, the technical specifics of which can be found in the tooltip.

Minimizer Options



The minimization method includes several numerical parameters that can be fine-tuned under the **Minimizer Options** tab. Detailed information about these parameters is available in the tooltips and can also be found in the published document by [Frank et al., 2024](#)^[143]. These options are intended for experts; the default values are generally suitable for common porous media.

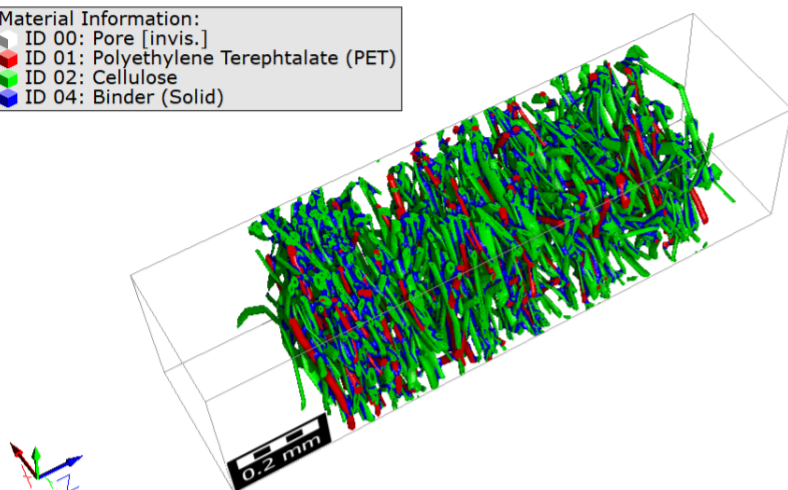
Results

After the **Thickness Estimation** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains six tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Data Visualization** tab. The other four tabs (**Input Map**, **Log Map**, **Post Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

As an example, we analyze a 3D model of a structure with a side length of 1500 μm (1.5 mm) in Z-direction (2000 voxels, voxel length of 0.75 μm) with the settings shown below.

Material Information:
 ID 00: Pore [invis.]
 ID 01: Polyethylene Terephthalate (PET)
 ID 02: Cellulose
 ID 04: Binder (Solid)



MatDict – Thickness Estimation

GEO

DICT

Result File Name (*.gdr)Example1-ThicknessEstimation.gdr

Fitting Options

Minimizer Options

Equations & References

Background Mode

Pore

(Pore/Fluid Material IDs: 00)

Direction

☐ X

☐ Y

☒ Z

Questionnaire

Does the medium have inlet and outlet?

☒ Y ☐ ? ☐ N

Is the transition from inlet and outlet to the inner medium smooth?

☒ Y ☐ ? ☐ N

Does the (inner) medium have a gradient?

☐ Y ☒ ? ☐ N

Fit Selection

☐ Fit 1 (Whole, Uniform)

☐ Fit 3 (Sharp, Uniform)

☒ Fit 5 (Smooth, Uniform)

☐ Fit 2 (Whole, Gradient)

☐ Fit 4 (Sharp, Gradient)

☒ Fit 6 (Smooth, Gradient)

Thickness SVP Threshold / (%)

50

☒ Write Inlet and Outlet to a .gdt file.

☒ Write Cropped Geometry to a .gdt file.

?

OK

Cancel

Thickness Estimation Results:

- [Report](#)¹⁷
See the computed results.
- [Plots](#)¹⁸
View result plots.
- [Data Visualization](#)²¹
Load results for a graphical visualization.

Report

At the top of the Report tab, in the **Layer analysis** section, the SVP of the entire structure is reported.

Below are the analysis results of the chosen directions. In this example, only the Z-direction was selected as through direction, therefore, only a **Z direction analysis** section is contained in the report. Initially, the **specific solid volume** and the **specific pore volume** are reported.

Following this, a table displays computed values from the thickness estimation algorithm for the selected fits. The first three rows showcase the thickness of the identified inlet, medium, and outlet, with their cumulative sum equating to the domain size in the Z-direction. The fourth row provides the SVP of the identified medium. The nodes correspond to the piecewise linear approximations that are illustrated in the thickness estimation input dialog, which indicate the coordinate in the through direction and the corresponding SVP. The final row shows the error of the SVP approximation in the L2 norm. Below the table, the chosen **Thickness SVP threshold** is reported.

Domain Size: 512 x 512 x 2000 Voxel Length: 750 nm Load Structure

Input Map Log Map Post Map Results Data Visualization Metadata

Fit Selection

☐ Fit 1 (Whole, Uniform)
☐ Fit 2 (Whole, Gradient)
☐ Fit 3 (Sharp, Uniform)
☐ Fit 4 (Sharp, Gradient)
☒ Fit 5 (Smooth, Uniform)
☒ Fit 6 (Smooth, Gradient)

Thickness SVP Threshold / (%) 50

Apply

☒ Back-up result file

Plot Options

Report Plots Map

Layer analysis

Solid volume percentage: 10.4399

Z direction analysis

Specific solid volume	156599 mm ³ /m ²
Specific pore volume	1.3434 L/m ²

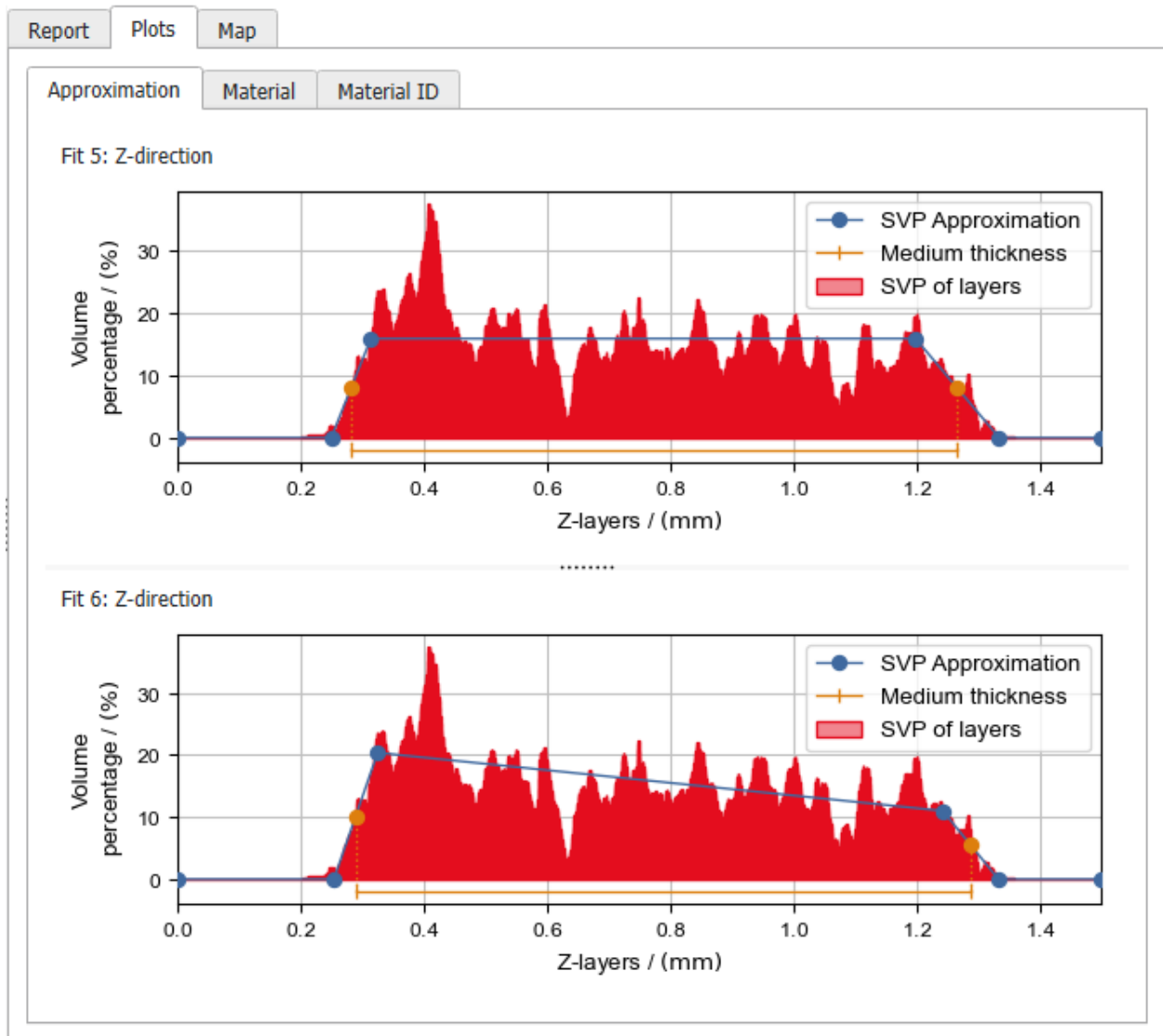
SVP approximation	Fit 5	Fit 6
Inlet thickness	280.719 μm	288.408 μm
Medium thickness	985.197 μm	999.011 μm
Outlet thickness	234.084 μm	212.581 μm
Medium SVP	15.4468	15.3395
Nodes	(0 m , 0) (248.489 μm , 0) (312.95 μm , 15.8588) (1.19793 mm , 15.8588) (1.33391 mm , 0) (1.5 mm , 0)	(0 m , 0) (252.826 μm , 0) (323.99 μm , 20.3559) (1.24223 mm , 10.9978) (1.3326 mm , 0) (1.5 mm , 0)
L2 Error (normalized)	0.0416729	0.0361442

Thickness SVP threshold: 50

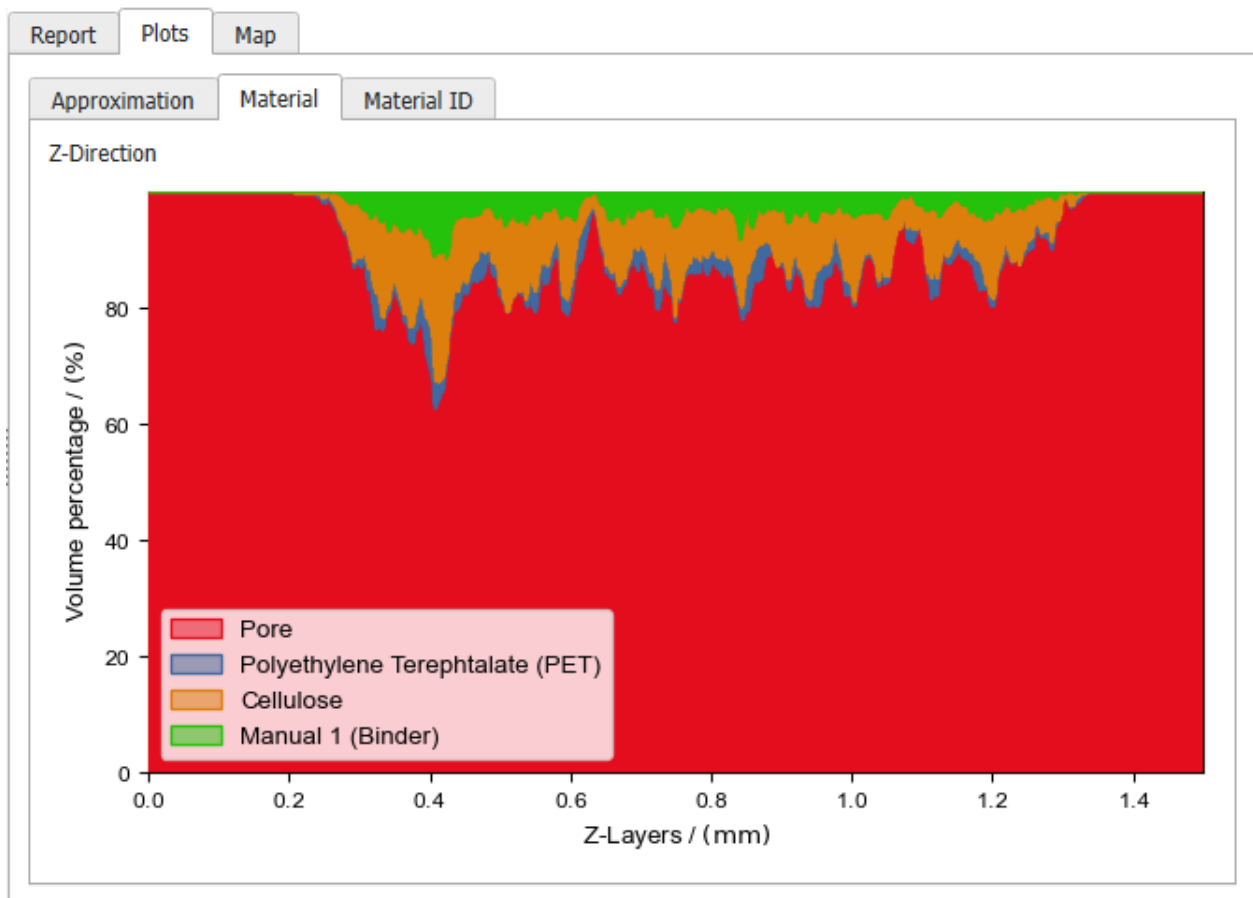
In the context menu shown on the left, the **Fit Selection** can be modified and executed as a post-processing step. Additionally, computations can be repeated with a different **Thickness SVP Threshold** value. Click **Apply...** to update the results, including **Report** and **Plots**.

Plots

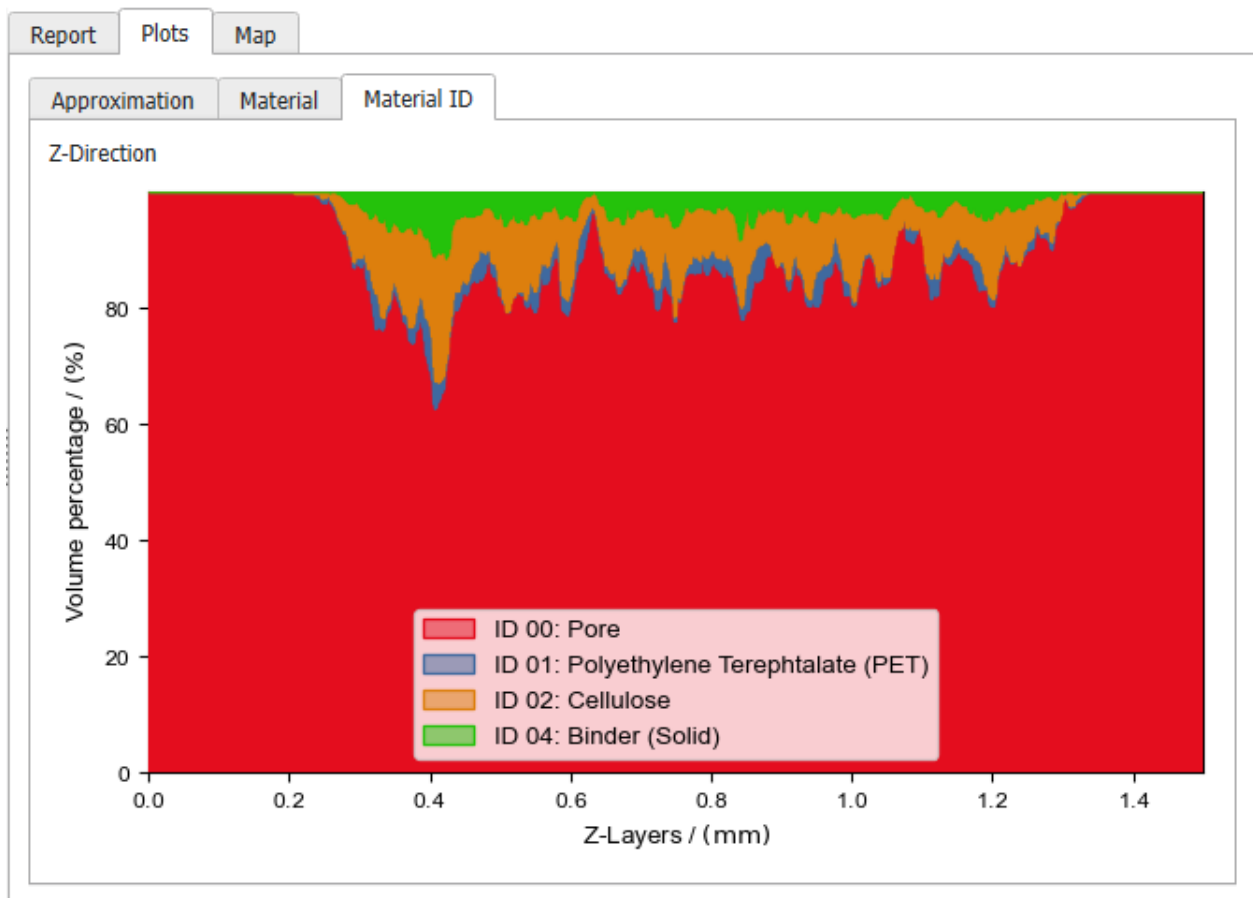
In the **Plots** tab, the SVP distribution corresponding to the layers of the through direction, their piecewise linear approximation, and the estimated medium thickness are visualized under the **Approximation** subtab for each selected fit. If exactly two fits are selected, two stacked plots will be displayed for comparison purposes. Otherwise, if three or more fits are chosen, you can select the plot you wish to view from the pull-down menu.



Furthermore, under the **Material** subtab, plots of the volume percentage of all existing materials for the layers in the analyzed direction are shown.



Under the **Material ID** subtab, plots of the volume percentage of the different Material IDs are shown. The plots differ only from those in the **Material** subtab if several Material IDs are assigned to the same material.

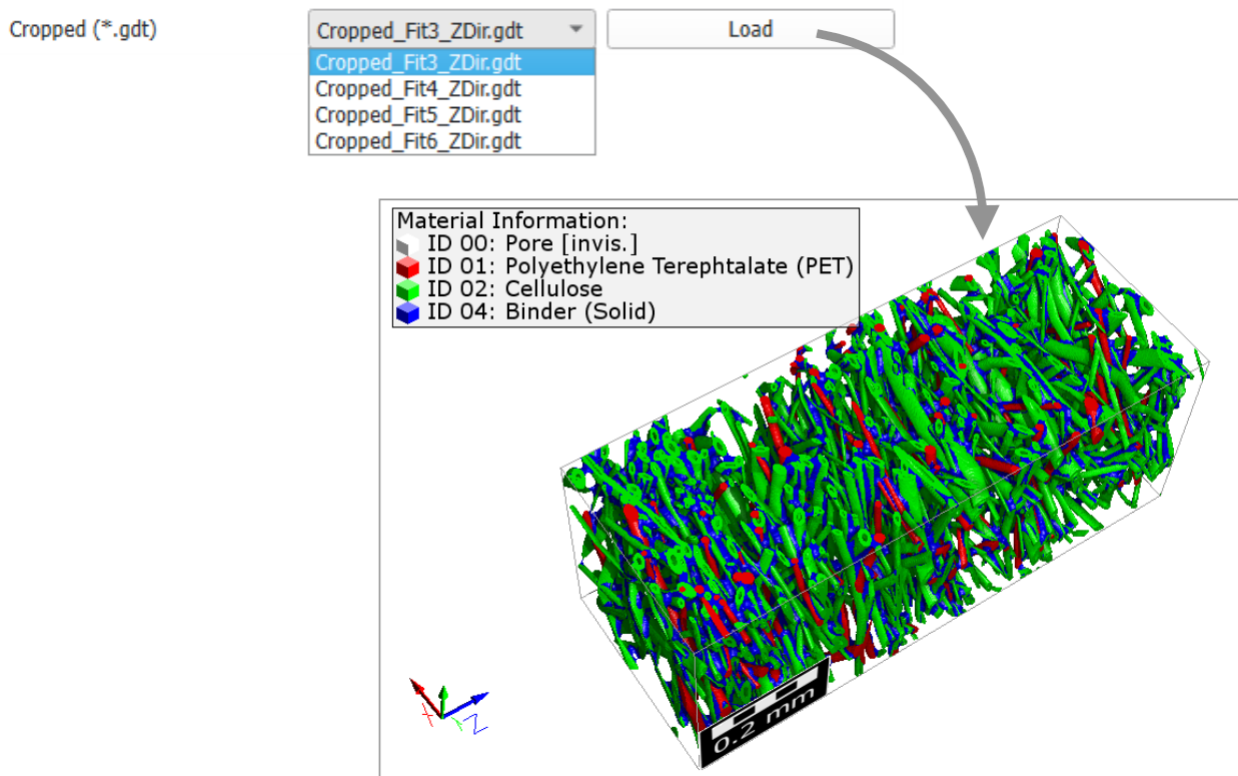


Data Visualization

Under the **Data Visualization** tab, additional saved structures are available if **Write Inlet and Outlet to a .gdt file** and/or **Write Cropped Geometry to a .gdt file** were checked in the [Options](#) ¹² dialog.

Cropped Geometry

If **Write Cropped Geometry to a .gdt file** was checked, the structure where the inlet and outlet regions are cropped can be loaded.

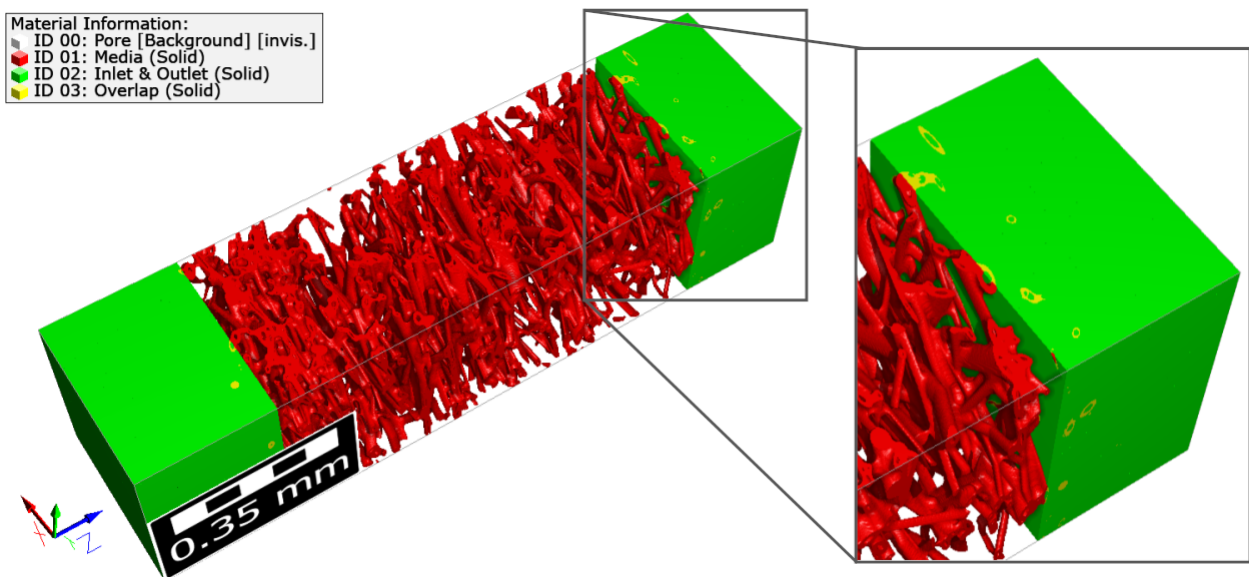


Inlet and Outlet

If **Write Inlet and Outlet to a .gdt file** was checked, a structure showing the identified inlet/outlet regions can be loaded. The inlet and outlet areas are calculated based on the measured SVP and the selected methods. If multiple methods with inlet/outlet are selected, a structure is saved for each of those methods.

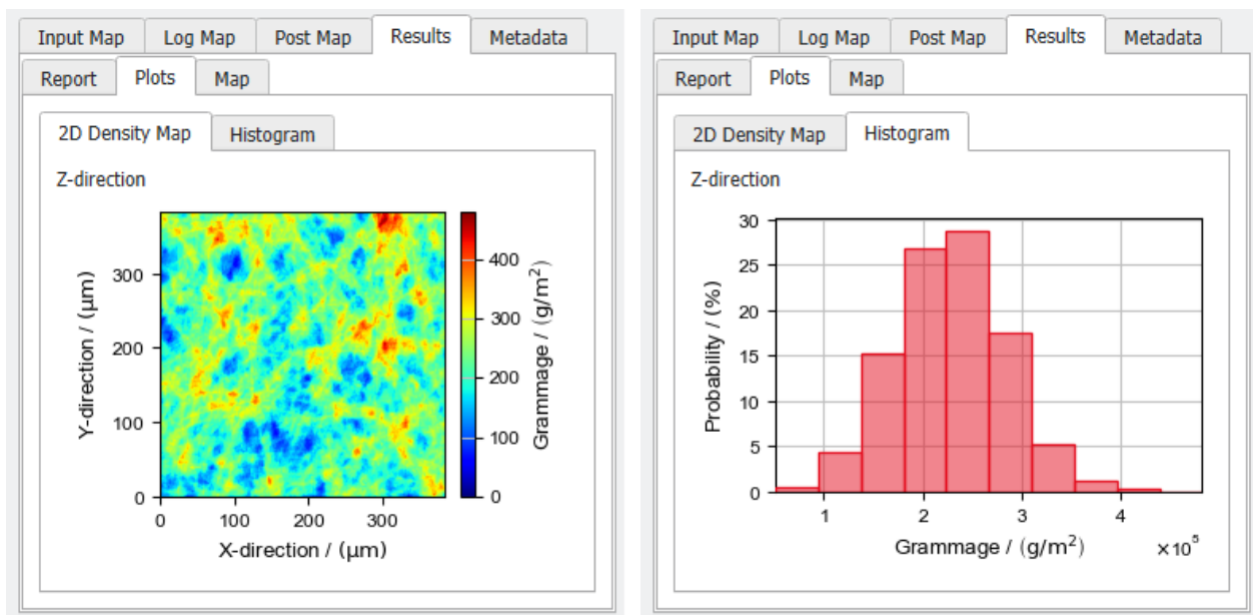


The inlet/outlet volume is assigned to Material ID 02 (here green) and the entire solid structure is assigned to Material ID 01 (here red). Intersections ("overlap") of the structure and the identified inlet/outlet volume are assigned to Material ID 03 (here yellow).



1.1.3 2D Density Map

The **2D Density Map** command calculates the distribution of **Grammage**, **Solid Volume Fraction (SVF)**, or the **Number of Objects** in a plane normal to the chosen direction. Each pixel in this plane is calculated by averaging the respective property in the direction of interest at this position.



The 2D Density Map command:

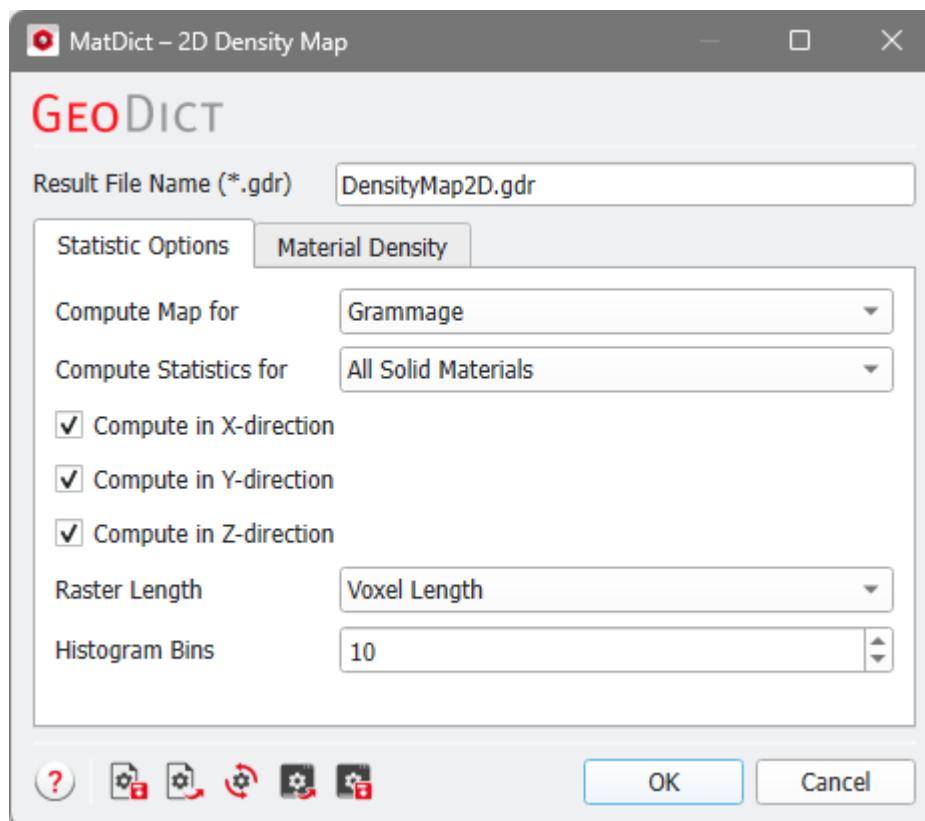
- [Options](#)²⁴
Set the parameters for the analysis.
- [Results](#)²⁷
View the computed results.

Options

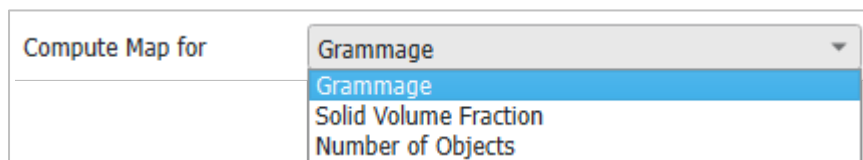
The **2D Density Map** dialog opens when clicking the **Edit...** button. It contains two tabs: **Statistic Options** and **Material Density** ²⁶.

At the top of the dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).

Statistic Options

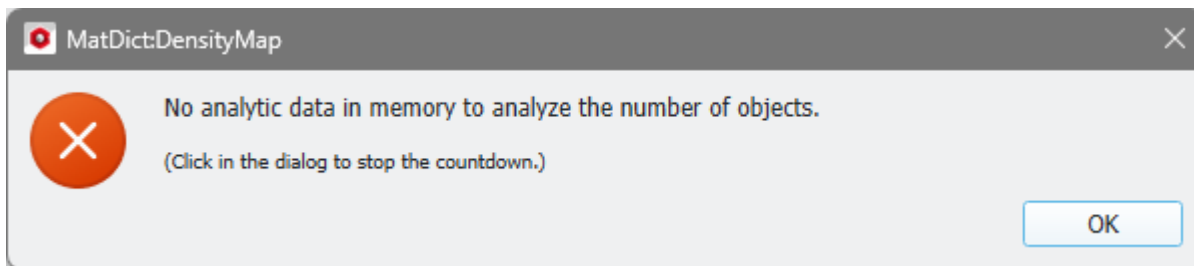


Choose the property to be computed from the **Compute Map for** pull-down menu.

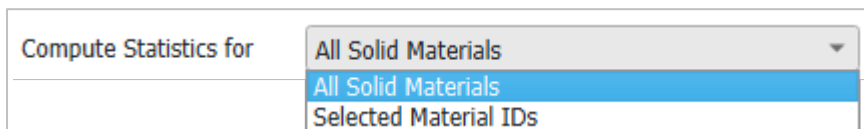


Only when choosing **Grammage**, the **Material Density** ²⁶ tab is selectable and the density values for the individual Material IDs must be defined there. For **Solid Volume Fraction** or **Number of Objects**, the density of the Material IDs is not considered in the calculations and the Material Density tab therefore not needed.

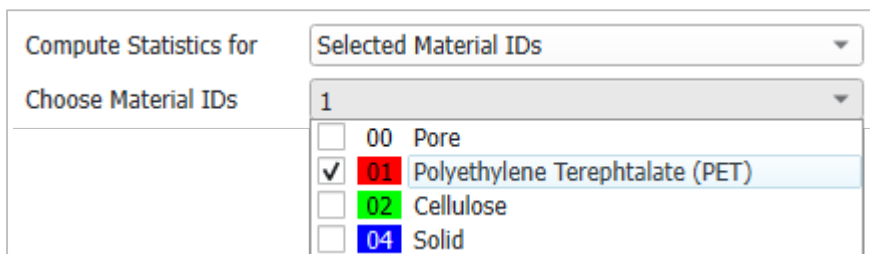
When choosing **Number of Objects**, analytic information about the objects in the current structure must be available. Otherwise, a warning message appears, and the density map cannot be computed.



The choice in the **Compute Statistics for** pull-down menu controls whether the property is computed for **All Solid Materials** or only for **Selected Material IDs**.

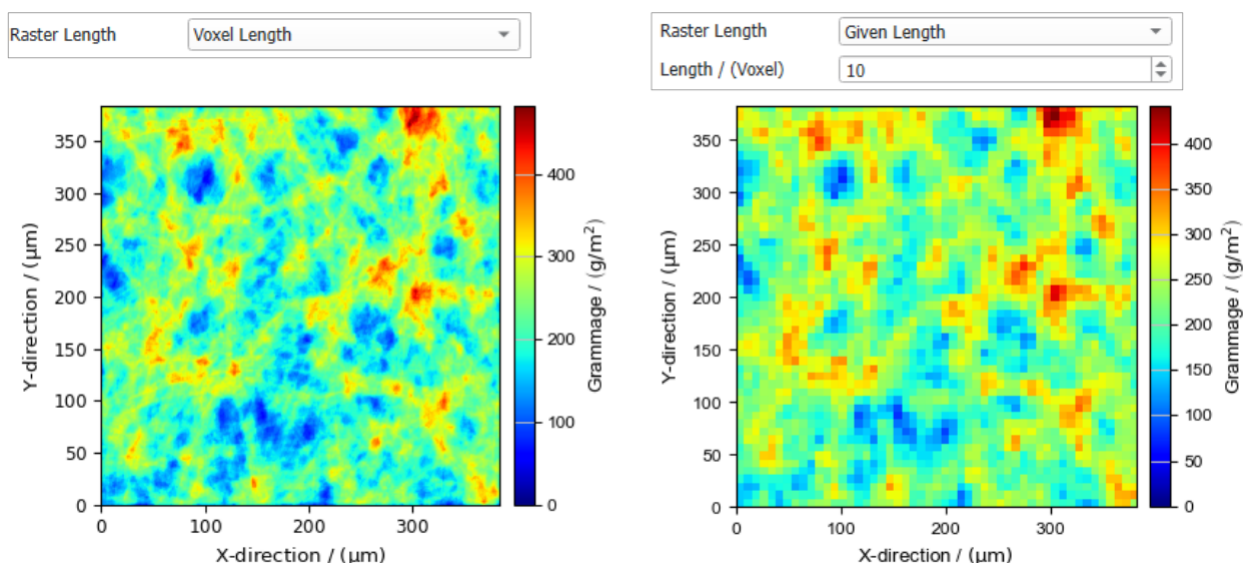


For **Selected Material IDs**, choose them from the materials present in the structure in the **Choose Material IDs** pull-down menu.



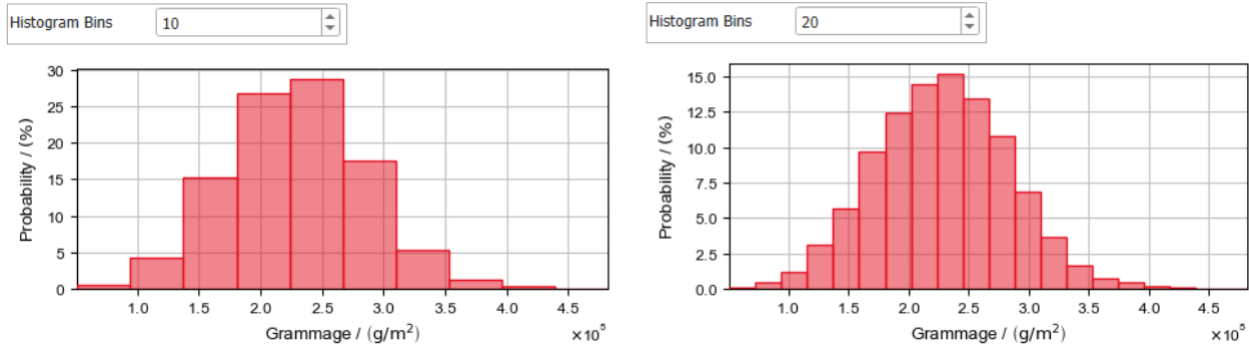
Check **Compute in X-direction**, **Compute in Y-direction**, and/or **Compute in Z-direction** to calculate the chosen properties in these directions.

From the **Raster Length** pull-down menu, choose **Voxel Length** or **Given Length**. This defines the side length of square areas in which Grammage, Solid Volume Fraction, or Number of Objects are computed. **Voxel Length** sets the raster length equal to the voxel size and, thus, the 2D density map is computed in the chosen directions for each voxel. If **Given Length** is chosen, the **Length** in units of voxel must be entered to define the resolution for the calculations. The following figures show the effect of the **Raster Length** on the results.



Histogram Bins refers to the number of bins used to divide the range of density values (Grammage, Solid Volume Fraction, or Object Number) into a series of equally sized intervals. In the result file, the number of histogram bins is used to create tables and plots with the frequency (probability) of values that fall into each interval.

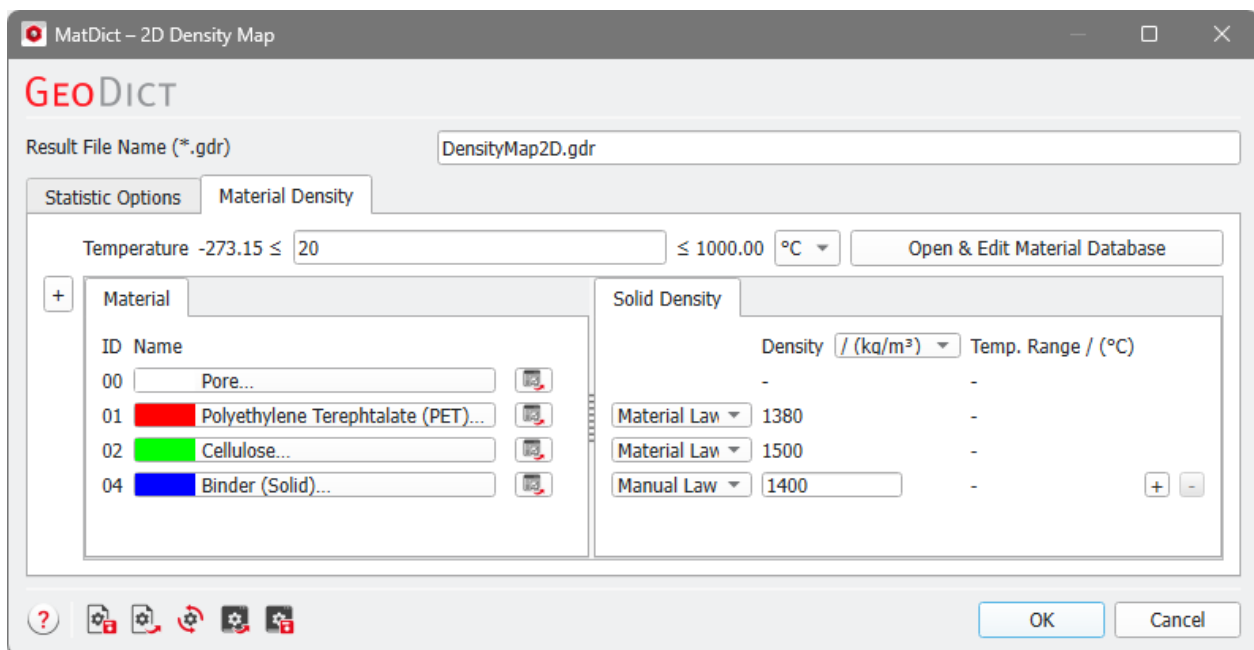
For example, the following plots are taken from result files for the same structure. In the left figure, the histogram is shown with 10 bins, and in the right figure with 20 bins.



Material Density

This tab is only available if **Grammage** is chosen as the property to do the computations for.

Under the **Material Density** tab, the temperature can be edited if the density of a material is temperature dependent. Additionally, the density of every solid material in the structure must be specified in this tab. The density can be given in kg/m³ or g/cm³. For materials from the GeoDict Material Database, the density value is entered automatically. If a material is set to **Manual**, the Material Law changes to **Manual Law** and more laws can be added or deleted by clicking the "+" or "-" button on the right of the corresponding row. You can enter the density for manual materials directly in this tab.

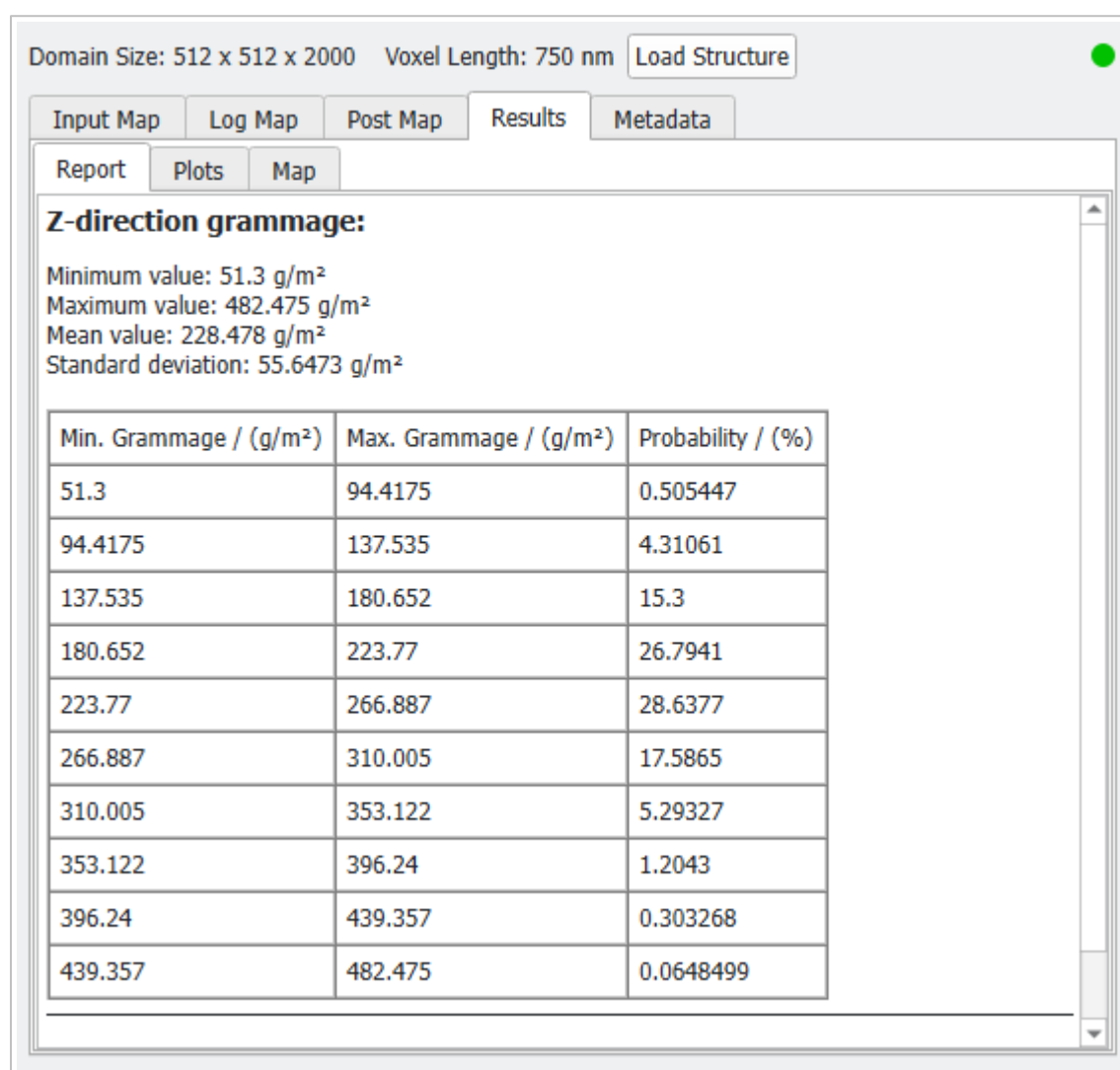


Results

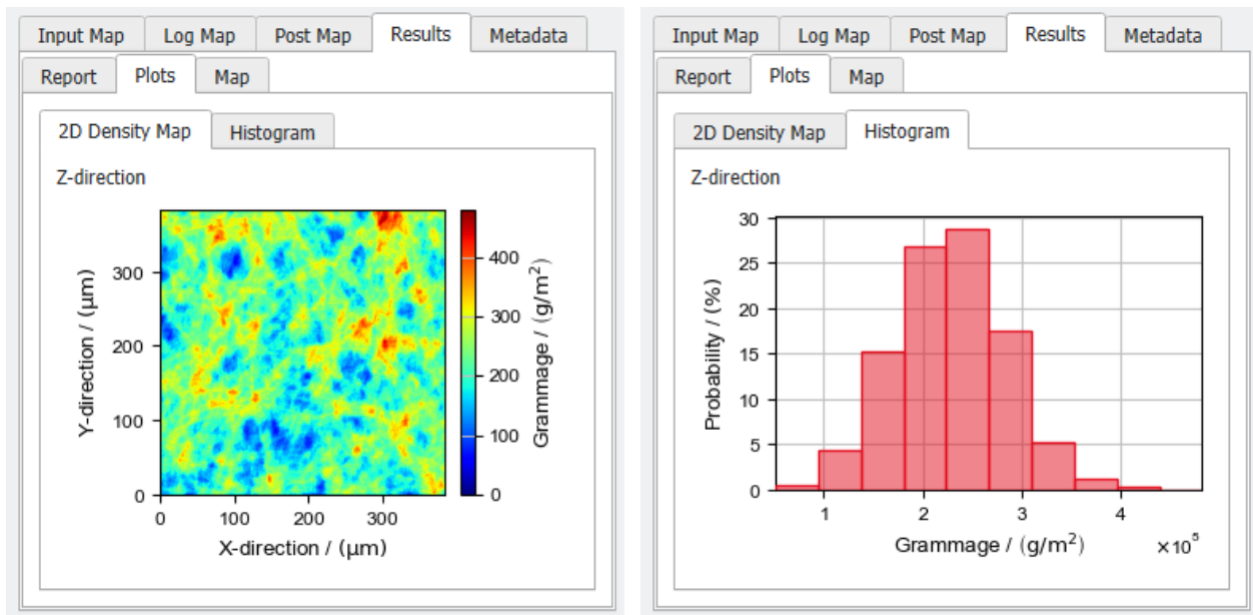
After the **2D Density Map** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains five tabs. The computational results are shown under the **Results** tab. The other four tabs (**Input Map**, **Log Map**, **Post Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

In the **Results - Report** tab, the **minimal**, **maximal**, and **mean values** of the computed parameter (here: Grammage) and the **standard deviation** are given. Below, a table shows the computed **density distribution** for the chosen number of **Histogram Bins**.

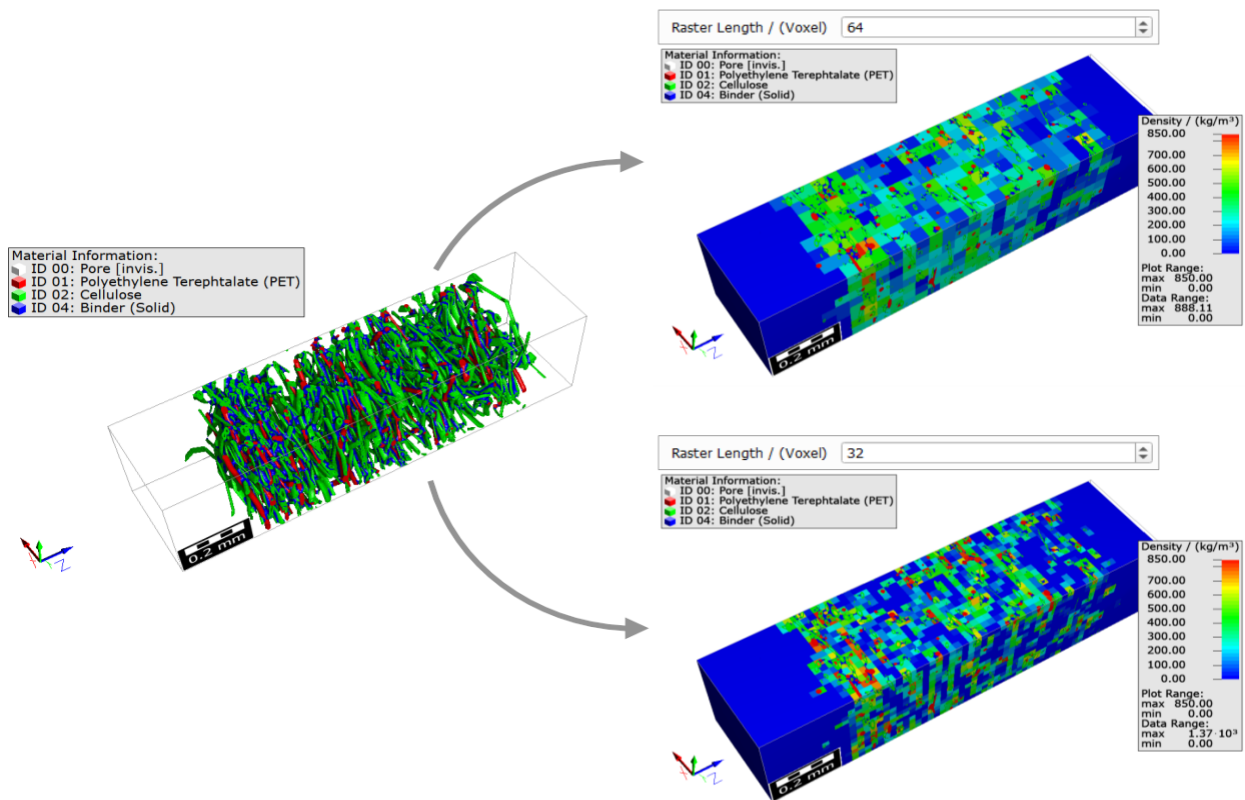


In the **Results – Plots** tab, the table entries are additionally available as a Histogram plot. The 2D Density Map subtab shows the computed result, where each pixel in this plane shows the average of the chosen property in the direction of interest at this position.



1.1.4 3D Inhomogeneity

The **3D Inhomogeneity** command calculates the distribution of the **Solid Volume Fraction**, **Solid Density**, or **Porosity** in specified adjacent sub-volumes. Each sub-volume is a cube with specified side length and the selected property is determined independently in each of the cubes.



The solution file of different Raster Lengths shows the density in the individual sub-volumes. In the middle of the structure, the boxes can be clearly distinguished.



Know how! The GeoApp [Compute Fractal Dimension](#)^[141] computes 3D Inhomogeneity with increasing raster lengths to analyze the structure.

The 3D Inhomogeneity command:

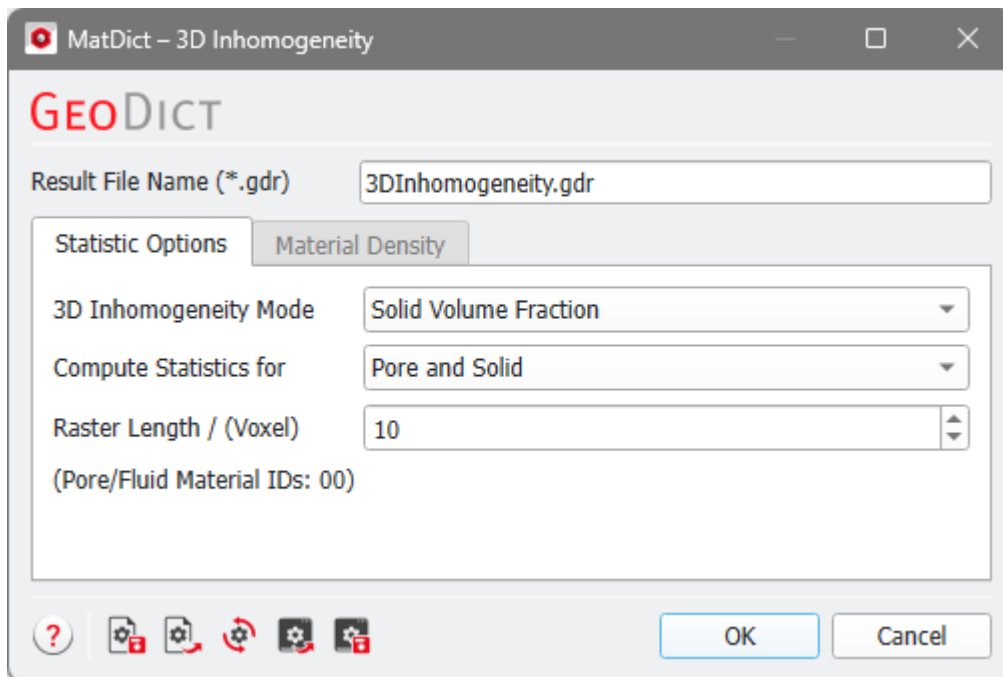
- [Options](#)^[29]
Set the parameters for the analysis.
- [Results](#)^[32]
View the computed results.

Options

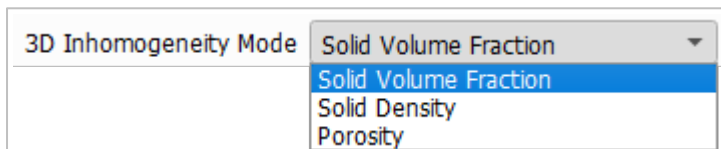
The **3D Inhomogeneity** dialog opens when clicking the **Edit...** button and includes the **Statistic Options** and **Material Density** tabs.

At the top of the dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).

Statistic Options

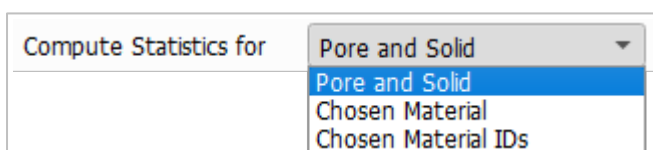


Choose the property to be computed from the **3D Inhomogeneity Mode** pull-down menu.

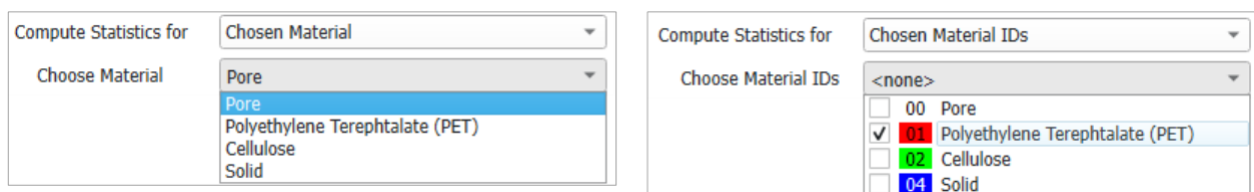


Only when choosing **Solid Density**, the **Material Density** ³¹ tab is selectable and the density values for the individual Material IDs must be defined there. For **Solid Volume Fraction** or **Porosity**, the density of the Material IDs is not considered in the calculations and the Material Density tab therefore not needed.

The choice in the **Compute Statistics for** pull-down menu controls whether the property is computed for all materials (**Pore and Solid**) or only for specified materials (**Chosen Material**) or for **Chosen Material IDs**.



For **Chosen Material** and **Chosen Material IDs**, the materials or IDs can be chosen from those present in the structure, which appear in a second pull-down menu below.



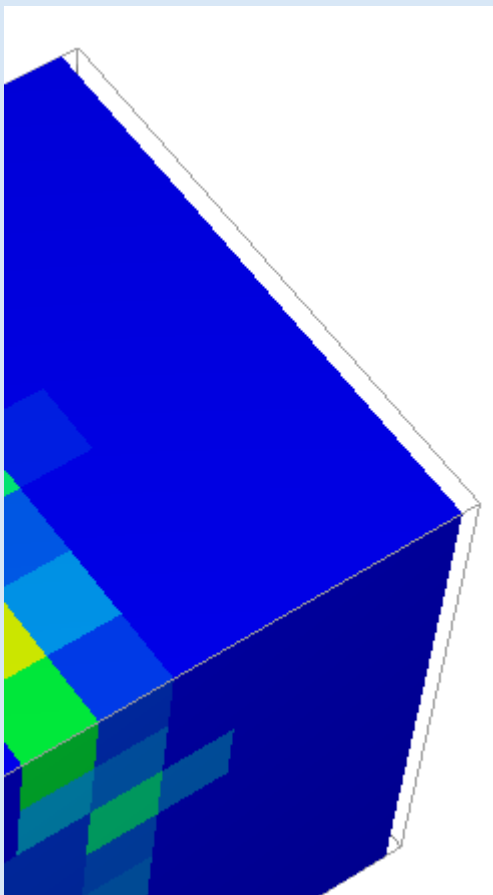
The **Raster Length** determines the side length of the cubic sub-volume in voxels.



Note! If the **Raster Length** is not a common divisor of the side lengths **NX**, **NY**, **NZ** of the current structure, some boundary layers of the current structure will not be contained in any sub-volume. In this case, a warning will be plotted in the result viewer.

Warning: dividing the geometry by the given raster length some voxels at the domain boundary remain (0, 0, 16). These voxels are neglected in the analysis.

You can observe this as blank space between the volume field and the bounding box of the structure after loading the solution file from the [Data Visualization](#)³⁴ tab in the Result Viewer.

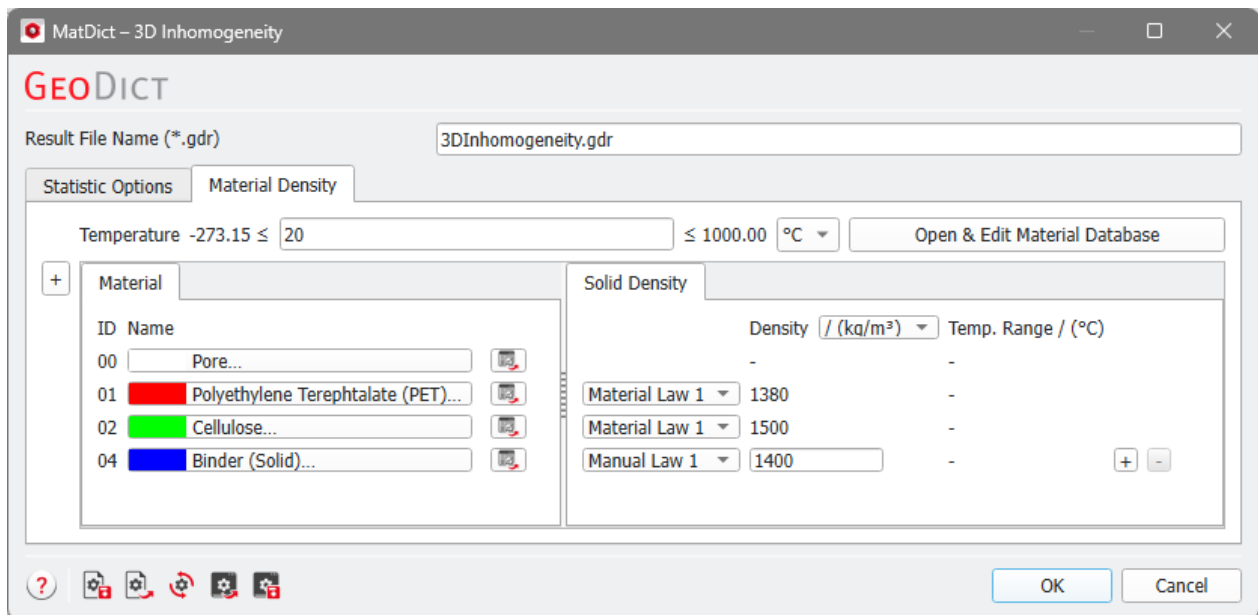


Material Density

This tab is only available if **Solid Density** is chosen as the material property to be computed.

Under the **Material Density** tab, the temperature can be edited if the density of a material is temperature dependent. Additionally, the density of every solid material in the structure must be specified in this tab. The density can be given in kg/m^3 or g/cm^3 . For materials from the GeoDict Material Database, the density value is entered automatically. If a material is set to **Manual**, the Material Law changes to **Manual Law** and more laws can be added or deleted by

clicking the "+" or "-" button on the right of the corresponding row. You can enter the density for manual materials directly in this tab.



Results

After the **3D Inhomogeneity** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains six tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Data Visualization** tab. The other four tabs (**Input Map**, **Log Map**, **Post Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

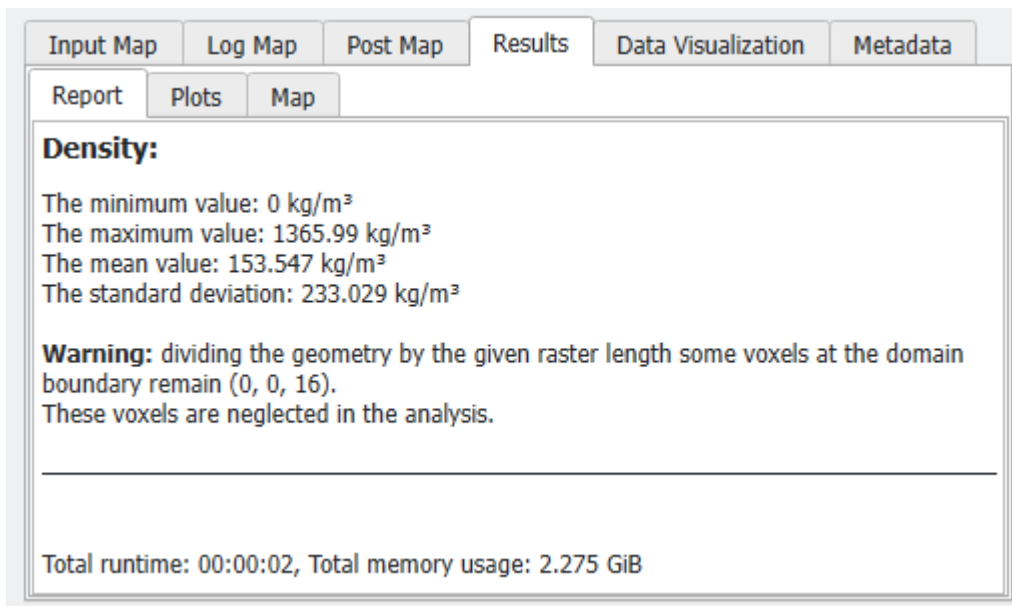
3D Inhomogeneity Results:

- [Results Tab](#)^[32]
Observe the computed results and plots.
- [Data Visualization](#)^[34]
Load results for a graphical visualization.

Results Tab

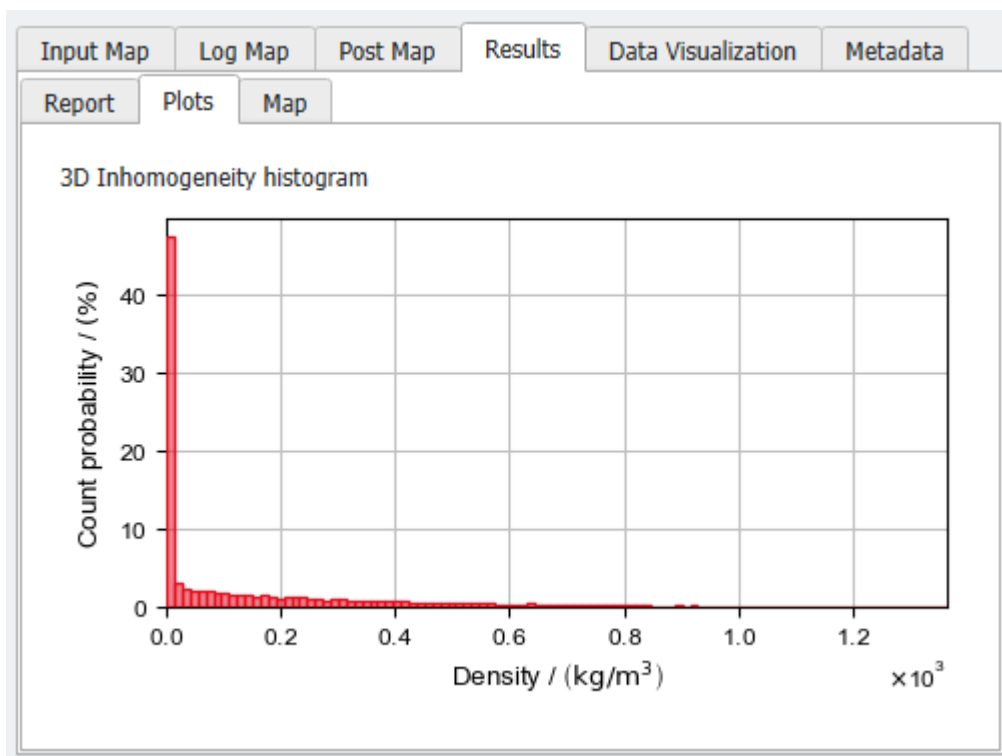
Report

In the **Results - Report** subtab, the **minimal** and **maximal value** of the chosen property found in any sub-volume are reported. Additionally, the **mean value** and the corresponding **standard deviation** are shown.



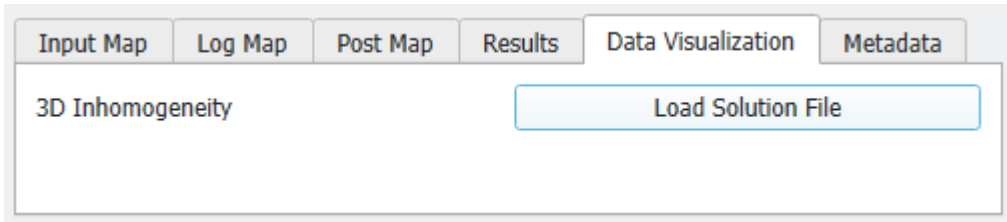
Plots

In the **Results – Plots** subtab, the histogram of the **Count Probability** of the selected property is plotted. It shows how much of the sub-volumes have certain property value. The number of bins in the histogram is fixed to 100, i.e., for analyzed **Solid Volume Fraction** or **Porosity**, the bin size is 1%. If **Density** is analyzed, the range of density values is divided in 100 equally sized bins.



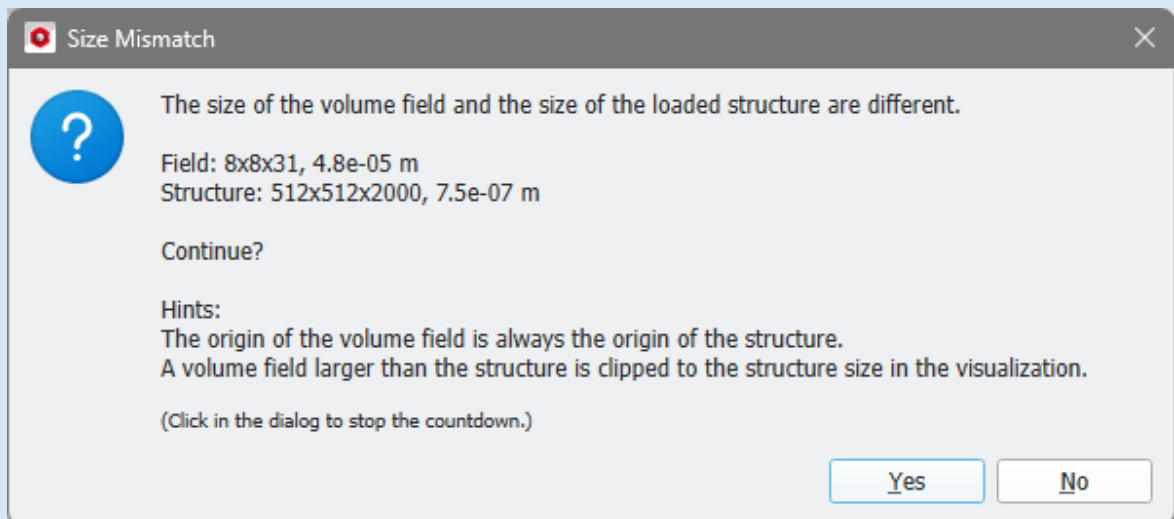
Data Visualization

Under the **Data Visualization** tab, it is possible to visualize the computed densities, porosities, or solid volume fractions of the sub-volumes.

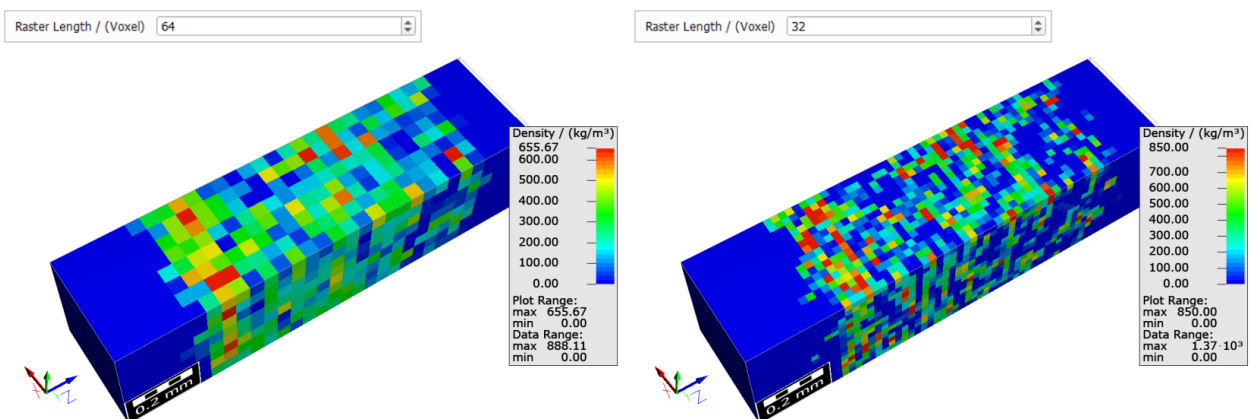


Clicking on **Load Solution File** loads the result field.

Note! If the raster length is not a [common divisor](#) of the side lengths, a message pops up when loading the solution file. However, you can still load the solution file by clicking **Yes**.



For each of the sub-volumes the computed property value is written in the solution file. You can also observe the varying results when a different **Raster Length** is chosen.



1.2 Material Characterization

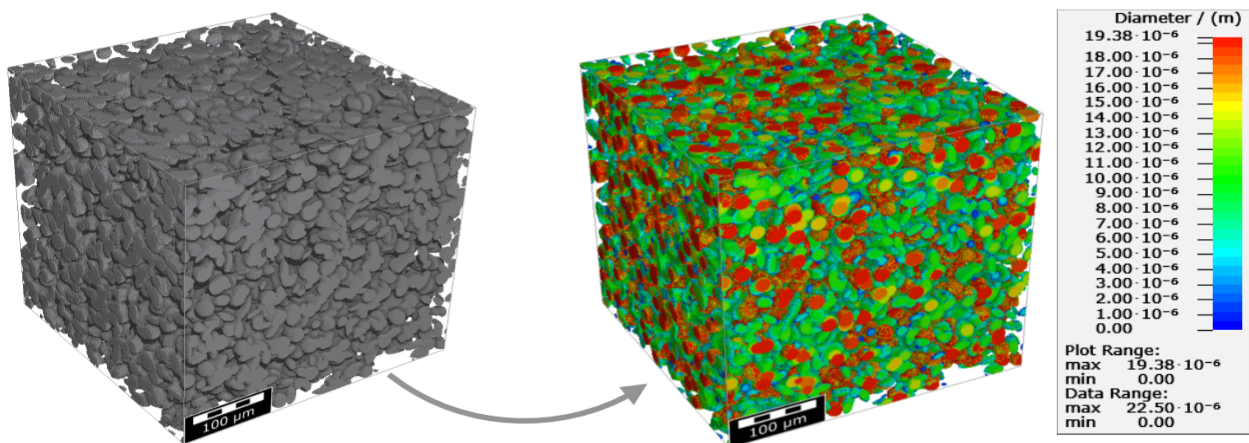
Select one of the **Material Characterization** commands from the second pull-down menu and click **Edit...** to enter the parameters for the simulation.

Commands of Material Characterization:

- [Solid Size Distribution \(Granulometry\)](#)^[35]
Determine the size distribution of solid objects by fitting spheres.
- [Percolation Path](#)^[48]
Check if there is a percolation path for a specified material in the structure and determine its length and minimal diameter.
- [Connected Components](#)^[59]
Find and count the number of connected components in the 3D structure.
- [Estimate Surface Area](#)^[71]
Approximate the surface area of a material by using statistical methods and by adding up the voxel surfaces.
- [Estimate Three-Phase Contact Line](#)^[78]
Compute the length of the contact line between the phases in a three-phase system.
- [Minkowski Parameters](#)^[80]
Compute the four Minkowski Parameters Volume, Surface Area, Integral of mean curvature, and Integral of total curvature.
- [Chord Length Distribution](#)^[85]
Determine the distribution of the length of a typical chord (number of connected voxels along the computational direction) of a structure.
- [Lineal Path Length Distribution](#)^[94]
- [Geodesic Tortuosity](#)^[99]
Find the shortest paths crossing the material, either through pore space or through solid materials.
- [2-Point Correlation](#)^[104]
Determine the probability for two points having a certain distance to be correlated, which means that they belong to the same type.

1.2.1 Solid Size Distribution (Granulometry)

The **Solid Size Distribution (Granulometry)** is determined by fitting spheres into the solid objects. Each voxel gets assigned the diameter of the largest sphere, that contains this voxel and fits inside the solid object.



On the right, the volume field (.gsd) showing the diameter for each solid voxel is visualized.*

The Solid Size Distribution (Granulometry) command:

- [Options](#)³⁶
Set the parameters for the analysis.
- [Results](#)⁴³
View the computed results.

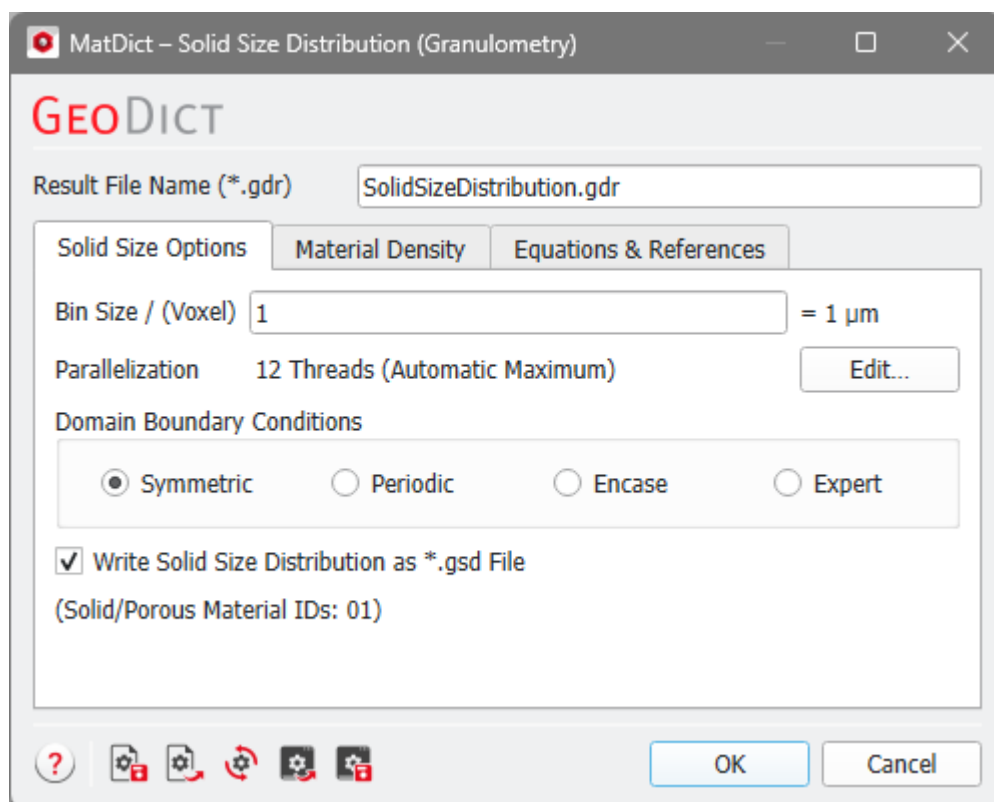
Options

The Solid Size Distribution dialog includes the **Solid Size Options** and the [Material Density](#)⁴² tabs. The last tab, **Equations & References**, provides further information about the underlying algorithm and cites [J. Becker](#)¹⁴³, [A. Wiegmann](#)¹⁴³, [T. Saito](#)¹⁴³, and [D. Silin](#)¹⁴³.

At the top of the dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).

Solid Size Options

The **Solid Size Options** are similar to those of Pore Size Distribution (Granulometry) in PoroDict.



✓ Bin Size

Enter the **Bin Size** in units of voxels. The equivalent in metric length units is shown on the right. The bin size determines the range of diameters that belong to one class of solid sizes.

All bins have equal bin size. Beginning with the largest possible diameter that is divisible by the bin size, the diameter is reduced by the bin size in each step. Every voxel is then assigned the diameter of the largest possible sphere that can be fitted in the solid and contains this voxel. Thus, each bin contains solid voxels with an assigned diameter in the range comprised between $[(i - 1) \cdot \text{bin size}]$ and $[i \cdot \text{bin size}]$, where i is the bin number.

For example, when analyzing a porous structure with a voxel size of 1 μm , you can set the bin size to 2 or to 4 (voxels) which would come to classify the solid by their diameter in ranges of 2 μm or 4 μm , and would result in the following bins:

Bin number (i)	Pore diameter between $[(i - 1) \cdot \text{bin size}] - [i \cdot \text{bin size}]$	
	Bin Size 2 μm	Bin Size 4 μm
1	0 μm - 2 μm	0 μm - 4 μm
2	2 μm - 4 μm	4 μm - 8 μm

Bin number (<i>i</i>)	Pore diameter between $[(i - 1) \cdot \text{bin size}] - [i \cdot \text{bin size}]$	
	Bin Size 2 μm	Bin Size 4 μm
3	4 μm - 6 μm	8 μm - 12 μm
..	...	...

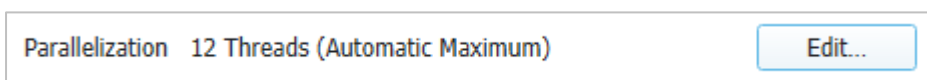
When choosing the bin size, be aware that the underlying algorithm to compute the Euclidean distance operates directly on the voxel grid. Thus, the smallest possible distance between two grid points is 1 voxel, which corresponds to a radius of 1 voxel. This means the smallest diameter that the algorithm will find is 2 voxels. In general, the error made when computing the solid size distribution is of the same order of magnitude as the discretization error of the structure, i.e., 1 voxel.

In the result viewer, for each bin the **Minimal Diameter**, which is the diameter of the smaller sphere, and the **Maximal Diameter**, which is the diameter of the larger sphere, are given. This means all solid voxels in that bin have a diameter that is larger than the minimal diameter and smaller or equal than the maximal diameter.

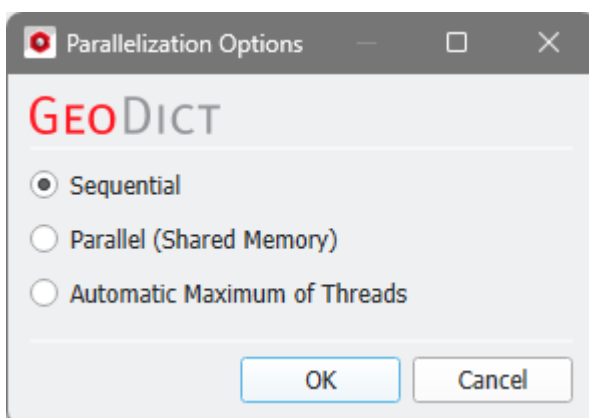
✓ Parallelization

Control how many threads are used for the computation. Parallelization is possible if your license and hardware allow it.

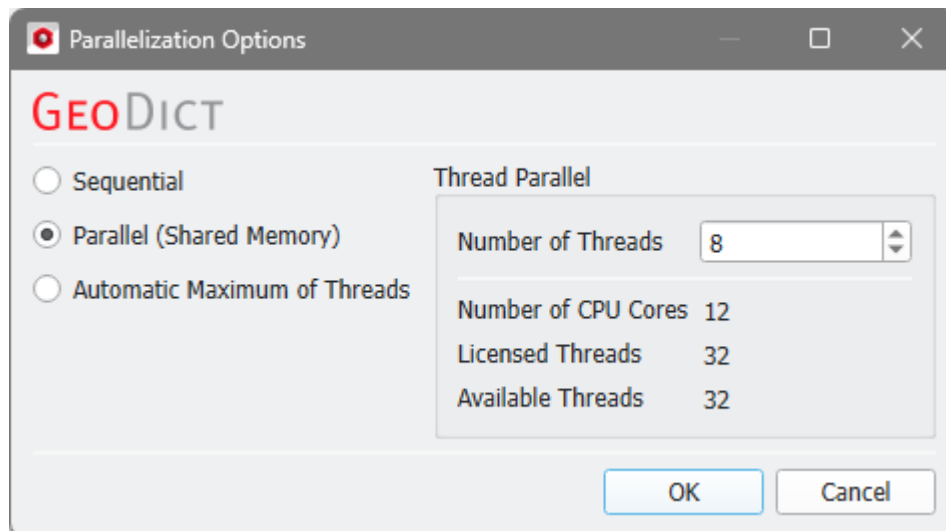
The **Parallelization Options** dialog opens when clicking the **Edit** button and you can choose between **Sequential**, **Parallel (Shared Memory)**, or **Automatic Maximum of Threads**.



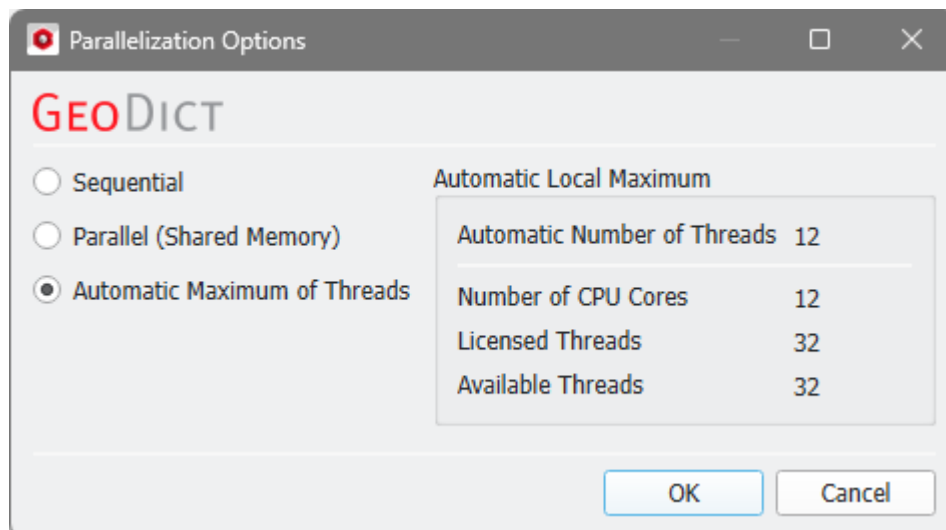
Selecting **Sequential** will not apply parallelization and only one thread is used for the computation.



When **Parallel (Shared Memory)** is selected, the **Number of Threads** can be entered. Below, the **Number of CPU Cores** that the current machine has, the maximum number of **Licensed Threads** and the number of those licensed threads that are available (**Available Threads**) are shown in the dialog. Of course, the maximal number of parallel processes you can use, is the smallest of those three numbers.



If **Automatic Maximum of Threads** is selected, the number of parallel processes is automatically selected for optimal speed, based on the CPU cores and licensed parallel processes.



The **Automatic Local Maximum** of processes is automatically selected, which is the minimum of **Number of CPU Cores**, **Licensed Threads**, and **Available Threads**.

✓ Domain Boundary Conditions

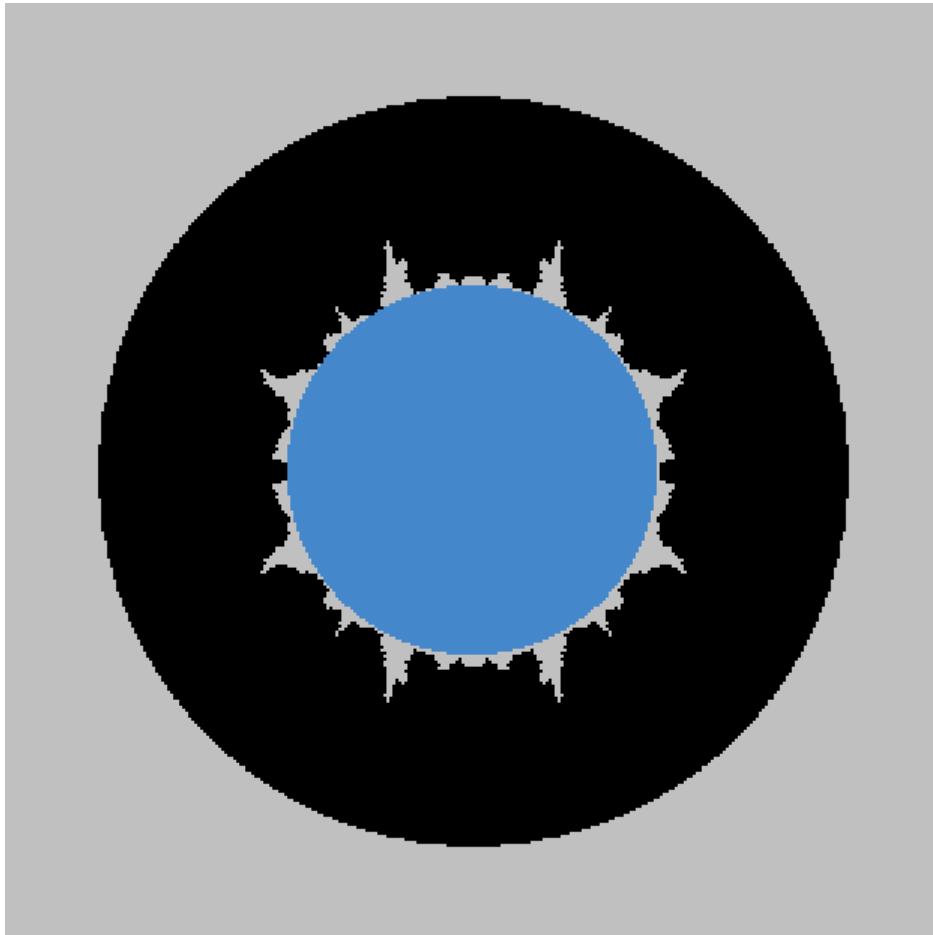
The **Domain Boundary Conditions** can be chosen to be **Symmetric**, **Periodic**, **Encase**, or any combinations of those boundary conditions in all three directions with the choice of **Expert**.

Choosing the appropriate boundary condition depends on the structure's design.
For example, imagine a structure with a cross-section as shown below.

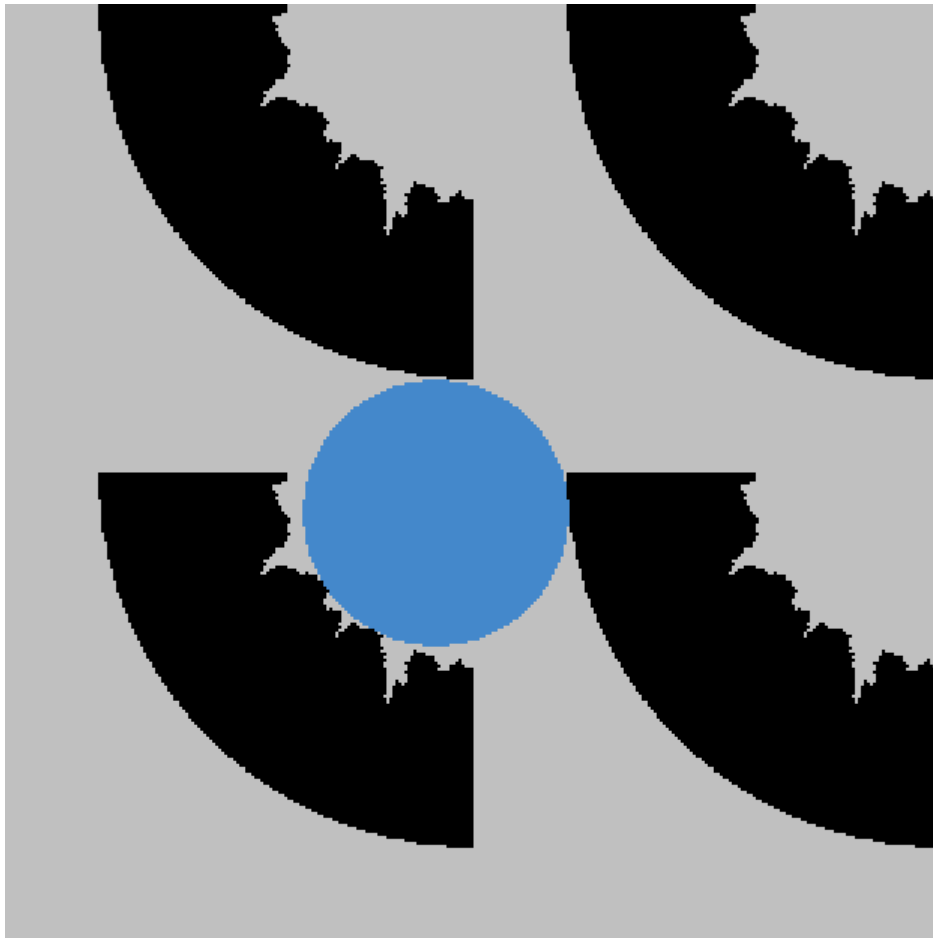


For the three boundary condition options the resulting solid size is visualized in blue.

- If **Symmetric** boundary conditions are taken, the geometry is mirrored at the domain boundary.



- If instead the expected pattern of the geometry is repeated in all directions, **Periodic** boundary conditions should be selected. That has the effect that the objects and pores of the structure that end on one side of the structure reappear on the opposite side.



- If the structure should be encased with a closed wall, the **Encase** boundary conditions are used.



Check **Expert** to apply different boundary conditions for each direction. You can combine the three above mentioned boundary conditions independently for the directions. For example, the boundary conditions could be chosen to be Encase in X-direction, Symmetric in the Y-direction and Periodic in Z-direction.

Domain Boundary Conditions

☐ Symmetric
☐ Periodic
☐ Encase
☒ Expert

Expert Settings

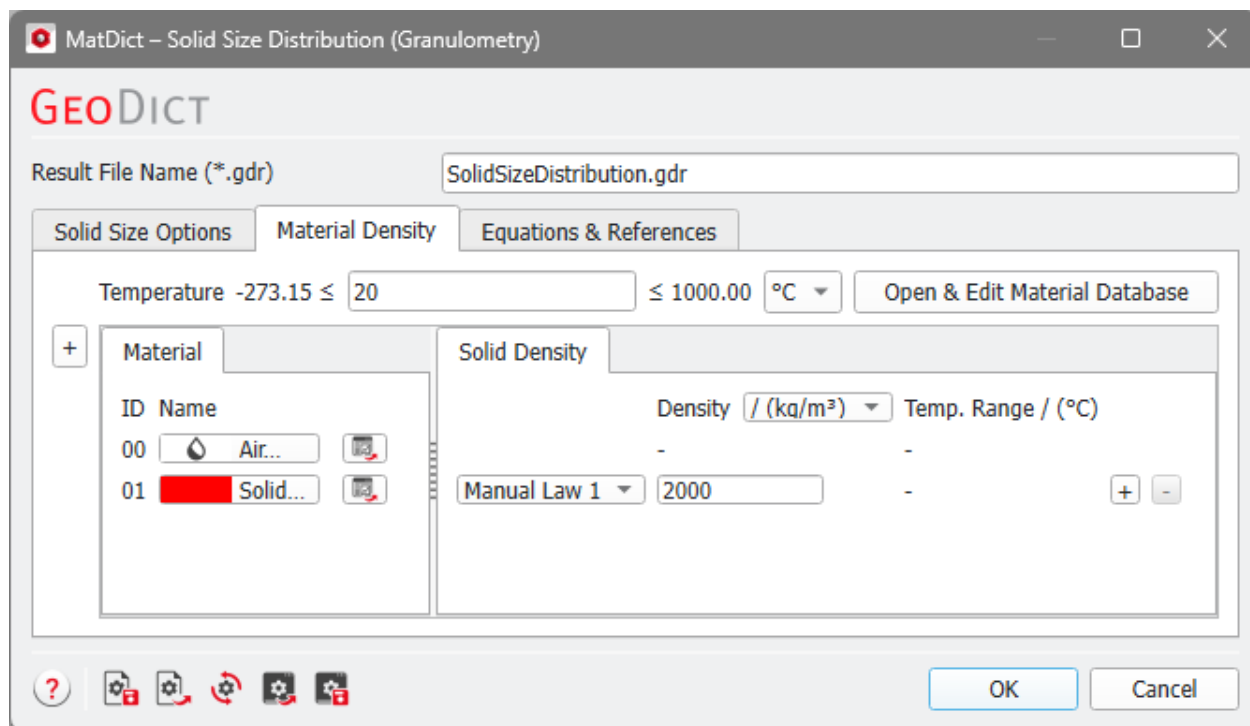
X
Encase
Y
Symmetric
Z
Periodic

✓ Write Solid Size Distribution as *.gsd File

When **Write Solid Size Distribution as *.gsd File** is checked, a file with the default name *SolidSizeDistribution.gsd*, in *.gsd (**GeoDict Size Distribution**) format, is saved in the results folder inside the project folder. The file contains the solid size (diameter of sphere) of each voxel written into a volume field that can be loaded in the [Solid Size Visualization tab](#)⁴⁷ of the Result Viewer.

Material Density

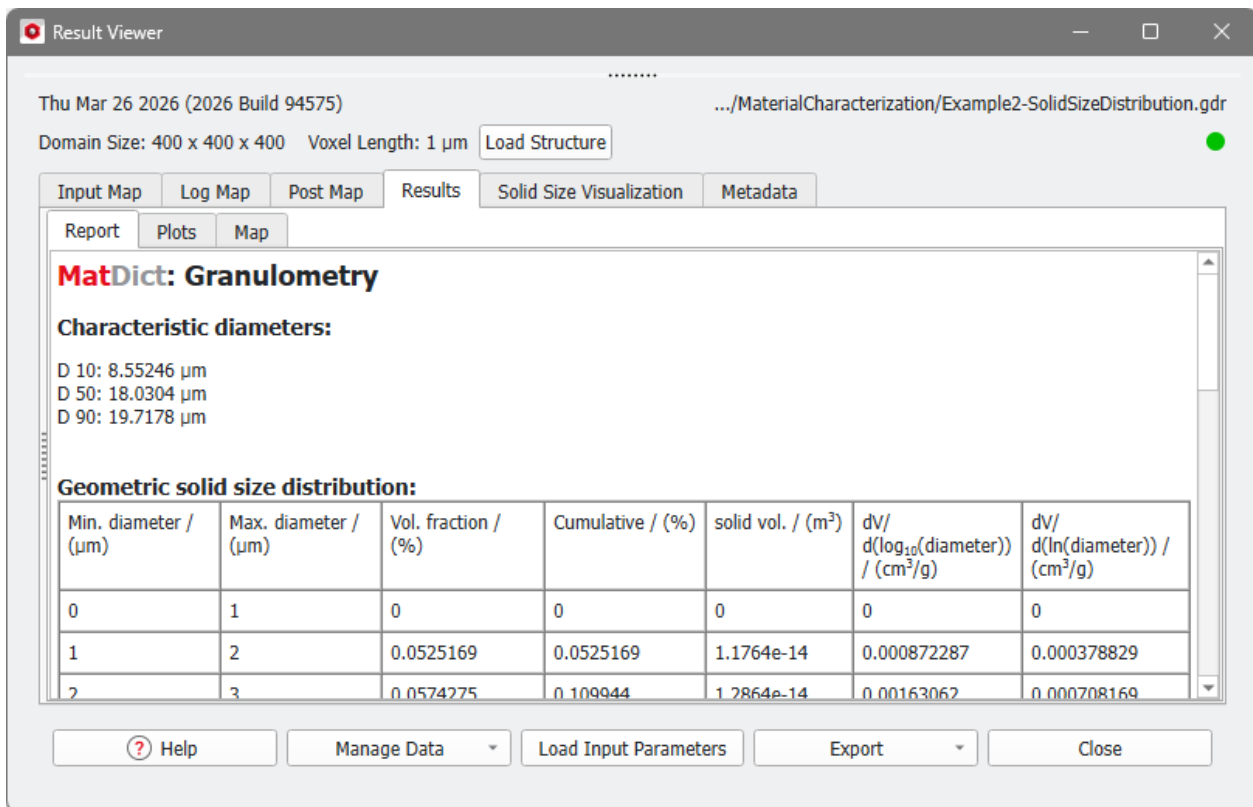
Under the **Material Density** tab, the temperature can be edited if the density of a material is temperature dependent. Additionally, the density of every solid material in the structure must be specified in this tab. The density can be given in kg/m³ or g/cm³. For materials from the GeoDict Material Database, the density value is entered automatically. If a material is set to **Manual**, the Material Law changes to **Manual Law** and more laws can be added or deleted by clicking the "+" or "-" button on the right of the corresponding row. You can enter the density for manual materials directly in this tab.



Results

After the **Solid Size Distribution** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains six tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Solid Size Visualization** tab. The other four tabs (**Input Map**, **Log Map**, **Post Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

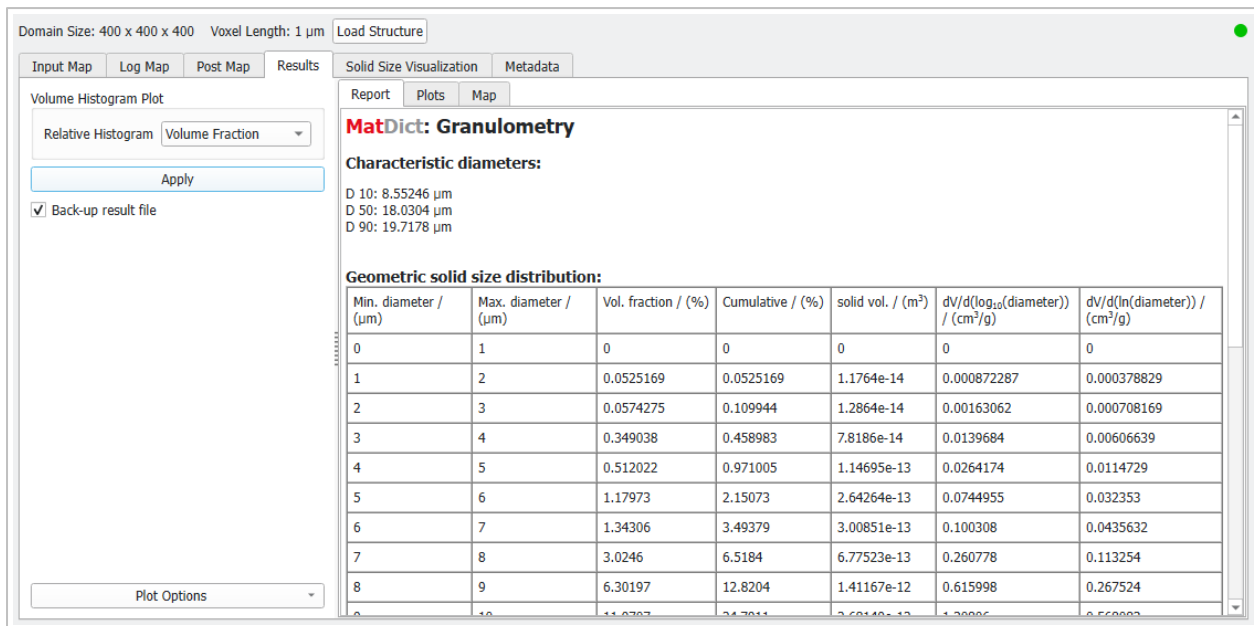


Solid Size Distribution Results:

- [Report](#)⁴⁴
Observe the computed results and plots.
- [Plots](#)⁴⁵
- [Solid Size Visualization](#)⁴⁷
Load results for a graphical visualization.

Report

Under the **Report** tab, the **Characteristic Diameters** D10, D50, and D90 are shown. These are the diameters such that 10%, 50%, or 90% of all solids have smaller diameter than the corresponding value. In this example, the D10 value of 8.55 μm means that 10% of all solids have a smaller diameter than 8.55 μm. The D50 value of 18.03 μm means that 50% of all solids have a diameter smaller than 18.03 μm, and the D90 value of 19.71 μm means that 90% of all solids have a diameter smaller than 19.71 μm. The discretization error is less than 1 voxel, which means for the presented example, that the D10 is 8.55 μm ± 1.0 μm.



Below the characteristic diameters, the **Geometric solid size distribution** table contains **Minimum** and **Maximum Diameters**, **Volume Fraction**, **Cumulative Volume Fraction**, the **Solid Volume**, and the **Differential Solid Volume Distribution** for every bin. Also, at the bottom of the Report tab, the total solid volume percentage of the structure is shown.

The **Volume Fraction** of the solid voxels in each bin and the **Cumulative Volume Fraction** (starting with the smallest solid diameters) based on the total solid volume of the structure are shown. For each bin, the **Solid Volume** in m^3 is computed as the summarized volume of the voxels that belong to this bin.

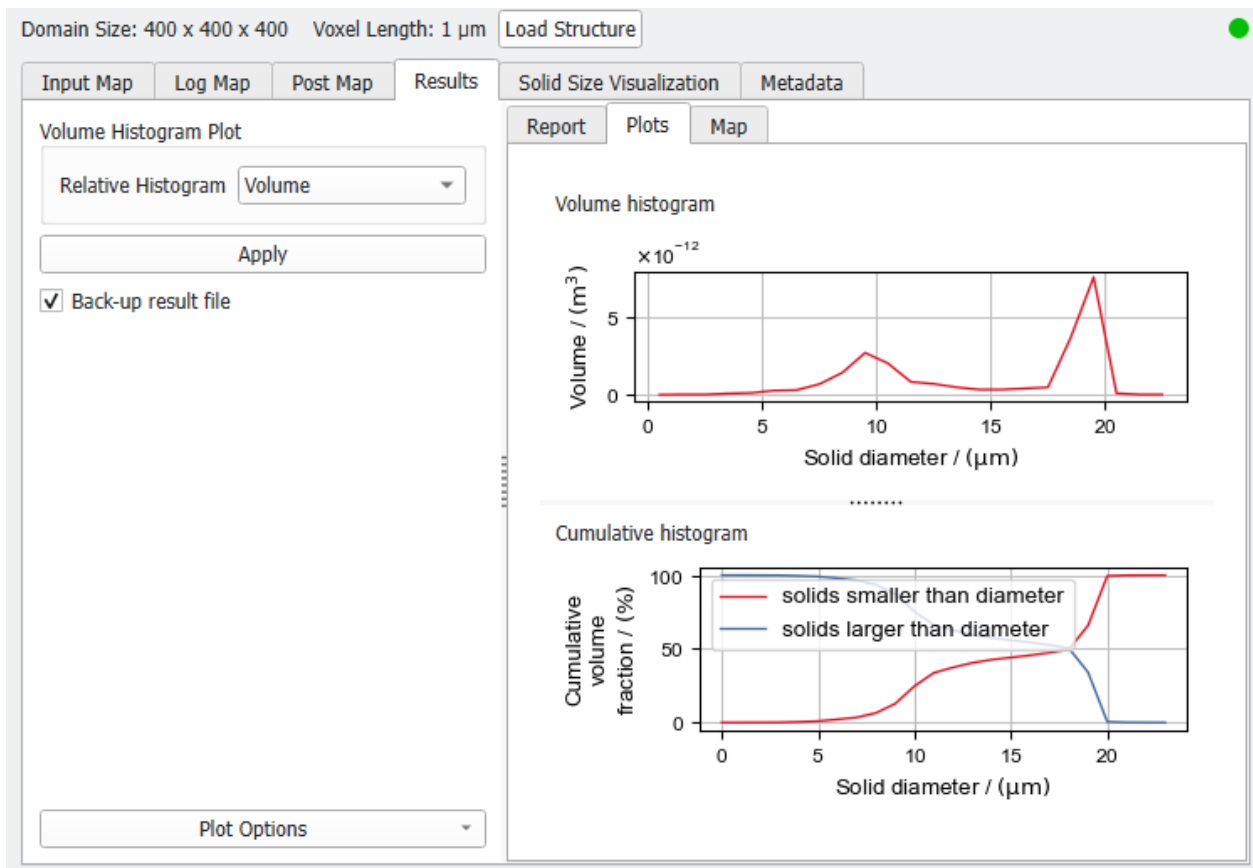
The **Differential Solid Volume** $dV/d(\log(\text{Diameter}))$ for each bin is computed, where both the common logarithm ($\log_{10}$) and the natural logarithm ($\ln$) are shown. The differential solid volume distribution is then computed as:

$$\frac{dV}{d(\log(\text{Diameter}))} = \frac{V_{cum}(d_{i+1}) - V_{cum}(d_i)}{(\log(d_{i+1}) - \log(d_i)) \cdot m} \quad (1) \text{ Differential Solid Volume}$$

with d_i the solid diameter of the i -th bin, V_{cum} the cumulative volume fractions, and m the mass of the solids. The latter is computed using the densities of the constituent materials of the sample entered in the Material Density tab. This normalization ensures that the value of the differential solid volume is independent of the domain size.

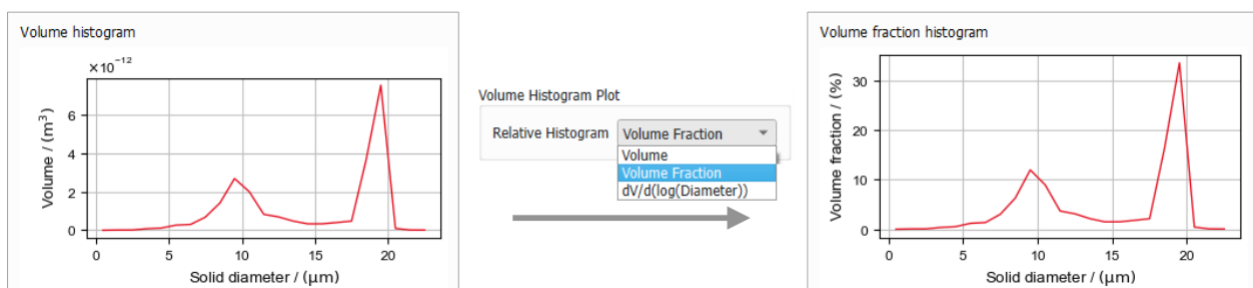
Plots

Under the **Results – Plots** subtab, a relative and a cumulative histogram is plotted.



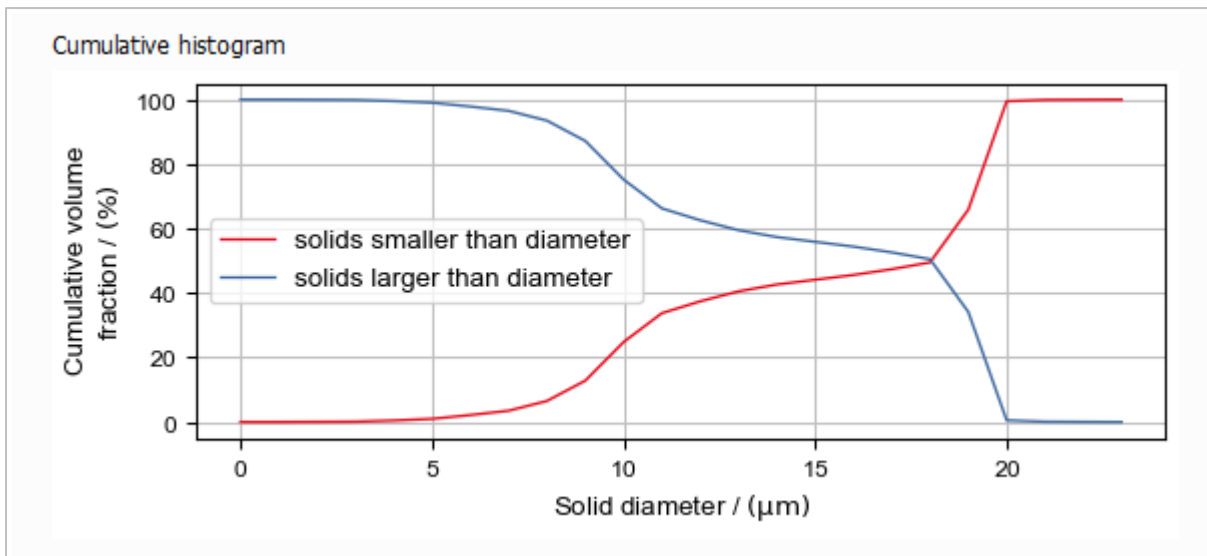
Relative Solid Size Histogram

The content of the relative histogram is defined by the selection in the **Volume Histogram Plot** section of the Post-Processing panel on the left of the Result Viewer. The solid diameter is plotted either against the Volume, Volume Fraction, or the differential pore volume ($dV/d(\log(\text{Diameter}))$). After choosing the histogram and clicking **Apply...**, the plots change accordingly.



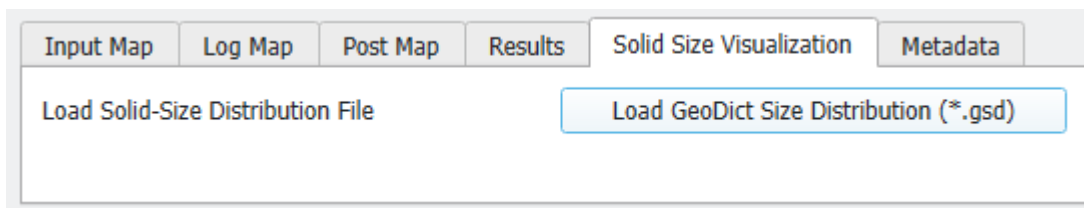
Cumulative Solid Size Histogram

In the **Cumulative Histogram** plot, the red curve shows the volume fraction of solids smaller than a given diameter and the blue curve shows the volume fraction of solids larger than or equal to a given diameter. Both curves sum up to 100% for any given diameter.



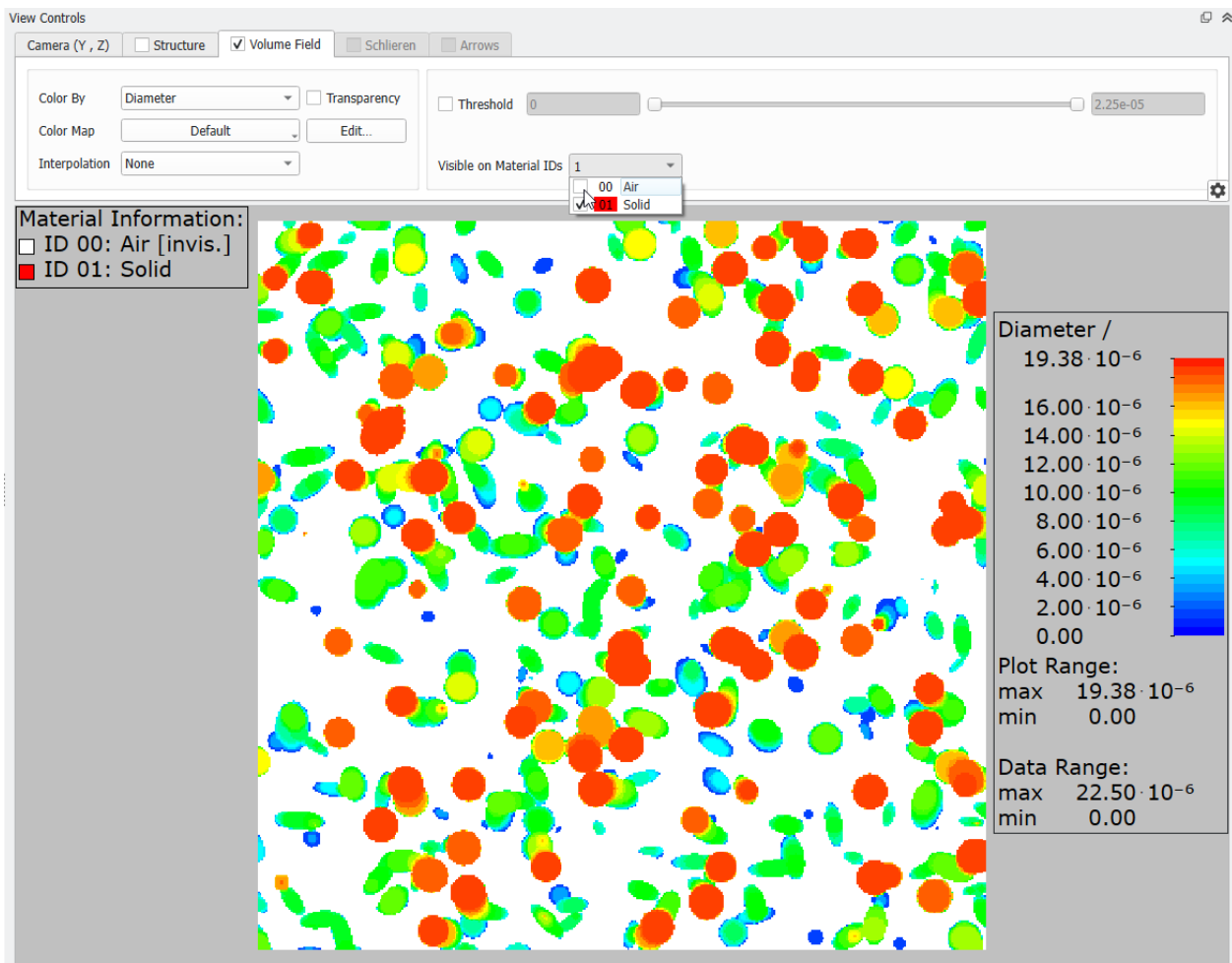
Solid Size Visualization

The size distribution of solids can also be visualized through the **Solid Size Visualization** tab. When **Write Solid Size Distribution as *.gsd File** was checked before running the command, it is possible to visualize the size distribution by clicking **Load GeoDict Size Distribution (*.gsd)**.



The value at each voxel is the diameter of the largest sphere, that contains this voxel and fits inside the solid object. Thus, the diameter for the pores is zero.

To see the solid size distribution inside of the structure, we recommend to deactivate the visualization of the structure itself. This can be done by unchecking **Structure** in the tab headers or alternatively in the **View** settings. Additionally, the visualization of the result field in the pore space (where the value is always zero) can be deactivated by unchecking all pore materials with the option **Visible on Material IDs** under the **Volume Field** tab.

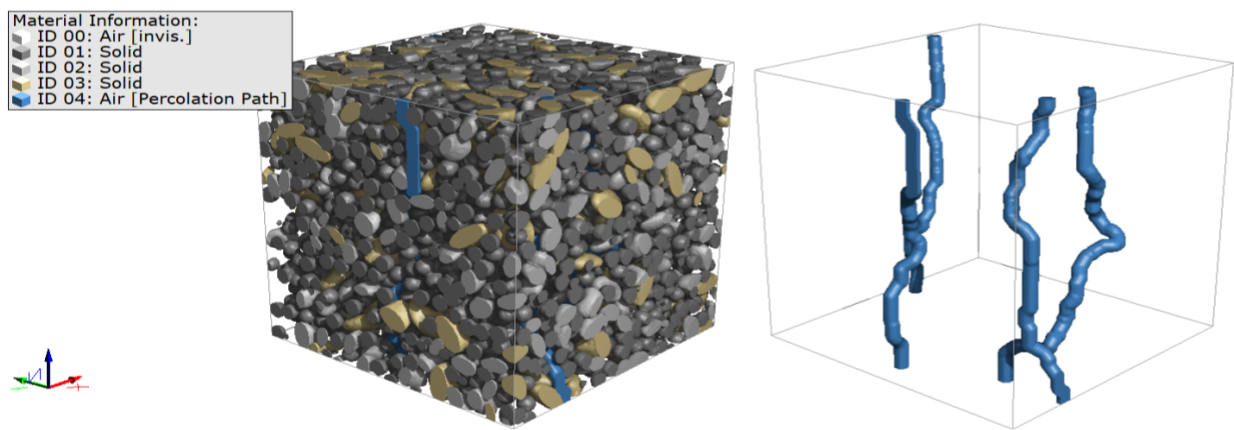


1.2.2 Percolation Path

The **Percolation Path** command is accessible from MatDict and PoroDict.

It determines the maximal diameters of spherical particles that can move through the medium. Two voxels of a percolation path are connected if they share a common face. In addition, the shortest paths of the largest particles are calculated and displayed. Also, the shortest path of a given sphere size through the medium can be computed when changing the Diameter Mode. Find more details about the theory behind the **Percolation Path** algorithm in the Theoretical Basics section of the PoroDict user guide.

The **Percolation Path** dialog opens when clicking the **Edit...** button.



On the left, the four largest percolation paths found in a grainy structure are shown. The analytic geometries of the paths are shown on the right.

The Percolation Path command:

- [Options](#)⁴⁹
Set the parameters for the analysis.
- [Results](#)⁵⁶
View the computed results.

Options

At the top of the dialog, enter the **Result File Name**. The result files are saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).

MatDict – Percolation Path

GEO DICT

μm

Result File Name (*.gdr) PercolationPath.gdr

Computational Direction Z-direction

Material to Analyze

Pore Space

Number of Paths 1

Domain Boundary Conditions

☒ Symmetric ☐ Periodic ☐ Encase ☐ Expert

☐ Search Periodic Path

Diameter Mode Maximum Diameter

Maximum Diameter / (μm) 0

☐ High Resolution

☐ Save Center-Line

☐ Optimize Path

(Pore/Fluid Material IDs: 00)

? [Icons] OK Cancel

✓ Computational Direction

Set the direction of the paths by selecting the **Computational Direction**.

Computational Direction

Z-direction

X-direction

Y-direction

Z-direction

✓ Material to Analyze

The algorithm searches for paths in the selected **Material to Analyze**, either **Pore Space**, **All Solid Materials**, **Chosen Material**, or a list of **Chosen Material IDs**.

Material to Analyze

Pore Space
Pore Space
All Solid Materials
Chosen Material
Chosen Material IDs

Material to Analyze

Chosen Material IDs

1

	00	Air
☒	01	Solid

For your convenience, all Material IDs which denote pore space are shown at the bottom of the dialog.

✓ Number of Paths

The number of percolation paths to be detected is set with the **Number of Paths** parameter. Then, the algorithm computes the n best percolation paths.

✓ Domain Boundary Conditions

The diameters of pores and solids near the domain boundary are strongly influenced by the selected **Domain Boundary Conditions**. The boundary condition in the chosen computational direction is always set to symmetric, for the tangential boundaries you are free to choose other boundary conditions.

The **Domain Boundary Conditions** can be chosen to be **Symmetric, Periodic, Encase**, or any combinations of those boundary conditions in all three directions with the choice of **Expert**.

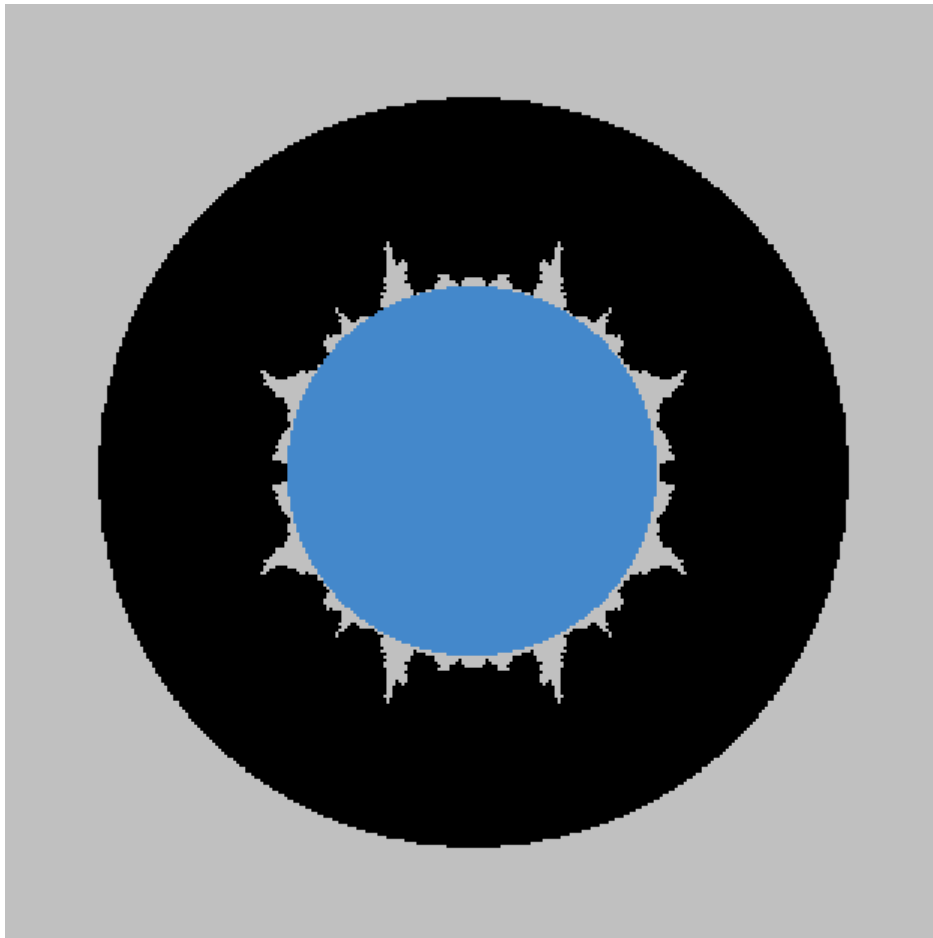
Choosing the appropriate boundary condition depends on the structure's design.

For example, imagine a structure with a cross-section as shown below.

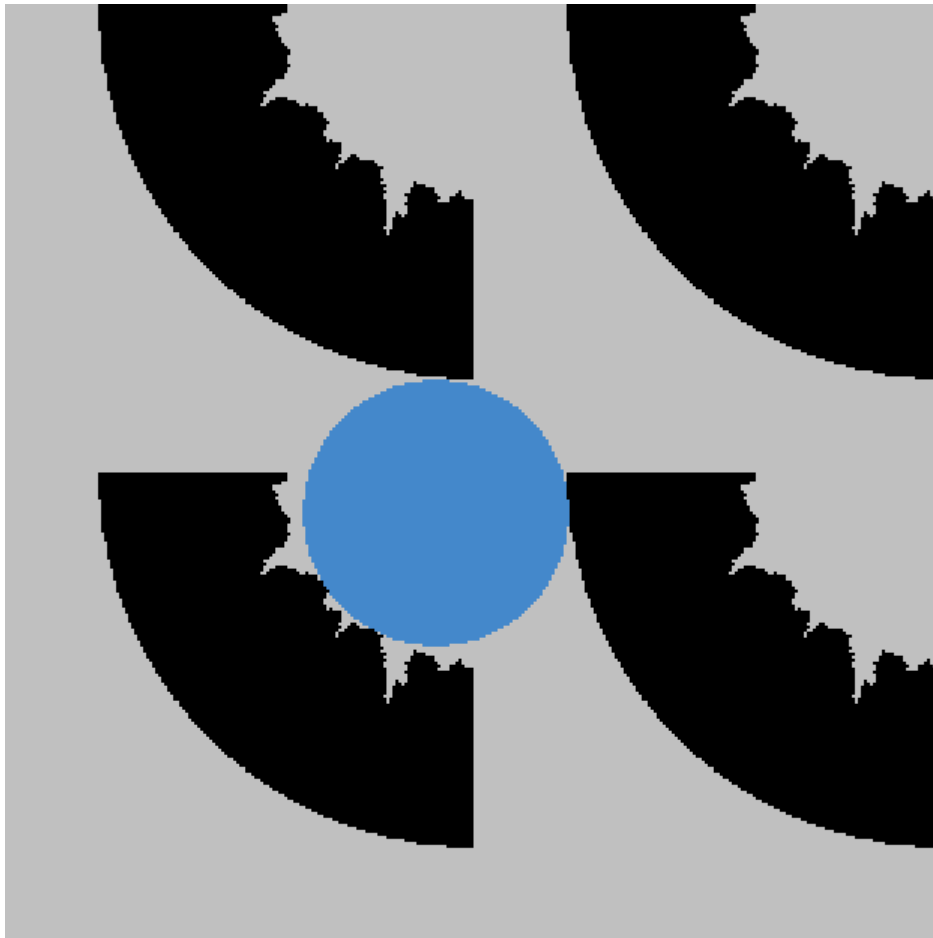


For the three boundary condition options the resulting solid size is visualized in blue.

- If **Symmetric** boundary conditions are taken, the geometry is mirrored at the domain boundary.



- If instead the expected pattern of the geometry is repeated in all directions, **Periodic** boundary conditions should be selected. That has the effect that the objects and pores of the structure that end on one side of the structure reappear on the opposite side.



- If the structure should be encased with a closed wall, the **Encase** boundary conditions are used.



Check **Expert** to apply different boundary conditions for each direction. You can combine the three above mentioned boundary conditions independently for the directions. For example, the boundary conditions could be chosen to be Encase in X-direction, Symmetric in the Y-direction and Periodic in Z-direction.

Domain Boundary Conditions

☐ Symmetric
☐ Periodic
☐ Encase
☒ Expert

Expert Settings

X Y Z

✓ Search Periodic Path

Search Periodic Path is only available for periodic boundary conditions. If checked, the Percolation Path is allowed to cross lateral periodic boundaries. Using this option increases the computation time. A periodic percolation path is not necessarily periodic in the computation direction.

✓ Diameter Mode

From the **Diameter Mode** pull-down menu, choose to detect percolation paths with the **Maximum Diameter** possible or **Specify Maximum Diameter** and enter a **Maximum Diameter** value below.

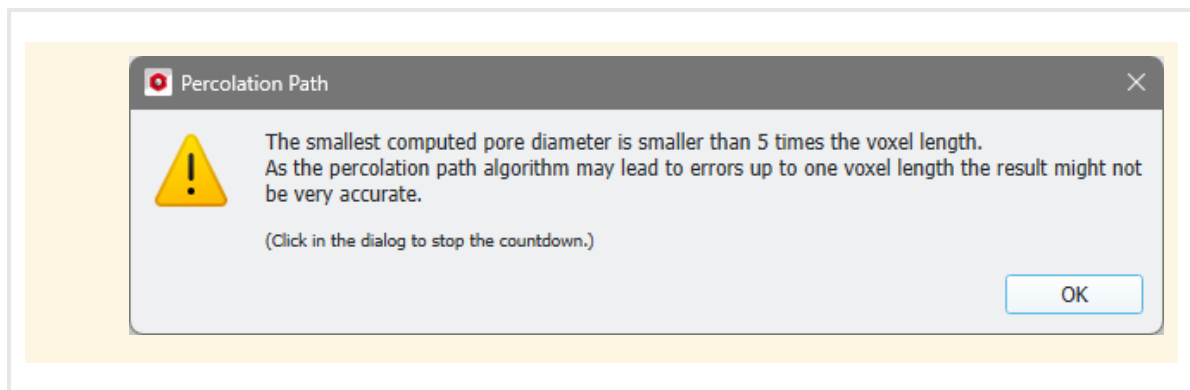
Diameter Mode	Maximum Diameter	Diameter Mode	Specify Maximum Diameter
Maximum Diameter / (μm)	0	Maximum Diameter / (μm)	5

✓ High Resolution

To run the calculations in **High Resolution** might be useful when the path space is expected to be narrow. The standard algorithm computes distances directly on the voxel grid, i.e., when determining a pore size, only the distances from the center of a pore voxel to the center of a solid voxel are taken into account. High Resolution also takes the voxel surfaces and edges into account, so the computed distances correspond to the distance to the next surface or edge. The disadvantage of the **High Resolution** mode is that the calculation runtime and memory usage may increase by a factor of eight.



Know how! If the largest computed path is smaller than five times the voxel length, and the simulation was run in the standard mode, a warning message is shown. In this case, it is recommended to re-run the simulation in **High Resolution** mode.



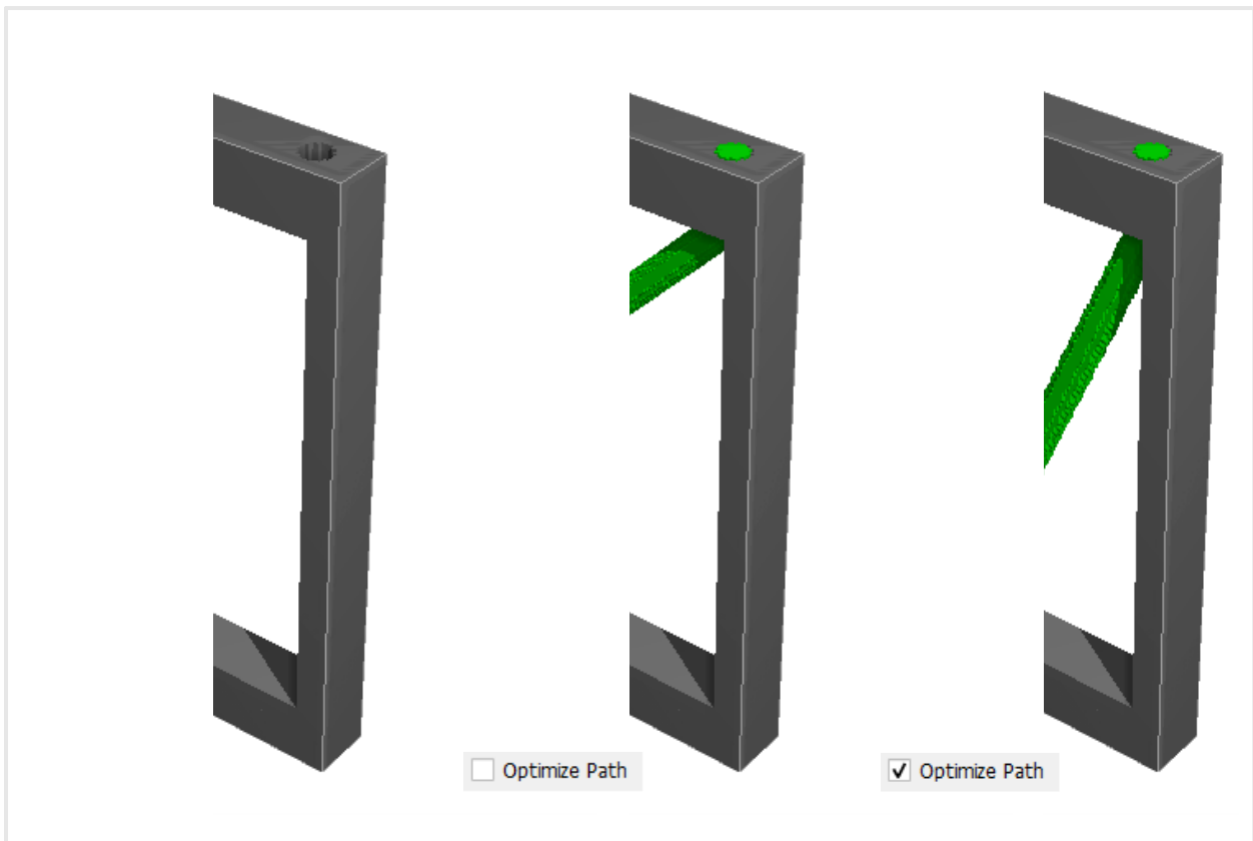
✓ Save Center-Line

When **Save Center-Line** is checked, the results folder additionally contains *.gdt files with the centerline of each computed percolation path.

- CenterlineParticle1.gdt
- CenterlineParticle2.gdt
- CenterlineParticle3.gdt
- CenterlineParticle4.gdt

✓ Optimize Path

With Optimize Path, the length of the path is optimized after the calculation. This shortens the calculated path by removing voxel staircase artifacts: The algorithm works on the voxel structure and can therefore only find paths which run directly through connected voxels. Therefore, the default method might not always find the best path in structures with large open pores. In these cases, it is recommended to select Optimize Path (see the examples below).



Results

After the **Percolation Path** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains five tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Data Visualization** tab. The other three tabs (**Input Map**, **Log Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

The **Results - Report** subtab shows for all found paths the **Maximum particle diameter** (in μm and **Voxel**) of spherical particles which may pass through the medium, as well as the **Path length** (in μm and **Voxel**) of the detected percolation path(s).

Input Map	Log Map	Results	Data Visualization	Metadata
Report Map				
Particle paths				
Path no	Maximum particle diameter / (μm)	Maximum particle diameter / (Voxel)	Path length / (μm)	Path length / (Voxel)
1	3.2	8	117.067	292.667
2	2.88444	7.2111	95.7205	239.301
3	2.88444	7.2111	96.6421	241.605
4	2.88444	7.2111	97.4232	243.558

Percolation Path Results:

- [Data Visualization](#)⁵⁷
Load results for a graphical visualization.

Data Visualization

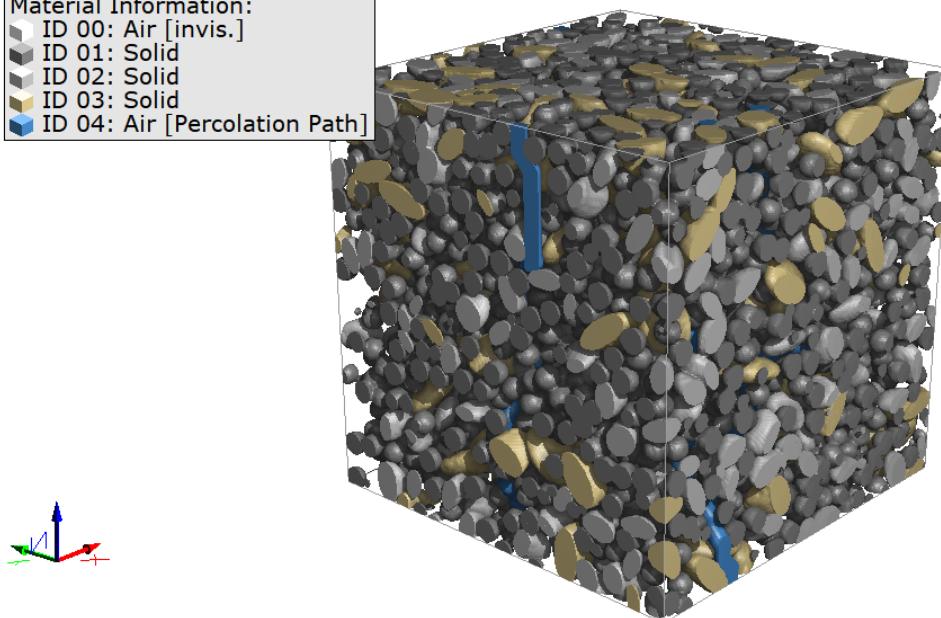
Under the **Data Visualization** tab up to four result files can be loaded for visualization.

Input Map	Log Map	Results	Data Visualization	Metadata
Voxel Geometry with Percolation Path(s)			Load *.gdt	
Analytic Percolation Path(s) Geometry			Load *.gad	
Center Line Geometry			Load *.gdt	
Percolation Path(s) Trajectories			Load Particles	

✓ Percolation Path with Structure

To show the **Voxel Geometry with Percolation Path(s)** click the corresponding **Load *.gdt** button. Only the voxel geometry is saved in this file, i.e., any analytic information that was present in the original structure is lost in this representation.

Material Information:
ID 00: Air [invis.]
ID 01: Solid
ID 02: Solid
ID 03: Solid
ID 04: Air [Percolation Path]

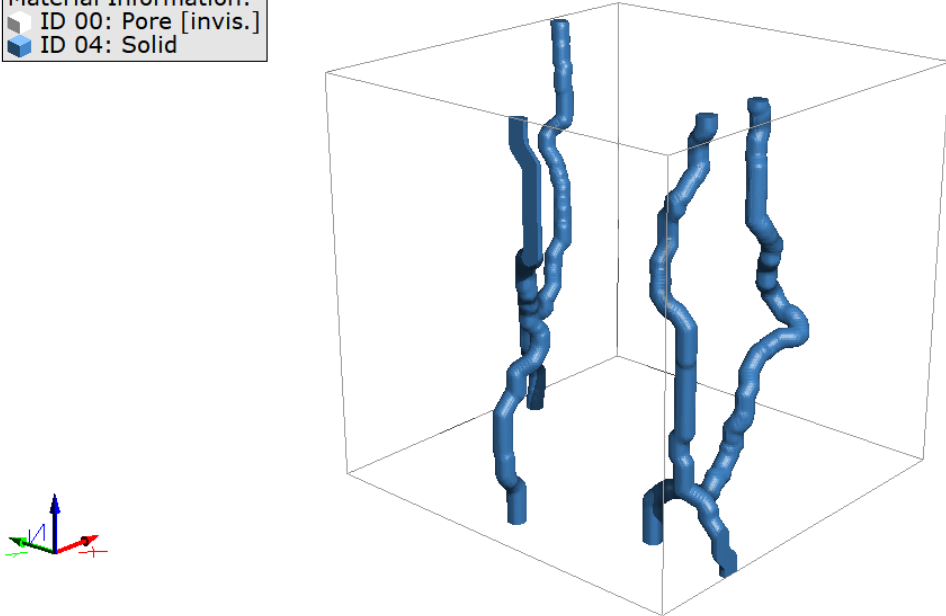


✓ Percolation Path without Structure

The **Analytic Percolation Path(s) Geometry** can be loaded by clicking the **Load *.gad** button and shows only the percolation path(s) without the structure. Each path is saved

as GAD object and is represented by a curved circular fiber.

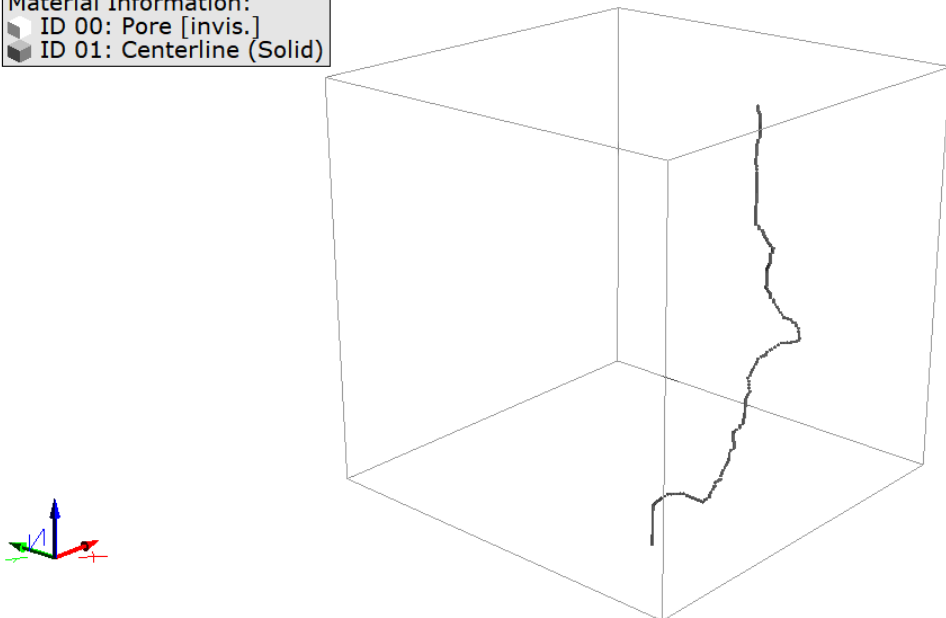
Material Information:
 ID 00: Pore [invis.]
 ID 04: Solid



✓ Center Line Geometry

The option **Center Line Geometry** is only available if **Save Center-Line** was selected before running the computation. It loads a structure file that contains the center line of the path with the largest diameter.

Material Information:
 ID 00: Pore [invis.]
 ID 01: Centerline (Solid)



✓ Particles and Trajectories

The **Percolation Path(s) Trajectories** can also be visualized with animated spheres

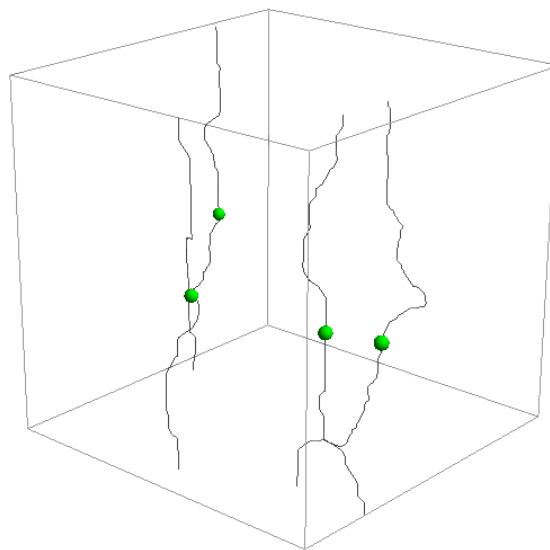
moving through the structure. For this, click **Load Particles**. Deactivate the structure visualization by unchecking the **Structure** tab in the Visualization panel, above the Visualization area, or set all Material IDs to **invisible**.



Note! Check the Visualization user guide for options to best visualize particles and their trajectories.

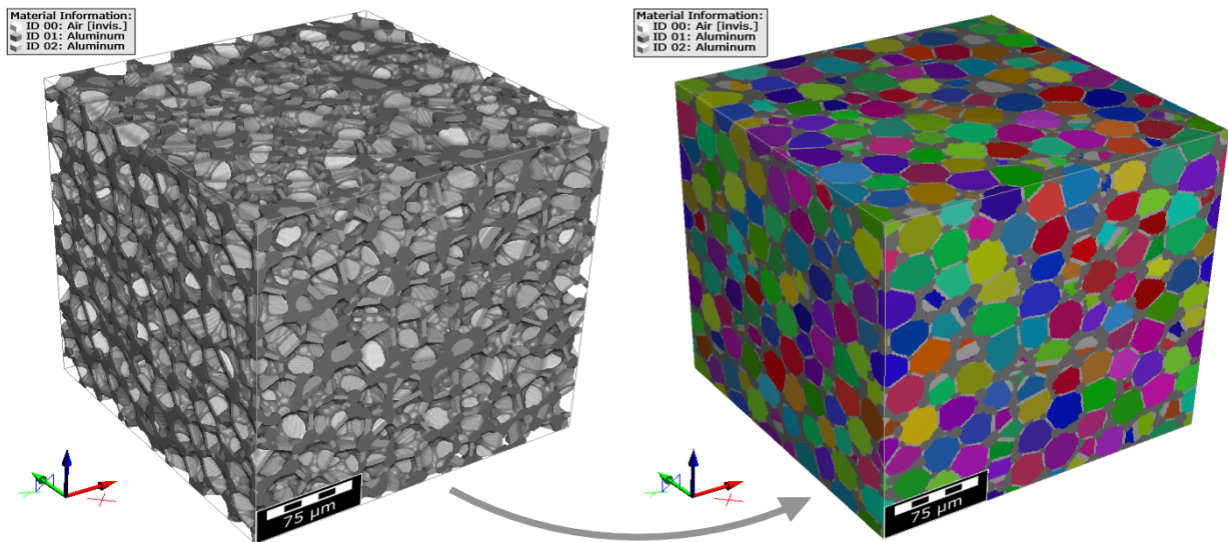
In this example, you can observe four spheres (here green) and their trajectories, corresponding to the four percolation paths, along which they move through the volume.

Material Information:	
	ID 00: Air [invis.]
	ID 01: Solid [invis.]
	ID 02: Solid [invis.]
	ID 03: Solid [invis.]



1.2.3 Connected Components

The solid fraction of a porous medium is not necessarily a homogeneous medium but can be composed of individual components that (all together) form the solid. Neighborhood relations between voxels inside a component differ from those among different components and between component and pore. The **Connected Components** command analyzes the voxel-to-voxel relations of the solid material and computes the components that build up the solid fraction. A connected component consists of all voxels that are in contact with each other, and which belong to the same phase, the same material, or the same Material ID. Results of the method include the number of defined components (material and background), mean number of components per 2D slice in each spatial direction, and their size with respect to volume visualized as a histogram.



Analyze Connected Components of a foam structure. The individual foam cells form single connected components.

The Connected Components command:

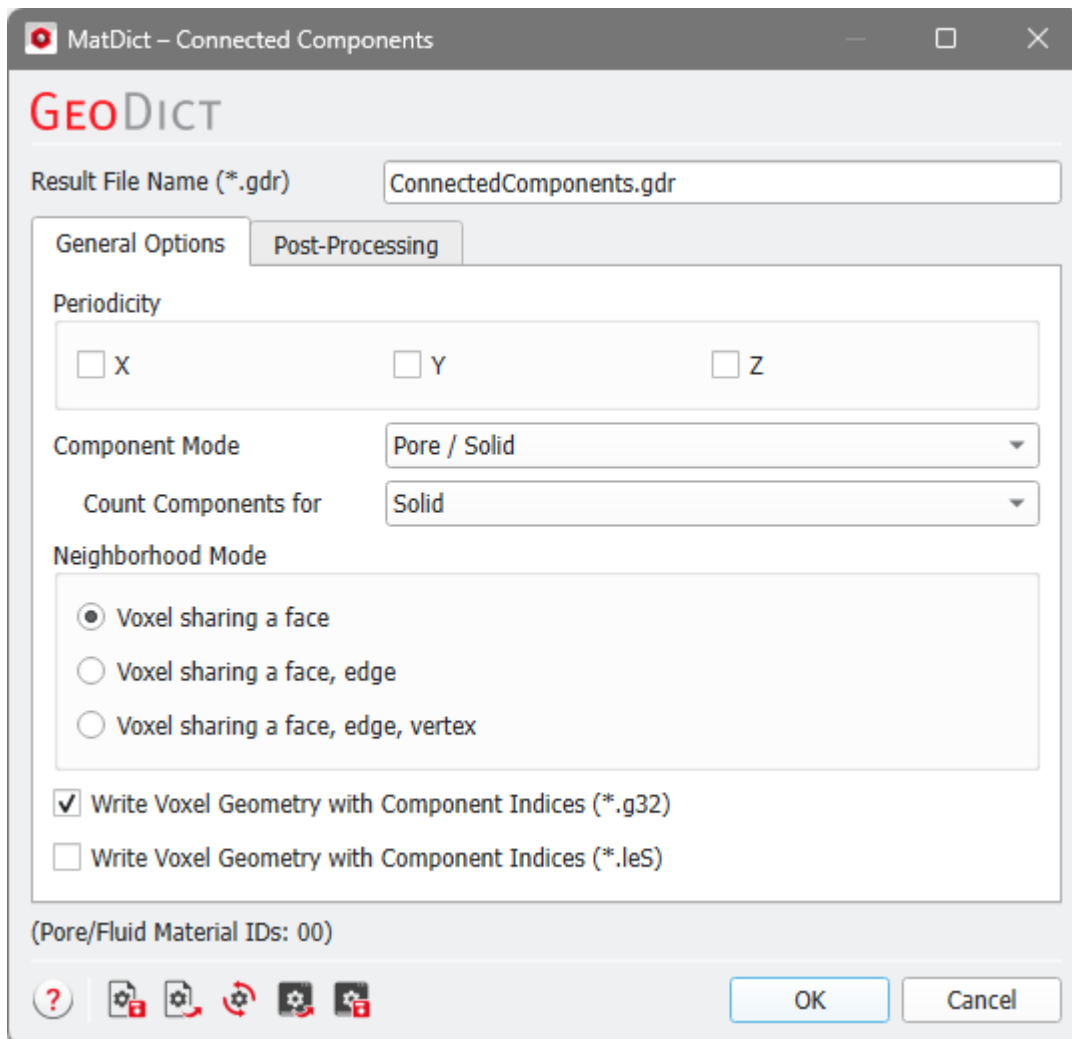
- [Options](#) ⁶⁰
Set the parameters for the analysis.
- [Results](#) ⁶⁴
View the computed results.

Options

The **Connected Components** dialog opens when clicking the **Edit...** button and includes the **General Options** and the **Post-Processing** tabs.

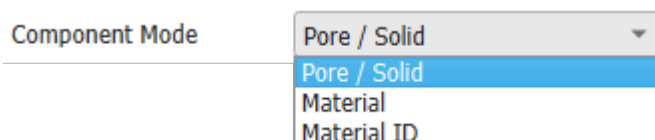
At the top of the dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).

General Options

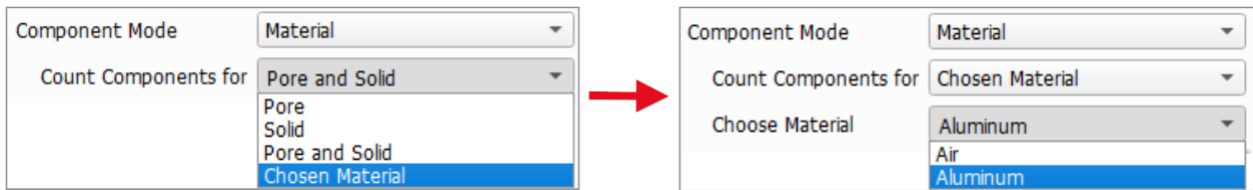


In the **Periodicity** panel, periodic boundaries can be set in the three spatial directions. If a box is checked, every voxel located on the corresponding boundary of the domain is connected to a voxel on the opposite side of the domain. Thus, components can be connected across the domain boundary. If a box is not checked, no connections exist across the domain boundary.

If the **Component Mode** is set to **Material ID**, all voxels belonging to one component must have the same Material ID. If it is set to **Material**, all voxels belonging to one component must belong to the same material. If it is set to **Pore / Solid**, the distinction happens only between solid or pore voxels. Thus, in the Pore / Solid mode, voxels with different Material IDs may form one component. For your convenience, all Material IDs which denote pore space are shown at the bottom of the dialog.

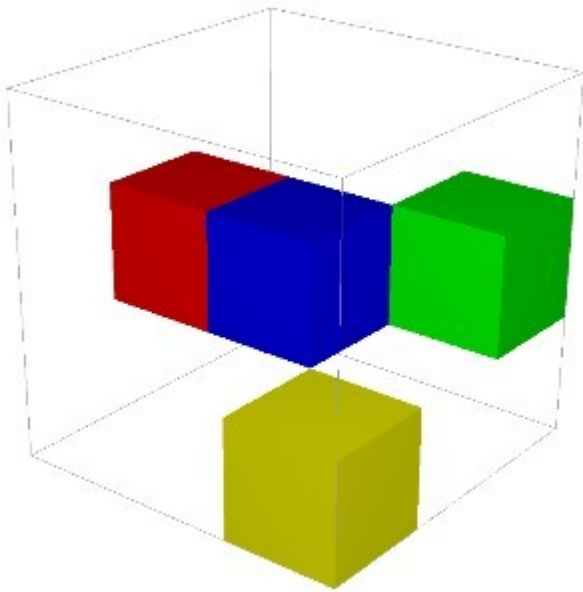


While the **Component Mode** defines which parts may belong to one component, with **Count Components for** you can set what is counted and reported. Always available are **Pore**, **Solid**, and **Pore and Solid**. The additional options depend on the selected **Component Mode**, so it is possible to count components only for a **Chosen Material** or for **Chosen Material IDs**.



The **Neighborhood Mode** defines if two voxels are connected (and belong, depending on the component mode, to the same connected component) or not. Voxels can be connected through faces, edges, and corners (vertices).

The different **Neighborhood Modes** are explained using this example.



Two voxels can be connected through faces, edges, and vertices (corners). Voxels that share a face, do also share edges and corners, as you can observe for the red and the blue voxel. The blue and the green voxel share an edge and the corner points of this edge. Finally, the blue and the yellow voxel share only one vertex (corner point).

Thus, checking **Face** is more restrictive than choosing **Face or Edge**, and this is more limiting than selecting **Face, Edge, or Vertex**.

When choosing the Neighborhood Mode **Face** only the red and the blue voxel are connected.

When choosing **Face or Edge** the red and the blue voxel and the blue and the green voxel are connected.

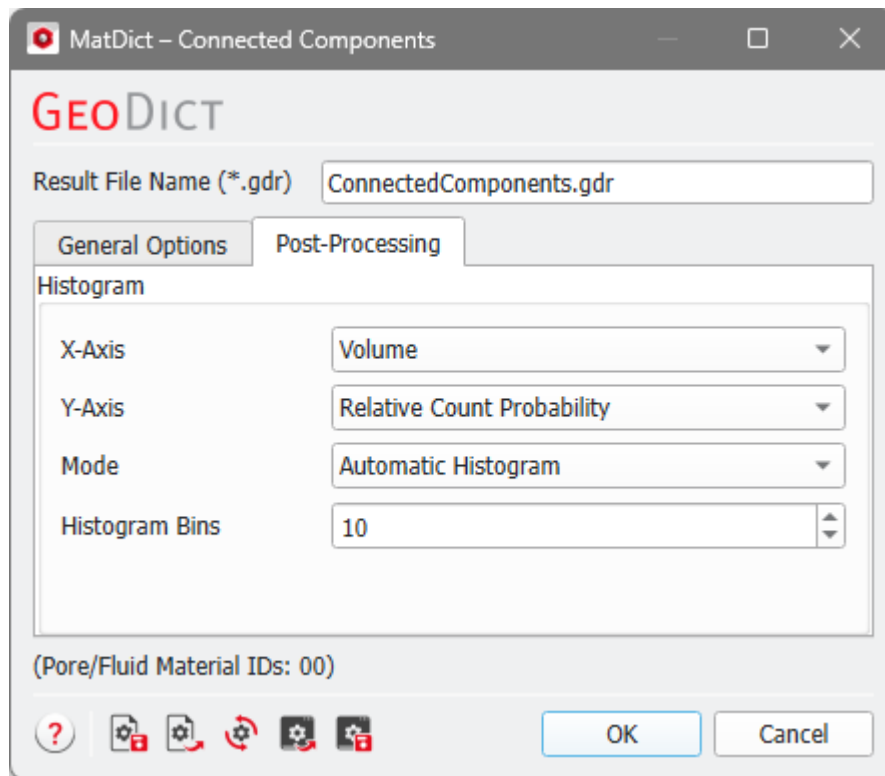
Finally, if **Face, Edge, or Vertex** is chosen, the red and the blue voxel, the blue and the green voxel and the blue and the yellow voxel are connected.

When checking **Write Voxel Geometry with Component Indices (*.g32)**, the indices of the connected components are saved as objects in a .g32 file. This file can be opened in the [Data Visualization](#) ⁶⁸ tab in the Result Viewer.

When checking **Write Voxel Geometry with Component Indices (*.leS)**, the object indices are stored in an *.leS ASCII file, which can also be opened in the [Data Visualization](#) ⁶⁸ tab. This file is human readable, but will be considerably larger and slower to read into GeoDict than

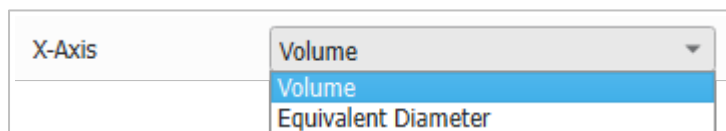
the *.g32 file. Therefore, if you need the index file for further processing in GeoDict, we recommended to use the *.g32 format.

Post-Processing



Under the Post-Processing tab, the settings used to create the histogram of the analyzed components are defined. It is possible to modify those settings after the computation has been run in the [Result Viewer](#)⁶⁵.

The **X-Axis** pull-down menu allows choosing whether the components should be classified based on volume (**Volume**) or based on volume equivalent sphere diameter (**Equivalent Diameter**).



For the **Y-Axis** pull-down menu, the **Relative Count Probability** provides the number of components in each bin normalized to the total number of components. The **Cumulative Count Probability** is the sum of the Relative Count Probability over all bins starting from the bin with the smallest value. **Relative Volume Probability** gives the volume of the components within one bin normalized to the total volume of all components. The **Cumulative Volume Probability** sums up the Relative Volume Probability of each bin of the histogram starting from the smallest one.

Y-Axis	Relative Count Probability Relative Count Probability Cumulative Count Probability Relative Volume Probability Cumulative Volume Probability
--------	---

The histogram **Mode** offers the choice between generating an **Automatic Histogram** without further specifications or to **Give Min. and Max Value** for the parameter defined in the X-Axis pull-down menu (Volume or Equivalent Diameter).

Mode	Automatic Histogram Automatic Histogram Give Min. and Max. Value
------	---

In the latter case, either **Min. Volume** and **Max. Volume** or **Min. Diameter** and **Max. Diameter** (depending on the choice for X-Axis) can be directly entered here.

Mode	Give Min. and Max. Value
Min. Volume / (m ³)	4.21875e-19
Max. Volume / (m ³)	3.15435937e-15

The number of **Histogram Bins** determines the number of rows in the **Enter value** table and the number of bars in the plot.

Histogram Bins	10
----------------	----

Results

After the **Connected Components** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains six tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Data Visualization** tab. The other four tabs (**Input Map**, **Log Map**, **Post Map**, and **Metadata**) display additional information about the computation.

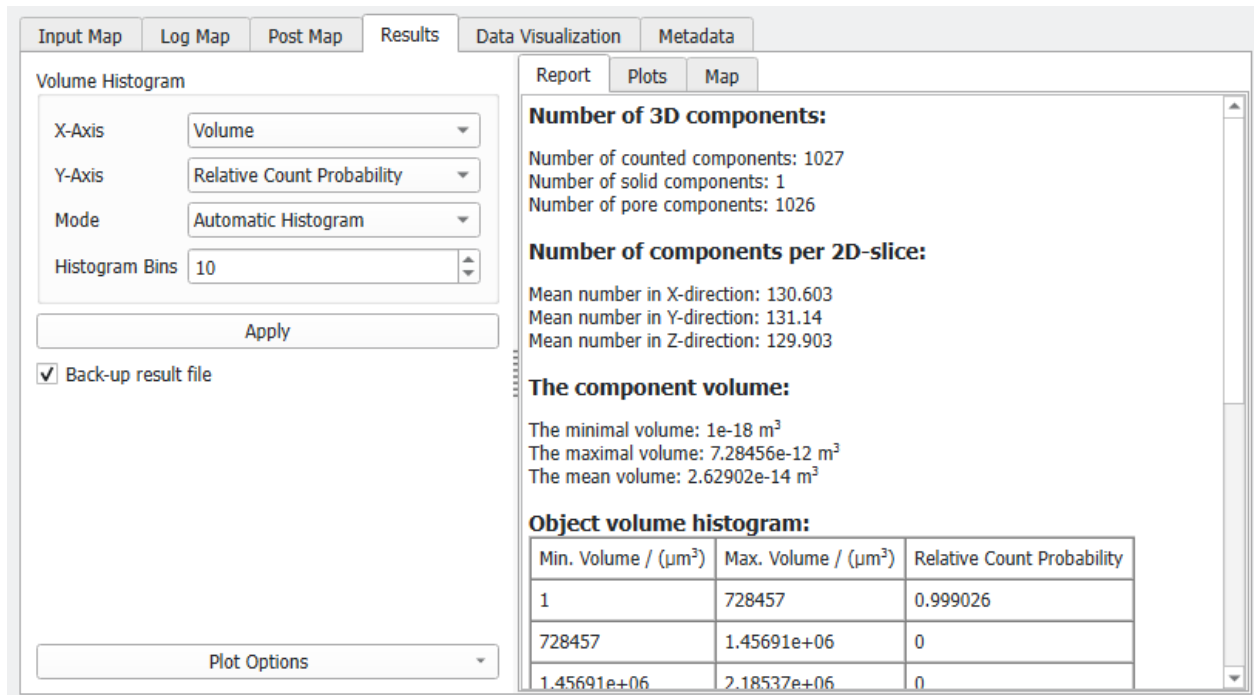
Find more details on the general functionalities in the Result Viewer user guide.

Connected Components Results:

- [Results Tab](#)⁶⁵
Observe the computed results and plots.
- [Data Visualization](#)⁶⁸
Load results for a graphical visualization.

Results Tab

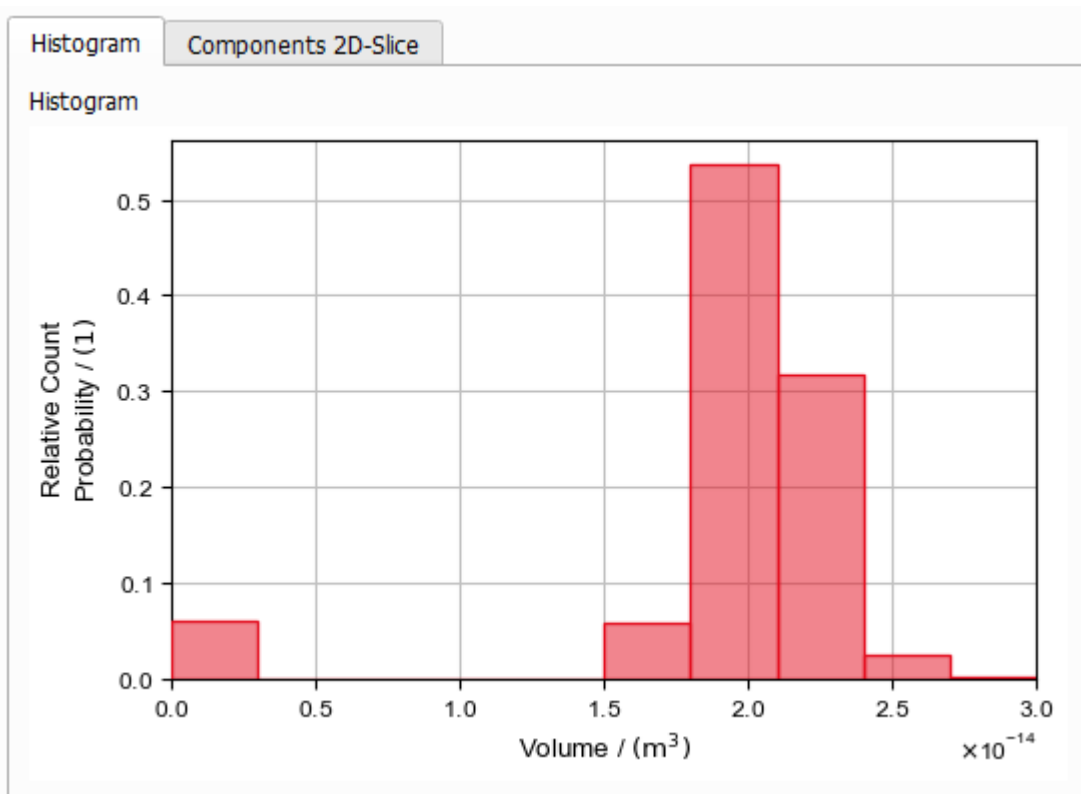
Report



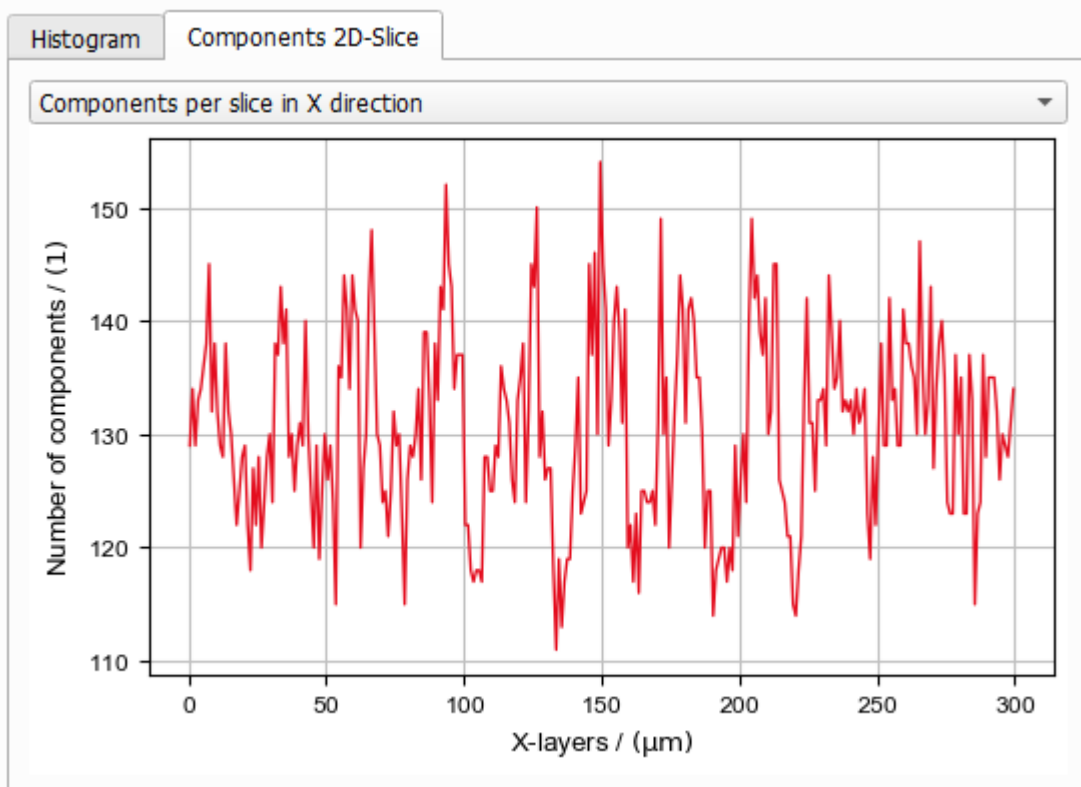
Under the **Results - Report** subtab, the information about the **Number of 3D components**, **Number of components per 2D-slice**, **The component volume** and the **Object volume histogram** is given.

Plots

The object volume histogram is also shown graphically under the **Results - Plots** subtab. In the plot, the values for each bin are visualized as bars.



Under the **Plots** tab, also the computed **Number of Components per 2D Slice** is visualized by three graphs, one for each direction, which are selectable in the drop-down menu.



Post-Processing

As a post-processing step, the content of the **Object volume histogram** can be adjusted by the choices made in the left panel of the **Results** tab. It can be collapsed (and expanded) by pulling left (or right) the dotted line between the post-processing options and the **Results – Report** subtab.

The table and plot are updated when the **Apply...** button is clicked after changing the Volume Histogram parameters.



Know how! The options are the same as the ones available under the **Post-Processing** tab in the Connected Components dialog.

The **X-Axis** pull-down menu allows choosing whether the components should be classified based on volume (**Volume**) or based on volume equivalent sphere diameter (**Equivalent Diameter**).

X-Axis	Volume
	Volume
	Equivalent Diameter

For the **Y-Axis** pull-down menu, the **Relative Count Probability** provides the number of components in each bin normalized to the total number of components. The **Cumulative Count Probability** is the sum of the Relative Count Probability over all bins starting from the bin with the smallest value. **Relative Volume Probability** gives the volume of the components within one bin normalized to the total volume of all components. The **Cumulative Volume Probability** sums up the Relative Volume Probability of each bin of the histogram starting from the smallest one.

Y-Axis	Relative Count Probability
	Relative Count Probability
	Cumulative Count Probability
	Relative Volume Probability
	Cumulative Volume Probability

The histogram **Mode** offers the choice between generating an **Automatic Histogram** without further specifications or to **Give Min. and Max Value** for the parameter defined in the X-Axis pull-down menu (Volume or Equivalent Diameter).

Mode	Automatic Histogram
	Automatic Histogram
	Give Min. and Max. Value

In the latter case, either **Min. Volume** and **Max. Volume** or **Min. Diameter** and **Max. Diameter** (depending on the choice for X-Axis) can be directly entered here.

Mode	Give Min. and Max. Value
Min. Volume / (m ³)	4.21875e-19
Max. Volume / (m ³)	3.15435937e-15

The number of **Histogram Bins** determines the number of rows in the **Object Volume Histogram** table and the number of bars in the plot.

Histogram Bins	10
----------------	----

Map

The **Results-Map** subtab additionally contains an overview of the computed parameters, such as component volume, number of 2D components in each direction and mean values of each. Moreover, the details for every found component are given:

- **VoxelCount** states the number of voxels inside of a component.
- **SeedVoxel** is an arbitrary voxel inside of this component.
- **IsPore** states if this component is pore or solid.
- **Counted** states if this component is counted.

Input Map

Log Map

Post Map

Results

Data Visualization

Metadata

Report

Plots

Map

Key	Unit	Value
NumberOf2DComponentsZDirection	1	123, 121, 120, 119, 126, 124, 135, ...
MeanNumberOf2DComponentsXDirection	1	130.6033333
MeanNumberOf2DComponentsYDirection	1	131.14
MeanNumberOf2DComponentsZDirection	1	129.9033333
ComponentVolume	m^3	2.1299e-14, 7.284562e-12, 2.0732e-...
Component1		
VoxelCount		21299
SeedVoxel		0, 0, 0
IsPore		True
Counted		True
Component2		
VoxelCount		7284562
SeedVoxel		12, 0, 0
IsPore		False
Counted		True
Component3		
Component4		
Component5		
Component6		
Component7		

Data Visualization

The detected connected components can be visualized in GeoDict in two different ways, as index image or as structure file.

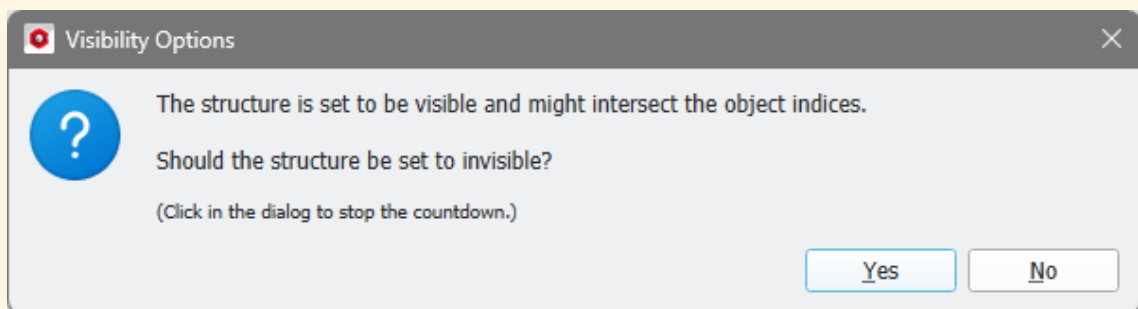
Input Map	Log Map	Post Map	Results	Data Visualization	Metadata
Index Image of Components (*.g32)			Load *.g32		
Index Image of Components (*.leS)			Load *.leS		
Components as Structure (*.gdt)			Load *.gdt		

Index Image of Components

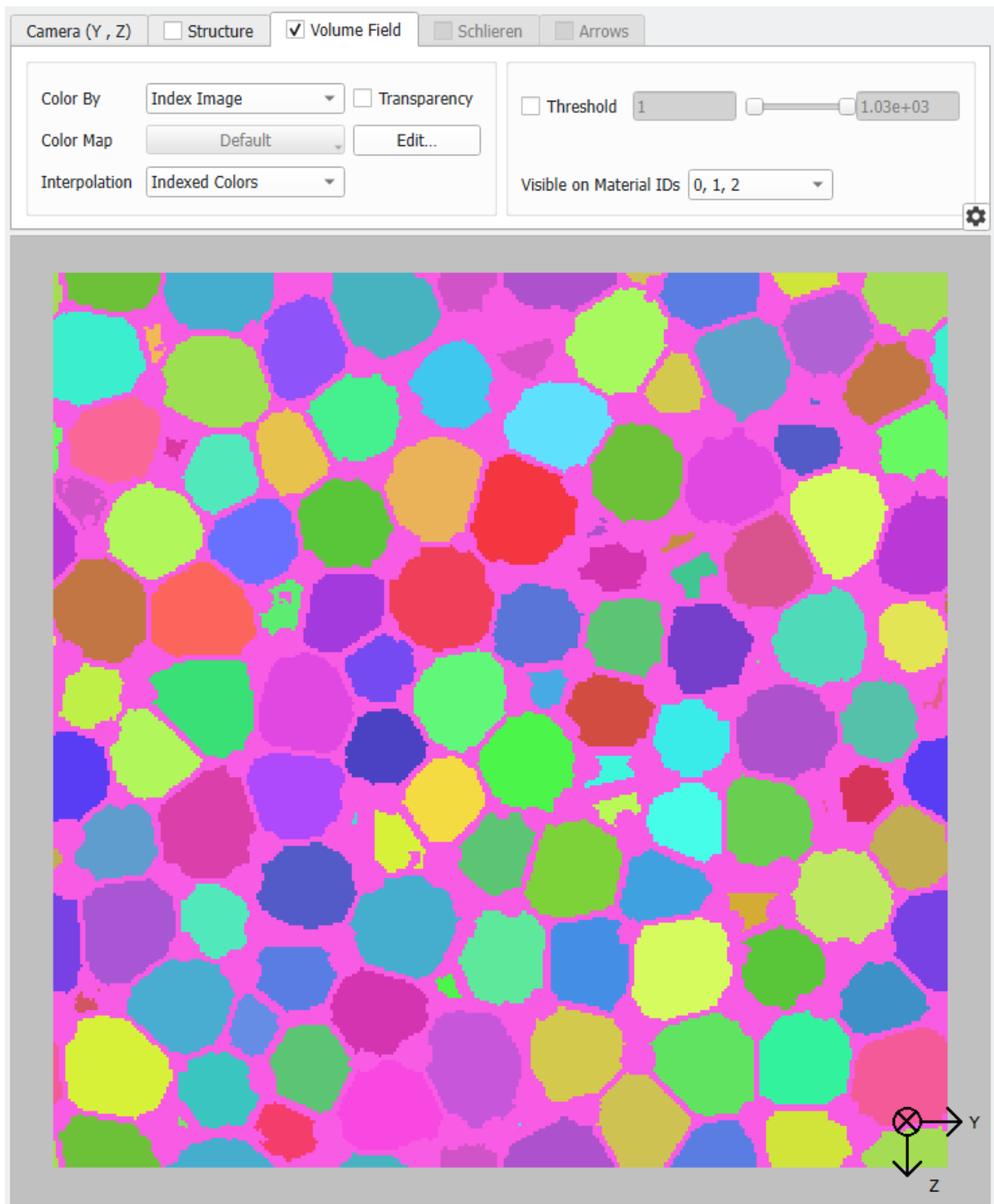
The first two options load the index image in *.g32 or *.leS format, depending on the choice made in the settings dialog. These are 3D images, where for every voxel the index number of the corresponding component is stored. For example, if the structure consists of 1027 components, the file will contain numbers from 1 to 1027. Click **Load *.g32** or **Load *.leS** to load the index image.



Know how! If the Visibility options dialog opens, we recommend to set the structure visualization to invisible by clicking **Yes**, so that the indices can also be seen in the solid parts of the structure.



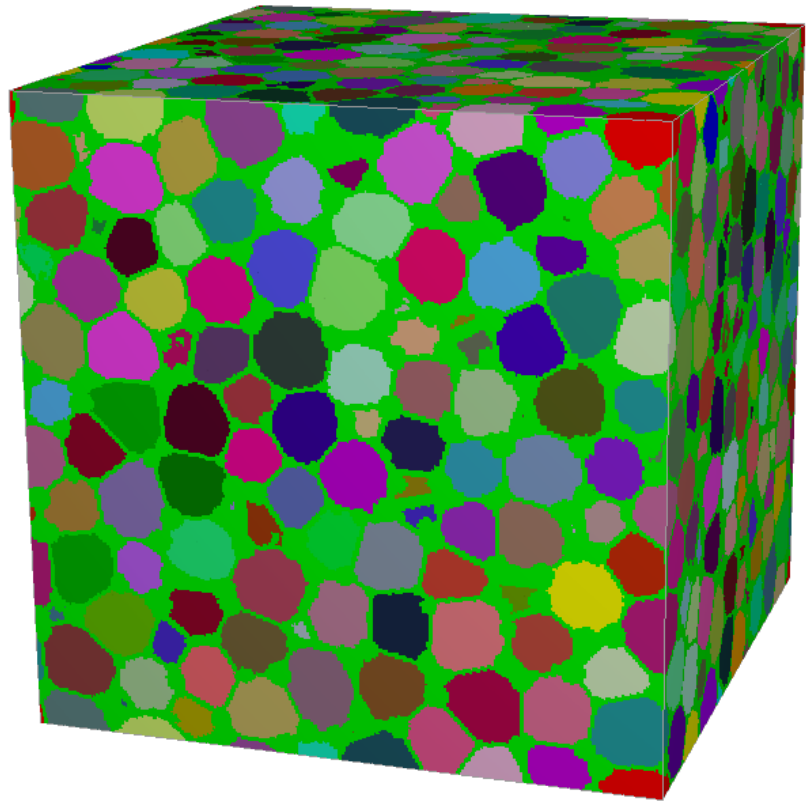
In the index image visualization, every index is highlighted with a different color. The example below shows the index image of a closed-cell foam in 2D, where every cell of the foam belongs to another connected component of the pore space.



Components as Structure

The third option is to load the components as a structure file in *.gdt file format. Every component is assigned a Material ID based on the index number as shown in the following picture.

Material Information:		
●	ID 01: Index 1,256,511,...	(Solid)
●	ID 02: Index 2,257,512,...	(Solid)
●	ID 03: Index 3,258,513,...	(Solid)
●	ID 04: Index 4,259,514,...	(Solid)
●	ID 05: Index 5,260,515,...	(Solid)
●	ID 06: Index 6,261,516,...	(Solid)
●	ID 07: Index 7,262,517,...	(Solid)
●	ID 08: Index 8,263,518,...	(Solid)
●	ID 09: Index 9,264,519,...	(Solid)
●	ID 10: Index 10,265,520,...	(Solid)
●	ID 11: Index 11,266,521,...	(Solid)
●	ID 12: Index 12,267,522,...	(Solid)
●	ID 13: Index 13,268,523,...	(Solid)
●	ID 14: Index 14,269,524,...	(Solid)
●	ID 15: Index 15,270,525,...	(Solid)
●	ID 16: Index 16,271,526,...	(Solid)
●	ID 17: Index 17,272,527,...	(Solid)
●	ID 18: Index 18,273,528,...	(Solid)
●	ID 19: Index 19,274,529,...	(Solid)
●	ID 20: Index 20,275,530,...	(Solid)
●	ID 21: Index 21,276,531,...	(Solid)
●	ID 22: Index 22,277,532,...	(Solid)
●	ID 23: Index 23,278,533,...	(Solid)
●	ID 24: Index 24,279,534,...	(Solid)
●	ID 25: Index 25,280,535,...	(Solid)
●	ID 26: Index 26,281,536,...	(Solid)
●	ID 27: Index 27,282,537,...	(Solid)
●	ID 28: Index 28,283,538,...	(Solid)
●	ID 29: Index 29,284,539,...	(Solid)
●	ID 30: Index 30,285,540,...	(Solid)
●	ID 31: Index 31,286,541,...	(Solid)
●	ID 32: Index 32,287,542,...	(Solid)
●	ID 33: Index 33,288,543,...	(Solid)
●	ID 34: Index 34,289,544,...	(Solid)
●	ID 35: Index 35,290,545,...	(Solid)
●	ID 36: Index 36,291,546,...	(Solid)
●	ID 37: Index 37,292,547,...	(Solid)
●	ID 38: Index 38,293,548,...	(Solid)
●	ID 39: Index 39,294,549,...	(Solid)
●	ID 40: Index 40,295,550,...	(Solid)
●	ID 41: Index 41,296,551,...	(Solid)
●	ID 42: Index 42,297,552,...	(Solid)
●	ID 43: Index 43,298,553,...	(Solid)
●	ID 44: Index 44,299,554,...	(Solid)
●	ID 45: Index 45,300,555,...	(Solid)
●	ID 46: Index 46,301,556,...	(Solid)
●	ID 47: Index 47,302,557,...	(Solid)
●	ID 48: Index 48,303,558,...	(Solid)
●	ID 49: Index 49,304,559,...	(Solid)
●	ID 50: Index 50,305,560,...	(Solid)

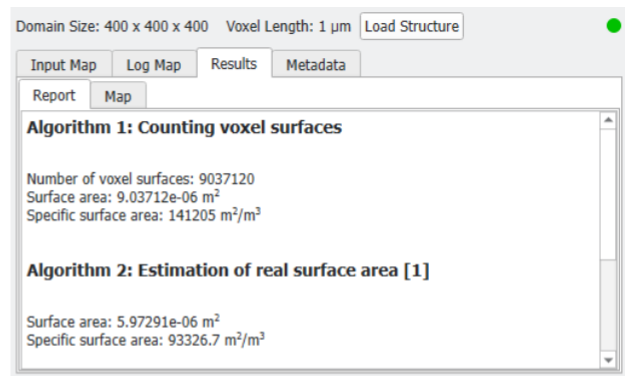
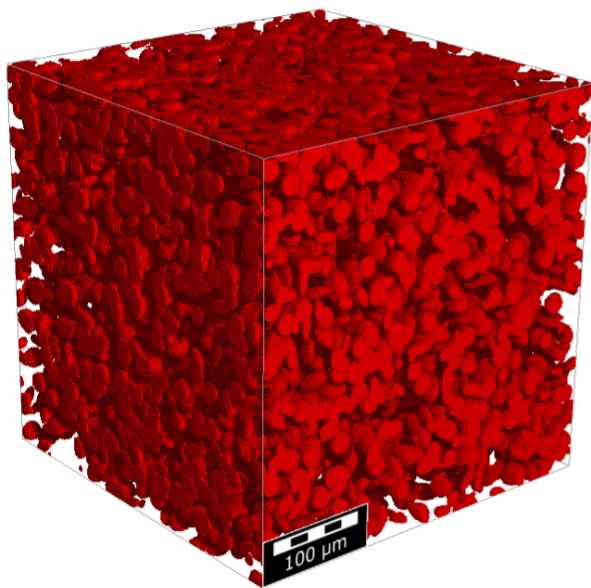


Be aware, that this format supports only 256 different Material IDs. This might lead to neighboring components getting assigned to the same ID. In the example, every 255th foam cell gets assigned to the same ID as the cell walls, and therefore seems to disappear in the visualization.

1.2.4 Estimate Surface Area

With **Estimate Surface Area**, the surface area of the structure is estimated by counting voxel surfaces (**Algorithm 1**) and by using a method based on statistical measures (**Algorithm 2**).

Algorithm 2 calculates an approximation of the surface area by statistical methods and not simply by adding up the voxel surfaces. Therefore, the surface of a sphere is approximated correctly. However, the estimation is slightly biased in case of highly anisotropic media. The method originates from statistical image analysis, where the determination of the four Minkowski measures (Volume, Surface Area, Integral of mean curvature, Integral of total curvature) from voxelized images is an essential task. To determine the surface area, the Crofton formula is used, which relates at first the 3D surface area to an integral over 2D boundary lengths of planar cross sections and then second these lengths to an integral over 1D rays. Based on this formula, an analysis of the intersection points of rays in all space directions with the structure allows determining the surface area.



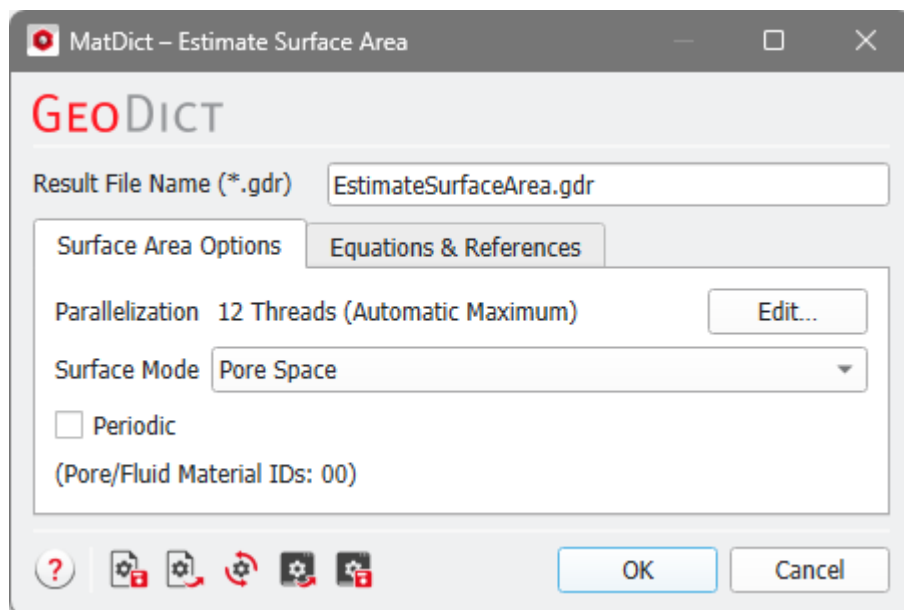
The Estimate Surface Area command:

- [Options](#)⁷²
Set the parameters for the analysis.
- [Results](#)⁷⁷
View the computed results.

Options

The **Estimate Surface Area** options open when clicking the **Edit...** button. The Estimate Surface Area dialog includes the **Surface Area Options** tab and the **Equations & References** tab, which provides further information about the underlying algorithm from [J. Ohser, F. Mücklich](#)¹⁴³.

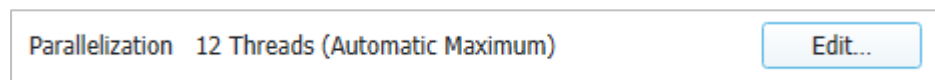
At the top of the dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).



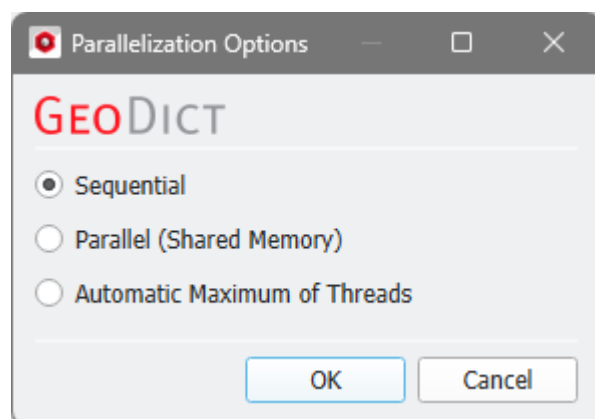
✓ Parallelization

Control how many threads are used for the computation. Parallelization is possible if your license and hardware allow it.

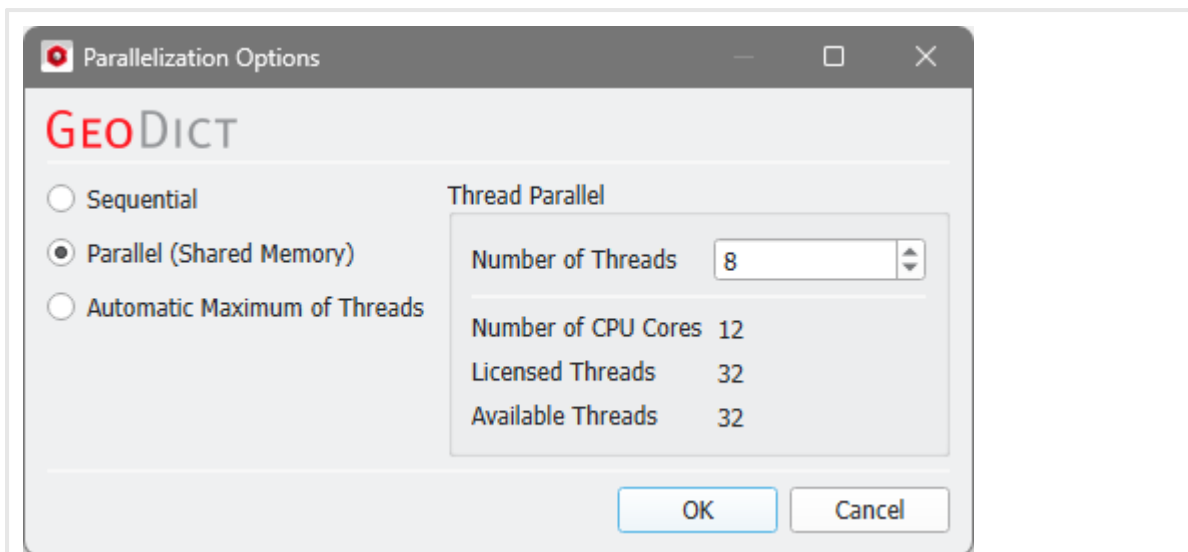
The **Parallelization Options** dialog opens when clicking the **Edit** button and you can choose between **Sequential**, **Parallel (Shared Memory)**, or **Automatic Maximum of Threads**.



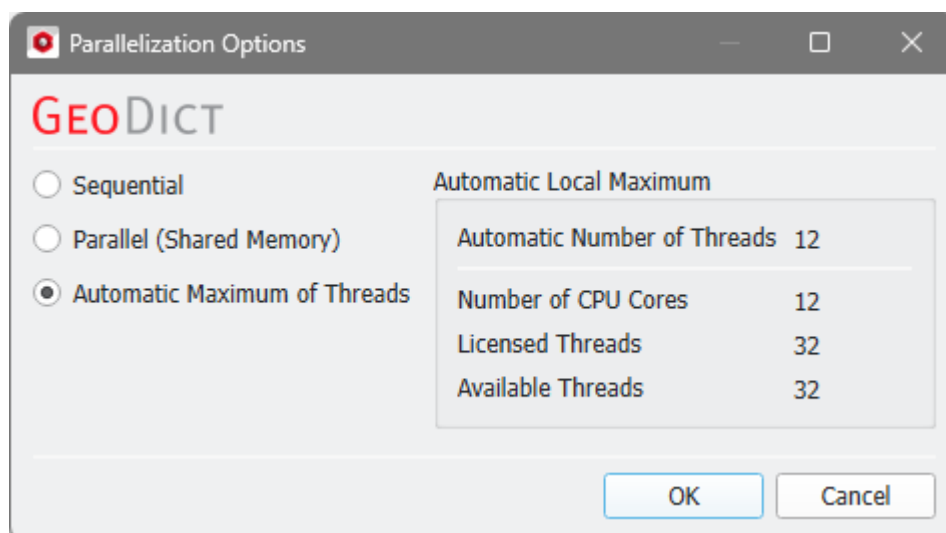
Selecting **Sequential** will not apply parallelization and only one thread is used for the computation.



When **Parallel (Shared Memory)** is selected, the **Number of Threads** can be entered. Below, the **Number of CPU Cores** that the current machine has, the maximum number of **Licensed Threads** and the number of those licensed threads that are available (**Available Threads**) are shown in the dialog. Of course, the maximal number of parallel processes you can use, is the smallest of those three numbers.



If **Automatic Maximum of Threads** is selected, the number of parallel processes is automatically selected for optimal speed, based on the CPU cores and licensed parallel processes.



The **Automatic Local Maximum** of processes is automatically selected, which is the minimum of **Number of CPU Cores**, **Licensed Threads**, and **Available Threads**.

✓ Surface Mode

Under **Surface Mode** choose the Materials or Material IDs for which the surface area should be calculated. The surface is defined as the boundary between the chosen quantity and the rest of the structure.

Surface Mode: Pore Space

- Pore Space
- All Solid Materials
- Chosen Material
- Chosen Material ID
- Between Materials
- Between Material IDs

Pore Space computes the surface of the pore space, which is the union of *Pore* and all *Fluid* materials. It returns the same result as **All Solid Materials**, which computes the surface of all *solid* and *porous* materials combined to one material. Please note that **All Solid Materials** does not include the inner surfaces between different solid Materials or Material IDs. For your convenience, all Material IDs which denote pore space are shown at the bottom of the dialog.

If **Chosen Material** is selected, choose the desired Material from the pull-down menu, listing all materials present in the structure, that appears below. This will estimate the surface area between the chosen Material and any other Materials.

Surface Mode: Chosen Material

Material 1: Air

- Air
- Graphite

If **Chosen Material ID** is selected, choose the desired Material ID from the pull-down menu that appears below. This will estimate the surface area between the chosen Material ID and any other Material IDs.

Surface Mode: Chosen Material ID

Material ID: 00 Air

- 00 Air
- 01 Graphite
- 02 Graphite
- 03 Undefined
- 04 Undefined
- 05 Undefined
- 06 Undefined
- 07 Undefined
- 08 Undefined
- 09 Undefined

You can also estimate the surface between only two selected Materials or Material IDs. Choose the surface mode **Between Materials** or **Between Material IDs** and select the two materials or Material IDs to be considered for the surface area.

Surface Mode	Between Materials	Surface Mode	Between Material IDs
Material 1	Air	Material ID 1	00 Air
Material 2	Graphite	Material ID 2	01 Graphite

Periodic

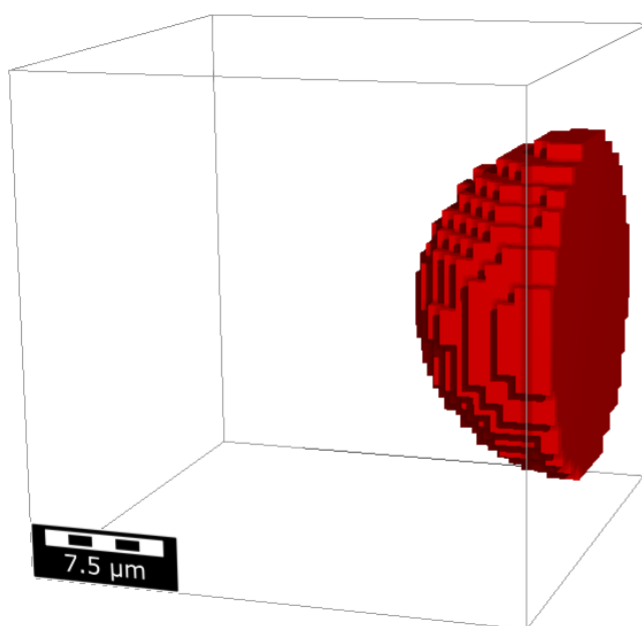
When selecting **Periodic**, the algorithm estimates the surface area assuming that the structure is periodic, so that the material that ends on one side of the volume reappears on the opposite side.

Observe the different results for the half sphere with radius 10 μm touching the domain boundary. The surface area of a half sphere with 10 μm radius is approximately 628 μm^2 and the area of the circle from the cutting plane is approx. 314 μm^2 .

GeoDict uses two methods to estimate the surface area, counting voxel surfaces (algorithm 1) and using an algorithm provided by [J. Ohser, F. Mücklich](#)^[143] (algorithm 2). Find out more about the algorithms in the [Results](#)^[77] section.

When not checking **Periodic**, the staggered grid causes half a voxel to be cut off at the domain boundary. Thus, the counted voxels are those from the sphere surface and the cutting plane at the domain boundary, while the algorithm by [J. Ohser, F. Mücklich](#)^[143] corrects it to the area of the curved sphere surface.

If **Periodic** is checked, the spherical surface of the cutting plane is counted twice in algorithm 1, as it is additionally reached from the opposite domain boundary. The algorithm by [J. Ohser, F. Mücklich](#)^[143] for the real surface area corrects this doubled counted surface area because the half voxels on each opposite domain side are connected.



☐ Periodic
Algorithm 1: Counting voxel surfaces Number of voxel surfaces: 948 Surface area: 9.48e-10 m ² Specific surface area: 35111.1 m ² /m ³
Algorithm 2: Estimation of real surface area Surface area: 6.30021e-10 m ² Specific surface area: 23334.1 m ² /m ³
☒ Periodic
Algorithm 1: Counting voxel surfaces Number of voxel surfaces: 1264 Surface area: 1.264e-09 m ² Specific surface area: 46814.8 m ² /m ³
Algorithm 2: Estimation of real surface area Surface area: 9.13935e-10 m ² Specific surface area: 33849.4 m ² /m ³

Results

After the **Estimate Surface Area** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains four tabs. The computational results are shown under the **Results** tab. The other three tabs (**Input Map**, **Log Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

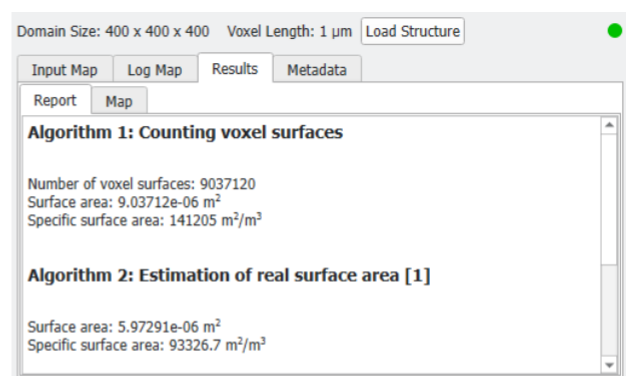
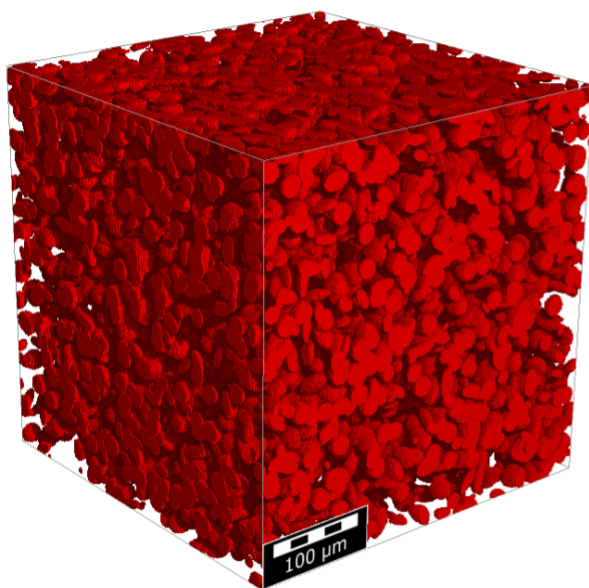
As mentioned in [Estimate Surface Area](#)^[71], GeoDict uses two algorithms to estimate the surface area.

Algorithm 1 computes the surface area by adding up the voxel surfaces. Thus, the **Number of voxel surfaces** is only given for this algorithm.

Algorithm 2 estimates the real surface area, originating from statistical image analysis, where the determination of the four Minkowski measures (Volume, Surface Area, Integral of mean curvature, Integral of total curvature, see also [J. Ohser, F. Mücklich](#)^[143]) from voxelized images is an essential task. This algorithm uses a staggered grid, which means it uses the voxel centers of the original grid as corners. In this grid, half a voxel cell is left over on each side. When using **Periodic** boundary conditions, those half-cells are completed across the domain boundary again to full grid cells, and this way the whole volume is taken into account. Without periodic boundary conditions, these half-cells are discarded. This means, that without periodic boundary conditions half a voxel is cut away on every side, so a slightly smaller volume is considered when computing the specific surface area.

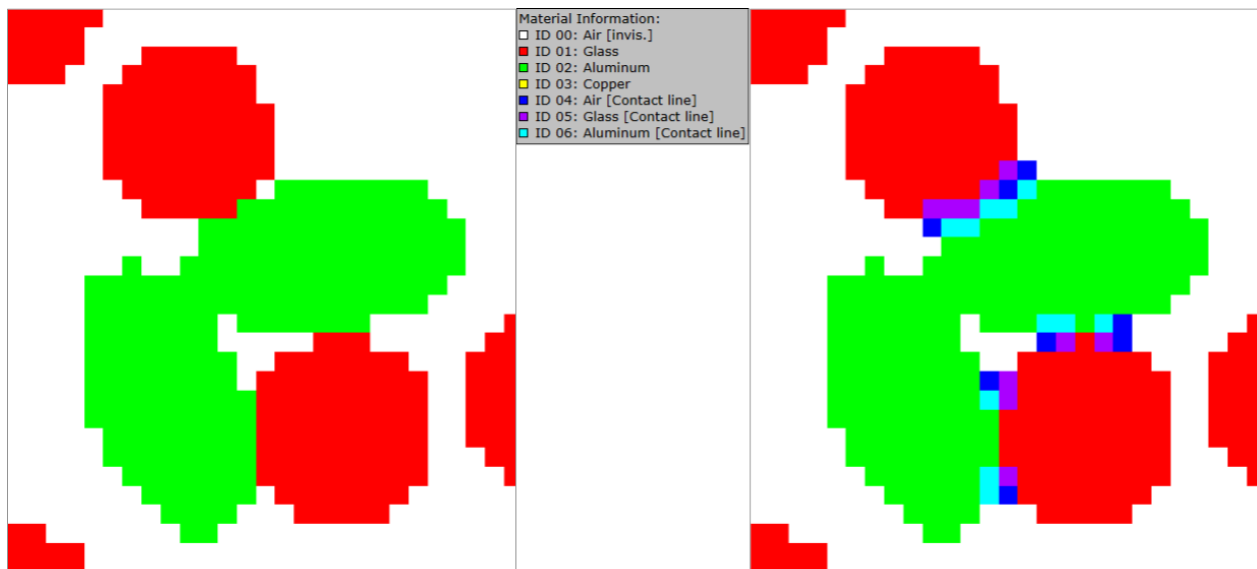
For both algorithms the **Surface area**, and the **Specific surface area**, defined as the Surface Area normalized by the total volume of the structure, are stated in the result file.

In the example below, the surface area between solid and pore was calculated with non-periodic boundaries.



1.2.5 Estimate Three-Phase Contact Line

The **Estimate Three-Phase Contact Line** algorithm estimates the length of the contact line between the phases in a three-phase system and the number of voxel edges of the contact line in the Cartesian directions. The length of the contact line, which strongly depends on the structure's topology, is often important for the performance of a material (for example for catalysts).



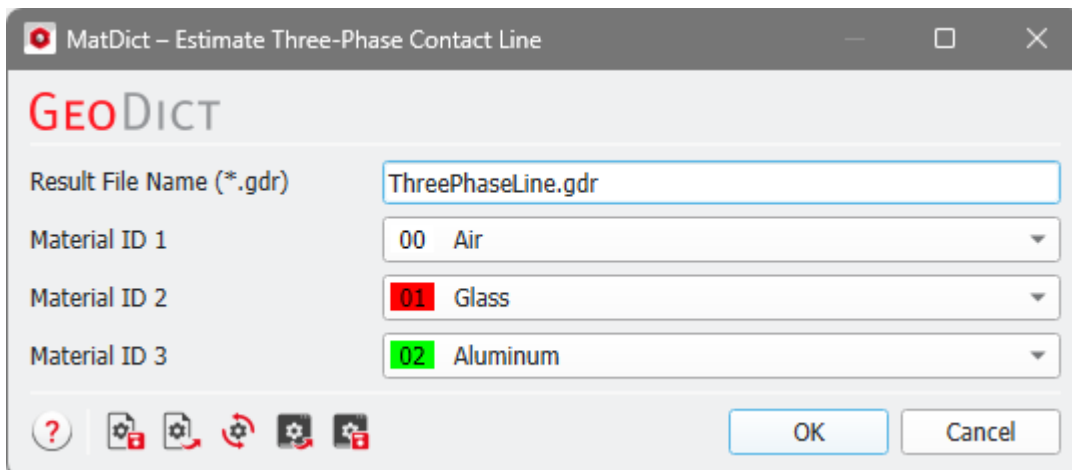
The Estimate Three-Phase Contact Line command:

- [Options](#)⁷⁸
Set the parameters for the analysis.
- [Results](#)⁷⁹
View the computed results.

Options

The **Estimate Three-Phase Contact Line** options are opened by clicking the **Options' Edit...** button.

At the top of the dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).



Through the **Material ID 1**, **Material ID 2**, and **Material ID 3** pull-down menus, the three-phase Material IDs for which the Three-Phase Contact Line length should be computed are selected.

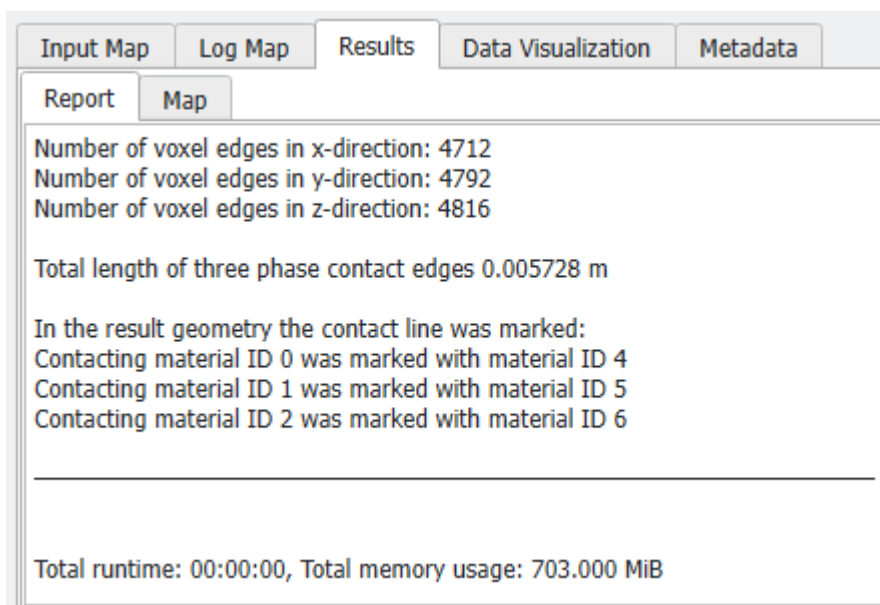


Note! The Material IDs you want to analyze do not need to be IDs 01 to 03. Material ID 1 in this context means the first Material ID that will be analyzed. Analogously, Material ID 2 and Material ID 3 refer to the second and third analyzed Material ID.

Results

After the **Estimate Three-Phase Contact Line** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains five tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Data Visualization** tab. The other three tabs (**Input Map**, **Log Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

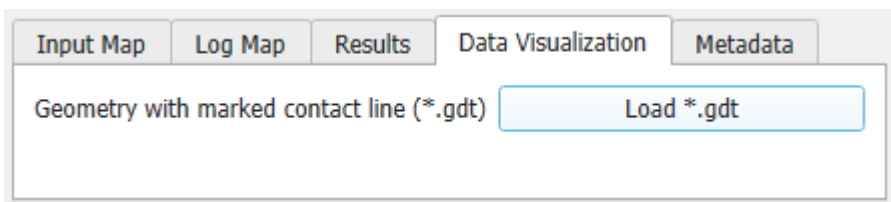


In this algorithm, all voxel edges are found that are adjacent to all three materials. The report contains the computed values for **Number of voxel edges in x-, y-, and z-direction**, as well as the **Total length of three phase contact edges**, which is computed by multiplying the sum of the above numbers with the voxel length.

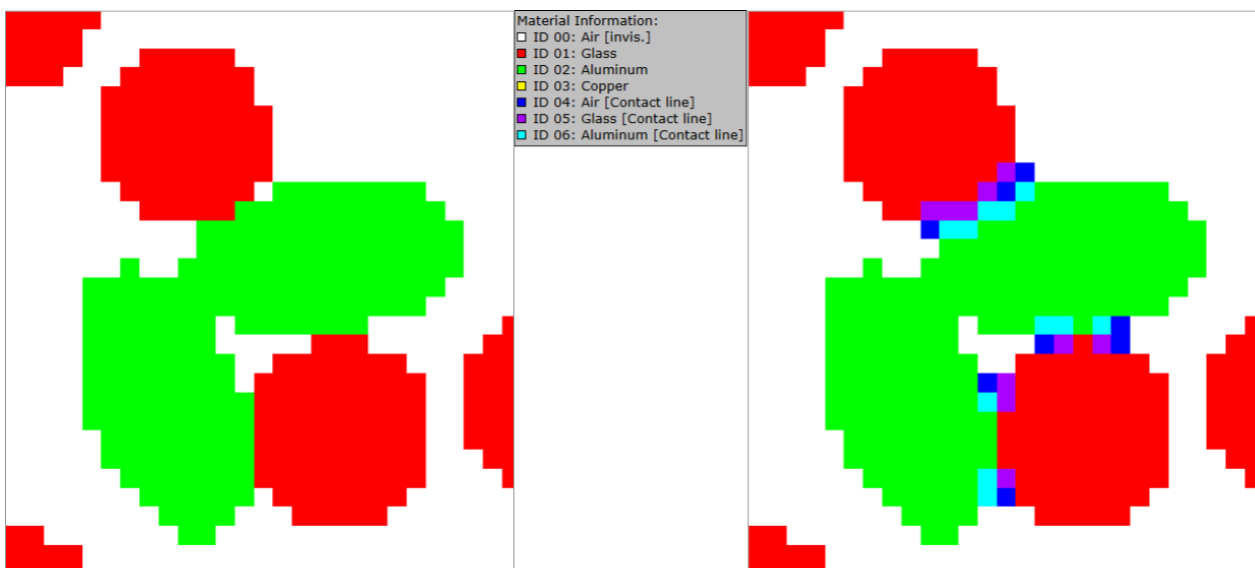
The result geometry where the contact lines are marked can be loaded from the [Data Visualization](#)  tab.

Data Visualization

Click **Load *.gdt** to load the **Geometry with marked contact line** in the visualization area.



The voxels belonging to the contact line are assigned to additional Material IDs depending on the initial Material IDs in the structure. In the example shown below, the dark blue voxels in the structure with marked contact line (shown on the right) belong to Material ID 00 in the original structure (shown on the left). Analogously, the magenta colored voxels belong to Material ID 01 in the original structure and the light blue voxels to Material ID 02.



Know how! While the Material ID is changed for the voxels of the contact line, the material stays the same.

1.2.6 Minkowski Parameters

The four **Minkowski Parameters** (Volume, Surface Area, Integral of mean curvature, and Integral of total curvature) are the structures characterizing parameters to analyze

mathematical topology and can be computed for a selected Material ID. These parameters can be used, e.g., for image processing, estimating root lengths, or hysteresis.

Minkowski parameters:

Volume	2.24004e+07 μm^3
Volume fraction	0.35
Surface area	5.97291 mm^2
Specific surface area	9.333e+04 m^{-1}
Integral of mean curvature	0.2864 m
Specific integral of mean curvature	4.474e+09 m^{-2}
Integral of total curvature (neighborhood mode: face)	-2.635e+04
Specific integral of total curvature (neighborhood mode: face)	-4.117e+14 m^{-3}
Euler characteristic (neighborhood mode: Face)	-2096.79
Euler characteristic (neighborhood mode: face, edge or vertex)	-3320.17

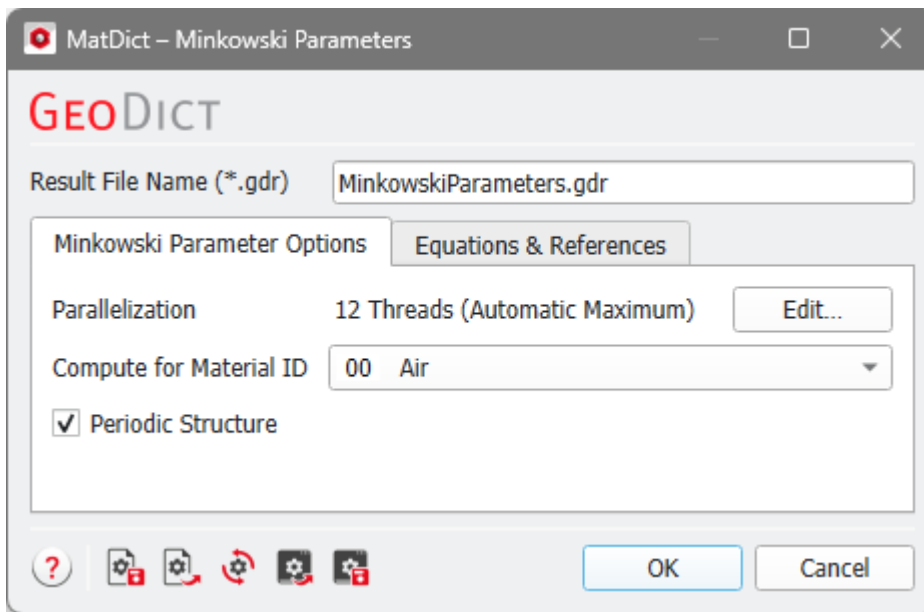
The Minkowski Parameters command:

- [Options](#)⁸¹
Set the parameters for the analysis.
- [Results](#)⁸⁴
View the computed results.

Options

The needed parameters can be entered by clicking the **Edit...** button. The **Minkowski Parameters** dialog includes the **Minkowski Parameter Options** tab and the **Equation & References** tab, which cites [J.Ohser, F.Mücklich](#)¹⁴³ on which the algorithm is based.

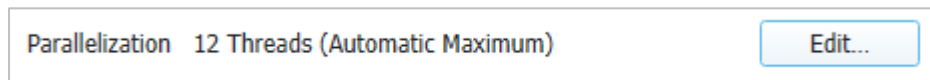
At the top of the dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).



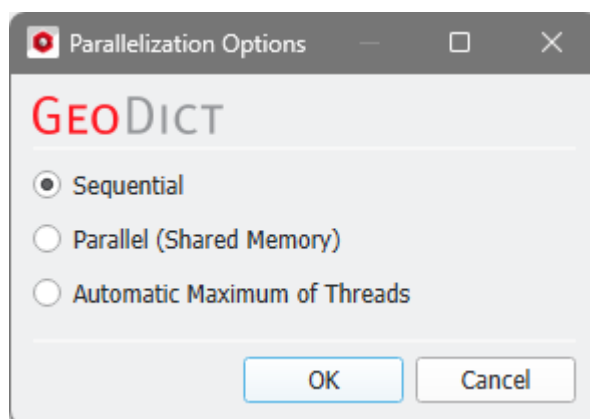
✓ Parallelization

Control how many threads are used for the computation. Parallelization is possible if your license and hardware allow it.

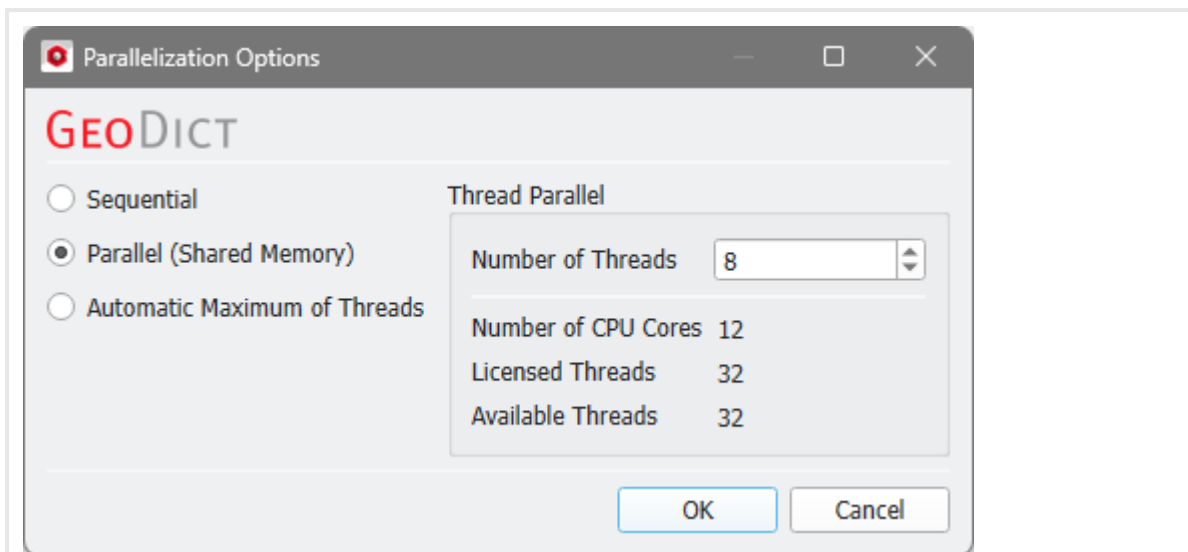
The **Parallelization Options** dialog opens when clicking the **Edit** button and you can choose between **Sequential**, **Parallel (Shared Memory)**, or **Automatic Maximum of Threads**.



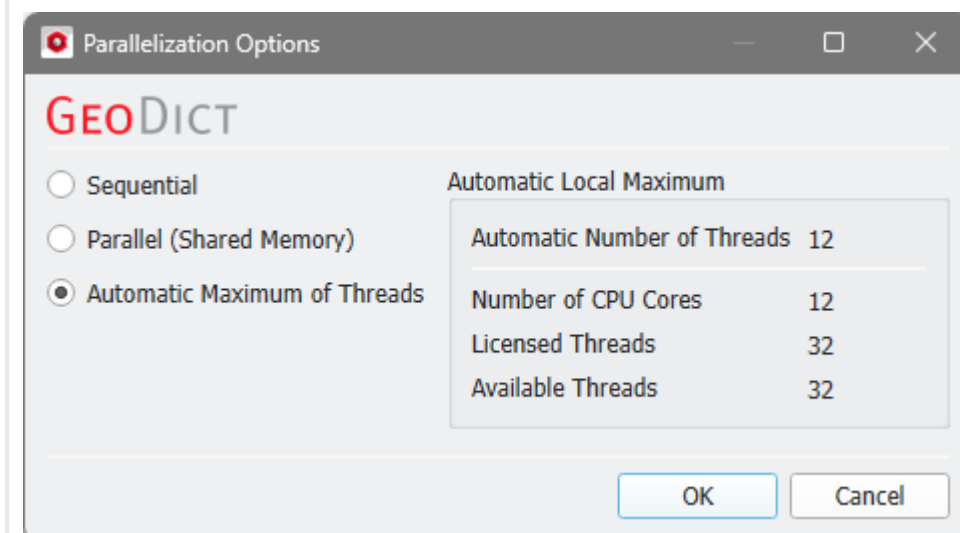
Selecting **Sequential** will not apply parallelization and only one thread is used for the computation.



When **Parallel (Shared Memory)** is selected, the **Number of Threads** can be entered. Below, the **Number of CPU Cores** that the current machine has, the maximum number of **Licensed Threads** and the number of those licensed threads that are available (**Available Threads**) are shown in the dialog. Of course, the maximal number of parallel processes you can use, is the smallest of those three numbers.



If **Automatic Maximum of Threads** is selected, the number of parallel processes is automatically selected for optimal speed, based on the CPU cores and licensed parallel processes.



The **Automatic Local Maximum** of processes is automatically selected, which is the minimum of **Number of CPU Cores**, **Licensed Threads**, and **Available Threads**.

Compute for Material ID defines the Material ID for which the Minkowski Parameters are computed.

Selecting **Periodic**, the structure is assumed to be periodic, so that the material that ends on one side of the volume reappears on the opposite side. Otherwise, symmetric boundary conditions are used.

As Algorithm 2 from [Estimate Surface Area](#)^[77] is used in this command, a staggered grid will be used, too.

Results

After the **Minkowski Parameters** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains four tabs. The computational results are shown under the **Results** tab. The other three tabs (**Input Map**, **Log Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

Under the **Results-Report** subtab the four Minkowski Parameters characterize the mathematical topology of the structure:

The parameter **Volume** is the volume occupied of the chosen Material ID. Its percentage is also given by **Volume Fraction**.

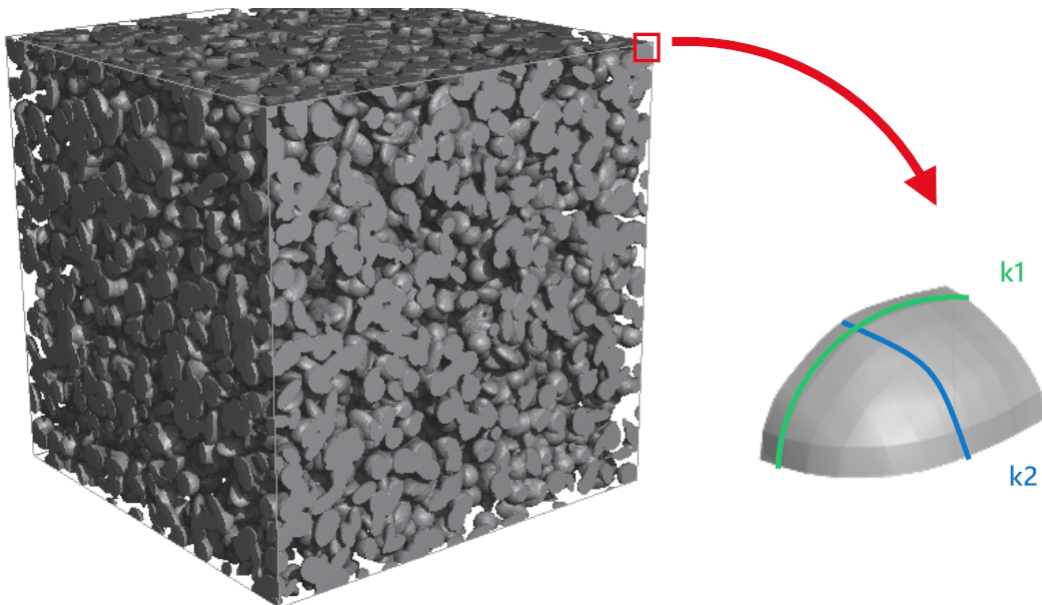
The **Surface area** is the boundary between the chosen Material ID and all other Material IDs. It is computed as in **Algorithm 2** of the [Estimate Surface Area](#) ^[77] command (see also [J. Ohser, F. Mücklich](#) ^[143]).

The **Integral of mean curvature** describes the mean curvature of the selected Material ID, given by the following formula

$$C_M(X) = \frac{1}{2} \int_{\delta X} k_1 + k_2 ds = \frac{1}{2} \int_{\delta X} \frac{1}{r_1(s)} + \frac{1}{r_2(s)} ds$$

(2) Integral of mean curvature

where X is the chosen Material ID, s is a surface element of the chosen Material ID and the parameters $r_1(s)$ and $r_2(s)$ are defined as the radii of the two principal curvatures k_1 and k_2 from the respective surface element.



The **Integral of total curvature** describes the total curvature of the selected Material ID:

$$C_T(X) = \int_{\delta X} k_1 k_2 ds = \int_{\delta X} \frac{1}{r_1(s)r_2(s)} ds$$

(3) Integral of total curvature

The surface area and the curvature values are given additionally as specific values, which are normalized by the total volume of the structure.

The **Euler characteristic** (E) is a topological number, that describes to what extent the structure is connected. It equals $1/4\pi$ times the integral of total curvature. This results in $E = N - L + C$, where N is the number of objects, L is the number of loops and C is the number of cavities. If symmetric boundary conditions are used (Periodic Structure not checked), the staggered grid leads to half-cells at the domain boundary. Therefore, non-integer Euler characteristics might occur.

The screenshot shows two side-by-side windows of the MatDict software. Both windows display the 'Results' tab with a table of Minkowski parameters. The left window is for Material ID00 (pore space) and the right window is for Material ID01 (solid material). Both windows show the same set of parameters, but with different numerical values. A note at the bottom of each table states: 'The specific surface area and the specific curvature integrals in the table above are normalized by the total volume of the structure.'

Minkowski parameters:	
Volume	4.15996e+07 μm³
Volume fraction	0.65
Surface area	5.97291 mm²
Specific surface area	9.333e+04 m⁻¹
Integral of mean curvature	-0.2864 m
Specific integral of mean curvature	-4.474e+09 m⁻²
Integral of total curvature (neighborhood mode: face)	-4.172e+04
Specific integral of total curvature (neighborhood mode: face)	-6.519e+14 m⁻³
Euler characteristic (neighborhood mode: Face)	-3320.17
Euler characteristic (neighborhood mode: face, edge or vertex)	-2096.79

Minkowski parameters:	
Volume	2.24004e+07 μm³
Volume fraction	0.35
Surface area	5.97291 mm²
Specific surface area	9.333e+04 m⁻¹
Integral of mean curvature	0.2864 m
Specific integral of mean curvature	4.474e+09 m⁻²
Integral of total curvature (neighborhood mode: face)	-2.635e+04
Specific integral of total curvature (neighborhood mode: face)	-4.117e+14 m⁻³
Euler characteristic (neighborhood mode: Face)	-2096.79
Euler characteristic (neighborhood mode: face, edge or vertex)	-3320.17

The screenshot shows the computed Minkowski parameters for the pore space (here Material ID00, on the left), and the solid material (ID01, right) of the structure shown above.

1.2.7 Chord Length Distribution

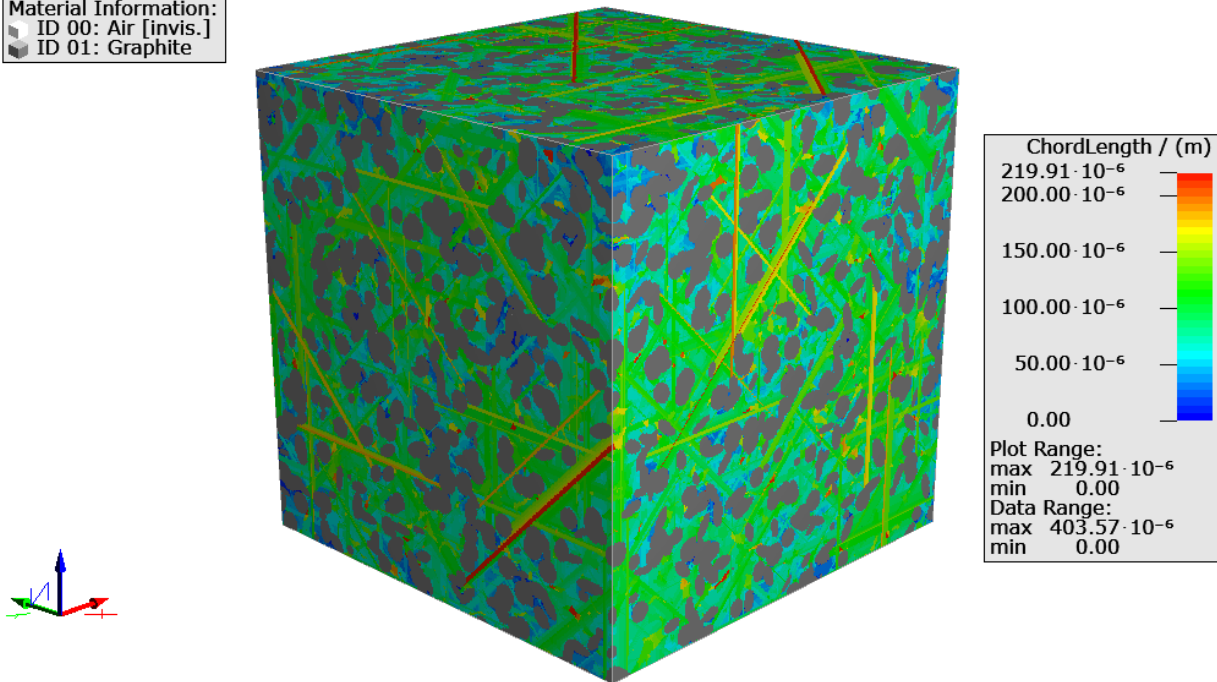
The **Chord Length Distribution** command is accessible from MatDict and PoroDict.

A **Chord Length Distribution** (CLD) is the distribution of the length of a typical chord of a structure. By being characteristic for any given geometry class, it is a highly precise and sensitive measure to compare the geometries of porous media. The calculation of CLD is particularly useful in 2D tomographic cross-sections, for which the pore size distribution cannot be determined by granulometry or by porosimetry.

The **Chord Length** is defined as the number of connected voxels along the computational direction. Pseudo-code of the algorithm used for the computation can be found in [J. Ohser, F. Mücklich](#)¹⁴³.

The **Chord Length Distribution** dialog opens when clicking the **Edit...** button.

Material Information:
 ID 00: Air [invis.]
 ID 01: Graphite



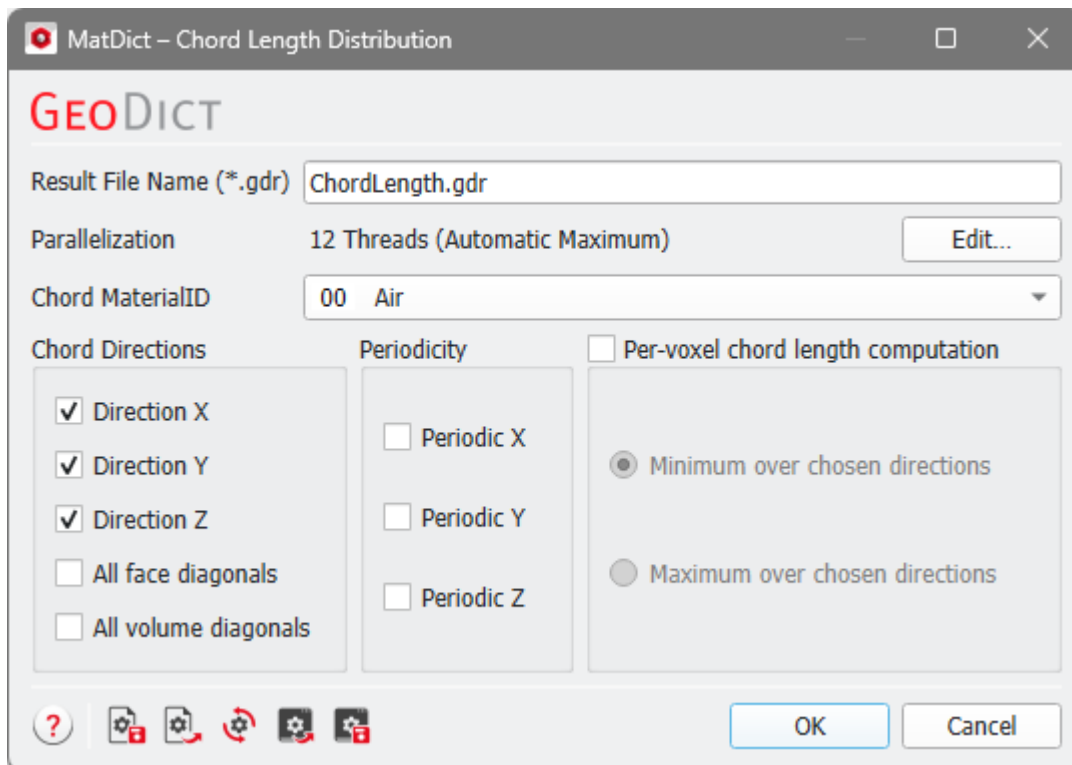
The Chord Length was computed in the pore space for all directions.

The Chord Length Distribution command:

- [Options](#)₈₆
Set the parameters for the analysis.
- [Results](#)₉₀
View the computed results.

Options

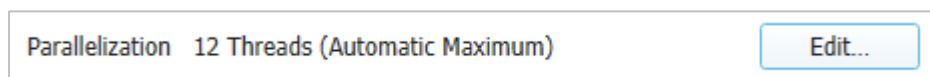
At the top of the dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).



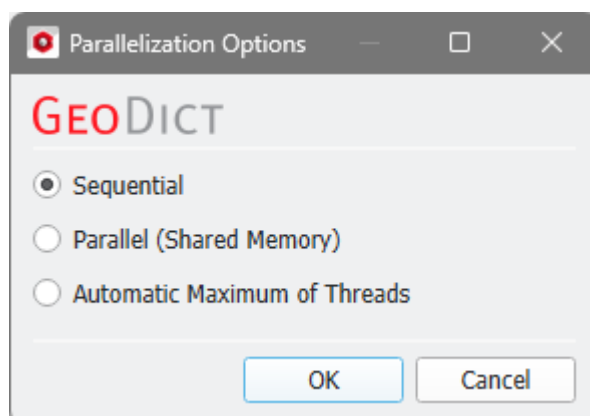
✓ Parallelization

Control how many threads are used for the computation. Parallelization is possible if your license and hardware allow it.

The **Parallelization Options** dialog opens when clicking the **Edit** button and you can choose between **Sequential**, **Parallel (Shared Memory)**, or **Automatic Maximum of Threads**.

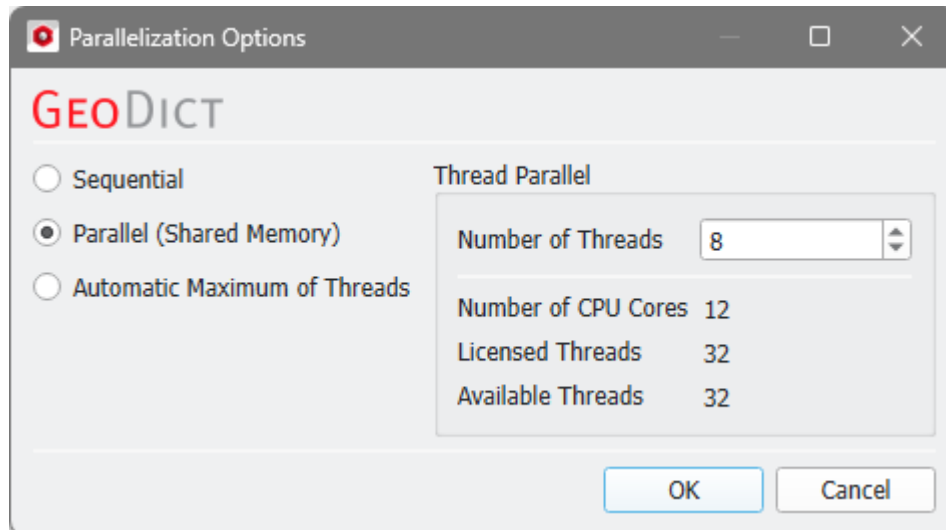


Selecting **Sequential** will not apply parallelization and only one thread is used for the computation.

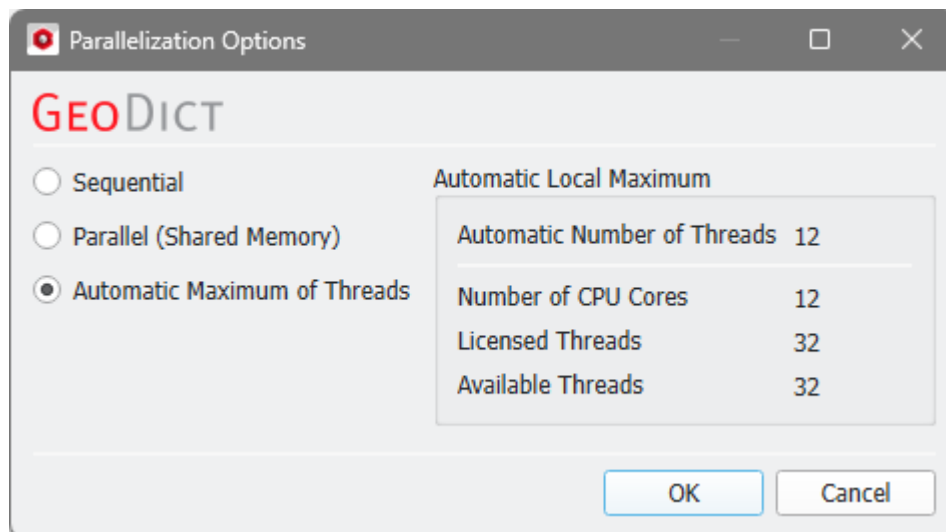


When **Parallel (Shared Memory)** is selected, the **Number of Threads** can be entered. Below, the **Number of CPU Cores** that the current machine has, the maximum number

of **Licensed Threads** and the number of those licensed threads that are available (**Available Threads**) are shown in the dialog. Of course, the maximal number of parallel processes you can use, is the smallest of those three numbers.



If **Automatic Maximum of Threads** is selected, the number of parallel processes is automatically selected for optimal speed, based on the CPU cores and licensed parallel processes.



The **Automatic Local Maximum** of processes is automatically selected, which is the minimum of **Number of CPU Cores**, **Licensed Threads**, and **Available Threads**.

✓ Chord Material ID

Select the **Chord MaterialID** for which the chord length distribution is calculated. This can be done for pore or solid materials alike.

Chord MaterialID	
00	Air
00	Air
01	Graphite
02	Graphite
03	Undefined
04	Undefined
05	Undefined
06	Undefined
07	Undefined
08	Undefined
09	Undefined

✓ Chord Directions

In the **Chord Directions** section, select the direction(s) in which the chord lengths are determined.

Chord Directions

☒ Direction X
☒ Direction Y
☒ Direction Z
☒ All face diagonals
☒ All volume diagonals

This can be done along the main axes (**Direction X**, **Direction Y**, or **Direction Z**), along the two-dimensional diagonals of the domain (**All face diagonals**), or along the three-dimensional diagonals of the domain (**All volume diagonals**).

✓ Periodicity

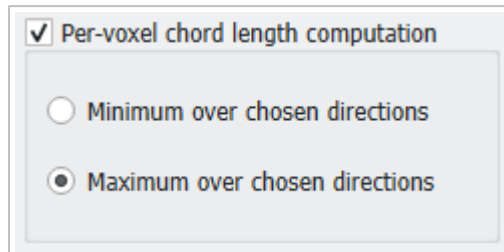
Periodicity can be applied in the X-, Y-, and/or Z-direction for the calculation. Periodicity means, that chords continue on the opposite side of the domain. This can lead to infinitely long chord lengths, if a complete ray along the chosen direction is inside of the selected **Chord MaterialID**. Such chords are neglected when computing the distribution results, and a warning is plotted on top of the resulting report if this occurs:

Report
Plots
Map

Warning: 50 chords of infinite length did not count for mean chord length and L10/L50/L90 in Z-direction

✓ Per-voxel chord length computation

Check **Per-voxel chord length computation** to include a scalar field for the output in which, for each voxel, the length of the minimum or maximum chord through that voxel over all chosen directions is stored. For this, choose between **Minimum over chosen directions** or **Maximum over chosen directions**.



Results

After the **Chord Length Distribution** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains six tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Data Visualization** tab. The other four tabs (**Input Map**, **Log Map**, **Post Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

Chord Length Distribution Results:

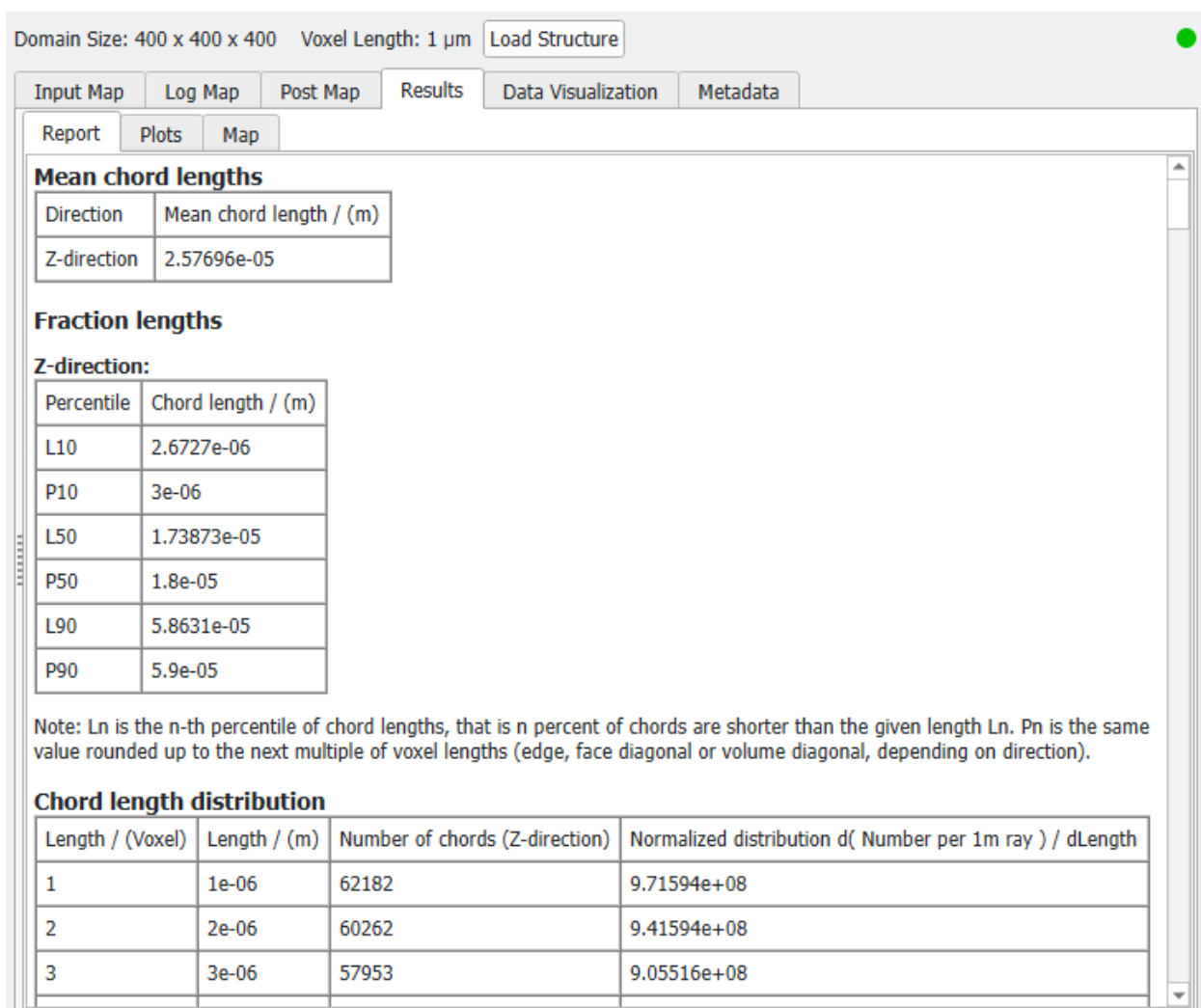
- [Results Tab](#)  ⁹⁰
Observe the computed results and plots.
- [Data Visualization](#)  ⁹³
Load results for a graphical visualization.

Results Tab

Due to the voxelization, the chord length can only be measured in multiples of the voxel length. A chord length of d meters includes all chord lengths with a distance of half the voxel length around d . For example, a chord length of 2 μm with voxel length 1 μm actually means all chords between 1.5 μm and 2.5 μm .

Report Tab

Under the **Report** tab, the **Mean chord lengths**, the **Fraction lengths** L10, L50, L90 and P10, P50, P90, and the complete **Chord length distribution** in the selected chord direction(s) are shown.



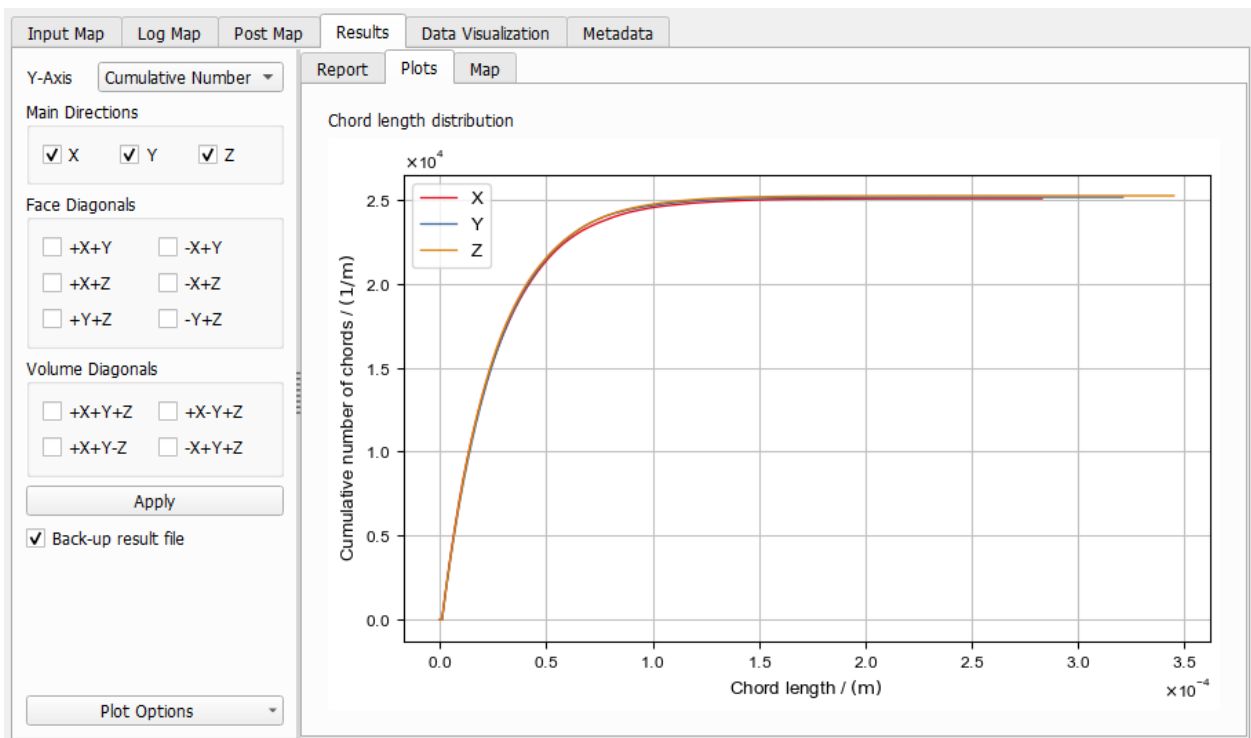
The fraction lengths table reports the chord lengths smaller than 10%, 50%, 90% of all chord lengths (L10, L50, L90). The P-values (P10, P50, P90) are the same, but rounded up to the next largest multiple of the voxel length.

For example, a L10 of 2.6 μm means that 10% of all chords are smaller than this length. A L50 of 17.4 μm means that 50% of all chords are smaller than this length. A L90 of 58.6 μm means that 90% of all chords are smaller than this length.

For P10 the L10 value of 2.6 is rounded up to 3e-6, because the voxel length is 1 μm , and it means that this length (3 μm) is larger than or equal to the length of 10% of all chords. A P50 of 1.8e-5 means that this length (18 μm) is larger than or equal to the length of 50% of all chords. A P90 of 5.9e-5 means that this length (59 μm) is larger than or equal to the length of 90% of all chords.

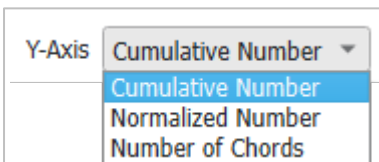
Plots Tab

The plot of the complete chord length distribution is shown in the **Results-Plots** subtab.



Post-processing options

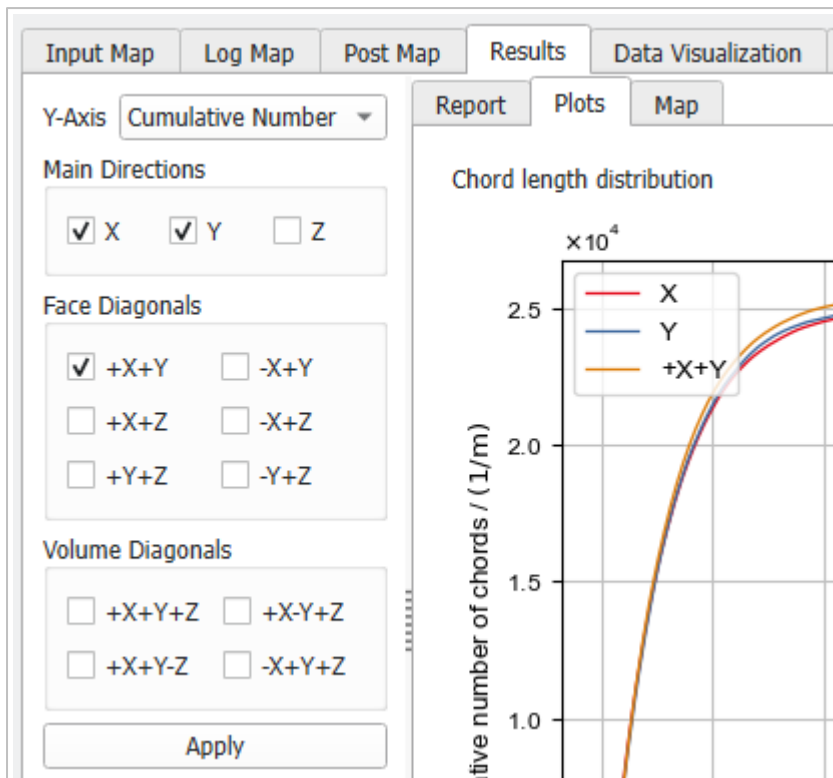
In the context menu on the left, the chord length distribution plot can be customized. For the **Y-Axis**, the **Cumulative Number**, the **Normalized Number**, or the **Number of Chords** can be selected.



The normalized number of chords is the difference quotient of the cumulative chord length distribution, where the step size is the current voxel length.

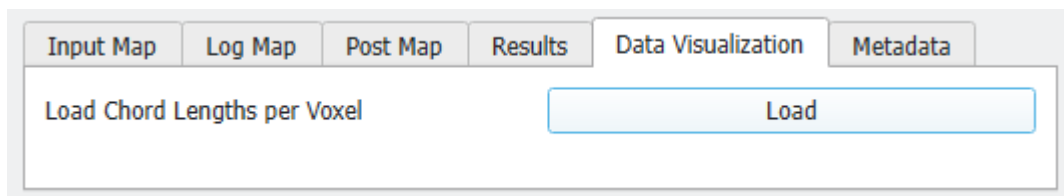
The normalized number of chords can be obtained from the number of chords histogram. For example, in X-direction it can be computed as follows: First, the number of chords is divided by $N_Y \cdot N_Z$, which equals the total number of rays, to obtain the number of chords per ray. Then, this number is normalized by $N_X \cdot \text{voxel length}$ to obtain the number of chords per meter. As the accuracy of the measurement of the chord length is restricted by the voxel length, the histogram bin size is also given in voxels. To reflect this, the number of chords per meter must again be divided by the voxel length (which equals the bin size) in the last step. This allows to compare results for structures with different voxel lengths.

In addition, if more than one direction was chosen for the computations, it can be chosen for which of these directions the distribution should be shown (**Main Directions**, **Face Diagonals**, **Volume Diagonals**). Click **Apply...** to update the displayed plot.

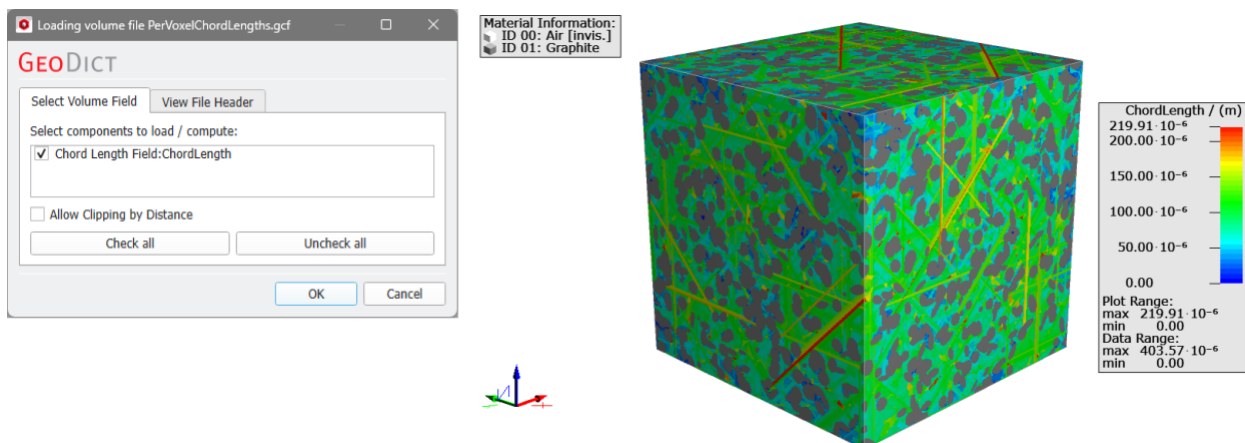


Data Visualization

If **Per-voxel chord length computation** was previously checked, you can click the **Load** button in the **Data Visualization** tab.



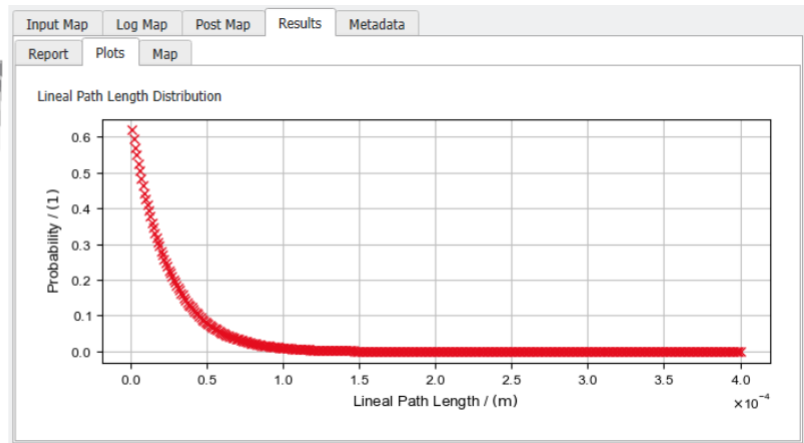
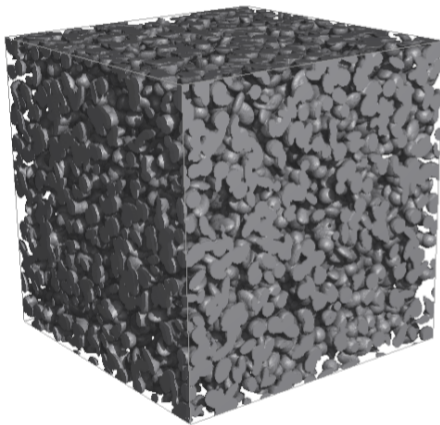
This loads a volume field, where for every voxel the minimal or maximal (depending on the selection in the options dialog) chord length over all chosen directions is saved.



1.2.8 Lineal Path Length Distribution

The **Lineal Path Length Distribution** calculates the probability that a random straight line segment consists of only one selected Material ID.

The Lineal Path Length Distribution is implemented as described in [Lu et al. \(1992\)](#)^[143].



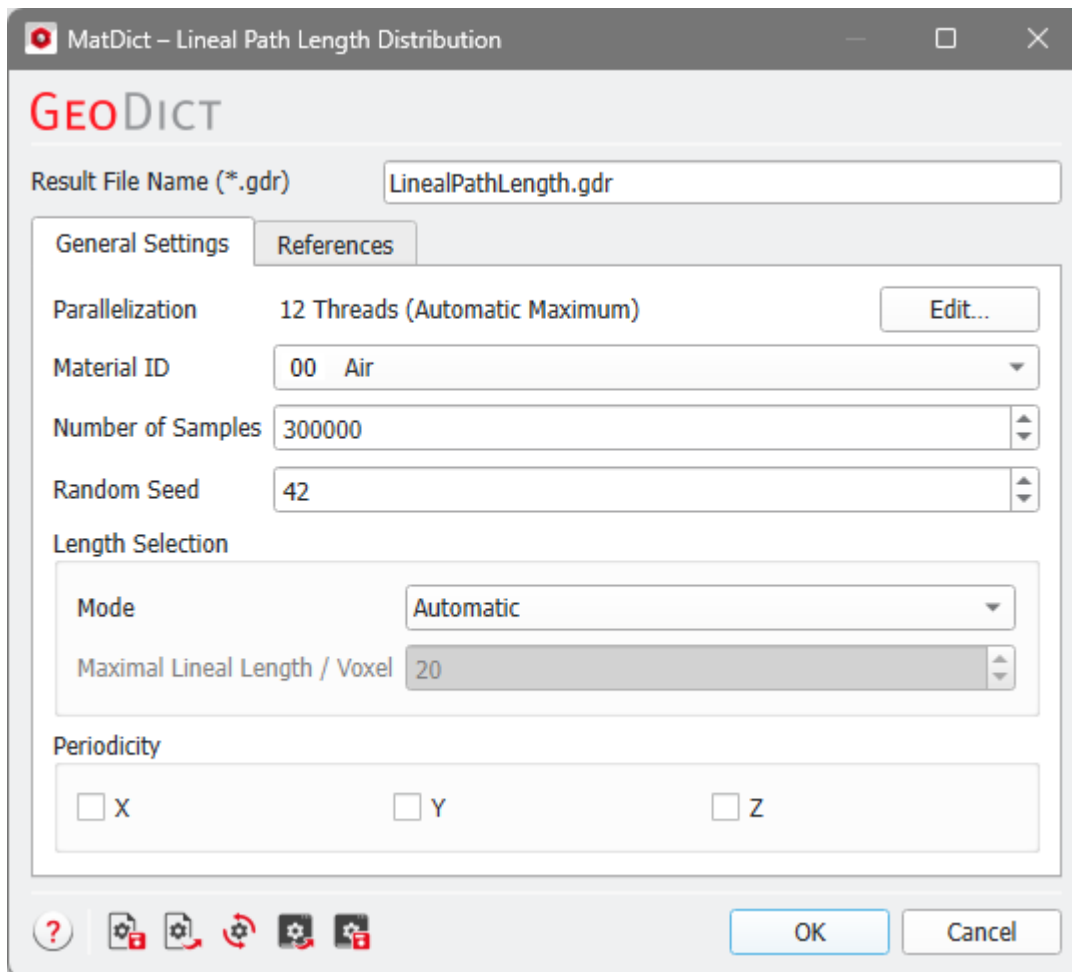
The **Lineal Path Length Distribution** command:

- [Options](#)^[94]
Set the parameters for the analysis.
- [Results](#)^[98]
View the computed results.

Options

The **Lineal Path Length Distribution** dialog opens when clicking the **Edit...** button and includes the **General Settings** tab and the **References** tab, which provides further information about the underlying algorithm and cites [Lu et al. \(1992\)](#)^[143].

At the top of the **Lineal Path Length Distribution** dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).

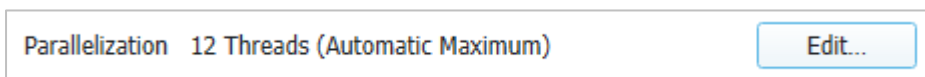


The settings are similar to those of [2-Point Correlation](#)¹⁰⁴.

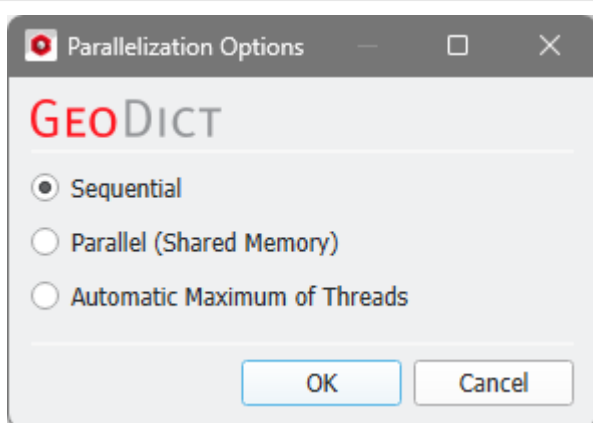
✓ Parallelization

Control how many threads are used for the computation. Parallelization is possible if your license and hardware allow it.

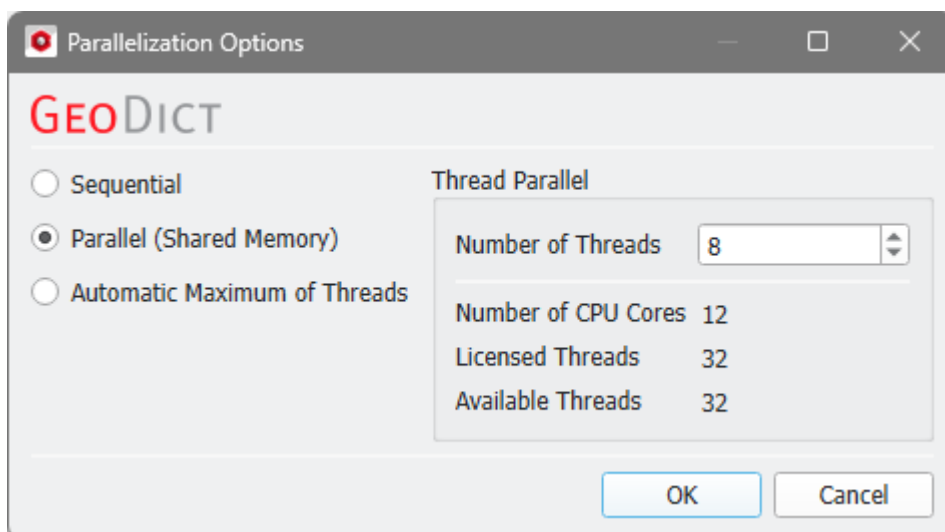
The **Parallelization Options** dialog opens when clicking the **Edit** button and you can choose between **Sequential**, **Parallel (Shared Memory)**, or **Automatic Maximum of Threads**.



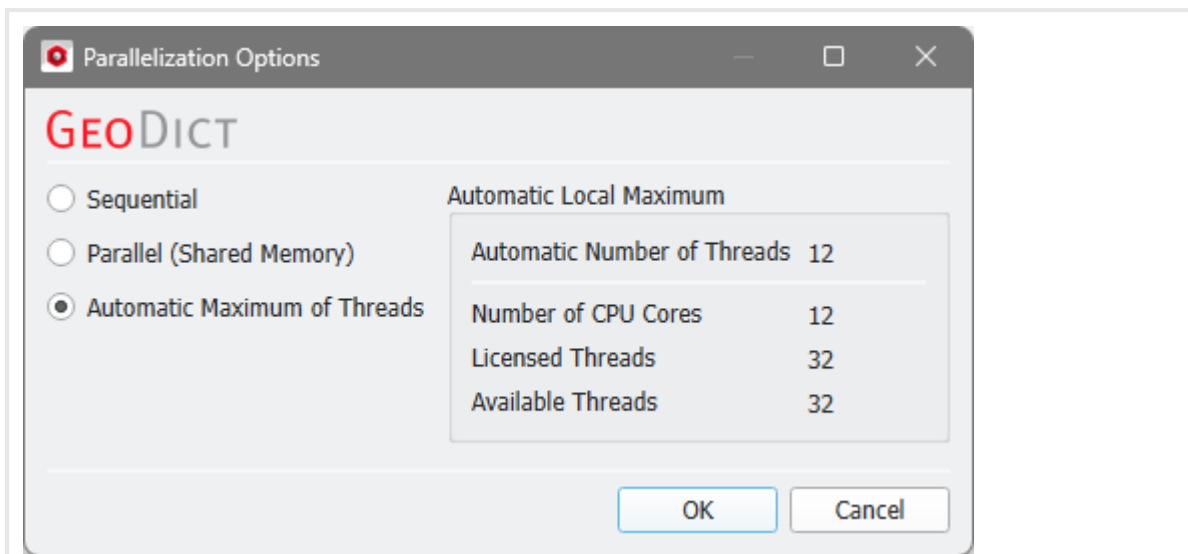
Selecting **Sequential** will not apply parallelization and only one thread is used for the computation.



When **Parallel (Shared Memory)** is selected, the **Number of Threads** can be entered. Below, the **Number of CPU Cores** that the current machine has, the maximum number of **Licensed Threads** and the number of those licensed threads that are available (**Available Threads**) are shown in the dialog. Of course, the maximal number of parallel processes you can use, is the smallest of those three numbers.



If **Automatic Maximum of Threads** is selected, the number of parallel processes is automatically selected for optimal speed, based on the CPU cores and licensed parallel processes.



The **Automatic Local Maximum** of processes is automatically selected, which is the minimum of **Number of CPU Cores**, **Licensed Threads**, and **Available Threads**.

✓ Material ID

Select the **Material ID** for which the lineal path length distribution is calculated.

Material ID	
01	Graphite
00	Air
01	Graphite
02	Graphite
03	Undefined
04	Undefined
05	Undefined
06	Undefined
07	Undefined
08	Undefined
09	Undefined

✓ Number of Samples and Random Seed

To determine the probability distribution of lineal path lengths, the algorithm generates a number of samples for each length. The **Number of Samples** specifies how many samples are generated per length. The **Random Seed** controls the random number generator. A different random seed results in the selection of a different set of random points. Increasing the number of samples increases the accuracy of the resulting distribution.

✓ Length Selection

Choose how the maximal lineal path length is determined.

Length Selection

Mode

Automatic

Maximal Lineal Length / Voxel

Automatic

Manual

In the **Automatic** mode, the **Maximal Lineal Length** is set to the length of the smallest domain side.

In **Manual** mode, you can enter any value for **Maximal Lineal Length** in voxel.

✓ Periodicity

If **Periodicity** is checked, the structure is treated as periodic in the selected directions. Thus, point samples can also be connected across domain boundaries.

If no **Periodicity** is selected in a direction, the structure is treated as encased. Thus, samples of lines where one point lies outside of domain are rejected.

Results

After the **Lineal Path Length Distribution** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains five tabs. The computational results are shown under the **Results** tab. The other four tabs (**Input Map**, **Log Map**, **Post Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

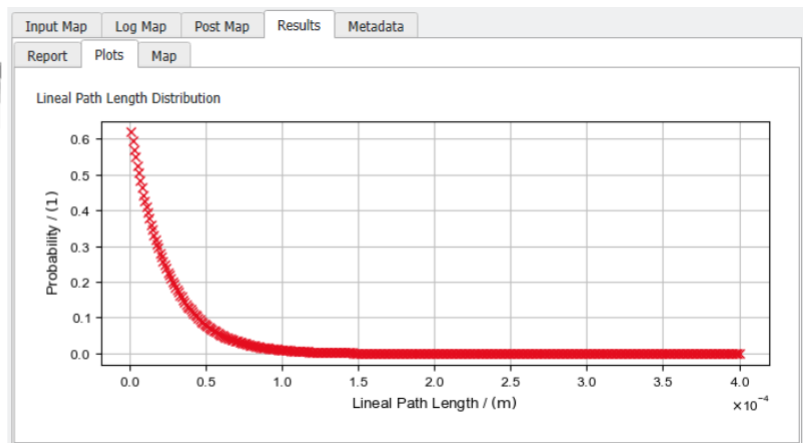
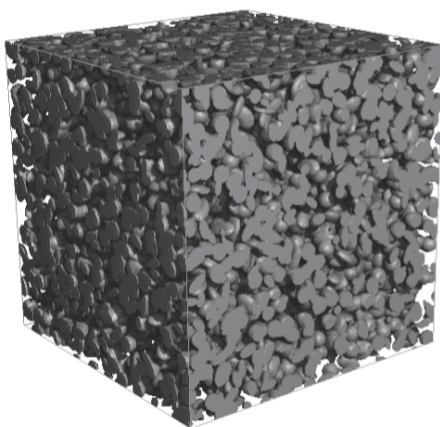
Report

In the **Results – Report** tab a table shows for each length (given in voxel and meters) the computed **Lineal Path Probability**. This is the probability that a lineal path of this length completely lies in the chosen Material ID.

Input Map	Log Map	Post Map	Results	Metadata
Report	Plots	Map		
Lineal Path Length Distribution				
Length / (Voxel)	Length / (m)	Lineal Path Probability		
1	1e-06	0.618487		
2	2e-06	0.595697		
3	3e-06	0.570003		
4	4e-06	0.548273		
5	5e-06	0.525317		
6	6e-06	0.50461		
7	7e-06	0.48422		
8	8e-06	0.463623		
9	9e-06	0.443137		

Plots

In the **Report – Plots** subtab, the values from the table are graphically shown as **Lineal Path Length Distribution** graph. In this example, the Lineal Path Length Distribution was computed for the pore space (Material ID 00).

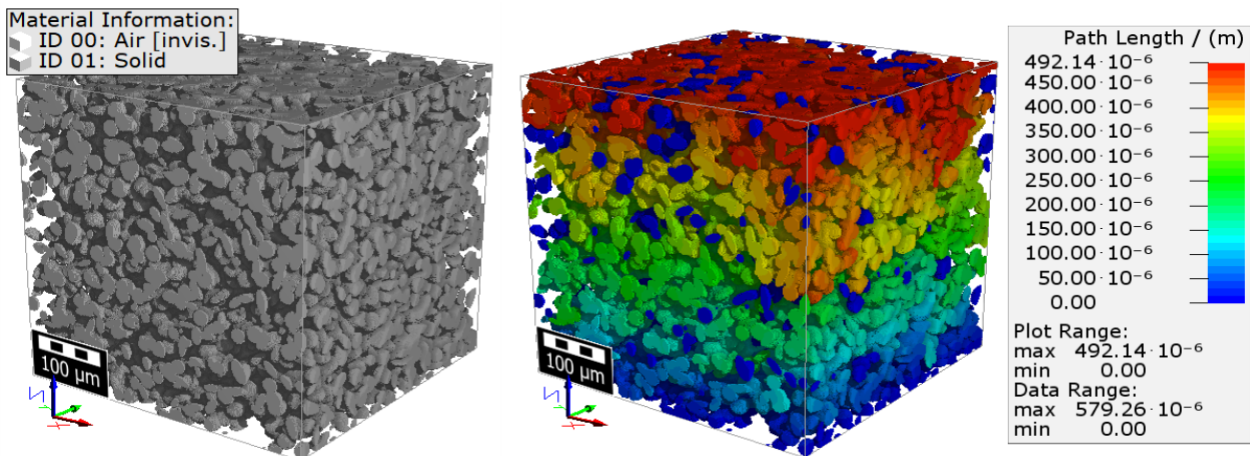


1.2.9 Geodesic Tortuosity

The **Geodesic Tortuosity** command is accessible from MatDict and PoroDict.

This command computes the tortuosity of paths crossing the material, either through pore space or through solid materials. For every voxel on the outflow plane, the algorithm finds the shortest path through the selected material.

The **Geodesic Tortuosity** dialog opens when clicking the **Edit...** button.



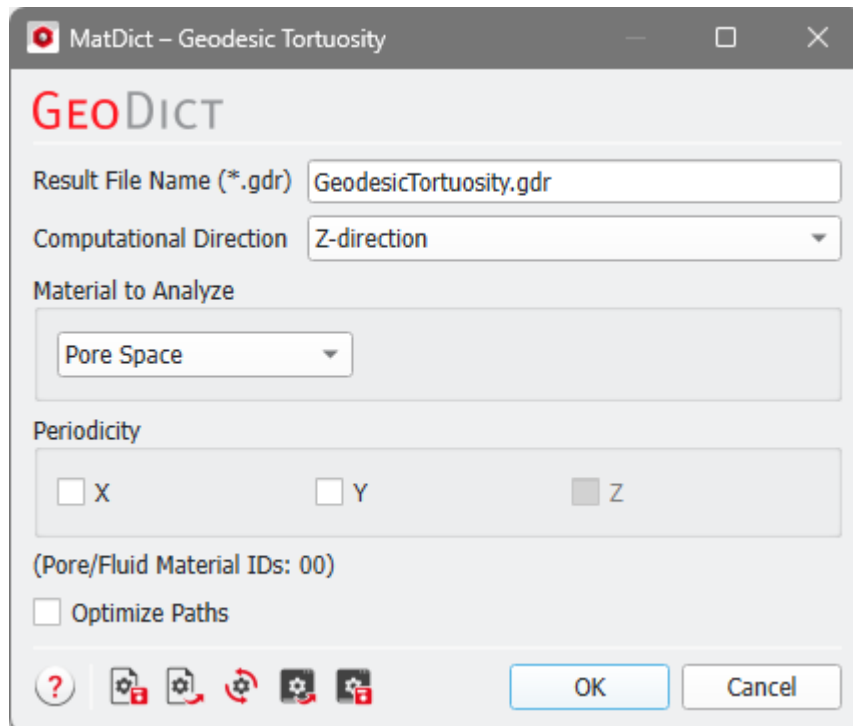
The Geodesic Tortuosity was computed in Z-direction for the solid grains.

The Geodesic Tortuosity command:

- [Options](#) ¹⁰⁰
Set the parameters for the analysis.
- [Results](#) ¹⁰²
View the computed results.

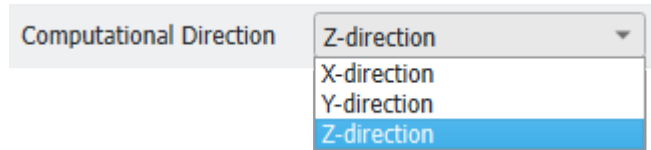
Options

At the top of the **Geodesic Tortuosity** dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).



✓ Computational Direction

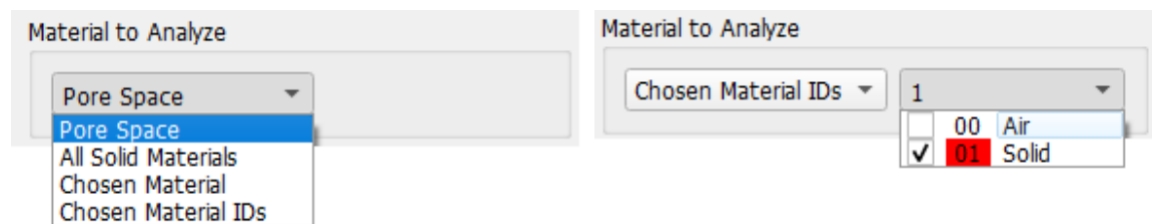
Set the direction of the paths by selecting the **Computational Direction**.



A dropdown menu titled "Computational Direction" with a list of options: "Z-direction", "X-direction", "Y-direction", and "Z-direction". The "Z-direction" option at the bottom is highlighted in blue.

✓ Material to Analyze

The algorithm searches for paths in the selected **Material to Analyze**, either **Pore Space**, **All Solid Materials**, **Chosen Material**, or a list of **Chosen Material IDs**.



Two screenshots of the "Material to Analyze" dialog. The left screenshot shows a dropdown menu with options: "Pore Space", "Pore Space", "All Solid Materials", "Chosen Material", and "Chosen Material IDs". The right screenshot shows a "Chosen Material IDs" dropdown set to "1", with a table below it:

☐	00	Air
☒	01	Solid

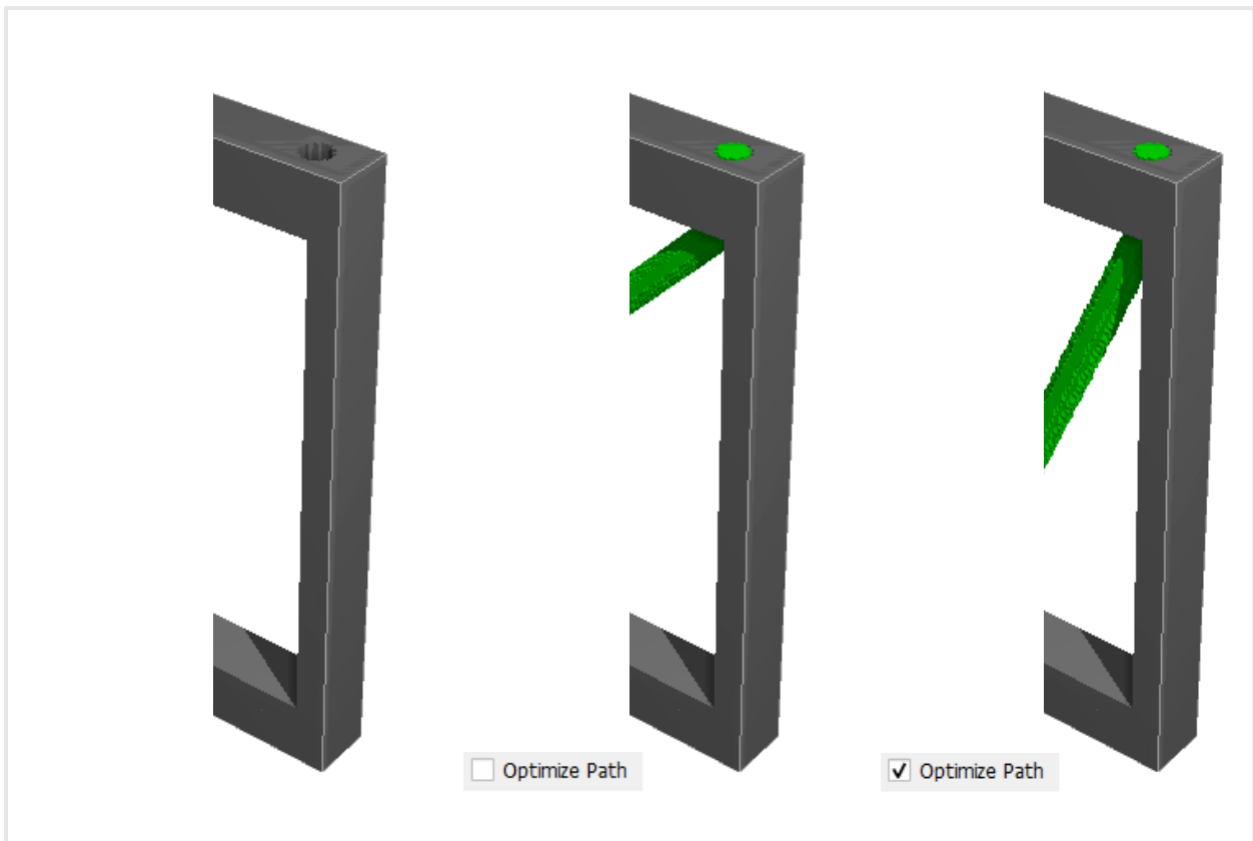
For your convenience, all Material IDs which denote pore space are shown at the bottom of the dialog.

✓ Periodicity

Paths might leave the domain and enter again on the opposite side if **Periodicity** is selected for one or both tangential directions. The chosen computational direction, however, cannot be chosen to be periodic.

✓ Optimize Path

With Optimize Path, the length of the path is optimized after the calculation. This shortens the calculated path by removing voxel staircase artifacts: The algorithm works on the voxel structure and can therefore only find paths which run directly through connected voxels. Therefore, the default method might not always find the best path in structures with large open pores. In these cases, it is recommended to select Optimize Path (see the examples below).



Results

After the **Geodesic Tortuosity** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains five tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Data Visualization** tab. The other three tabs (**Input Map**, **Log Map**, and **Metadata**) display additional information about the computation.

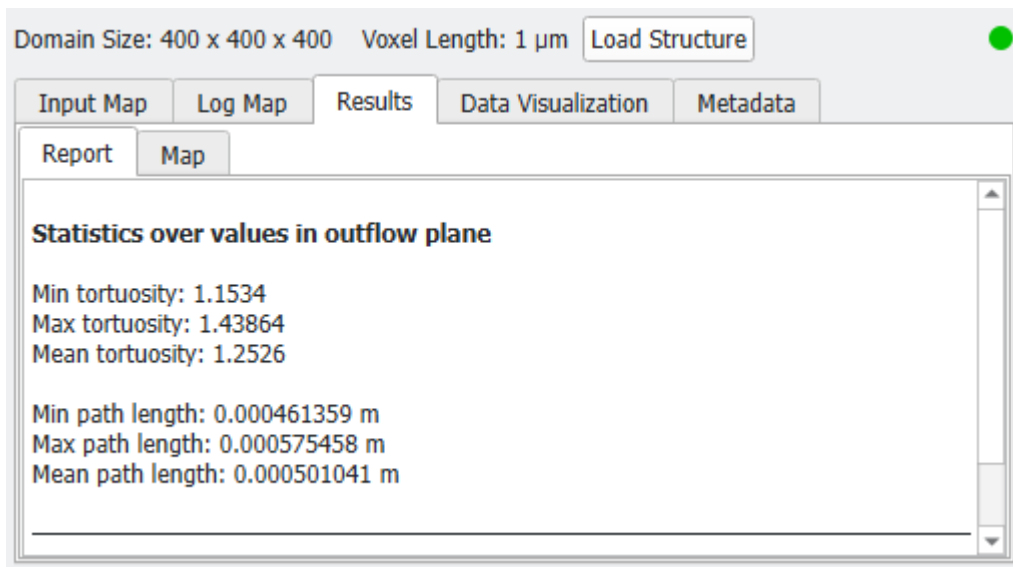
Find more details on the general functionalities in the Result Viewer user guide.

For every voxel on the outflow plane, the algorithm finds the shortest path through the selected **Material to Analyze**. The corresponding geodesic tortuosity is then computed as

$$\tau = \frac{\text{shortest path to inflow plane}}{\text{distance to inflow plane}}$$

(4) Geodesic
Tortuosity

In the **Results - Report** tab, the minimal, maximal, and mean geodesic tortuosity are shown. The corresponding minimal and maximal path lengths and the mean length of all paths are also given.

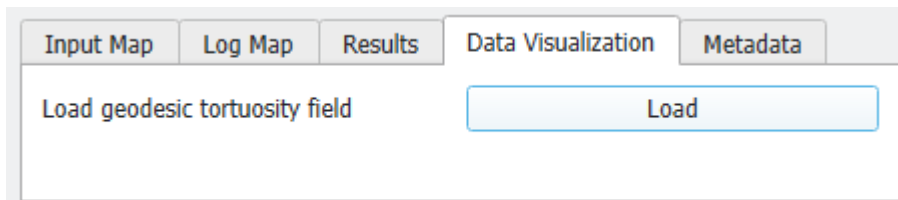


Geodesic Tortuosity Results:

- [Data Visualization](#)¹⁰³
Load results for a graphical visualization.

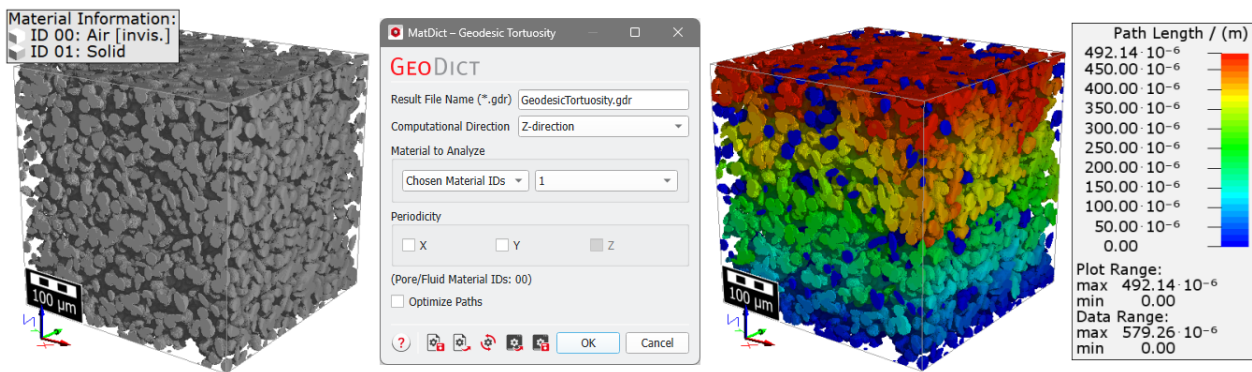
Data Visualization

The **geodesic tortuosity field** can also be visualized through the **Data Visualization** tab when clicking the **Load** button.



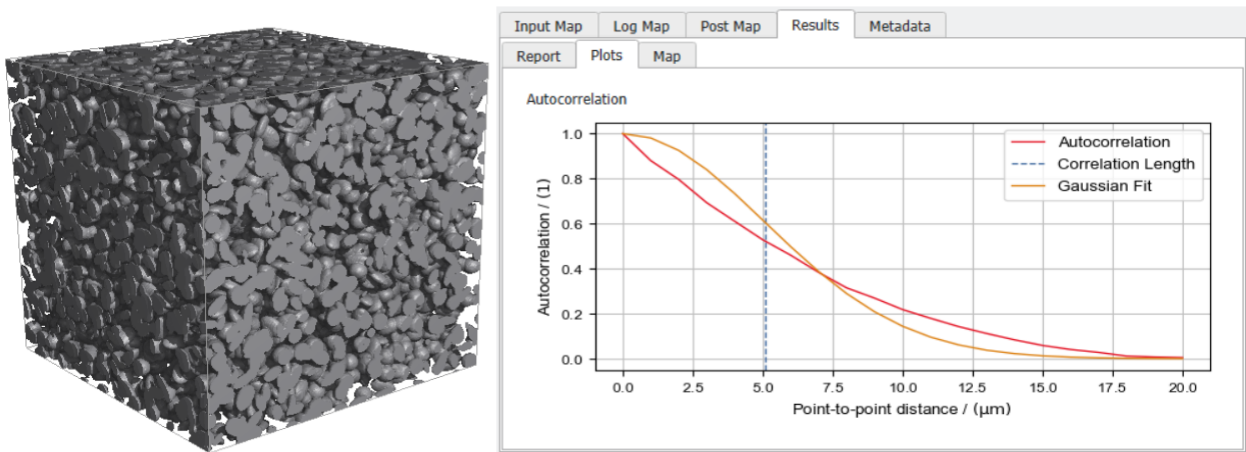
It contains for each voxel the shortest path distance between this voxel and the inflow plane. Therefore, on the inflow plane all voxels contain the value 0. Voxels that do not belong to the **Material to Analyze** also have the value 0.

In the example below, the visualization of the geodesic tortuosity field is only activated for Material ID 01 on which the calculations were performed. The inflow plane is Z- and you can observe the grains that are not connected to this plane. These are the blue grains in the upper Z-slices.



1.2.10 2-Point Correlation

The **2-Point Correlation** command computes the probability for two voxels having a certain distance to belong to the same material phase. For each distance, several voxels are compared if they belong to the same phase and a probability is computed based on this information. If two voxels are correlated, the probability is 1, if they are not correlated, for example in a completely random structure, the probability is 0. An average probability for each distance is given as result.



Isotropic correlation was computed for a maximum point-to-point distance of 20 µm.



New in GeoDict 2026

- You can now also compute on index images ([Geometry Mode](#)¹⁰⁵) and you are able to choose how the calculated correlation function is [normalized](#)¹⁰⁷.
- Additionally, the resulting [plots](#)¹⁰⁸ have been revised.

The 2-Point Correlation command:

- [Options](#)¹⁰⁵
Set the parameters for the analysis.
- [Results](#)¹⁰⁸

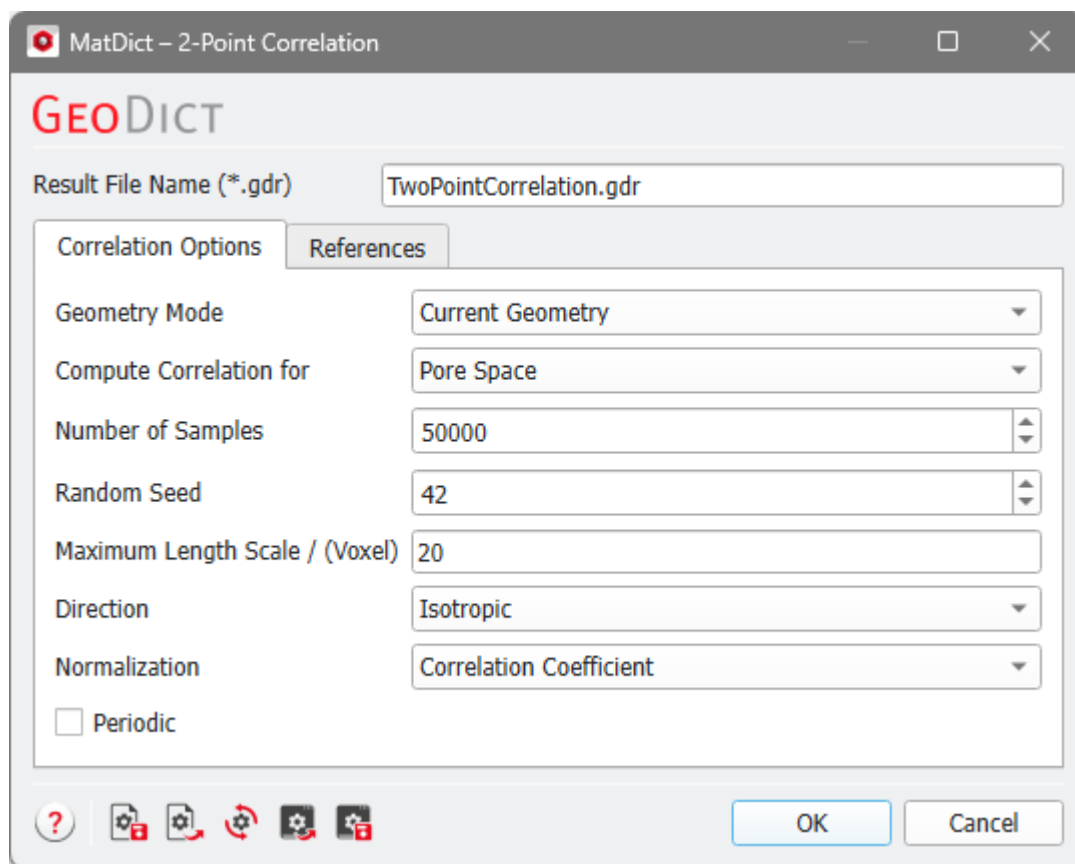
The 2-Point Correlation command:

View the computed results.

Options

The **2-Point Correlation** dialog opens when clicking the **Edit...** button and includes the **Correlation Options** tab and the **References** tab, which provides further information about the underlying algorithm and cites [S. Blair](#)^[143] and [S. Torquato](#)^[143].

At the top of the **2-Point Correlation** dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).



✓ Geometry Mode

From the **Geometry Mode** pull-down menu decide if you want to compute the two point correlation on the currently loaded structure (**Current Geometry**) or on the **Current Index Image** (for example from a GrainFind - Identify Grains run). In the second case, the name of the currently loaded index image is displayed below.

Geometry Mode	Current Index Image
Index Image (*.g32)	Grains.g32

If you compute on an index image, it gives the probability that two points at a certain distance belong to the same object or cluster, i.e., they share the same index.

✓ Compute Correlation for

If you choose the Geometry Mode **Current Geometry**, you have to select for which material phases you want to **Compute Correlation for**.

Either **Pore**, **Chosen Material**, or **Chosen Material IDs** can be selected.

Compute Correlation for	Pore Space
	Pore Space
	Chosen Material
	Chosen Material IDs

The current structure is then converted into a binary image where the value of a voxel is set to 1, if the voxel belongs to the chosen material phase, and 0 if not. This binary image is used to calculate the correlation function.

If you select **Chosen Material**, choose one of the materials present in the structure from the pull-down menu below.

Compute Correlation for	Chosen Material
Choose Material	Air
	Air
	Graphite

With the mode **Chosen Material IDs**, you can select multiple Material IDs, also of different assigned materials.

Compute Correlation for	Chosen Material IDs
Choose Material IDs	1
	☐ 00 Air
	☒ 01 Graphite

✓ Number of Samples and Random Seed

To find the probability distribution for different distances, several samples of point pairs for each distance are generated. The **Number of Samples** determines how many point pairs are generated. For different **Random Seeds** different randomly chosen points are compared if they belong to the same type. The resulting probability is more accurate the more samples are taken.

✓ Maximal Length Scale

The **Maximal Length Scale / (Voxel)** defines the largest distance for which correlations are computed.

Only distances smaller or equal than the domain size in the computational direction are allowed. If **Isotropic** is chosen as direction, the distance is not allowed to be larger than the smallest domain length.

However, in case **Periodic** is checked, the entered length is allowed to be larger than the domain size. In this case the correlation repeats periodically.

✓ Direction

The correlation can be calculated either in **X Direction**, **Y Direction**, or **Z Direction** or as an average over all three directions by choosing **Isotropic**.

Direction	Isotropic ▼
	X-Direction
	Y-Direction
	Z-Direction
	Isotropic

✓ Normalization

Two different methods to normalize the computed correlation function are available: **Correlation Coefficient** and **Probability** (new in GeoDict 2026).

Normalization	Correlation Coefficient ▼
	Correlation Coefficient
	Probability

- For **Correlation Coefficient**, the correlation value varies between -1 and 1, where 1 means perfect correlation, 0 means no correlation, and the value -1 means perfect anti-correlation. The correlation function is scaled by the variance of the selected phase, such that for distance 0, the correlation is always 1, since a voxel has always the same property as itself.
- When choosing **Probability**, the correlation function has values between 0 and 1, as it measures the probability that two points at a certain distance belong to the same phase. At distance 0 the correlation equals the phase volume fraction of the material phase selected under **Compute Correlation for**. If for example **Pore** is selected, the correlation at distance 0 equals the solid volume fraction of the structure. For very large distances, the correlation tends to the square of the phase volume fraction. Both the phase volume fraction and its square are shown in the resulting [correlation plot](#)¹⁰⁸.

✓ Periodic

If **Periodic** is checked, the structure is assumed to be periodic in the chosen computational directions. Thus, point samples can also be connected across domain boundaries.

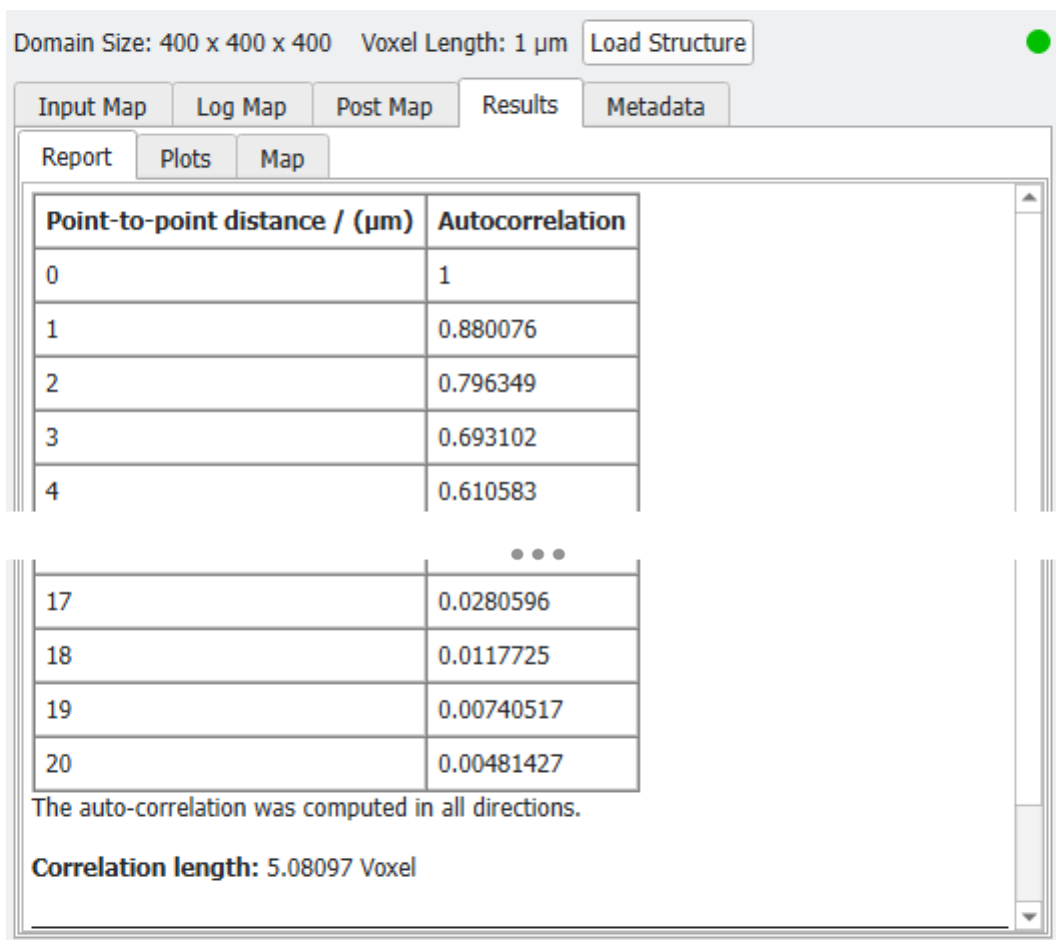
Results

After the **2-Point Correlation** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains five tabs. The computational results are shown under the **Results** tab. The other four tabs (**Input Map**, **Log Map**, **Post Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

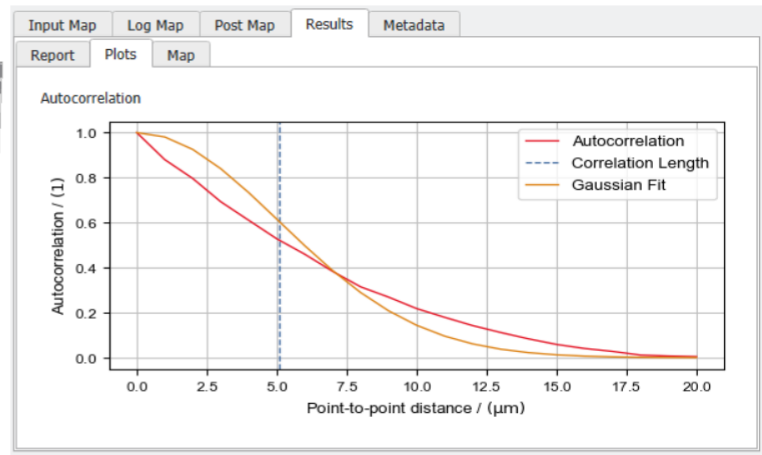
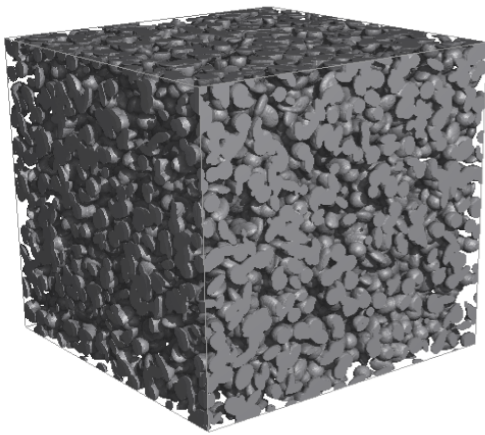
Report

In the **Results – Report** tab a table shows for each distance the computed **Autocorrelation** of two points having this distance. Below the table, the computed direction is shown. At the bottom, the **Correlation Length** in voxels is given. It is computed as the standard deviation of the fitted gaussian.

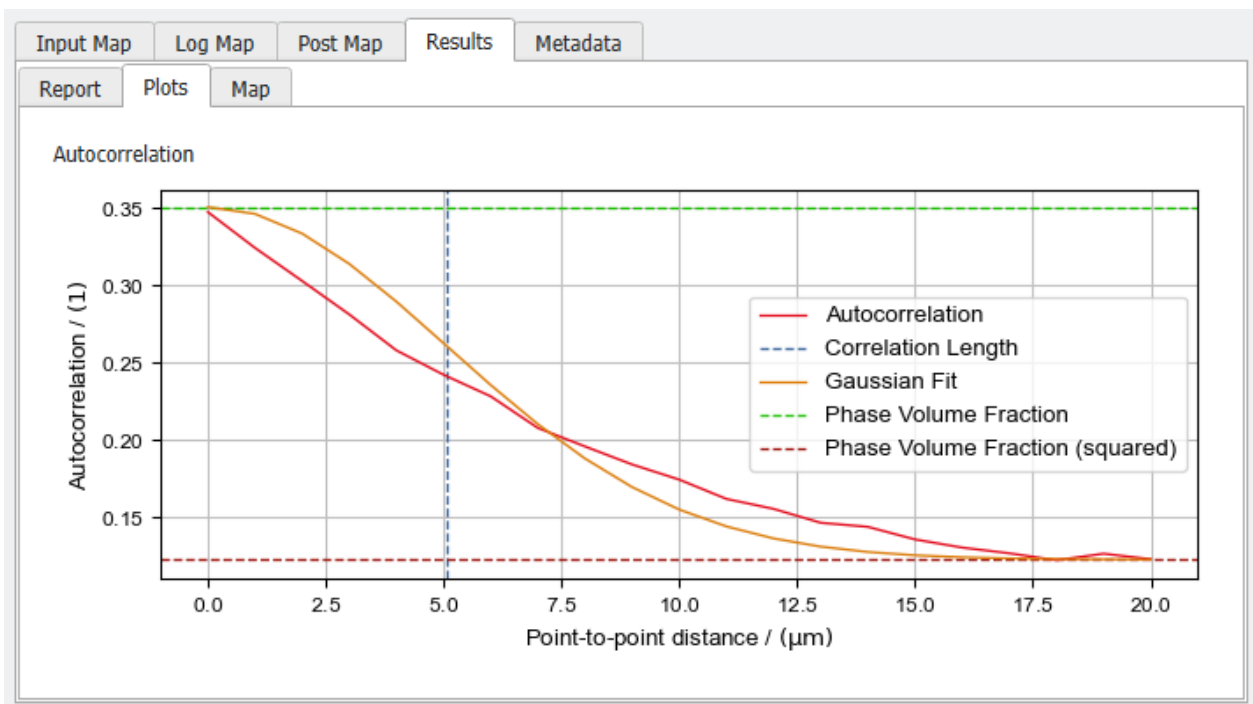


Plots

In the **Report – Plots** subtab, the values from the table are graphically shown as **Autocorrelation** graph (here red). The reported **Correlation Length** is visualized with the blue dashed line, as well as the **Gaussian Fit** (here yellow) that was used to calculate the correlation length.



The plots have additional graphs if the normalization mode **Probability**^[107] is selected. The **Phase Volume Fraction** and the **Phase Volume Fraction (squared)** are additionally plotted. They support the visualization of the correlation function that is limited by these two values.



1.3 GAD Objects Analysis

Select one of the **GAD Objects Analysis** commands from the second pull-down menu and click **Edit...** to enter the parameters for the simulation.

Commands of GAD Objects Analysis:

- [Analyze Objects](#)¹¹⁰
Analyze different properties, such as object overlap and contacts, of the analytic objects in the structure.
- [GAD Objects Orientation](#)¹²⁸
Calculate the direction tensor and anisotropy for individual classes of GAD objects.

1.3.1 Analyze Objects

With the **Analyze Objects** command, you can analyze the geometrical objects forming the 3D micro-structure, e.g., fibers, spheres, or ellipsoids, and how they are in contact with each other. Therefore, this command requires that the structure is not only described by a voxel grid, but also that the underlying **Analytic Object Data (GAD Data)** is available. Alternatively, you can analyze an index image of objects, e.g., the resulting index image from an Identify Grains analysis of a segmented gray-value image.

The analysis includes the total number of GAD objects, number of overlap objects (i.e. the overlaps between different objects), number of objects, overlap solid volume percentage, total number of contacts, mean coordination number, and the individual volume of each component. It provides histograms for object volume and contact area.



New in GeoDict 2026

- When analyzing Object Contacts, a coordination number histogram is generated.

The **Analyze Objects** command:

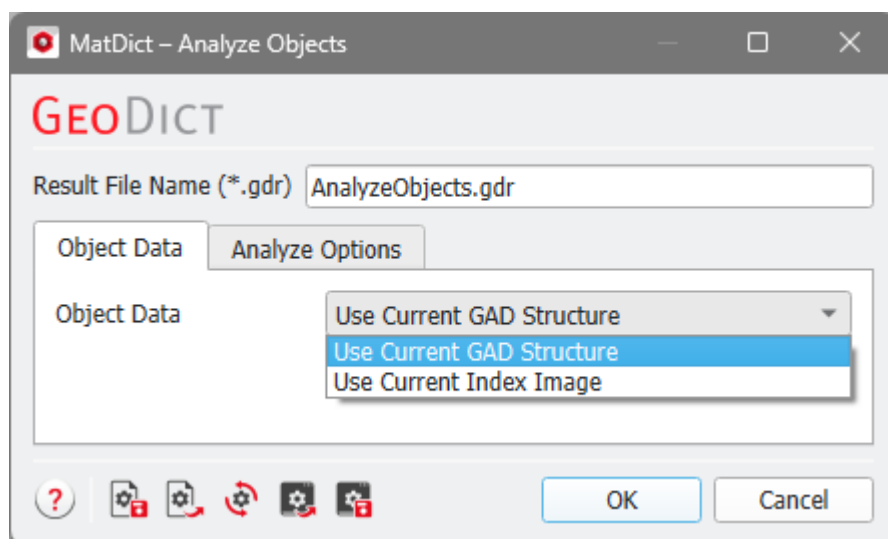
- [Options](#)¹¹⁰
Set the parameters for the analysis.
- [Results](#)¹¹⁴
View the computed results.

Options

The **Analyze Objects** dialog opens when clicking the **Options' Edit...** button and includes the **Object Data** and the **Analyze Options** tabs.

At the top of the dialog, enter a **Result File Name**.

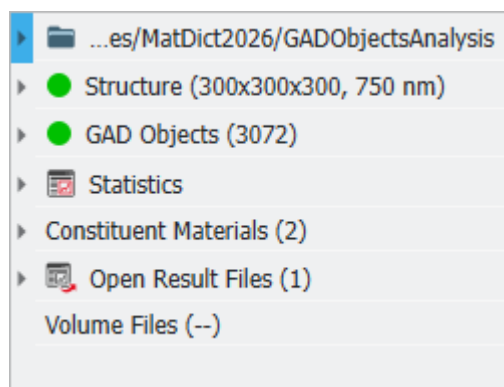
Object Data



The necessary geometrical information required by the analysis can be taken from two different sources:

Use Current GAD Structure

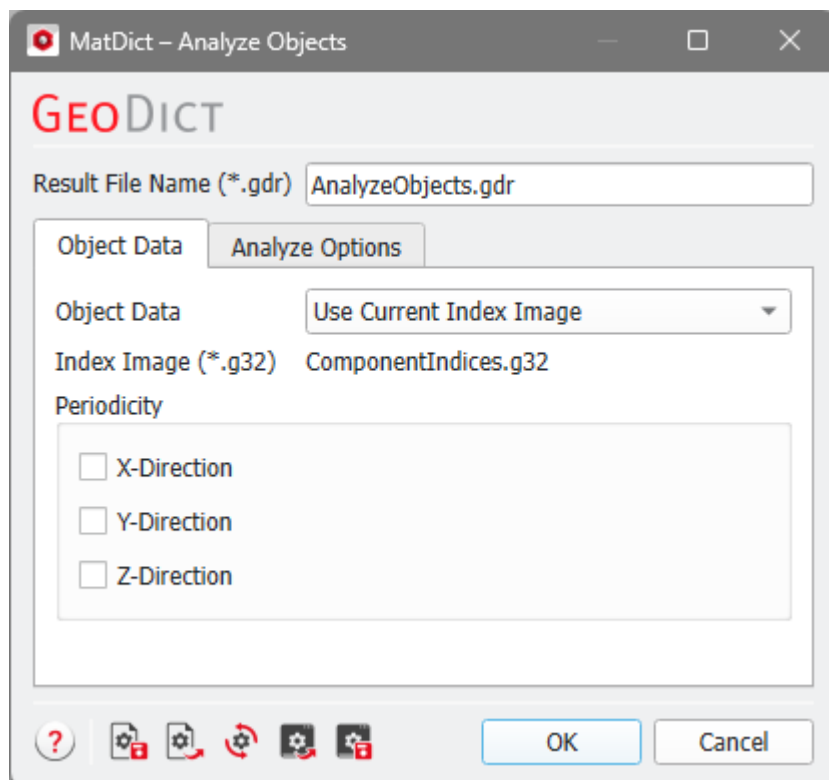
Select this if analytic data is already available in the current 3D structure. If this is the case, a green dot is displayed in the **GAD Objects** row in the Project Status section, at the left of the GUI.



Use Current Index Image

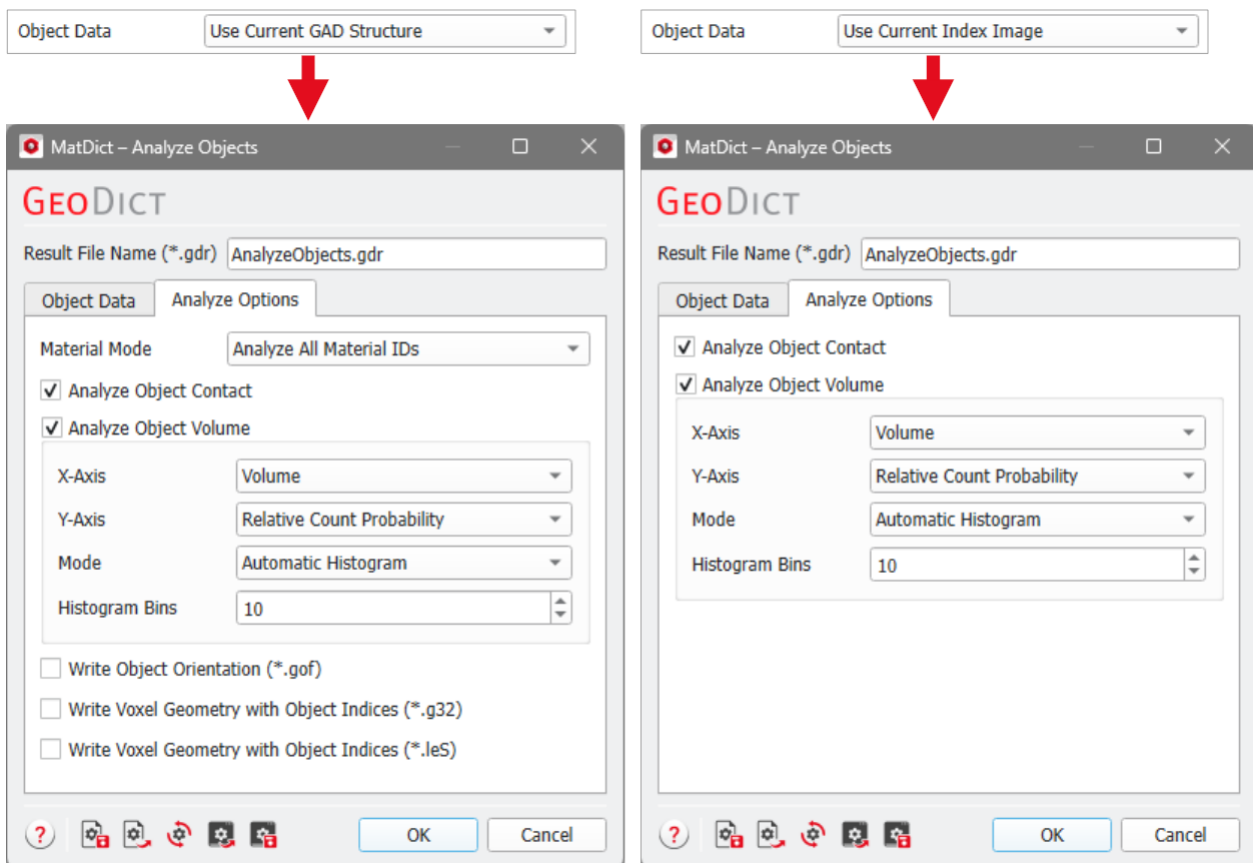
To use this option, a *.g32 file must be loaded as Volume Field. This file type might be the result of object analysis commands in GeoDict, e.g., the [Connected Components](#)⁵⁹ analysis.

Additionally, you can select the **Periodicity** of the domain if necessary. This option is not available if the current structure is chosen as source, because the periodicity is saved in the analytic data.

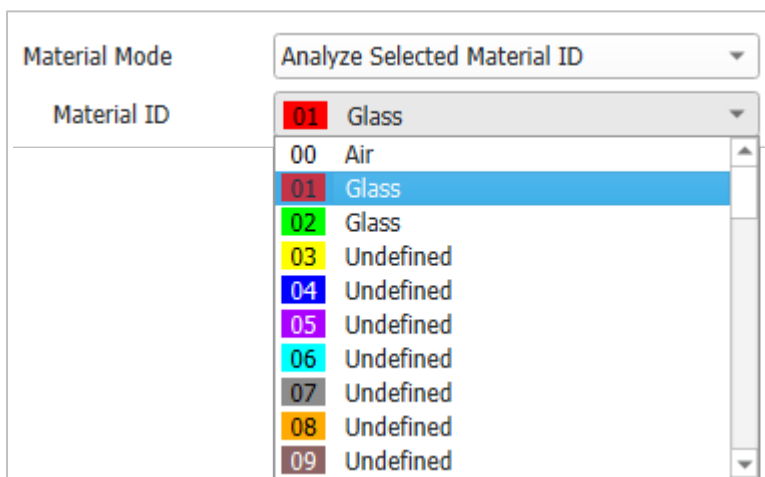


Analyze Options

The content of this tab depends on the selection in the **Object Data** tab.



In the **Material Mode** pull-down menu, choose **Analyze All Material IDs** to analyze all materials present in the structure, or select **Analyze Selected Material ID** to analyze only one Material ID which must be chosen from the appearing pull-down menu. This is only available if **Use Current GAD Structure** is checked as no Material IDs are saved in the Index Images.



When **Analyze Object Contact** is checked, the number of contacts and the mean coordination number are computed. Additionally, histograms of the contact area and the coordination number are plotted and a *.gdt file with the [objects and their contacts](#)¹²³ is written and saved as **Contacts.gdt** in the result folder.

When **Analyze Object Volume** is checked, the volume of each object is computed, and a histogram of all object sizes is created. The parameters in the panel below the checkbox

describe the settings for the object volume histogram plot. They can also be changed in the post-processing step and are explained in the [Results](#)^[121] section.



Know how! As the object volume is calculated based on the voxel counts, the result depends on the resolution of the structure.

If **Use Current GAD Structure** is selected in the **Object Data tab**, the following options appear in the Analyze Options tab:

Check **Write Object Orientation (*.gof)** to save a **GeodDict Orientation File (gof)** which contains the [orientation of the objects](#)^[125] and is saved as **ObjectOrientation.gof**.

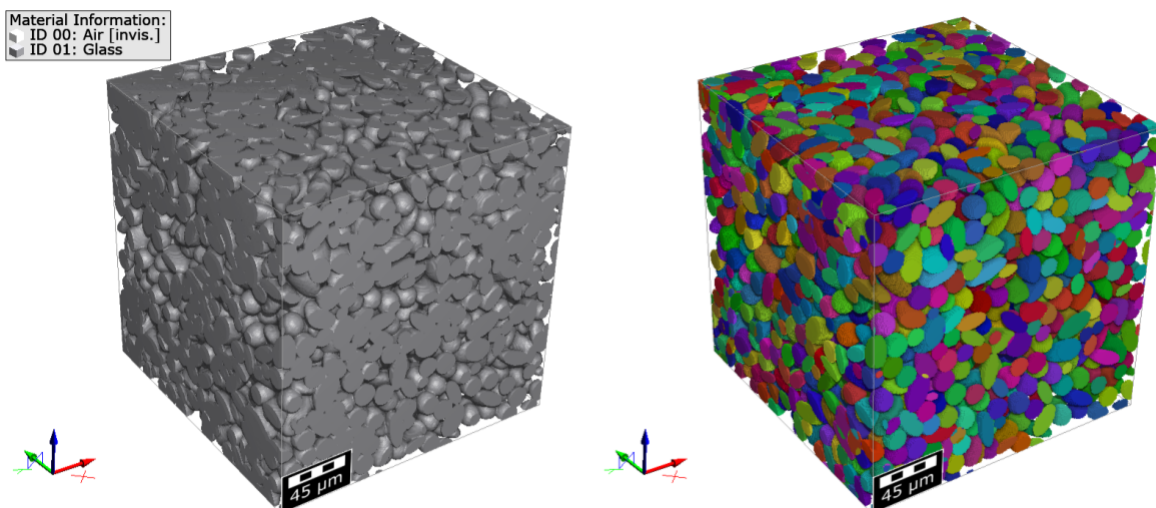
Check **Write Voxel Geometry with Object Indices (*.g32)** or **Write Voxel Geometry with Object Indices (*.leS)** saves an [index image of the objects](#)^[126] in the current structure. Choosing these options generates one file in GeoDict's format in binary format (*.g32) or one file in human readable ASCII format (*.leS).

Results

After the **Analyze Objects** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains six tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Data Visualization** tab. The other four tabs (**Input Map**, **Log Map**, **Post Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

As an example, we analyze a grain structure with analytic data and the structure which was converted to an index image using Create GAD Index Image from GadGeo.



Analyze Objects Results:

- [Results Tab](#)^[115]

Analyze Objects Results:

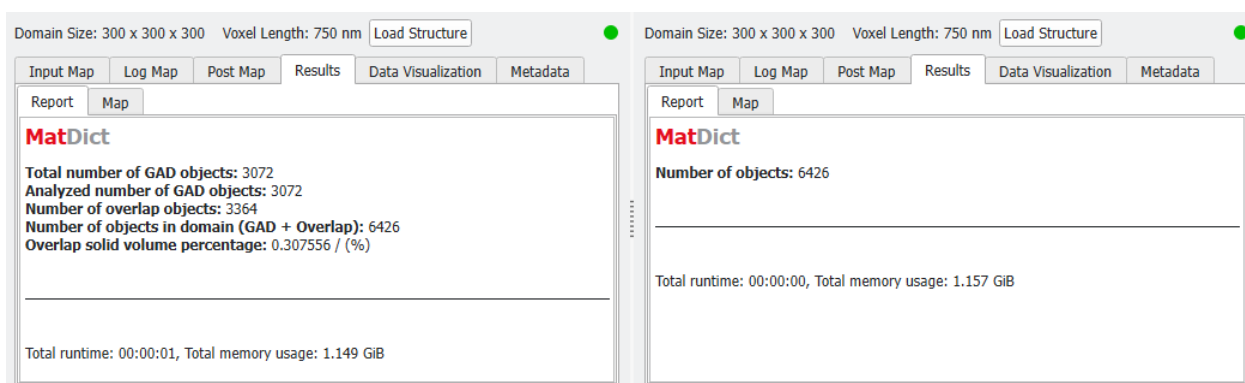
Observe the computed results and plots.

- [Data Visualization](#)^[122]

Load results for a graphical visualization.

Results Tab

The content of the Results tab differs, depending on the origin of the [Object Data](#)^[110] and the chosen [Analyze Options](#)^[112].



Left: Use Current GAD Structure

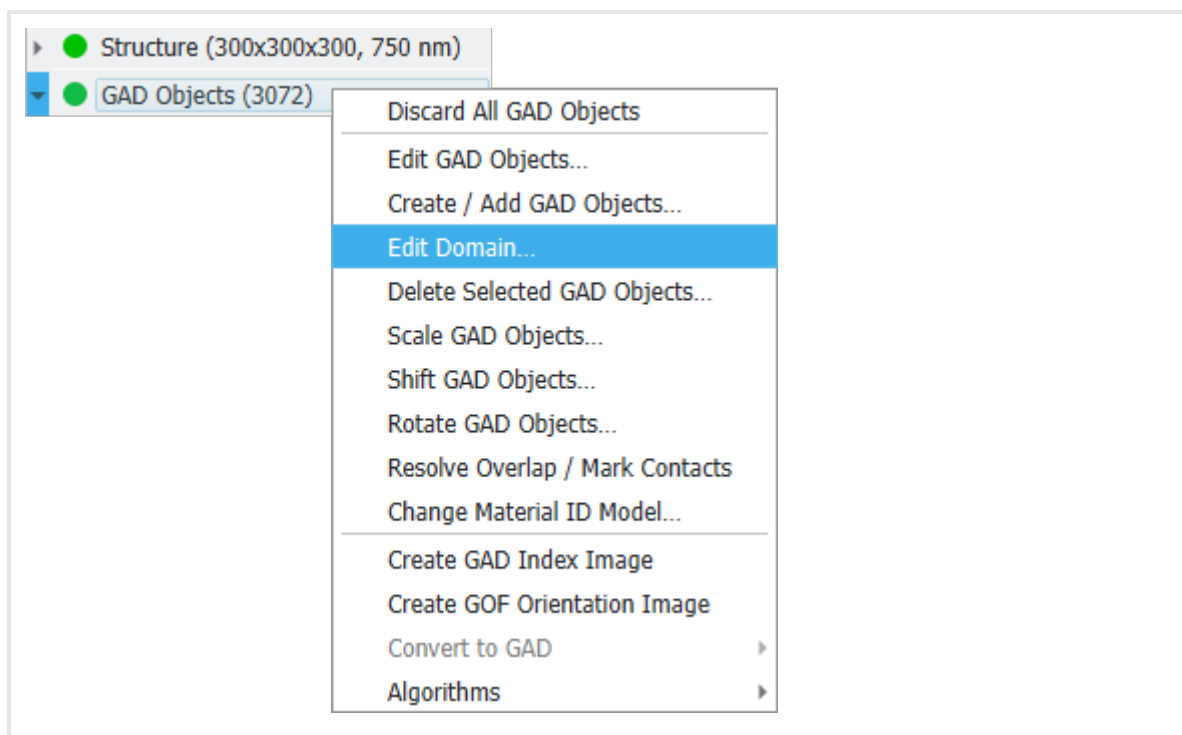
Right: Use Current Index Image

✓ Results for Use Current GAD Structure

In the **Results - Report** subtab, the following values are reported:

- **Total number of GAD objects** is the number of all analytical objects present in the 3D structure.
- **Analyzed number of GAD objects** is the number of objects considered in the analysis. This number is different from the above number if **Analyze Selected Material ID** was chosen. In this case only the number of GAD objects of the selected Material ID is reported here.
- The **Number of overlap objects** counts how many overlaps between GAD objects are present in the structure.
- The **Number of objects in domain (GAD + Overlap)** is the sum of the total number of GAD objects and the number of overlap objects inside the current domain. It is possible that some objects lie completely outside of the domain, and in this case, they are not counted here.
- **Overlap solid volume percentage** is the volume fraction of the overlap objects.

The resulting numbers depend on the way overlapping objects are treated. How overlap is handled is typically defined at the creation of the structure but can also be modified later using the **Edit Domain** command from the **GAD Objects** context menu in the status section.



✓ Results for Use Current Index Image

In this case, only the number of objects is reported. No overlap is present in index images as each voxel is assigned to a unique index.

In this example, each overlap object has its own index.

✓ Results for Analyze Object Contact

If **Analyze Object Contact** was checked in the [Analyze Options](#)¹¹² tab, the total number of contacts and the mean coordination number are additionally reported in the **Contact** section of the report.

Contact:

Total number of contacts: 12999

Mean coordination number: 4.04575

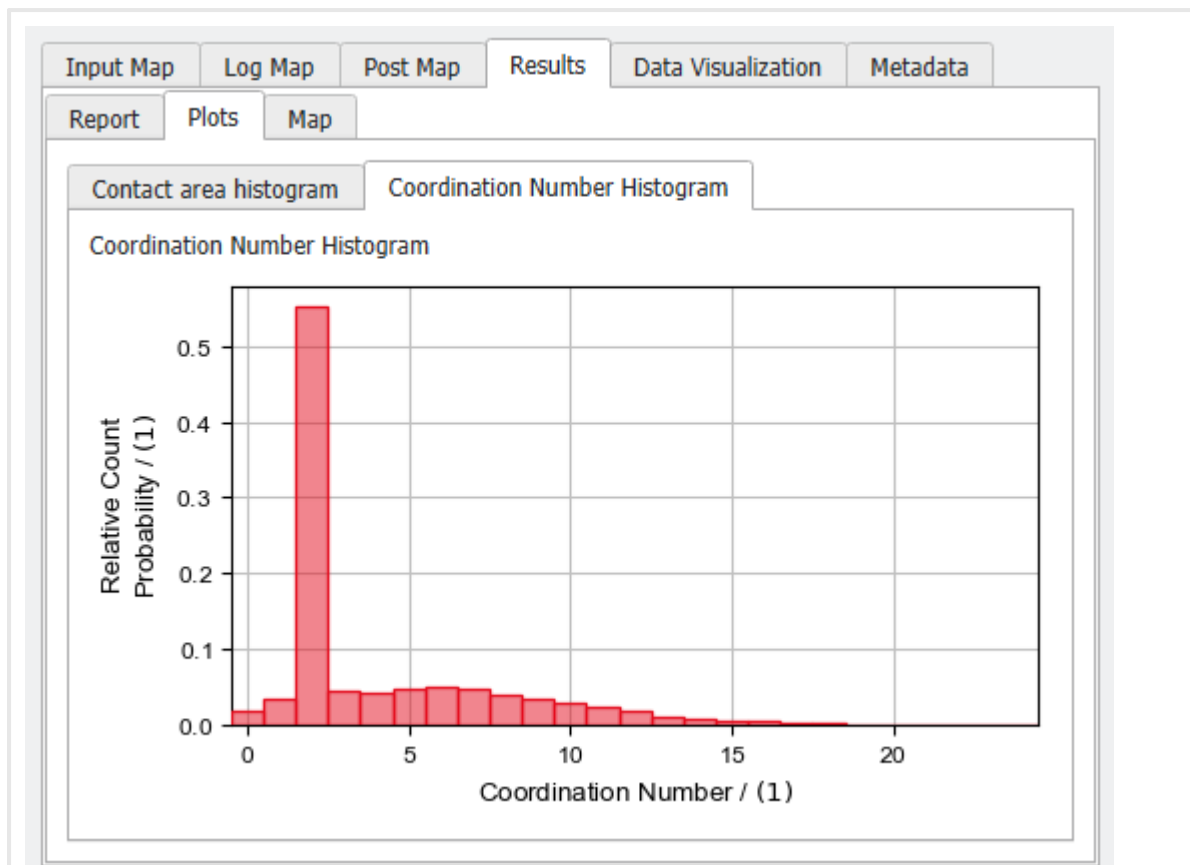
Information: the result map contains detailed object-contact information

Here, the **Mean Coordination Number** is defined as:

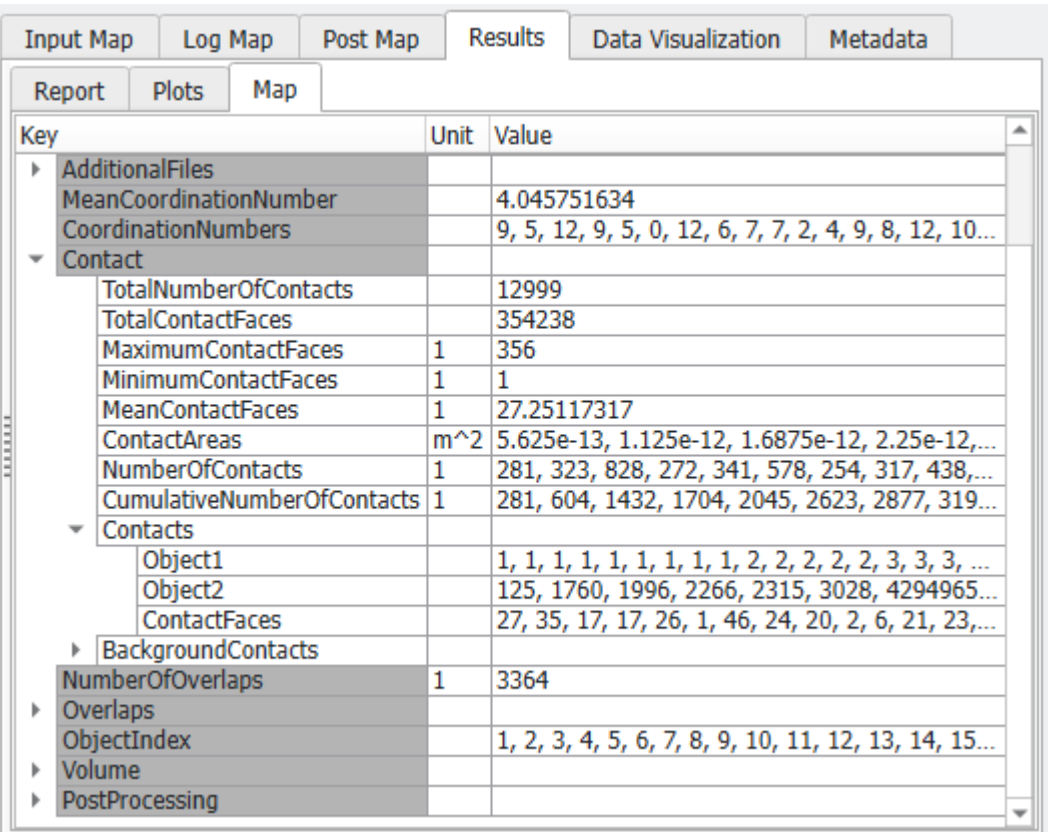
$$\frac{2 * \text{Total Number of Contacts}}{\text{Number of Objects in Domain (GAD + Overlap)}}$$

(5) Mean
Coordination
Number

A histogram of the coordination numbers is added to the **Results - Plots** subtab.



Its functionality is identical to the coordination number histogram in Identify Grains. More detailed results for all contacts are available under the **Results - Map** subtab:

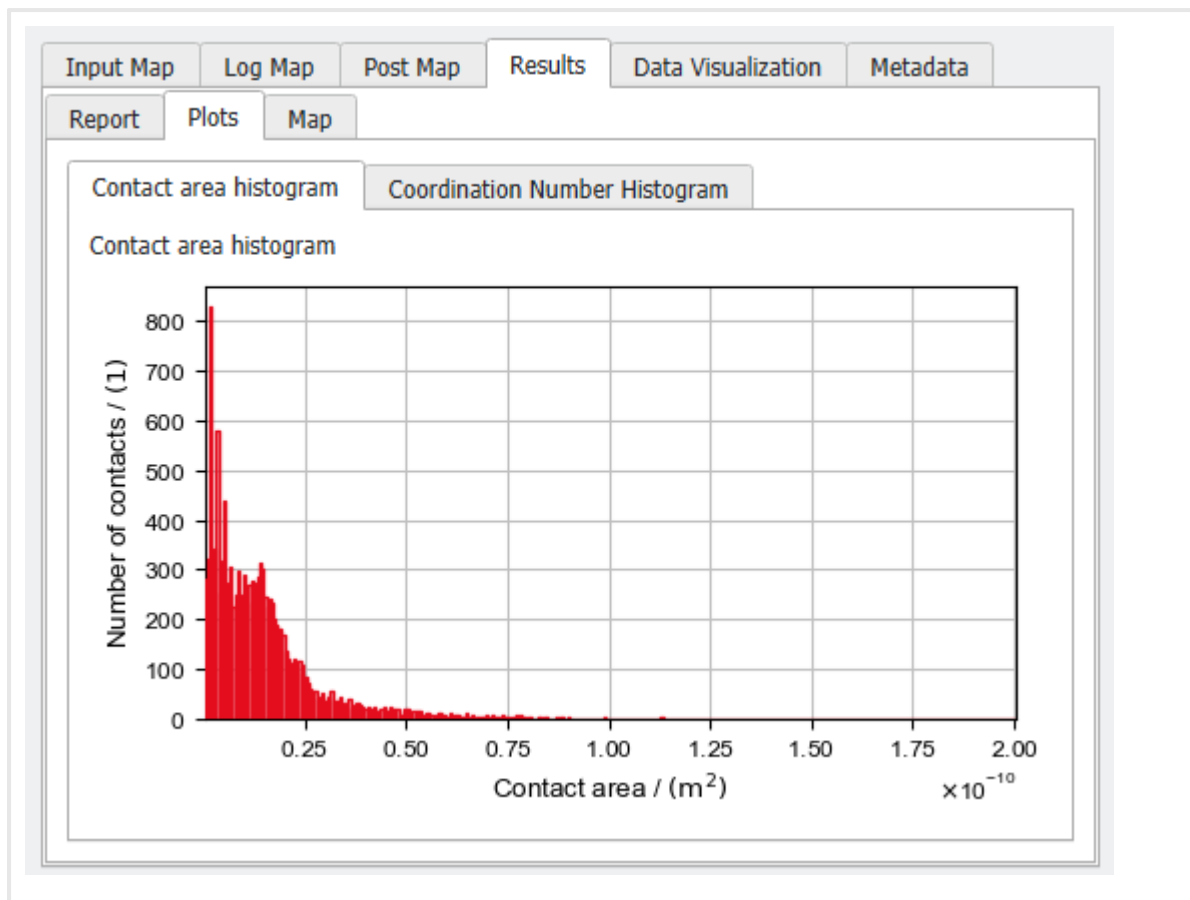


The screenshot shows the MatDict software interface with the 'Results' tab selected. The interface includes tabs for 'Input Map', 'Log Map', 'Post Map', 'Results', 'Data Visualization', and 'Metadata'. Under the 'Results' tab, there are sub-tabs for 'Report', 'Plots', and 'Map'. The 'Report' sub-tab is active, displaying a table with columns 'Key', 'Unit', and 'Value'.

Key	Unit	Value
▶ AdditionalFiles		
MeanCoordinationNumber		4.045751634
CoordinationNumbers		9, 5, 12, 9, 5, 0, 12, 6, 7, 7, 2, 4, 9, 8, 12, 10...
▼ Contact		
TotalNumberOfContacts		12999
TotalContactFaces		354238
MaximumContactFaces	1	356
MinimumContactFaces	1	1
MeanContactFaces	1	27.25117317
ContactAreas	m ²	5.625e-13, 1.125e-12, 1.6875e-12, 2.25e-12,...
NumberOfContacts	1	281, 323, 828, 272, 341, 578, 254, 317, 438,...
CumulativeNumberOfContacts	1	281, 604, 1432, 1704, 2045, 2623, 2877, 319...
▼ Contacts		
Object1		1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, ...
Object2		125, 1760, 1996, 2266, 2315, 3028, 4294965...
ContactFaces		27, 35, 17, 17, 26, 1, 46, 24, 20, 2, 6, 21, 23,...
▶ BackgroundContacts		
NumberOfOverlaps	1	3364
▶ Overlaps		
ObjectIndex		1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15...
▶ Volume		
▶ PostProcessing		

Under the **Contacts** key, for each contact the index numbers of both objects and the number of contact faces are given. In the above example, the first contact is between object number 1 and object number 125 and has a size of 27 voxel faces. The second contact is between object number 1 and object number 1760 and has a size of 35 voxel faces.

Under the **Results - Plots** subtab, the **Contact Area Histogram** visualizes the size distribution of the contact areas:



✓ Results for Analyze Object Volume

If **Analyze Object Volume** was checked in the [Analyze Options](#)¹¹² tab, the minimal, maximal, and mean volume are stated in the **Object Volume** section.

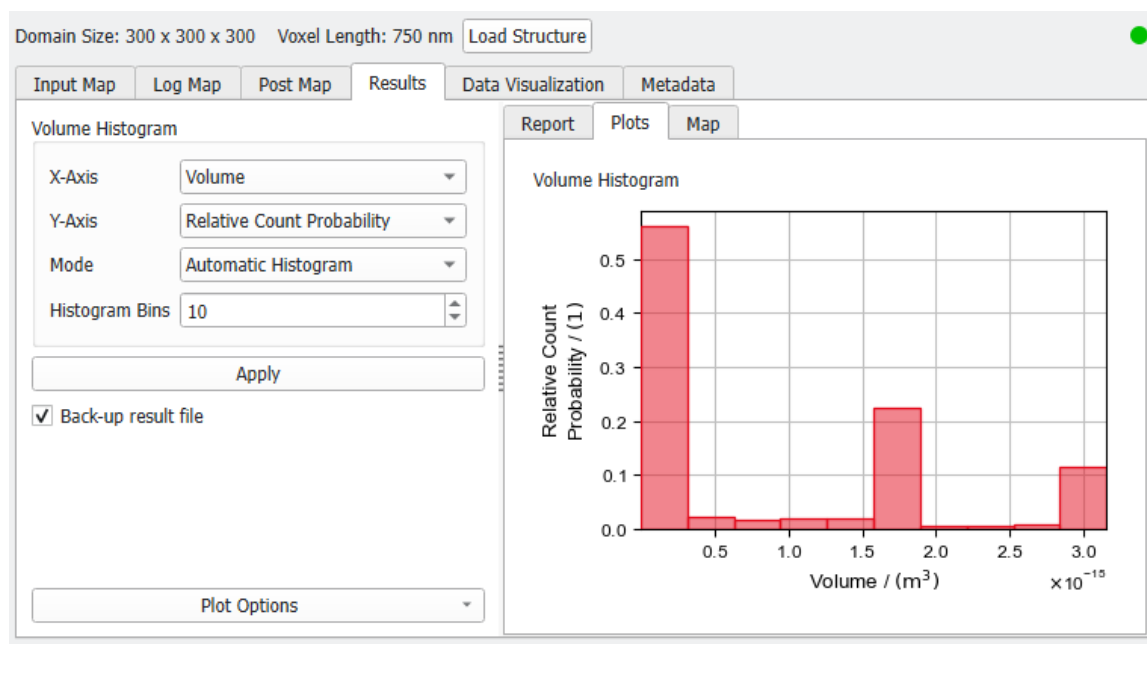
Object volume:The minimal volume: 4.21875e+08 nm³The maximal volume: 3154.36 μm³The mean volume: 880.723 μm³**Object volume histogram:**

Min. Volume / (nm ³)	Max. Volume / (nm ³)	Relative Count Probability
4.21875e+08	3.15816e+11	0.561936
3.15816e+11	6.31209e+11	0.0231871
6.31209e+11	9.46603e+11	0.0166511
9.46603e+11	1.262e+12	0.0186741
1.262e+12	1.57739e+12	0.0208528
1.57739e+12	1.89278e+12	0.223778
1.89278e+12	2.20818e+12	0.00451292
2.20818e+12	2.52357e+12	0.00529101
2.52357e+12	2.83897e+12	0.00949269
2.83897e+12	3.15436e+12	0.115624

Information: the result-map contains detailed object-volume information

Furthermore, an **Object volume histogram** table is created based on the **Volume Histogram** settings defined in the Options dialog.

The object volume histogram is graphically shown under the **Result - Plots** subtab. In the plot, the values for each bin are visualized as bars.



You can edit the volume histogram afterwards in the [post-processing panel](#)¹²¹ on the left-hand side of the **Report** tab. The table and plot update when you click the **Apply** button after changing the parameters.

More parameters can be defined by clicking **Plot Options** at the bottom of the panel and choose **Edit Axis Settings** or **Edit Graph Styles** for the desired plot. See also the Result Viewer user guide for detailed explanations.

✓ Volume histogram options

The **X-Axis** pull-down menu allows choosing whether the components should be classified based on volume (**Volume**) or based on volume equivalent sphere diameter (**Equivalent Diameter**).

X-Axis	Volume
	Volume
	Equivalent Diameter

For the **Y-Axis** pull-down menu, the **Relative Count Probability** provides the number of components in each bin normalized to the total number of components. The **Cumulative Count Probability** is the sum of the Relative Count Probability over all bins starting from the bin with the smallest value. **Relative Volume Probability** gives the volume of the components within one bin normalized to the total volume of all components. The **Cumulative Volume Probability** sums up the Relative Volume Probability of each bin of the histogram starting from the smallest one.

Y-Axis	Relative Count Probability
	Relative Count Probability
	Cumulative Count Probability
	Relative Volume Probability
	Cumulative Volume Probability

The histogram **Mode** offers the choice between generating an **Automatic Histogram** without further specifications or to **Give Min. and Max Value** for the parameter defined in the X-Axis pull-down menu (Volume or Equivalent Diameter).

Mode	Automatic Histogram
	Automatic Histogram
	Give Min. and Max. Value

In the latter case, either **Min. Volume** and **Max. Volume** or **Min. Diameter** and **Max. Diameter** (depending on the choice for X-Axis) can be directly entered here.

Mode	Give Min. and Max. Value
Min. Volume / (m ³)	4.21875e-19
Max. Volume / (m ³)	3.15435937e-15

The number of **Histogram Bins** determines the number of rows in the **Object Volume Histogram** table and the number of bars in the plot.

Histogram Bins

10

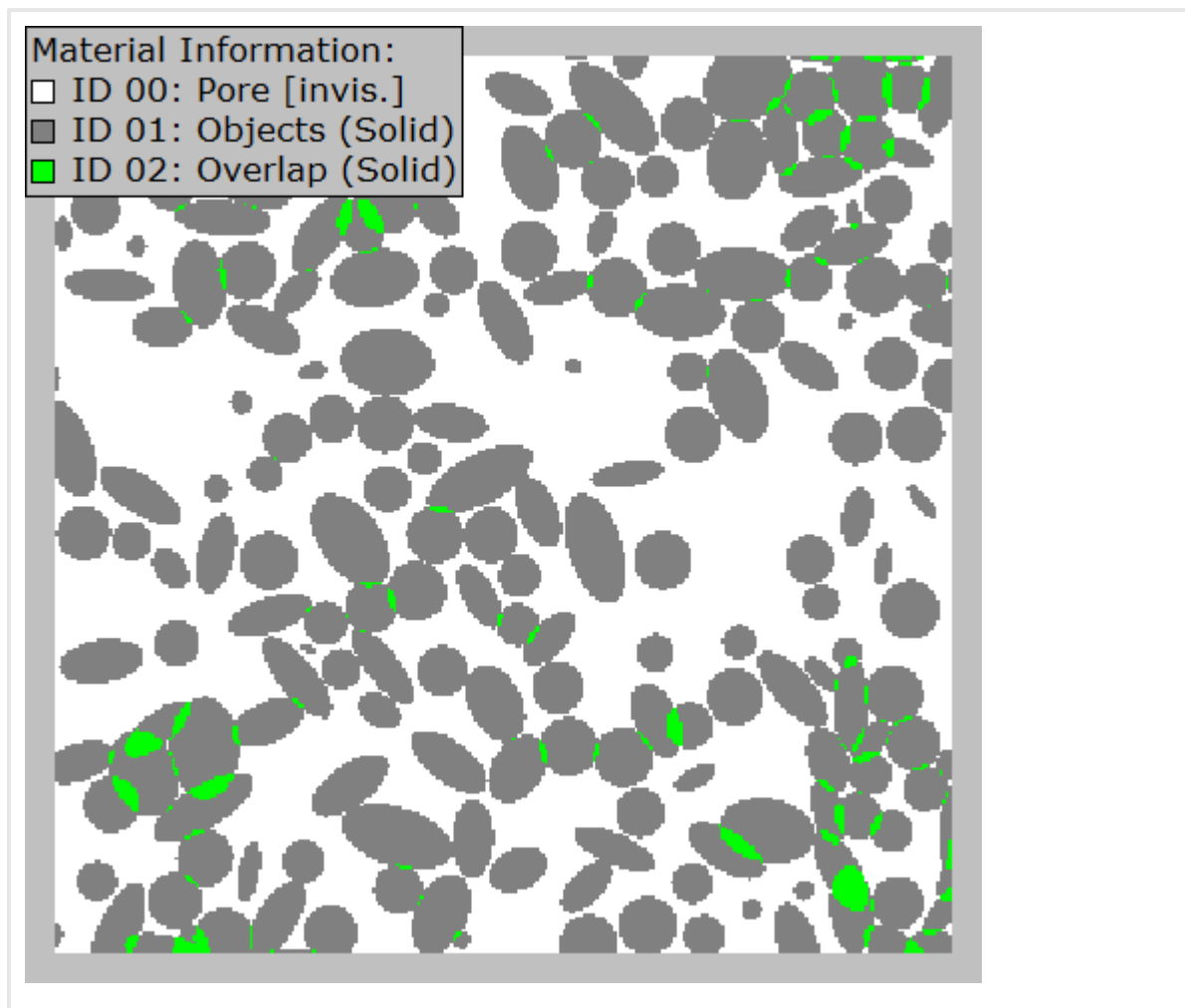
Data Visualization

Depending on the input data file type and the options chosen in the input dialog, the **Data Visualization** tab contains up to 5 files that can be loaded for visualization pupose.

Input Map	Log Map	Post Map	Results	Data Visualization	Metadata
Objects and Overlap (*.gdt)				Load *.gdt	
Objects and Contacts (*.gdt)				Load *.gdt	
GeoDict Orientation File (*.gof)				Load *.gof	
Index Image of Objects (*.g32)				Load *.g32	
Index Image of Objects (*.leS)				Load *.leS	

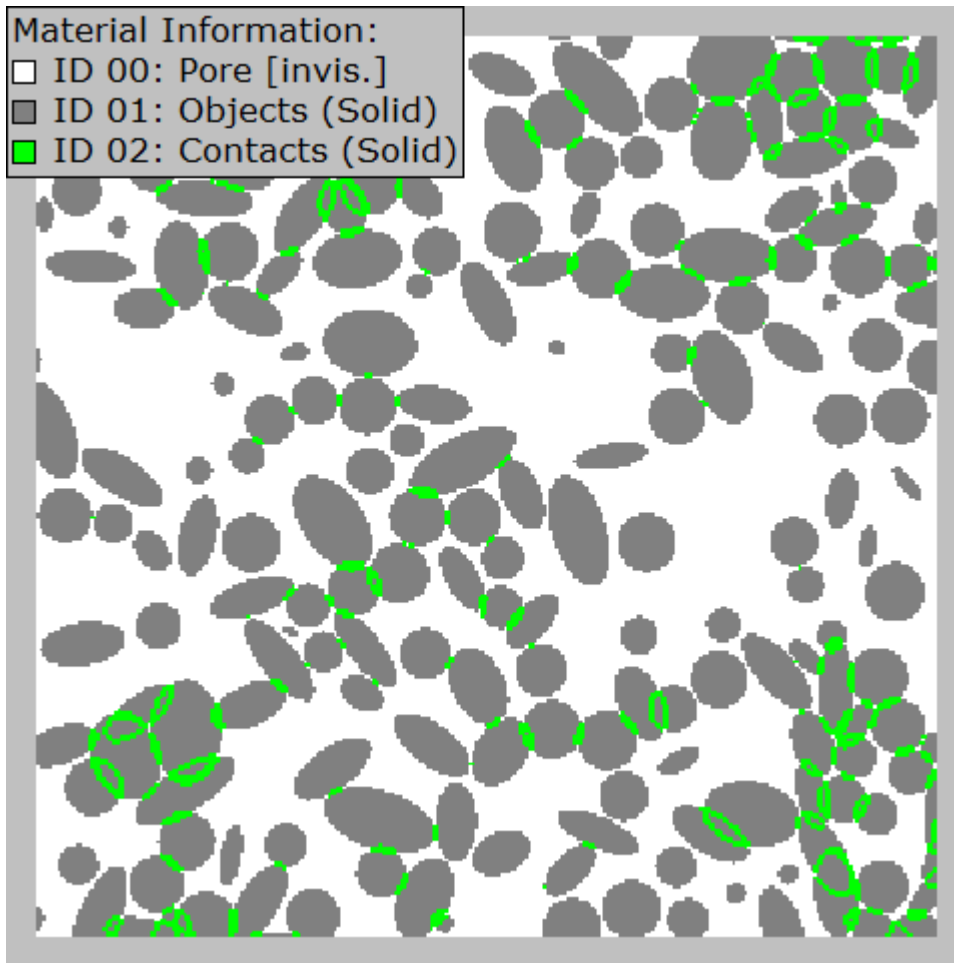
✓ Objects and Overlap (*.gdt)

This file is available if **Use Current GAD Structure** was used as **Object Data** input. Loading this file shows the overlap between objects. All objects are assigned to Material ID 01 and the overlap is assigned to Material ID 02.

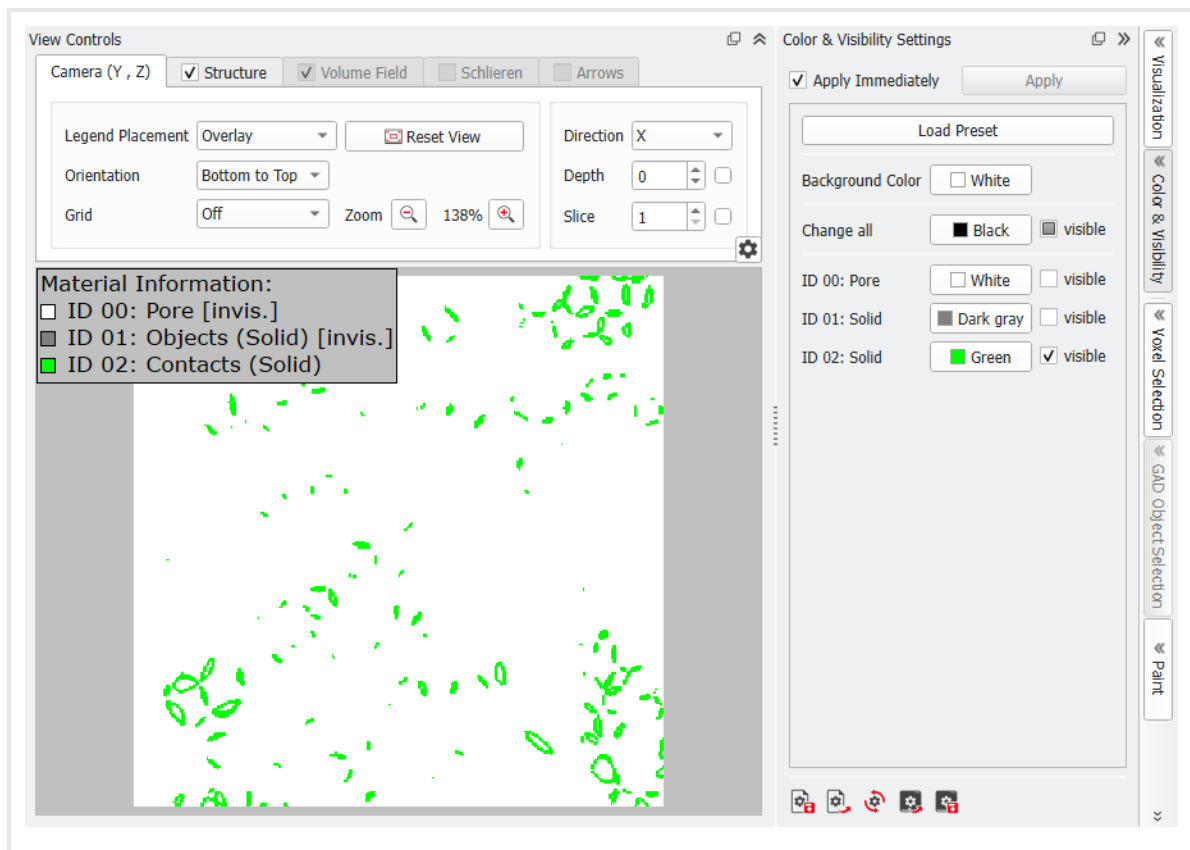


✓ Objects and Contacts (*.gdt)

This file is available if **Analyze Object Contact** was checked in the **Analyze Options** tab. Loading this file shows the contacts between objects. All objects are assigned to Material ID 01 and the contacts are assigned to Material ID 02.



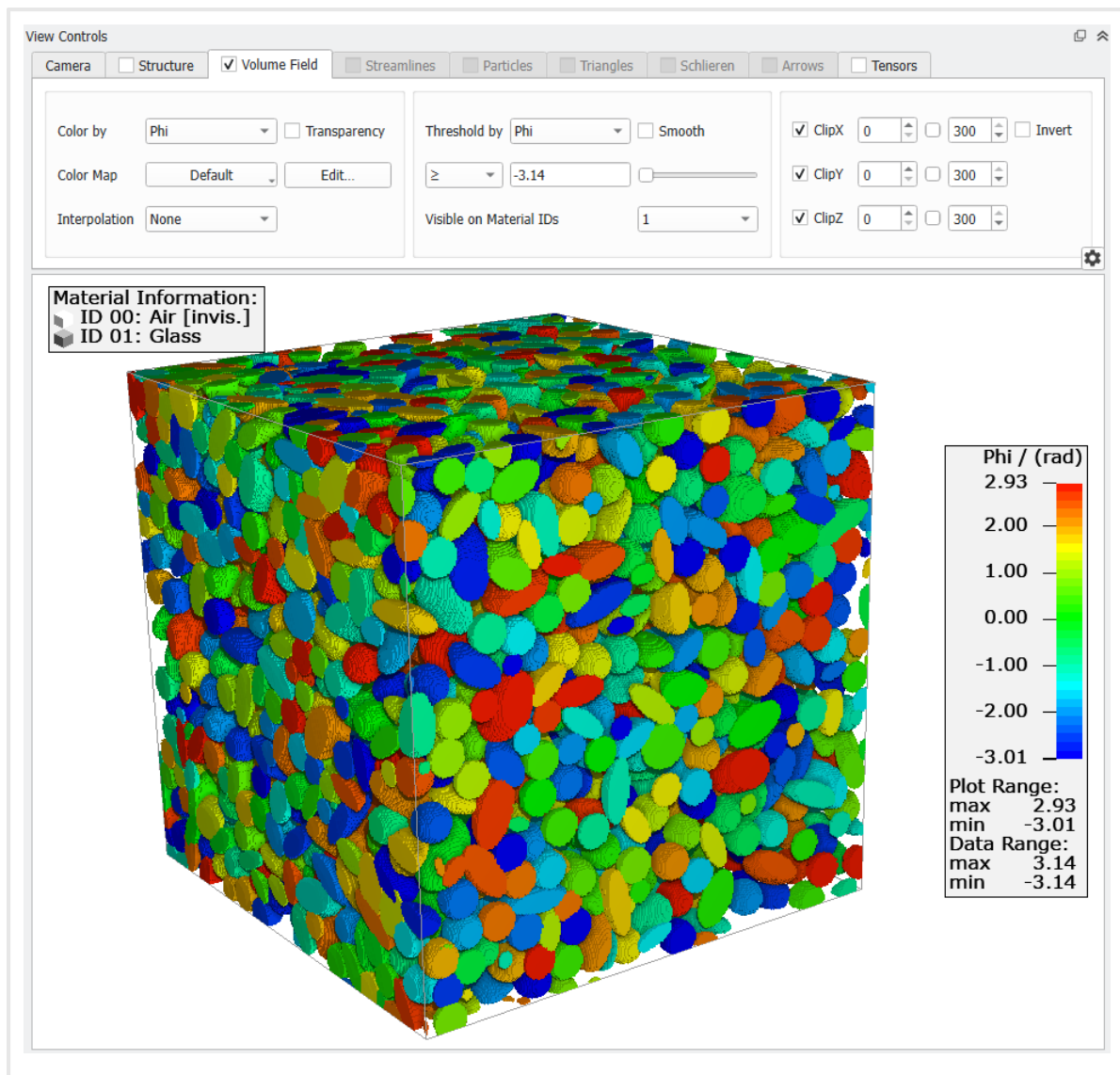
For the visualization of the labeled contacts only, select **Settings** → **Color & Visibility Settings** in the menu bar. Uncheck the visibility of the objects (Material ID 01) in the structure and leave only the visibility of Material ID 02 checked.



✓ GeoDict Orientation File (*.gof)

If **Write Object Orientation (*.gof)** was checked in the [Analyze Objects](#)^[112] tab, the orientation of the objects can be displayed by loading the orientation volume file.

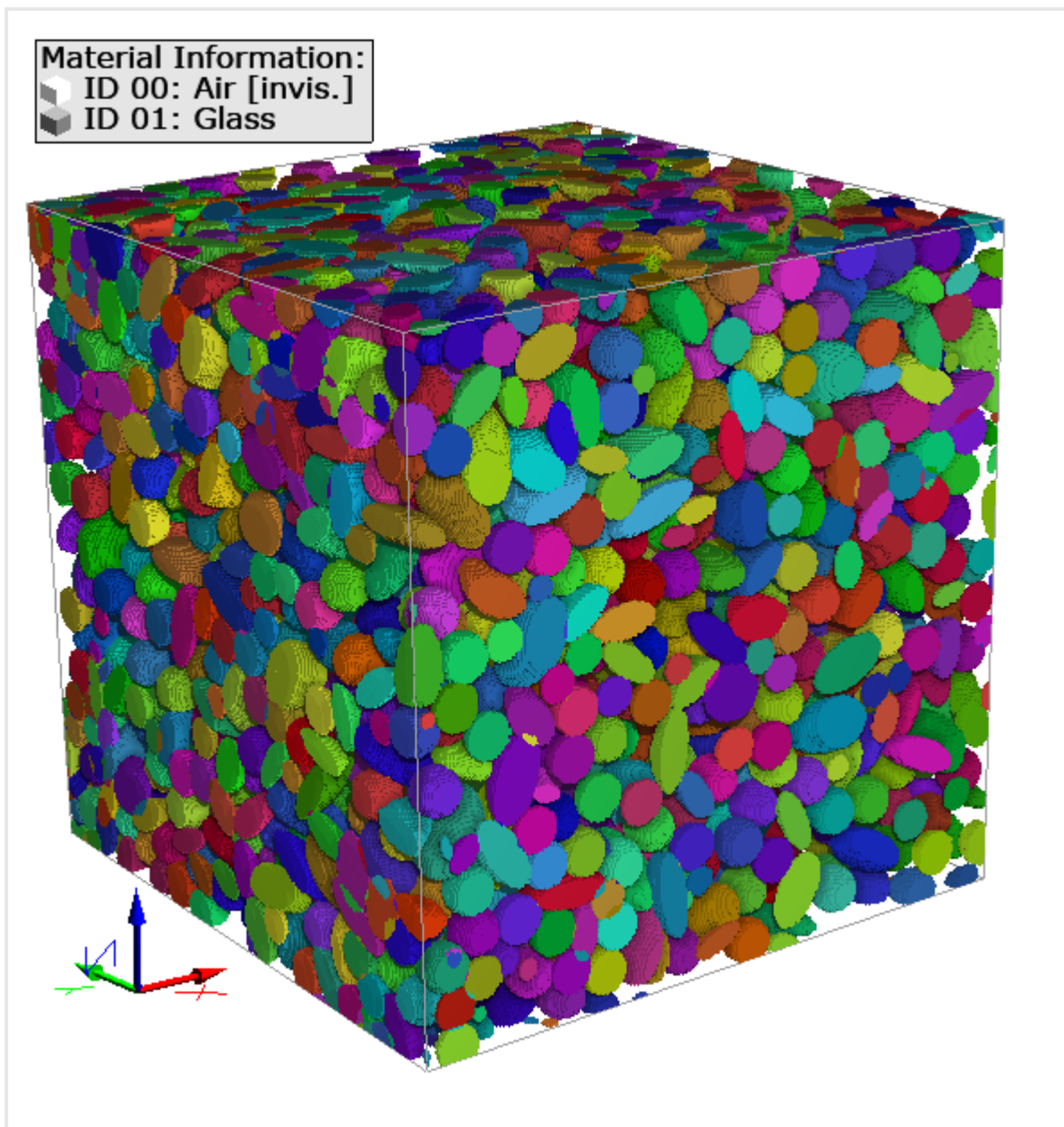
To properly see the orientation data of each object, uncheck **View** → **Structure** in the main menu, and uncheck the Pore material in the **Material** selector under the **Visible on Material IDs** menu under the **Volume Field** tab as shown below.



✓ Index Image of Objects (*.g32)

If **Write Voxel Geometry with Object Indices (*.g32)** was checked in the [Analyze Objects](#)^[112] tab you can load the index image of the identified objects as *.g32 index image. If the currently loaded index image was chosen as [Object Data](#)^[110], the *.g32 can be reloaded after the computation has finished.

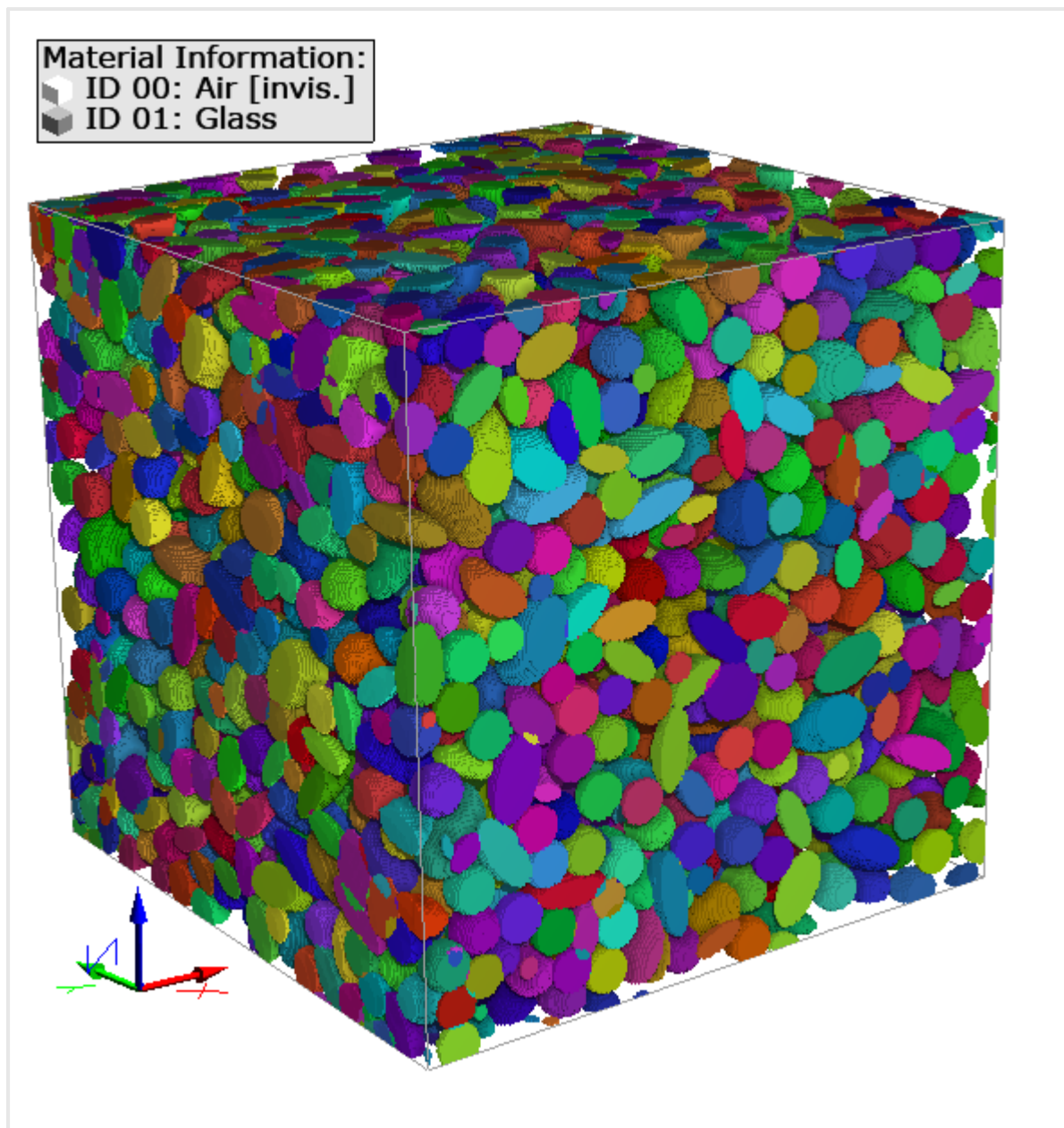
In this image, every object is visualized with a different color. Again, to visualize the results, it is important to uncheck **View** → **Structure** in the main menu.



✓ Index Image of Objects (*.leS)

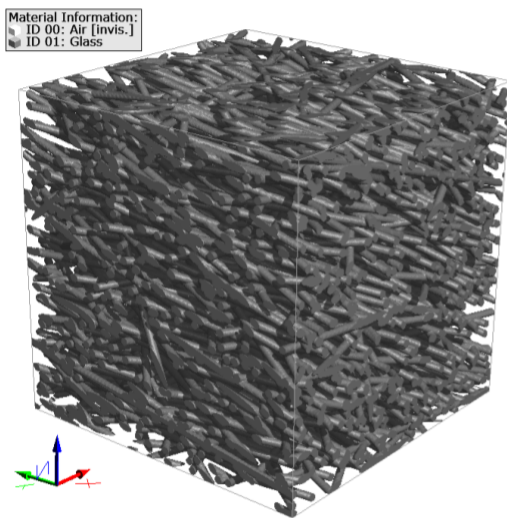
If **Write Voxel Geometry with Object Indices (*.leS)** was checked in the [Analyze Objects](#) ¹¹² tab you can load the index image of the identified objects as *.leS index image. This format is human readable, e.g., when opening it in an external text editor as Notepad++, but writing this file takes longer than writing a *.g32 file.

In this image, every object is visualized with a different color. Again, to visualize the results, it is important to uncheck **View** → **Structure** in the main menu.



1.3.2 GAD Objects Orientation

The **GAD Objects Orientation** command computes the orientation tensor and anisotropy of GAD objects from a selected type.



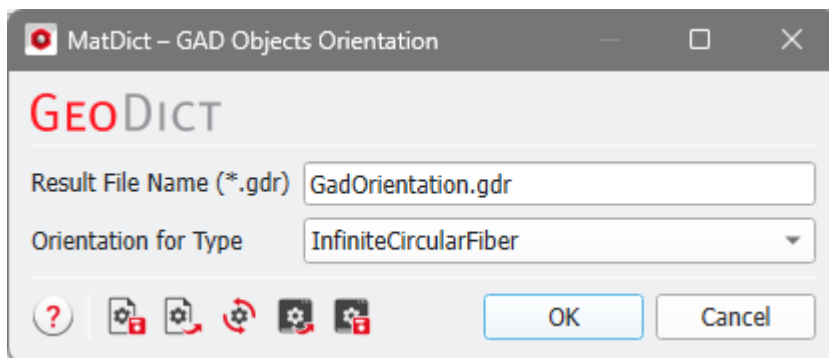
Input Map	Log Map	Results	Metadata
Report Map			
Direction tensor:			
0.3772	-0.1080	-0.0962	
-	0.5186	0.1702	
-	-	0.1043	
Anisotropy 1: 4.934			
Anisotropy 2: 1.992			
Euler angles (Phi, Theta, Psi): 30.457, 19.805, -1.718			

The GAD Objects Orientation command:

- [Options](#)¹²⁹
Set the parameters for the analysis.
- [Results](#)¹³⁰
View the computed results.

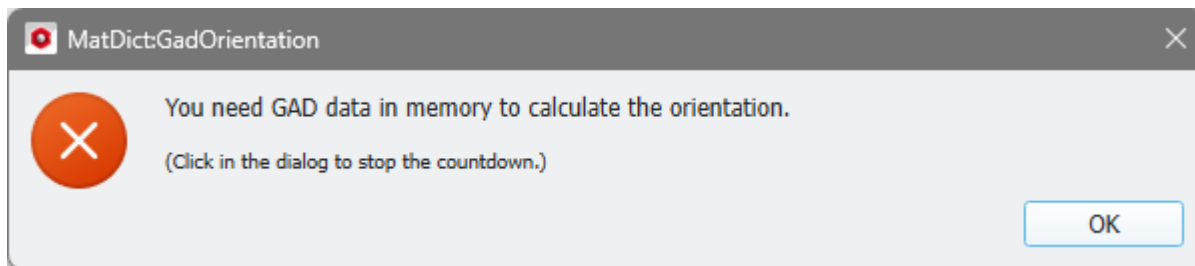
Options

The **GAD Objects Orientation** dialog opens when clicking the Options' **Edit...** button. At the top of the dialog, enter the **Result File Name**. The result file is saved in the chosen project folder (**File** → **Choose Project Folder** in the menu bar).

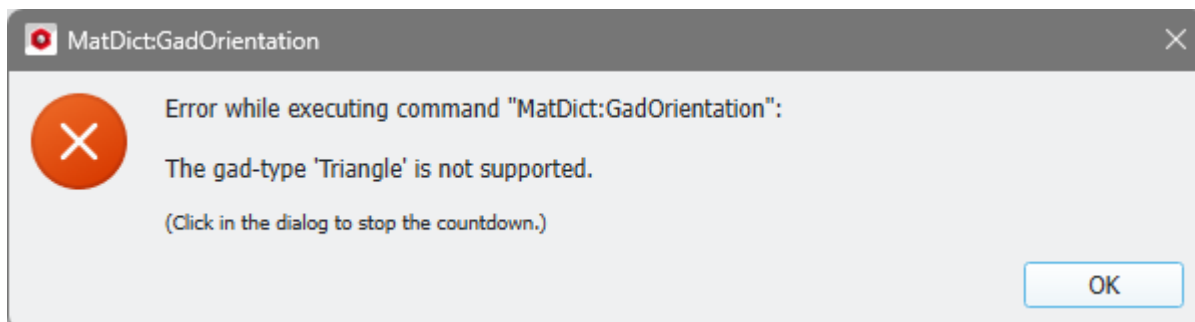


From the **Orientation for Type** pull-down menu, select the object type that should be analyzed. All object types present in the current structure are identified automatically and are listed in the pull-down menu.

If no analytic data is available for the current structure, the object orientation analysis is not carried out after clicking **Run** in the MatDict section, and an error message appears.



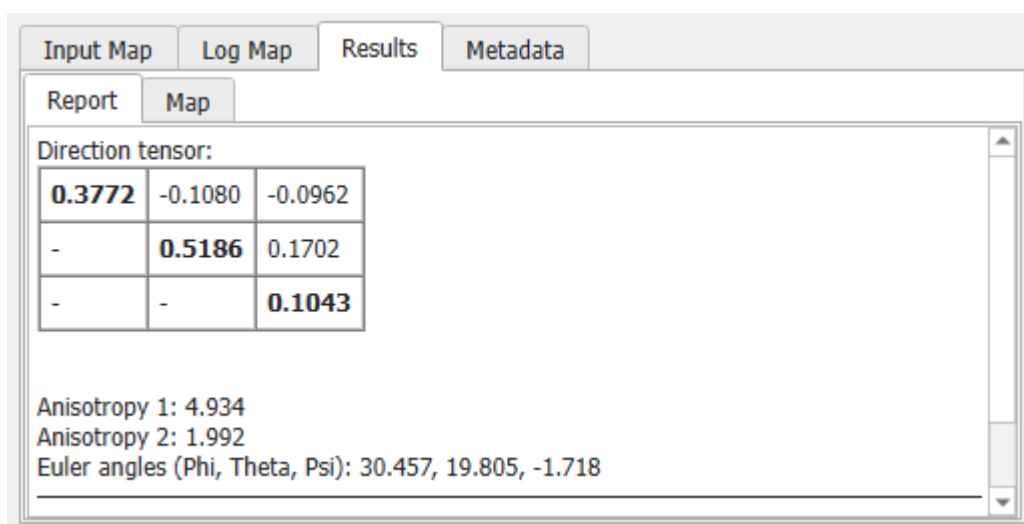
Not all object types are suitable for an orientation analysis. If this is the case another error message appears.



Results

After the **GAD Objects Orientation** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains four tabs. The computational results are shown under the **Results** tab. The other three tabs (**Input Map**, **Log Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.



The definition of these parameters is the same as in other modules, e.g., in FiberGeo. See [Fiber Orientation Parameters](#) for a more detailed description of these parameters.

You can then use the results of MatDict **GAD Objects Orientation** to generate a 3D structure that has a similar orientation using one of the Material Modeling modules.

1.4 Algorithms

Select one of the **Algorithms** commands from the second pull-down menu and click **Edit...** to enter the parameters for the simulation.

Commands of Algorithms:

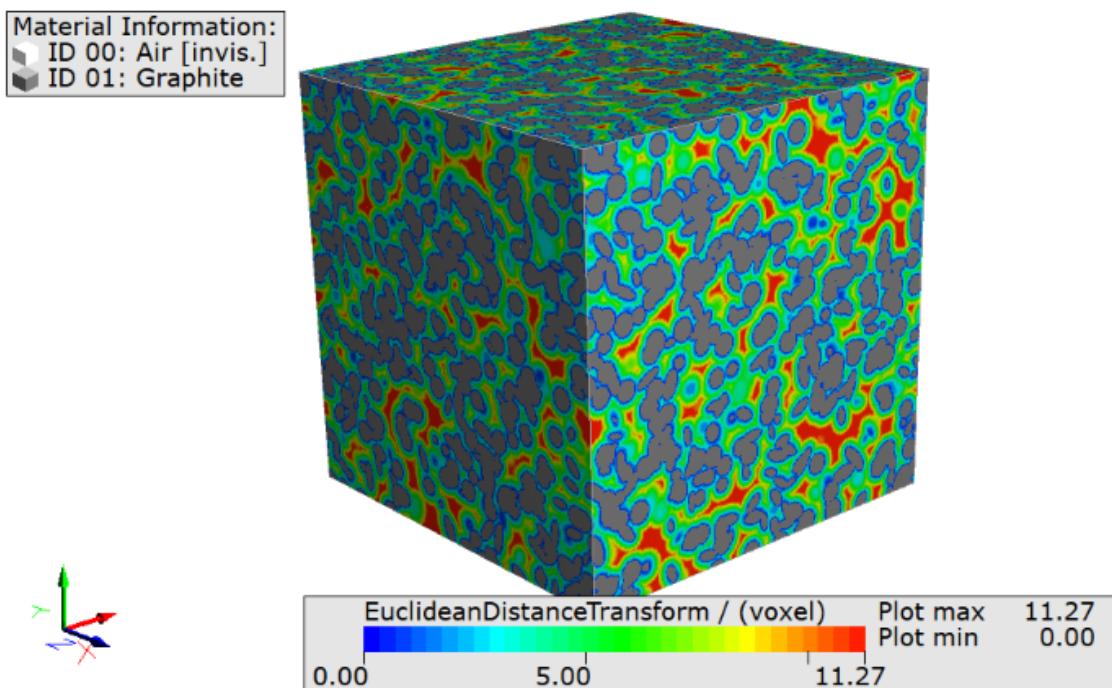
- [Euclidean Distance Transform](#)^[131]
The Euclidean Distance Transform (EDT) calculates the distance from any point (voxel) inside a pore to the nearest pore/solid boundary.
- [Skeletonizer](#)^[139]
The Skeletonizer reduces any given structure to its center lines.

1.4.1 Euclidean Distance Transform

For a given material in a structure, a [distance transform](#) algorithm computes the distance to the boundary of the material for every point (voxel) in the structure. This is useful when characterizing the structure's pore morphology.

In GeoDict, the algorithm presented by [Saito et. al. \(1994\)](#)^[143] is implemented.

After selecting **Euclidean Distance Transform** (EDT) from the pull-down menu, the settings for the calculations can be modified through the **Edit...** button.



The Euclidean Distance Transform (EDT) was computed for the pore space and is visualized there.

The Euclidean Distance Transform command:

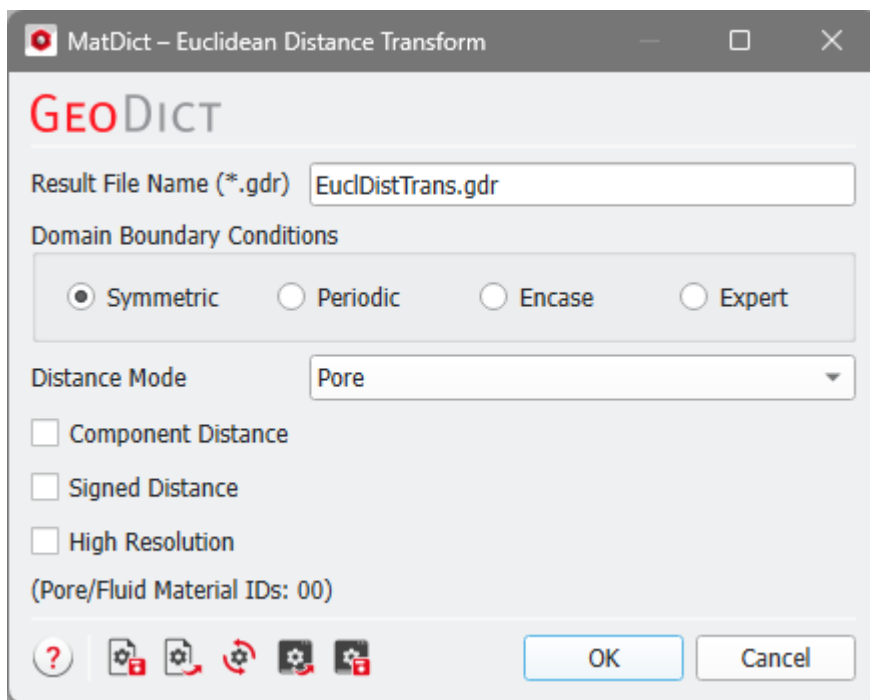
- [Options](#)^[132]
Set the parameters for the analysis.

The Euclidean Distance Transform command:

- [Results](#)¹³⁷
View the computed results.

Options

At the top of the **Euclidean Distance Transform** dialog, choose the **Result File Name**.



✓ Domain Boundary Conditions

Decide which **Domain Boundary Conditions** should be used during the calculations.

The **Domain Boundary Conditions** can be chosen to be **Symmetric**, **Periodic**, **Encase**, or any combinations of those boundary conditions in all three directions with the choice of **Expert**.

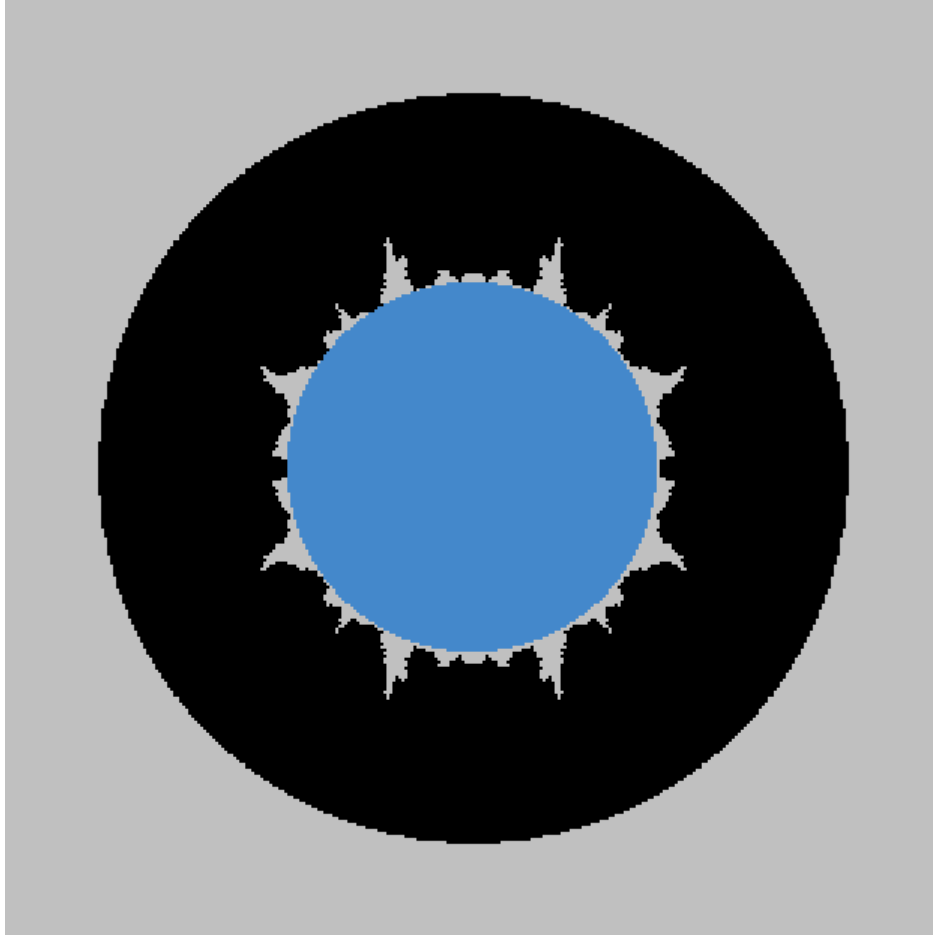
Choosing the appropriate boundary condition depends on the structure's design.

For example, imagine a structure with a cross-section as shown below.

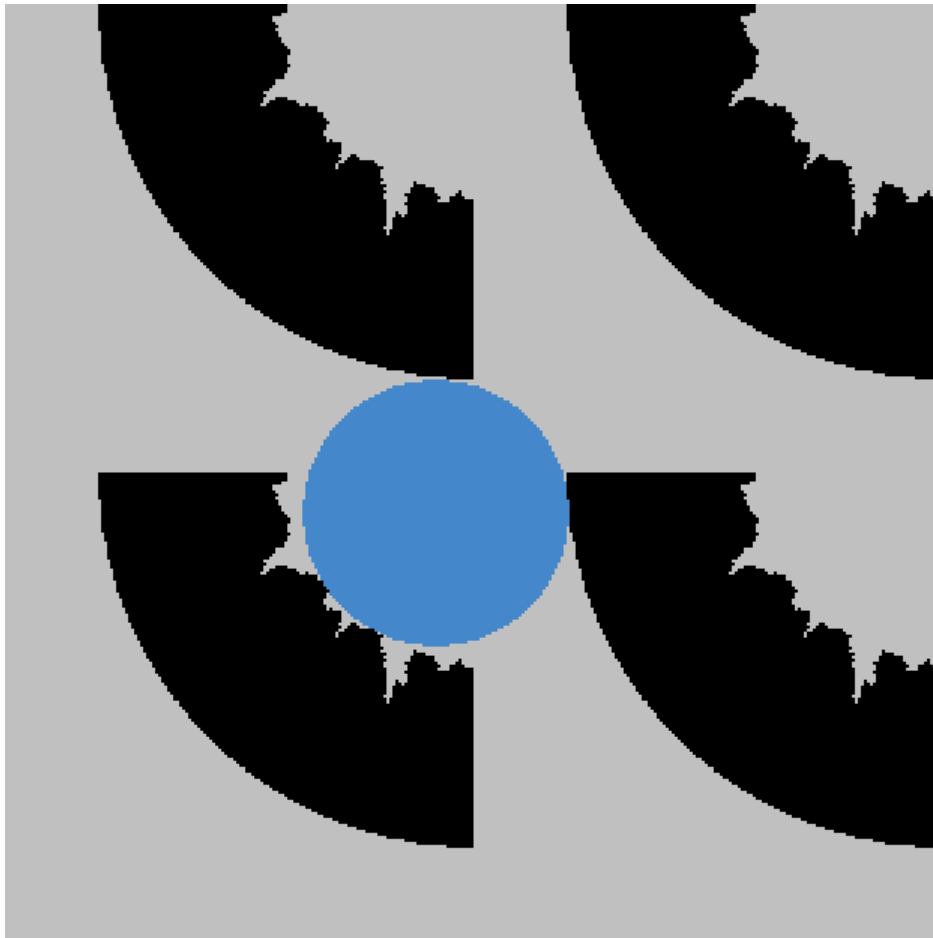


For the three boundary condition options the resulting solid size is visualized in blue.

- If **Symmetric** boundary conditions are taken, the geometry is mirrored at the domain boundary.



- If instead the expected pattern of the geometry is repeated in all directions, **Periodic** boundary conditions should be selected. That has the effect that the objects and pores of the structure that end on one side of the structure reappear on the opposite side.



- If the structure should be encased with a closed wall, the **Encase** boundary conditions are used.



Check **Expert** to apply different boundary conditions for each direction. You can combine the three above mentioned boundary conditions independently for the directions. For example, the boundary conditions could be chosen to be Encase in X-direction, Symmetric in the Y-direction and Periodic in Z-direction.

Domain Boundary Conditions

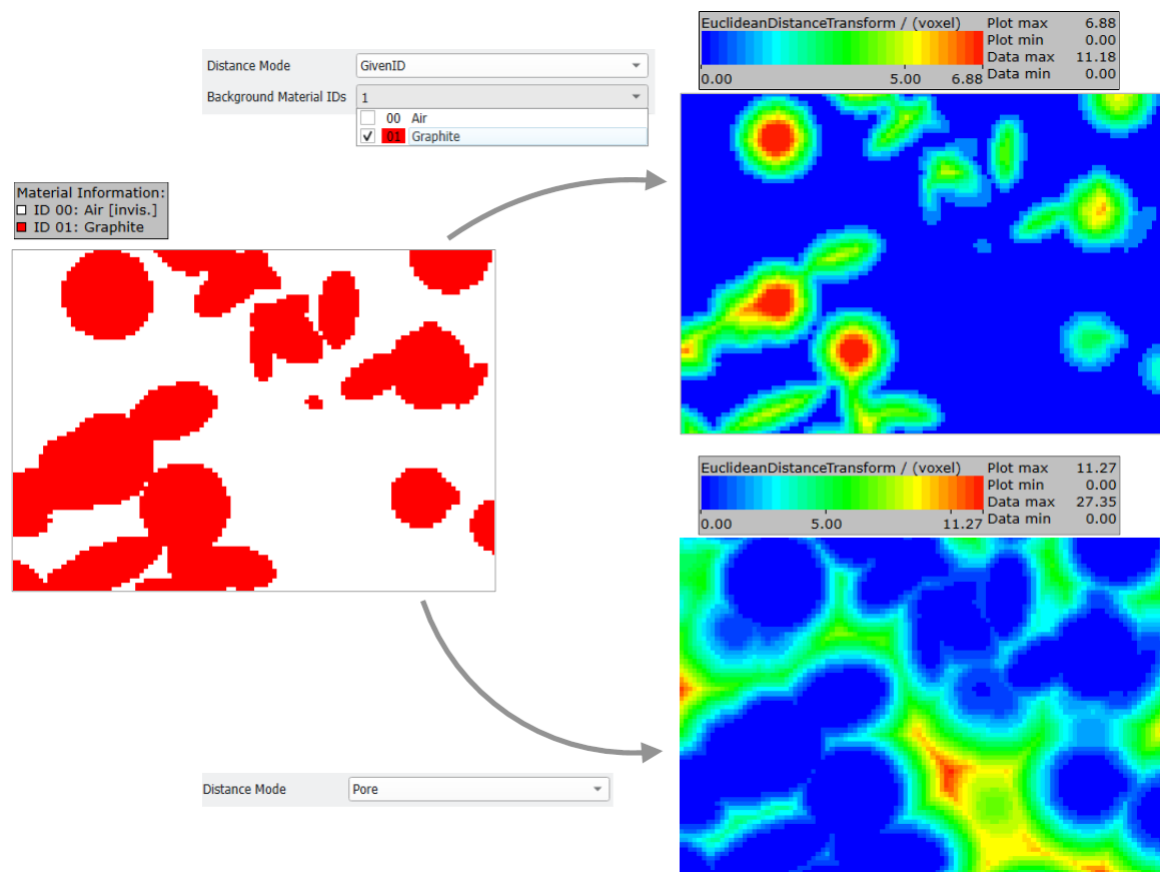
☐ Symmetric
☐ Periodic
☐ Encase
☒ Expert

Expert Settings

X
Encase
Y
Symmetric
Z
Periodic

Distance Mode

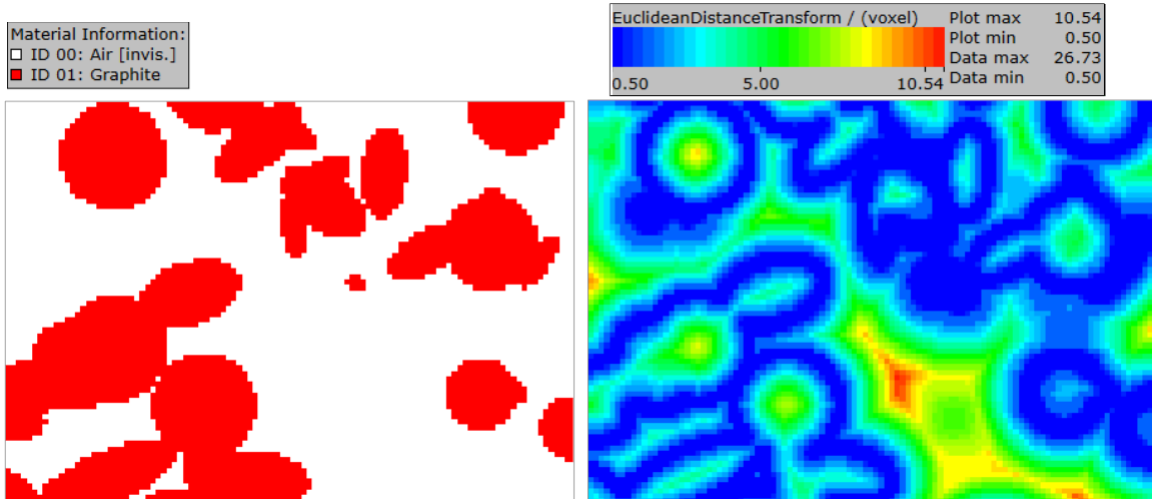
The **Distance Mode** defines the Material IDs that are considered. From any point (voxel) inside these Material IDs the distance to the nearest boundary to all other Material IDs is calculated. The default is to analyze the pore space, so that the distance of any pore voxel to the next solid material is computed. However, if switching the Distance Mode to **GivenID**, you can select from all Material IDs present in the structure.



Component Distance

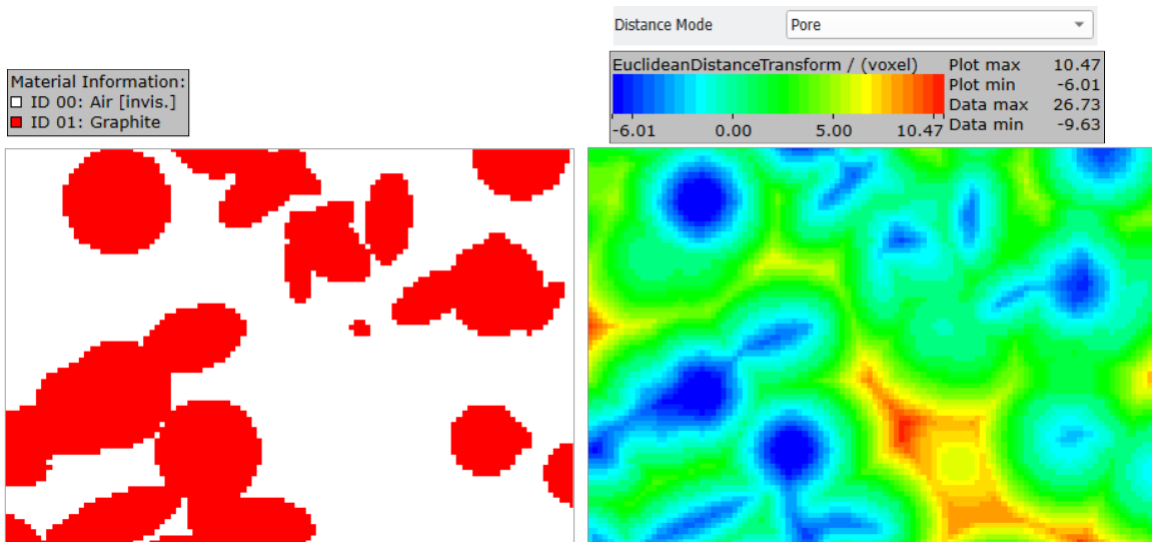
If **Component Distance** is checked, for each point of the domain the distance to the next boundary is computed. In this case all boundaries between the materials are considered, including the pore space. When **Component Distance** is checked, the

selection of Distance Mode is disabled, as the EDT is computed for all structure components at once. Also, **High Resolution** will be applied for the computation in this case.



✓ Signed Distance

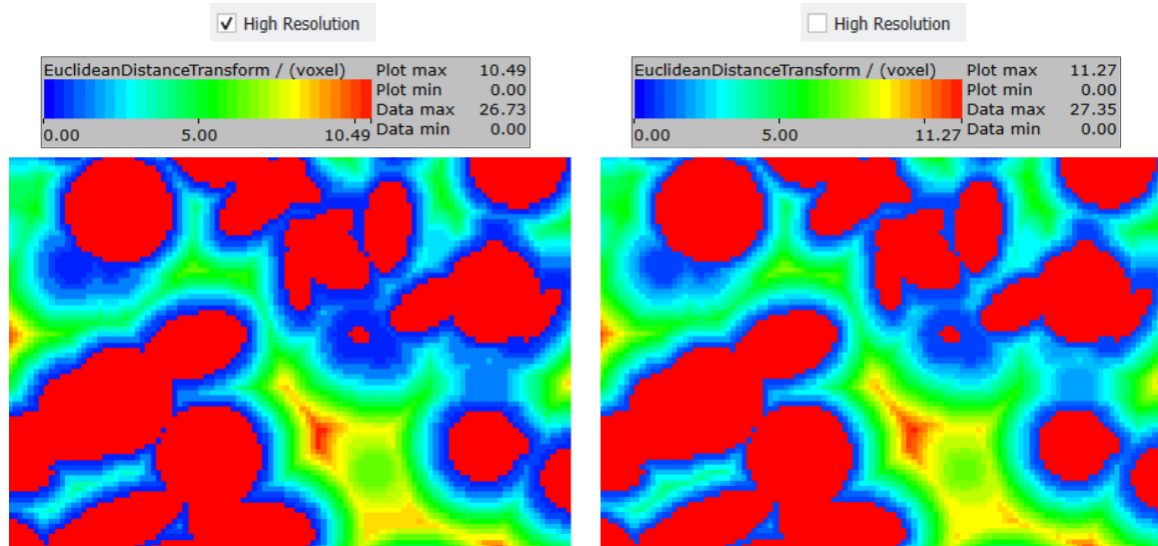
If **Signed Distance** is checked, a modified version of the EDT is used. In the pore space or background materials, the signed EDT will be the same as in the original version, but the signed EDT will also compute a negative distance inside of the solid or foreground material. Also, **High Resolution** will be applied for the computation in this case.



✓ High Resolution

To run the calculations with **High Resolution** might be useful when the pore space is expected to be especially narrow. The standard algorithm computes distances directly on the voxel grid, i.e., only the distances between voxel centers are taken into account. High Resolution also takes the voxel surfaces and edges into account, so the computed

distances correspond to the distance to the next surface or edge. The disadvantage of the **High Resolution** mode is that the calculation runtime and memory usage may increase by a factor of eight.

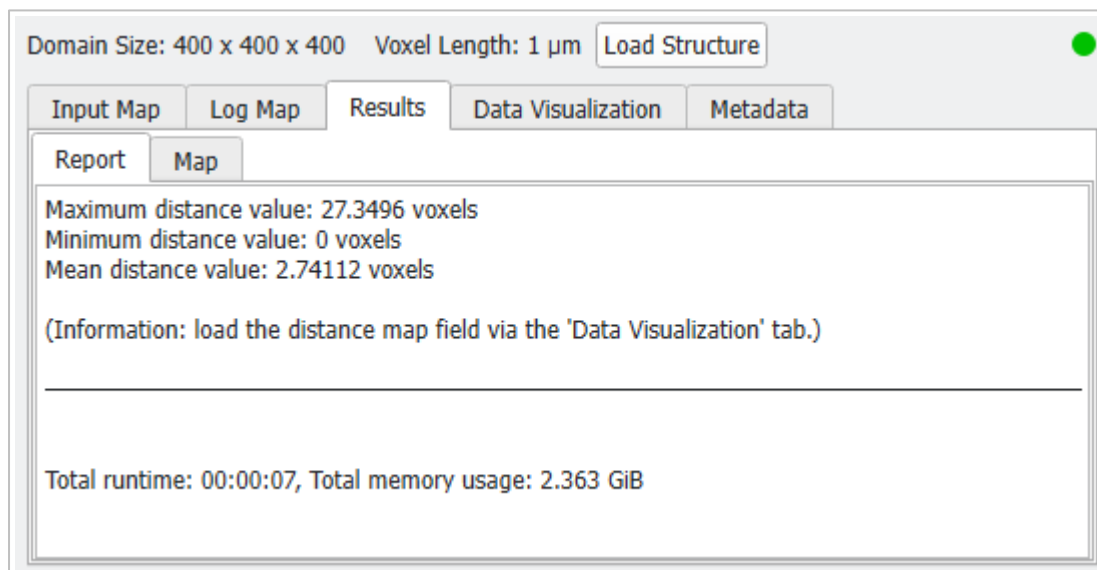


Results

After the **Euclidean Distance Transform** calculation is finished, the resulting files are saved in the project folder and a Result Viewer with the GeoDict result file opens automatically. The created GeoDict result file (*.gdr) contains five tabs. The computational results are shown under the **Results** tab, and can be loaded for visualization via the **Data Visualization** tab. The other three tabs (**Input Map**, **Log Map**, and **Metadata**) display additional information about the computation.

Find more details on the general functionalities in the Result Viewer user guide.

In the **Results – Report** tab three values can be found.



The **Maximum distance value** is the maximum value found in the computed Euclidean distance map. It corresponds to the maximal distance a point within the selected Material ID(s) can have to the next boundary.

The **Minimum distance value** is the minimum value found in the computed Euclidean distance map. Be aware, that this is in general not the minimum distance a point within the selected Material ID(s) can have to the next boundary, because also the values inside of the solid materials are taken into account. In the standard case, the **Minimum distance value** will be 0. For signed distance maps, the result corresponds to the maximum (negative) distance a point within the foreground material can have to the boundary.

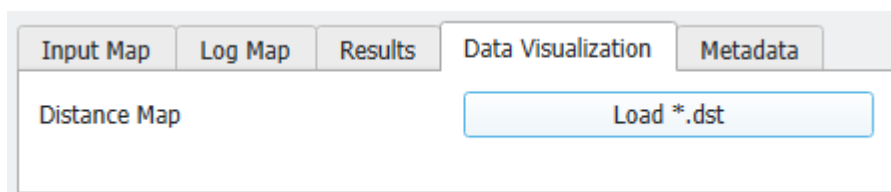
The **Mean distance value** is the average of all values in the computed Euclidean distance map. All materials (foreground and background) are taken into account when the average distance is determined.

Euclidean Distance Transform Results:

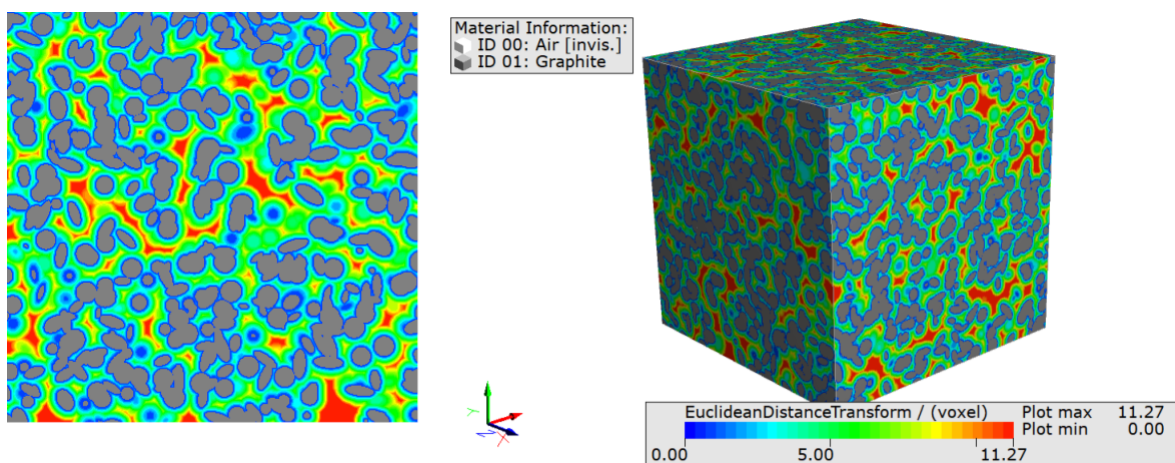
- [Data Visualization](#)  ¹³⁸
Load results for a graphical visualization.

Data Visualization

The **Euclidean Distance Transform** result can be visualized in 2D-Cross section view or 3D-Rendering. In the **Data Visualization** tab of the result file click **Load *.dst**, to load the computed **Distance Map** as volume field into GeoDict. It contains for every voxel the computed distance value.



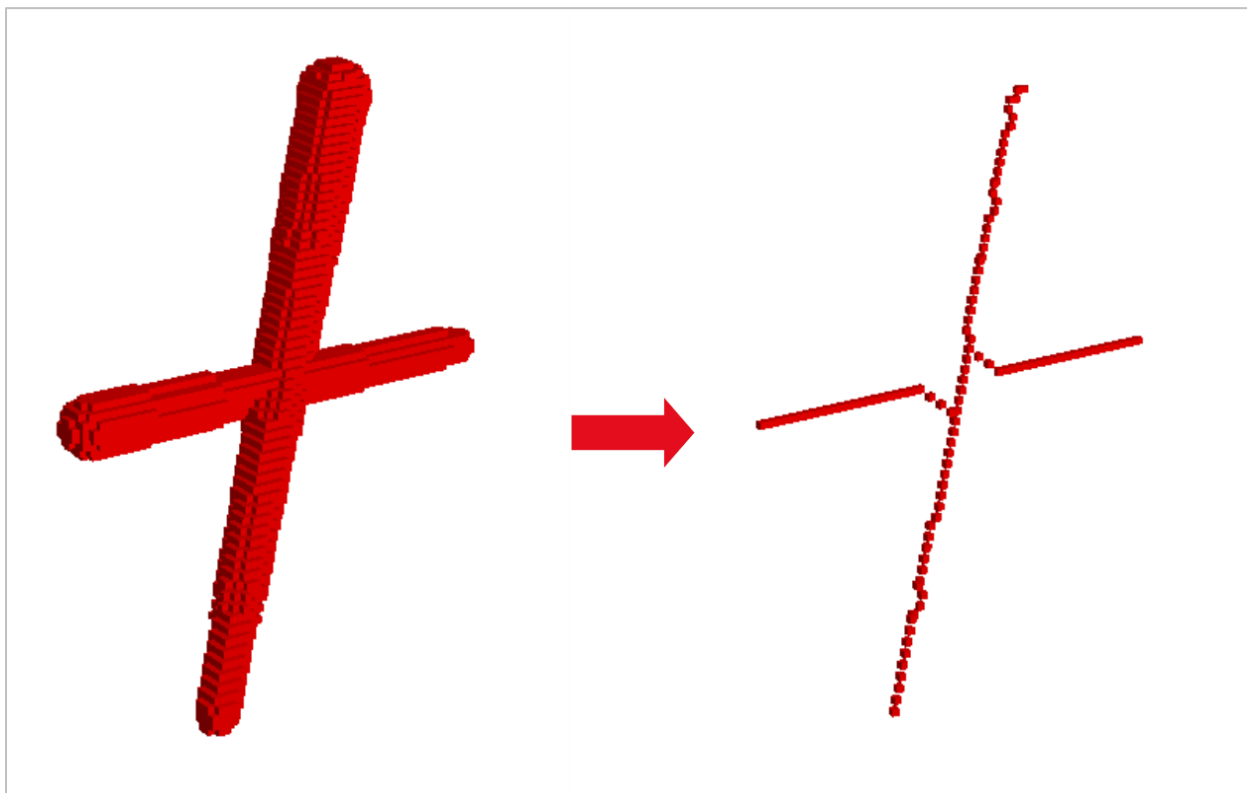
See the Visualization chapter how you can fine-tune the visualization settings.



1.4.2 Skeletonizer

The **Skeletonizer** reduces a structure to its center lines. This command might be useful as an intermediate step in some workflows creating or analyzing certain structure types.

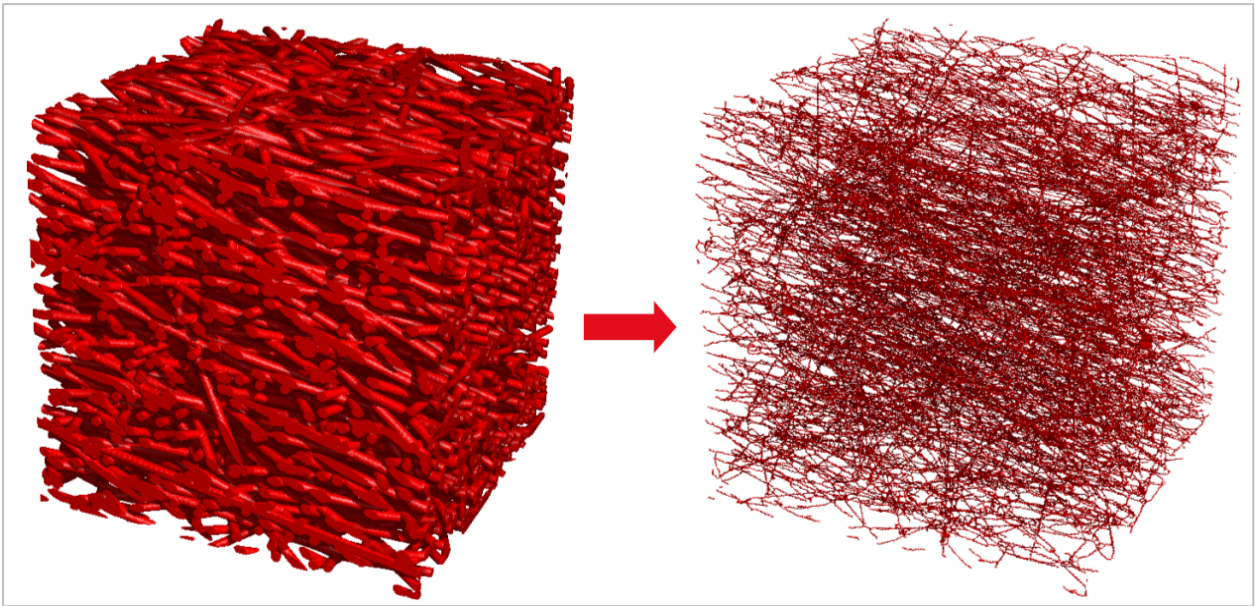
The command requires no parameters. It can directly be started by clicking **Run** in the MatDict section.



In contrast to all other commands in MatDict, the Skeletonizer command does not create a result file. Rather, it directly modifies the current structure and creates a new voxel structure which consists only of the center lines.



Important! The modified structure is **not** automatically saved to the hard disk. You have to Save the structure manually.



1.5 Material Analysis GeoApps

A single GeoApp is available in the selection box, the **Compute Fractal Dimension** app.

The Material Analysis GeoApps:

- [Compute Fractal Dimension](#)^[141]
Compute the fractal dimension of the solid materials of a loaded geometry.

1.5.1 Compute Fractal Dimension

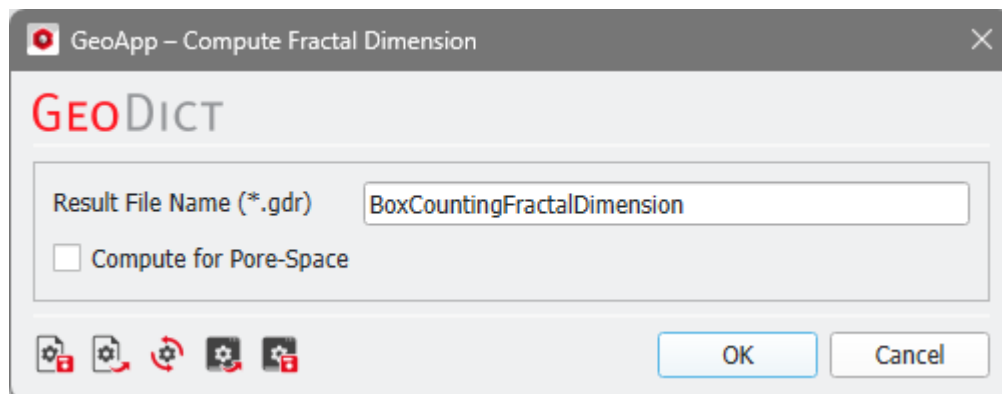
The **Compute Fractal Dimension** GeoApp calculates the fractal dimension of the solid materials or the pore space of a loaded geometry. It mathematically describes the complexity of the current structure by analyzing how it changes in detail with respect to a change in scale. The used method is the box-counting algorithm. The fractal dimension is another measure for microstructures and is used, e.g., to characterize carbon particle agglomerates. The GeoApp executes the MatDict command [3D Inhomogeneity](#)^[28] several times with increasing side length of the boxes.



Modules needed to run this GeoApp:

PoroDict

Click **Edit** to open the **Compute Fractal Dimension** parameter dialog.



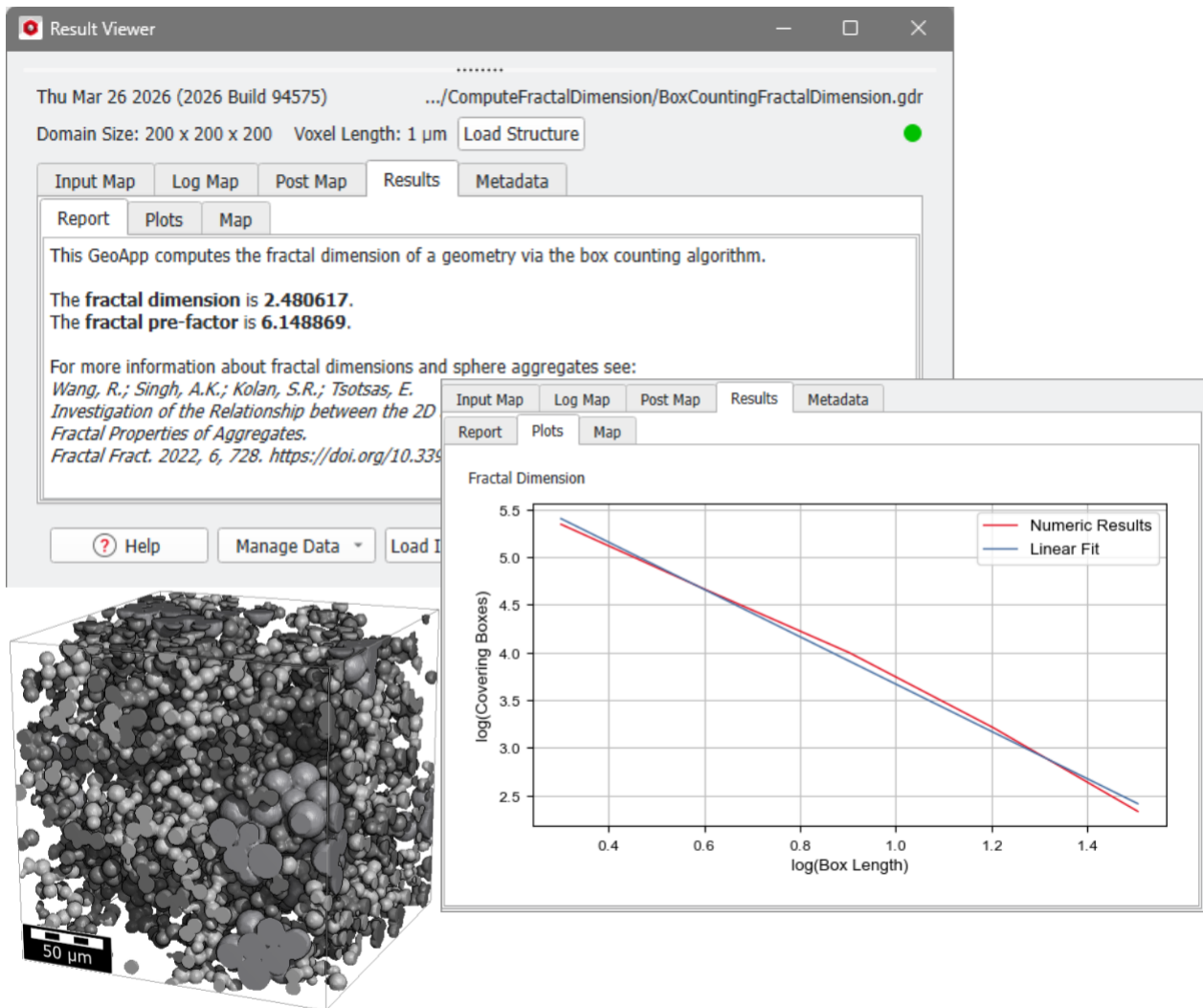
Select a **Result File Name**, then decide whether to compute the fractal dimension for the pore space or solid materials by checking or unchecking **Compute for Pore-Space**, respectively.

Results

The result file opens in the **Result Viewer** when the **Compute Fractal Dimension** app is finished.

The result file shows the **fractal dimension** and the **fractal pre-factor** described by Wang et al. (2022).

In the plots tab find the fractal dimension visualized in a 2D plot.



1.6 References

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