

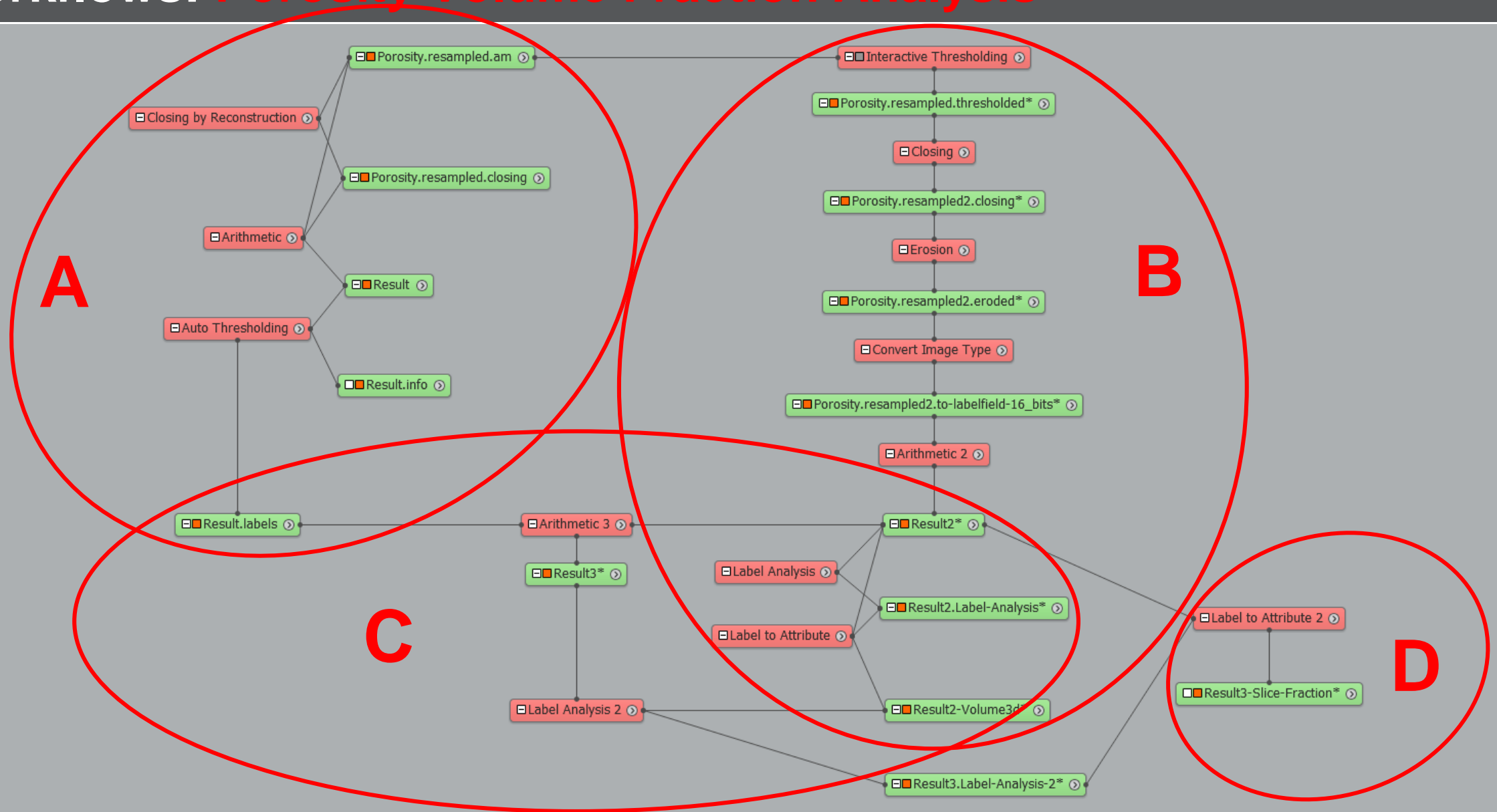


Volume Fraction Analysis using **Avizo**

Sarawuth Wantha, PhD
Product Application Specialist

October 2019

Workflows: Porosity Volume Fraction Analysis



Workflow A: Porosity Volume

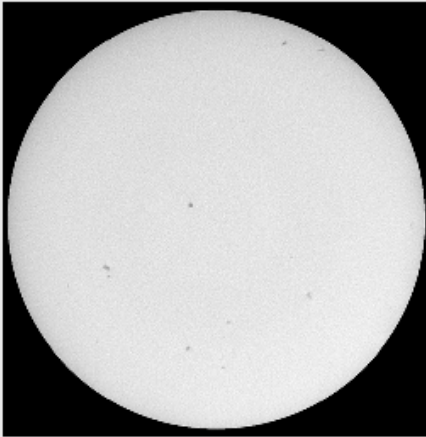
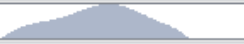


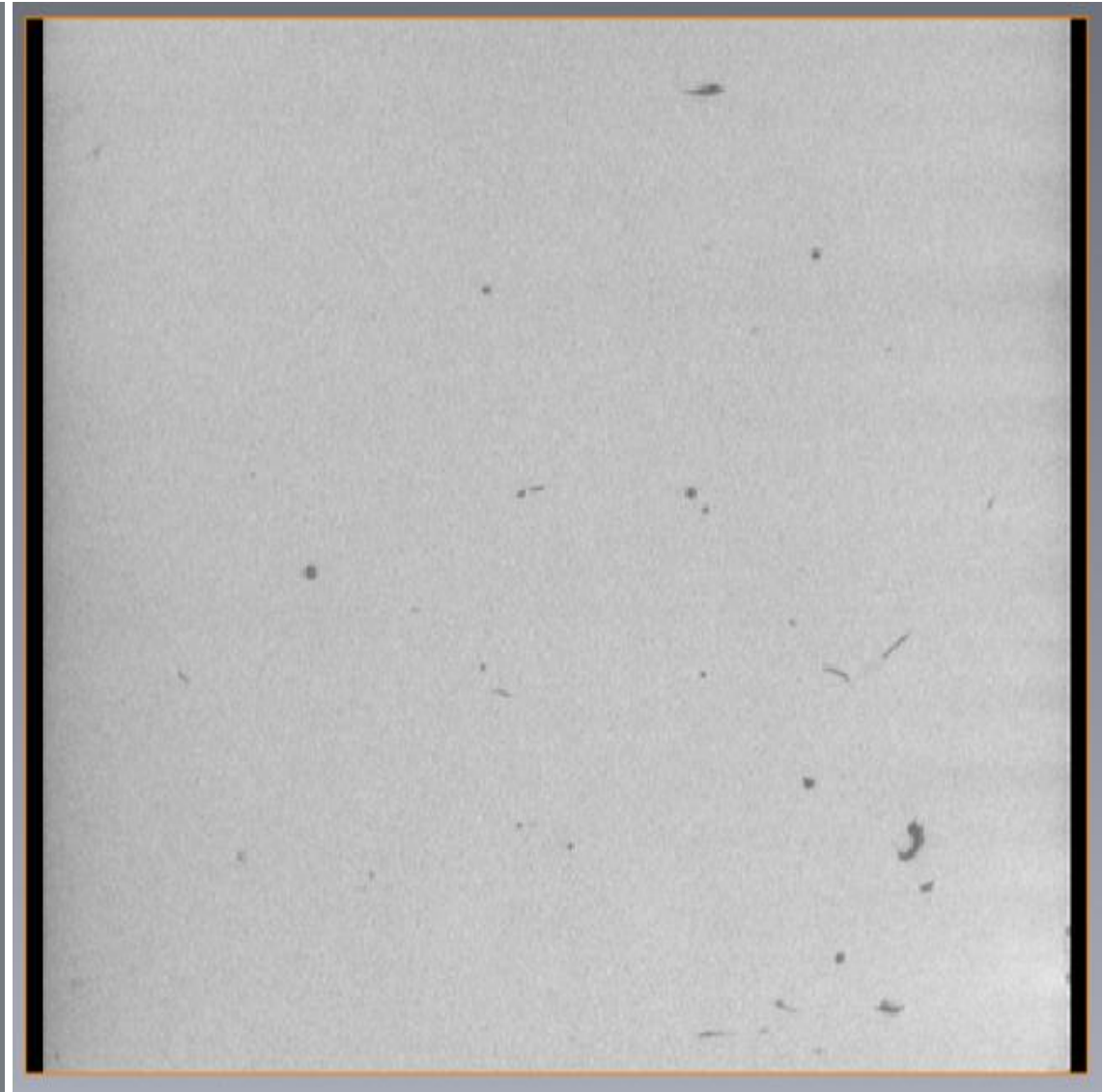
Step A1 : Load data

Workflow diagram showing the connection between **Porosity.resampled.am** and **Ortho Slice 2**.

Properties

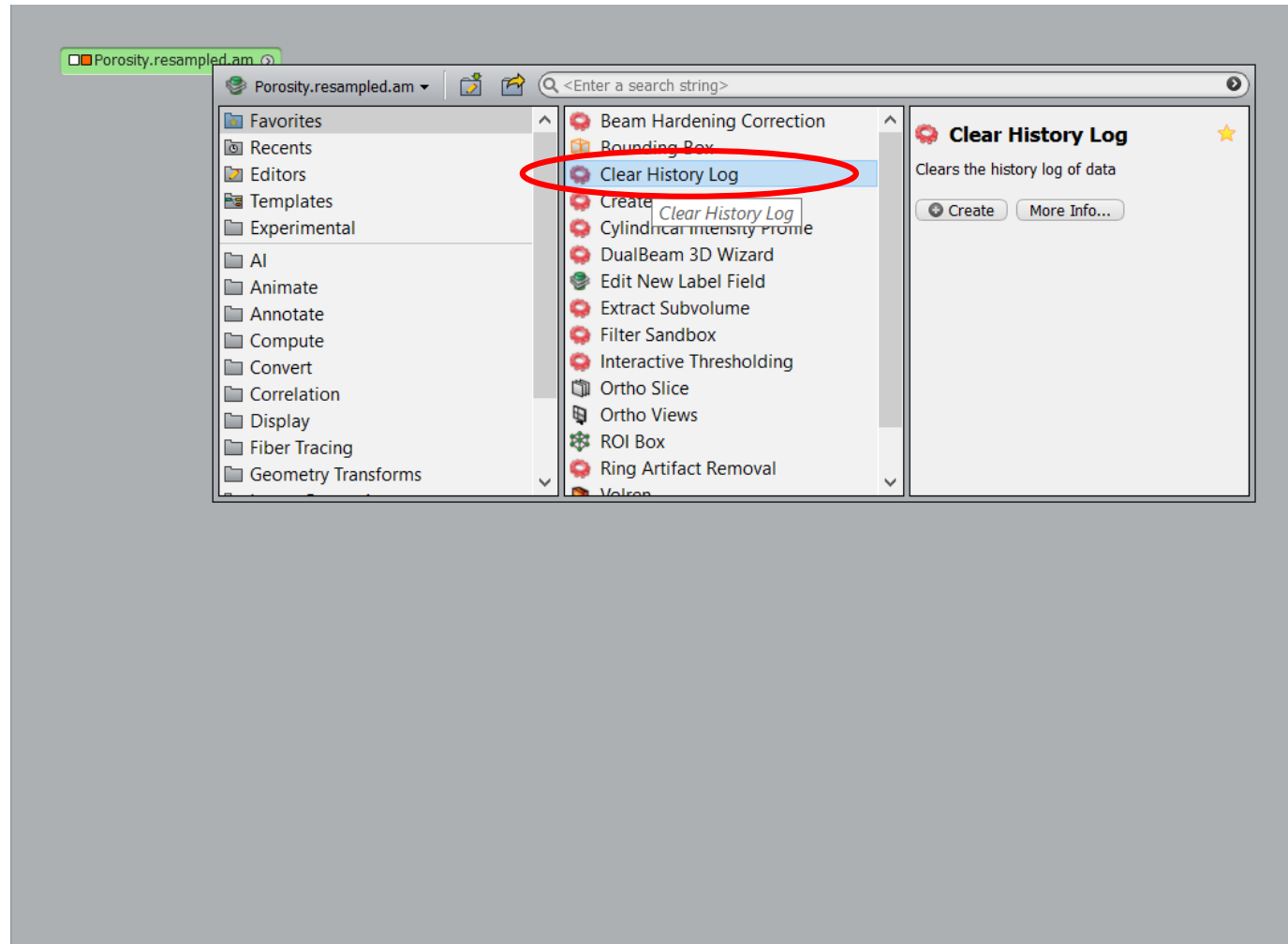
Porosity.resampled.am

- Lattice Info:** 496 x 507 x 377, uniform coordinates
- Data Info:** grayscale, 16-bit unsigned, min-max: 0...58569, window: 26623...65535, intensity ranges: 2
- Memory Size:** 180.8 MB
- Physical Size:** 9900, 10120, 7520 [mm] from 5, 5, 199.927 [mm]
- Voxel Size:** 20 x 20 x 20 [mm]
- Preview:** 
- Master:** NO SOURCE
- Histogram:** 0  5.857e+04
- Shared Colormap:** Edit



Resample image size if needed

Step A2 : Clear History Log



Clear History Log for creating Recipe (Optional)

Step A3 : Closing by Reconstruction

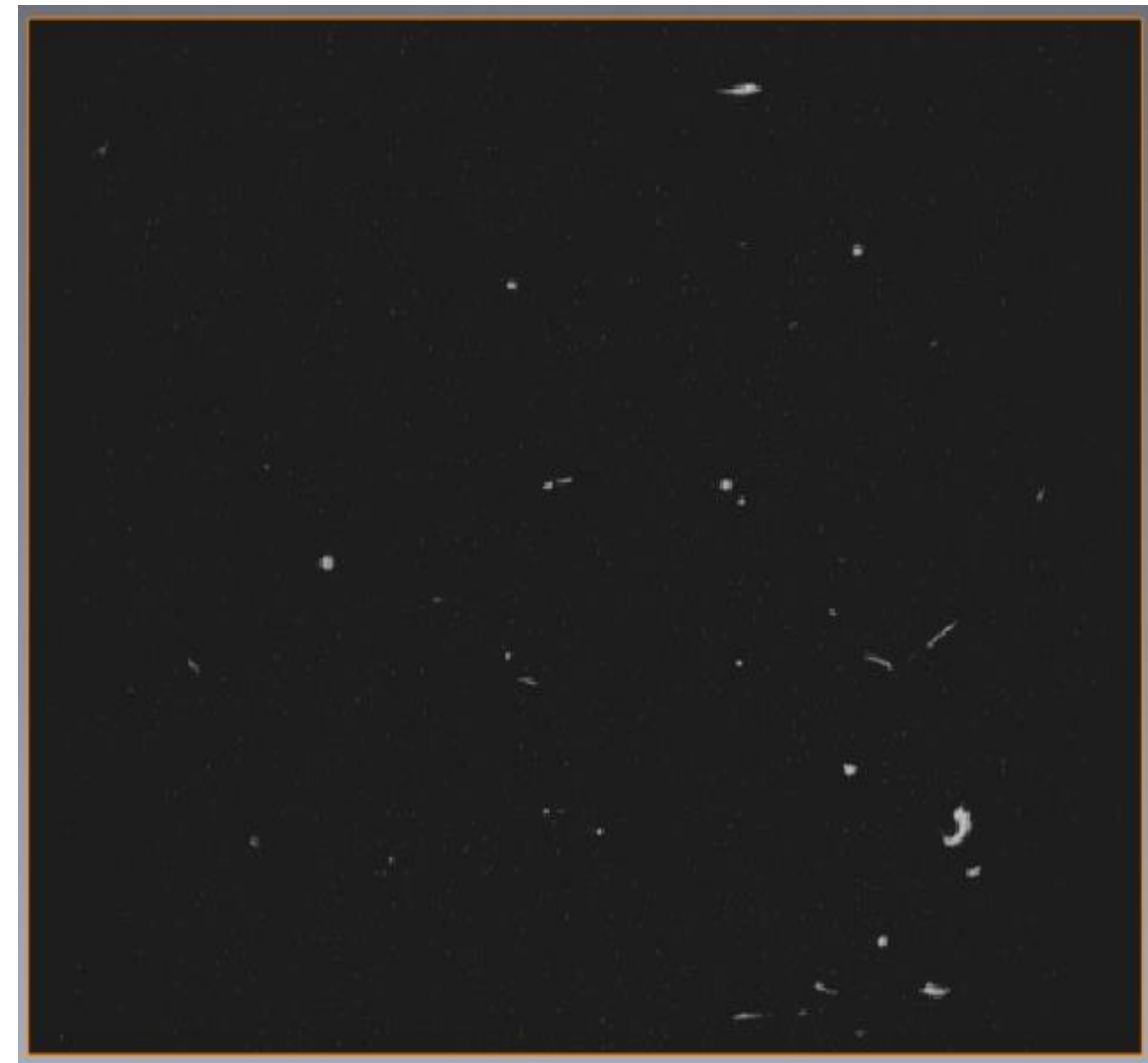
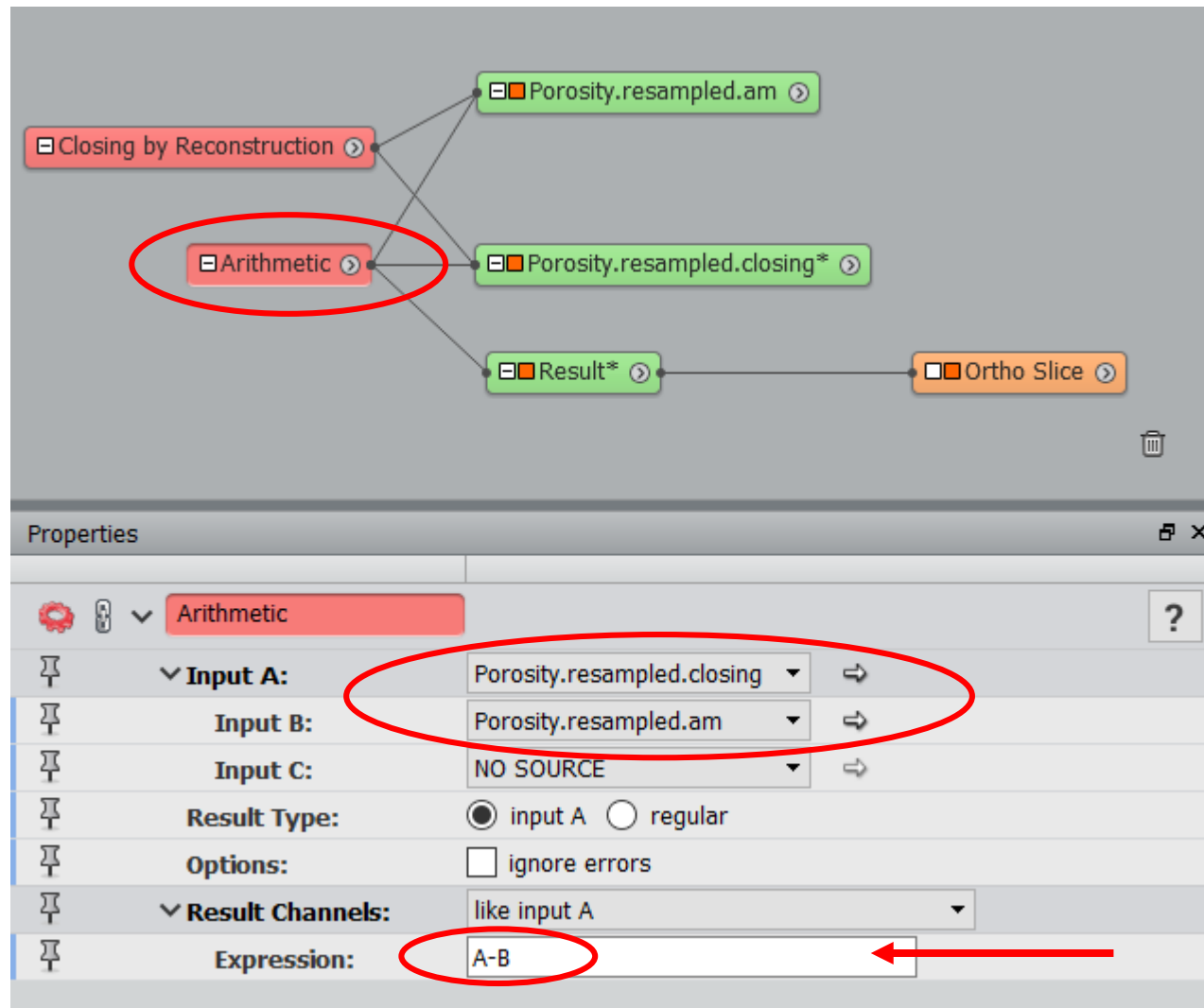
The screenshot displays a workflow diagram at the top with three nodes: 'Closing by Reconstruction' (highlighted with a red circle), 'Porosity.resampled.am', and 'Porosity.resampled.closing*'. Arrows indicate a flow from 'Closing by Reconstruction' to both 'Porosity.resampled.am' and 'Porosity.resampled.closing*', and from 'Porosity.resampled.closing*' to 'Ortho Slice'. Below the workflow is a 'Properties' panel for the 'Closing by Reconstruction' node. The properties are as follows:

Property	Value
Input Image:	Porosity.resampled.am
Type:	Ball
Interpretation:	<input checked="" type="radio"/> 3D <input type="radio"/> XY planes
Size [px]:	9
Precision:	Faster

A red arrow points to the 'Interpretation' section, specifically towards the '3D' radio button.

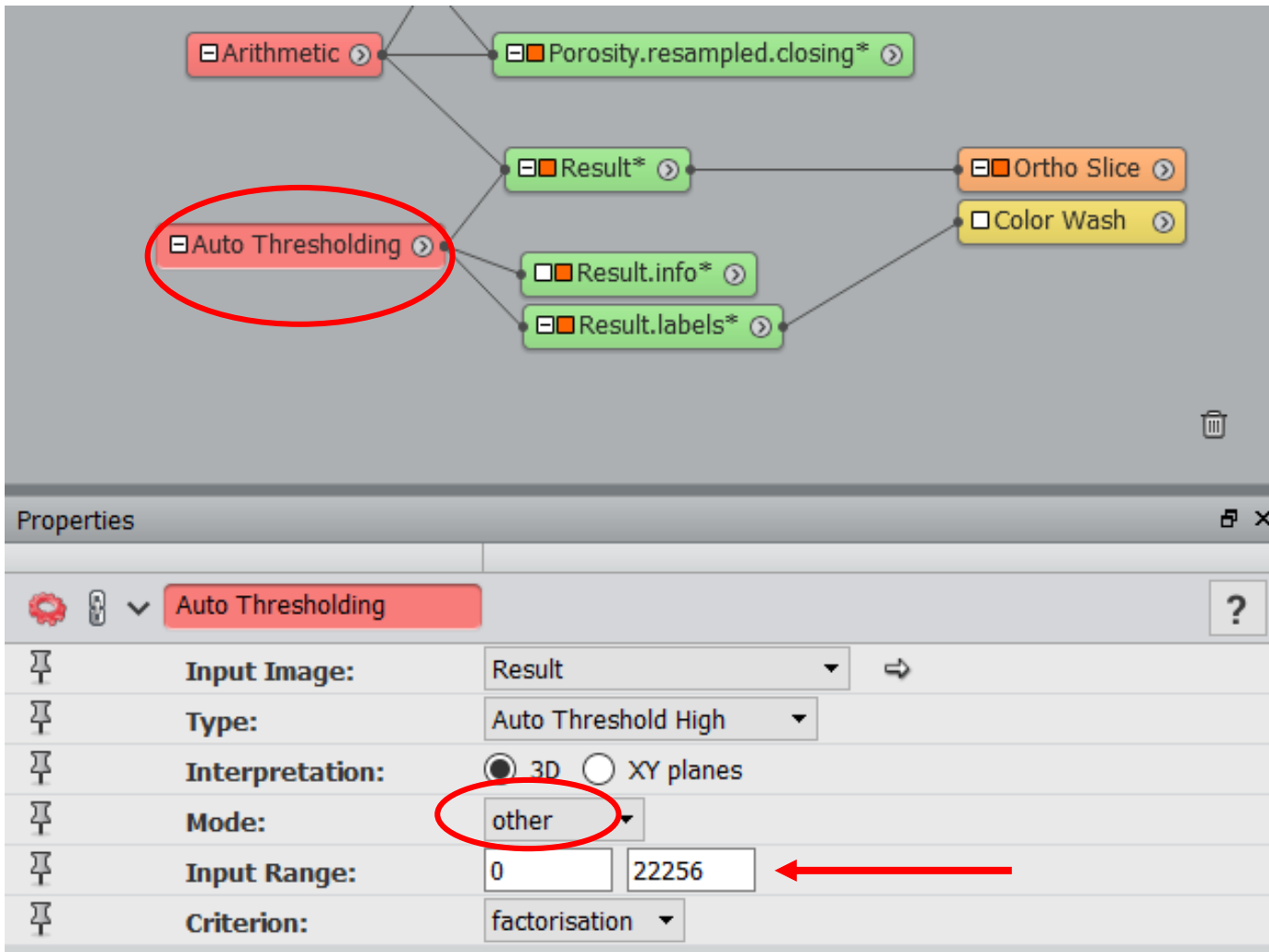


Step A4 : Arithmetic



Subtract Porosity intensity from the background

Step A5 : Auto Thresholding



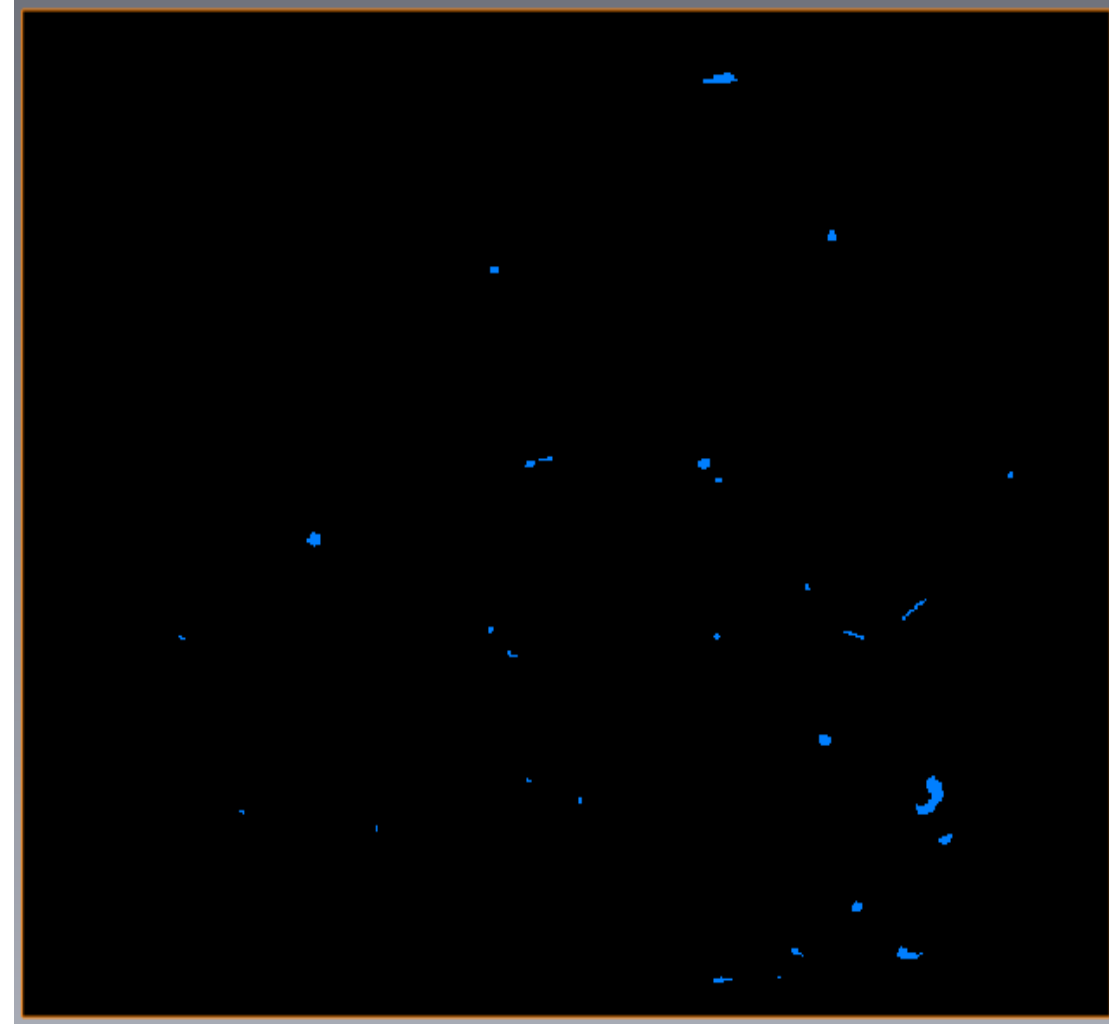
The screenshot displays a workflow graph and the properties panel for the 'Auto Thresholding' node.

Workflow Graph:

- Arithmetic** (red node) connects to **Porosity.resampled.closing*** (green node).
- Auto Thresholding** (red node, circled in red) receives input from **Porosity.resampled.closing*** and connects to **Result*** (green node).
- Result*** connects to **Ortho Slice** (orange node) and **Color Wash** (yellow node).
- Result*** also connects to **Result.info*** (green node) and **Result.labels*** (green node).

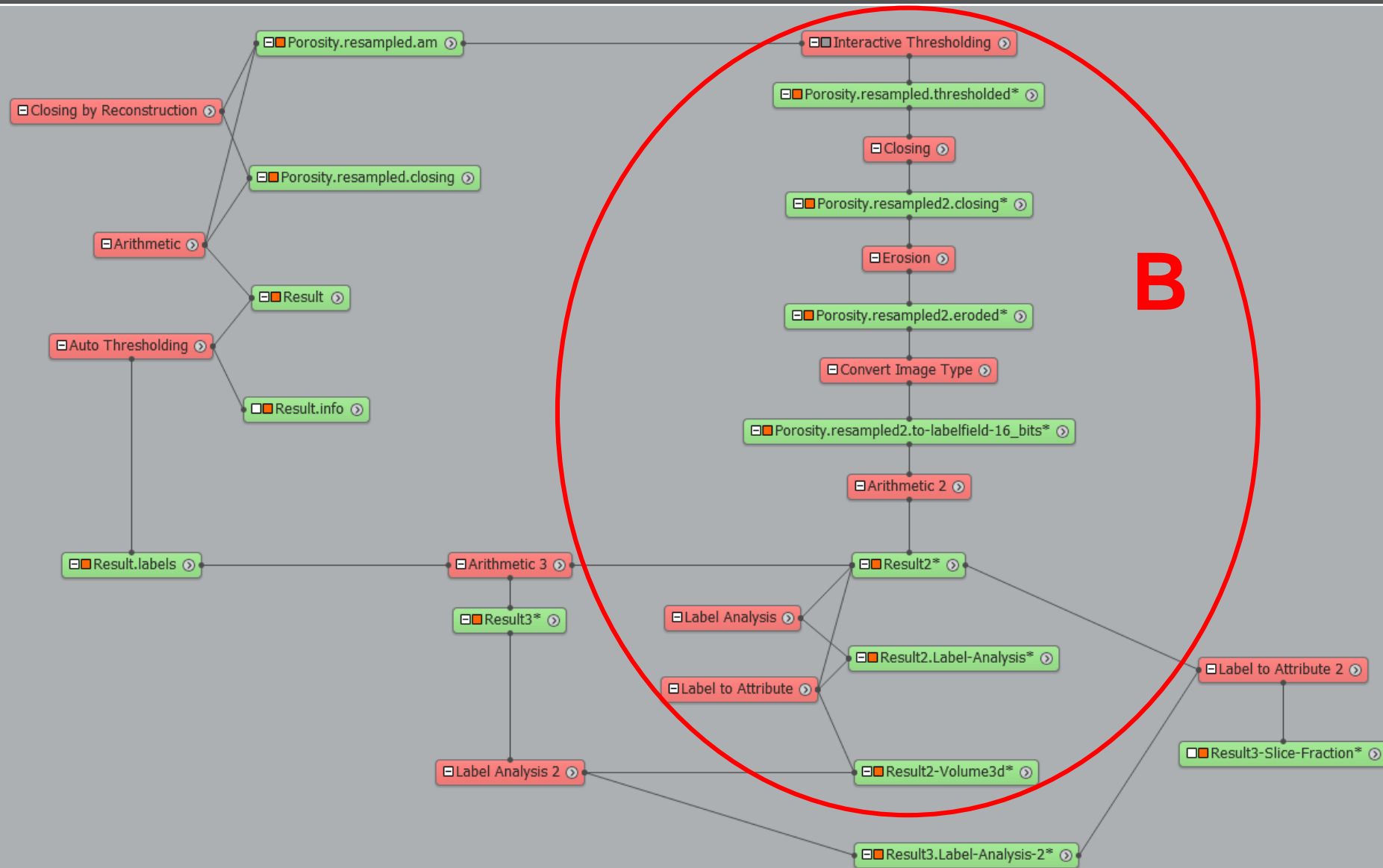
Properties Panel (Auto Thresholding):

Property	Value
Input Image:	Result
Type:	Auto Threshold High
Interpretation:	<input checked="" type="radio"/> 3D <input type="radio"/> XY planes
Mode:	other (circled in red)
Input Range:	0 to 22256 (with a red arrow pointing to the value 22256)
Criterion:	factorisation



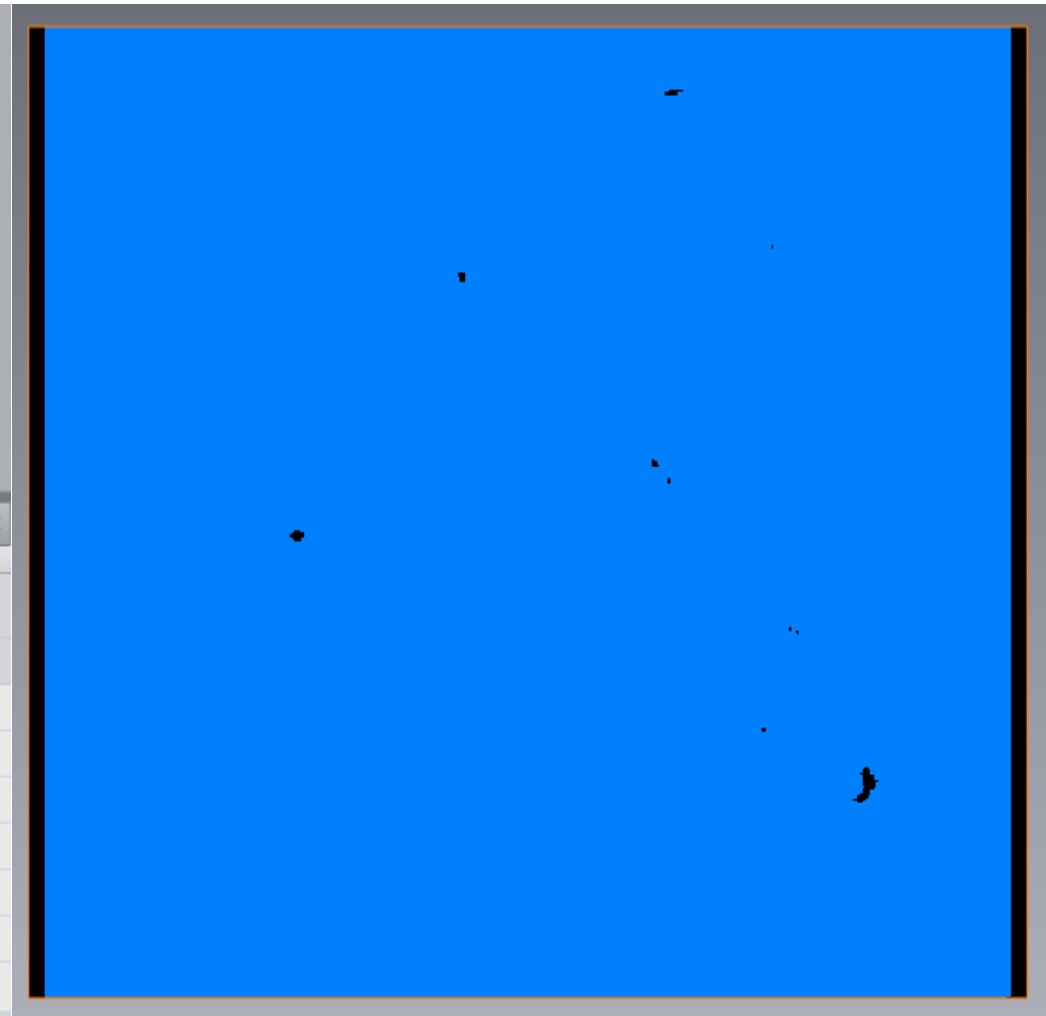
Adjust Input Range to threshold the Porosity

Workflow B: Create Total Volume Mask



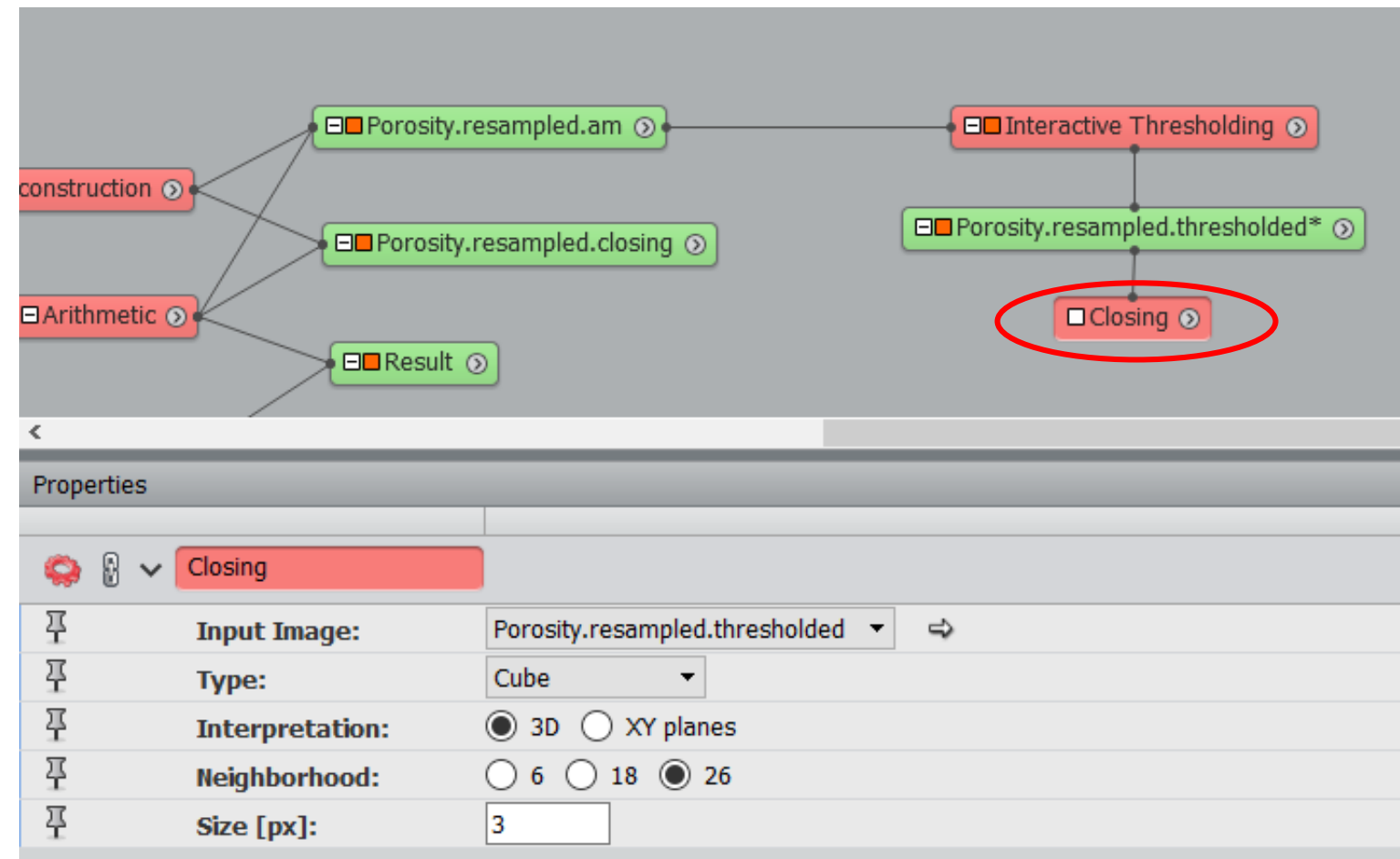
Step B1 : Interactive Thresholding

The screenshot displays a software interface for image processing. At the top, a workflow graph shows several nodes: 'Closing by Reconstruction', 'Arithmetic', 'Auto Thresholding', 'Porosity.resampled.am', 'Porosity.resampled.closing', 'Result', 'Result.info', and 'Result.labels'. The 'Interactive Thresholding' node is highlighted with a red circle. Below the graph is the 'Properties' panel for the 'Interactive Thresholding' node. The panel includes a 'Data' dropdown set to 'Porosity.resampled.am', a 'Preview Type' section with '2D' selected, a 'Preview Orientation' section with 'xy' selected, a 'Colormap' section with a value of 0, a 'Preview Slice Number' section with a value of 75, a 'Rendering' section with 'opaque' selected, an 'Intensity Range' section with values 29052 and 62157, and a 'Color Mask' section with a blue square.



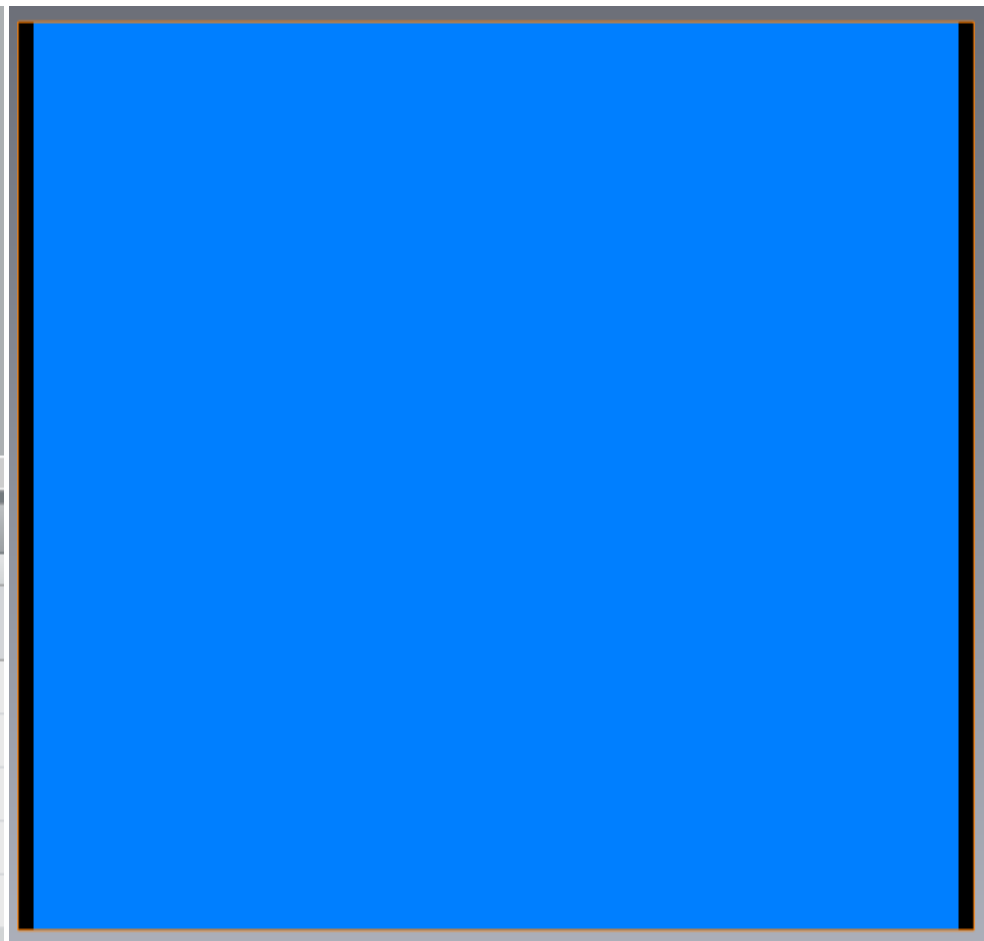
Creating a whole volume mask

Step B2 : Closing



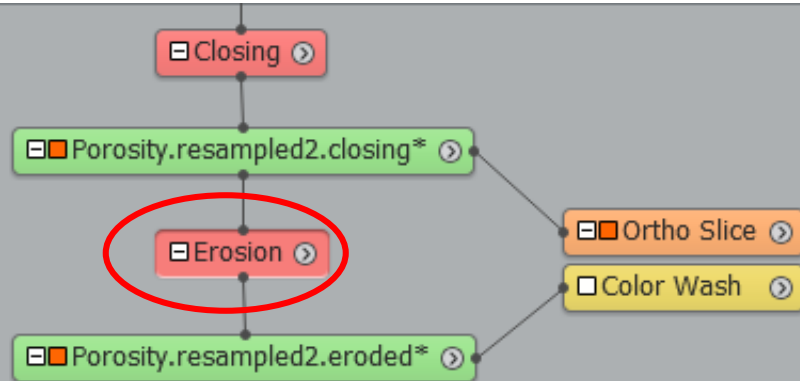
The screenshot displays a software interface for image processing. The top section shows a workflow diagram with several nodes: 'construction', 'Arithmetic', 'Porosity.resampled.am', 'Porosity.resampled.closing', 'Result', 'Interactive Thresholding', 'Porosity.resampled.thresholded*', and 'Closing'. The 'Closing' node is highlighted with a red circle. Below the diagram is a 'Properties' panel for the 'Closing' step. The panel includes a gear icon, a pin icon, and a dropdown menu set to 'Closing'. The properties are as follows:

Property	Value
Input Image:	Porosity.resampled.thresholded
Type:	Cube
Interpretation:	<input checked="" type="radio"/> 3D <input type="radio"/> XY planes
Neighborhood:	<input type="radio"/> 6 <input type="radio"/> 18 <input checked="" type="radio"/> 26
Size [px]:	3



Creating a whole volume mask

Step B3 : Erosion



Properties

	Erosion
	Input Image: Porosity.resampled2.closing
	Type: Cube
	Interpretation: <input checked="" type="radio"/> 3D <input type="radio"/> XY planes
	Neighborhood: <input type="radio"/> 6 <input type="radio"/> 18 <input checked="" type="radio"/> 26
	Size [px]: 1

Erode by 1 px to shrink mask from the border

Step B4 : Convert Image Type

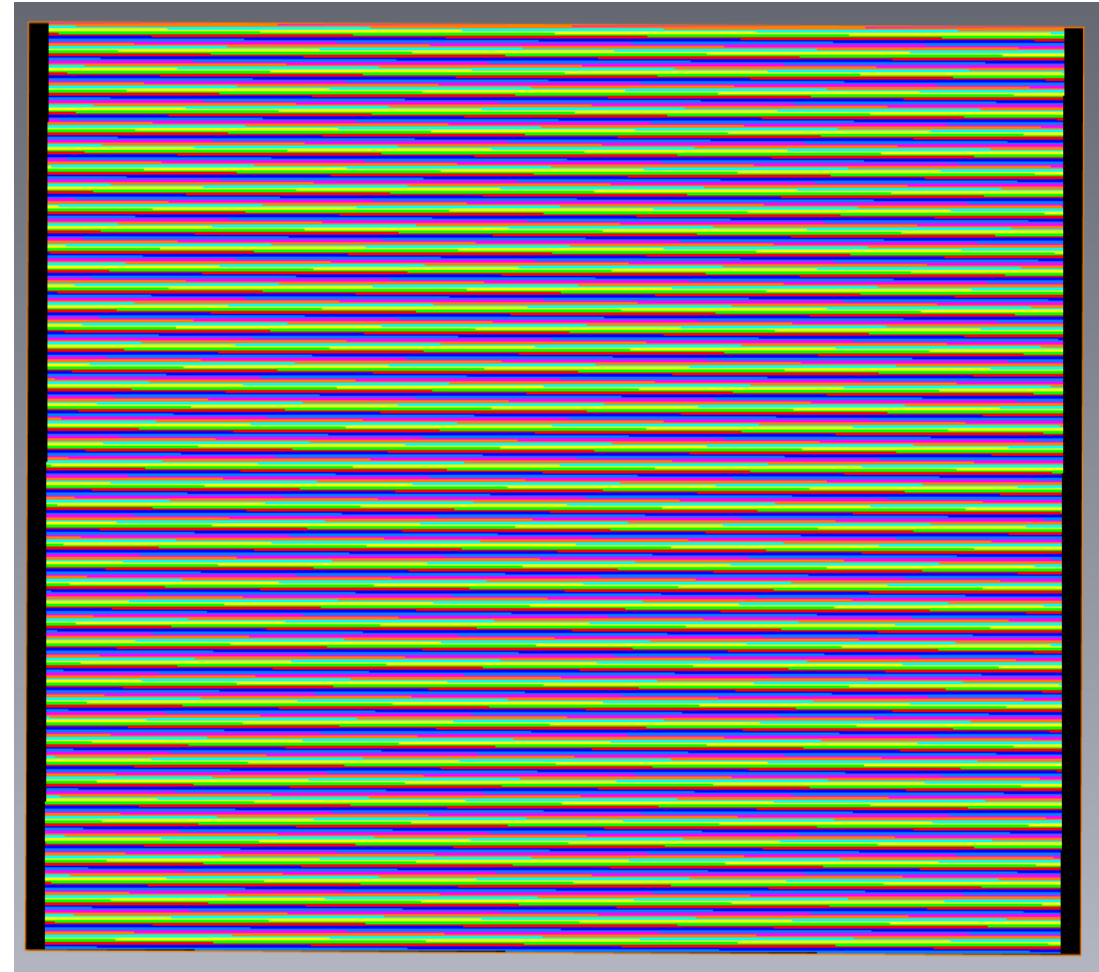
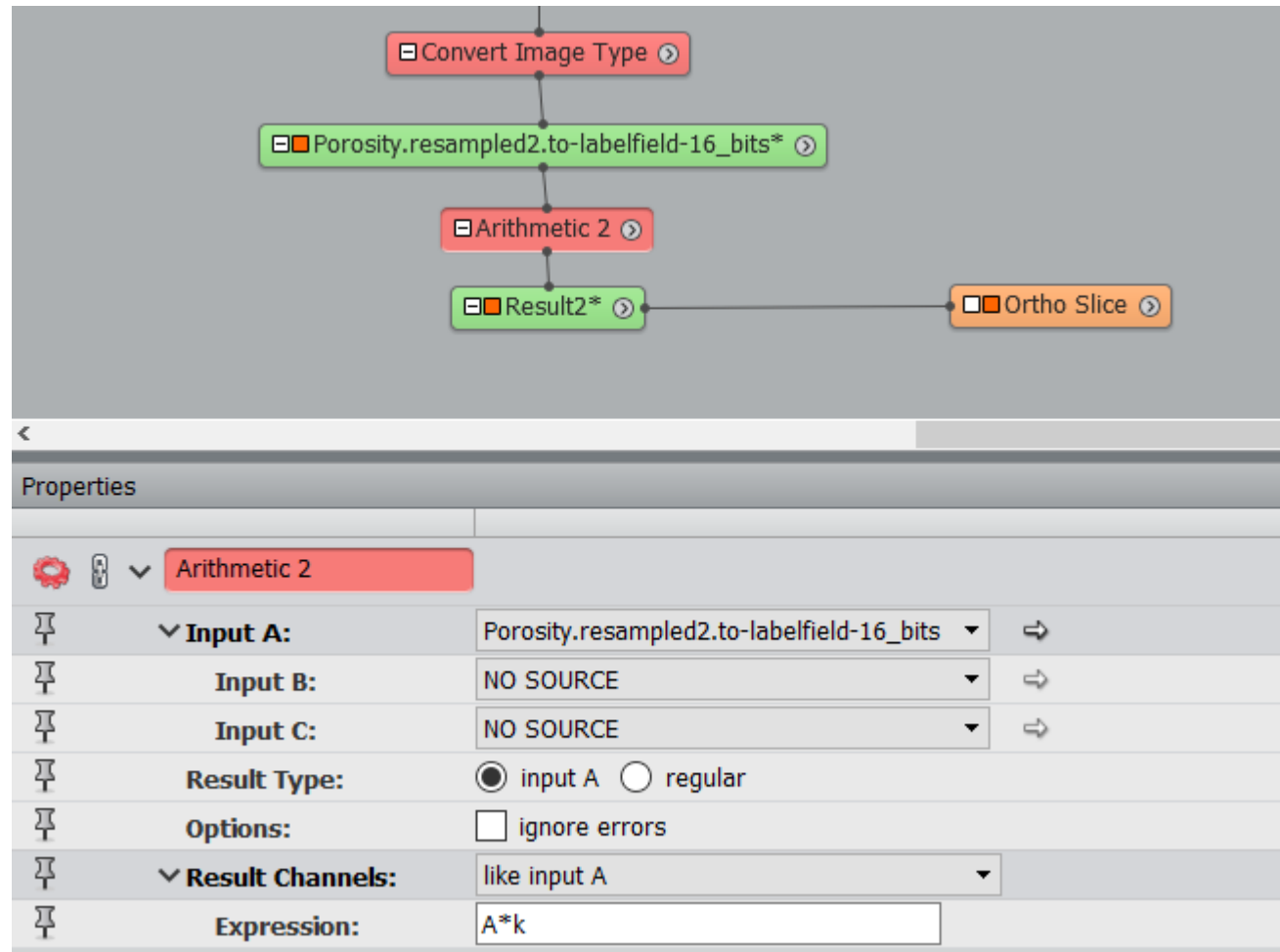
The screenshot displays the software interface for Step B4: Convert Image Type. The top section shows a workflow diagram with the following steps: Erosion, Porosity.resampled2.eroded*, **Convert Image Type** (highlighted with a red circle), and Porosity.resampled2.to-labelfield-16_bits*. To the right of the workflow are two additional steps: Ortho Slice and Color Wash. Below the workflow is the Properties panel for the 'Convert Image Type' step. The properties are as follows:

Property	Value
Data:	Porosity.resampled2.eroded
Info:	8-bit unsigned (0...1) -> 16-bit unsigned (0...1)
Output Type:	16-bit label (highlighted with a red circle)
Options:	<input checked="" type="checkbox"/> clean labels
Colormap:	1, 254, Edit

On the right side of the interface, a large rectangular area displays a solid purple image, representing the output of the conversion process.

Convert a mask to 16-bit label image

Step B5 : Arithmetic



**Multiply a mask by index 'k' to calculate a volume per Z-slice
(one voxel thick each) -> i, j, k = x, y, z**

Step B6 : Label Analysis

The screenshot displays a software interface for label analysis. On the left, a workflow diagram shows a sequence of steps: 'Arithmetic 2' leads to 'Result2*', which then branches into 'Label Analysis' (highlighted with a red circle) and 'Result2.Label-Analysis*'. 'Label Analysis' also leads to 'Ortho Slice'. Below the diagram is the 'Properties' panel for the 'Label Analysis' step. It includes fields for 'Data' (set to 'Result2'), 'Intensity Image' (set to 'NO SOURCE'), 'Interpretation' (radio buttons for '3D' and 'XY planes', with '3D' selected), and 'Measures' (set to 'basic'). Two red arrows point to the 'Interpretation' and 'Measures' fields. On the right, a table displays statistical data for the analysis.

	Volume3d (mm ³)	Area3d (mm ²)	BaryCenterX (mm)
Mean	1.48792e+09	1.38051e+08	4995.36
Min	1.48559e+09	1.37838e+08	4989.22
Max	1.48832e+09	1.38088e+08	4997.07
Median	1.48797e+09	1.38055e+08	4995.25
Variance	1.37161e+11	1.15084e+09	1.80048
Kurtosis	inf	6.88432e+06	-1.8946e+06
Skewness	--	-2501.82	--

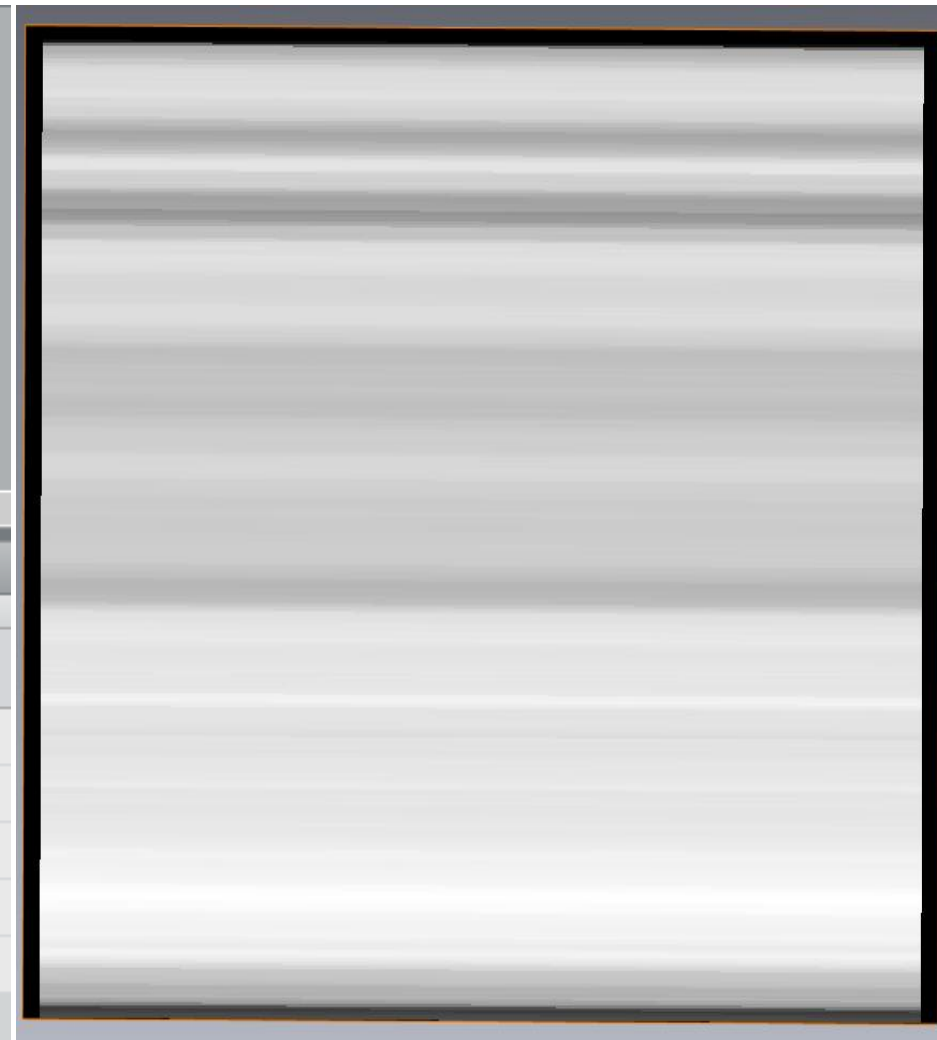
	Volume3d (mm ³)	Area3d (mm ²)	BaryCenterX (mm)
1	1.48686e+09	1.37954e+08	4992.56
2	1.48685e+09	1.37952e+08	4992.57
3	1.48679e+09	1.37947e+08	4992.54
4	1.48673e+09	1.37941e+08	4992.57
5	1.48688e+09	1.37955e+08	4992.66
6	1.48729e+09	1.37992e+08	4993.27
7	1.48754e+09	1.38016e+08	4993.83
8	1.48762e+09	1.38023e+08	4994.01
9	1.48772e+09	1.38032e+08	4994.13

Calculate total volume per Z-slice

Step B7 : Label to Attribute

The screenshot displays the software's workflow editor and properties panel. In the workflow editor, the 'Label to Attribute' node is highlighted with a red circle. Red arrows point from this node to its configuration fields in the properties panel: 'Data' points to 'Result2.Label-Analysis*', 'Label Image' points to 'Result2', 'Attribute' points to 'Volume3d', and 'Padding Value' points to the '0' input field. The properties panel is titled 'Properties' and shows the 'Label to Attribute' node selected. The configuration fields are as follows:

Property	Value
Data:	Result2.Label-Analysis
Label Image:	Result2
Attribute:	Volume3d
Labels Column:	index
Padding Value:	<input type="checkbox"/> Auto <input type="text" value="0"/>

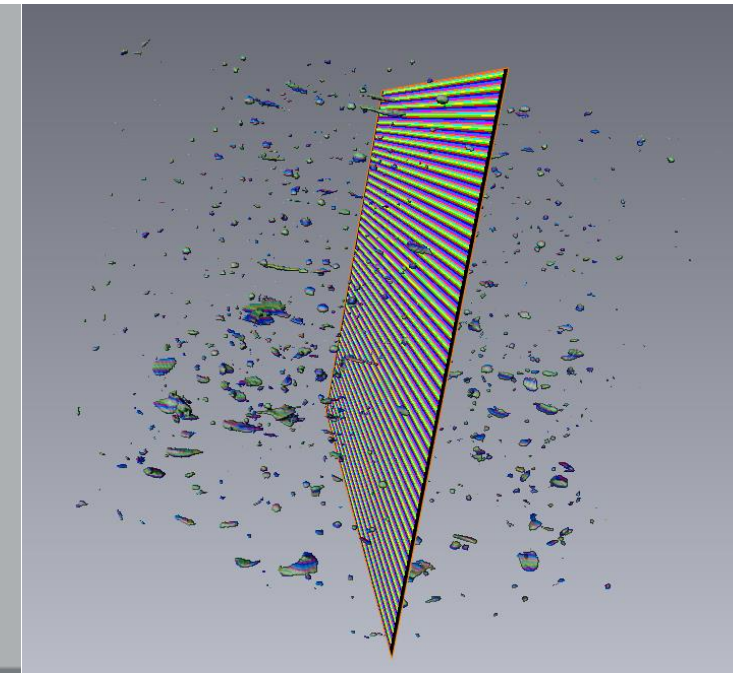
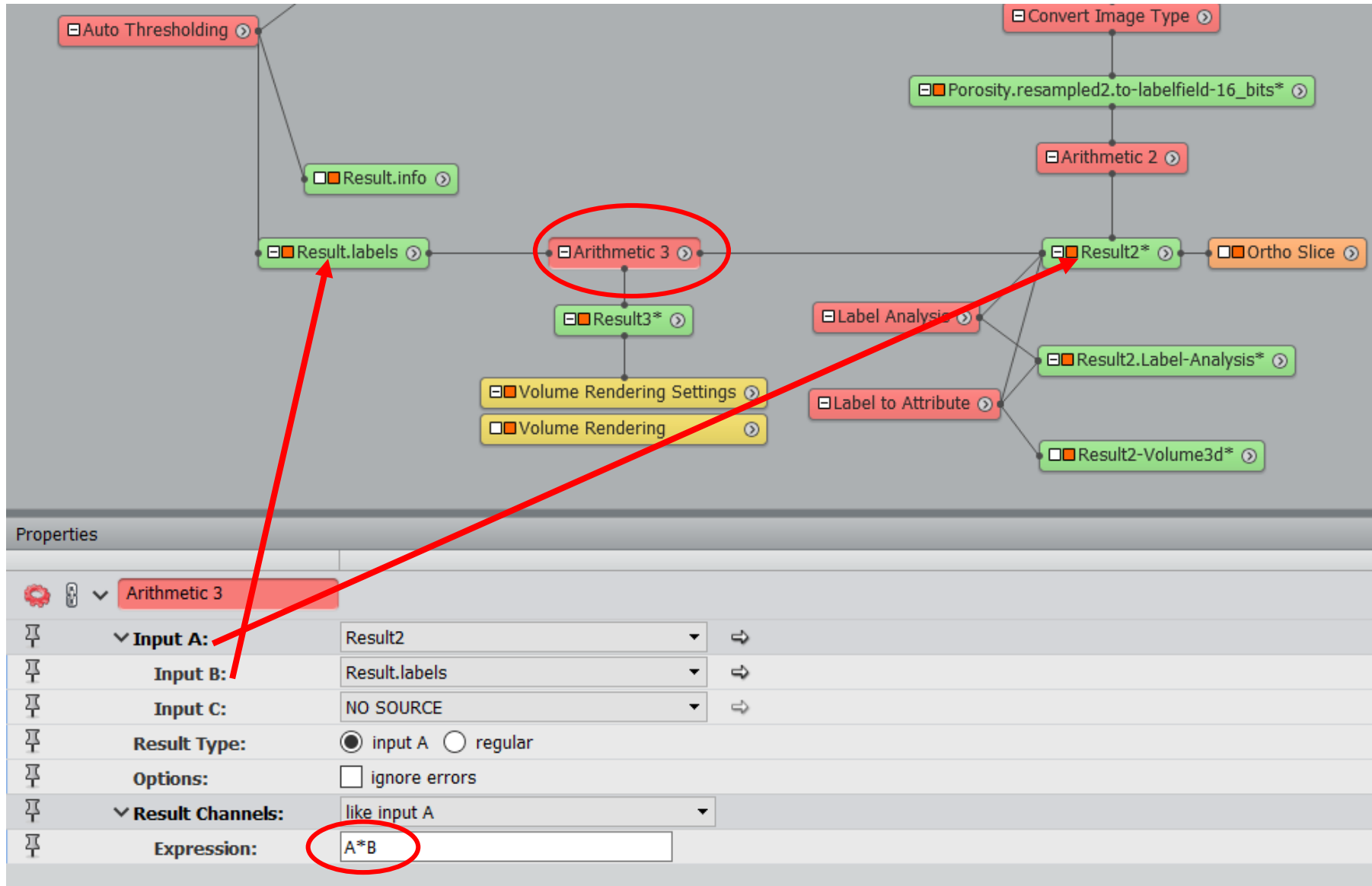


Display total volume per Z-slice

Workflow C: Porosity Volume Fraction per Slice



Step C1 : Arithmetic A * B



Multiply (masking) the result from A (porosity) with 'k' pattern from B (mask), to link porosity to its position in Z-axis

Step C2 : Label Analysis

The screenshot illustrates the process of calculating porosity fraction per Z-slice in Avizo. The workflow is as follows:

- Auto Thresholding** (red node) leads to **Result** (green node).
- Result** leads to **Result.info** (green node).
- Result.info** leads to **Result.labels** (green node).
- Result.labels** leads to **Arithmetic 3** (red node).
- Arithmetic 3** leads to **Result3*** (green node).
- Result3*** leads to **Label Analysis 2** (red node, highlighted with a red circle).

The **Label Analysis 2** node is configured with the following settings:

- Data:** Result3
- Intensity Image:** NO SOURCE
- Interpretation:** 3D (selected), XY planes
- Measures:** NewMeasure

The **Selection of measure groups** dialog shows the **NewMeasure** group selected. The custom measures list includes:

Name	Formula
Slice Fraction	(100/ Maximum)* Volume3d

The **Measure Editor** dialog shows the **Slice Fraction** measure selected. The output unit dimension is set to **(100/ Maximum)* Volume3d**.

The **Measure Editor** also includes a list of native measures and a list of functions.

Native measures:

Name
Intensity
GreyMass
IntensityCount
Majority
Maximum
Mean
Median

Functions:

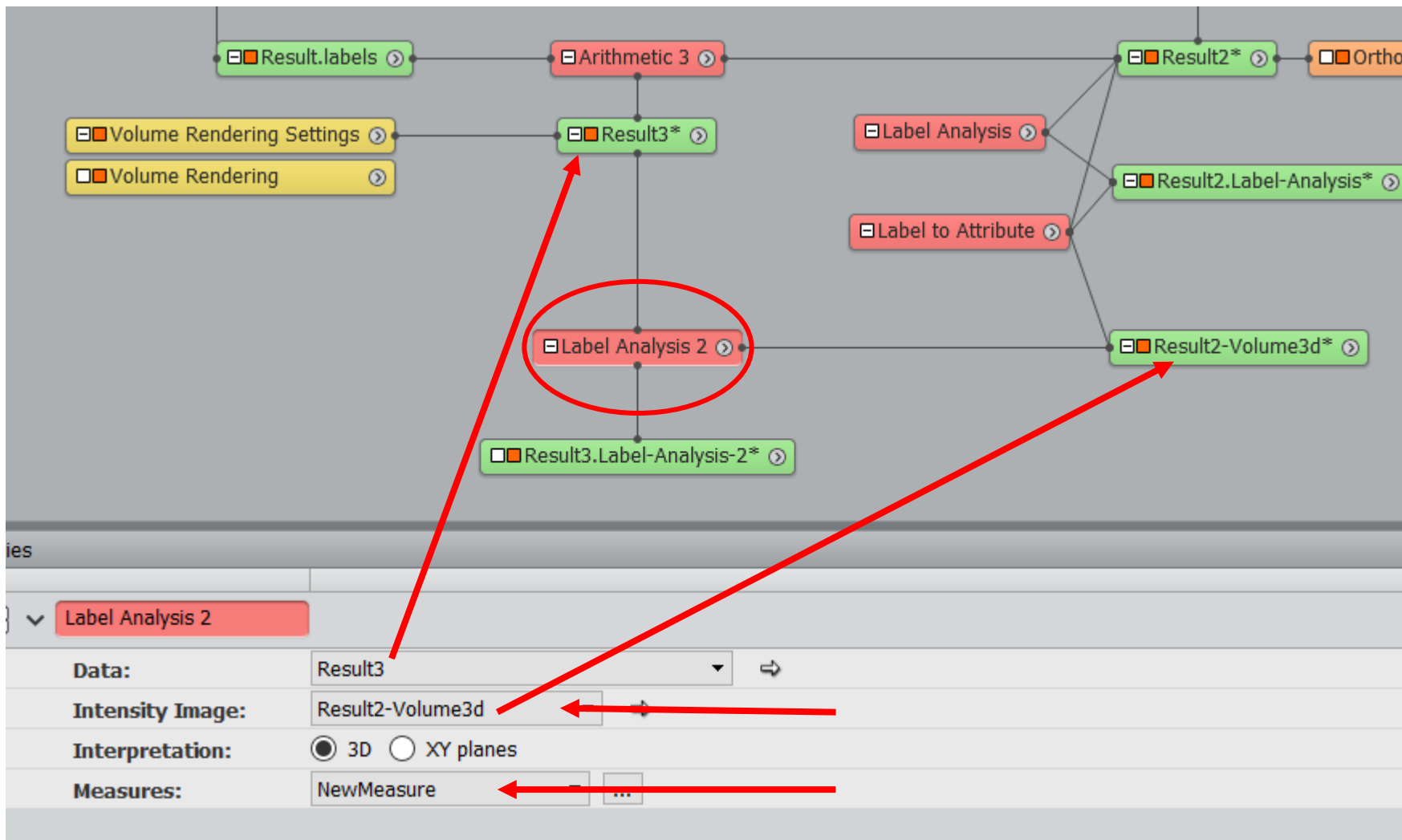
Variables	Description	Functions
cx	width of voxel (dis...	abs(a)
cy	height of voxel (di...	sqrt(a)
cz	depth of voxel (di...	log(a)
gx	width of input ima...	exp(a)
gy	height of input im...	cos(a)
gz	depth of input im...	sin(a)

Measures:

- > Cooccurrence
- > Feret
- > Geometry
- > Histogram
- > Inertia
- > Intensity

Calculate Porosity fraction per Z-slice

Step C3 : Label Analysis

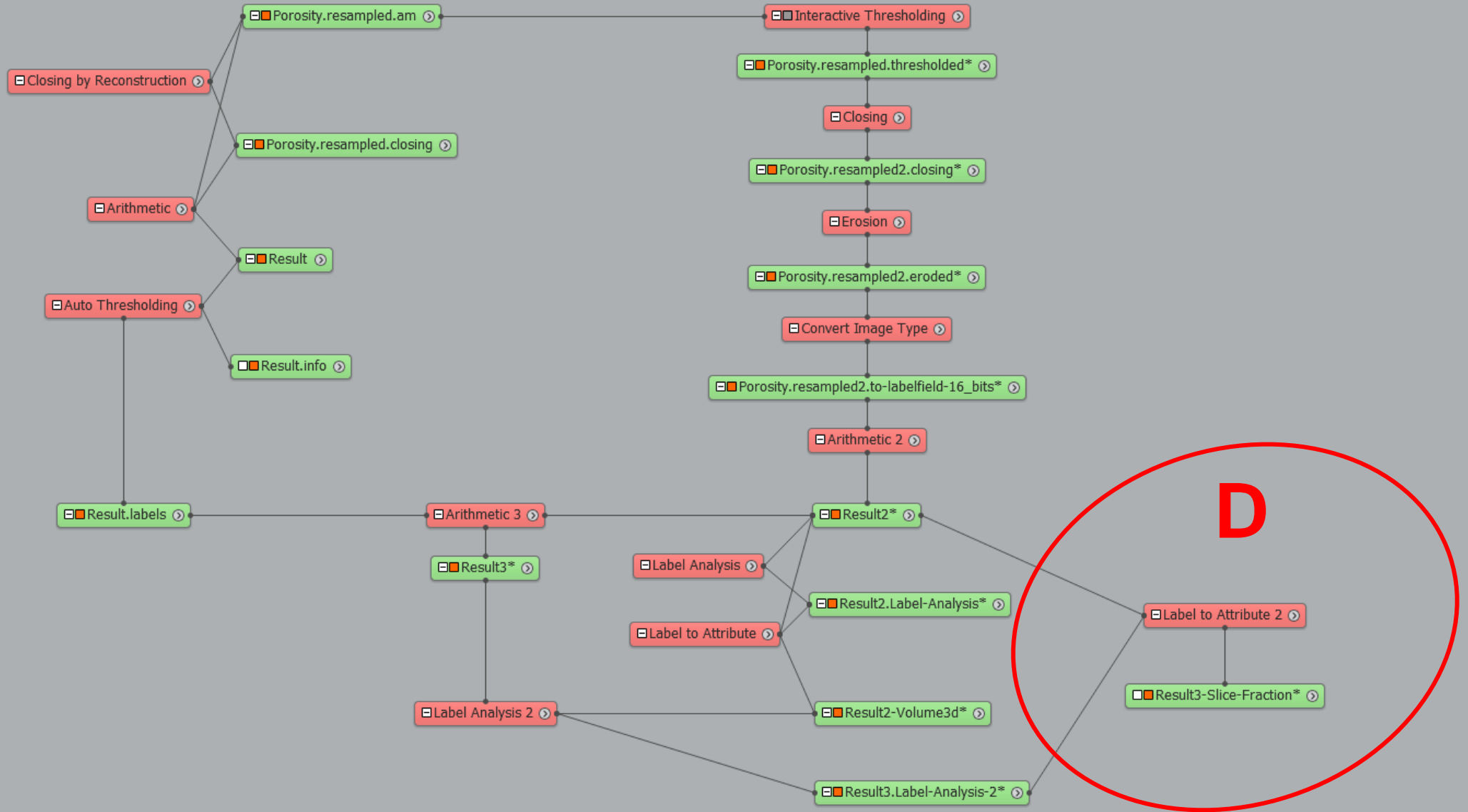


	Volume3d (mm ³)	Maximum	Slice Fraction	index
Mean	1.68828e+06	1.48792e+09	0.113461	188.5
Min	32000.0	1.48559e+09	0.00215386	1.0
Max	1.256e+07	1.48832e+09	0.844181	376.0
Median	1.27488e+06	1.48797e+09	0.0857196	188.0
Variance	3.46667e+12	1.37161e+11	0.0156575	11781.2
Kurtosis	7.57146	inf	7.57475	-1.20005
Skewness	2.40198	--	2.40236	7.5284e-06

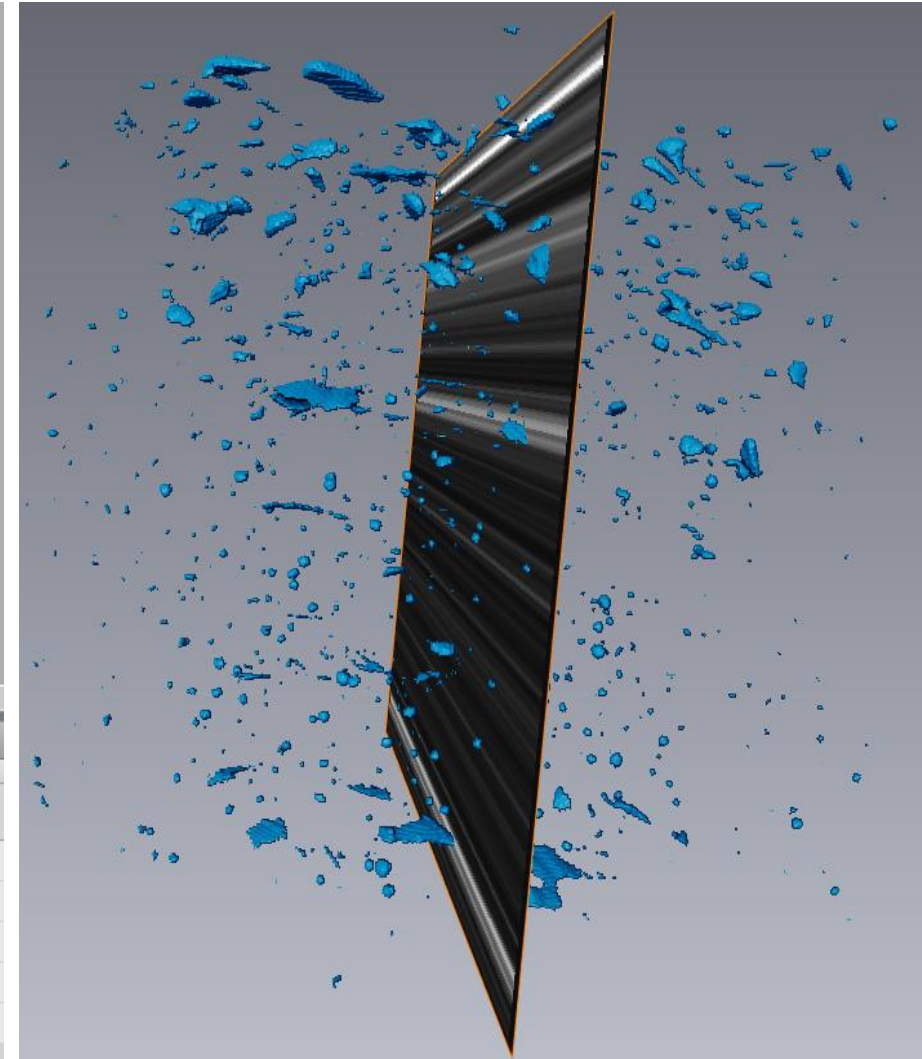
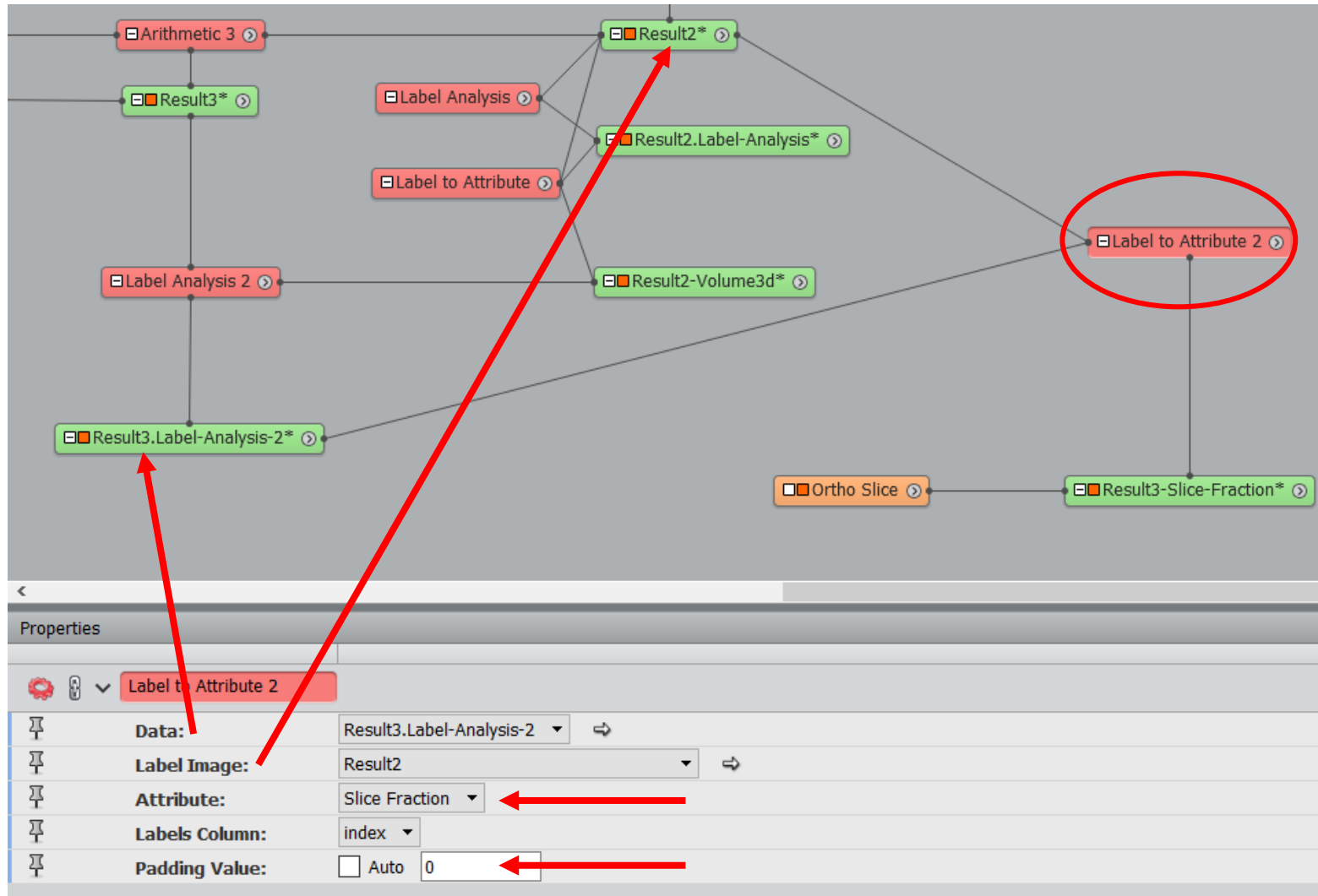
	Volume3d (mm ³)	Maximum	Slice Fraction	index
1	2.528e+06	1.48686e+09	0.170022	1
2	2.912e+06	1.48685e+09	0.195851	2
3	3.432e+06	1.48679e+09	0.230833	3
4	3.8e+06	1.48673e+09	0.255595	4
5	3.696e+06	1.48688e+09	0.248574	5
6	3.048e+06	1.48729e+09	0.204937	6
7	2.224e+06	1.48754e+09	0.149508	7
8	2.256e+06	1.48762e+09	0.151652	8
9	2.976e+06	1.48772e+09	0.200038	9
10	4.648e+06	1.48768e+09	0.312433	10
11	5.736e+06	1.48771e+09	0.385558	11
12	6.672e+06	1.4877e+09	0.448479	12

Calculate Porosity fraction per Z-slice

Workflow D: Visualize Porosity Volume Fraction per Slice



Step D1 : Label to Attribute



Visualize Porosity fraction per Z-slice

Results: Porosity Volume Fraction per Z-slice

Result3.Label-Analysis-2				
	Volume3d (mm^3)	Maximum	Slice Fraction	index
Mean	1.68828e+06	1.48792e+09	0.113461	188.5
Min	32000.0	1.48559e+09	0.00215386	1.0
Max	1.256e+07	1.48832e+09	0.844181	376.0
Median	1.27488e+06	1.48797e+09	0.0857196	188.0
Variance	3.46667e+12	1.37161e+11	0.0156575	11781.2
Kurtosis	7.57146	inf	7.57475	-1.20005
Skewness	2.40198	--	2.40236	7.5284e-06

	Volume3d (mm^3)	Maximum	Slice Fraction	index
1	2.528e+06	1.48686e+09	0.170022	1
2	2.912e+06	1.48685e+09	0.195851	2
3	3.432e+06	1.48679e+09	0.230833	3
4	3.8e+06	1.48673e+09	0.255595	4
5	3.696e+06	1.48688e+09	0.248574	5
6	3.048e+06	1.48729e+09	0.204937	6
7	2.224e+06	1.48754e+09	0.149508	7
8	2.256e+06	1.48762e+09	0.151652	8
9	2.976e+06	1.48772e+09	0.200038	9
10	4.648e+06	1.48768e+09	0.312433	10
11	5.736e+06	1.48771e+09	0.385558	11
12	6.672e+06	1.4877e+09	0.448479	12
13	9.224e+06	1.48772e+09	0.620009	13
14	1.1736e+07	1.4878e+09	0.788816	14
15	1.256e+07	1.48783e+09	0.844181	15
16	1.108e+07	1.48784e+09	0.744704	16
17	7.184e+06	1.48786e+09	0.482842	17
18	4.816e+06	1.48786e+09	0.323685	18
19	3.152e+06	1.48787e+09	0.211846	19
20	1.552e+06	1.48798e+09	0.104303	20
21	872000.0	1.48802e+09	0.0586012	21
22	1.032e+06	1.4881e+09	0.06935	22
23	1.712e+06	1.48815e+09	0.115042	23
24	2.008e+06	1.48818e+09	0.13493	24
25	1.896e+06	1.48822e+09	0.1274	25
26	2.12e+06	1.48822e+09	0.142452	26

