

We are Nitinol.TM

Volume Fraction Strain Amplitude: Step-by-Step process using ImageJ, JMP, Excel

Get ImageJ



A screenshot of a Mac OS X desktop showing a web browser window. The title bar says "Inbox (19) - craig.bonsign..." and the tab says "rsbweb.nih.gov/ij/download.html". The page content includes a navigation bar with links like "home", "news", "docs", "download", "plugins", "resources", "list", and "links". A large blue button labeled "Download" is prominent. Below it, a section titled "Platform Independent" describes how to install ImageJ 1.46 on a Mac. Other sections for Mac OS X, Linux, Windows, and Documentation are also visible.

Platform Independent

To install ImageJ 1.46 on a computer with Java pre-installed, or to upgrade to the latest full distribution (including macros, plugins and LUTs), download [ij146.zip](#) (3.2MB) and extract the ImageJ directory. Use the *Help>Update ImageJ* command to upgrade to newer versions.

Mac OS X

Download [ImageJ 1.46](#) (5.7MB) as a double-clickable Mac OS X application. Includes ImageJ64, which uses Java 1.6 in 64-bit mode on Intel Macs running OS X 10.5 or later. ([Instructions](#))

Linux

Download ImageJ 1.46 [bundled with 64-bit Java](#) (40MB) or with [32-bit Java](#) (46MB). Both versions include Java 1.6.0_24 from Sun and the ImageJ source code. ([Instructions](#))

Windows

Download ImageJ 1.46 [bundled with 64-bit Java](#) (24MB; requires 64-bit Windows), [32-bit Java](#) (28MB) or [without Java](#) (3MB). ([Instructions](#))

Documentation

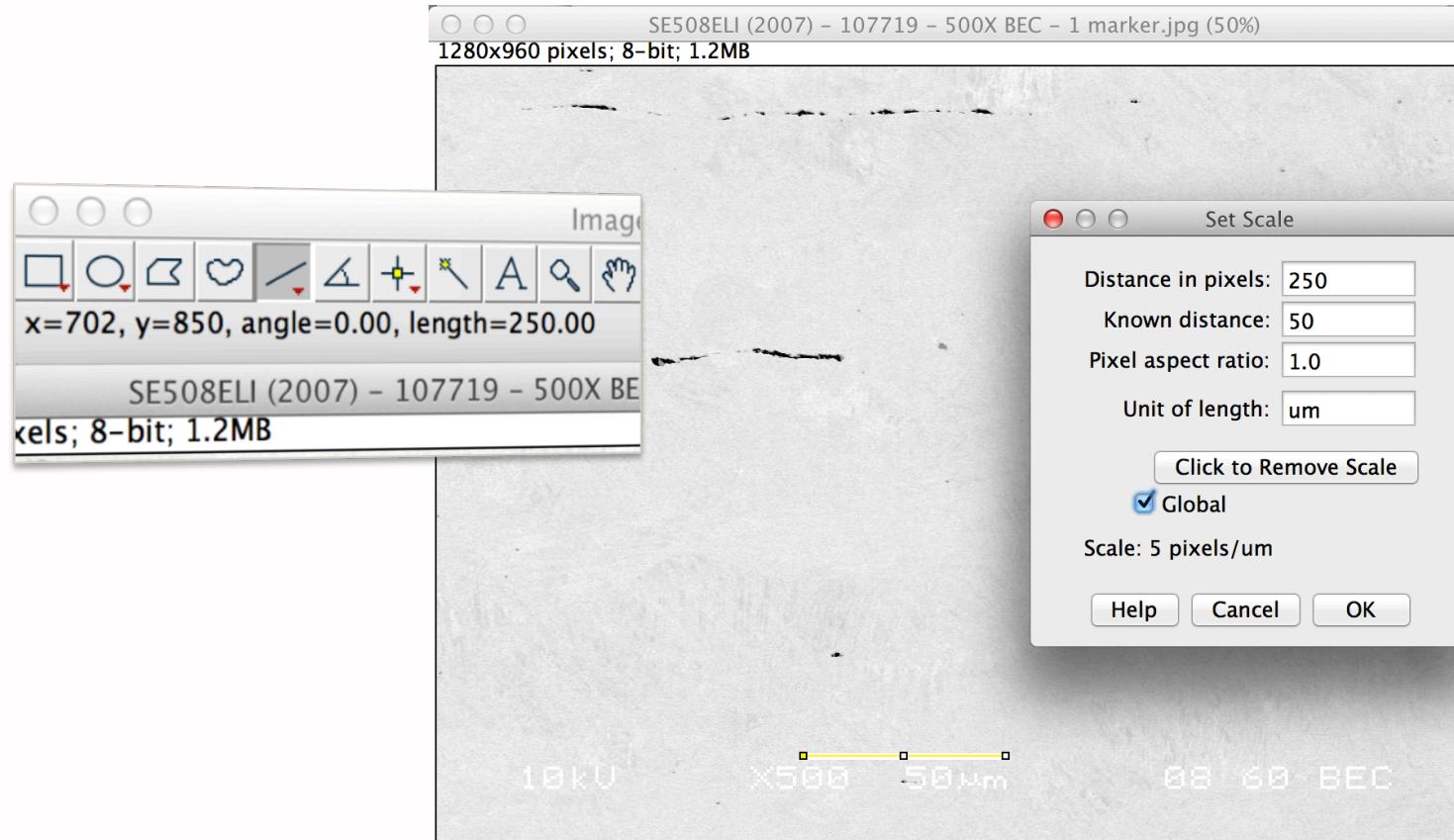
Tiago Ferreira's comprehensive [ImageJ User Guide](#) is available as an 8MB PDF document and as a [ZIP archive](#). The online [JavaDoc API documentation](#) is also available as a [ZIP archive](#).

<http://rsbweb.nih.gov/ij/download.html>

ImageJ: Open Image with Marker

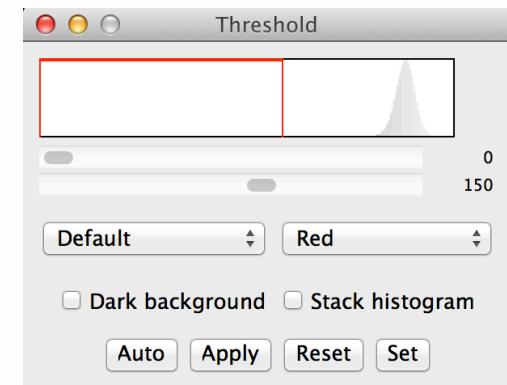
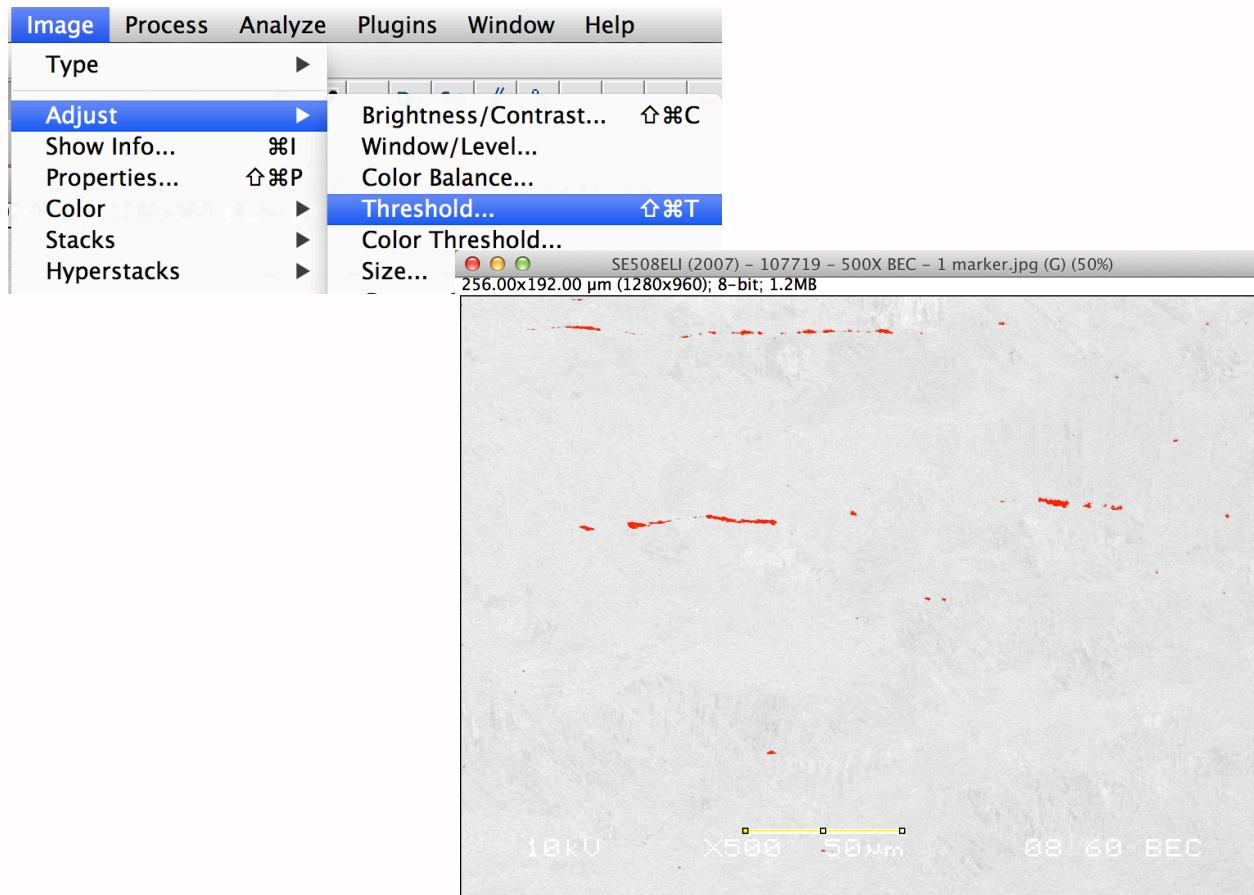


ImageJ: Measure image marker to determine scale



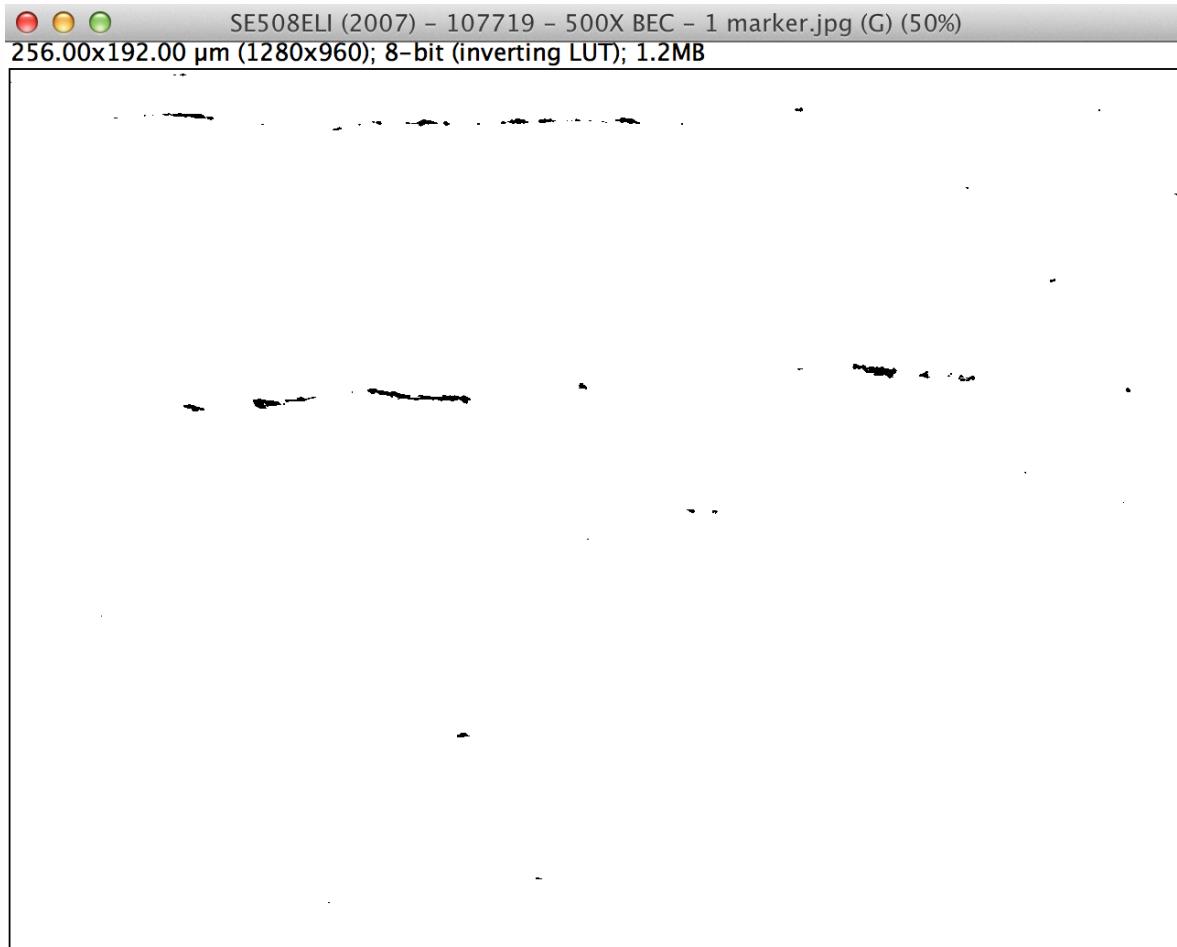
analyze > set scale > 250 pixels = 50 μm .
select “global” so this scale applies to all images

Adjust threshold to isolate dark regions

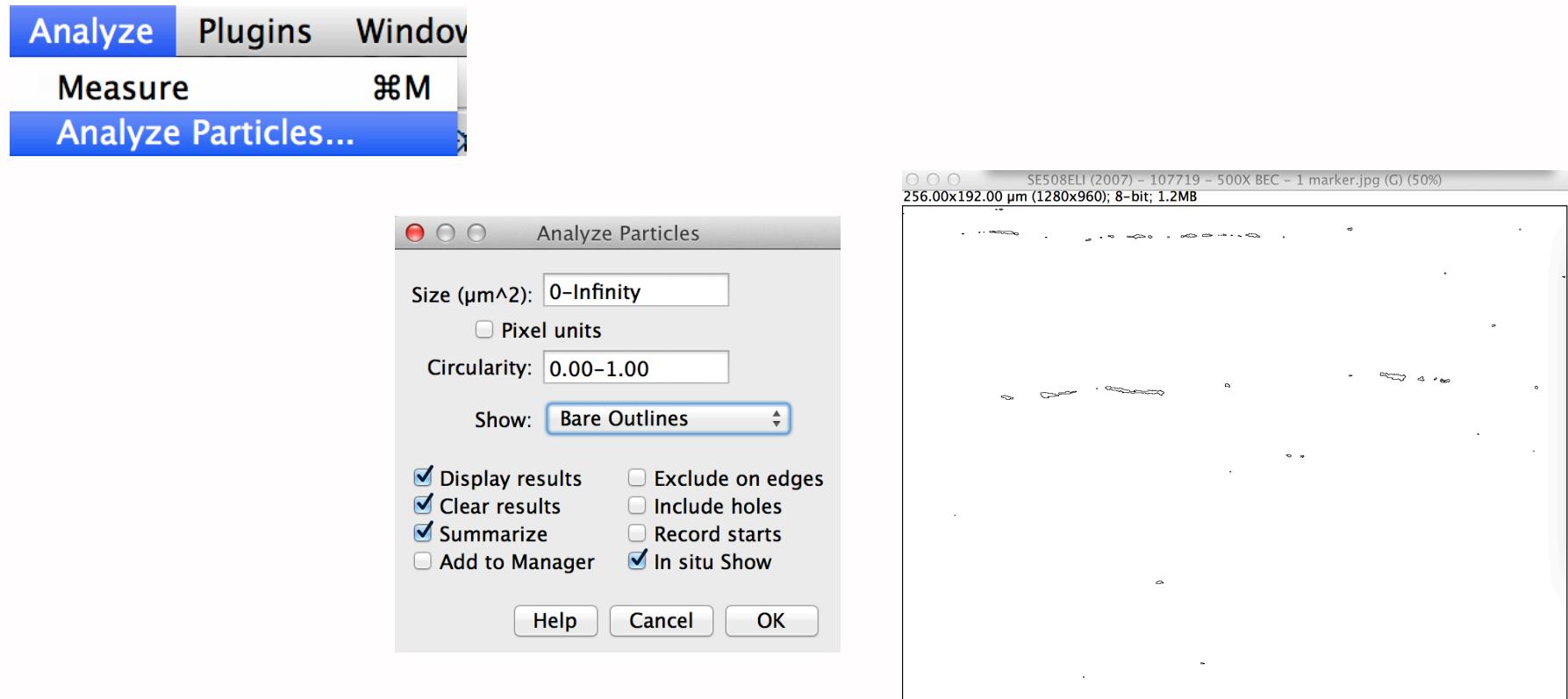


ImageJ analyzes the image and auto-sets a threshold
I accepted the default for all images

ImageJ: After threshold analysis



ImageJ: Analyze Particles



options are available to filter by size or circularity.
for this analysis, I did not filter out anything.

ImageJ: Analyze Particles - Results

Summary					
Slice	Count	Total Area	Average Size	%Area	
SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	55	92.680	1.685	0.189	

	Label	Area	StdDev	Min	Max	%Area
1	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.440	0	255	255	100
2	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.120	0	255	255	100
3	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.040	0	255	255	100
4	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	1.080	0	255	255	100
5	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.160	0	255	255	100
6	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	7.120	0	255	255	100
7	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.120	0	255	255	100
8	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.040	0	255	255	100
9	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.160	0	255	255	100
10	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	4.280	0	255	255	100
11	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	3.560	0	255	255	100
12	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	2.400	0	255	255	100
13	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.480	0	255	255	100
14	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	3.920	0	255	255	100
15	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.040	0	255	255	100
16	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.040	0	255	255	100
17	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.120	0	255	255	100
18	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.200	0	255	255	100
19	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.800	0	255	255	100
20	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.960	0	255	255	100
21	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.560	0	255	255	100
22	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.120	0	255	255	100
23	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.360	0	255	255	100
24	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.080	0	255	255	100
25	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.240	0	255	255	100
26	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.160	0	255	255	100
27	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.ind	0.120	0	255	255	100

in this example,
there are 55 particles
with an average
area of 1.685 μm
comprising 0.189%
of the total area

ImageJ: Save results



		Results					
		Area	StdDev	Min	Max	%Area	
	Save As... ⌘S						
	Rename...						
	Duplicate...						
1	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.440	0	255	255	100	
2	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.120	0	255	255	100	
3	SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.040	0	255	255	100	
m (128)	4 SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	1.080	0	255	255	100	
	5 SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.160	0	255	255	100	
	6 SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	7.120	0	255	255	100	
	7 SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.120	0	255	255	100	
	8 SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.040	0	255	255	100	
	9 SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	0.160	0	255	255	100	
	10 SE508ELI (2007) - 107719 - 500X BEC - 1 marker.jpg	1.080	0	255	255	100	

results were saved for each analysis, then consolidated in Excel, then imported into JMP for further analysis (as described in previous slides)

ImageJ: Combine results



```
Results01.xls  Results04.xls  Results07.xls  Results10.xls  Results13.xls  Results16.xls  Results19.xls  Results22.xls  Results25.xls  
Results02.xls  Results05.xls  Results08.xls  Results11.xls  Results14.xls  Results17.xls  Results20.xls  Results23.xls  Results26.xls  
Results03.xls  Results06.xls  Results09.xls  Results12.xls  Results15.xls  Results18.xls  Results21.xls  Results24.xls  Results_All.txt  
Craigs-MacBook-Pro:fwcomparisonofnitinmis cbonsignore$ cat Results* > Results_All.txt
```

Combine the results into a single text file. Edit text file to remove label rows.
Import into JMP.

JMP: Import Data Table



	Particle	Label	Area	Alloy	Location	Volume	field_area_um	%Area
1	1	var (standard) -	0.555	VAR	1	0.4134656878	52272	0.0000106175
2	2	var (standard) -	0.256	VAR	1	0.129526893	52272	4.8974594e-6
3	3	var (standard) -	2.177	VAR	1	3.2120895431	52272	0.0000416475
4	4	var (standard) -	0.47	VAR	1	0.3222157662	52272	8.9914294e-6
5	5	var (standard) -	0.213	VAR	1	0.0983035961	52272	4.0748393e-6
6	6	var (standard) -	0.768	VAR	1	0.6730414787	52272	0.0000146924

JMP: Formula to convert area to volume



```
If {  
    Area <= 25 ⇒  $\sqrt[3]{Area}$   
    else               ⇒ Area * 5  
}
```

JMP: Distribution



The distribution of values in each column

Select Columns

- Particle
- Label
- Area
- Alloy
- Location
- Volume
- field_area_um
- %Area

Histograms Only

Distribution

Cast Selected Columns into Roles

Y, Columns	<input checked="" type="checkbox"/> Volume <i>optional</i>
Weight	<i>optional numeric</i>
Freq	<i>optional numeric</i>
By	<i>optional</i>

Action

OK

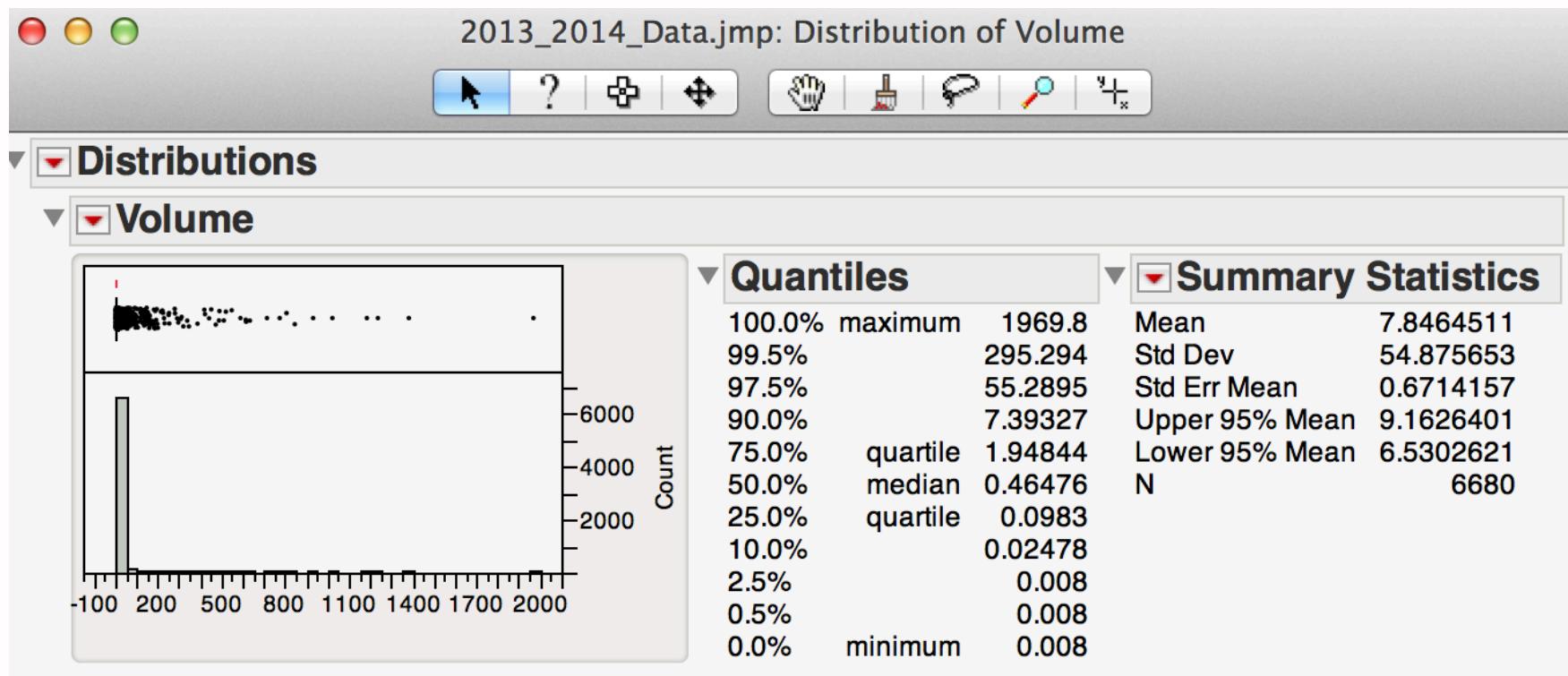
Cancel

Remove

Recall

Help

JMP: Distribution



JMP: Format histogram. Bin width = 20.



The screenshot shows the JMP software interface with the 'Distributions' platform open. Under the 'Volume' node, the 'Histogram Options' menu is selected, displaying options like Histogram, Shadowgram, Vertical, Std Error Bars, Set Bin Width, and Histogram Color. A tooltip for 'Set Bin Width' explains its function: 'Sets the histogram bin width, using the axis as the origin.' To the right, the 'Summary Statistics' table provides numerical values for various statistical measures.

	1969.8	Mean	7.8464511
295.294	Std Dev	54.875653	
55.2895	Std Err Mean	0.6714157	
7.39327	Upper 95% Mean	9.1626401	
Sets the histogram bin width, using the axis as the origin.			
0.0983			

JMP: Save histogram level midpoints (each row is tagged with midpoint value of its bin)



2013_2014_Data.jmp: Distribution of Volume

Distributions

Volume

- Display Options
- Histogram Options
- Normal Quantile Plot
- ✓ Outlier Box Plot
- Quantile Box Plot
- Stem and Leaf
- CDF Plot
- Test Mean
- Test Std Dev
- Confidence Interval
- Prediction Interval
- Tolerance Interval
- Capability Analysis
- Continuous Fit
- Save
- Remove

Count

Quantiles

Percentile	Statistic	Value
100.0%	maximum	1969.8
99.5%		295.294
97.5%		55.2895
90.0%		7.39327
75.0%	quartile	1.94844
50.0%	median	0.46476
25.0%	quartile	0.0983
10.0%		0.02478
2.5%		0.008
0.5%		0.008
0.0%	minimum	0.008

Summary Statistics

Statistic	Value
Mean	7.8464511
Std Dev	54.875653
Std Err Mean	0.6714157
Upper 95% Mean	9.1626401
Lower 95% Mean	6.5302621
N	6680

Level Numbers

Level Midpoints

Ranks

Ranks averaged

Excel: Import or copy/paste from JMP



A	B	C	D	E	F	G	H	I	
1	Particle	Area	Alloy	Location	Volume	field_area_um	%Area	Level Volume	Midpoint Volume
2	1	0.555	VAR	1	0.413465688	52272	1.06175E-05	8	10
3	2	0.256	VAR	1	0.129526893	52272	4.90E-06	8	10
4	3	2.177	VAR	1	3.212089543	52272	4.16475E-05	8	10
5	4	0.47	VAR	1	0.322215766	52272	8.99E-06	8	10
6	5	0.213	VAR	1	0.098303596	52272	4.07E-06	8	10
7	6	0.768	VAR	1	0.673041479	52272	1.46924E-05	8	10
8	7	2.732	VAR	1	4.515658	52272	5.22651E-05	8	10
9	8	0.64	VAR	1	0.512	52272	1.22436E-05	8	10
10	9	0.64	VAR	1	0.512	52272	1.22436E-05	8	10
11	10	2.732	VAR	1	4.515658	52272	5.22651E-05	8	10
12	11	0.213	VAR	1	0.098303596	52272	4.07E-06	8	10
13	12	0.128	VAR	1	0.045794672	52272	2.45E-06	8	10
14	13	0.085	VAR	1	0.024781546	52272	1.63E-06	8	10
15	14	0.043	VAR	1	0.00891667	52272	8.23E-07	8	10
16	15	0.043	VAR	1	0.00891667	52272	8.23E-07	8	10
17	16	0.299	VAR	1	0.163495868	52272	5.72E-06	8	10
18	17	10.459	VAR	1	33.82480056	52272	0.000200088	9	30
19	18	4.696	VAR	1	10.17635227	52272	8.98378E-05	8	10
20	19	15.453	VAR	1	60.74621276	52272	0.000205627	11	70

Excel: Create Pivot table



- columns = alloy label
- rows = histogram bins
(midpoint of 20um³ wide bin)
- data = sum of inclusion volume

[B] Pivot table summary of all data: sum of volume for each histogram bin								
Sum of Volume	Column Labels							
Row Labels	E	F	HP_VAR	HP_VAR_07	R	S	VAR	W
1,970								1,970
1,390								1,383
1,230								1,237
1,190								1,186
1,030							1,023	
930							933	
850								846
810							807	
770								775
710								715
630							635	
610							617	616
590							590	
550								549
530								522
510								512
490							491	489
470								474
450				453				443
430								844
390			388					
350			351					348
330			321					340
310			313				309	316
290		292	281				297	282
250								255
230								230
210								417
190		194	184	181		189	566	383
170			327				505	482
150			153		285		433	1,028
130				254		253	274	456
110						106	100	220
90			84	169		353	166	445
70			141	200	131	189	72	839
50			55		201	245	50	254
30			106	414	186	266	114	774
10			143	1,056	650	1,013	572	787

Excel: Consolidate similar alloy groups



[C] Number of images analyzed per group - consolidated				
HP VAR (n=24)	VAR (n=16)	VIM/VAR (n=6)	OPT VIM/ VAR(n=3)	VIM (n=3)
24	16	6	3	3
[D] Consolidated sum of volume for each histogram bin				
HP VAR	VAR	VIM/VAR	OPT VIM/VAR	VIM
0	1,970	0	0	0
0	1,383	0	0	0
0	1,237	0	0	0
0	1,186	0	0	0
0	0	1,023	0	0
0	933	0	0	0
0	846	0	0	0
0	0	807	0	0
0	775	0	0	0
0	715	0	0	0
0	0	635	0	0
0	1,232	0	0	0
0	0	590	0	0
0	549	0	0	0
0	522	0	0	0
0	512	0	0	0
0	981	0	0	0
0	474	0	0	0
0	443	0	0	453
0	0	844	0	0
388	0	0	0	0
351	348	0	0	0
321	340	0	0	0
313	316	309	0	0
292	282	297	0	281
0	761	0	0	0
0	913	0	0	0
0	417	0	0	0
375	949	0	189	184
327	810	505	0	0
438	1,484	433	0	0
507	395	137	274	0
106	444	328	100	0
522	1,283	166	0	84
460	1,274	277	72	200
502	1,603	379	50	0
557	2,132	422	114	414
1,806	4,003	2,438	572	1,056

Excel: Normalize to volume fraction for each group: (each row: volume fraction per bin)



[G] Volume fraction of inclusions at each histogram bin							
Midpoint Vol	Min Vol	Max Vol	HP VAR	VAR	VIM/VAR	OPT VIM/VAR	VIM
1,970	1,960	1,970	0.00%	0.05%	0.00%	0.00%	0.00%
1,390	1,380	1,390	0.00%	0.03%	0.00%	0.00%	0.00%
1,230	1,220	1,230	0.00%	0.03%	0.00%	0.00%	0.00%
1,190	1,180	1,190	0.00%	0.03%	0.00%	0.00%	0.00%
1,030	1,020	1,030	0.00%	0.00%	0.07%	0.00%	0.00%
930	920	930	0.00%	0.02%	0.00%	0.00%	0.00%
850	840	850	0.00%	0.02%	0.00%	0.00%	0.00%
810	800	810	0.00%	0.00%	0.05%	0.00%	0.00%
770	760	770	0.00%	0.02%	0.00%	0.00%	0.00%
710	700	710	0.00%	0.02%	0.00%	0.00%	0.00%
630	620	630	0.00%	0.00%	0.04%	0.00%	0.00%
610	600	610	0.00%	0.03%	0.00%	0.00%	0.00%
590	580	590	0.00%	0.00%	0.04%	0.00%	0.00%
550	540	550	0.00%	0.01%	0.00%	0.00%	0.00%
530	520	530	0.00%	0.01%	0.00%	0.00%	0.00%
510	500	510	0.00%	0.01%	0.00%	0.00%	0.00%
490	480	490	0.00%	0.02%	0.00%	0.00%	0.00%
470	460	470	0.00%	0.01%	0.00%	0.00%	0.00%
450	440	450	0.00%	0.01%	0.00%	0.00%	0.06%
430	420	430	0.00%	0.00%	0.05%	0.00%	0.00%
390	380	390	0.01%	0.00%	0.00%	0.00%	0.00%
350	340	350	0.01%	0.01%	0.00%	0.00%	0.00%
330	320	330	0.01%	0.01%	0.00%	0.00%	0.00%
310	300	310	0.00%	0.01%	0.02%	0.00%	0.00%
290	280	290	0.00%	0.01%	0.02%	0.00%	0.04%
250	240	250	0.00%	0.02%	0.00%	0.00%	0.00%
230	220	230	0.00%	0.02%	0.00%	0.00%	0.00%
210	200	210	0.00%	0.01%	0.00%	0.00%	0.00%
190	180	190	0.01%	0.02%	0.00%	0.02%	0.02%
170	160	170	0.01%	0.02%	0.03%	0.00%	0.00%
150	140	150	0.01%	0.04%	0.03%	0.00%	0.00%
130	120	130	0.01%	0.01%	0.01%	0.03%	0.00%
110	100	110	0.00%	0.01%	0.02%	0.01%	0.00%
90	80	90	0.01%	0.03%	0.01%	0.00%	0.01%
70	60	70	0.01%	0.03%	0.02%	0.01%	0.03%
50	40	50	0.01%	0.04%	0.02%	0.01%	0.00%
30	20	30	0.01%	0.05%	0.03%	0.01%	0.05%
10	-	10	0.03%	0.10%	0.16%	0.07%	0.13%

Excel: Cumulative volume fraction for charts

(each row: cumulative volume fraction per bin)



[G] Volume fraction of inclusions at each histogram bin							
Midpoint Vol	Min Vol	Max Vol	HP VAR	VAR	VIM/VAR	OPT VIM/VAR	VIM
1,970	1,960	1,970	0.00%	0.05%	0.00%	0.00%	0.00%
1,390	1,380	1,390	0.00%	0.03%	0.00%	0.00%	0.00%
1,230	1,220	1,230	0.00%	0.03%	0.00%	0.00%	0.00%
1,190	1,180	1,190	0.00%	0.03%	0.00%	0.00%	0.00%
1,030	1,020	1,030	0.00%	0.00%	0.07%	0.00%	0.00%
930	920	930	0.00%	0.02%	0.00%	0.00%	0.00%
850	840	850	0.00%	0.02%	0.00%	0.00%	0.00%
810	800	810	0.00%	0.00%	0.05%	0.00%	0.00%
770	760	770	0.00%	0.02%	0.00%	0.00%	0.00%
710	700	710	0.00%	0.02%	0.00%	0.00%	0.00%
630	620	630	0.00%	0.00%	0.04%	0.00%	0.00%
610	600	610	0.00%	0.03%	0.00%	0.00%	0.00%
590	580	590	0.00%	0.00%	0.04%	0.00%	0.00%
550	540	550	0.00%	0.01%	0.00%	0.00%	0.00%
530	520	530	0.00%	0.01%	0.00%	0.00%	0.00%
510	500	510	0.00%	0.01%	0.00%	0.00%	0.00%
490	480	490	0.00%	0.02%	0.00%	0.00%	0.00%
470	460	470	0.00%	0.01%	0.00%	0.00%	0.00%
450	440	450	0.00%	0.01%	0.00%	0.00%	0.06%
430	420	430	0.00%	0.00%	0.05%	0.00%	0.00%
390	380	390	0.01%	0.00%	0.00%	0.00%	0.00%
350	340	350	0.01%	0.01%	0.00%	0.00%	0.00%
330	320	330	0.01%	0.01%	0.00%	0.00%	0.00%
310	300	310	0.00%	0.01%	0.02%	0.00%	0.00%
290	280	290	0.00%	0.01%	0.02%	0.00%	0.04%
250	240	250	0.00%	0.02%	0.00%	0.00%	0.00%
230	220	230	0.00%	0.02%	0.00%	0.00%	0.00%
210	200	210	0.00%	0.01%	0.00%	0.00%	0.00%
190	180	190	0.01%	0.02%	0.00%	0.02%	0.02%
170	160	170	0.01%	0.02%	0.03%	0.00%	0.00%
150	140	150	0.01%	0.04%	0.03%	0.00%	0.00%
130	120	130	0.01%	0.01%	0.01%	0.03%	0.00%
110	100	110	0.00%	0.01%	0.02%	0.01%	0.00%
90	80	90	0.01%	0.03%	0.01%	0.00%	0.01%
70	60	70	0.01%	0.03%	0.02%	0.01%	0.03%
50	40	50	0.01%	0.04%	0.02%	0.01%	0.00%
30	20	30	0.01%	0.05%	0.03%	0.01%	0.05%
10	-	10	0.03%	0.10%	0.16%	0.07%	0.13%