

Image Analysis in Earth Sciences

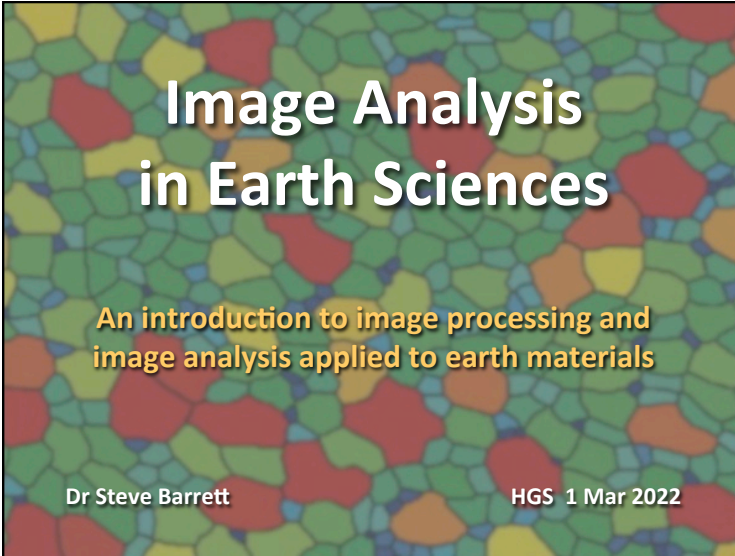


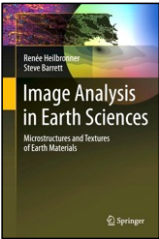
Image Analysis in Earth Sciences

An introduction to image processing and
image analysis applied to earth materials

Dr Steve Barrett HGS 1 Mar 2022

Contents

- Why do geologists need Image Analysis?
- An introduction to Image Processing Image Analysis
- The Nature of Light
- Microscopy of Earth Materials



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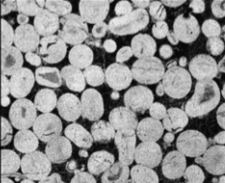
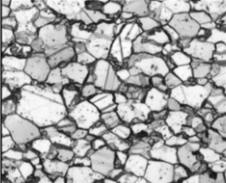
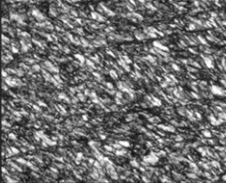
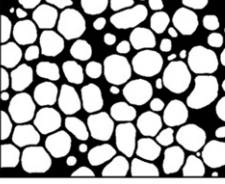
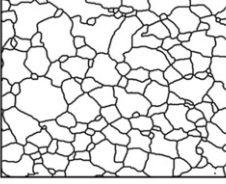

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Why Image Analysis?

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Microstructures

Particles in Matrix	Aggregate	Visual Texture
		
		

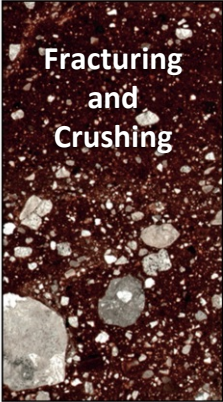
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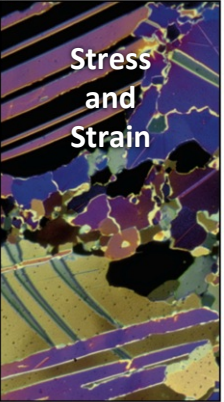
Grain Structure and Physical Processes

Cataclastic rock



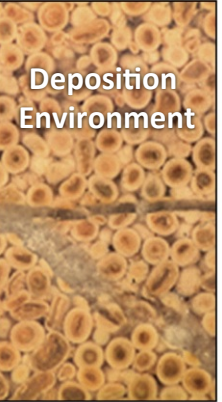
Fracturing and Crushing

Recrystallized marble



Stress and Strain

Oolitic limestone



Deposition Environment

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Image Processing

Image Analysis

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Processing vs Analysis

This talk is about images and how we look at images in a scientific context. Two concepts are important in what follows:

Image Processing

>>>

Interpretation

Image Analysis

>>>

Quantification

The talk will be illustrated with images taken from various research projects, not just those of earth materials.

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Images Are Just Numbers



166	89	72	89	79	82	139	84	22	44	99	131	156	183	193	168
102	49	39	51	62	70	72	31	22	56	124	161	180	205	212	190
70	34	31	62	65	107	114	70	56	72	114	143	180	205	207	171
44	29	24	44	124	92	67	70	56	46	60	151	226	188	141	99
31	29	7	14	84	39	14	27	24	44	114	126	236	219	107	67
24	39	22	9	12	27	19	29	19	54	109	89	183	255	193	97
24	27	24	17	17	39	75	102	82	94	126	141	168	231	231	178
22	22	27	36	19	29	114	121	121	141	168	188	193	207	200	168
19	22	36	41	17	22	60	75	116	107	87	161	193	188	156	129
17	24	56	54	17	14	94	158	97	79	82	89	126	134	119	111
14	27	27	9	12	19	84	156	77	75	102	60	79	104	97	84
12	17	9	2	19	29	54	114	87	89	109	79	79	87	72	94
14	17	14	41	77	99	131	178	151	153	168	139	121	75	65	82
27	36	72	129	156	158	163	200	180	175	195	180	136	49	17	17
29	54	134	180	188	180	158	168	195	190	183	146	107	22	0	2
24	36	67	148	163	175	171	161	168	173	143	99	67	12	7	7

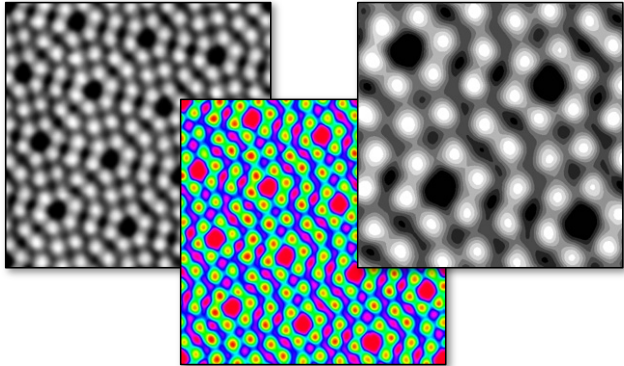
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Image Display

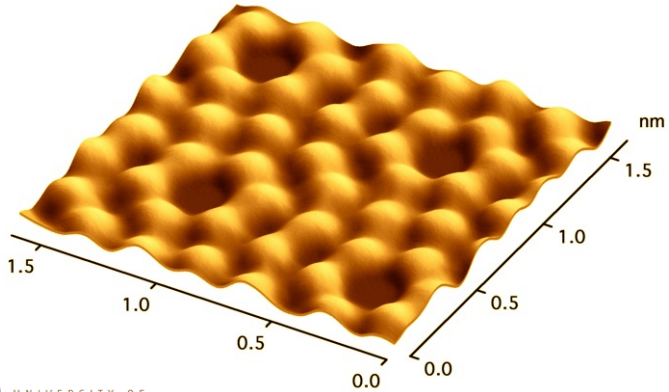
An image is a 2-dimensional collection of pixel values that can be displayed or printed by assigning a shade of grey (or colour) to every pixel value.



The figure shows three square images arranged in a cross pattern. The top-left and right images are grayscale, showing a pattern of black and white pixels. The bottom image is a color heatmap, showing the same pattern with a gradient from blue to red. The University of Liverpool logo is in the bottom left, and the number 9 is in the bottom right.

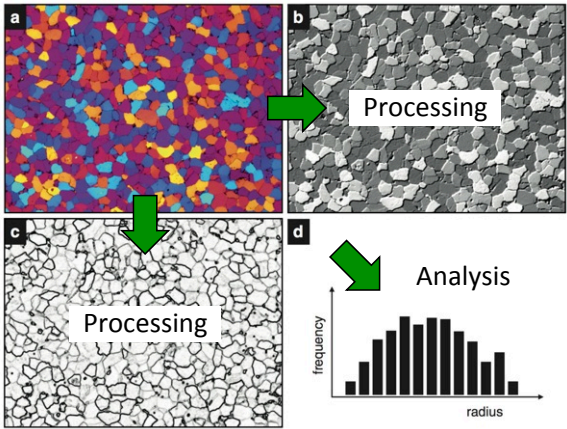
Image Display

An image is a 2-dimensional collection of pixel values that can be displayed or printed by assigning a shade of grey (or colour) to every pixel value.



A 3D surface plot showing a textured surface. The surface is colored in shades of orange and yellow. The axes are labeled with values 0.0, 0.5, 1.0, and 1.5. The vertical axis is labeled 'nm'. The University of Liverpool logo is in the bottom left, and the number 10 is in the bottom right.

Processing and Analysis



The flowchart shows four stages: (a) a multi-colored image, (b) a grayscale image labeled 'Processing', (c) a binary image labeled 'Processing', and (d) a histogram labeled 'Analysis' with 'frequency' on the y-axis and 'radius' on the x-axis. Green arrows indicate the flow from (a) to (b), (a) to (c), and (c) to (d). The University of Liverpool logo is in the bottom left, and the number 11 is in the bottom right.

Software

The word 'Software' is centered on the slide. The University of Liverpool logo is in the bottom left, and the number 12 is in the bottom right.

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Scanning Tunnelling Microscope

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A World of Atoms

On this scale, a grain of sand would be about the size of the Moon.

" To see a world in a grain of sand ... "

William Blake

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A World of Atoms

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A World of Atoms

Sc(0001)

For many years I studied the rare-earth metals using a combination of spectroscopy, microscopy and diffraction techniques

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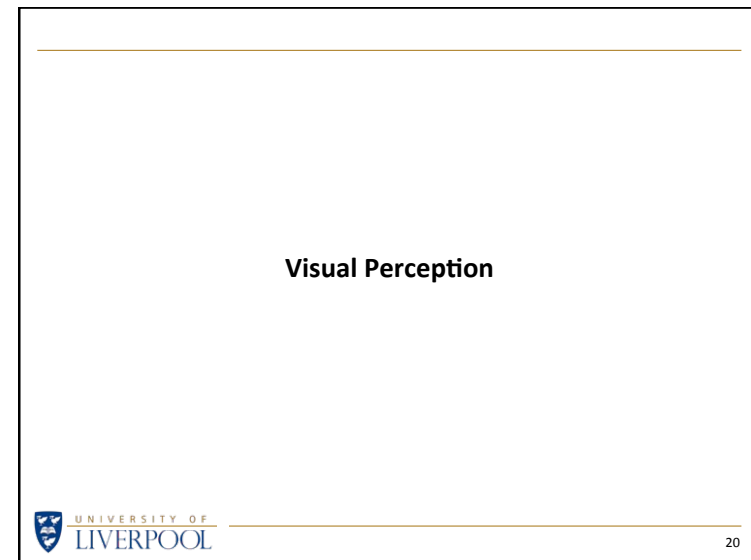
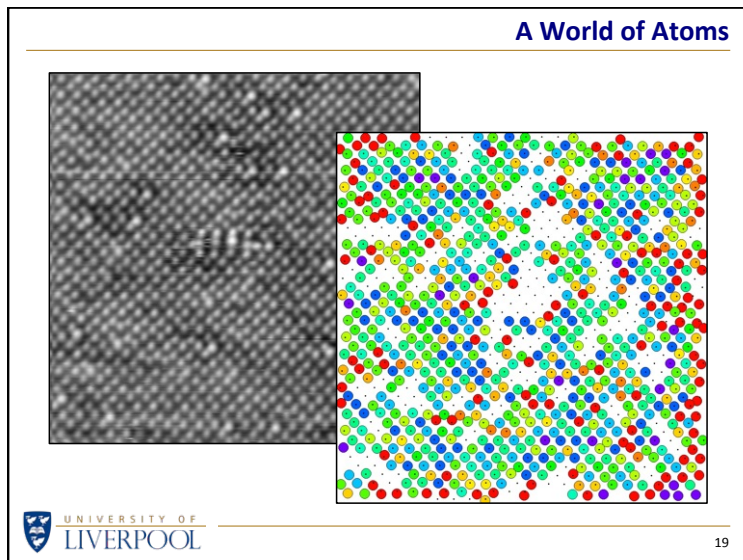
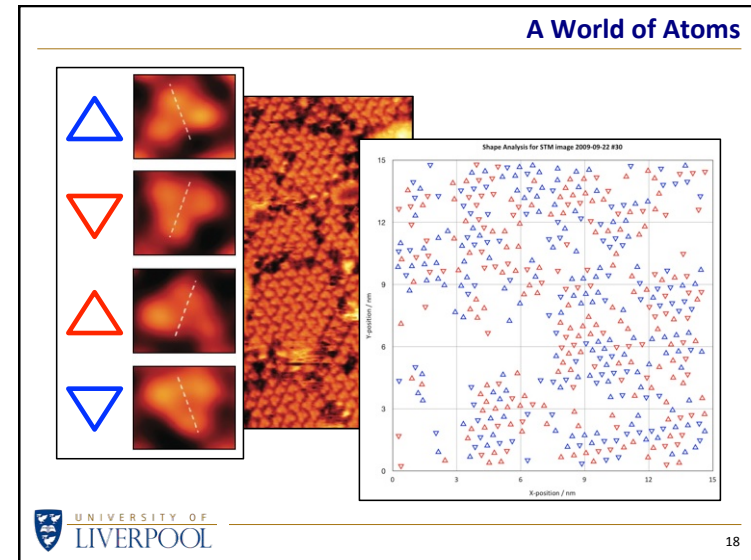
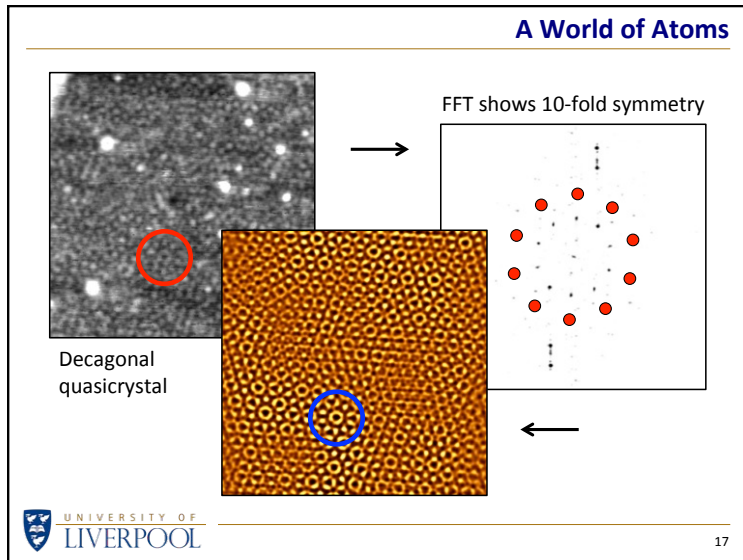


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Perception vs Reality

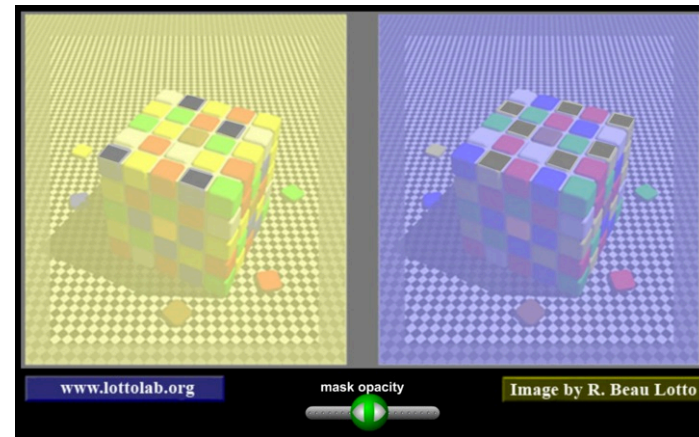
How we perceive images (what we *see*) can be VERY different from the actual information content (what is *there*). In most day-to-day situations we trust the former and don't worry about the latter.

Which is the better image processor?

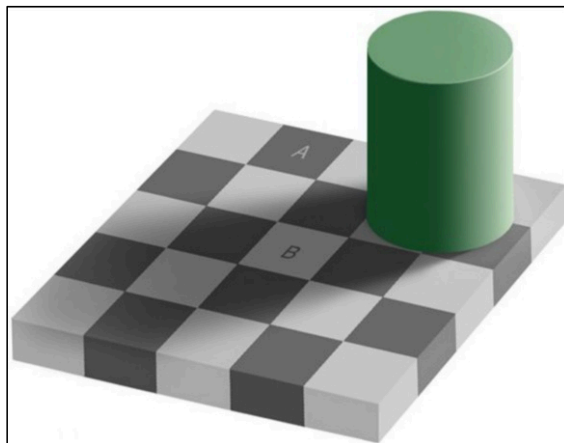
Brain vs *Computer*

Carbon vs *Silicon*

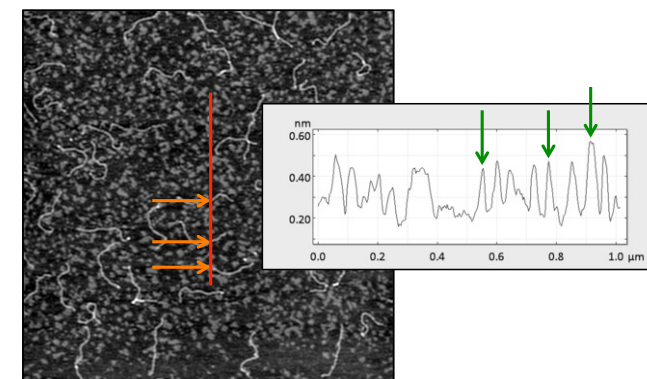
Perception vs Reality



Perception vs Reality



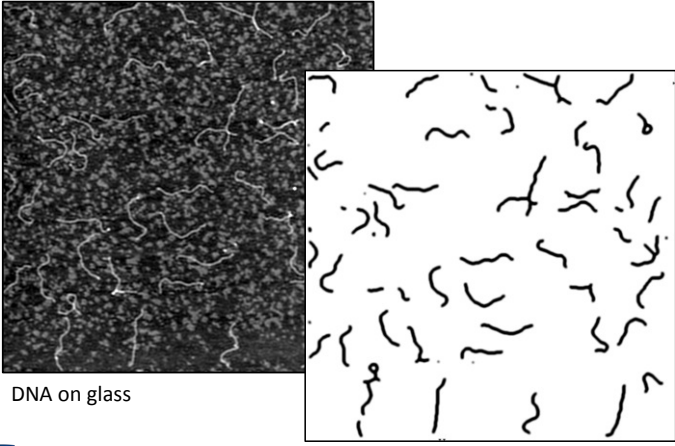
Perception vs Reality



DNA on glass

Image Analysis in Earth Sciences

Perception vs Reality



DNA on glass

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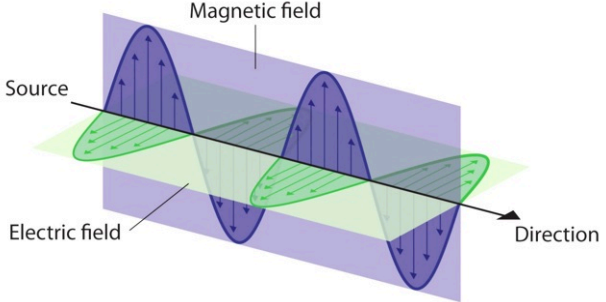
The Nature of Light

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Electromagnetic Wave

In 1865 James Clerk Maxwell showed that light is an electromagnetic wave. Electric fields and magnetic fields interact with each other and are interwoven to make a wave that can travel without a medium.

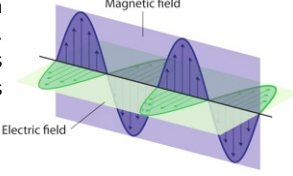


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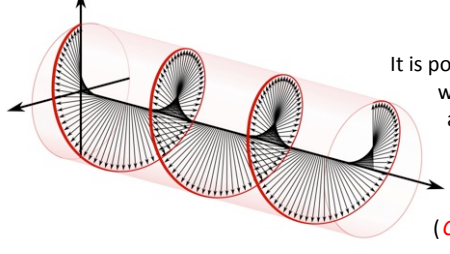
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Polarisation

The electric and magnetic fields (green and blue arrows) stay in the same plane. For instance, the magnetic field varies 'up-down' and the electric field varies 'left-right'. (*Linear Polarisation*)



It is possible to create light waves that corkscrew around the direction in which they travel. (*Circular Polarisation*)



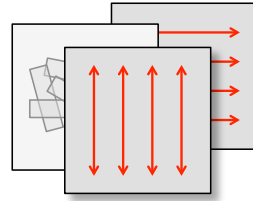
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Crossed Polarising Filters

Place two polarising filters together in perpendicular orientations so that no light is transmitted through them

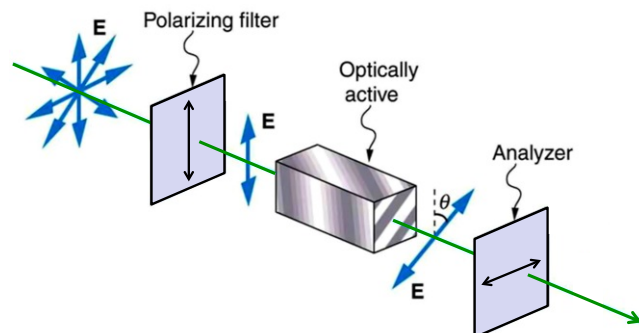


Place a sheet of plastic between them and see what happens. If the plastic has strips of sticky tape on it, they appear coloured dependent on the thicknesses of the tape.

Crossed Polarising Filters



Crossed Polarising Filters



Optical Activity

Calcite Crystal Double Refraction

Place the calcite crystal over this text or the crosses

You see two images of everything

Place a polarising filter over the crystal and rotate it

You see that each image has a different polarisation

This is because light takes two different paths through the crystal depending on its polarisation

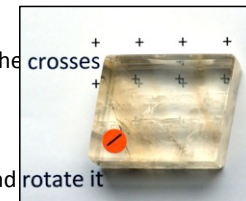
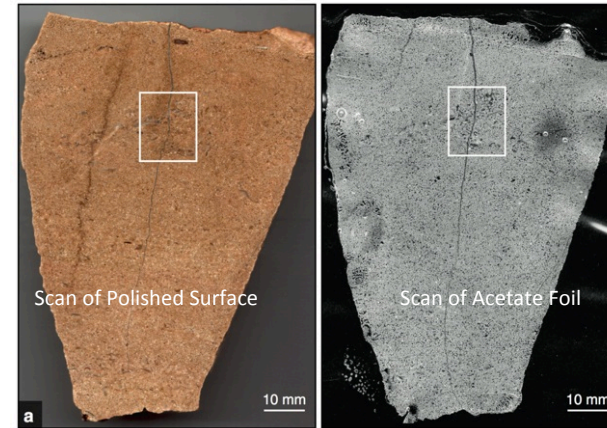


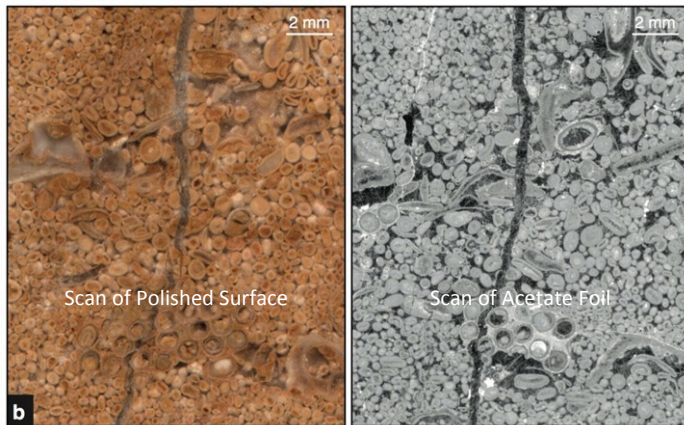
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Microscopy of Earth Materials

Acquiring Images



Acquiring Images



Thin Sections

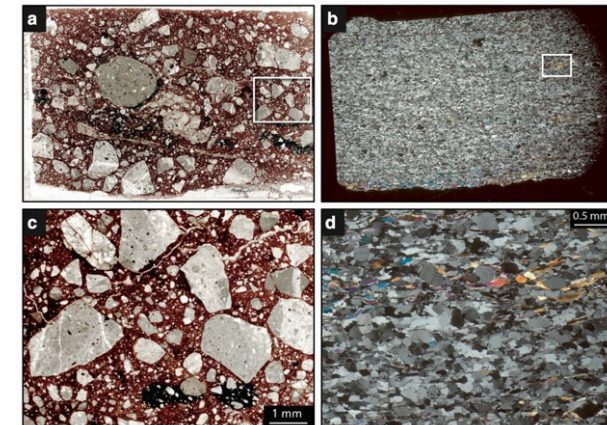


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Light Microscopy

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Colour Look-Up Tables (LUTs)

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Segmentation By Grey Level

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Segmentation By Tone

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Grain In Deformed Marble

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Grain Boundaries and Outlines

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Grain Size Analysis

	Area	Mean	Stdv	X	Y	Len	Majr	Minr	Angle	Min	Max
1.	324.36	0.74	0.07	109.15	529.47	105.67	34.59	11.94	43.0	0.59	0.91
2.	6.86	0.03	0.02	135.80	341.15	11.54	4.05	1.88	9.0	0.59	0.65
3.	5.39	0.59	0.01	294.51	341.03	8.74	3.33	2.06	177.5	0.59	0.60
4.	4.80	0.61	0.02	340.76	339.57	12.36	5.79	1.08	94.9	0.59	0.65
5.	1.47	0.59	0.00	43.40	340.90	4.37	2.37	0.79	0.0	0.59	0.59
6.	10.29	0.62	0.03	129.07	339.20	11.13	4.40	2.98	172.8	0.59	0.67
7.	34.50	0.67	0.05	198.94	335.79	17.89	6.72	4.64	170.9	0.59	0.77
8.	5.88	0.65	0.04	172.26	336.17	8.74	3.63	2.06	175.2	0.59	0.70
9.	48.02	0.70	0.08	312.58	332.72	27.79	9.18	6.66	54.0	0.59	0.87
10.	40.67	0.68	0.03	208.80	332.86	24.07	8.05	6.43	5.1	0.59	0.68
11.	34.30	0.73	0.09	279.41	332.26	21.44	7.83	5.57	20.0	0.59	0.89
12.	6.37	0.61	0.01	252.92	333.85	9.73	4.17	1.95	13.0	0.59	0.63
13.	1.96	0.60	0.01	14.70	333.02	4.95	1.91	1.30	0.0	0.59	0.61
14.	5.39	0.63	0.03	264.09	331.23	8.33	3.33	2.06	2.5	0.59	0.67
15.	21.56	0.65	0.04	198.71	329.05	16.08	5.95	4.61	149.8	0.59	0.73
16.	5.39	0.60	0.01	233.04	329.57	8.33	3.49	1.97	13.3	0.59	0.62
17.	96.04	0.73	0.12	335.38	321.78	46.50	15.97	7.66	118.2	0.59	1.00
18.	44.59	0.65	0.03	223.54	326.75	24.83	9.36	6.06	175.4	0.59	0.70
19.	19.60	0.61	0.02	144.71	325.83	18.88	7.72	3.23	169.3	0.59	0.64
...

Mean nearest neighbour distance = 13 ± 5 nm
 Nearest neighbour lies in azimuthal direction 83° (anisotropy = 0.19)

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Grain Boundary Maps

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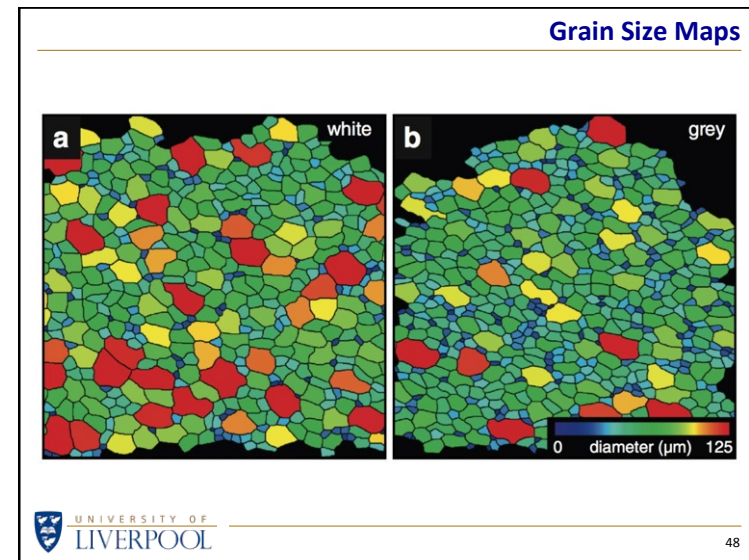
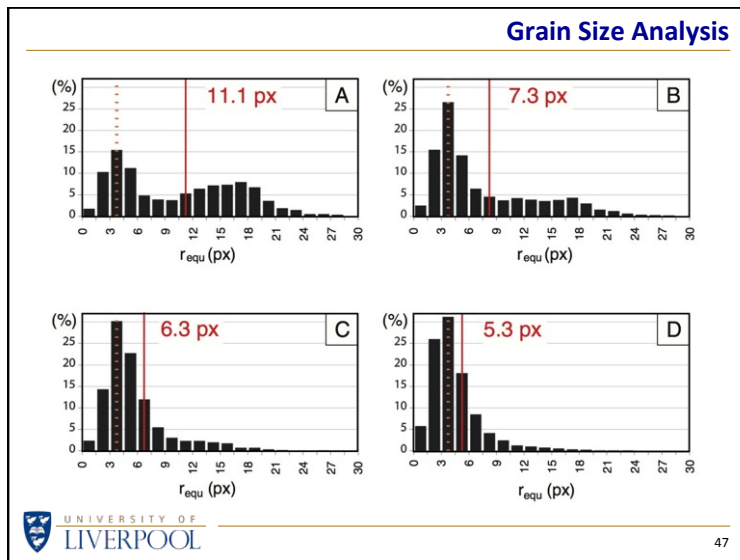
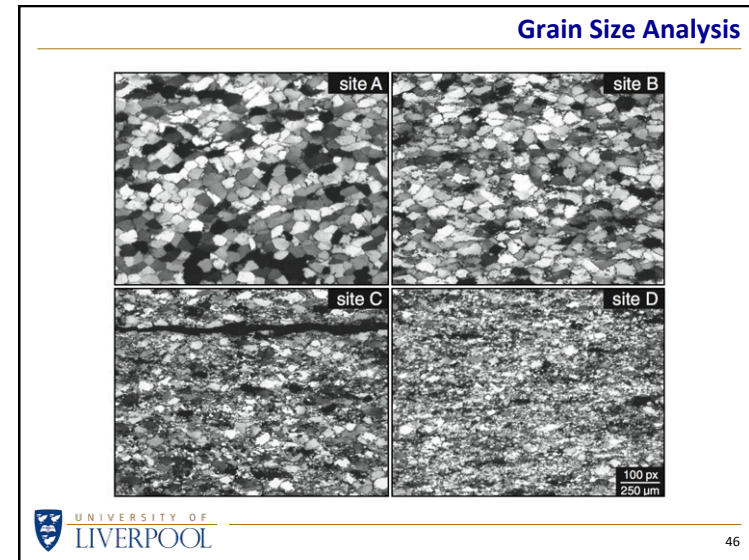
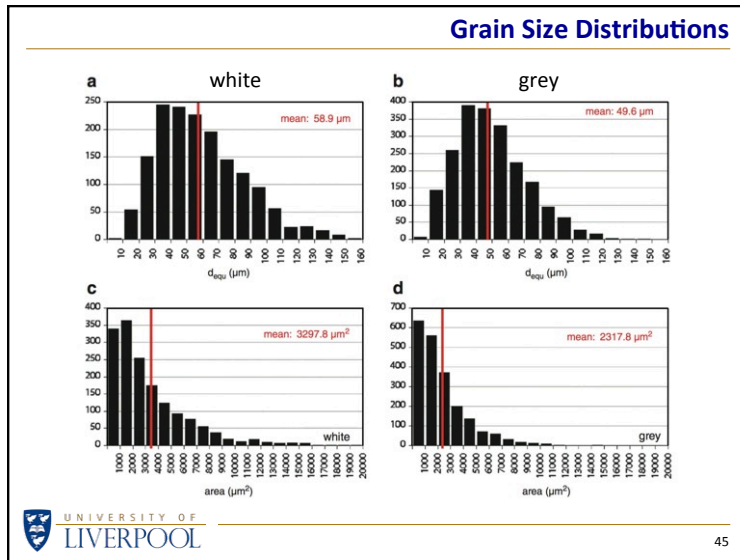
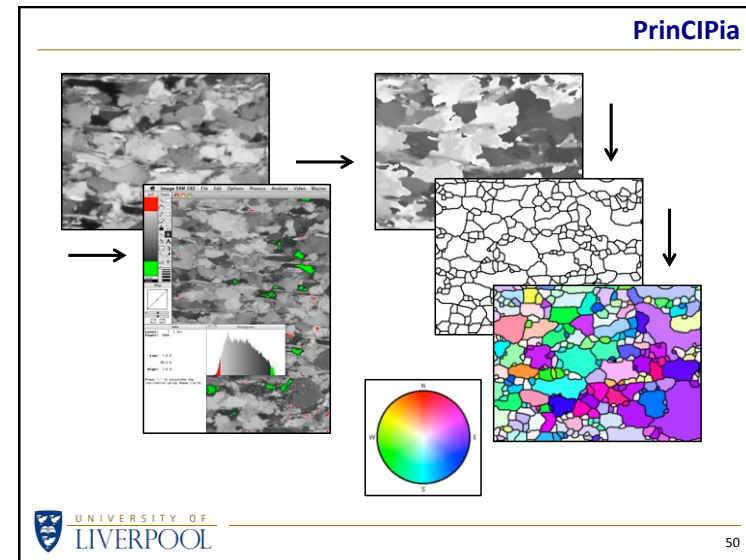
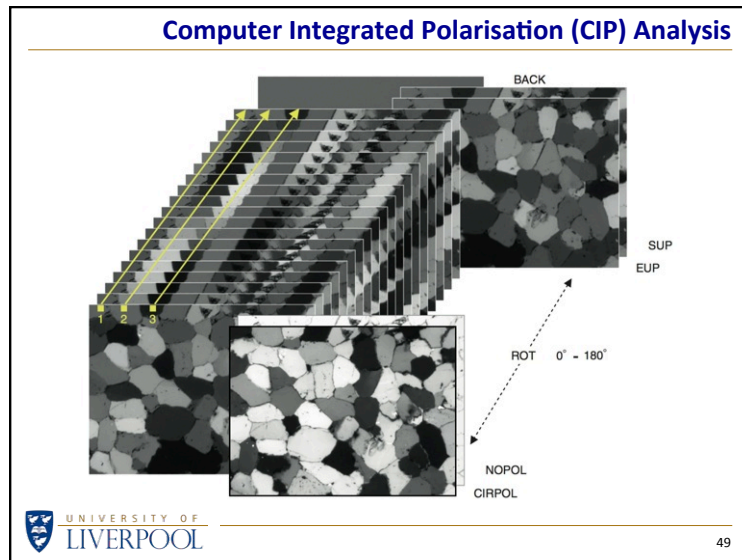


Image Analysis in Earth Sciences



Summary

- Why do geologists need Image Analysis?
- An introduction to Image Processing
Image Analysis
- The Nature of Light
- Microscopy of Earth Materials

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Image Analysis in Earth Sciences

www.liverpool.ac.uk/~sdb/Talks

Dr Steve Barrett

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