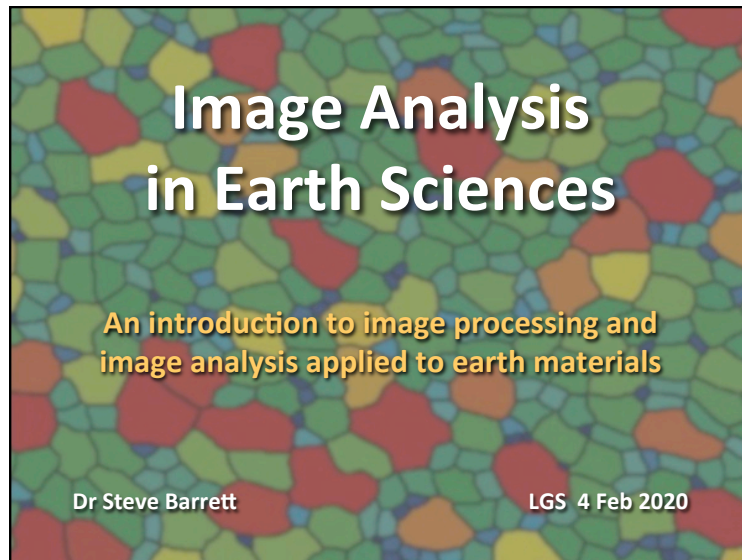
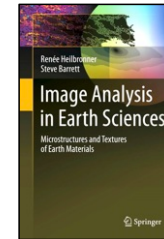


Image Analysis in Earth Sciences



Contents

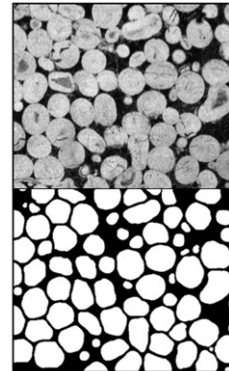
- Why do geologists need Image Analysis?
- An introduction to
Image Processing
Image Analysis
- The Nature of Light
- Microscopy of Earth Materials



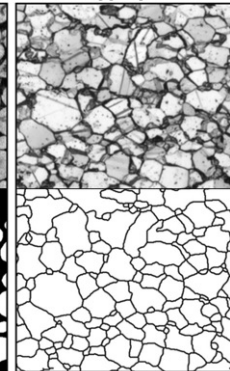
Why Image Analysis?

Microstructures

Particles in Matrix



Aggregate



Visual Texture

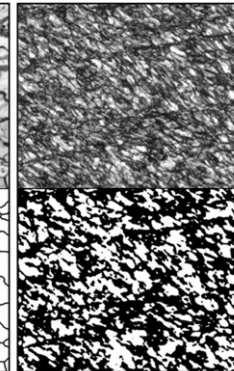


Image Analysis in Earth Sciences

Grain Structure and Physical Processes

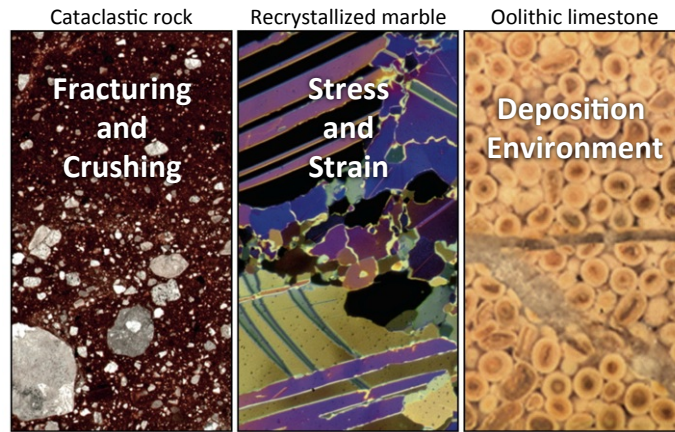


Image Processing

Image Analysis

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.

Images Are Just Numbers

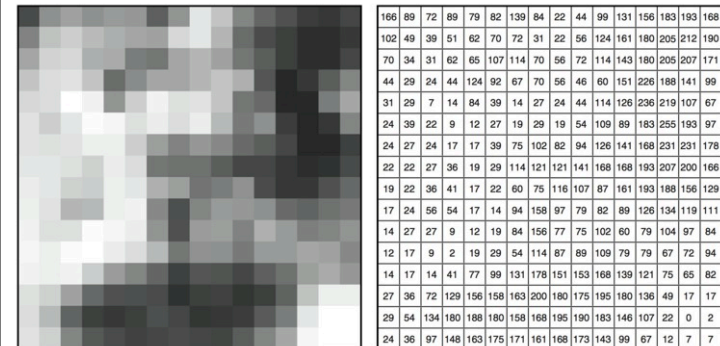


Image Analysis in Earth Sciences

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.

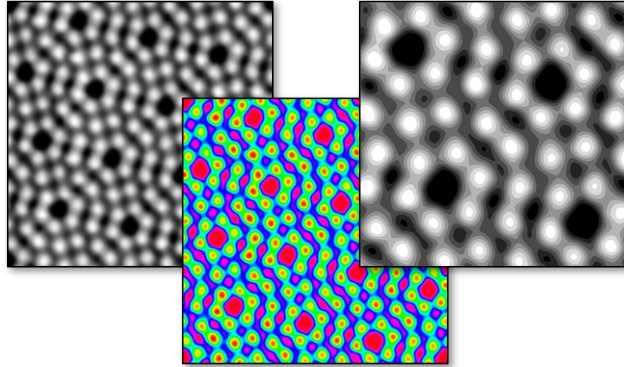
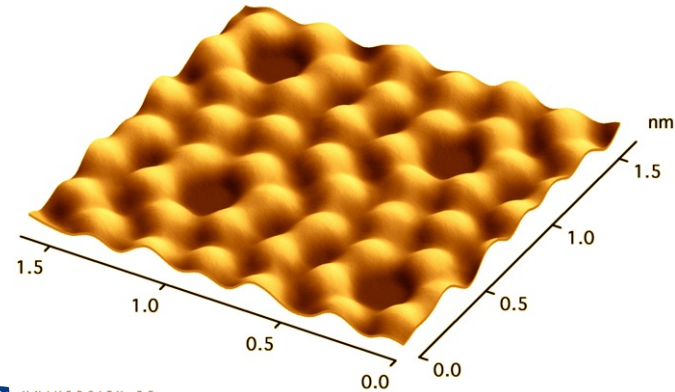
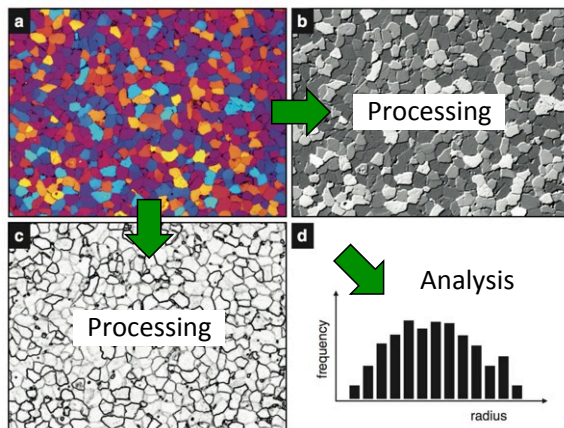


Image Display

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.



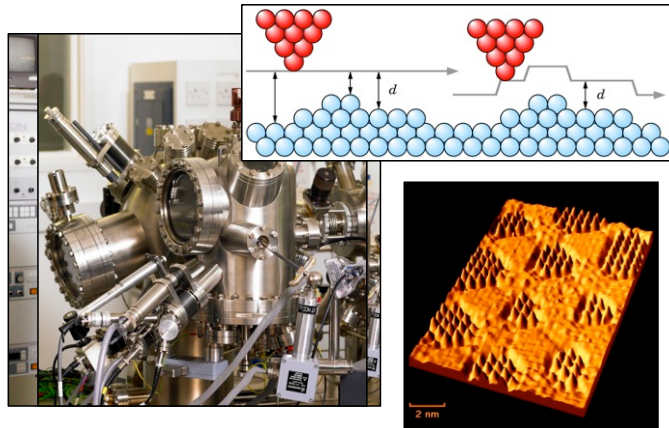
Processing and Analysis



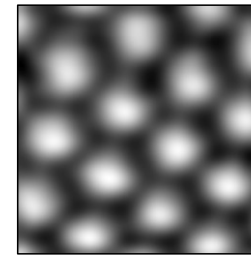
Software

Image Analysis in Earth Sciences

Scanning Tunnelling Microscope



A World of Atoms



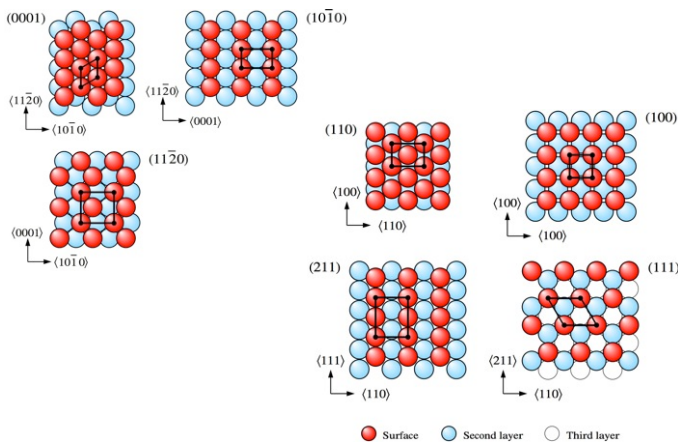
On this scale, a grain of sand would be about the size of the Moon.

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

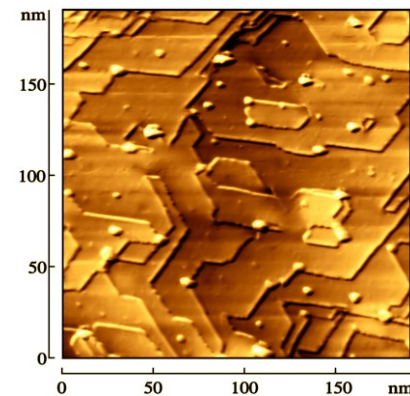
William Blake

850 pm

A World of Atoms



A World of Atoms



Sc(0001)

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

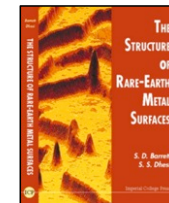


Image Analysis in Earth Sciences

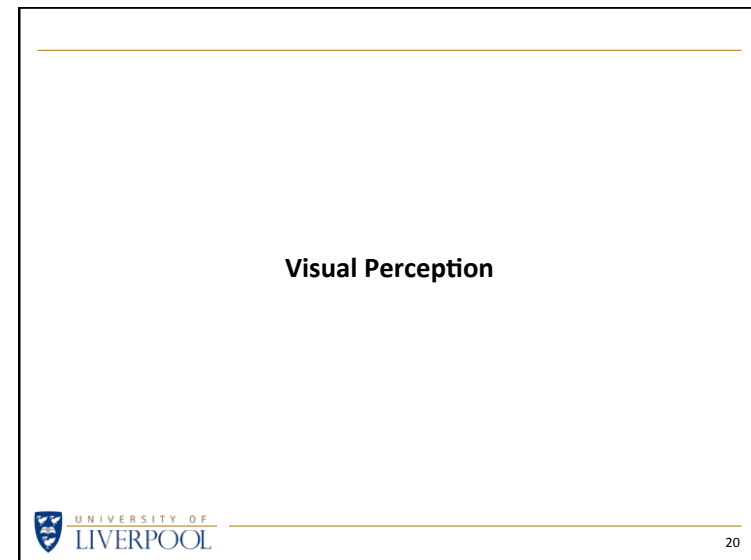
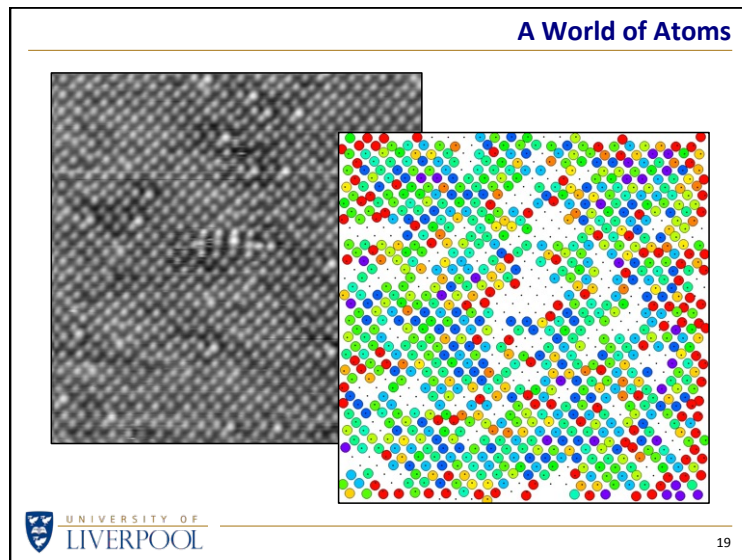
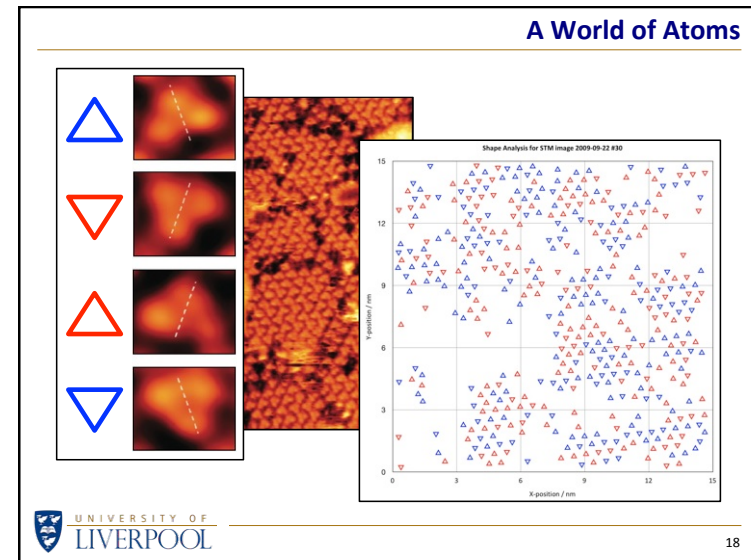
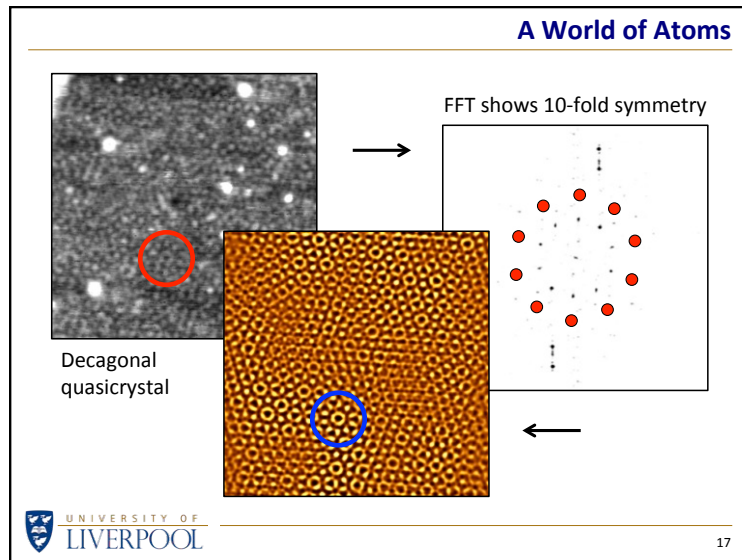


Image Analysis in Earth Sciences

Perception vs Reality

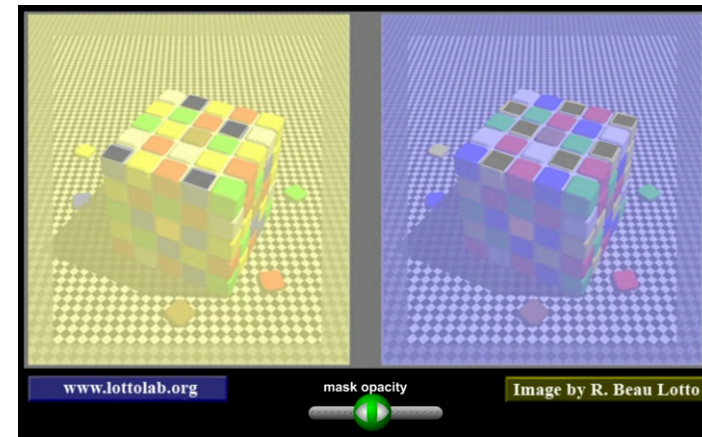
How we perceive images (what we *see*) can be VERY different from the actual information content (what is *there*). In most day-to-day situations we trust the former and don't worry about the latter.

Which is the better image processor?

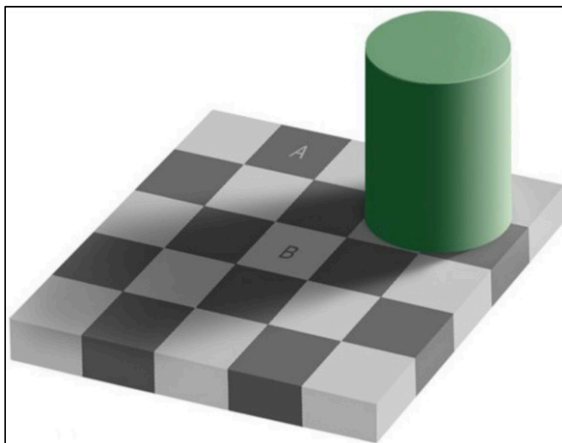
Brain vs *Computer*

Carbon vs *Silicon*

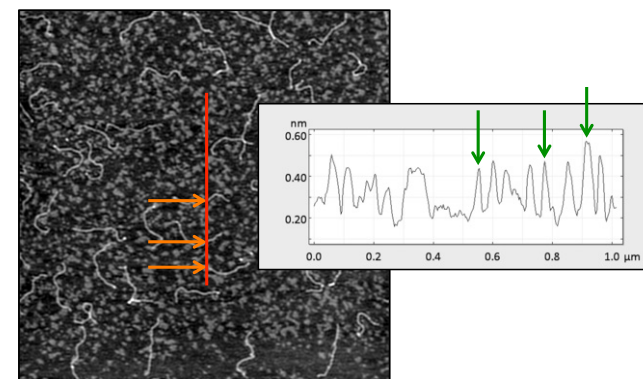
Perception vs Reality



Perception vs Reality



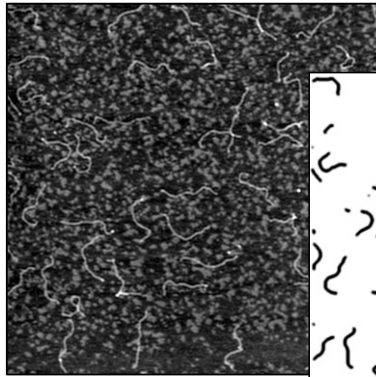
Perception vs Reality



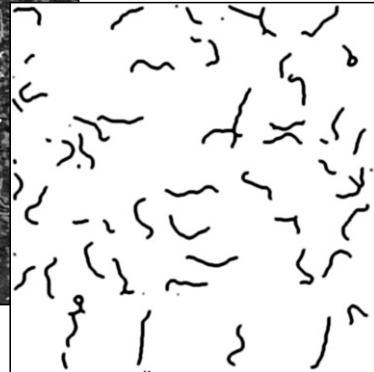
DNA on glass

Image Analysis in Earth Sciences

Perception vs Reality



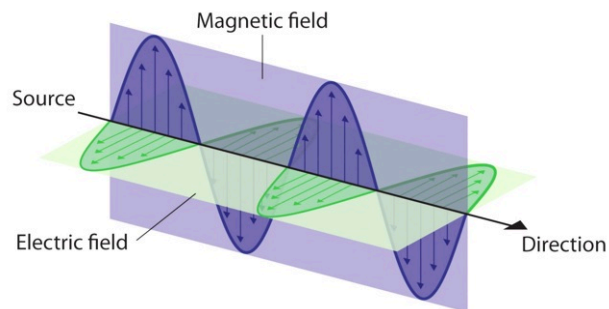
DNA on glass



The Nature of Light

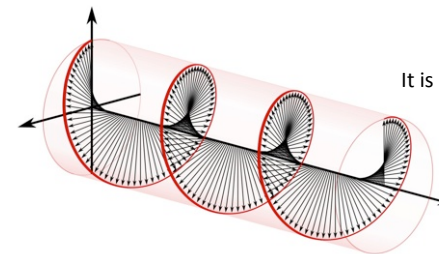
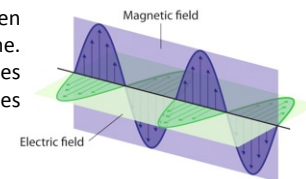
Electromagnetic Wave

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.



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*)



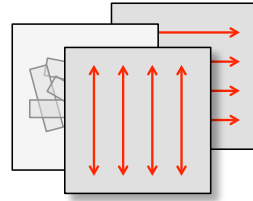
It is possible to create light waves that corkscrew around the direction in which they travel.

(*Circular Polarisation*)

Image Analysis in Earth Sciences

Crossed Polarising Filters

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

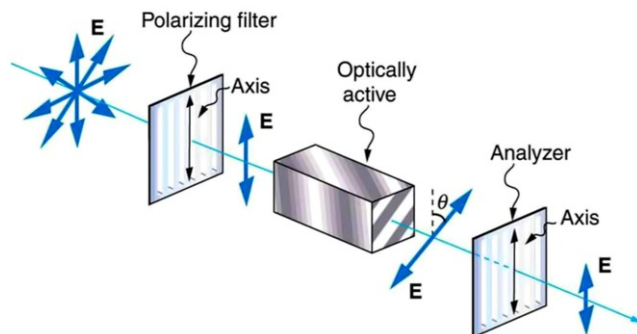


Place a sheet of plastic between them and see what happens. If the plastic has strips of sticky tape on it, they appear coloured dependent on the thicknesses of the tape.

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

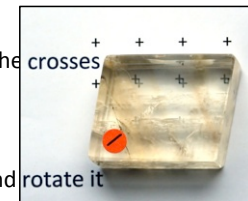
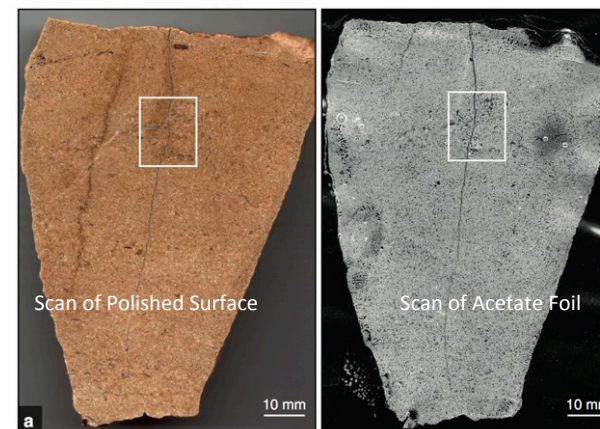


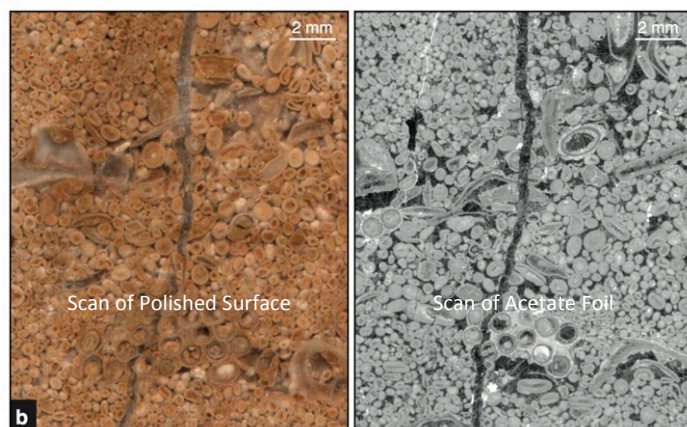
Image Analysis in Earth Sciences

Microscopy of Earth Materials

Acquiring Images



Acquiring Images



Thin Sections

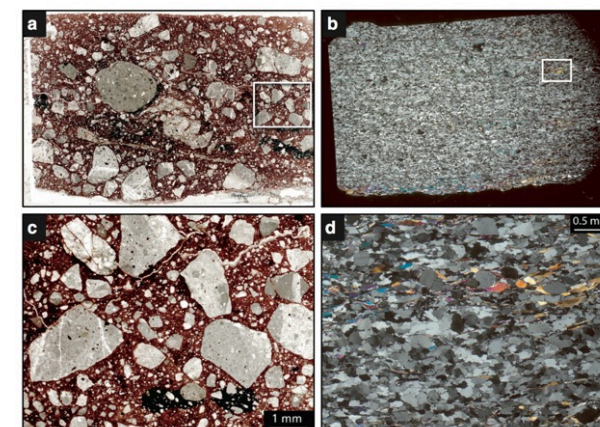
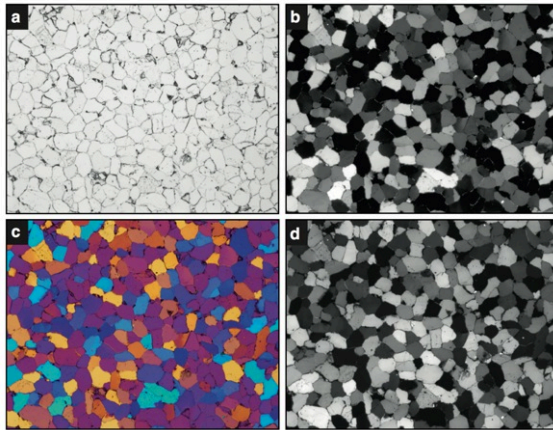
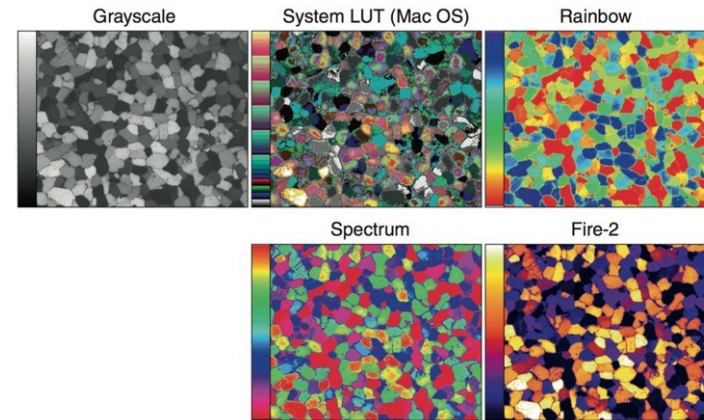


Image Analysis in Earth Sciences

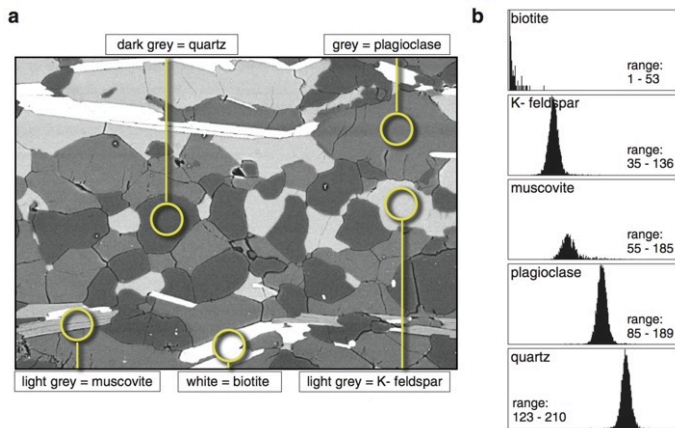
Light Microscopy



Colour Look-Up Tables (LUTs)



Segmentation By Grey Level



Segmentation By Tone

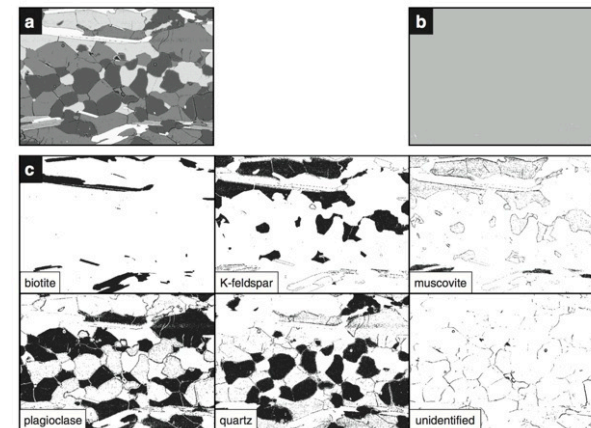
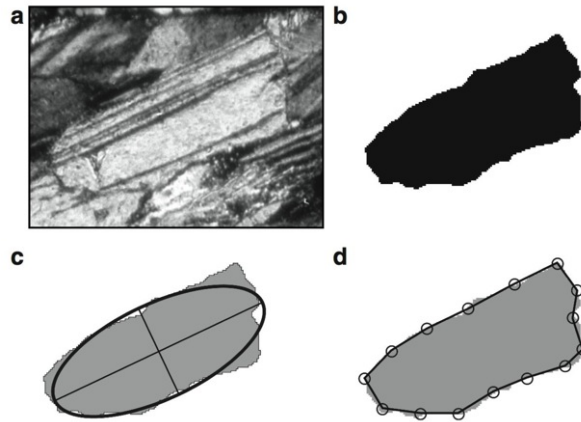
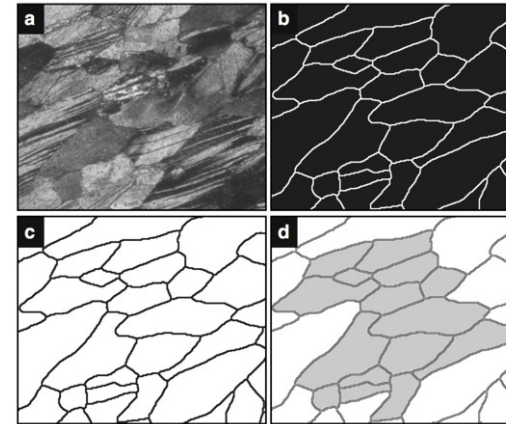


Image Analysis in Earth Sciences

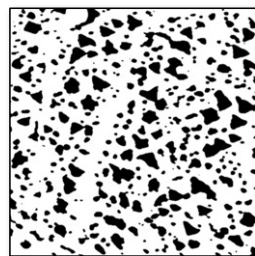
Grain In Deformed Marble



Grain Boundaries and Outlines



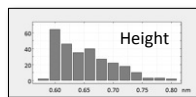
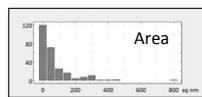
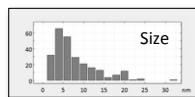
Grain Size Analysis



	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	0.63	0.02	135.40	141.15	11.54	4.05	1.88	9.0	0.59	0.65
3.	5.39	0.59	0.01	294.51	141.03	8.74	3.33	2.06	177.5	0.59	0.60
4.	4.90	0.61	0.02	140.76	139.57	12.36	5.79	1.08	94.9	0.59	0.65
5.	1.47	0.59	0.00	43.40	140.90	4.37	2.37	0.79	0.0	0.59	0.59
6.	10.29	0.62	0.03	129.07	139.20	11.13	4.40	2.98	172.8	0.59	0.67
7.	34.50	0.67	0.05	198.54	135.79	17.89	6.72	4.64	170.9	0.59	0.77
8.	5.88	0.65	0.04	172.26	136.17	8.74	3.63	2.06	175.2	0.59	0.70
9.	48.02	0.70	0.08	132.58	132.72	27.79	9.18	6.66	54.0	0.59	0.87
10.	40.67	0.64	0.03	28.80	132.86	24.07	8.05	6.43	5.1	0.59	0.68
11.	34.30	0.73	0.09	279.41	132.26	21.44	7.83	5.57	20.0	0.59	0.89
12.	6.37	0.61	0.01	252.92	133.85	9.73	4.17	1.95	13.0	0.59	0.63
13.	1.96	0.60	0.01	14.70	133.02	4.99	1.91	1.30	0.0	0.59	0.61
14.	5.39	0.63	0.03	264.09	131.23	8.33	3.33	2.06	2.5	0.59	0.67
15.	21.56	0.65	0.04	198.71	129.05	16.08	5.95	4.61	149.8	0.59	0.73
16.	5.39	0.60	0.01	233.04	129.57	8.33	3.49	1.97	13.3	0.59	0.62
17.	96.04	0.73	0.12	355.38	121.78	46.50	15.97	7.66	118.2	0.59	1.00
18.	44.59	0.65	0.03	123.54	126.75	24.82	9.36	6.06	175.4	0.59	0.70
19.	19.60	0.61	0.02	144.71	125.83	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)



Grain Boundary Maps

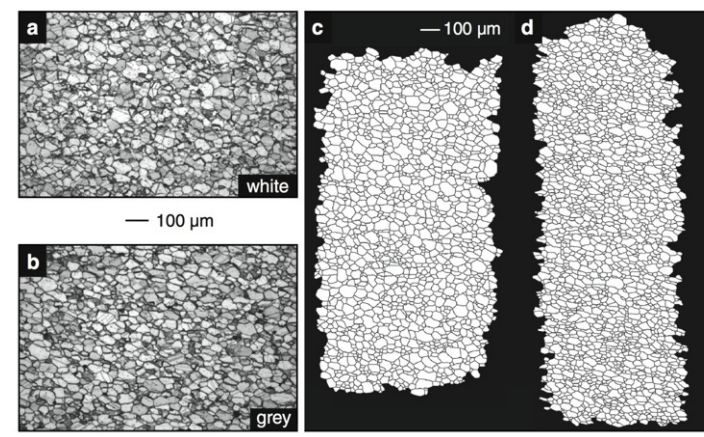
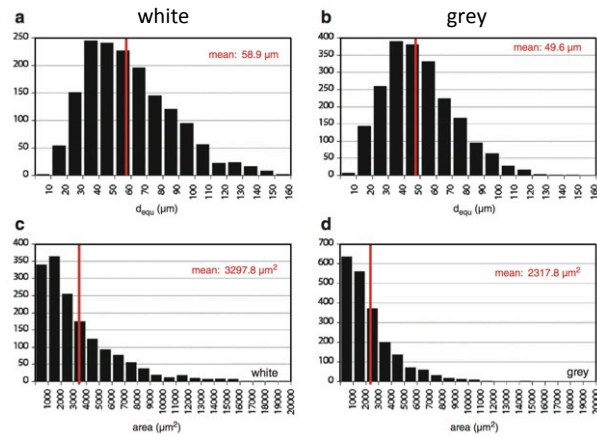
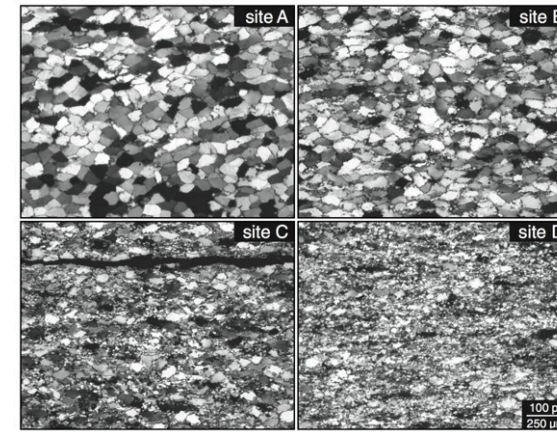


Image Analysis in Earth Sciences

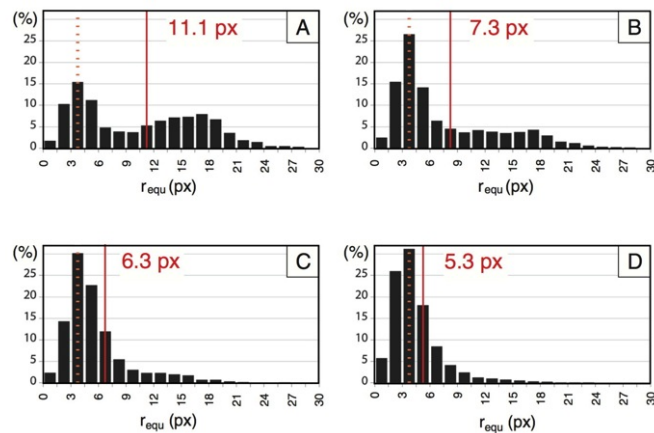
Grain Size Distributions



Grain Size Analysis



Grain Size Analysis



Grain Size Maps

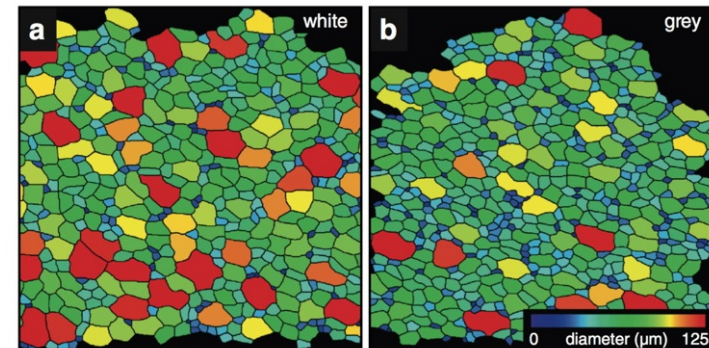
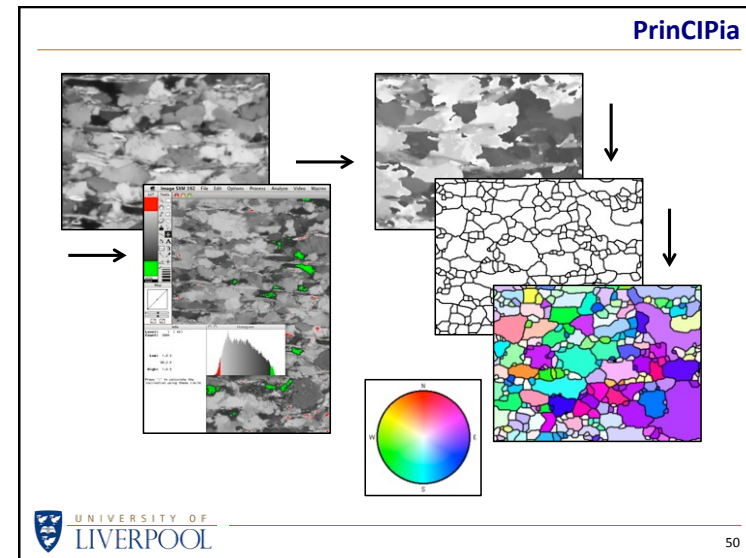
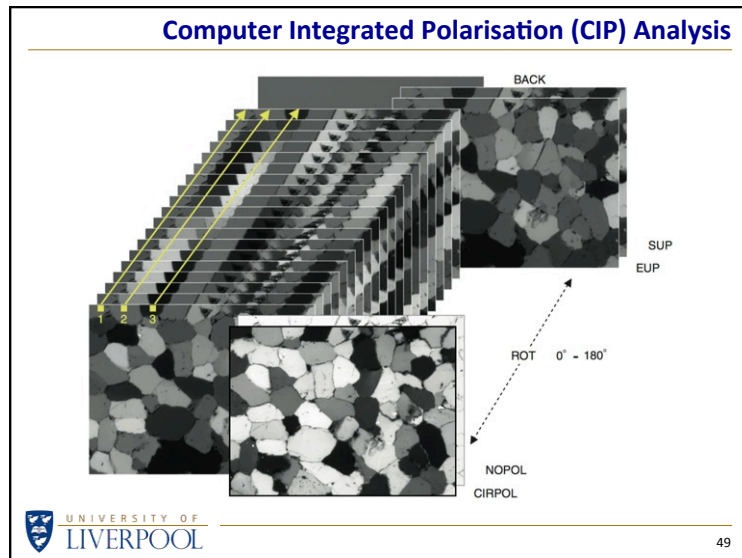


Image Analysis in Earth Sciences



Summary

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

The book cover for 'Image Analysis in Earth Sciences' by Renee Heibrock and Steve Barrett is shown. The title is 'Image Analysis in Earth Sciences' and the subtitle is 'Microstructures and Textures of Earth Materials'. The Springer logo is at the bottom right.

51

Image Analysis in Earth Sciences

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

Dr Steve Barrett

LGS 4 Feb 2020