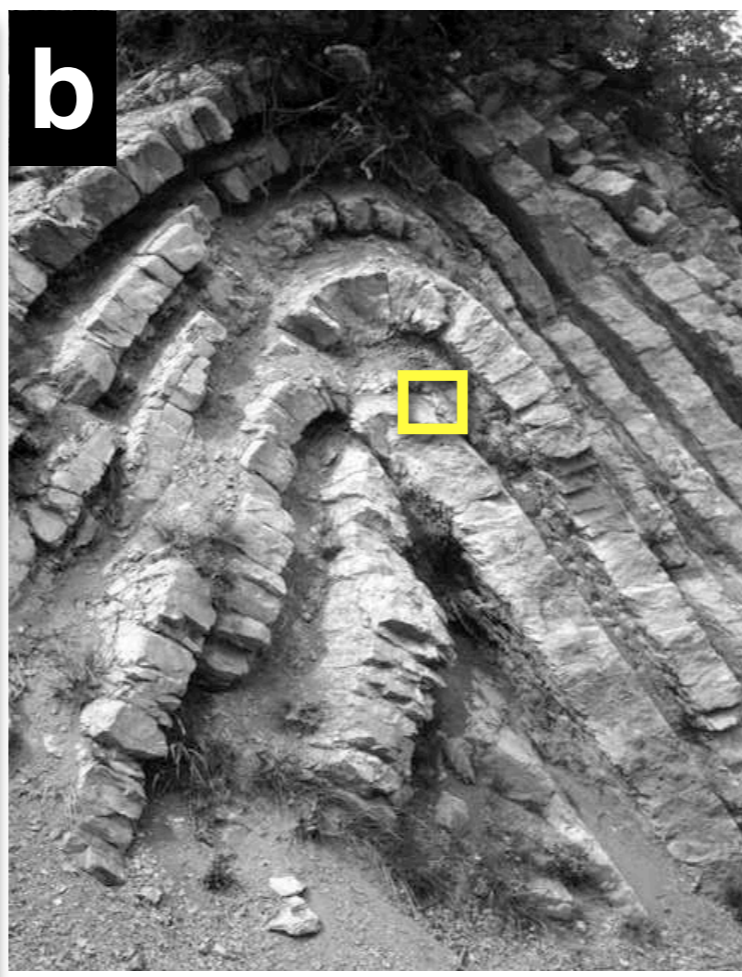
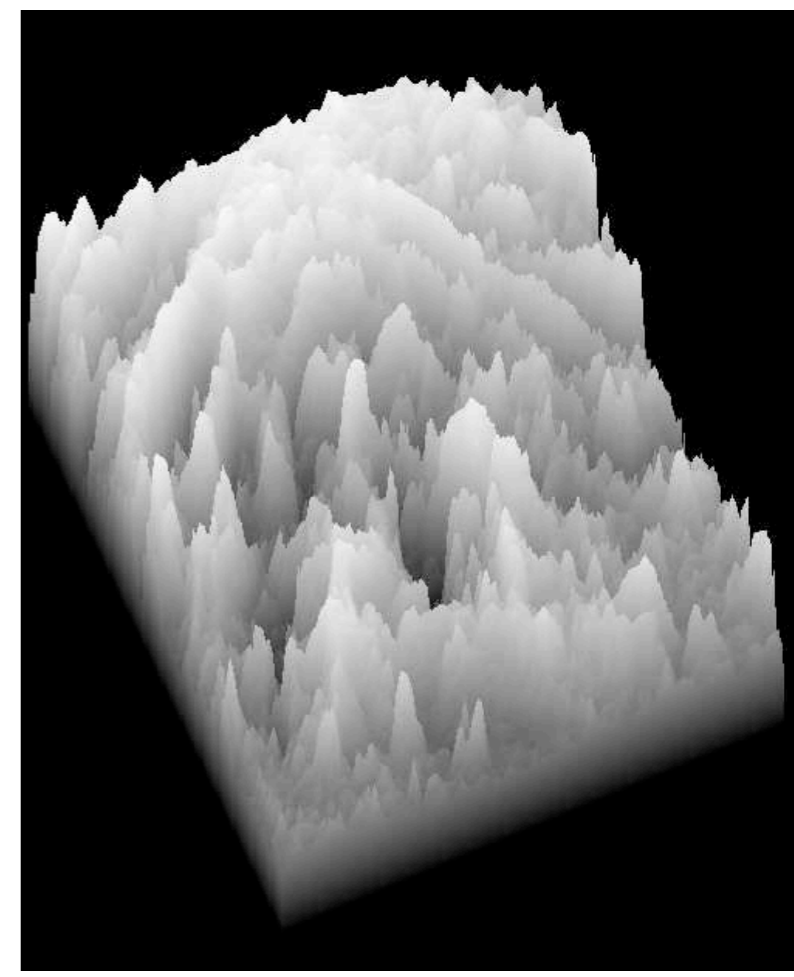
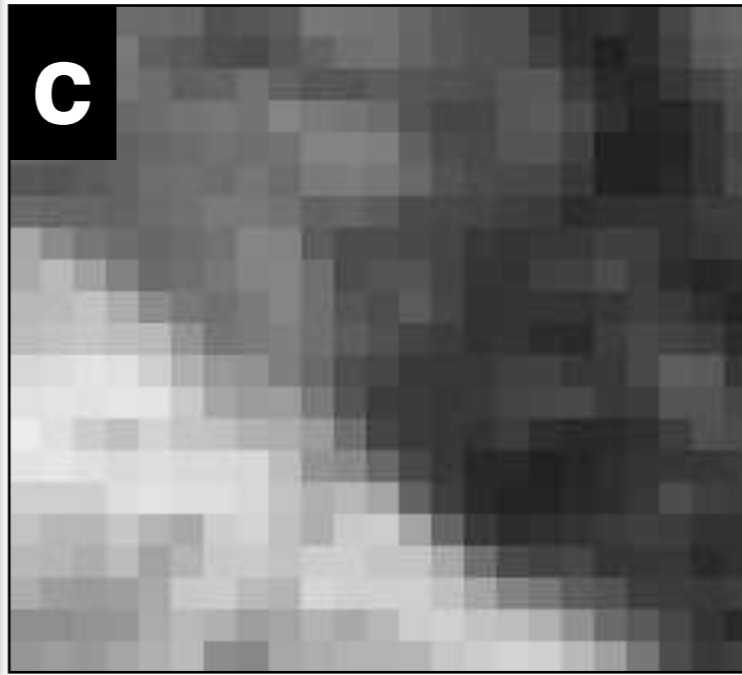


a

This is not an outcrop.

b**c**

134	131	135	146	148	151	173	168	161	135	137	139	152	167	173	174	198
155	131	124	133	158	165	176	180	168	156	143	141	154	165	172	175	188
168	142	138	137	145	158	155	141	157	167	169	161	169	172	176	168	167
150	151	143	149	145	139	135	139	122	132	137	146	171	184	184	168	164
148	157	162	157	151	147	141	144	140	123	123	128	157	178	181	171	170
167	169	164	156	145	143	146	137	146	132	130	137	150	171	180	181	184
148	152	152	155	147	141	132	134	140	157	153	163	179	181	185	191	195
87	116	136	146	151	146	140	121	124	162	178	177	181	185	198	202	199
85	69	94	126	148	143	135	124	121	144	178	171	171	186	202	203	191
71	69	60	82	116	133	142	132	121	142	169	177	164	184	205	202	203
67	61	57	65	70	107	136	133	127	142	162	174	186	195	205	203	209
40	36	28	31	48	78	102	109	127	149	176	185	198	200	198	190	189
31	28	30	26	27	54	88	100	98	132	169	193	196	199	199	187	185
18	31	50	62	43	58	61	78	82	99	143	186	196	199	203	195	208
28	25	31	37	32	38	38	39	67	108	117	150	182	198	215	213	221
48	49	48	34	28	33	33	40	61	79	71	90	156	192	212	218	217
61	72	72	57	75	86	50	44	64	81	54	50	91	153	197	209	207
71	73	81	67	92	75	54	53	61	50	49	58	59	86	144	179	187
82	97	101	96	85	54	51	68	75	42	47	47	48	63	89	124	136
112	113	107	105	84	70	78	98	90	76	86	72	51	47	61	65	78
105	98	103	91	80	68	114	120	89	82	76	76	74	56	50	43	48

This is not an outcrop.

Figure 1.1

Images are not objects.

(a) Following René Magritte's famous painting 'Ceci n'est pas une pipe', this picture points to the fact that a picture is not what it represents.

(b) To bring out the nature of images, the picture is shown as a monochrome image and as a 3-D rendition of the brightness distribution.

(c) To demonstrate what digital images 'really are', the number matrix for a small detail (frame in (b)) is shown also.

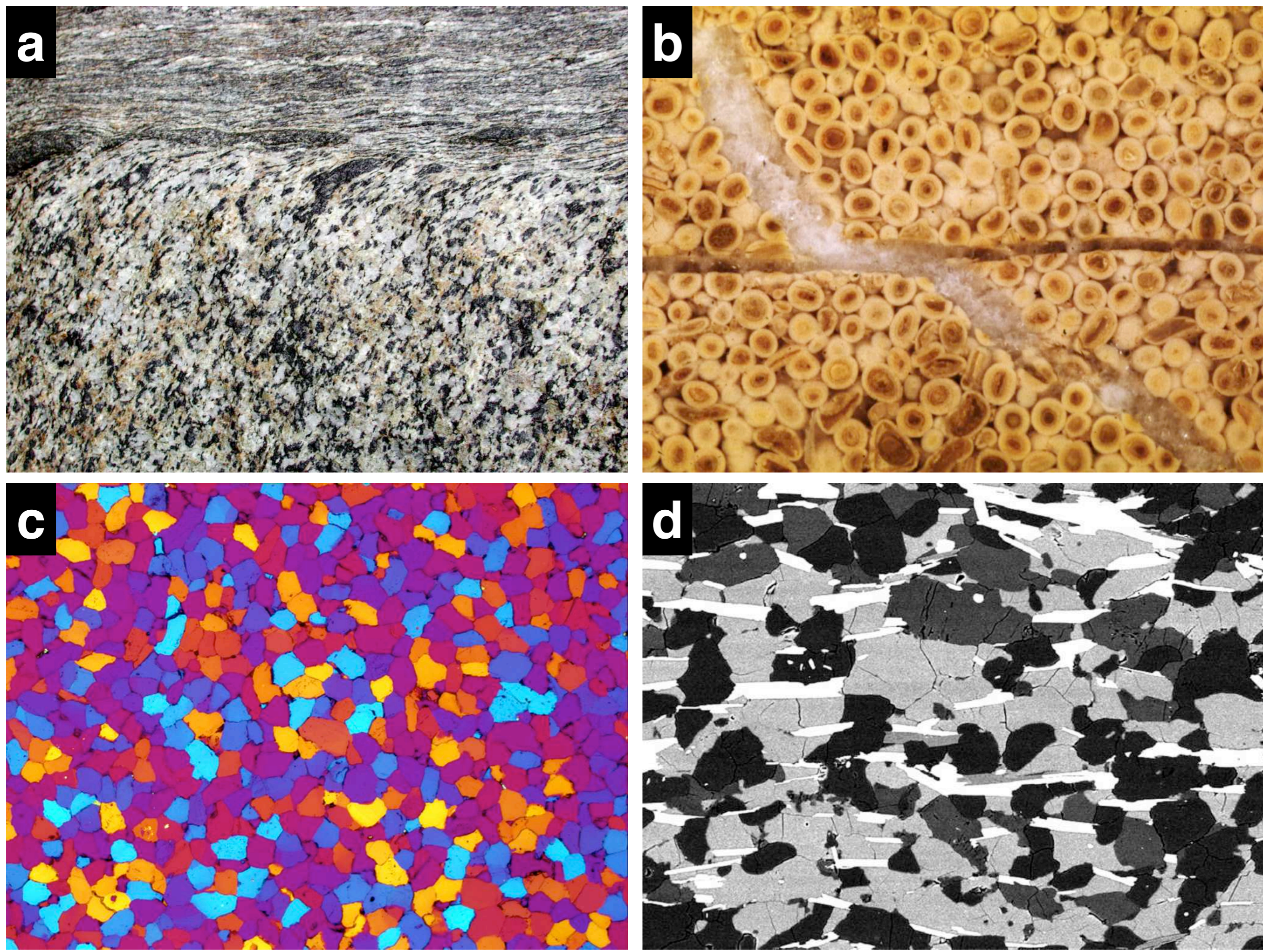


Figure 1.2

Typical input for image analysis.

(a) Photomacrograph of glacially polished surface of shear zone and wall rock;

(b) photomacrograph of polished surface of oolitic limestone;

(c) micrograph of thin section of quartzite, cross polarization and wave plate;

(d) scanning electron micrograph of polished surface of granitic rock, with back-scattered electron contrast (Image courtesy Rüdiger Kilian).

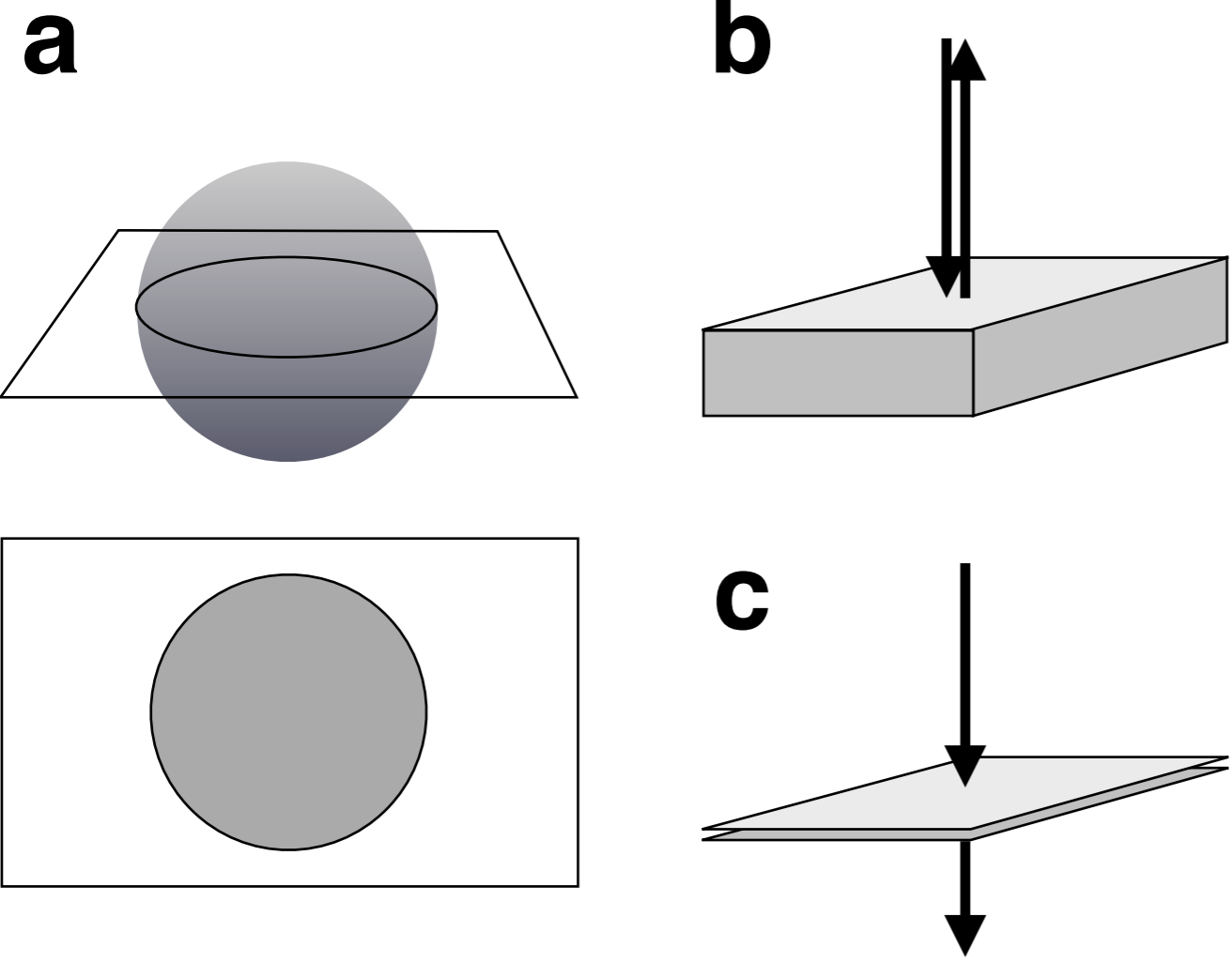


Figure 1.3
2-D section of 3-D body.
(a) Concept of a perfect 2-D section: section thickness = 0;
(b) surface (= plane) imaged in incident mode;
(c) section (= very thin volume) imaged in transmitted mode.

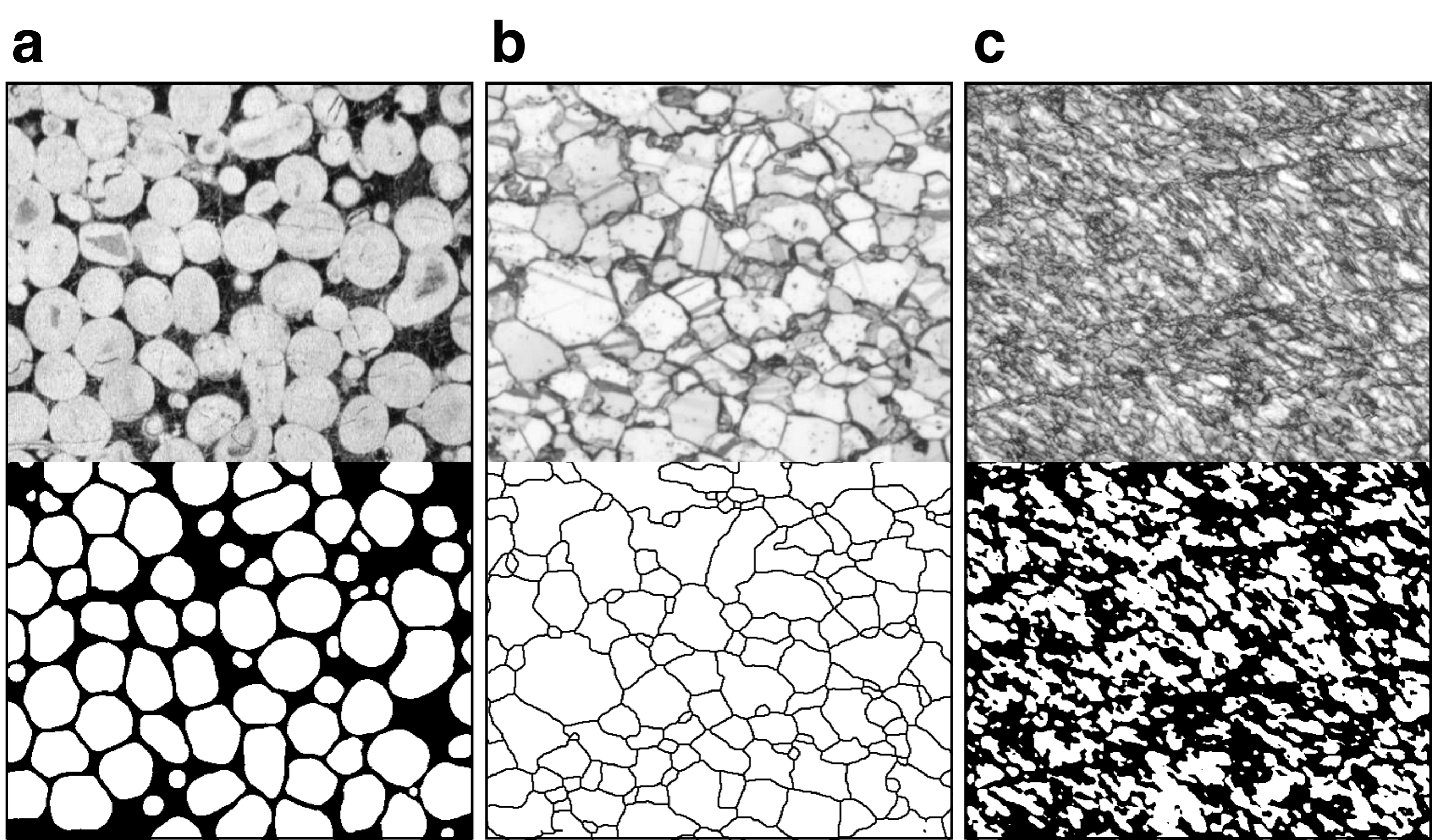


Figure 1.4

Type microstructures for image analysis.

The grayscale micrographs are shown on top; the model microstructures are shown below.

(a) In the particles-in-matrix type, two visually discernible phases exist: particles (white) and matrix (black);

(b) in the space-filling aggregate, only one (visual) phase is present: grains (white); there is no space between the grains; the outlines (black) do not represent a separate phase; they do not occupy any volume, they only denote the boundaries between grains;

(c) in the visual texture, the particles cannot be distinguished from one another; the model microstructure is a random pattern of black and white.

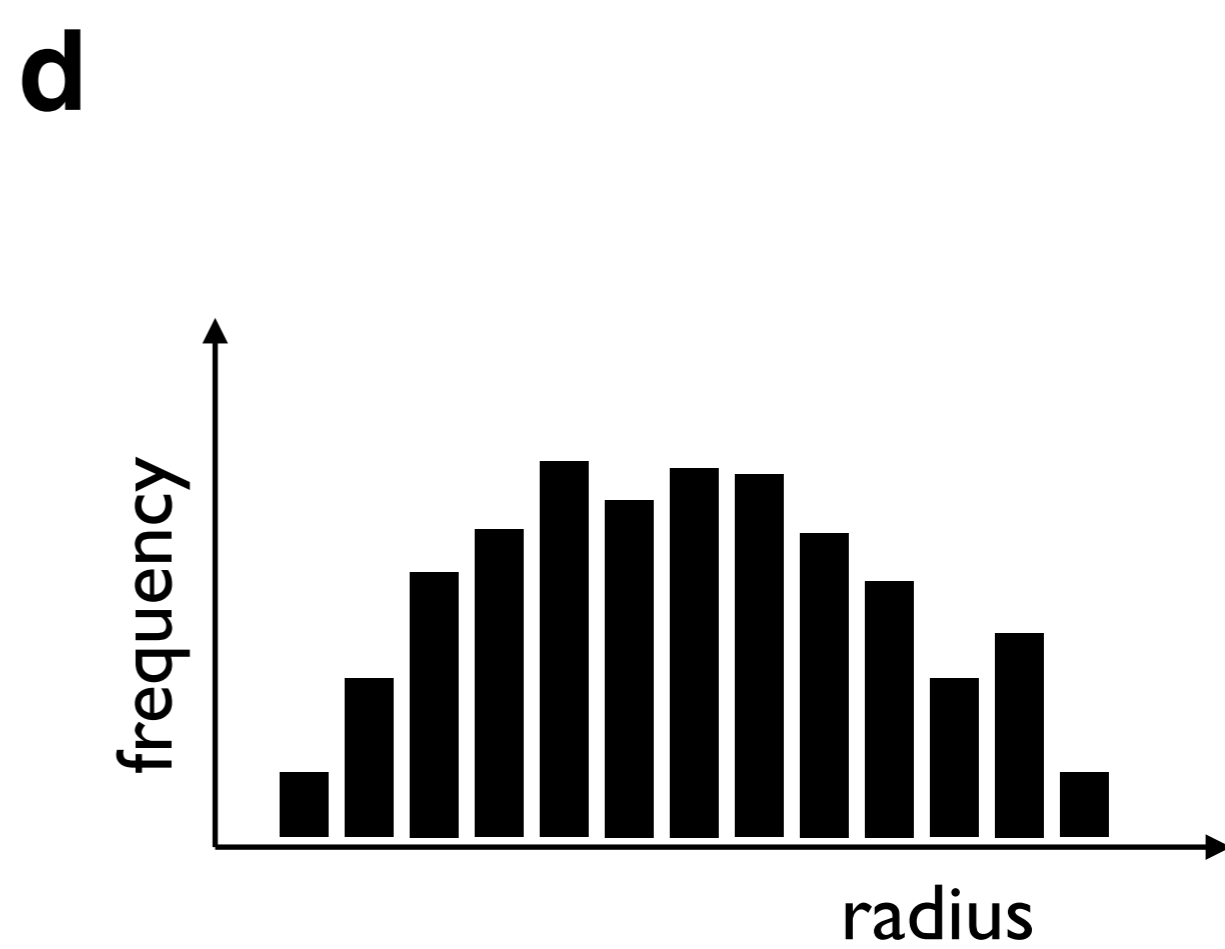
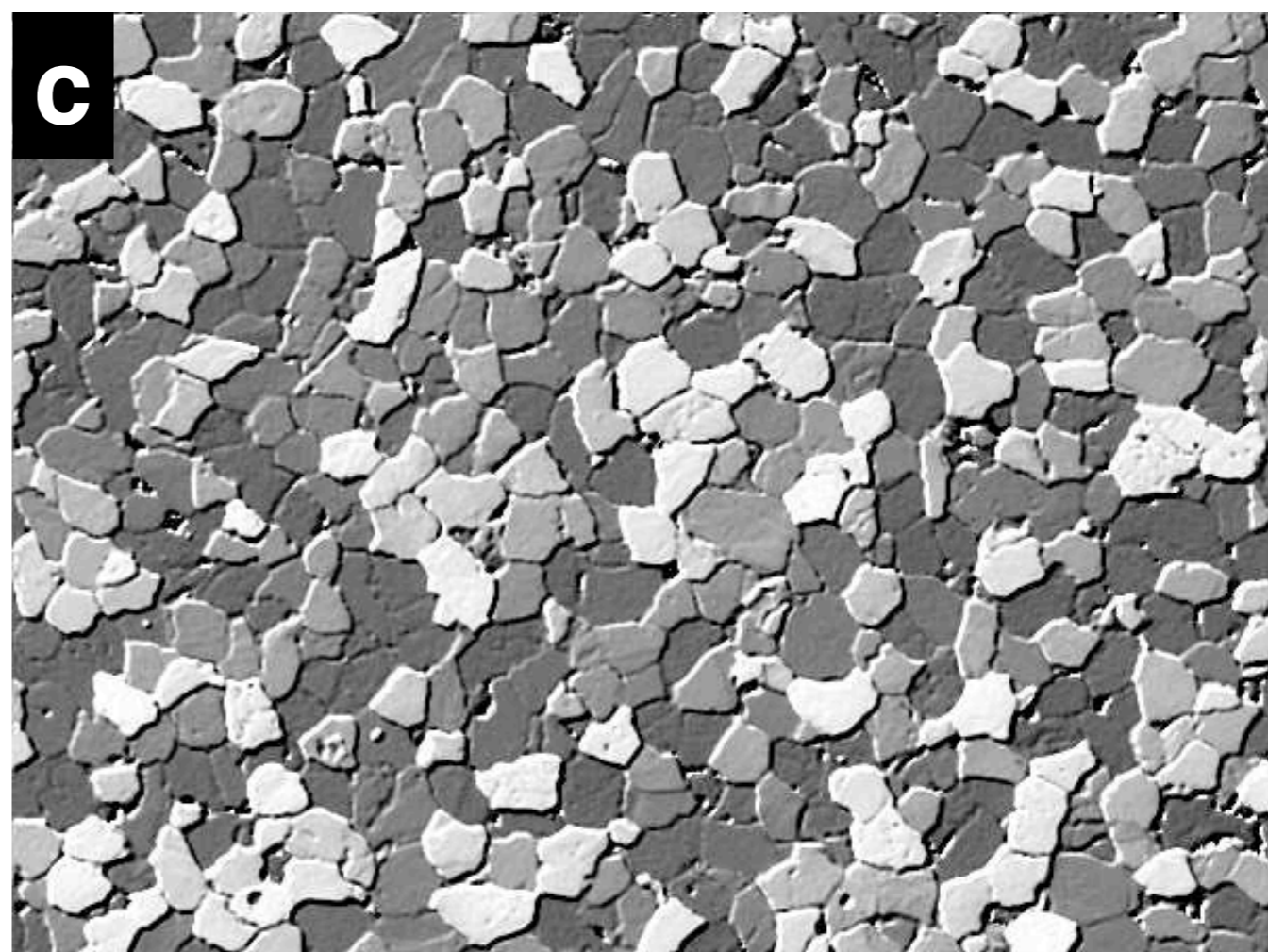
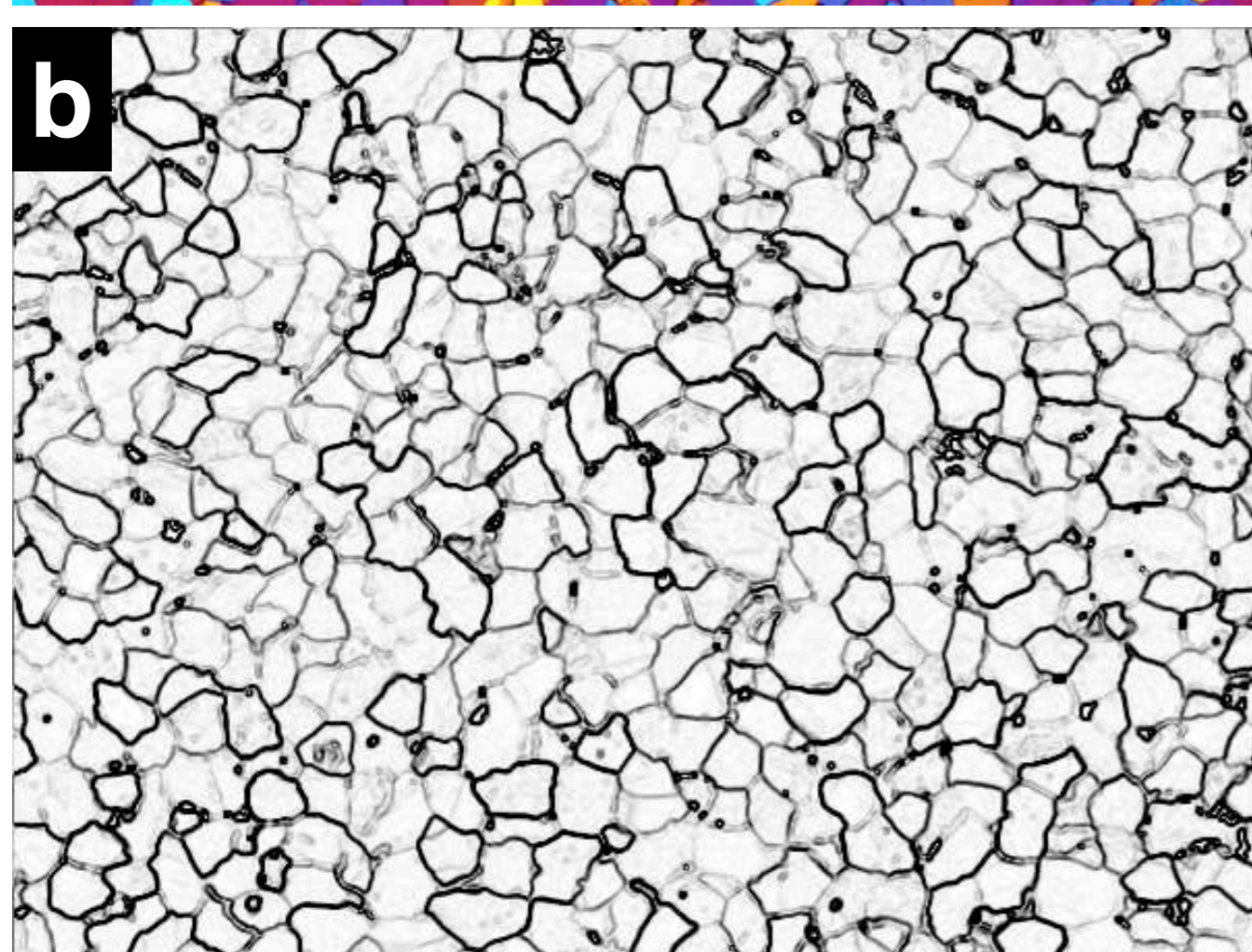
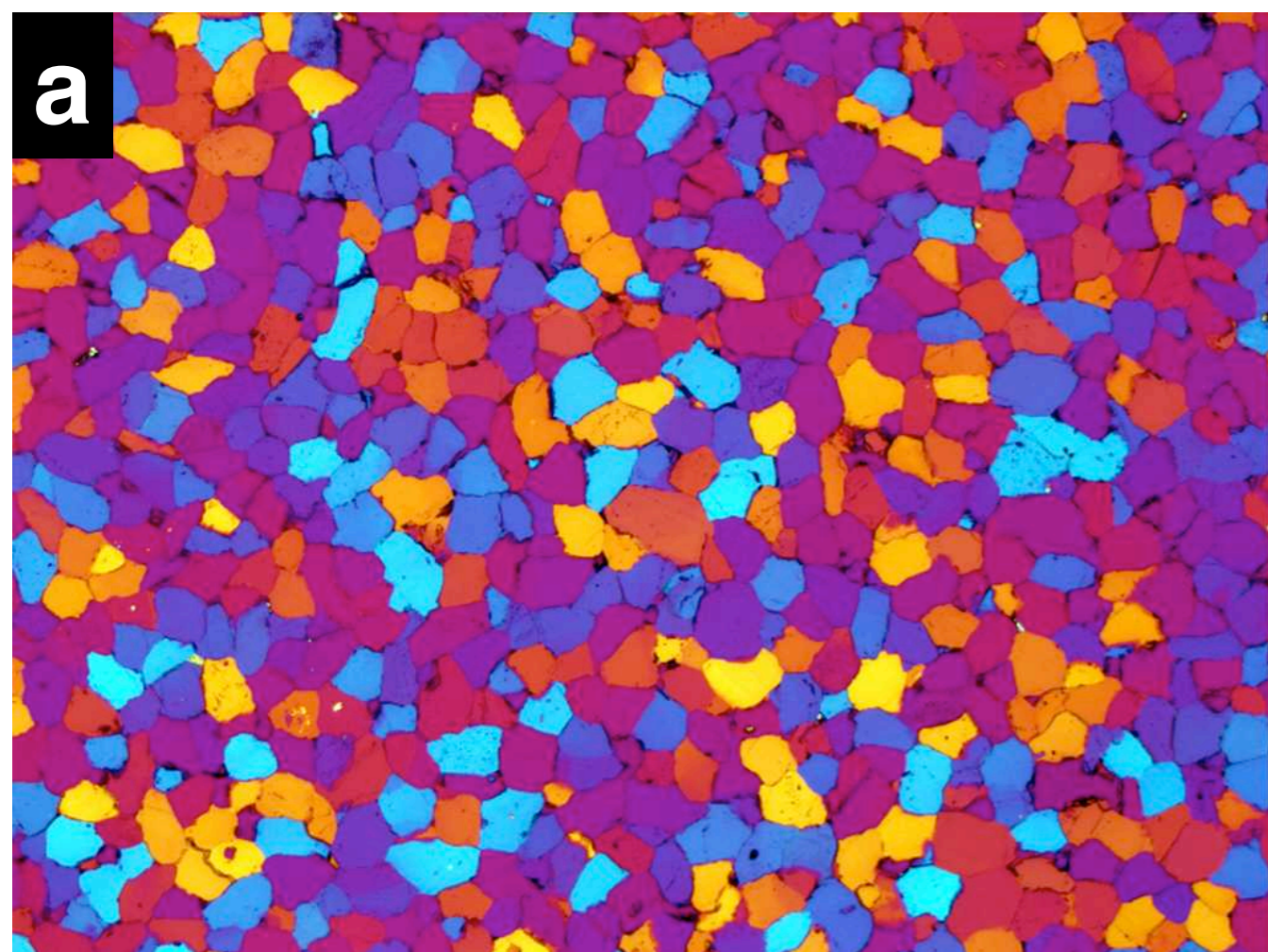


Figure 1.5

Image analysis versus image processing.

(a) Original image;

(b) result of image processing: image to image;

(c) result of image processing: image to image;

(d) result of image analysis: image to number(s).

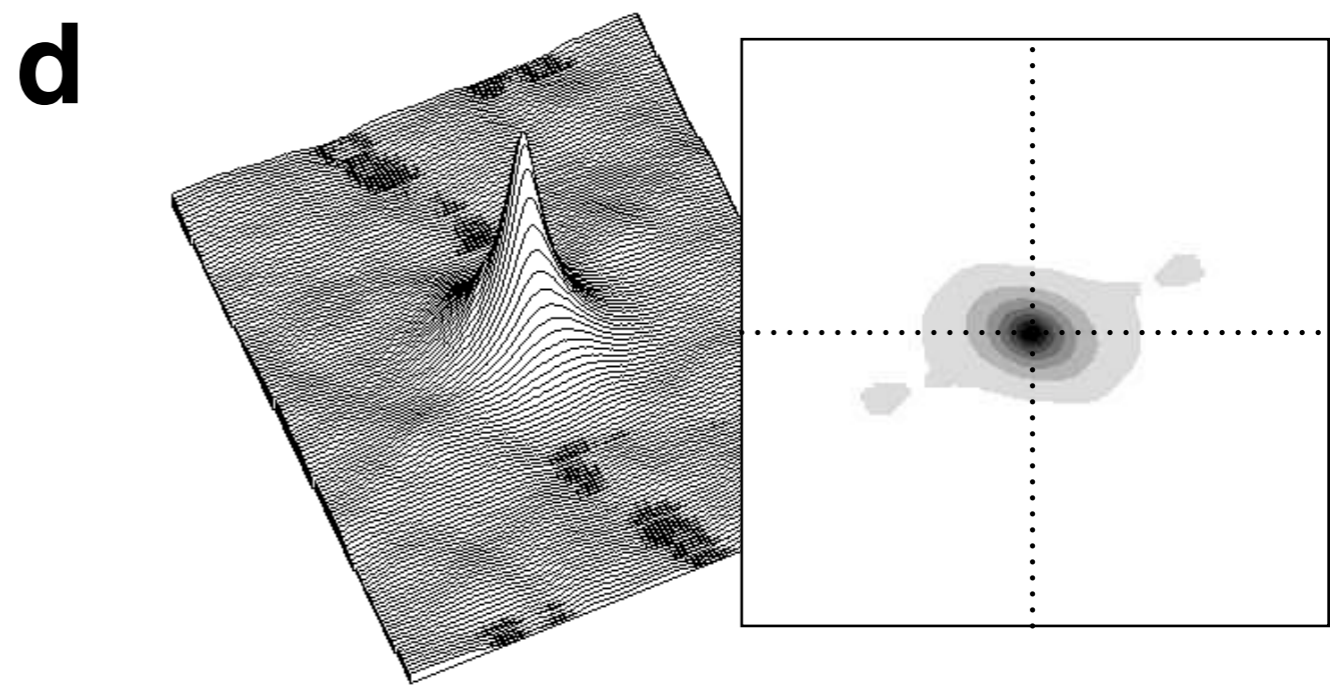
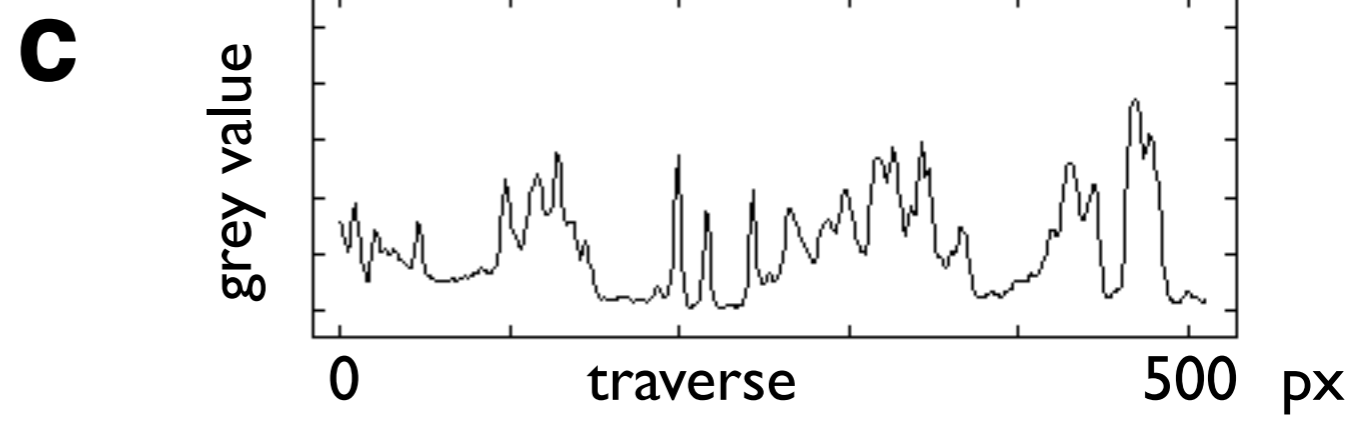
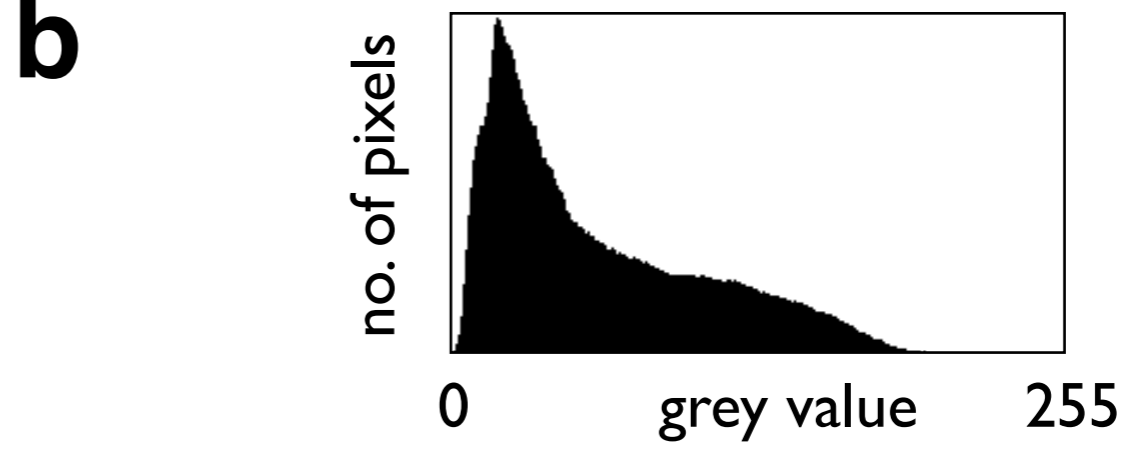
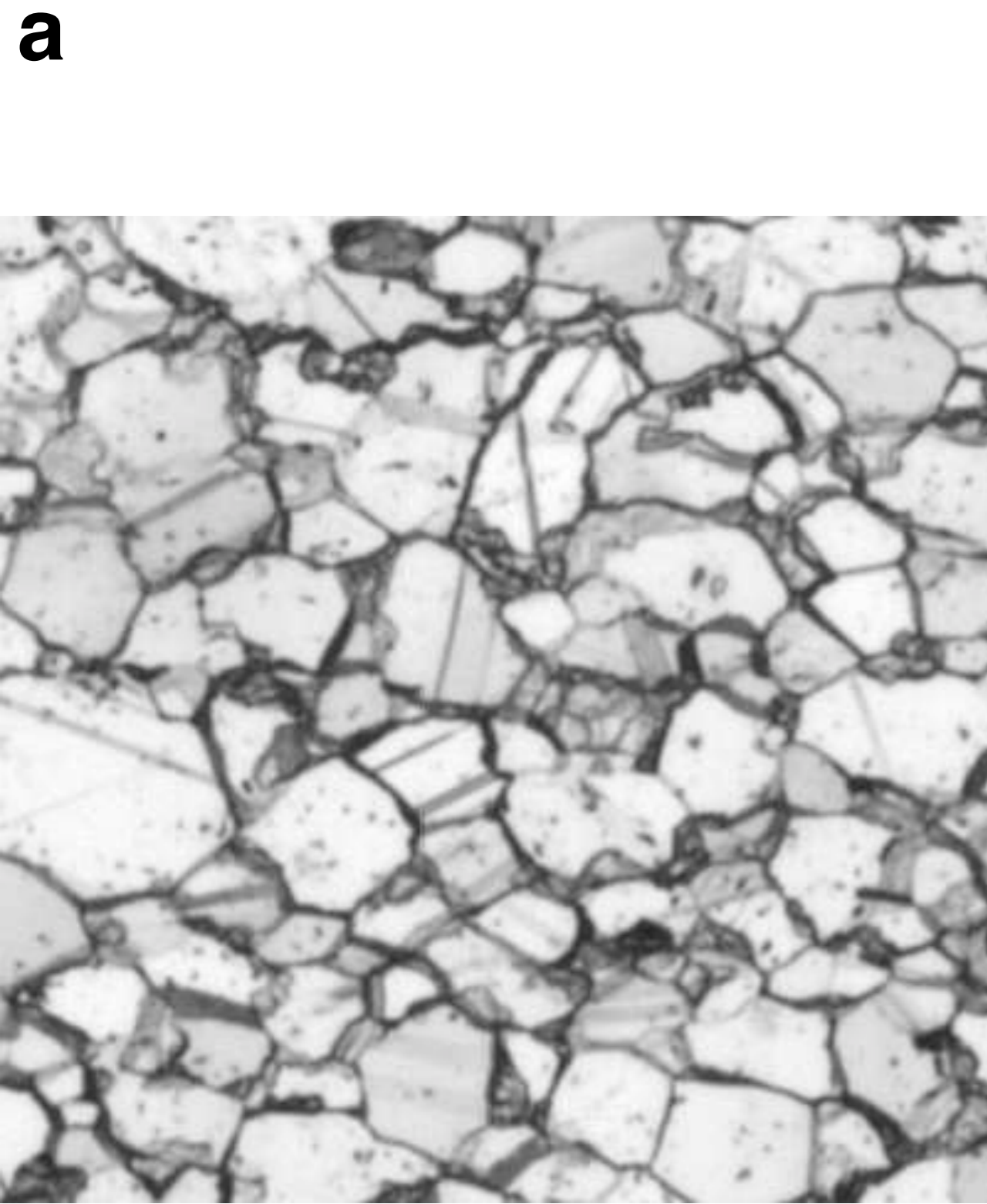


Figure 1.6
Direct image analysis.
(a) Image showing micrograph of marble in plane polarized light;
(b) statistics of gray values: histogram;
(c) spatial gray value changes: profile;
(d) correlation among gray values: autocorrelation function.

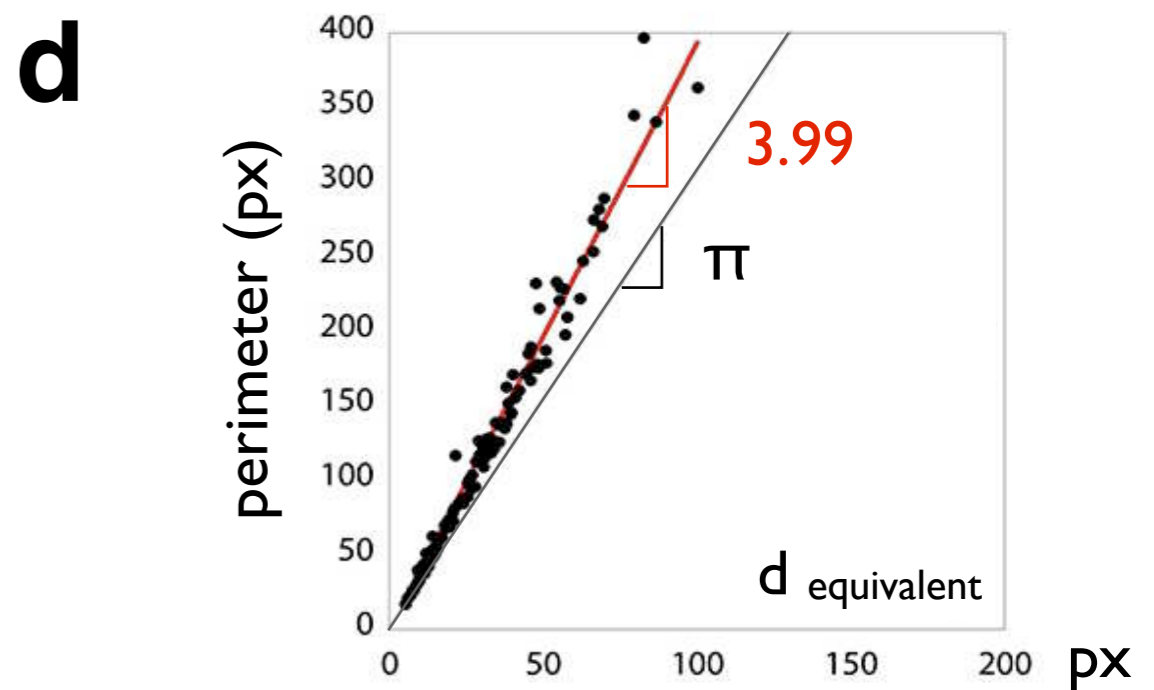
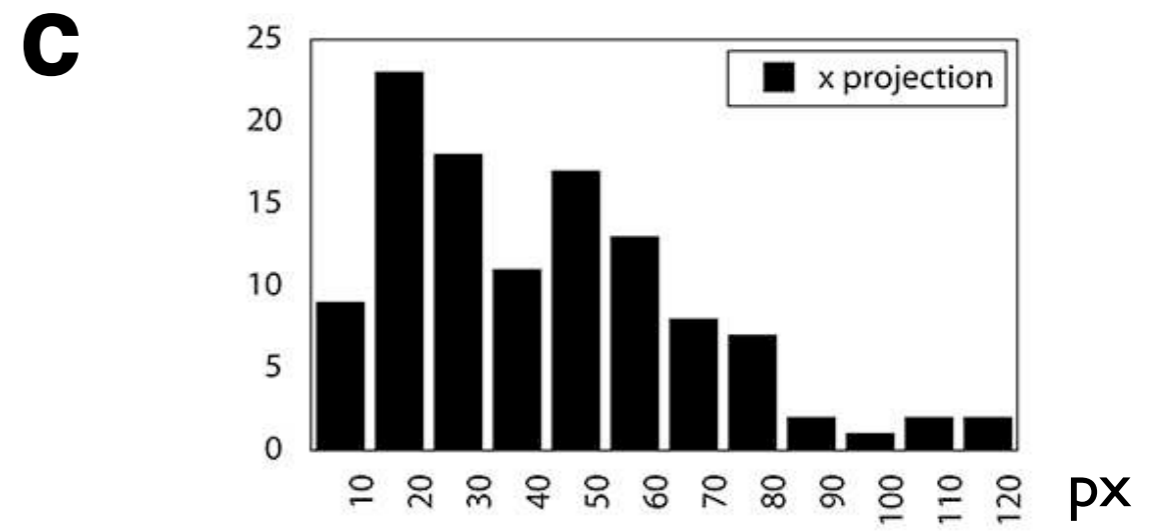
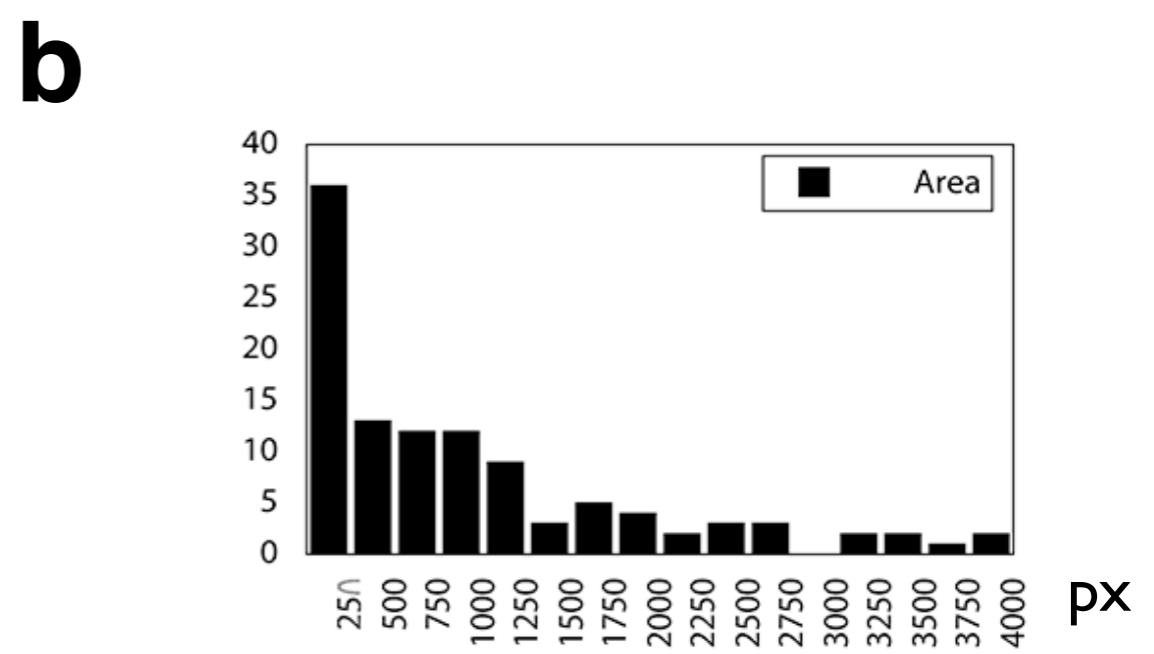
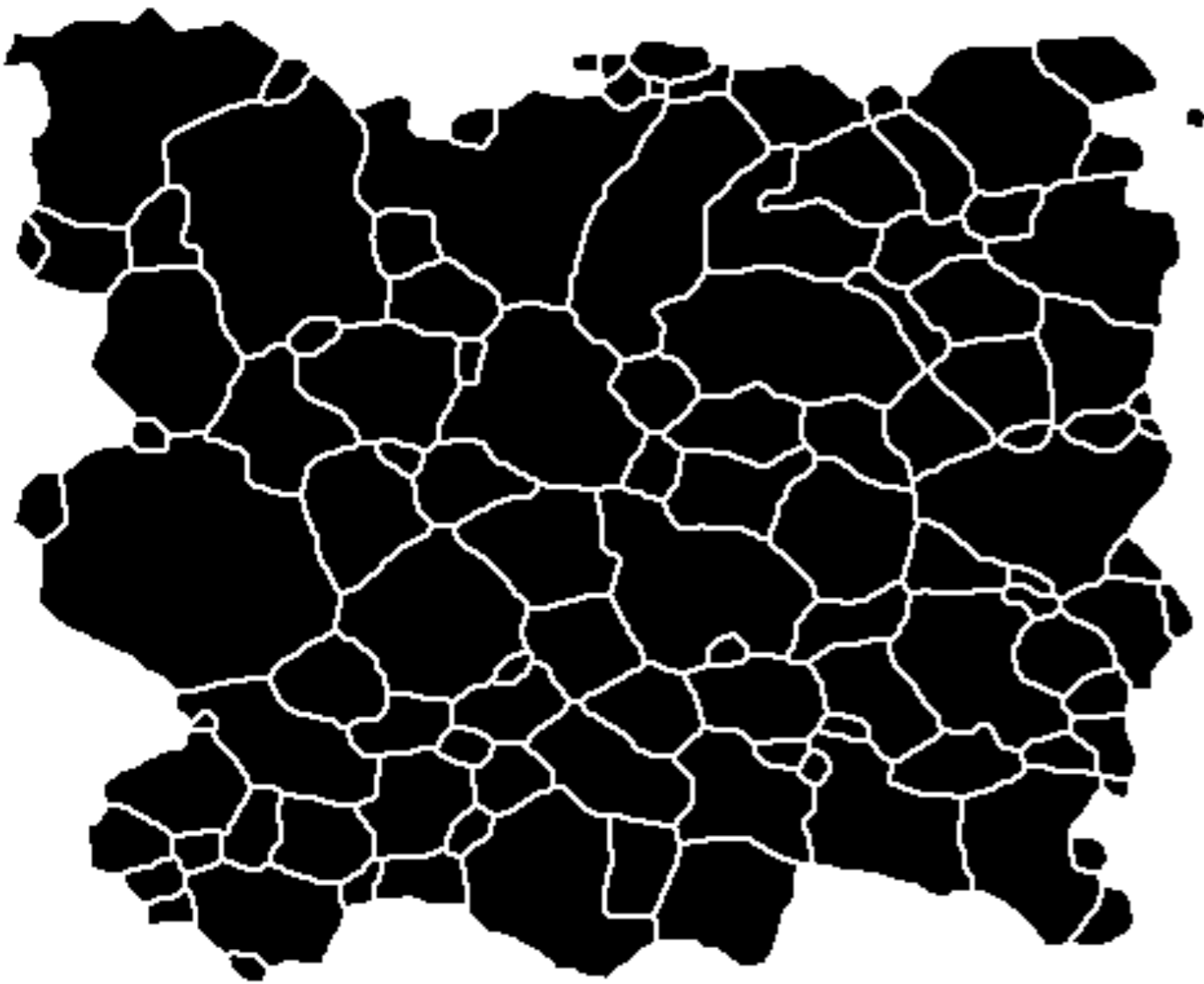
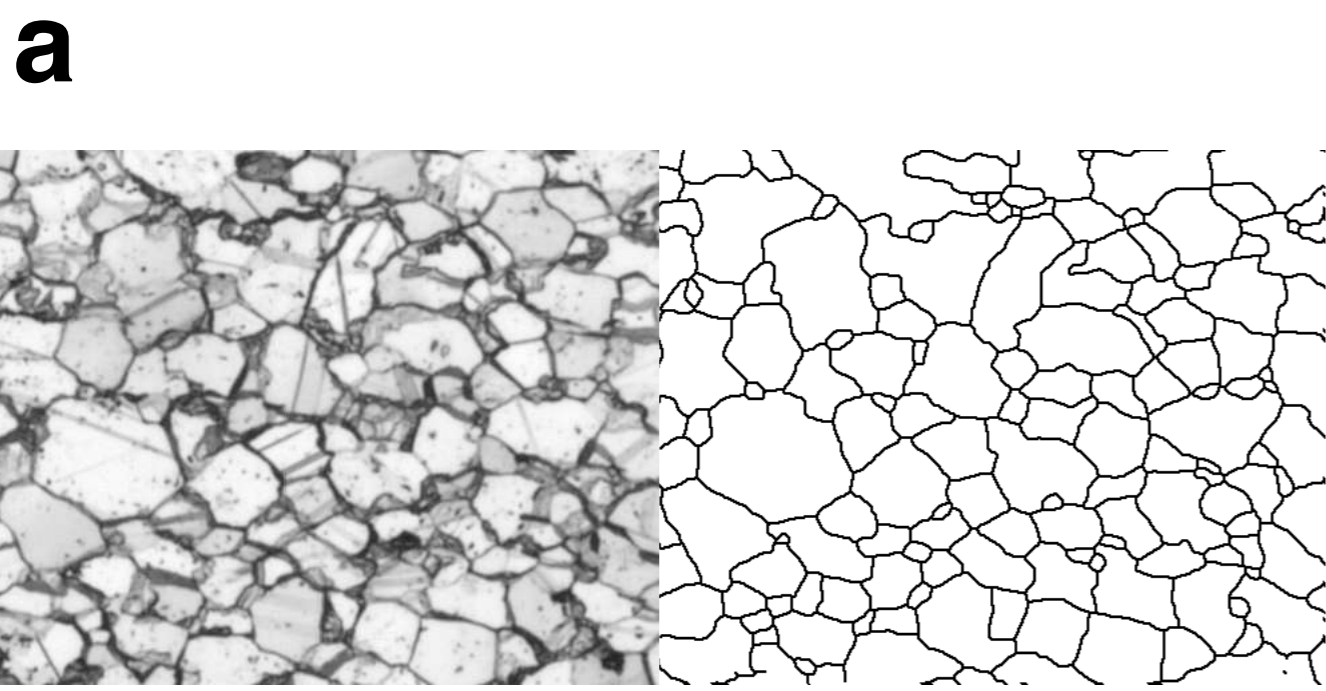


Figure 1.7

Image analysis using segments.

(a) Segmented image: cross sectional areas of calcite grains (original image and grain boundary map shown above);

(b) size distribution of segments: histogram of areas (= number of pixels per segment);

(c) projection of areas on x-axis (= difference between minimum and maximum x-coordinate, $X_{\text{max}} - X_{\text{min}}$, of each segment): histogram of lengths;

(d) length of perimeter of each segment (from number of boundary pixels) versus diameter of area equivalent circle, curve fit indicates a ratio of 3.99, slope π (= 3.14) for circle is indicated.

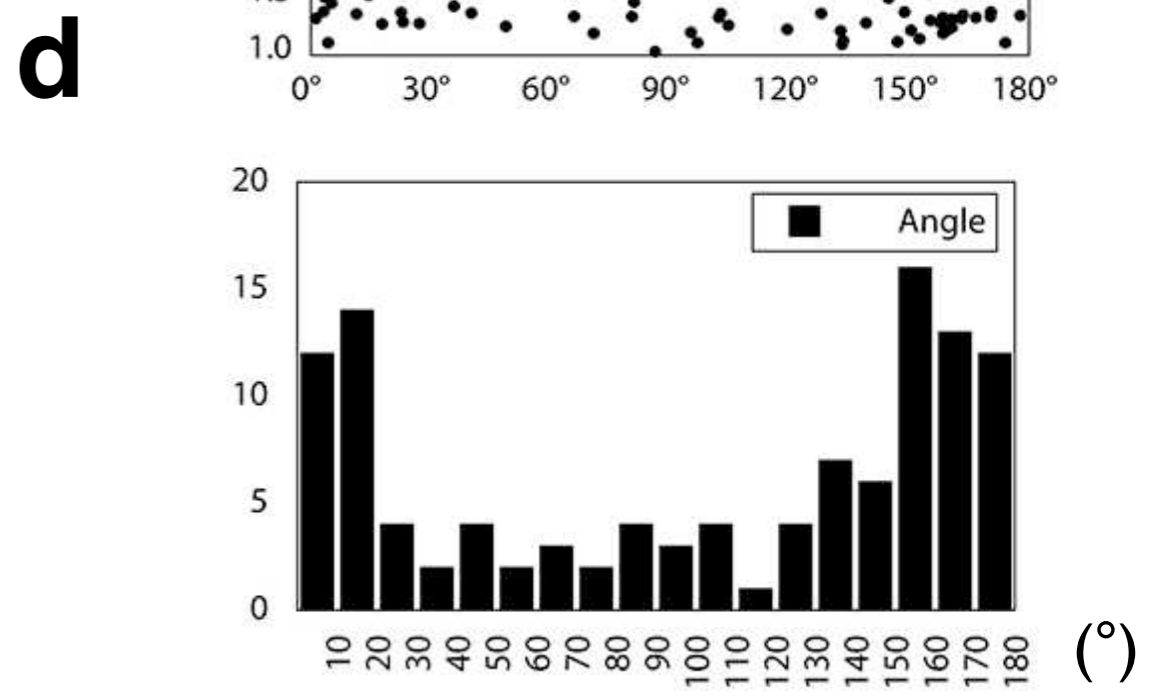
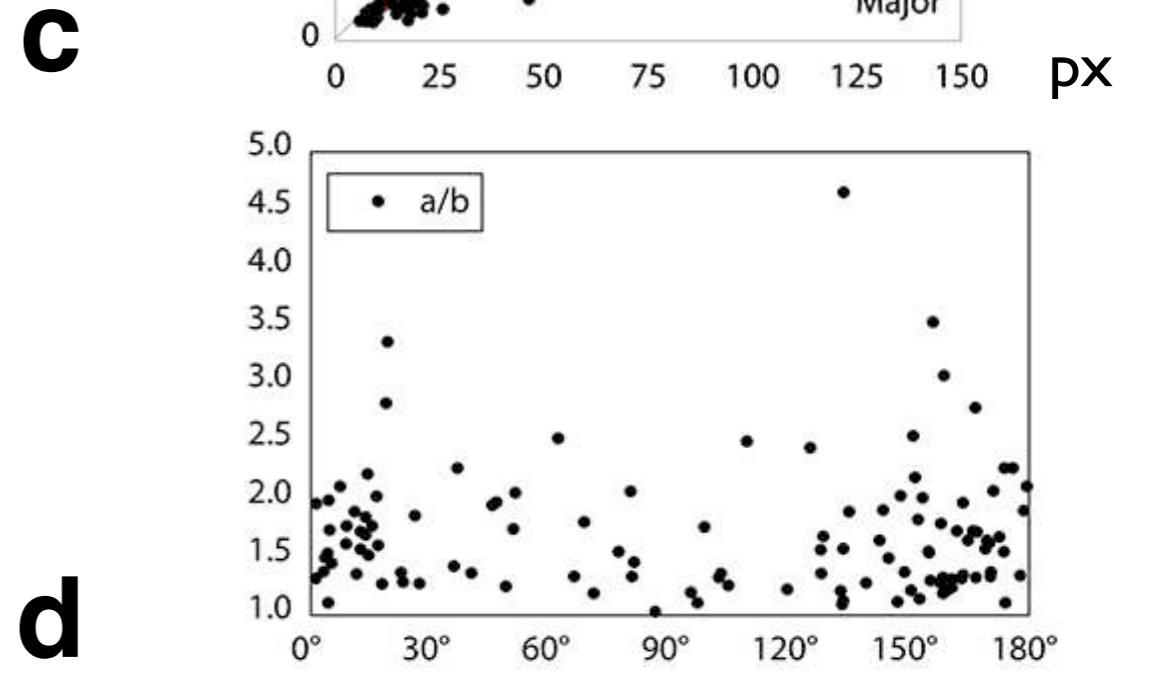
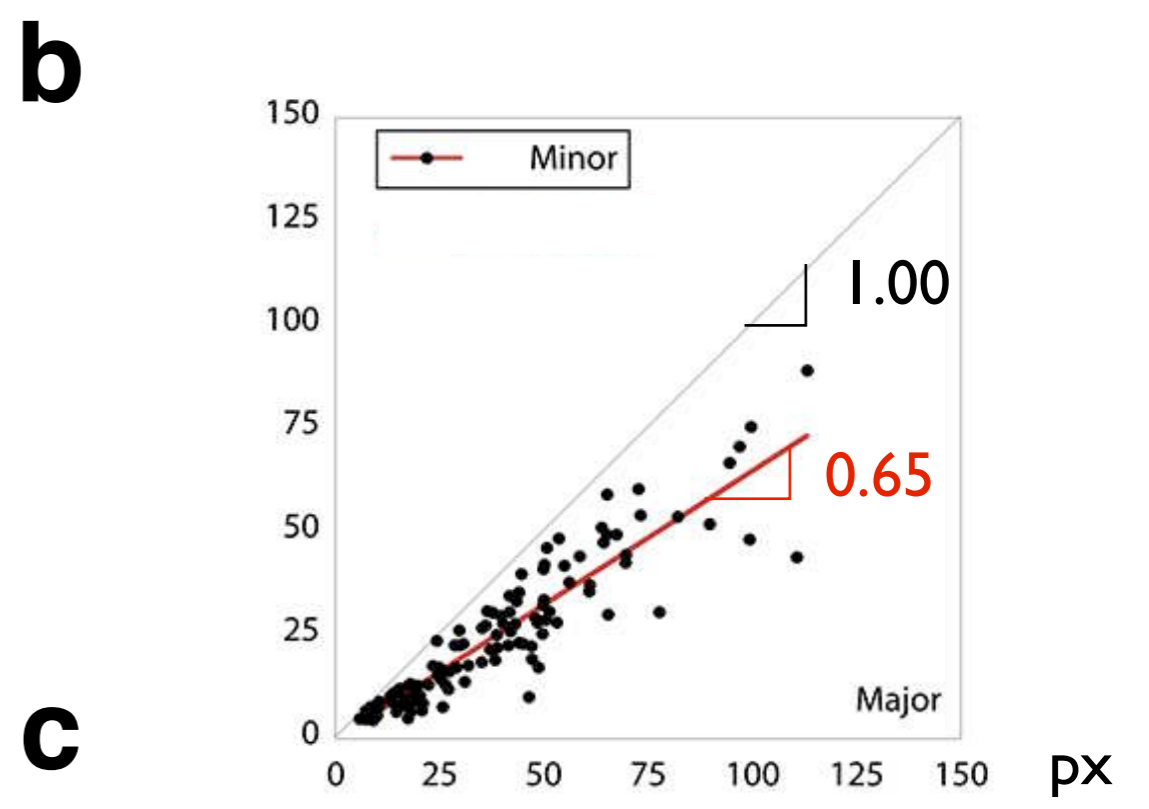
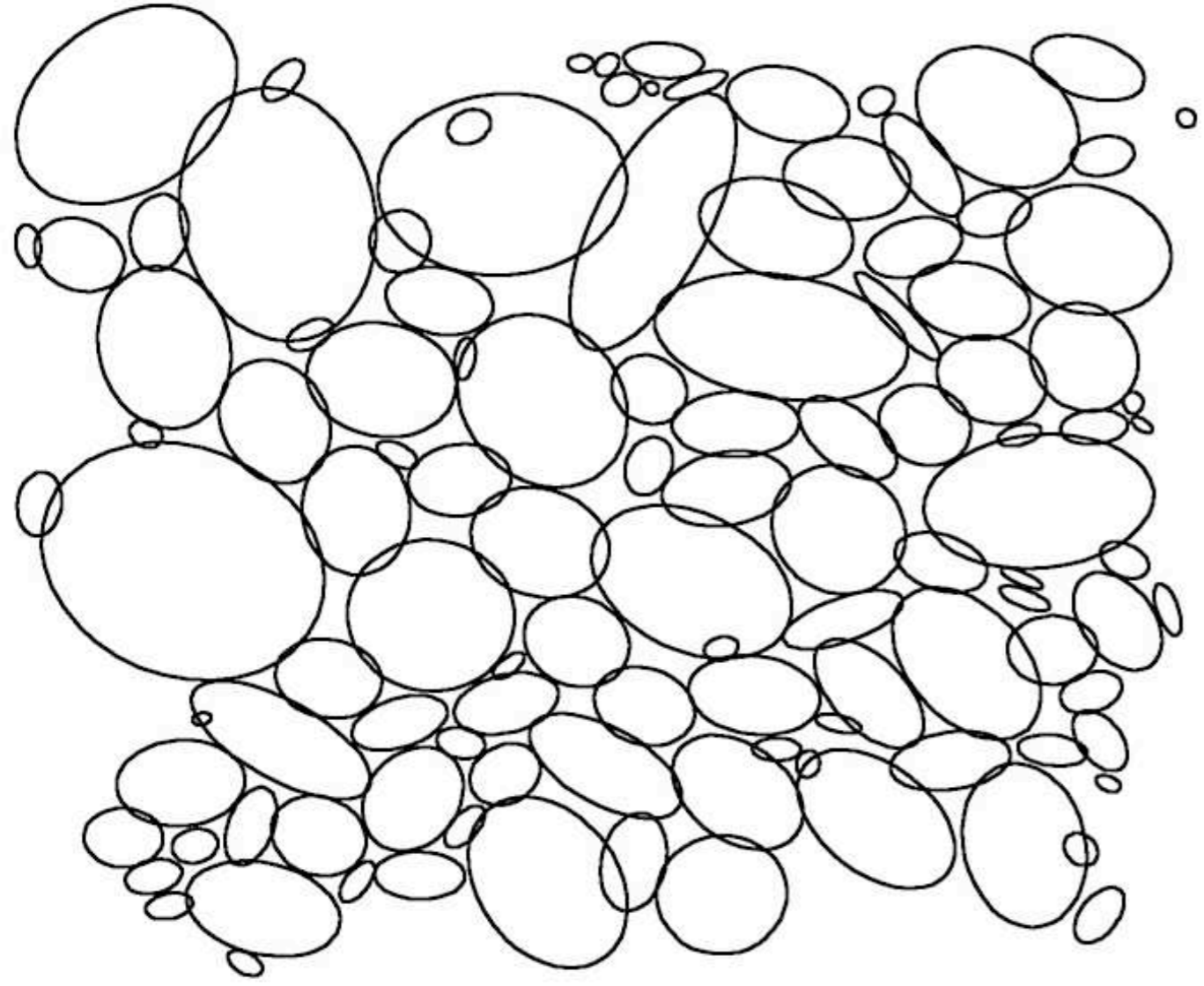
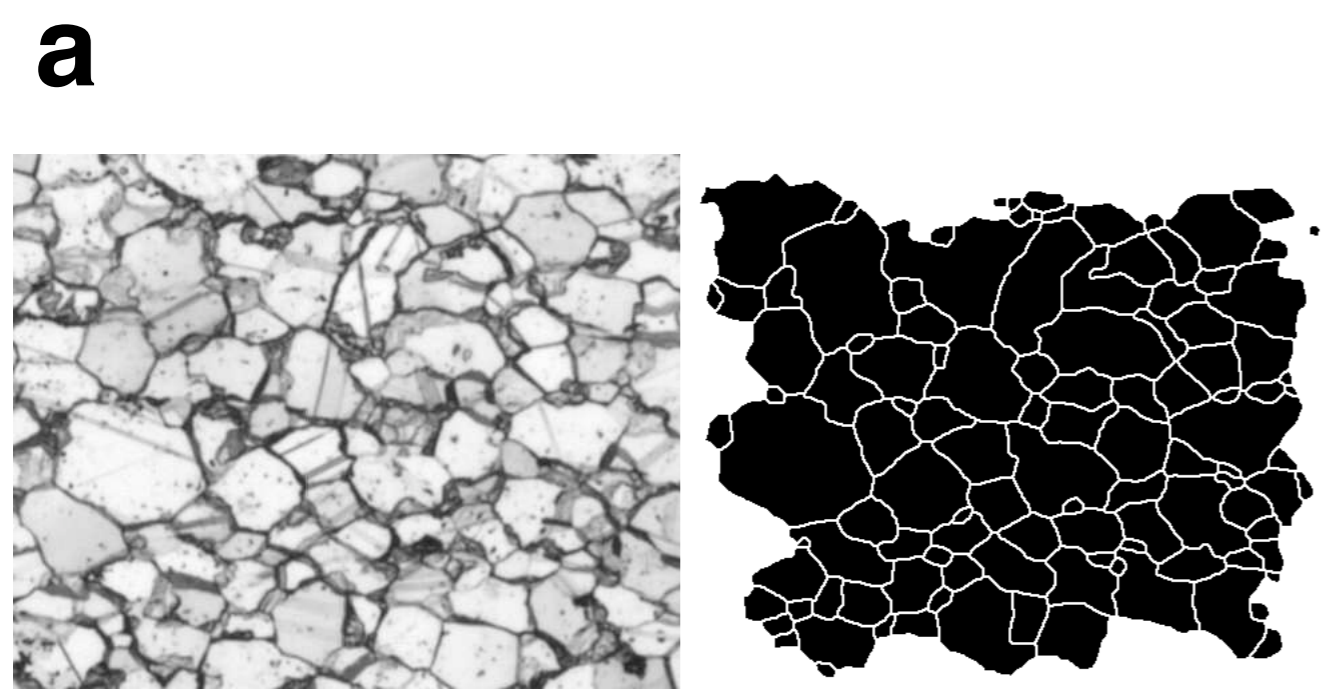


Figure 1.8

Image analysis using best-fit ellipses.

- (a) Plot of best-fit ellipses to cross sectional areas of calcite grains (original image and grain map shown above);
- (b) shape of ellipses: minor axis versus major axis; curve fit indicates axial ratio of 0.65; slope 1.00 for circle is also indicated;
- (c) shape fabric: aspect ratio (= major axis / minor axis) versus orientation of major axis (corresponds to Rf- φ plot);
- (d) preferred orientation: histogram of angles.

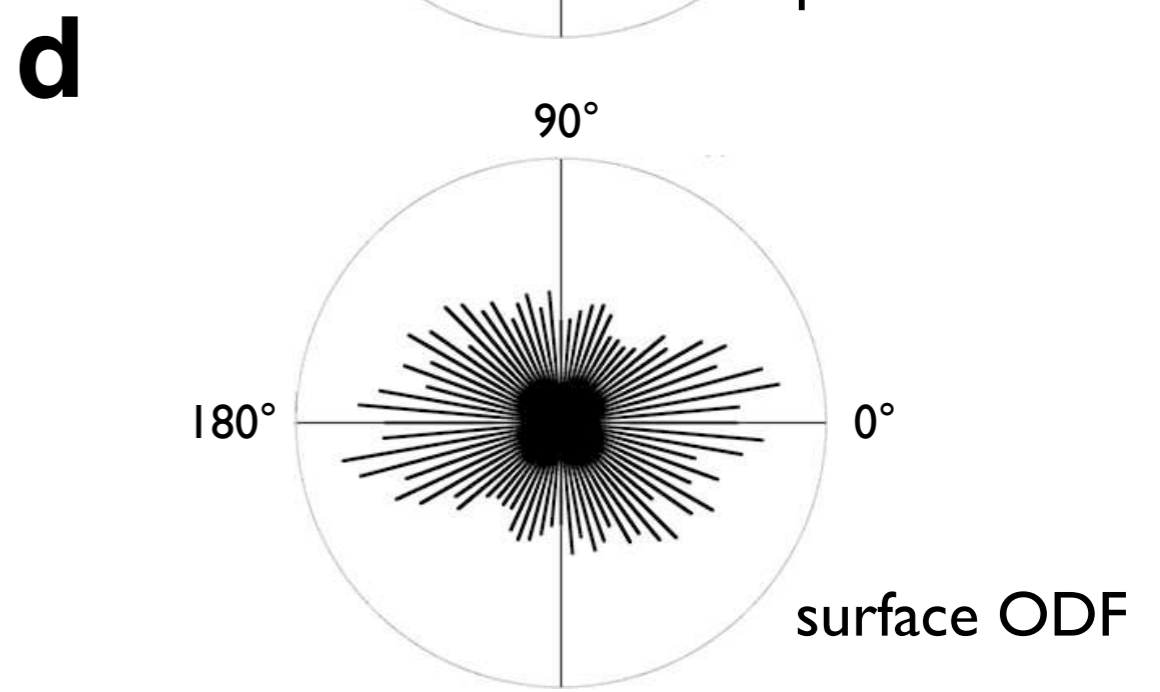
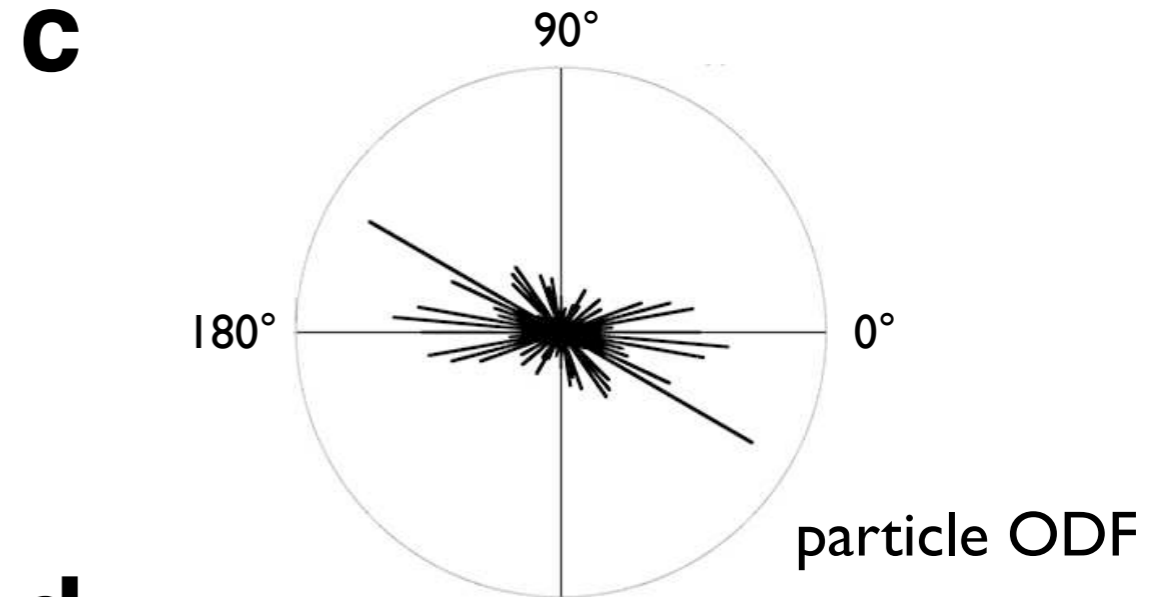
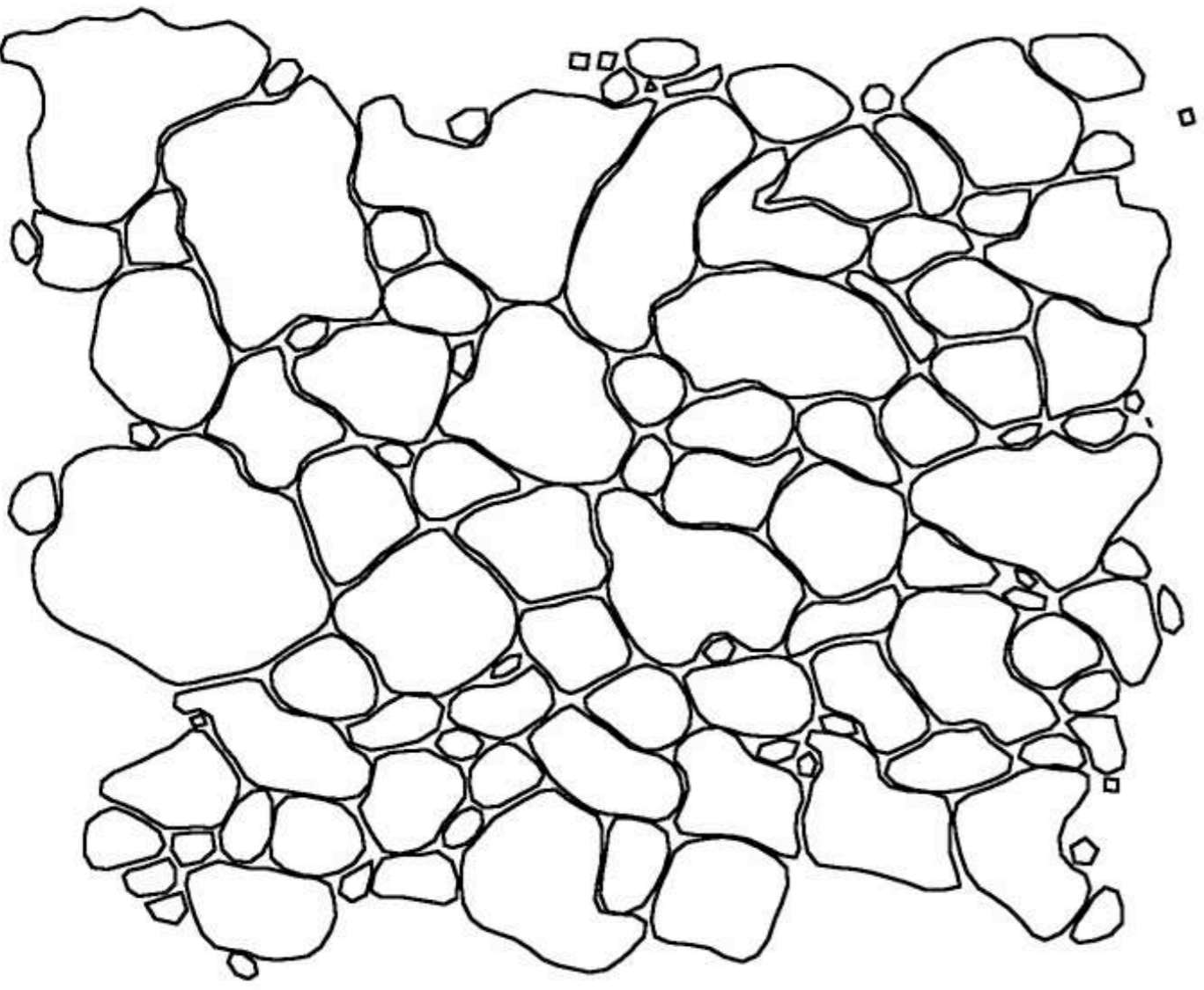
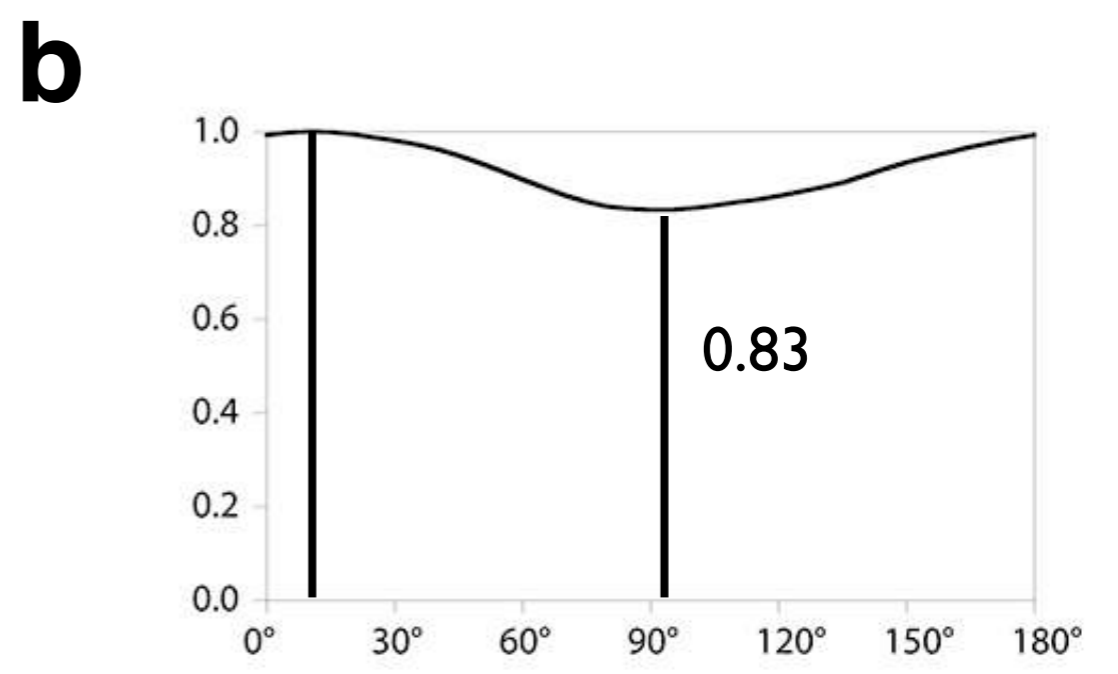
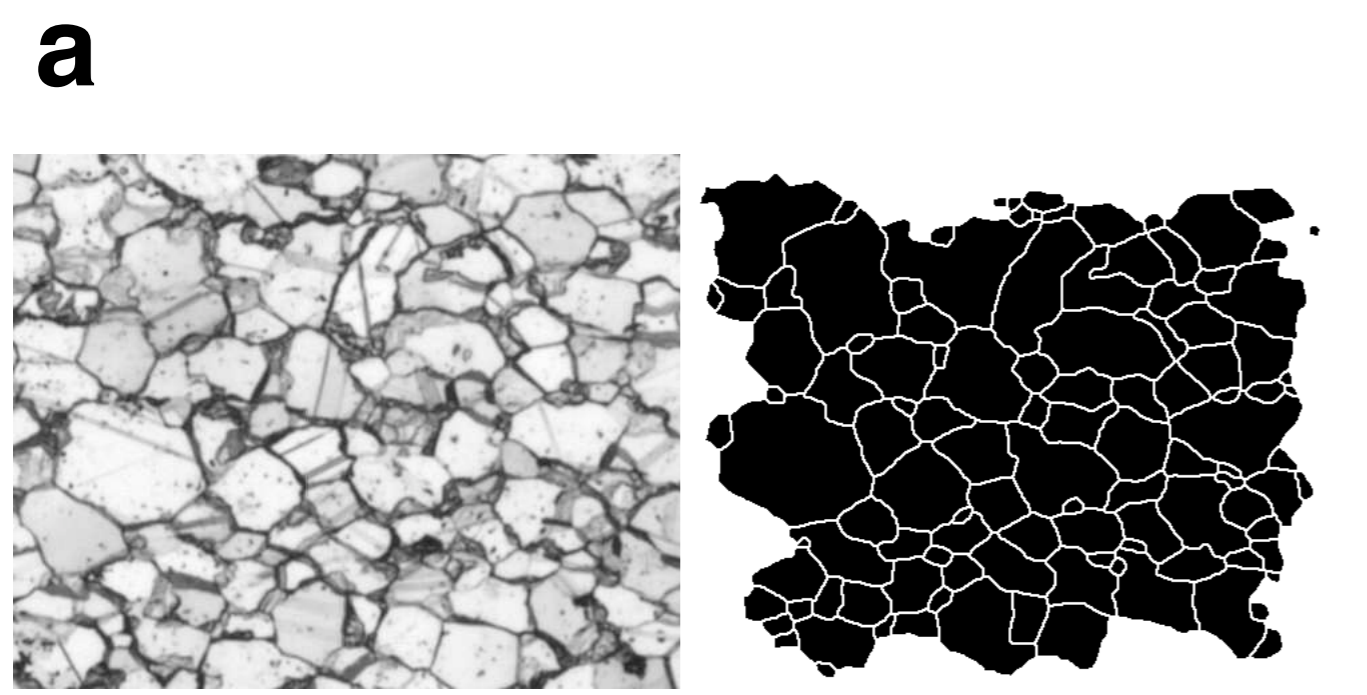


Figure 1.9

Image analysis using outlines.

- (a) Plot of x-y coordinates of outlines (original image and grain map shown above);
- (b) bulk shape fabric: projection function indicating bulk anisotropy ($b/a = 0.83$ and bulk preferred orientation ($= 10^\circ$);
- (c) particle fabric: orientation distribution function (ODF) of longest projection of grains;
- (d) surface fabric: ODF of grain boundary outlines.

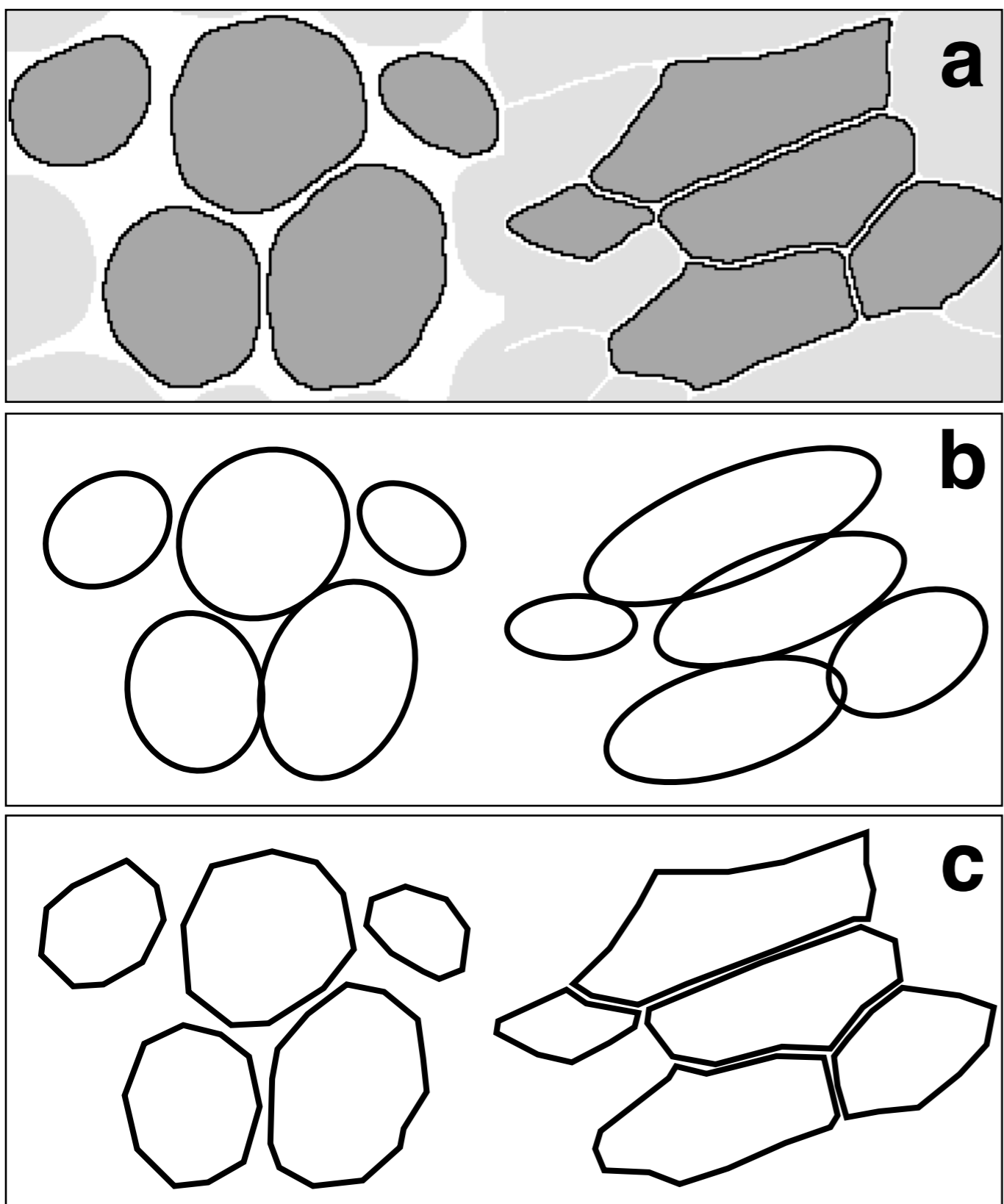


Figure 1.10

Segmentation.

(a) Segmented bitmaps of particles in matrix (left) and crystalline aggregates (right); five segments and segment boundaries are highlighted;

(b) approximation by best-fit ellipses;

(c) digitized outlines: approximation by polygonal chains.

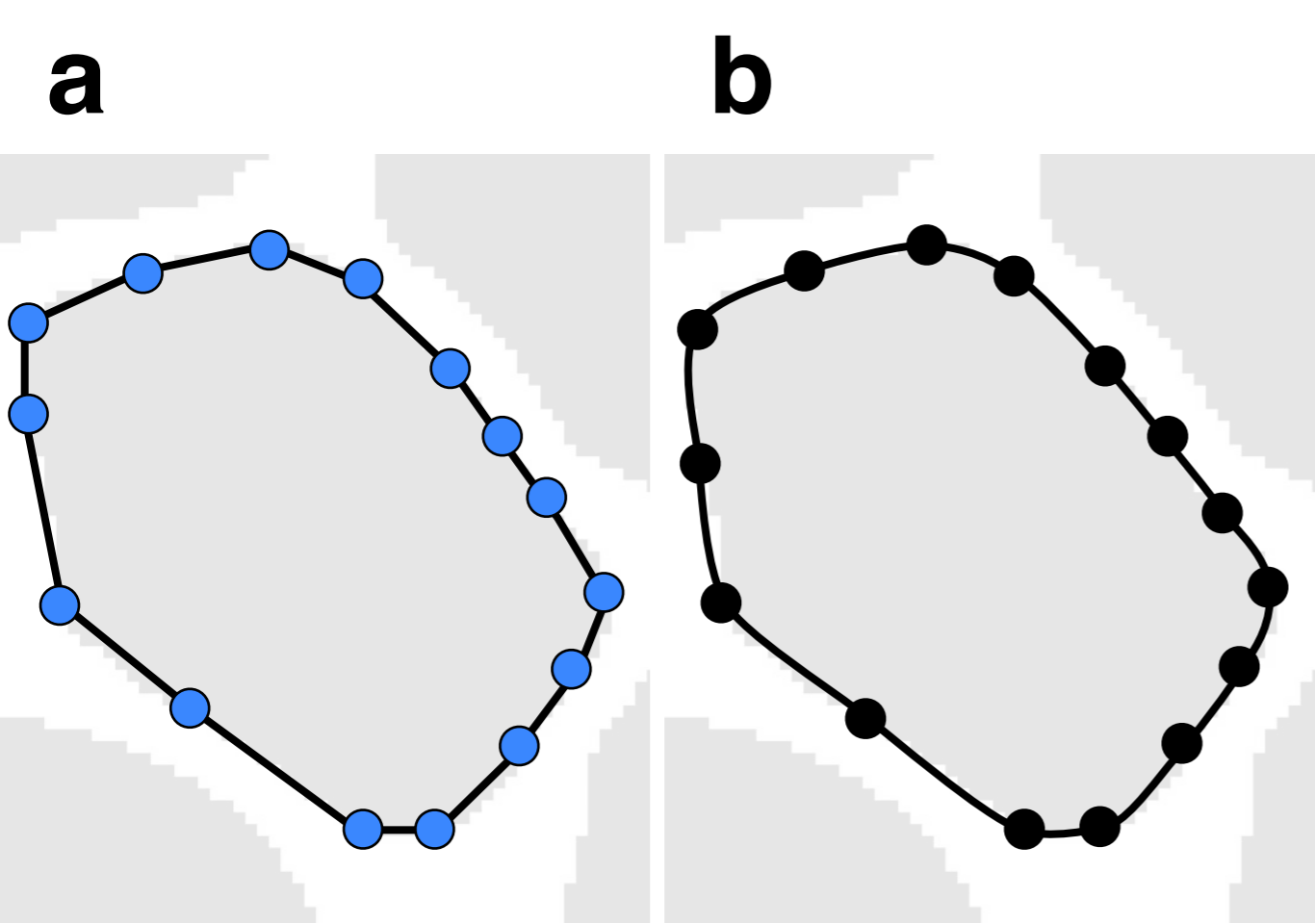


Figure 1.1

(a) Digitized outline connecting pixels (blue) along a segment boundary; note that the X-Y coordinates of the outline assume the same discrete (integer) values as the boundary pixels;
(b) the same segment after smoothing restoration: the x-y values of the vertices (black) now assume continuous values.

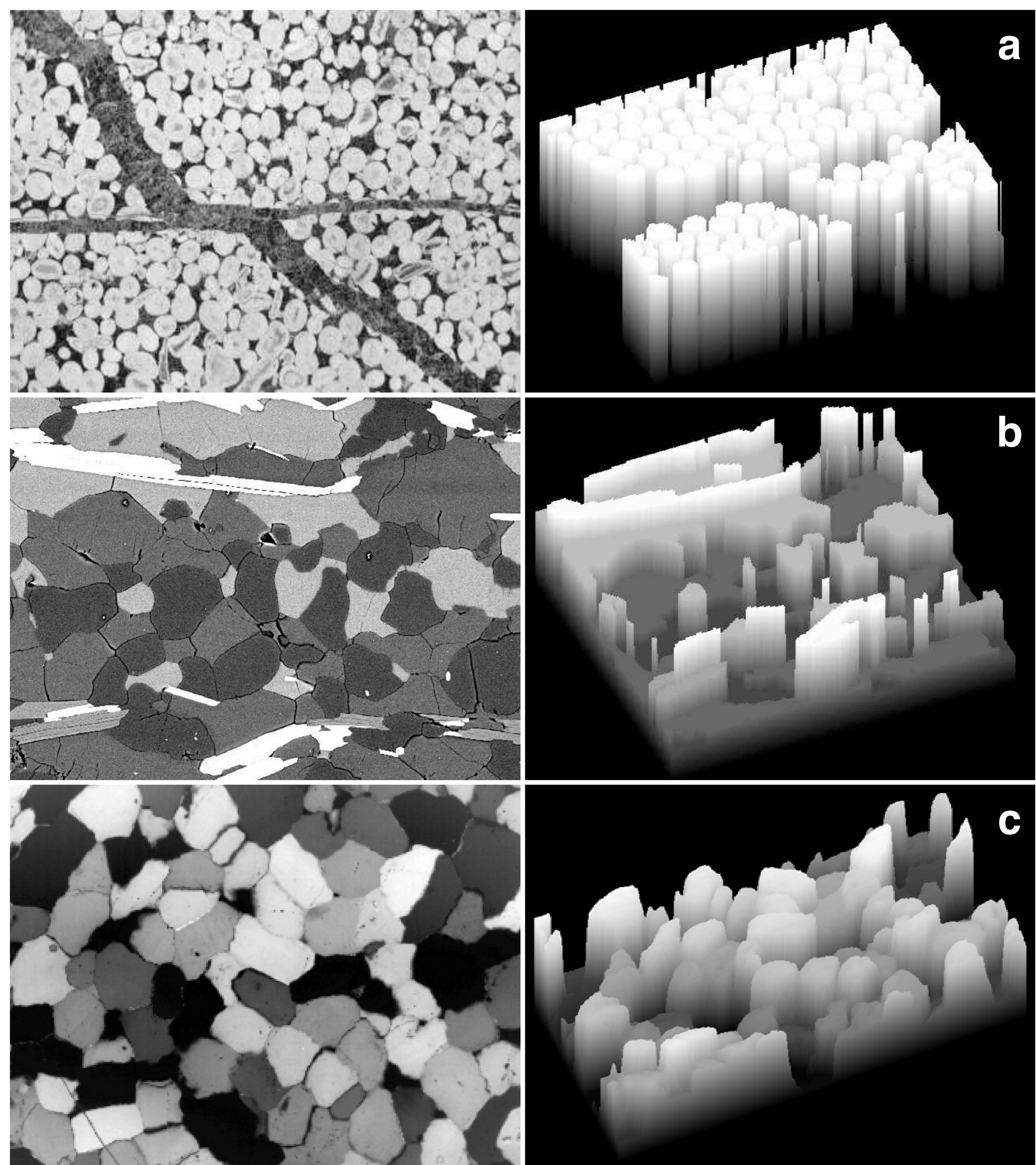


Figure 1.12

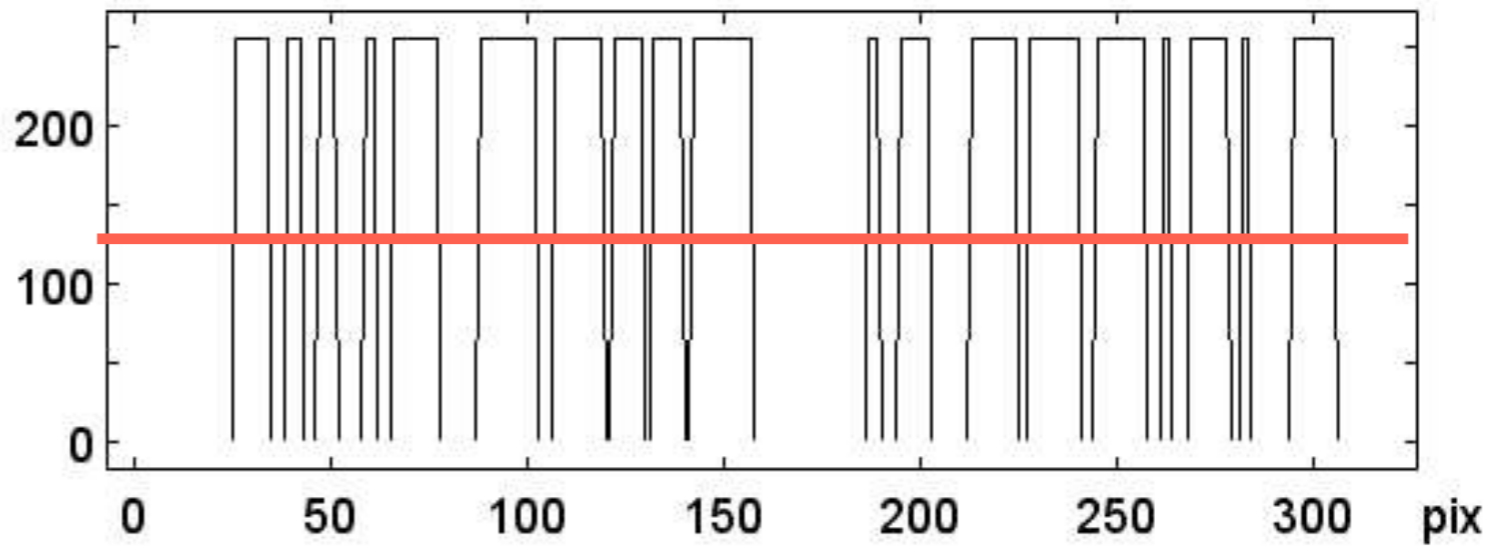
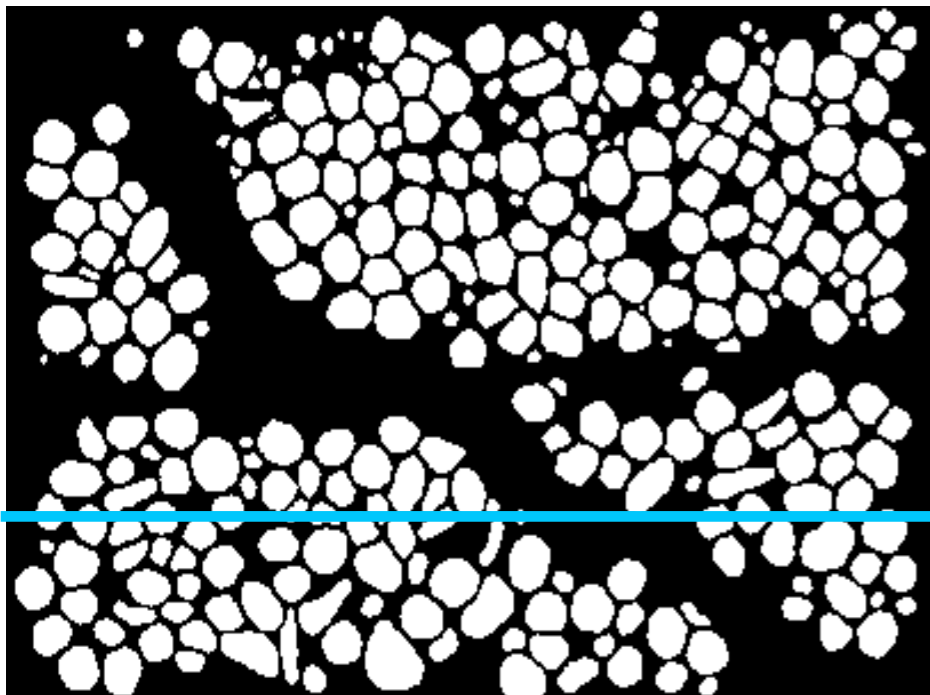
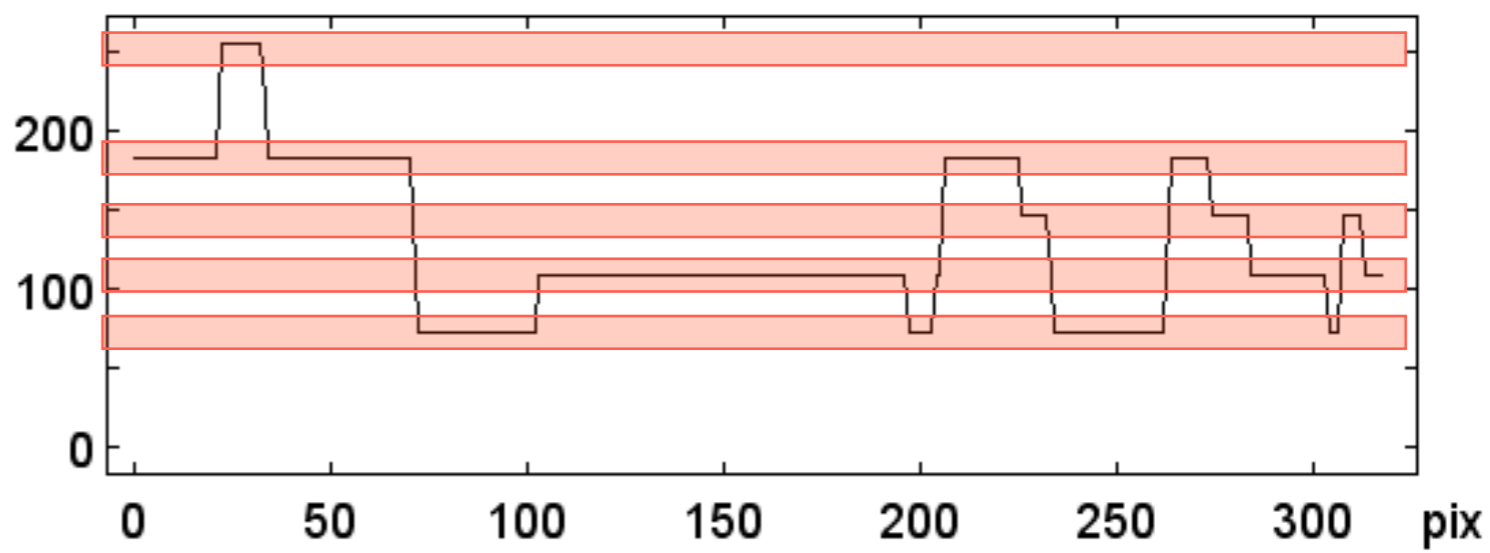
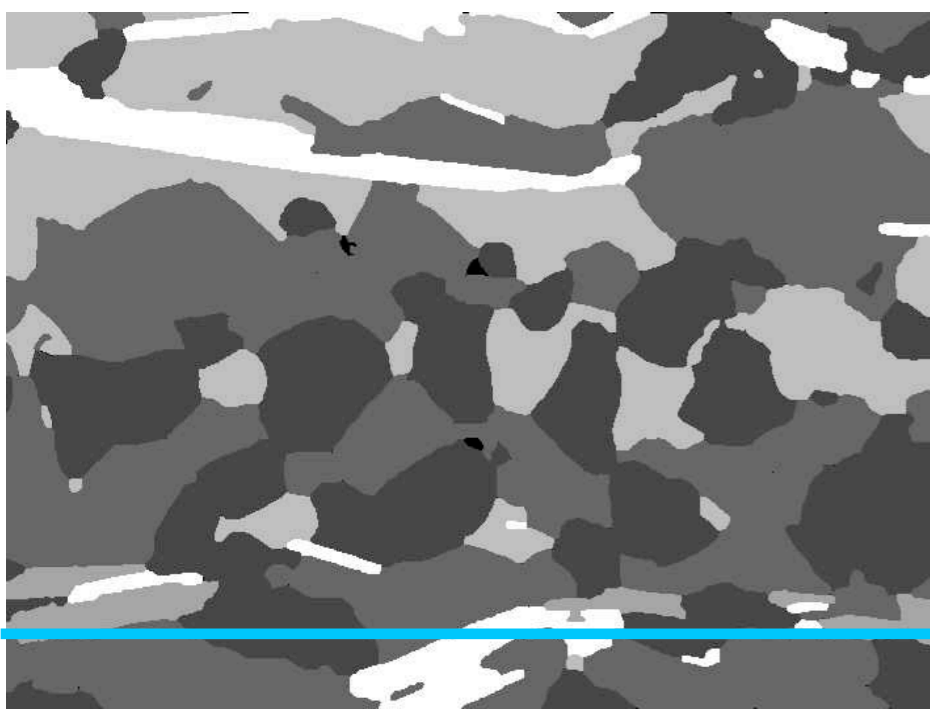
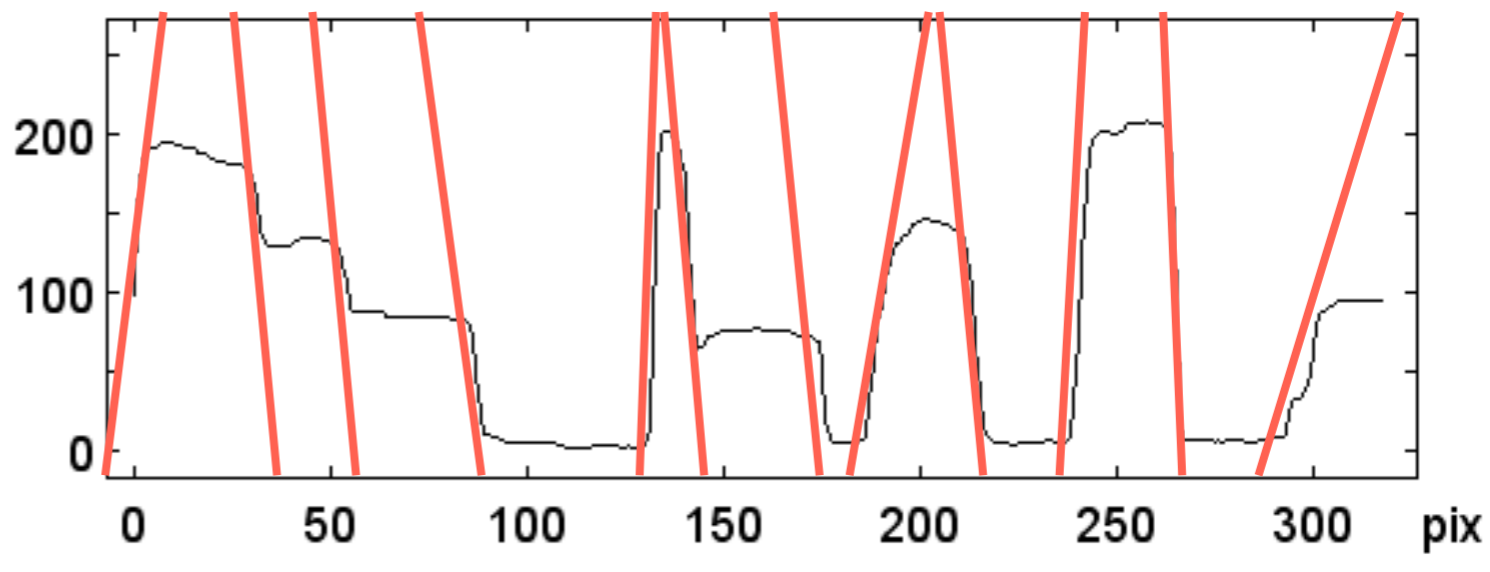
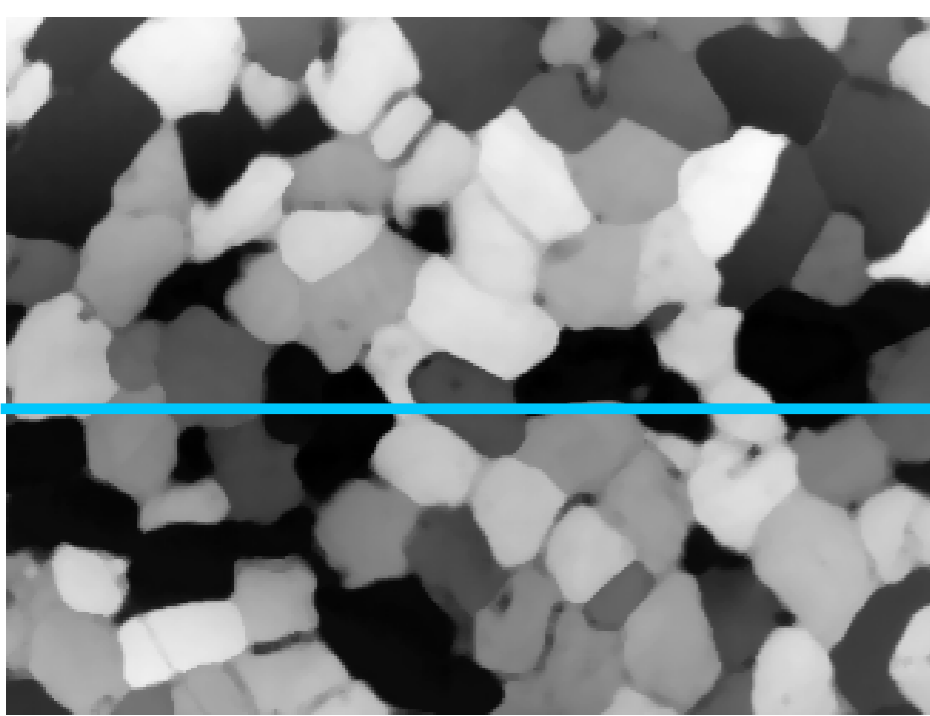
Image models.

Three original images (left) with 3-D topography of the corresponding image models (right).

(a) The image is essentially a bitmap: it shows two phases with two distinct gray levels: particles are white, the matrix is black;

(b) the image shows 5 discrete phases at five distinct gray levels;

(c) the image shows grains of one phase (quartz) at many gray levels (corresponding to different states of optical extinction).

a**b****c****Figure I.13**

Segmentation based on image model.

Brightness representations of image models shown in Figure I.12 (left) with profiles along blue traverses (right). The criteria for segmentation are superposed in red:

- (a) thresholding: define a segment by a threshold gray value;
- (b) gray level slicing: define a segment by a range of gray values, here five segments are created;
- (c) edge detection: define a segment boundary by a steep gray value gradient.

Thresholding and gray level slicing are point operations (POP), edge detection is a neighborhood operation (NOP).