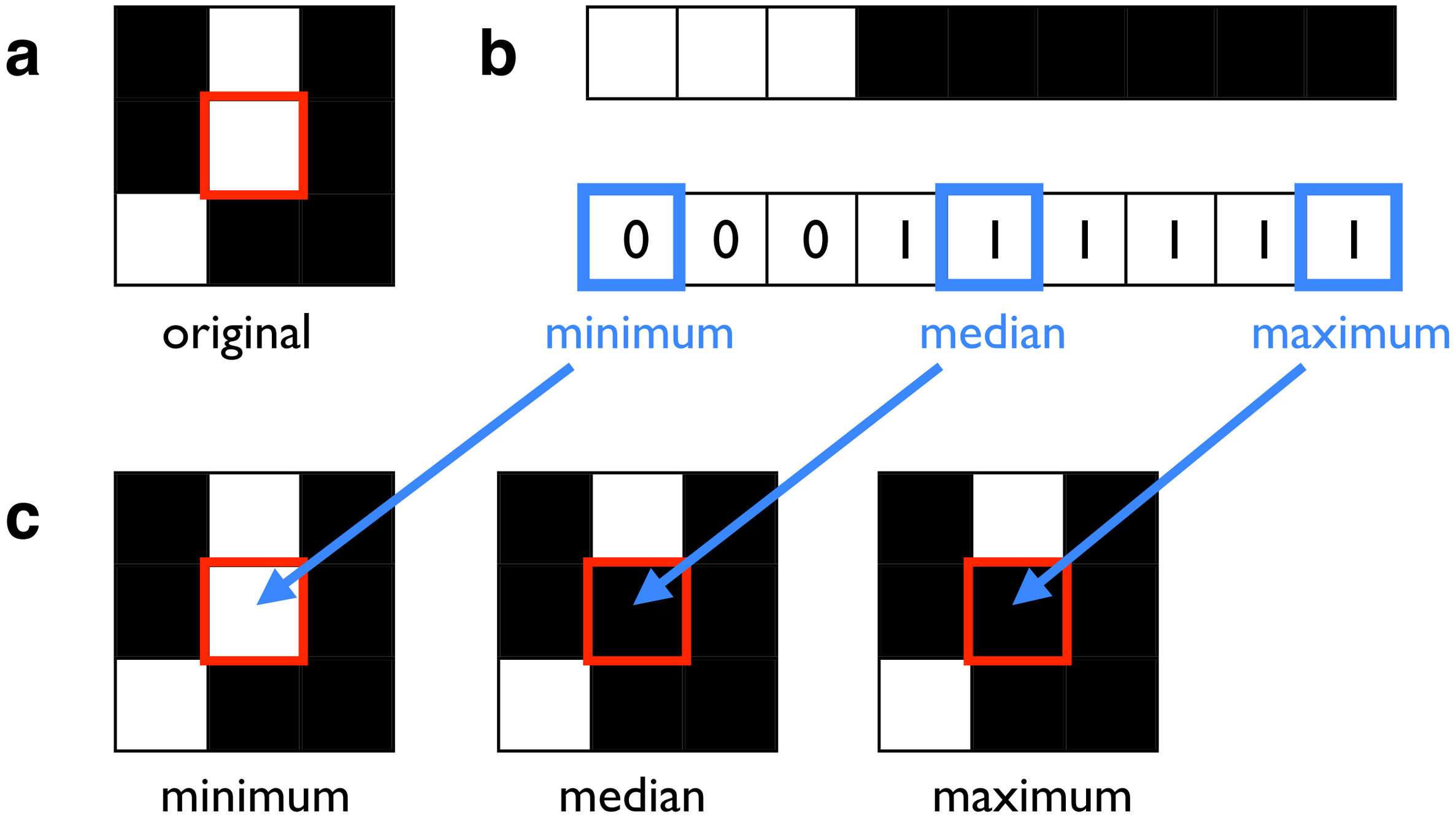



**Figure 6.1**
Ranking filters.
(a) 3 · 3 neighborhood, central pixel highlighted in red;
(b) ranked gray values of 3 · 3 neighborhood; minimum, median and maximum values are highlighted;
(c) central pixel is replaced by minimum, median or maximum value.

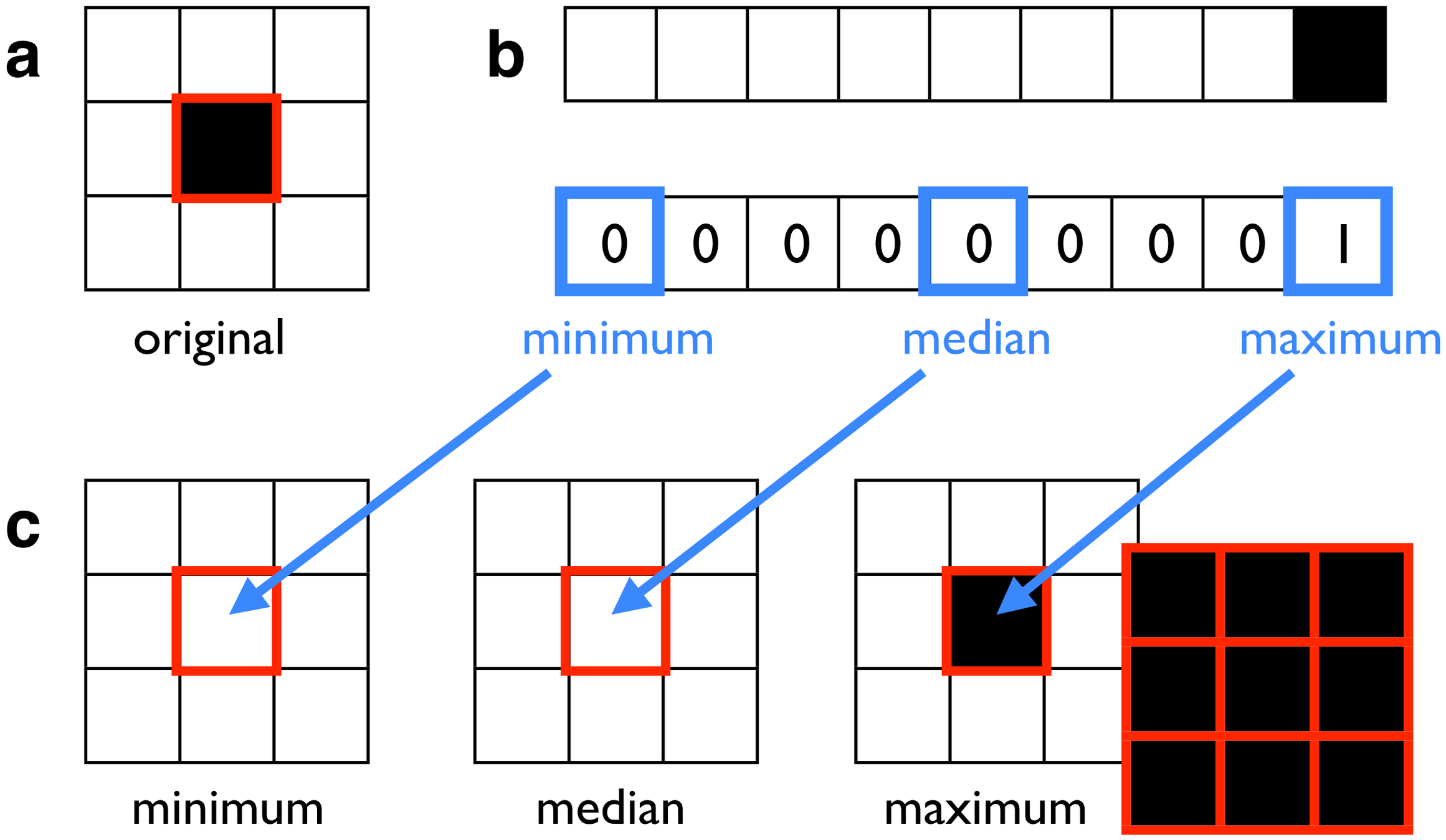



**Figure 6.2**
Effect of ranking filters on single black pixel in white neighborhood.
(a) 3 · 3 neighborhood, central pixel highlighted in red;
(b) ranked gray values of 3 · 3 neighborhood; minimum, median and maximum values are highlighted;
(c) central pixel is replaced by minimum, median or maximum value;
(d) effect of maximum filtering on all pixels of 3 · 3 neighborhood is shown separately.

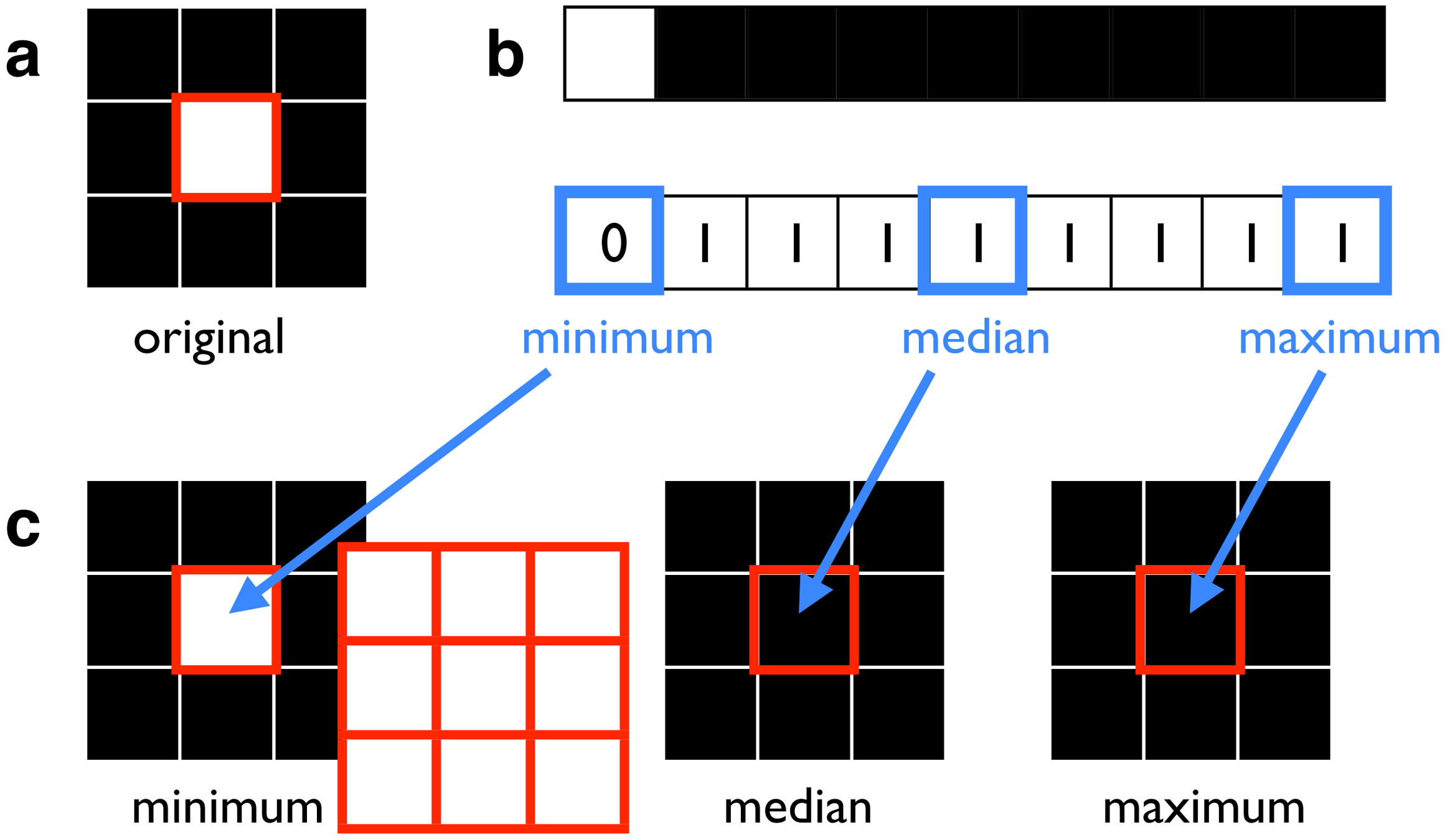



**Figure 6.3**
Effect of ranking filters on single white pixel in black neighborhood.
(a) 3 · 3 neighborhood, central pixel highlighted in red;
(b) ranked gray values of 3 · 3 neighborhood; minimum, median and maximum values are highlighted;
(c) central pixel is replaced by minimum, median or maximum value;
(d) effect of minimum filtering on all pixels of 3 · 3 neighborhood is shown separately.

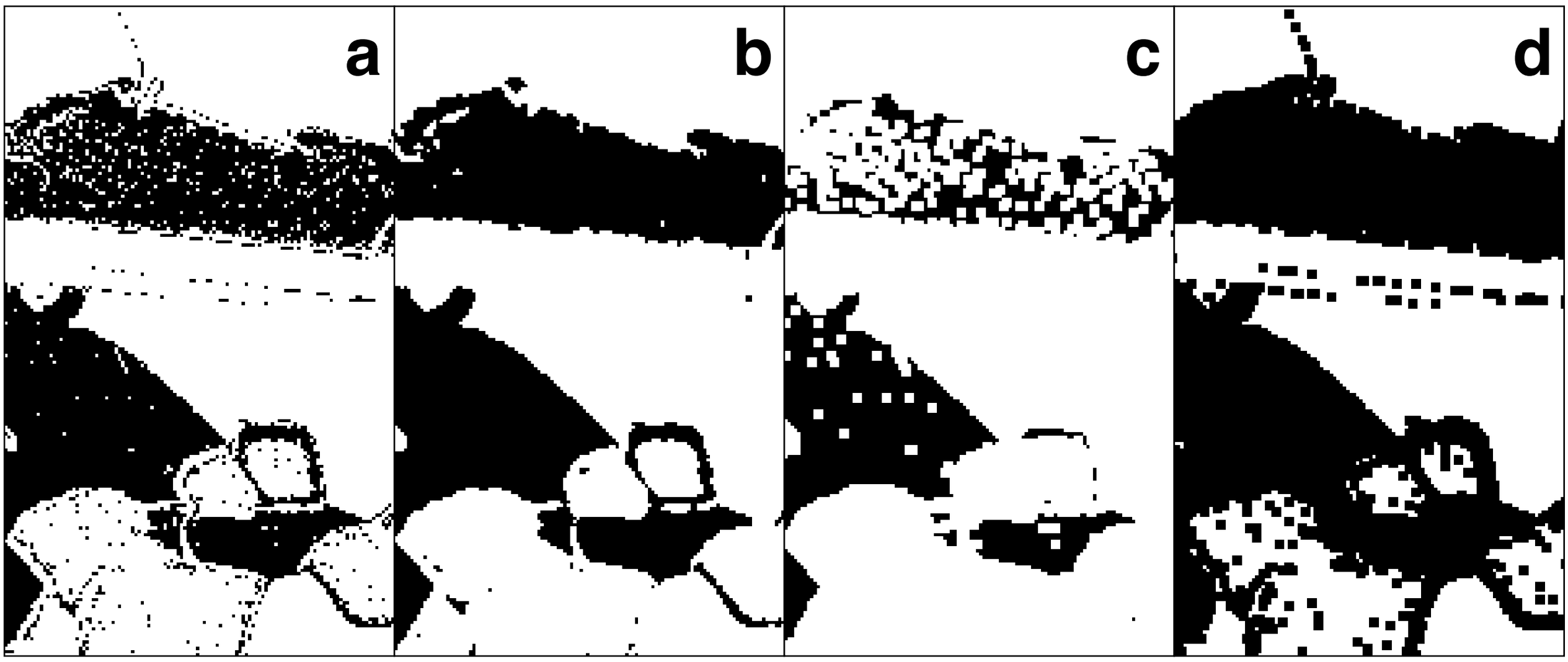



**Figure 6.4**
Effect of ranking filters on image detail.
(a) Original bitmap;
(b) selecting median value of 3 · 3 neighborhood;
(c) selecting minimum value of 3 · 3 neighborhood;
(d) selecting maximum value of 3 · 3 neighborhood.

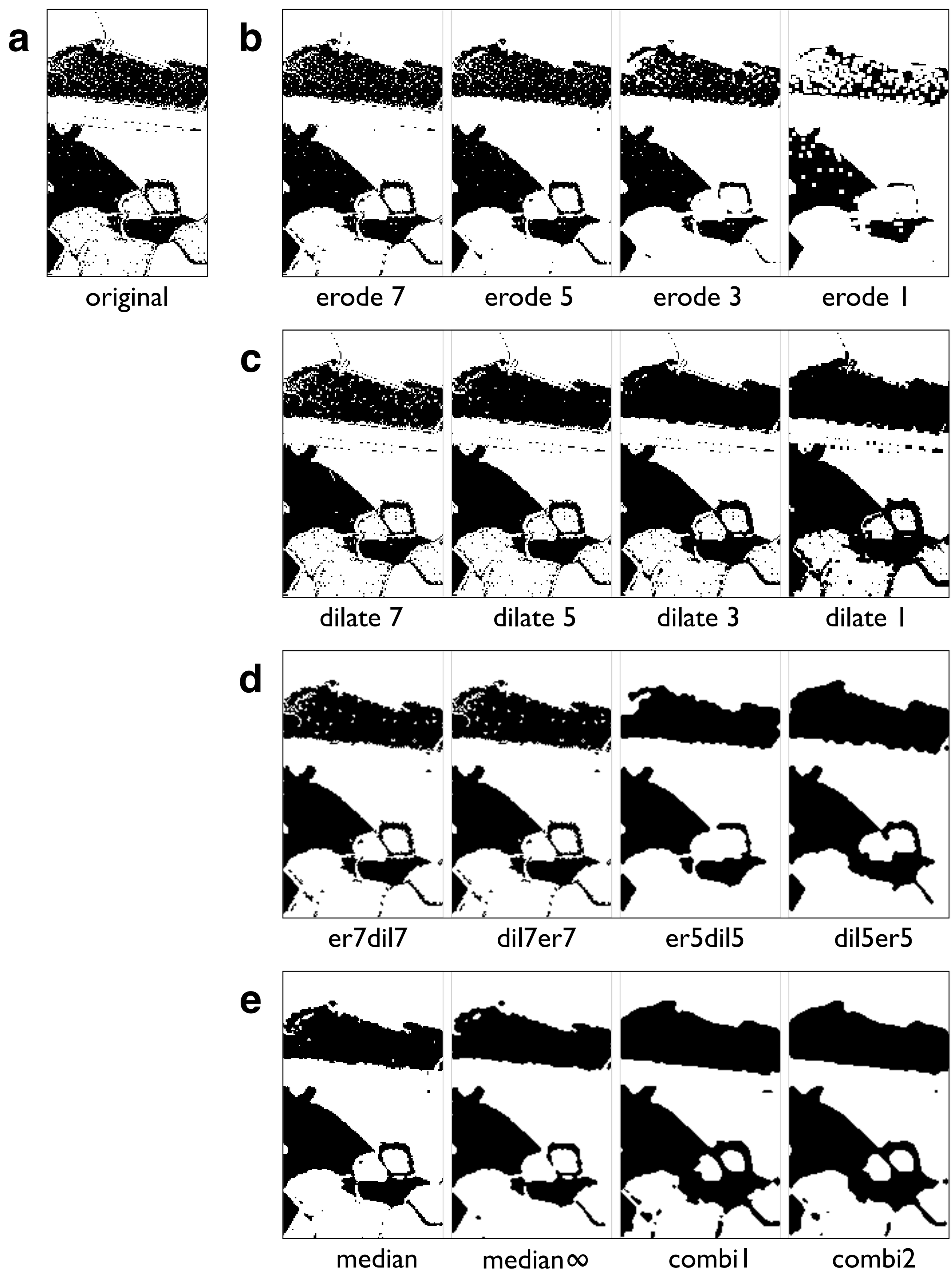



**Figure 6.5**
Fine tuning of the ranking filters. (a) Original bitmap; (b) erosion, using a neighborhood count of 7, 5, 3 and 1; (c) dilation, using a neighborhood count of 7, 5, 3 and 1; (d) sequences of erosions and dilations until no further changes occur: er7dil7, er5dil5 = erosion first, dilation second; dil7er7, dil5er5 = dilation first, erosion second;
(e) improving on the median: median∞ = repeated median until no further changes occur, combi1 = combination of dilations and erosions; combi2 = same as combi1 with 2 erosions at the end.

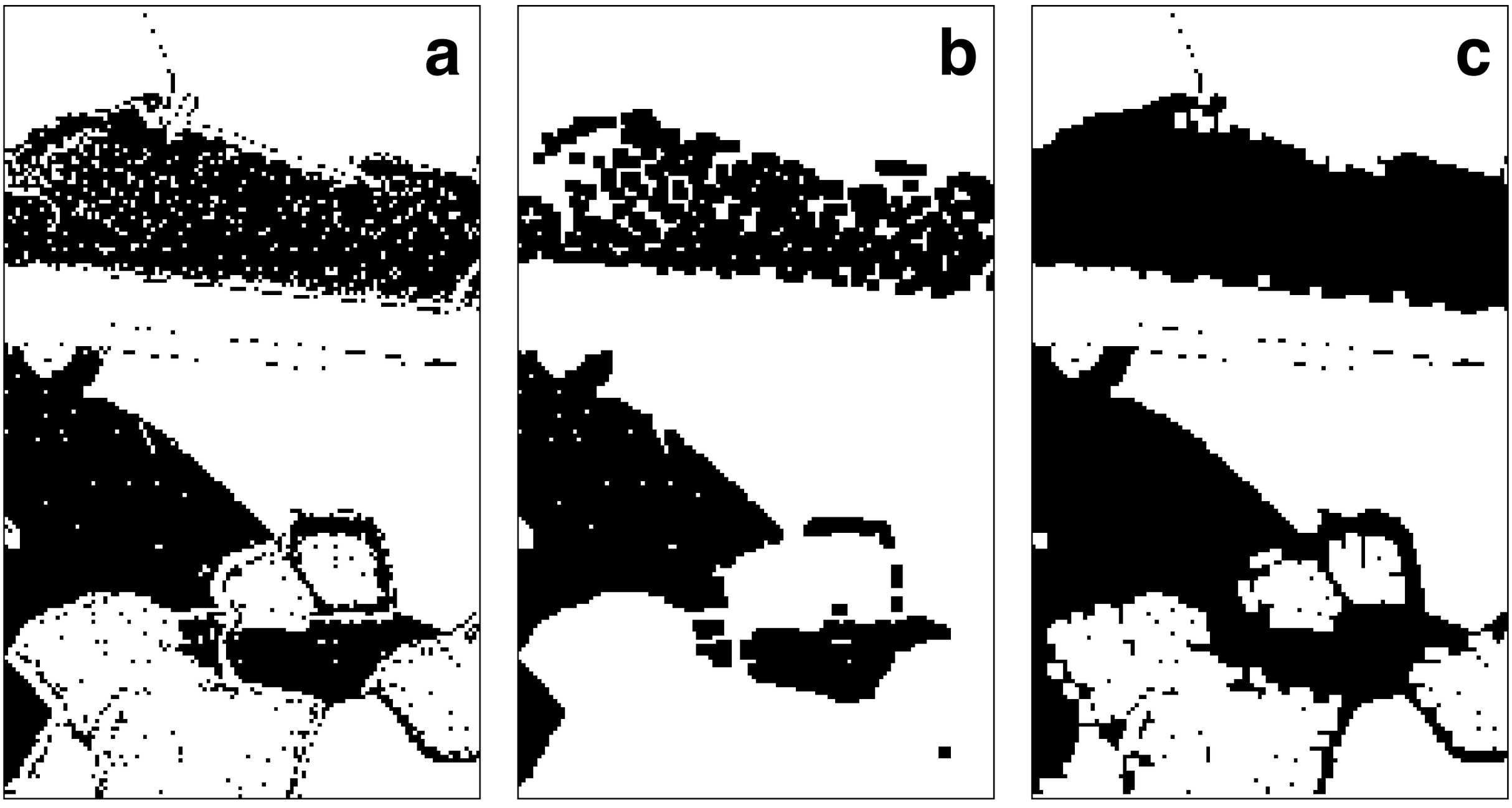



**Figure 6.6**
Morphological operations.
(a) Original bitmap;
(b) opening: erosion followed by dilation, using neighborhood count of 1;
(c) closing: dilation followed by erosion, using neighborhood count of 1.

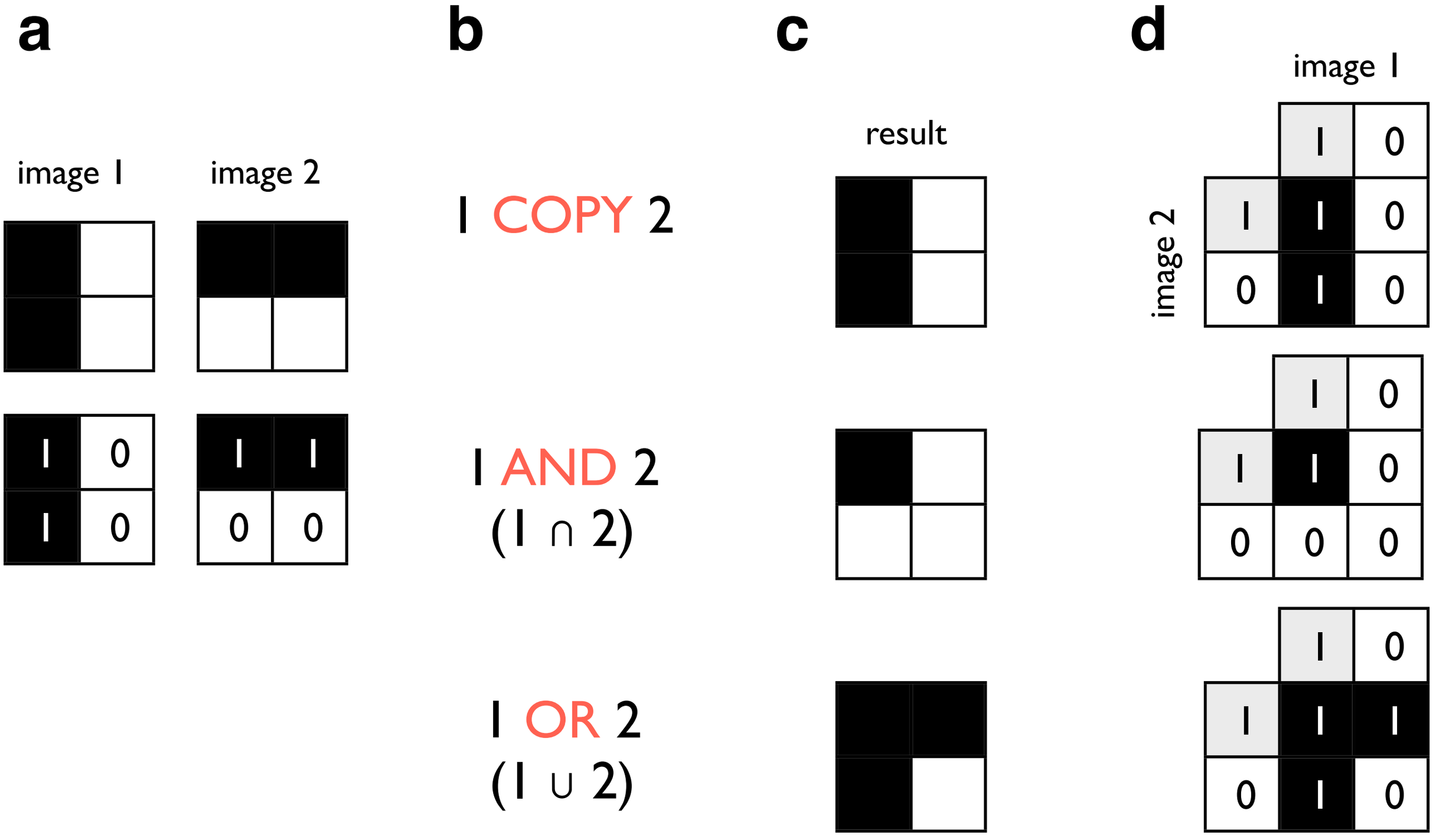



**Figure 6.7**
Logical operations on bitmaps.
(a) Two 2 · 2 bitmaps; image 1 and 2 (top) with number matrix (below);
(b) 4 logical operations, Boolean notation in brackets;
(c) resulting images;
(d) corresponding truth tables.

a

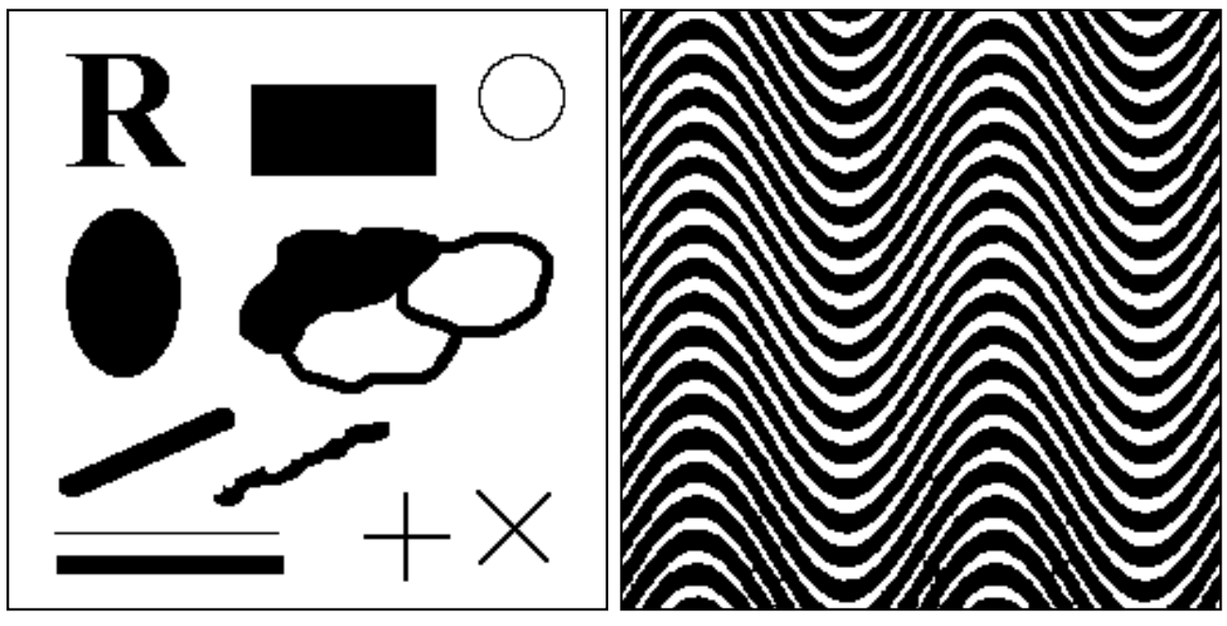
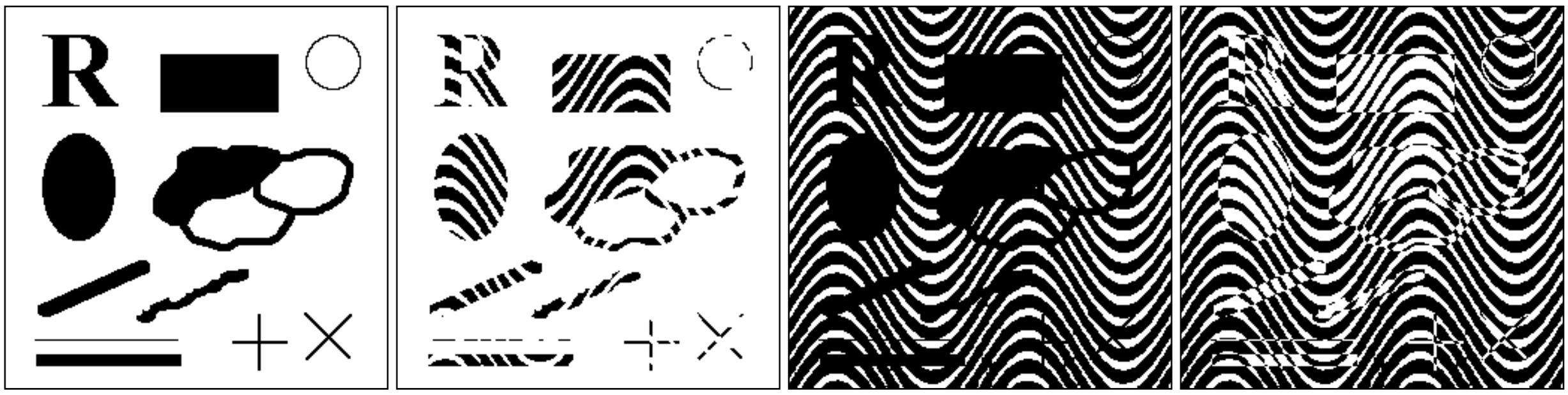


image 1 image 2

b



COPY AND OR XOR

**Figure 6.8**
Adding two images.
(a) Two different images (bitmaps);
(b) results of copying image 1 onto image 2, using four different copy modes.

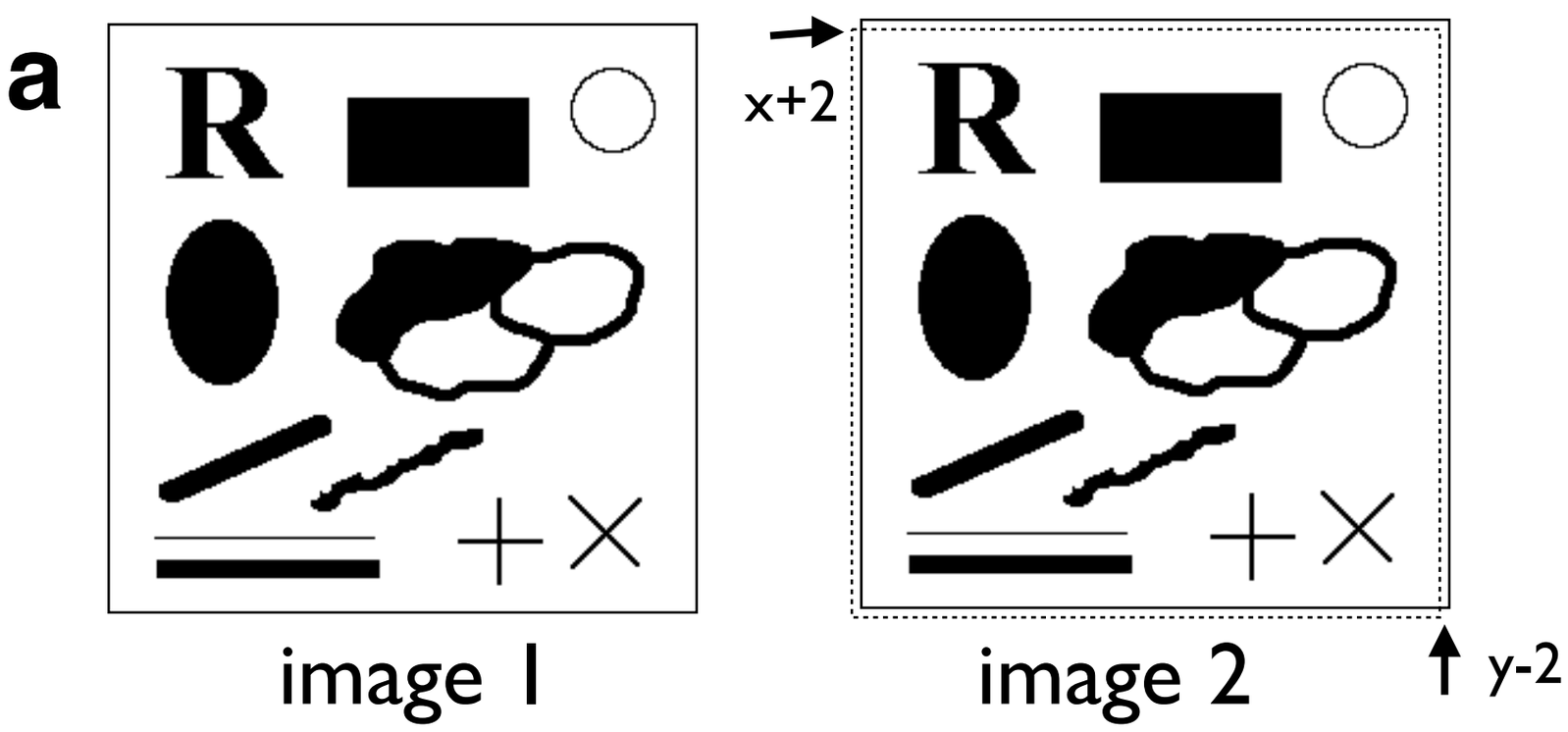



**Figure 6.9**
Adding an image to itself.
(a) Image and copy of image, shifted by 2 pixels in positive x- and negative y-direction (2 to the right, 2 upwards);
(b) results of copying image 1 onto the shifted copy, using four different copy modes.

a

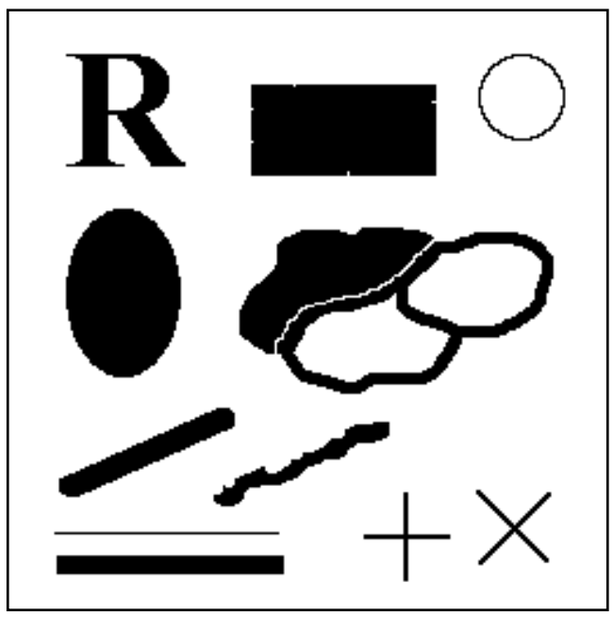
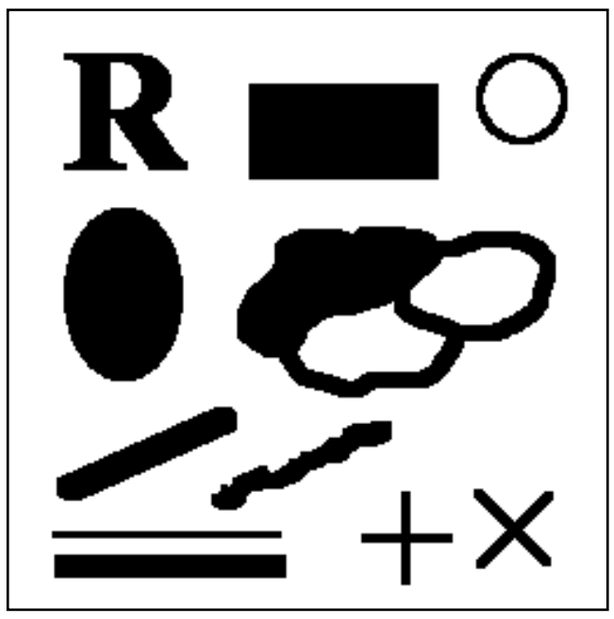
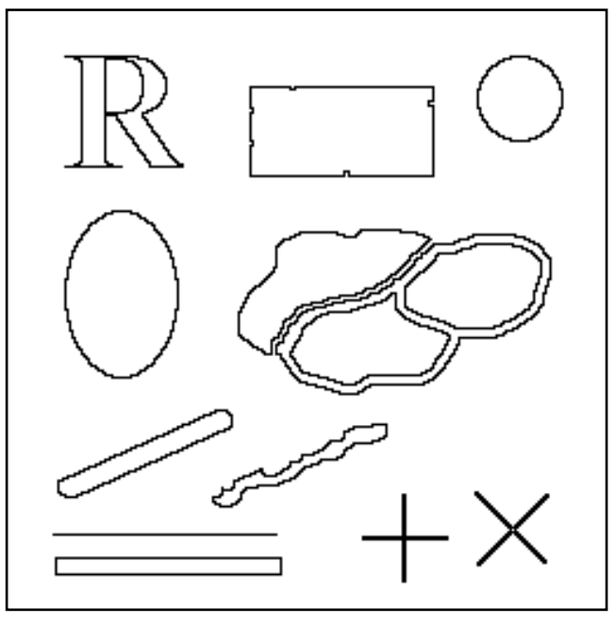


image I

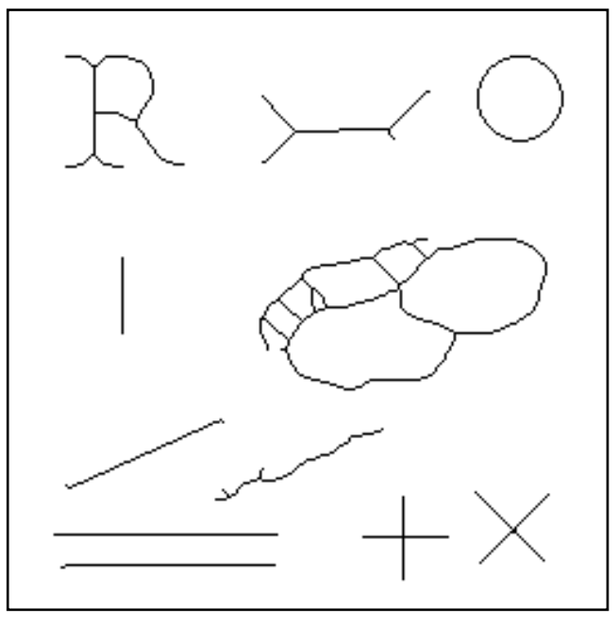
b



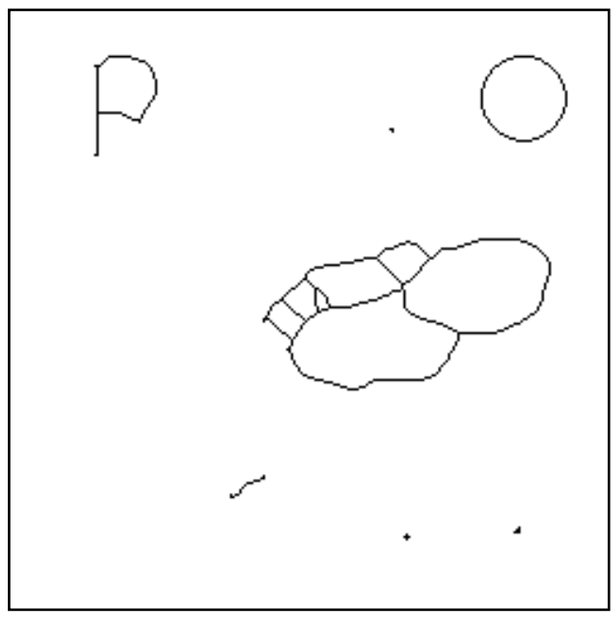
thicken



outline



skeletonize



prune

**Figure 6.10**
Structural filtering.
(a) Original image:
(b) filtered versions:
thicken: using OR copy mode;
outline: using 'Outline' command (Process > Binary menu);
skeletonize: using 'Skeletonize' command (same menu);
prune: using 'Prune Skeleton' command (same menu, option key pressed).

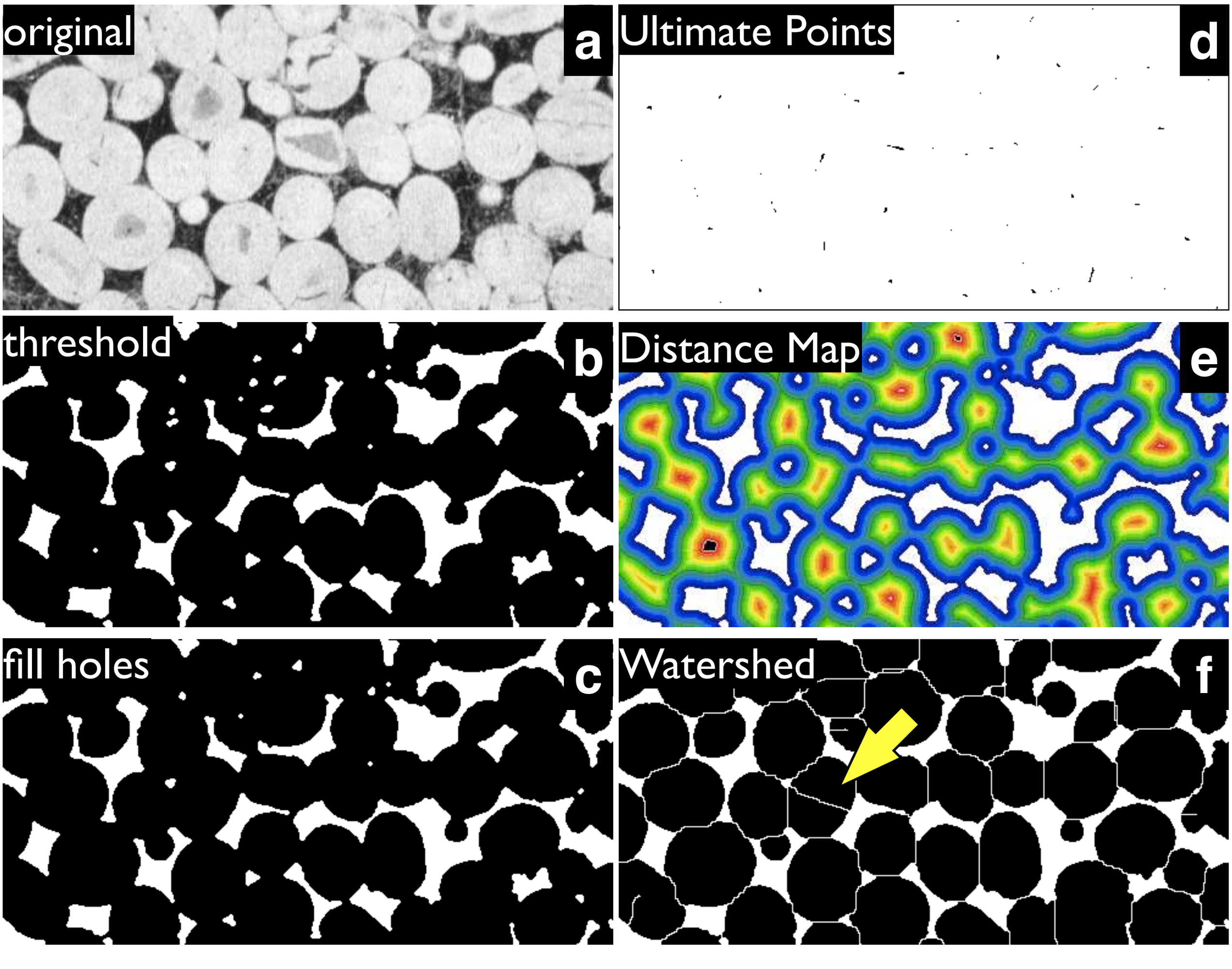



**Figure 6.11**
Special tools for segmentation.
(a) Acetate foil replica of oolithic limestone surface;
(b – c) interactive segmentation:
(b) threshold: median filtered original is thresholded;
(c) fill holes: using the bucket tool, holes are filled manually.
(d – f) separation of ooides, using Image SXM functions; note that some over-segmentation occurs (arrow).

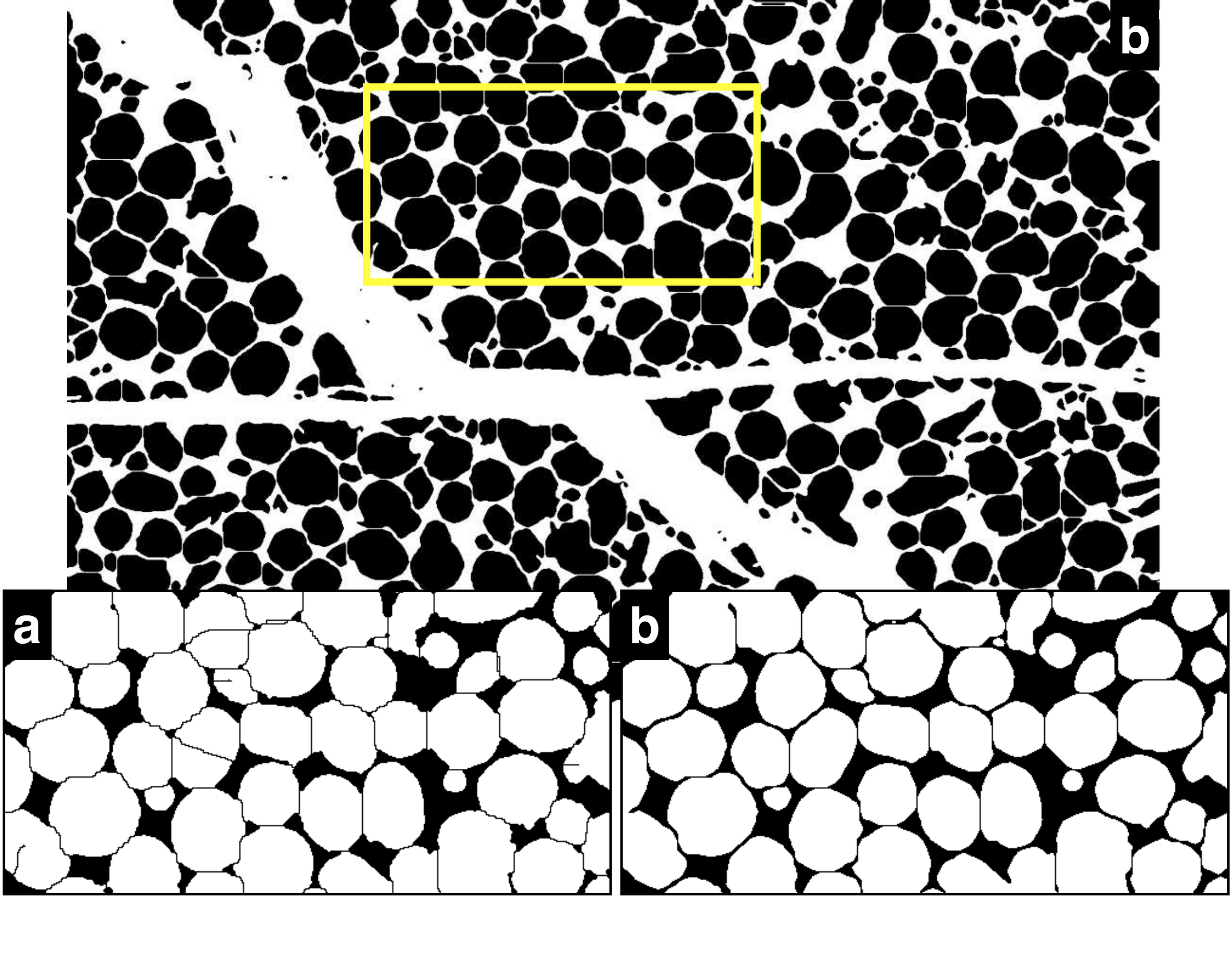
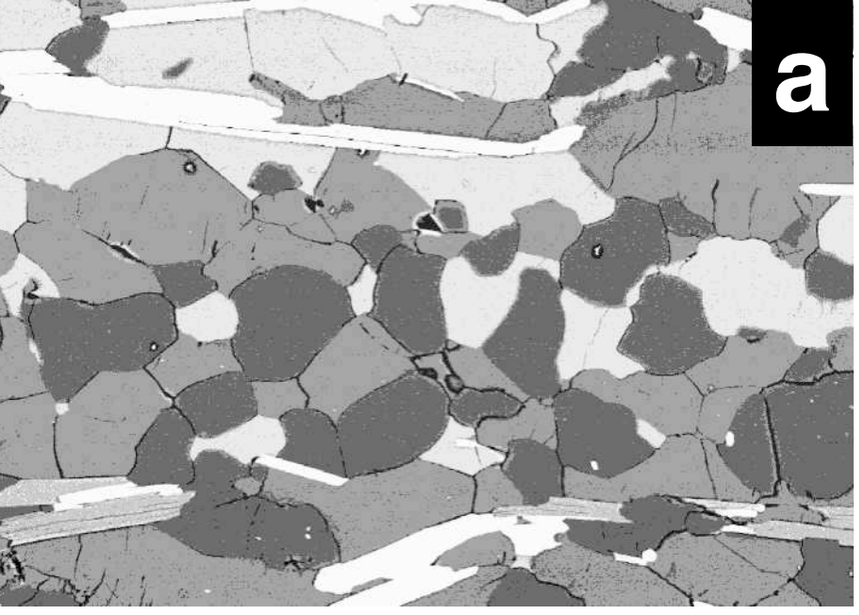



**Figure 6.12**
Post-processing.
(a) Inverted bitmap obtained by watershed algorithm (see Figure 6.11.f);
(b) clipping and pruning of erroneous boundaries, dilation with neighborhood count = 4;
(c) back-inverted result, frame denotes details shown in (a) and (b).





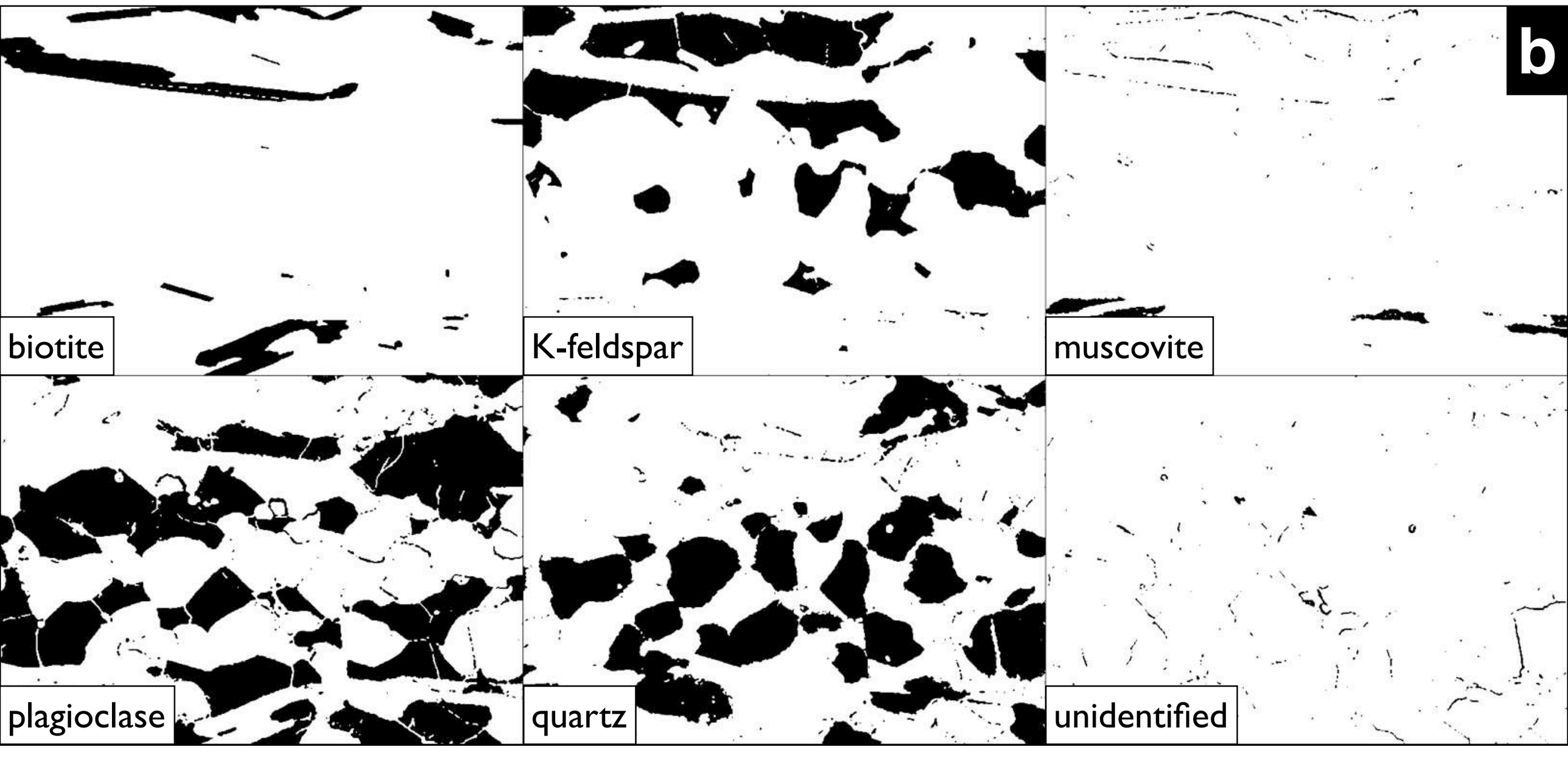



**Figure 6.13**
Median filtering of bitmaps.
(a) Segmented SEM micrograph of granitoid rock (Figure 5.12.a);
(b) the slices (Figure 5.12.b) are filtered twice using a Median filter;
(c) average of stack, note gap between phases compared to Figure 5.12.c.

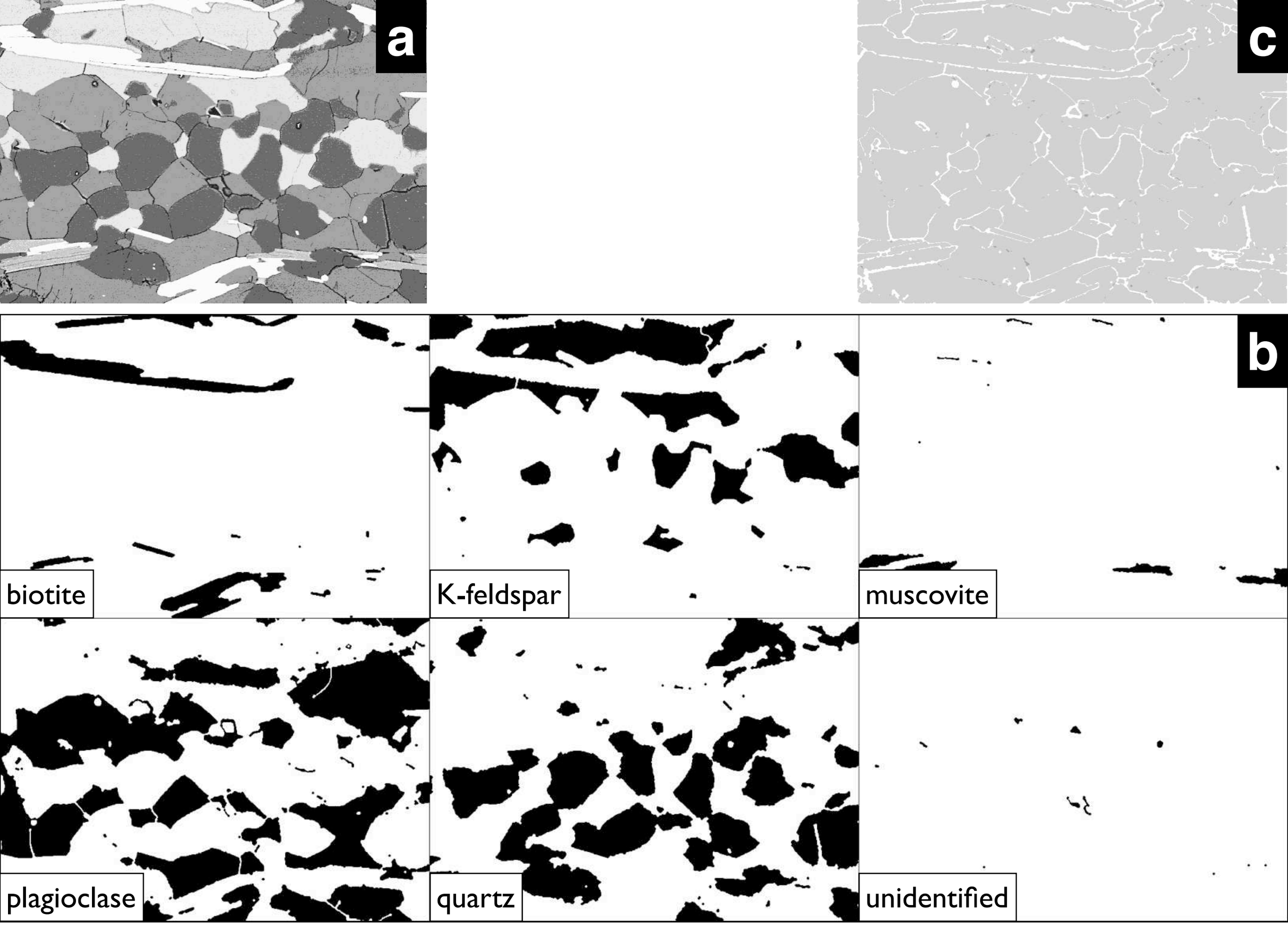



**Figure 6.14**
Erosion and dilation of bitmaps.
(a) Segmented SEM micrograph of granitoid rock (Figure 5.12.a);
(b) the slices (Figure 5.12.b) are eroded and dilated with options 8 (weakest), 7, 6, and 5 until no more changes occurred;
(c) average of stack, note gap between phases.

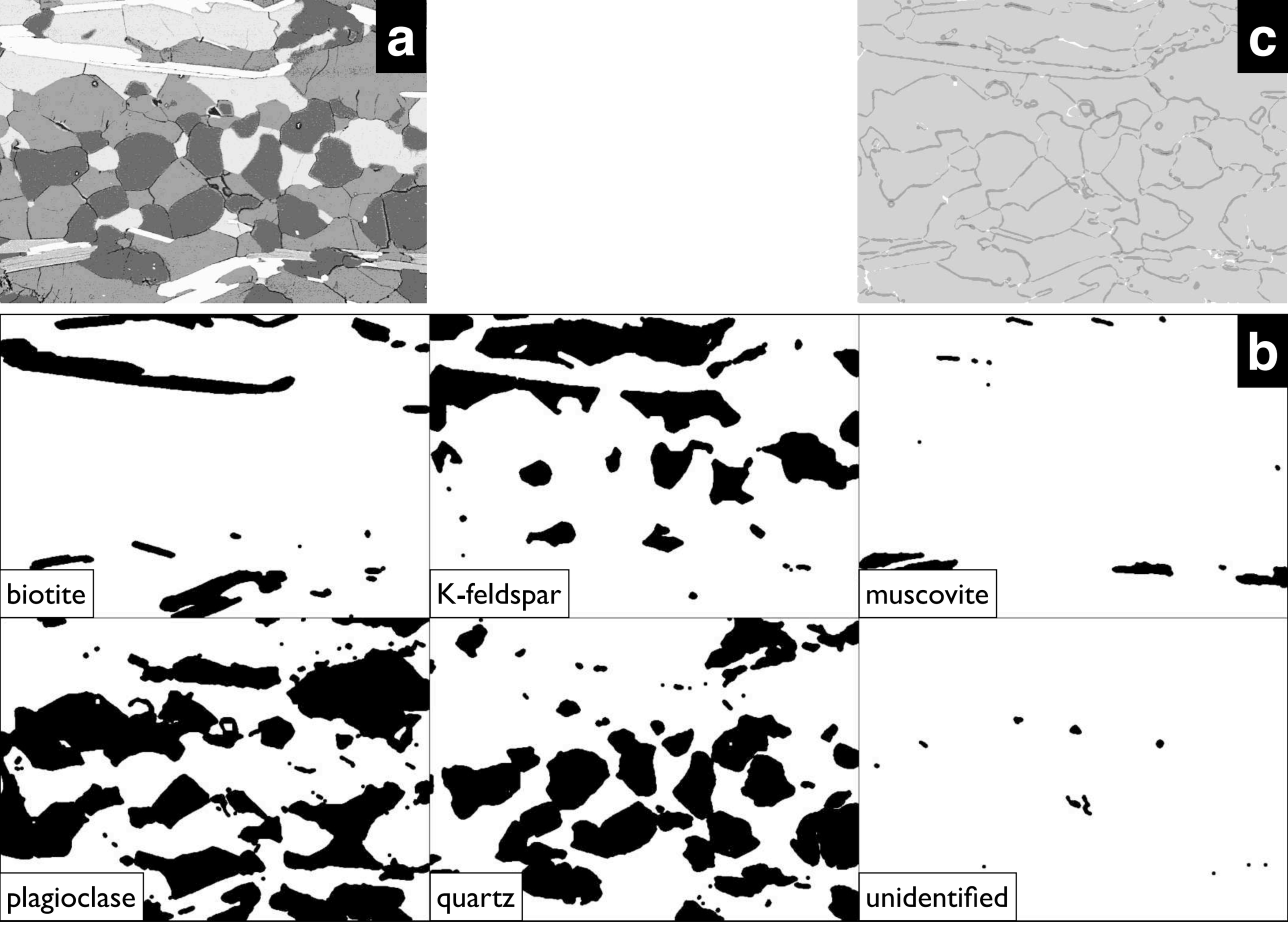



**Figure 6.15**
Dilation of phases.
(a) Segmented SEM micrograph of granitoid rock (Figure 5.12.a);
(b) the slices (Figure 5.12.b) are dilated three times using neighborhood option 3;
(c) average of stack, note overlap of phases.

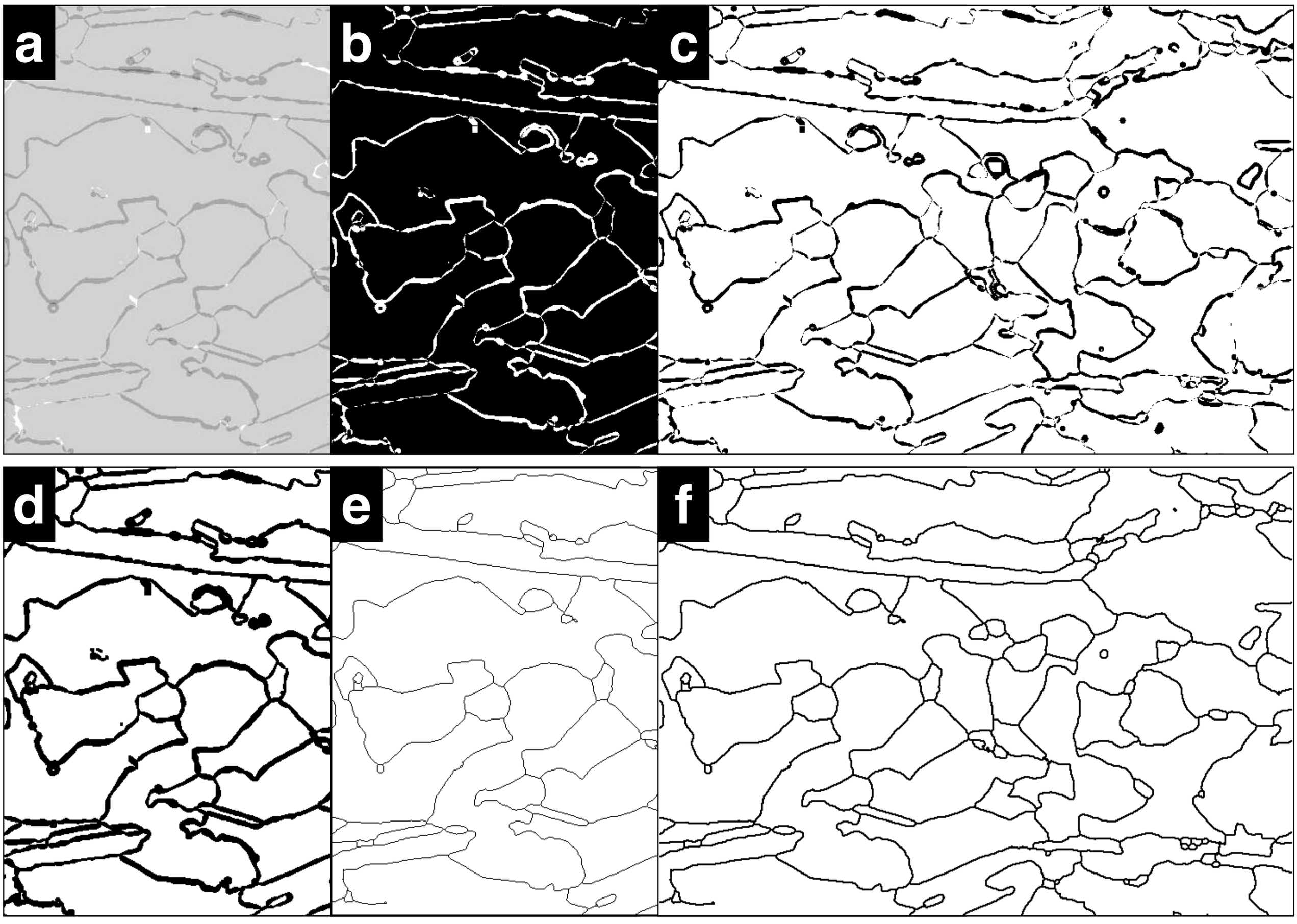
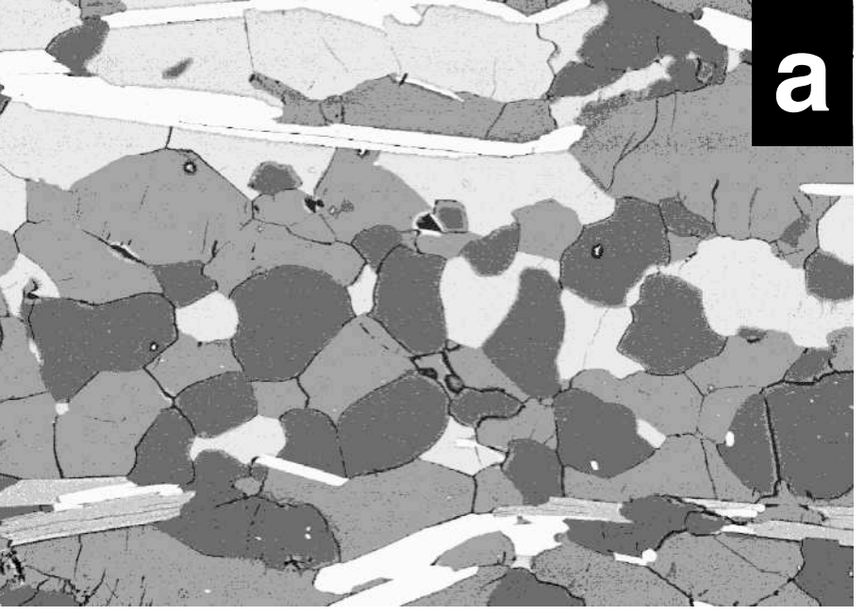
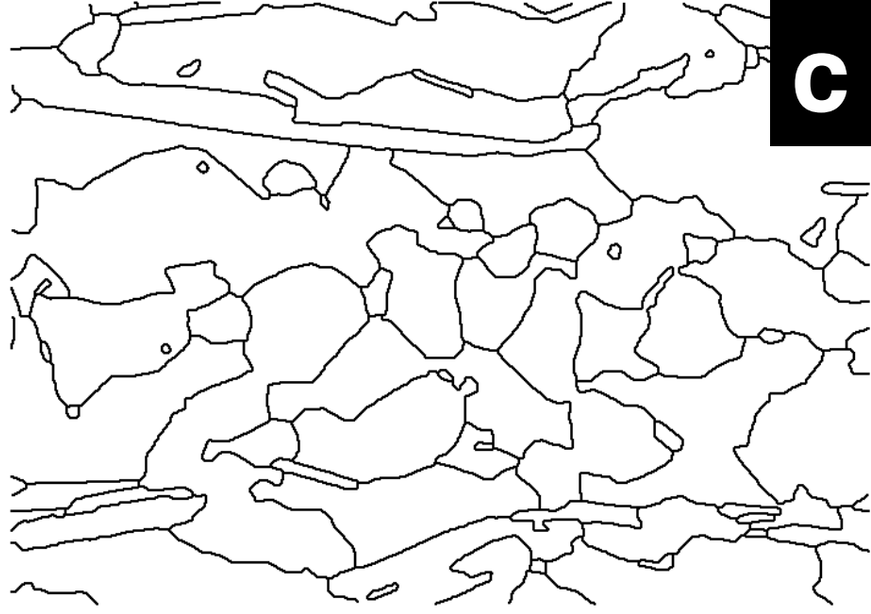



**Figure 6.16**
Derivation of phase boundaries.
(a) Average of stack with phase maps (see Figure 6.15);
(b) gray level slicing of (a);
(c) inverted (b);
(d) super-thickened version of (c);
(e) skeleton of (d), thick boundary of image added ('Select All', 'Draw Boundary'), pruning;
(f) same as (e), thick boundary subtracted again, thickened.



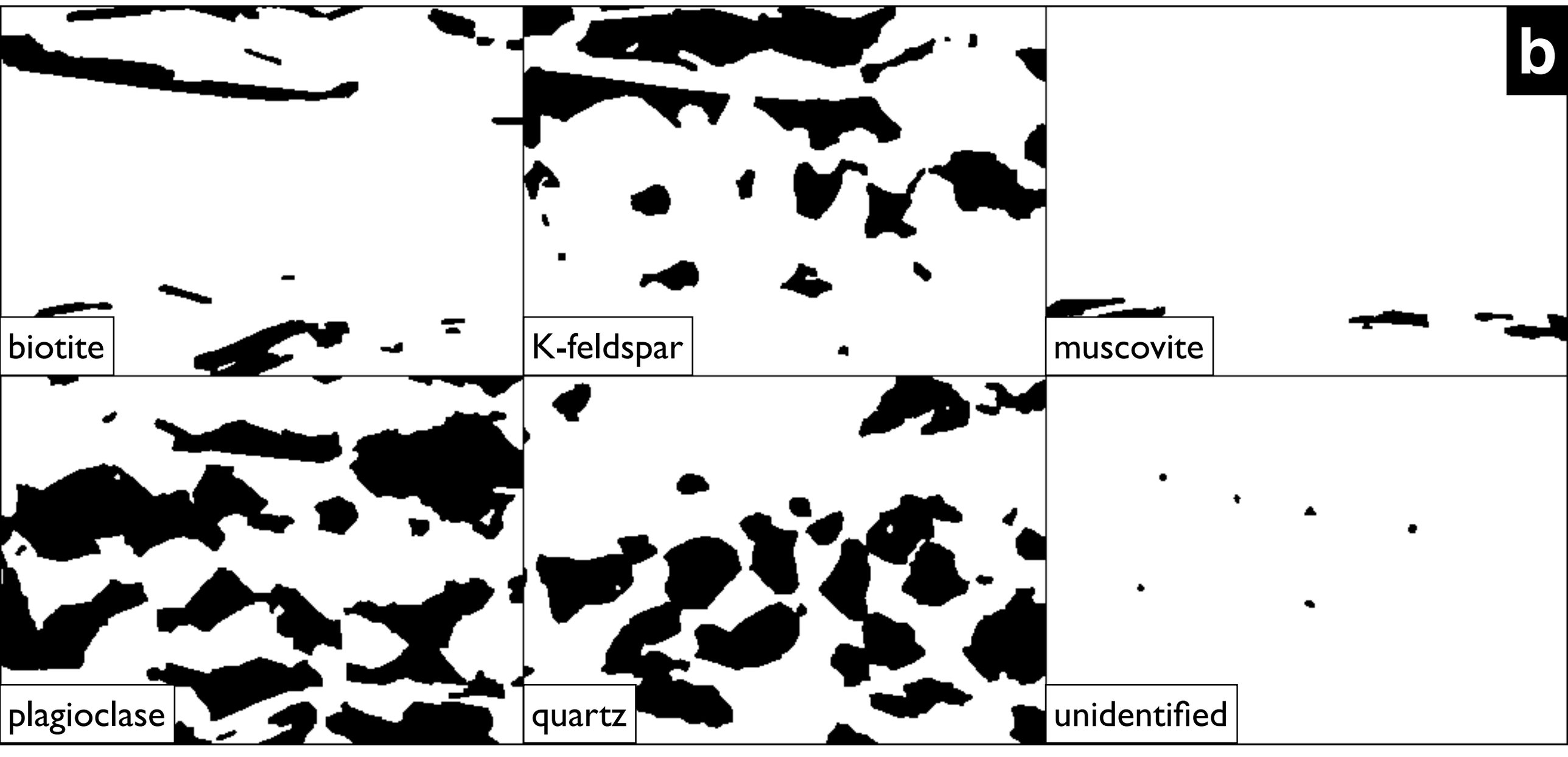




**Figure 6.17**
Final result of segmentation and post-processing.
(a) Segmented SEM micrograph of granitoid rock (Figure 5.12.a);
(b) mosaic of stack with six separated phase maps.
(c) phase boundary map.

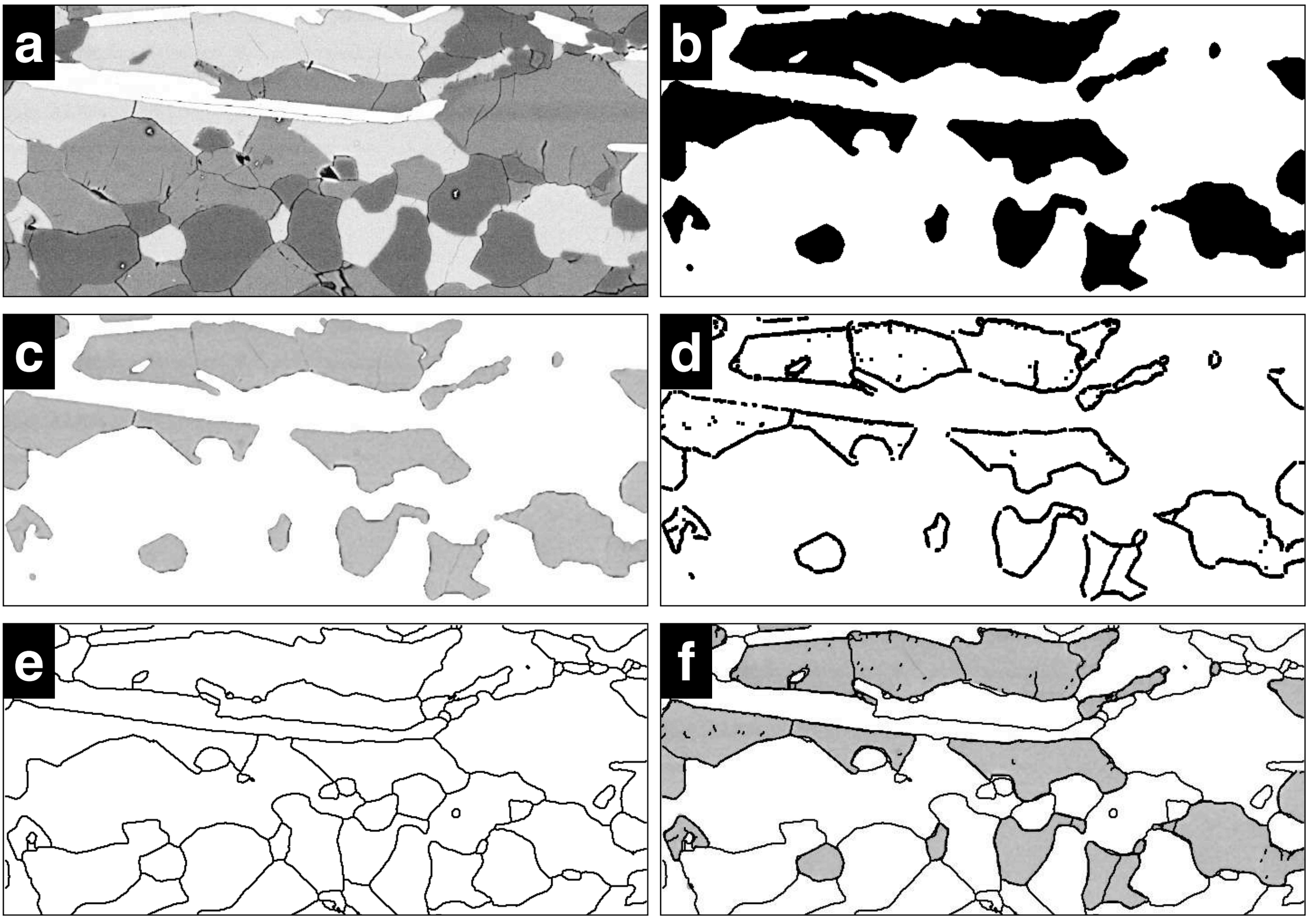



**Figure 6.18**
Derivation of grain boundaries.
(a) Detail of original SEM micrograph of granitoid rock;
(b) phase map of K-feldspar of same area as (a);
(c) copy of (b) onto (a) using AND-adding;
(d) thresholding of (c), super-thickening of the resulting bitmap;
(e) phase boundary map;
(f) copy of (d) onto (e) using the OR copy option; overlay (OR copy) with (c) is used to highlight the K-feldspar phase.

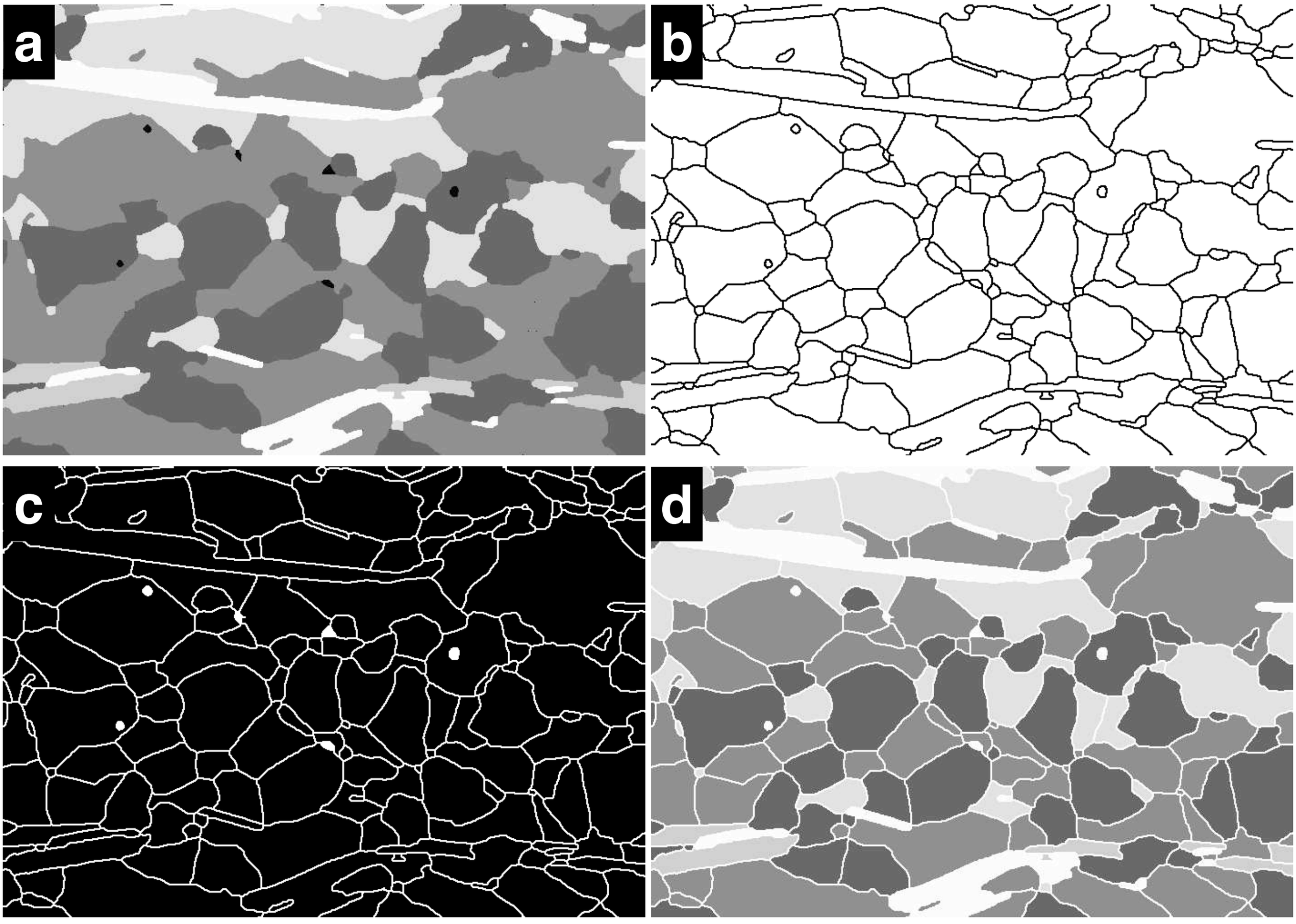



**Figure 6.19**
Complete segmentation.
(a) Phase map, showing each phase with a distinct gray level;
(b) grain boundary map;
(c) grain map = inverted grain boundary map, unidentified phase (= black in (a)) is subtracted;
(d) copy of (c) onto (a) using AND-adding yields the separated grains of different phases.

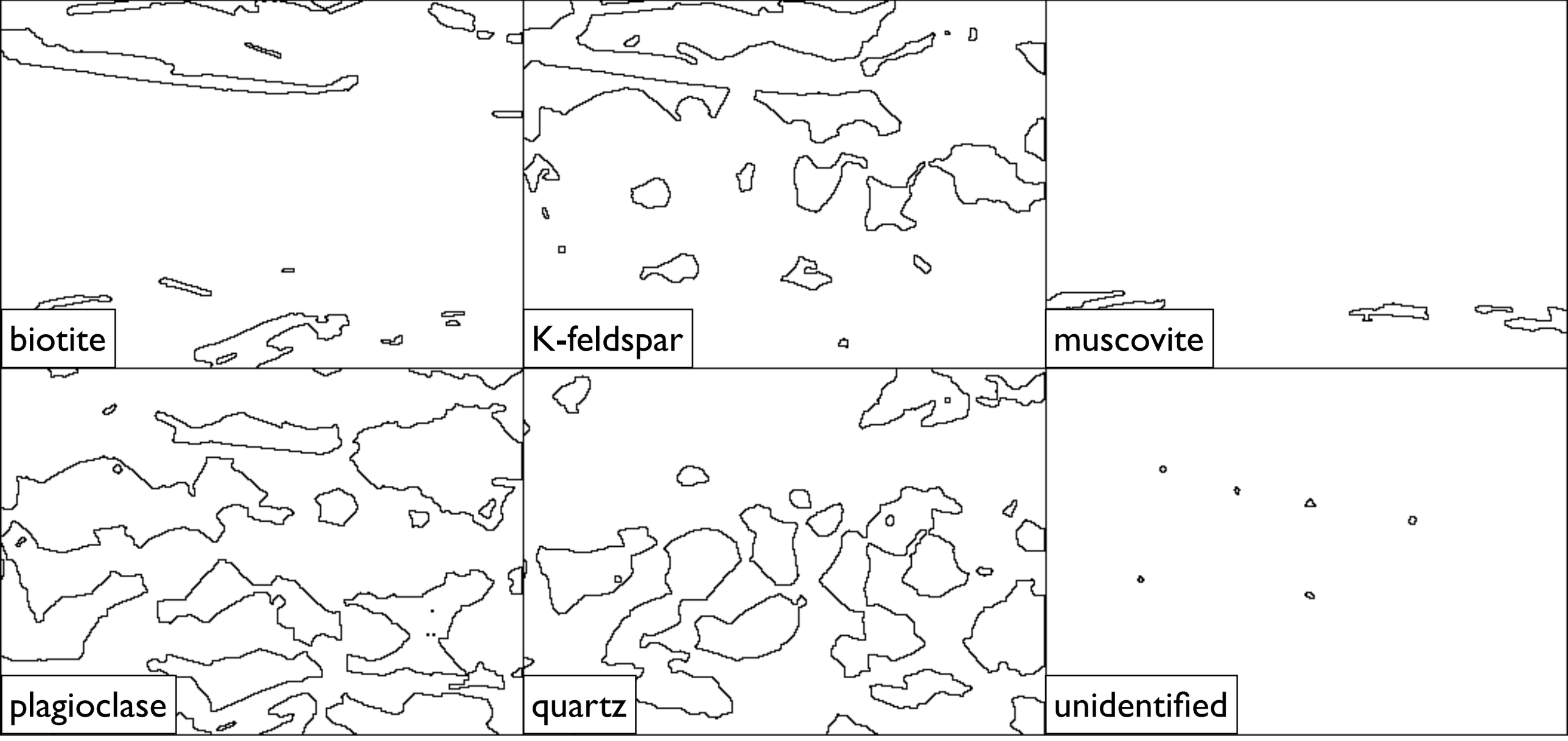



**Figure 6.20**
Phase boundary maps.
Individual phase boundary maps are shown for each of the six phases.

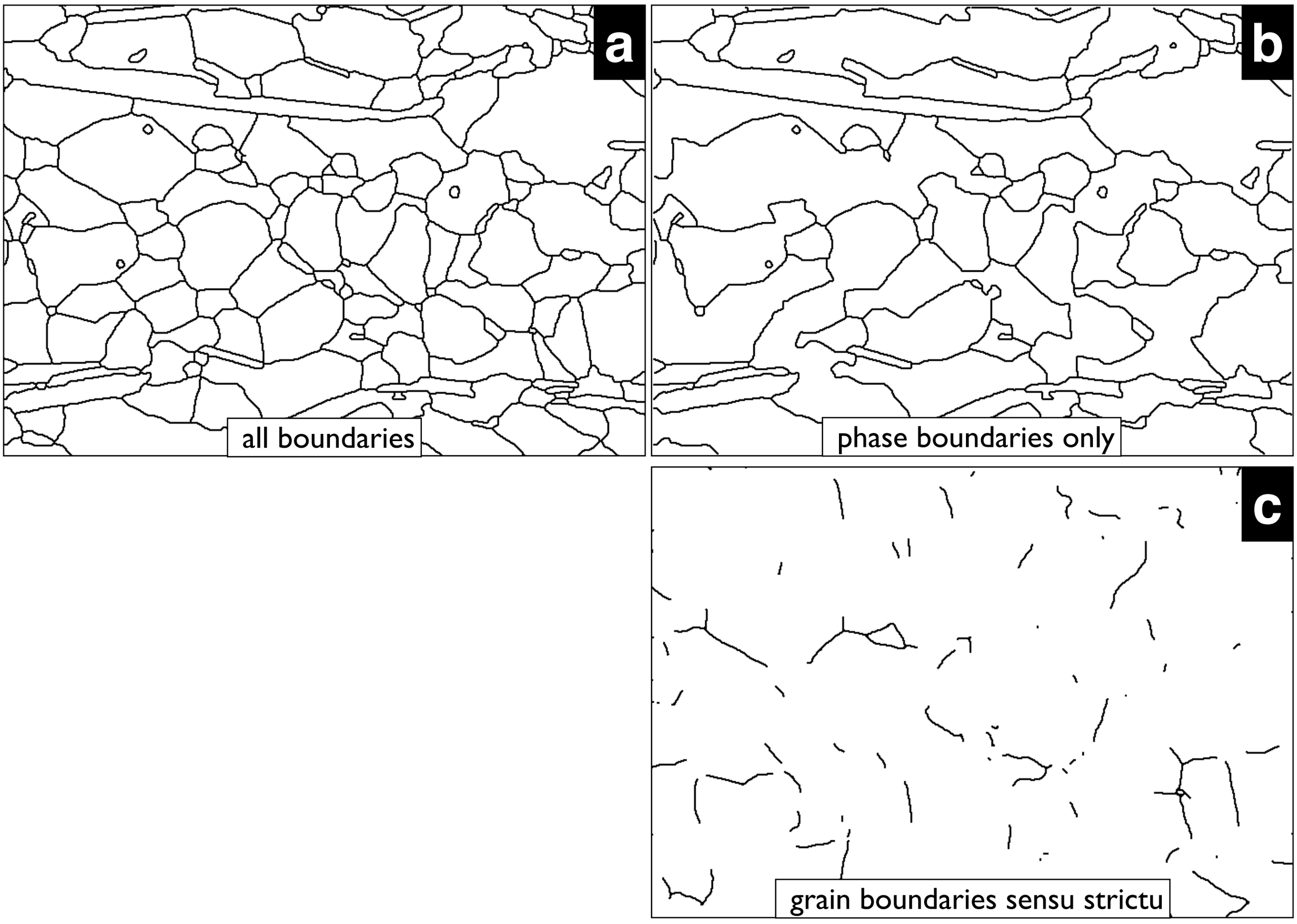



**Figure 6.21**
Phase and grain boundaries.
(a) complete grain boundary map showing the complete boundary of each grain (compare Figure 6.19.b);
(b) phase boundary map showing the boundary between phases only (compare Figure 6.17);
(c) AND-adding (a) and (b) yields the grain boundary map sensu strictu.

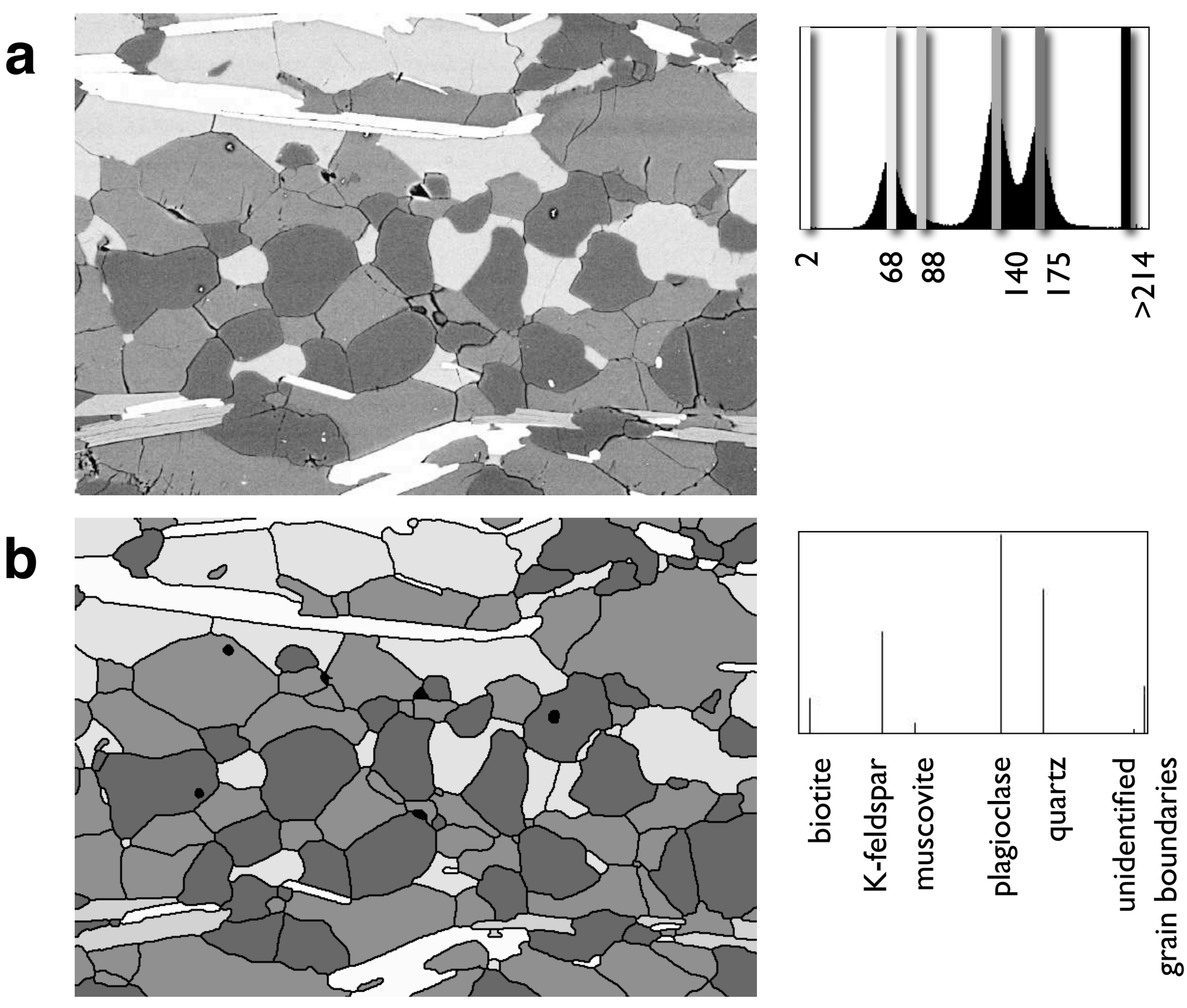



**Figure 6.22**
Comparison of original and segmentation.
(a) Pre-processed SEM micrograph of granitoid rock and histogram with modes of phases superposed;
(b) segmented image displaying six phases and grain boundaries.