Appendix C

Classified Textures

C.1 Open ended classification of texture

In Section 8.6 we used a set of 100 VisTex texture mosaics, courtesy of Computer Vision Group at the University Bonn [49], to test our open ended texture classification algorithm for various configurations of our nonparametric and strong nonparametric MRF models. The summary of these tests appear in Table 8.1. In the table, the percentage error for each model was calculated be combining the relative percentage error for false negatives with the relative percentage error for false positives. This meant, best results were achieved by the models which where able to classify correctly all the texture within the mosaics as being either the training texture class or another separate class. The percentage error was taken relative to the area of the classification region, which made the error rate independent of the respective areas for each classification region.

Best classification results were obtained for the strong MRF model with a 3×3 neighbourhood, pairwise cliques, and a multigrid height of one (*i.e.,* two grid levels). This model achieved a classification accuracy of 87% over 100 of VisTex texture mosaics. In Figs. C.1–C.32 we present the probability maps obtained from some of those experiments with this particular model.
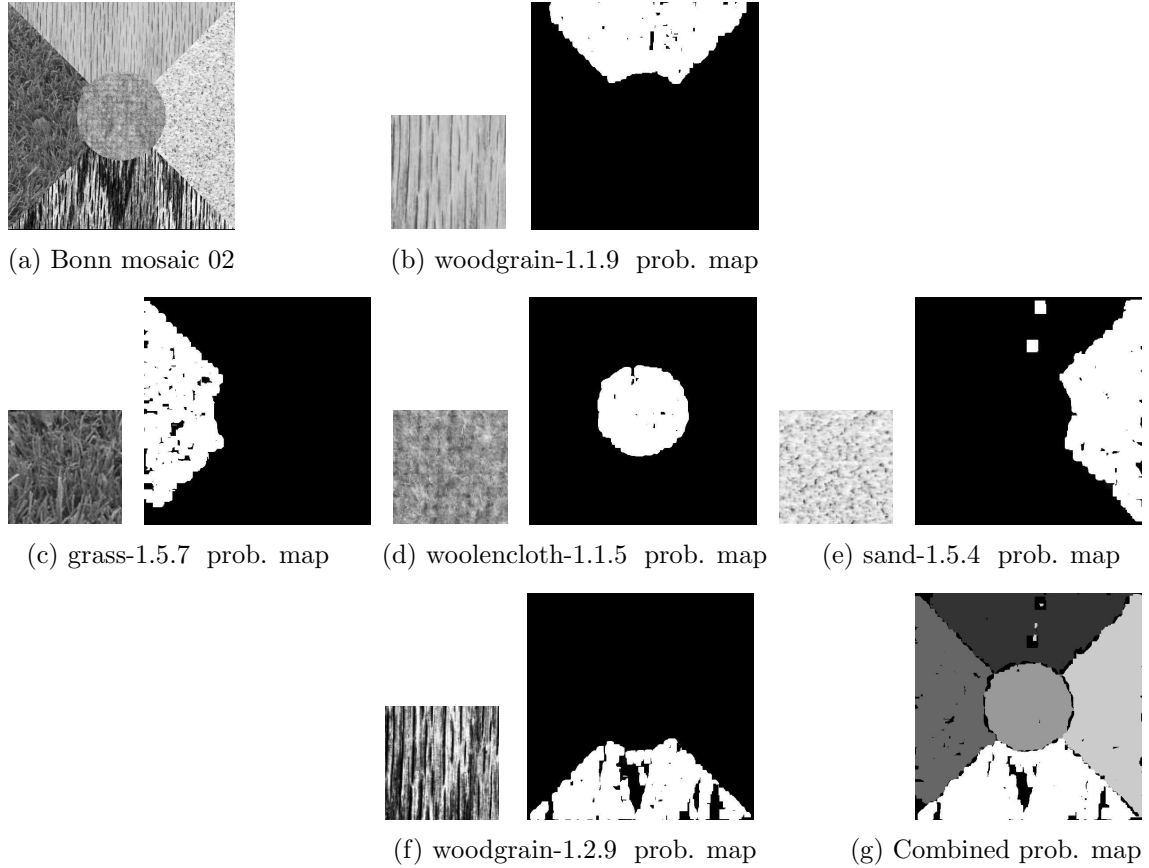
(a) Bonn mosaic 02

(b) woodgrain-1.1.9 prob. map

(c) grass-1.5.7 prob. map

(d) woolencloth-1.1.5 prob. map

(e) sand-1.5.4 prob. map

(f) woodgrain-1.2.9 prob. map

(g) Combined prob. map

Figure C.1: Open ended texture classification of Bonn mosaic 02: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture woodgrain-1.1.9; (c) probability map with respect to training texture grass-1.5.7; (d) probability map with respect to training texture woolencloth-1.1.5; (e) probability map with respect to training texture sand-1.5.4; (f) probability map with respect to training texture woodgrain-1.2.9; (g) combined probability map.
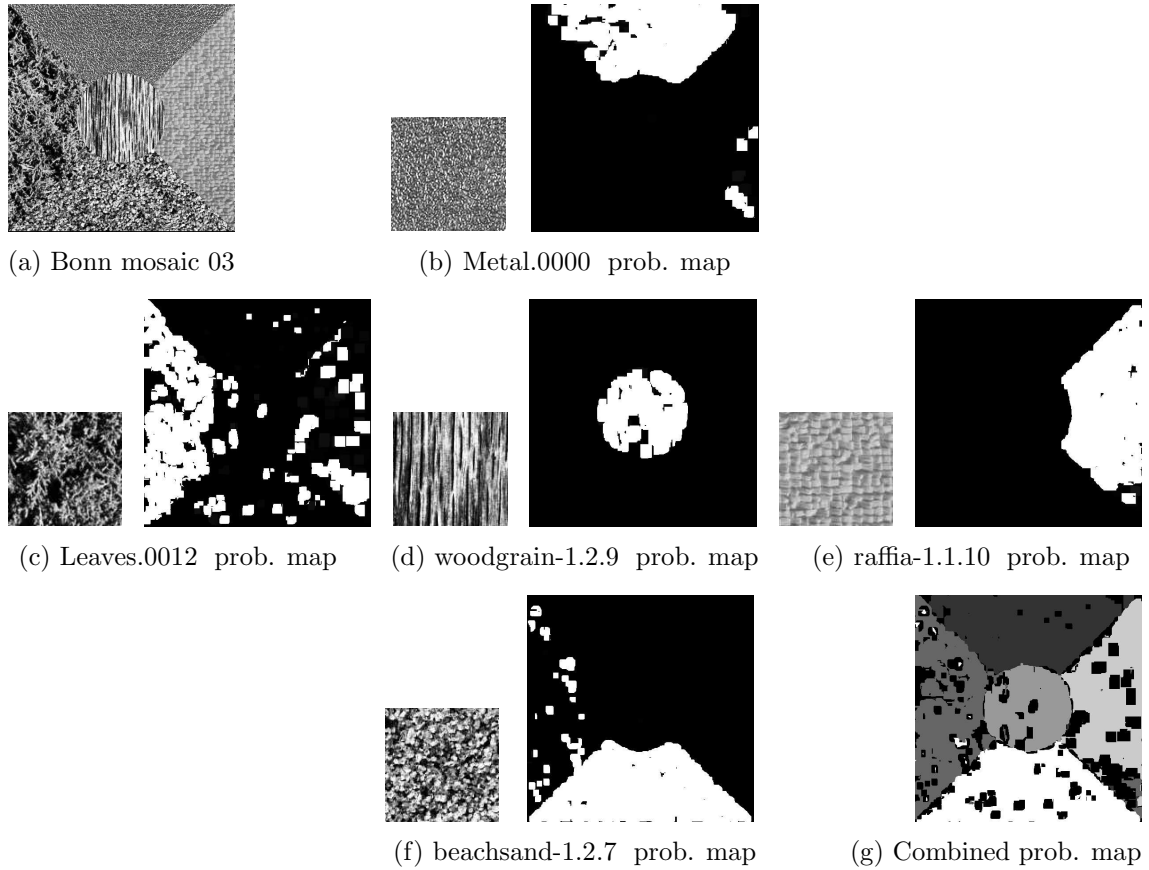
(a) Bonn mosaic 03

(b) Metal.0000 prob. map

(c) Leaves.0012 prob. map

(d) woodgrain-1.2.9 prob. map

(e) raffia-1.1.10 prob. map

(f) beachsand-1.2.7 prob. map

(g) Combined prob. map

Figure C.2: Open ended texture classification of Bonn mosaic 03: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture Metal.0000; (c) probability map with respect to training texture Leaves.0012; (d) probability map with respect to training texture woodgrain-1.2.9; (e) probability map with respect to training texture raffia-1.1.10; (f) probability map with respect to training texture beachsand-1.2.7; (g) combined probability map.
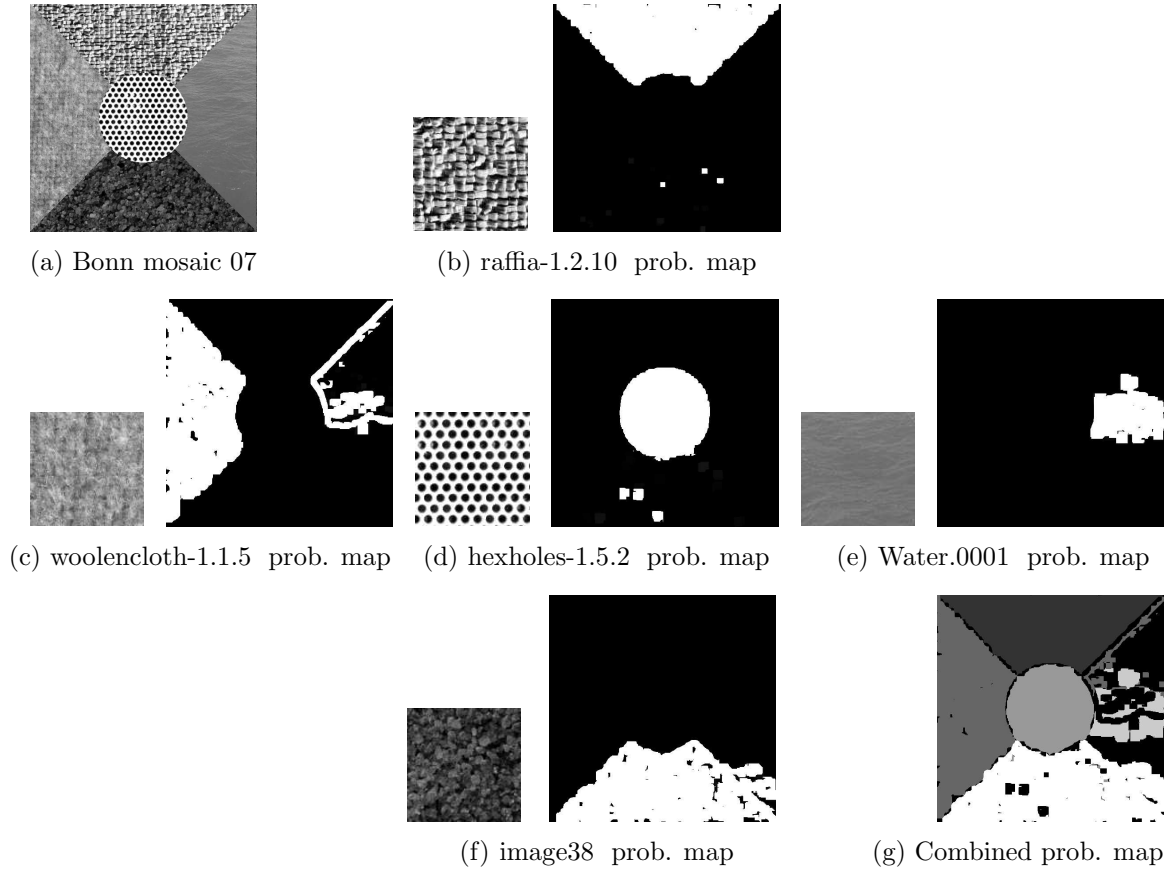
(a) Bonn mosaic 07

(b) raffia-1.2.10 prob. map

(c) woolencloth-1.1.5 prob. map

(d) hexholes-1.5.2 prob. map

(e) Water.0001 prob. map

(f) image38 prob. map

(g) Combined prob. map

Figure C.3: Open ended texture classification of Bonn mosaic 07: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture raffia-1.2.10; (c) probability map with respect to training texture woolencloth-1.1.5; (d) probability map with respect to training texture hexholes-1.5.2; (e) probability map with respect to training texture Water.0001; (f) probability map with respect to training texture image38; (g) combined probability map.
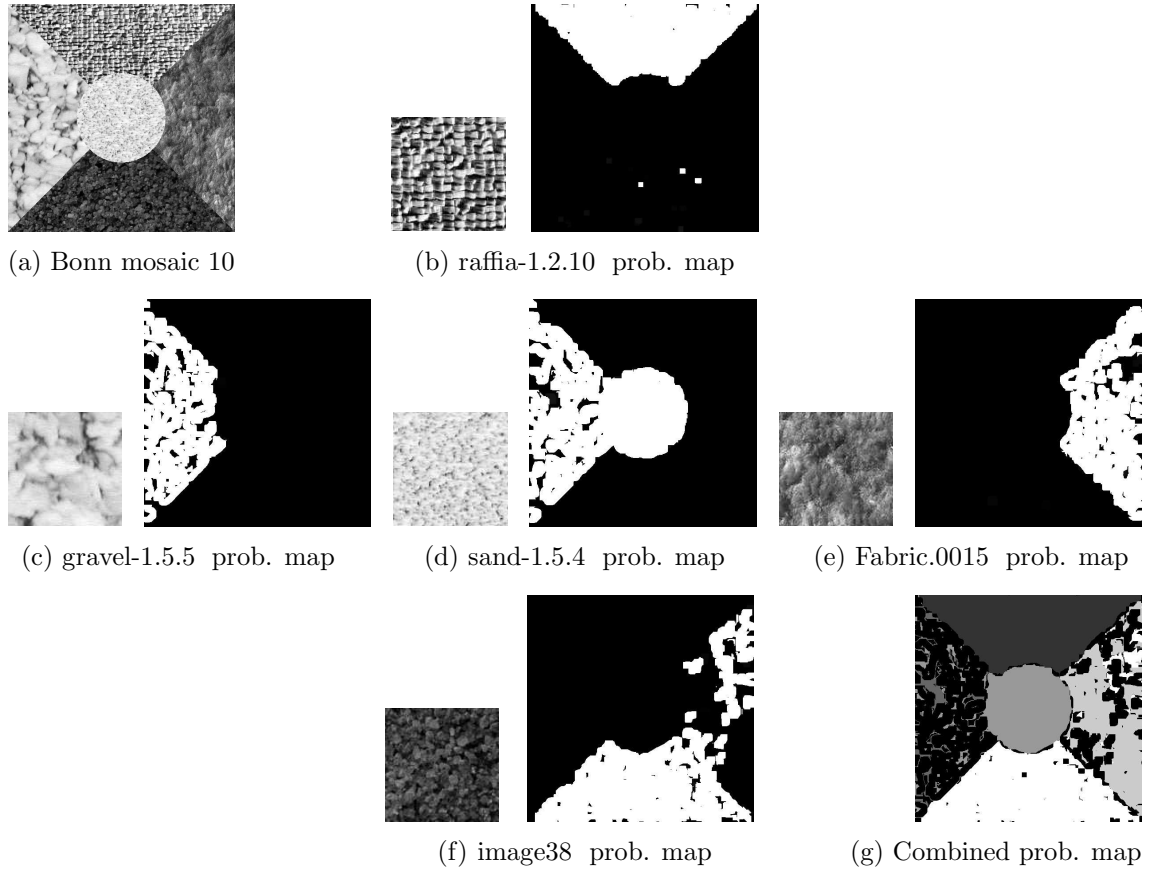
(a) Bonn mosaic 10

(b) raffia-1.2.10 prob. map

(c) gravel-1.5.5 prob. map

(d) sand-1.5.4 prob. map

(e) Fabric.0015 prob. map

(f) image38 prob. map

(g) Combined prob. map

Figure C.4: Open ended texture classification of Bonn mosaic 10: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture raffia-1.2.10; (c) probability map with respect to training texture gravel-1.5.5; (d) probability map with respect to training texture sand-1.5.4; (e) probability map with respect to training texture Fabric.0015; (f) probability map with respect to training texture image38; (g) combined probability map.
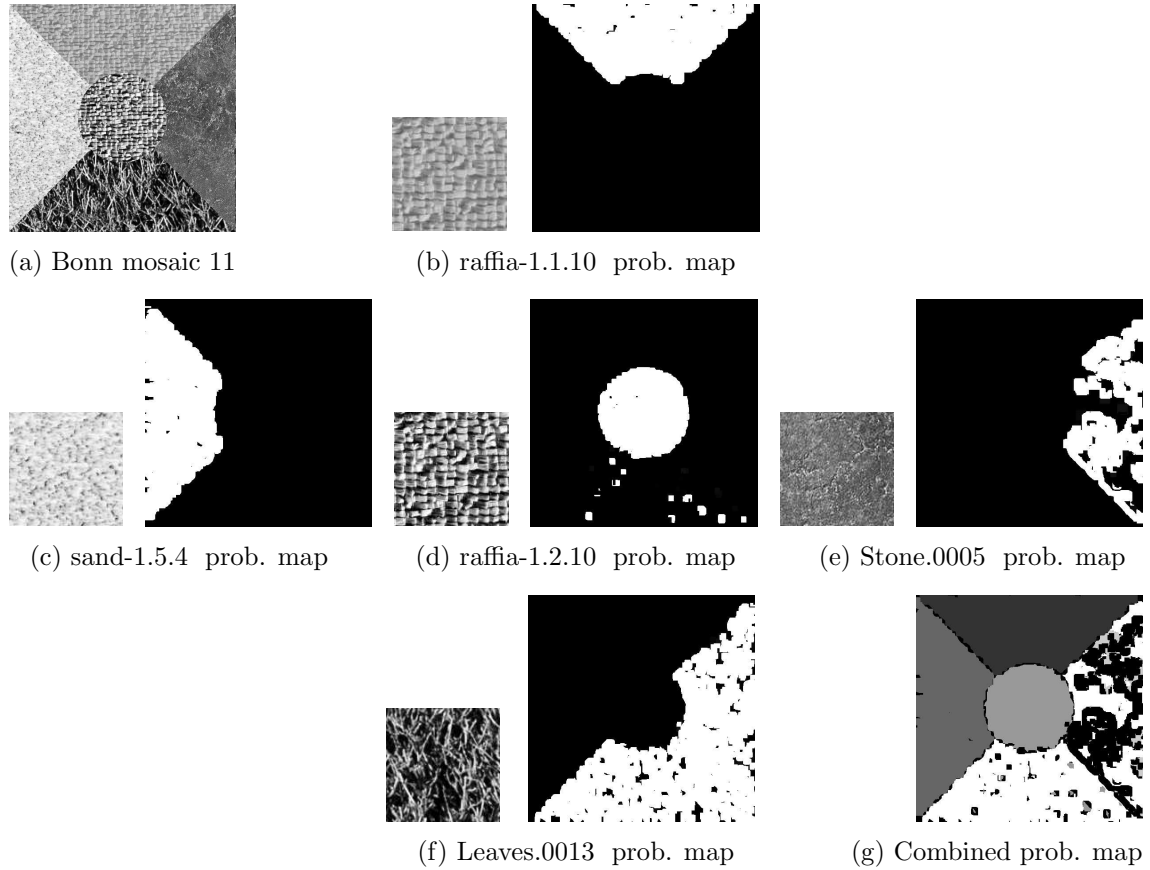
(a) Bonn mosaic 11

(b) raffia-1.1.10 prob. map

(c) sand-1.5.4 prob. map

(d) raffia-1.2.10 prob. map

(e) Stone.0005 prob. map

(f) Leaves.0013 prob. map

(g) Combined prob. map

Figure C.5: Open ended texture classification of Bonn mosaic 11: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture raffia-1.1.10; (c) probability map with respect to training texture sand-1.5.4; (d) probability map with respect to training texture raffia-1.2.10; (e) probability map with respect to training texture Stone.0005; (f) probability map with respect to training texture Leaves.0013; (g) combined probability map.
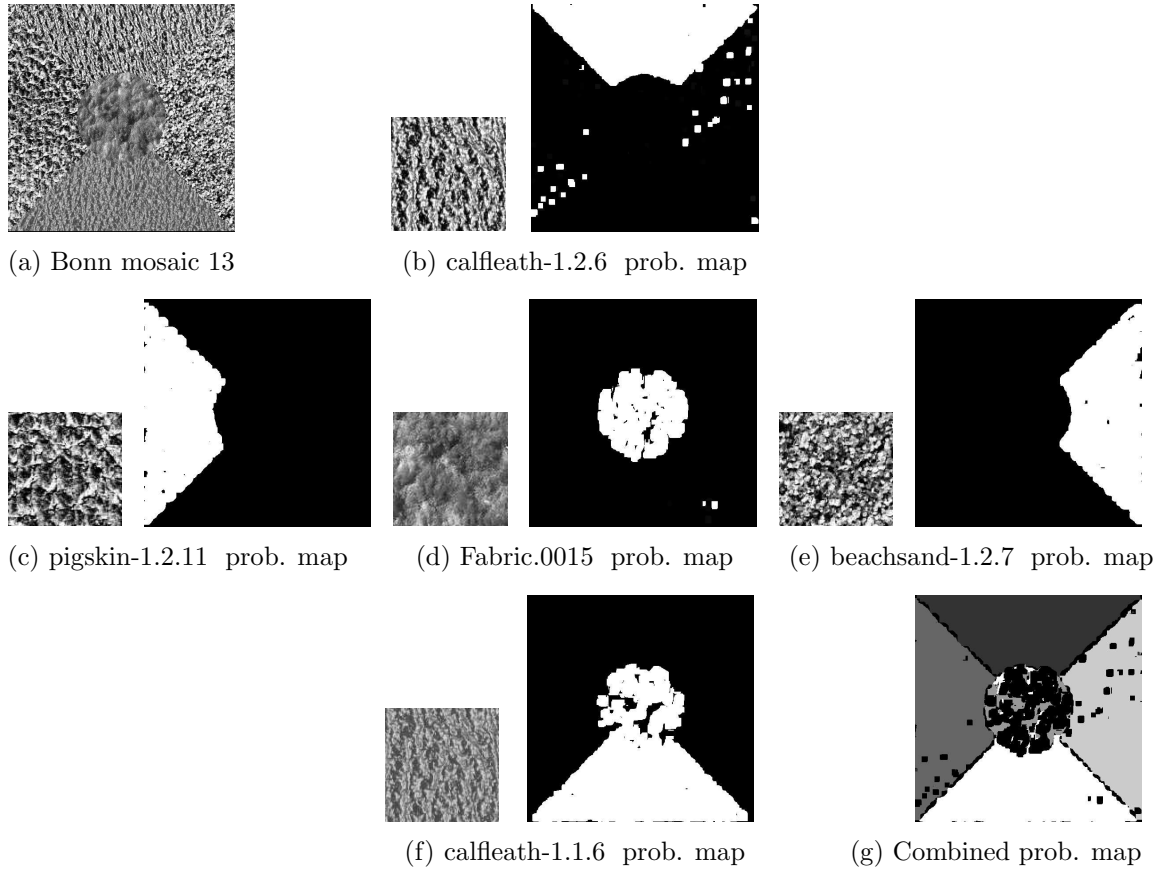
(a) Bonn mosaic 13

(b) calfleath-1.2.6 prob. map

(c) pigskin-1.2.11 prob. map

(d) Fabric.0015 prob. map

(e) beachsand-1.2.7 prob. map

(f) calfleath-1.1.6 prob. map

(g) Combined prob. map

Figure C.6: Open ended texture classification of Bonn mosaic 13: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture calfleath-1.2.6; (c) probability map with respect to training texture pigskin-1.2.11; (d) probability map with respect to training texture Fabric.0015; (e) probability map with respect to training texture beachsand-1.2.7; (f) probability map with respect to training texture calfleath-1.1.6; (g) combined probability map.
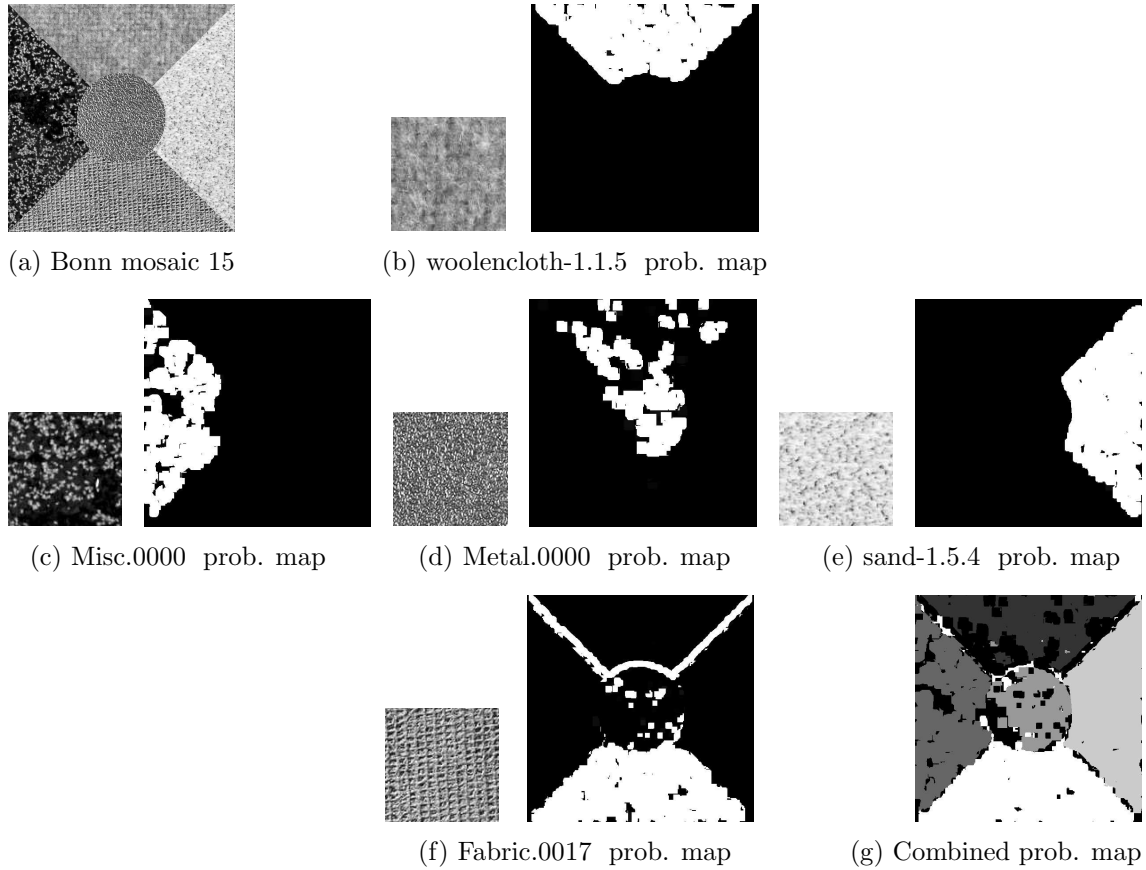
(a) Bonn mosaic 15   (b) woolencloth-1.1.5 prob. map

(c) Misc.0000 prob. map   (d) Metal.0000 prob. map   (e) sand-1.5.4 prob. map

(f) Fabric.0017 prob. map   (g) Combined prob. map

Figure C.7: Open ended texture classification of Bonn mosaic 15: (a) original $512 \times$ 512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture woolencloth-1.1.5; (c) probability map with respect to training texture Misc.0000; (d) probability map with respect to training texture Metal.0000; (e) probability map with respect to training texture sand-1.5.4; (f) probability map with respect to training texture Fabric.0017; (g) combined probability map.
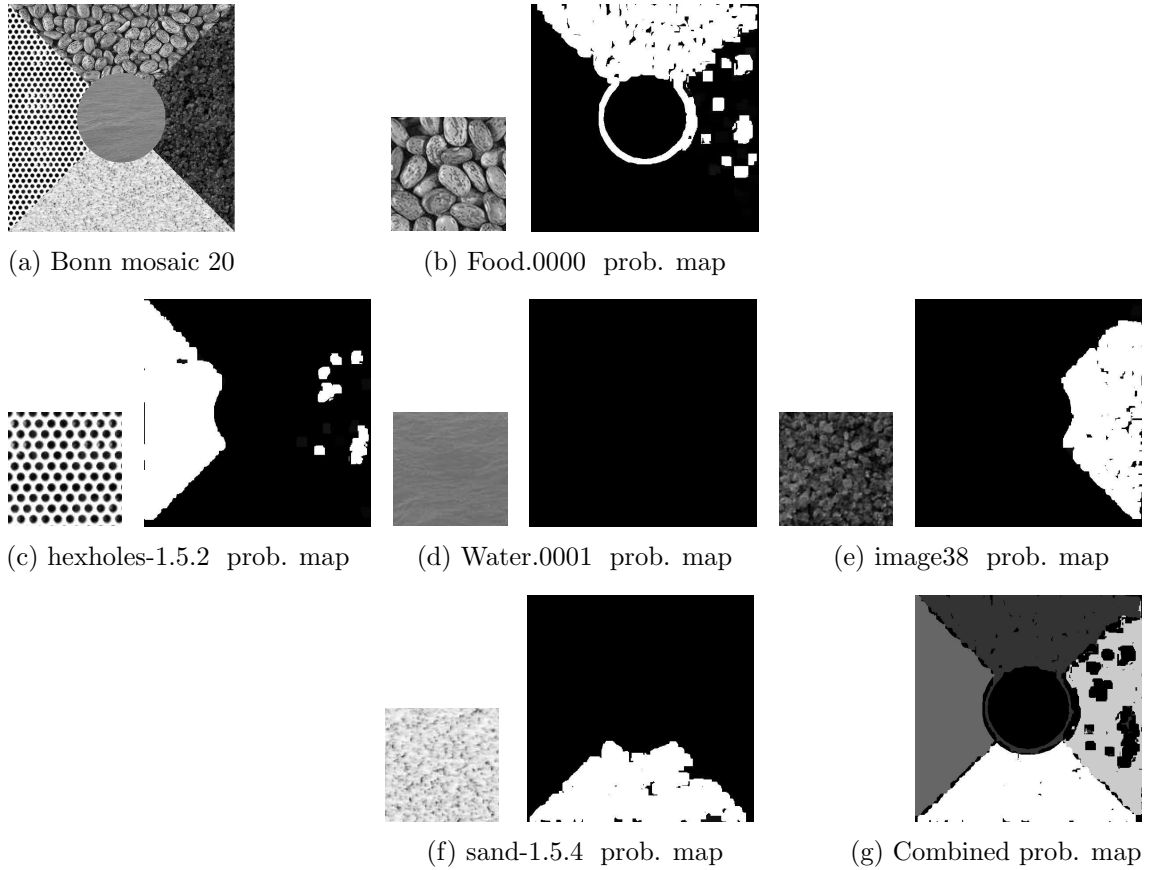
(a) Bonn mosaic 20

(b) Food.0000 prob. map

(c) hexholes-1.5.2 prob. map

(d) Water.0001 prob. map

(e) image38 prob. map

(f) sand-1.5.4 prob. map

(g) Combined prob. map

Figure C.8: Open ended texture classification of Bonn mosaic 20: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture Food.0000; (c) probability map with respect to training texture hexholes-1.5.2; (d) probability map with respect to training texture Water.0001; (e) probability map with respect to training texture image38; (f) probability map with respect to training texture sand-1.5.4; (g) combined probability map.
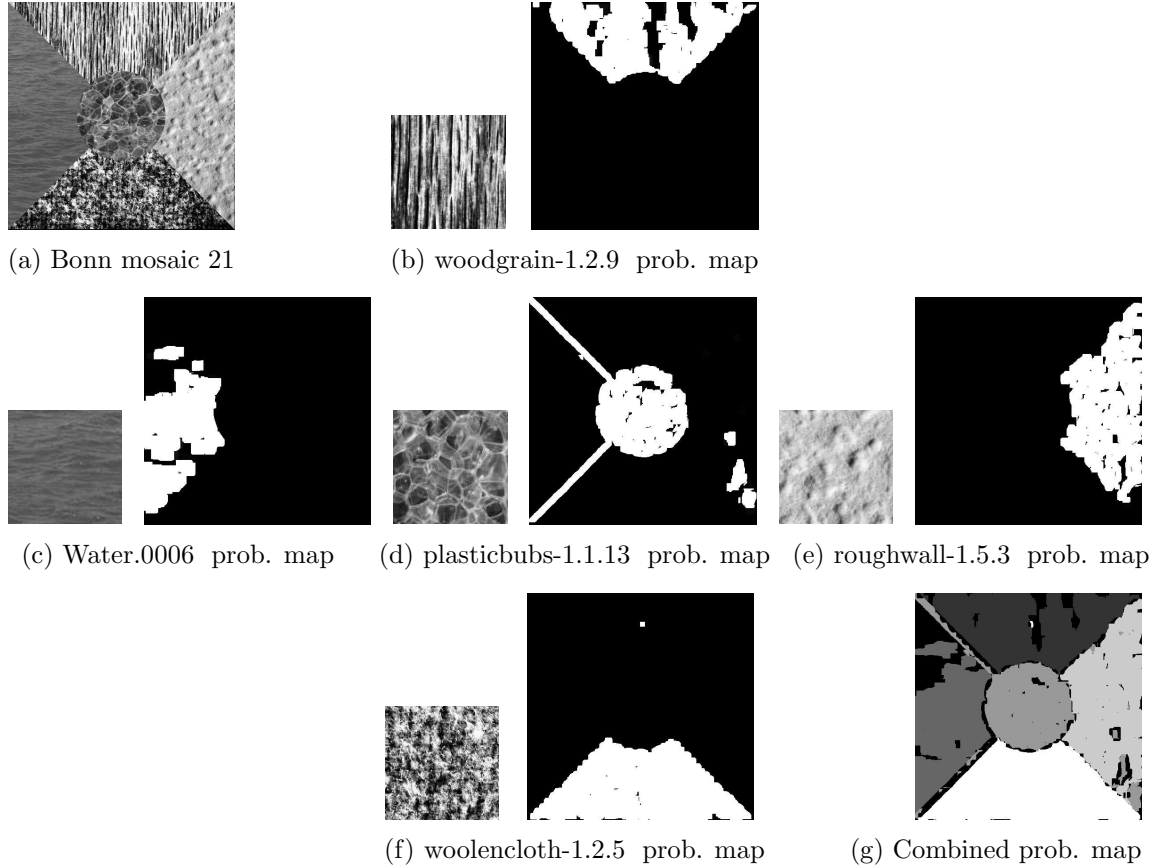
(a) Bonn mosaic 21

(b) woodgrain-1.2.9 prob. map

(c) Water.0006 prob. map

(d) plasticbubs-1.1.13 prob. map

(e) roughwall-1.5.3 prob. map

(f) woolencloth-1.2.5 prob. map

(g) Combined prob. map

Figure C.9: Open ended texture classification of Bonn mosaic 21: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture woodgrain-1.2.9; (c) probability map with respect to training texture Water.0006; (d) probability map with respect to training texture plasticbubs-1.1.13; (e) probability map with respect to training texture roughwall-1.5.3; (f) probability map with respect to training texture woolencloth-1.2.5; (g) combined probability map.
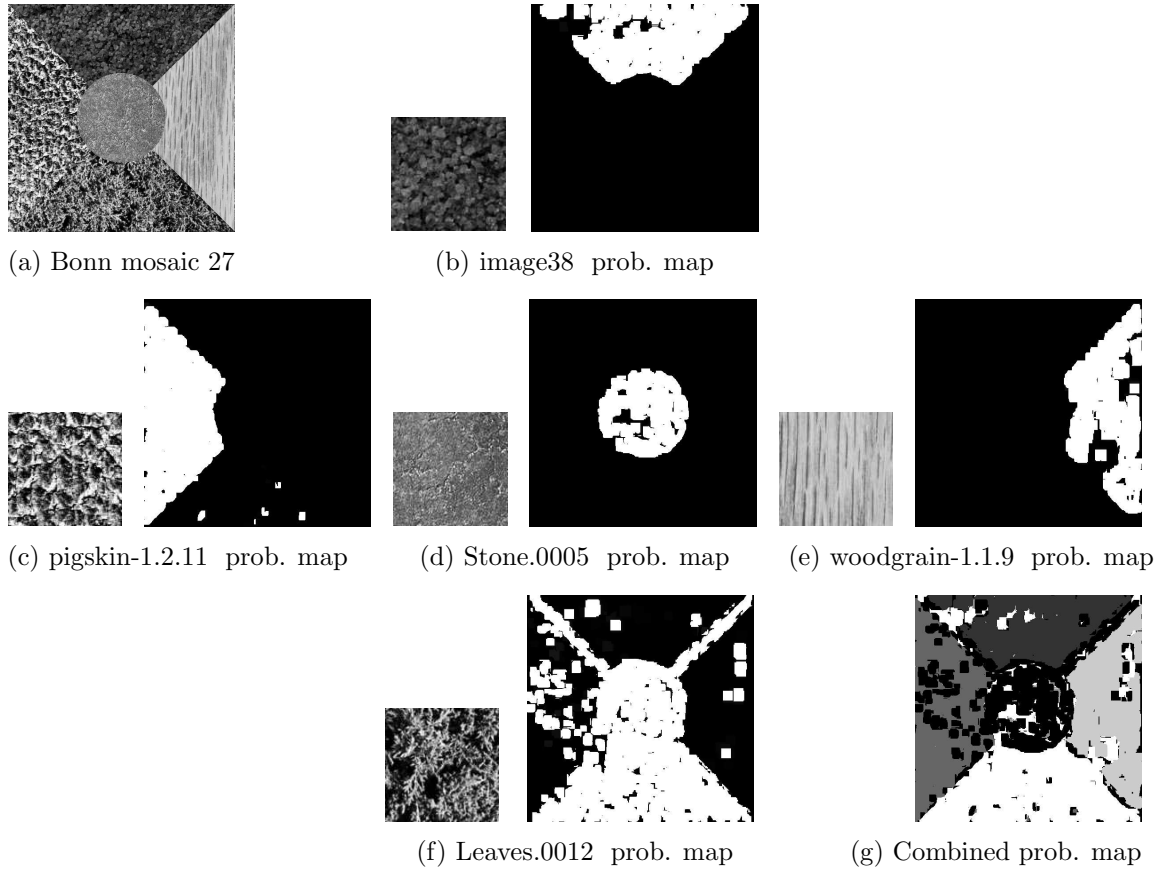
(a) Bonn mosaic 27

(b) image38 prob. map

(c) pigskin-1.2.11 prob. map

(d) Stone.0005 prob. map

(e) woodgrain-1.1.9 prob. map

(f) Leaves.0012 prob. map

(g) Combined prob. map

Figure C.10: Open ended texture classification of Bonn mosaic 27: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture image38; (c) probability map with respect to training texture pigskin-1.2.11; (d) probability map with respect to training texture Stone.0005; (e) probability map with respect to training texture woodgrain-1.1.9; (f) probability map with respect to training texture Leaves.0012; (g) combined probability map.
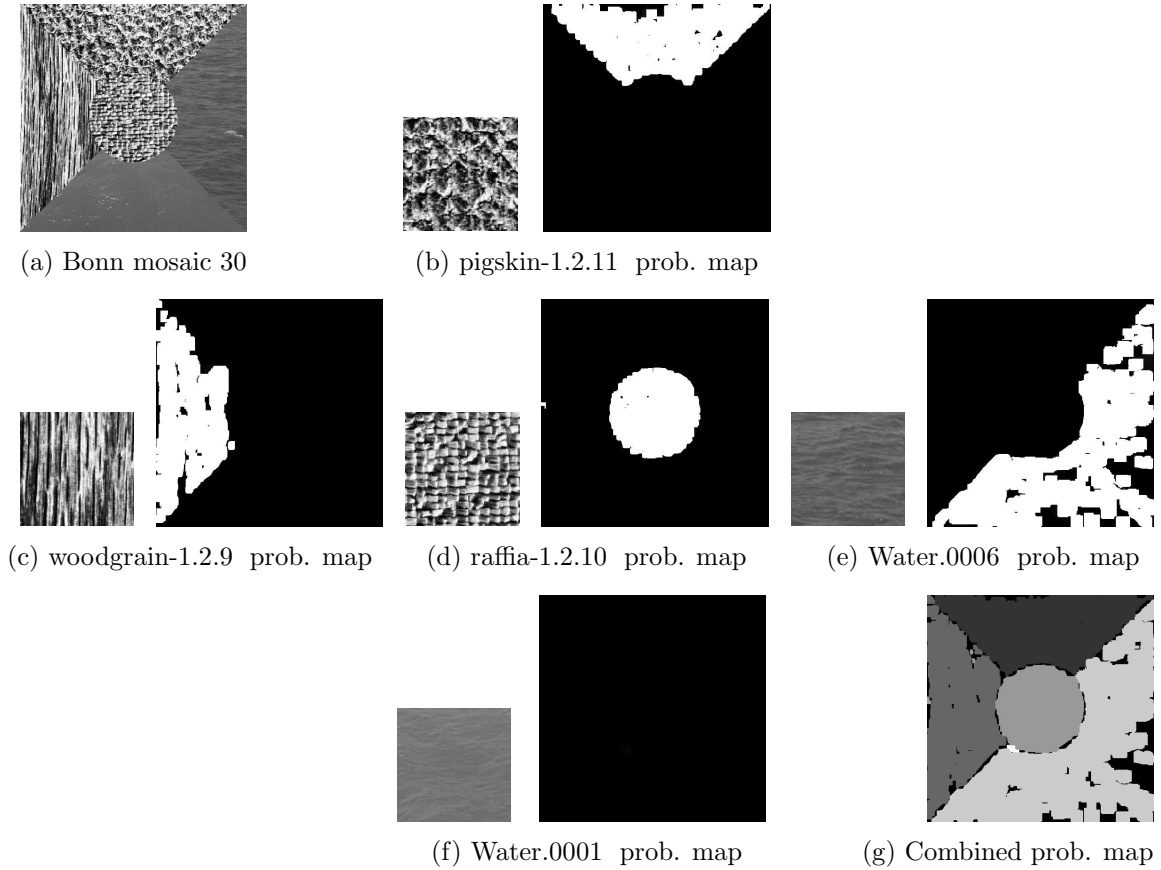
(a) Bonn mosaic 30

(b) pigskin-1.2.11 prob. map

(c) woodgrain-1.2.9 prob. map

(d) raffia-1.2.10 prob. map

(e) Water.0006 prob. map

(f) Water.0001 prob. map

(g) Combined prob. map

Figure C.11: Open ended texture classification of Bonn mosaic 30: (a) original
512×512 image; (b–f) probability maps with respect to a 128×128 image of
training texture; (b) probability map with respect to training texture pigskin-1.2.11;
(c) probability map with respect to training texture woodgrain-1.2.9; (d) probability
map with respect to training texture raffia-1.2.10; (e) probability map with respect
to training texture Water.0006; (f) probability map with respect to training texture
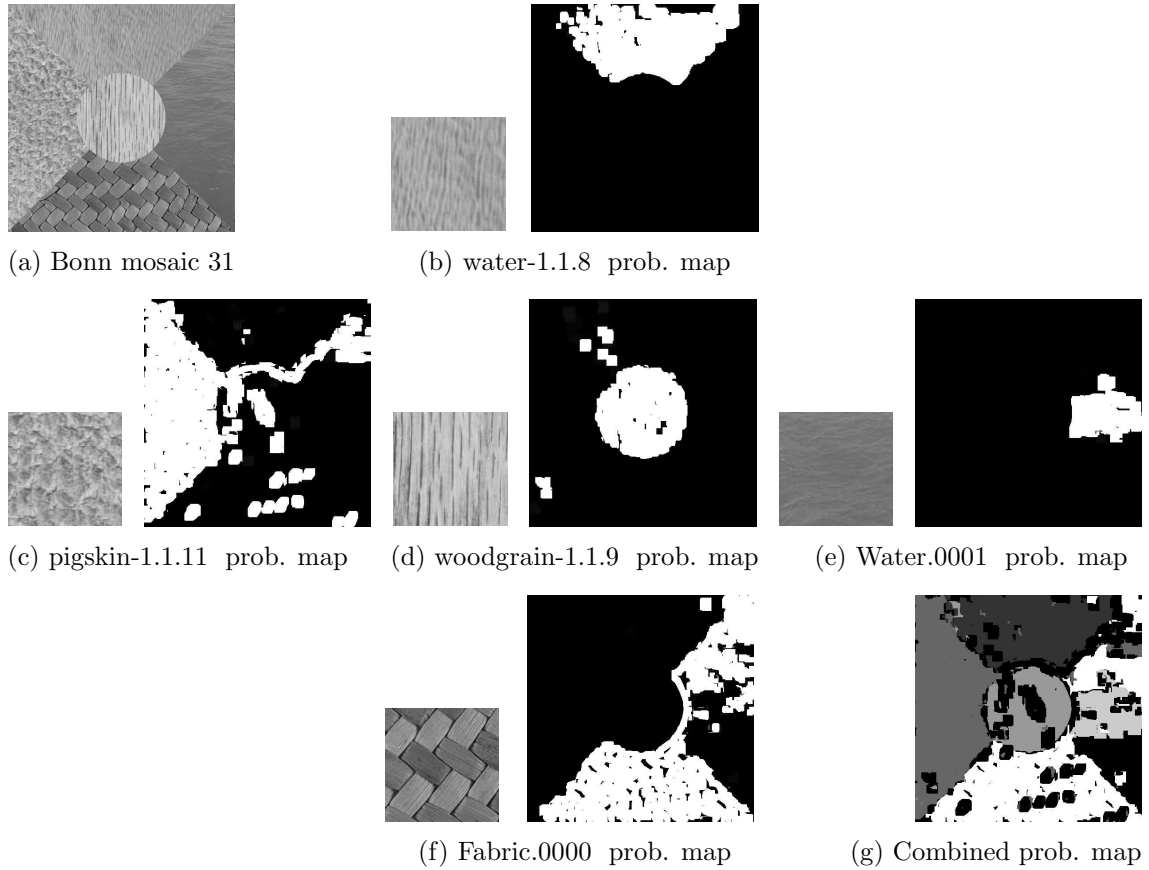Water.0001; (g) combined probability map.

(a) Bonn mosaic 31

(b) water-1.1.8 prob. map

(c) pigskin-1.1.11 prob. map

(d) woodgrain-1.1.9 prob. map

(e) Water.0001 prob. map

(f) Fabric.0000 prob. map

(g) Combined prob. map

Figure C.12: Open ended texture classification of Bonn mosaic 31: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture water-1.1.8; (c) probability map with respect to training texture pigskin-1.1.11; (d) probability map with respect to training texture woodgrain-1.1.9; (e) probability map with respect to training texture Water.0001; (f) probability map with respect to training texture Fabric.0000; (g) combined probability map.
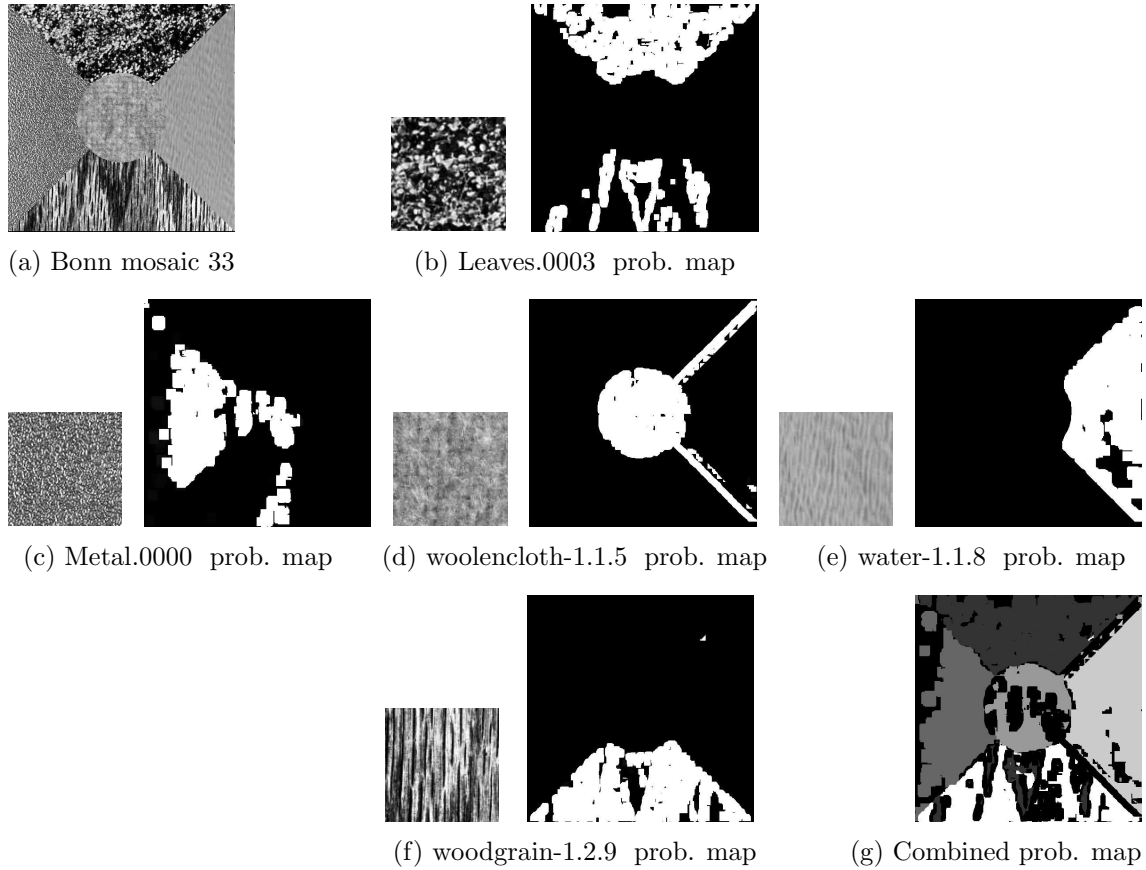
(a) Bonn mosaic 33   (b) Leaves.0003 prob. map

(c) Metal.0000 prob. map   (d) woolencloth-1.1.5 prob. map   (e) water-1.1.8 prob. map

(f) woodgrain-1.2.9 prob. map   (g) Combined prob. map

Figure C.13: Open ended texture classification of Bonn mosaic 33: (a) original
512×512 image; (b–f) probability maps with respect to a 128×128 image of
training texture; (b) probability map with respect to training texture Leaves.0003;
(c) probability map with respect to training texture Metal.0000; (d) probability map
with respect to training texture woolencloth-1.1.5; (e) probability map with respect
to training texture water-1.1.8; (f) probability map with respect to training texture
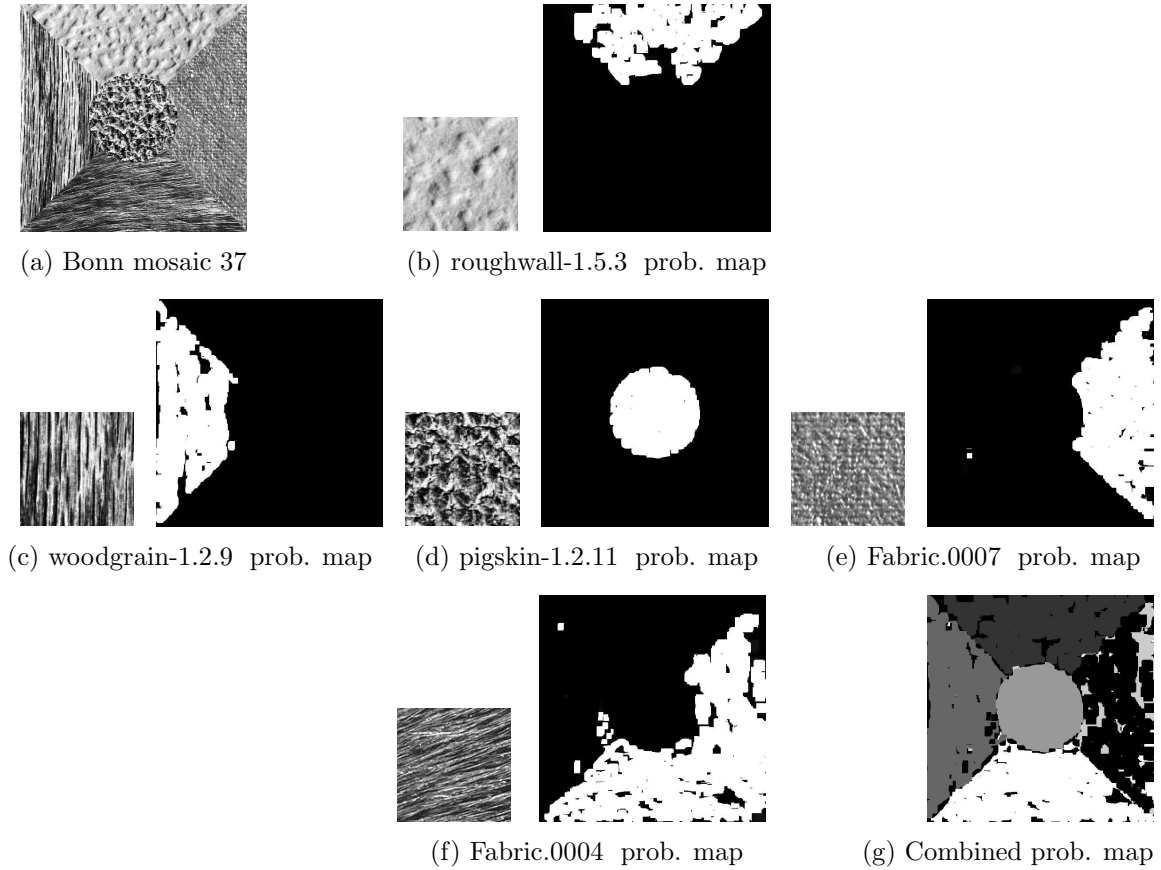woodgrain-1.2.9; (g) combined probability map.

(a) Bonn mosaic 37

(b) roughwall-1.5.3 prob. map

(c) woodgrain-1.2.9 prob. map

(d) pigskin-1.2.11 prob. map

(e) Fabric.0007 prob. map

(f) Fabric.0004 prob. map

(g) Combined prob. map

Figure C.14: Open ended texture classification of Bonn mosaic 37: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture roughwall-1.5.3; (c) probability map with respect to training texture woodgrain-1.2.9; (d) probability map with respect to training texture pigskin-1.2.11; (e) probability map with respect to training texture Fabric.0007; (f) probability map with respect to training texture Fabric.0004; (g) combined probability map.
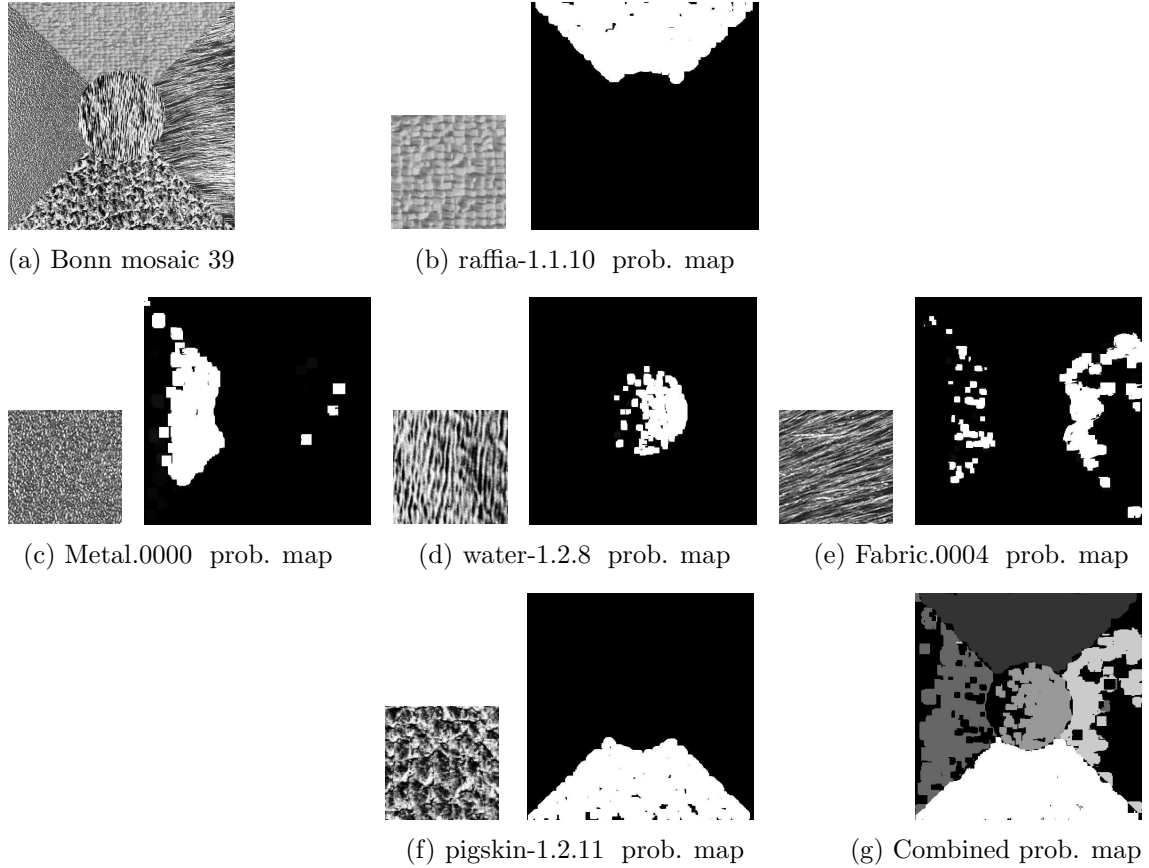
(a) Bonn mosaic 39

(b) raffia-1.1.10 prob. map

(c) Metal.0000 prob. map

(d) water-1.2.8 prob. map

(e) Fabric.0004 prob. map

(f) pigskin-1.2.11 prob. map

(g) Combined prob. map

Figure C.15: Open ended texture classification of Bonn mosaic 39: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture raffia-1.1.10; (c) probability map with respect to training texture Metal.0000; (d) probability map with respect to training texture water-1.2.8; (e) probability map with respect to training texture Fabric.0004; (f) probability map with respect to training texture pigskin-1.2.11; (g) combined probability map.
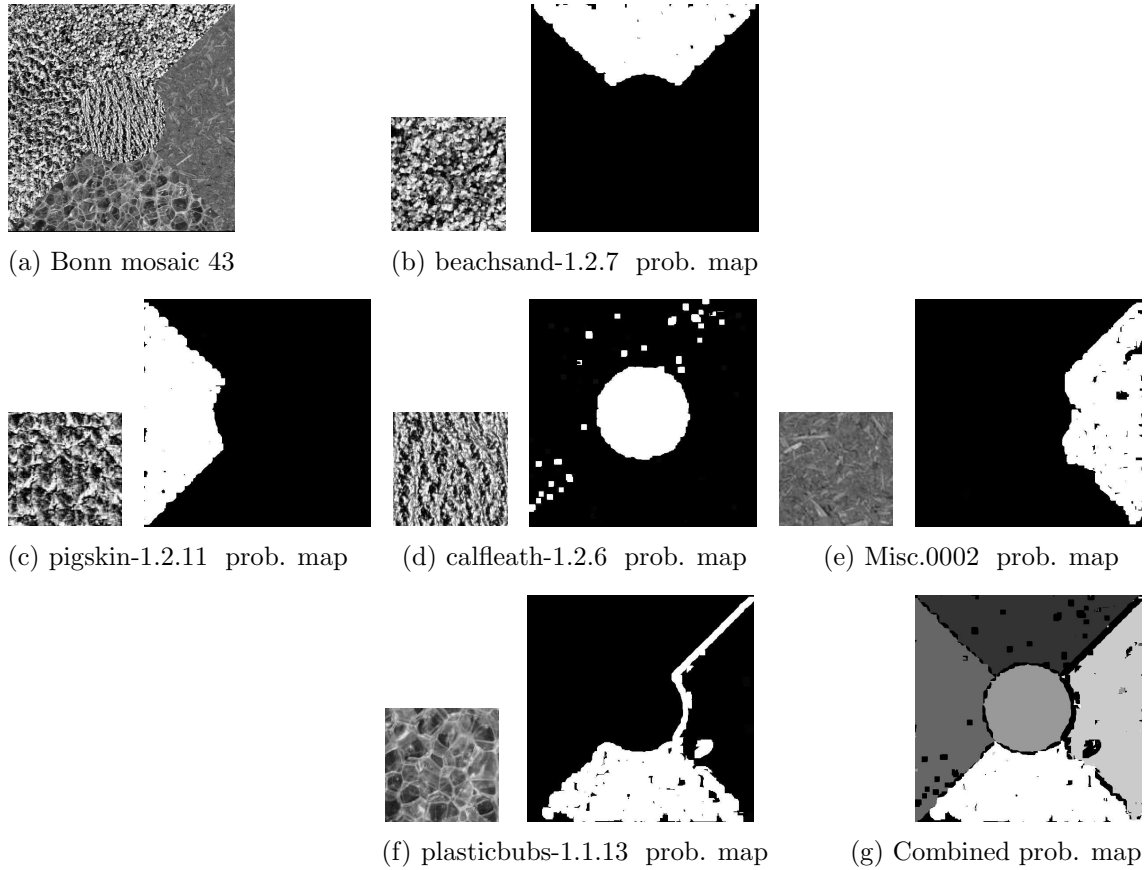
(a) Bonn mosaic 43

(b) beachsand-1.2.7 prob. map

(c) pigskin-1.2.11 prob. map

(d) calfleath-1.2.6 prob. map

(e) Misc.0002 prob. map

(f) plasticbubs-1.1.13 prob. map

(g) Combined prob. map

Figure C.16: Open ended texture classification of Bonn mosaic 43: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture beachsand-1.2.7; (c) probability map with respect to training texture pigskin-1.2.11; (d) probability map with respect to training texture calfleath-1.2.6; (e) probability map with respect to training texture Misc.0002; (f) probability map with respect to training texture plasticbubs-1.1.13; (g) combined probability map.
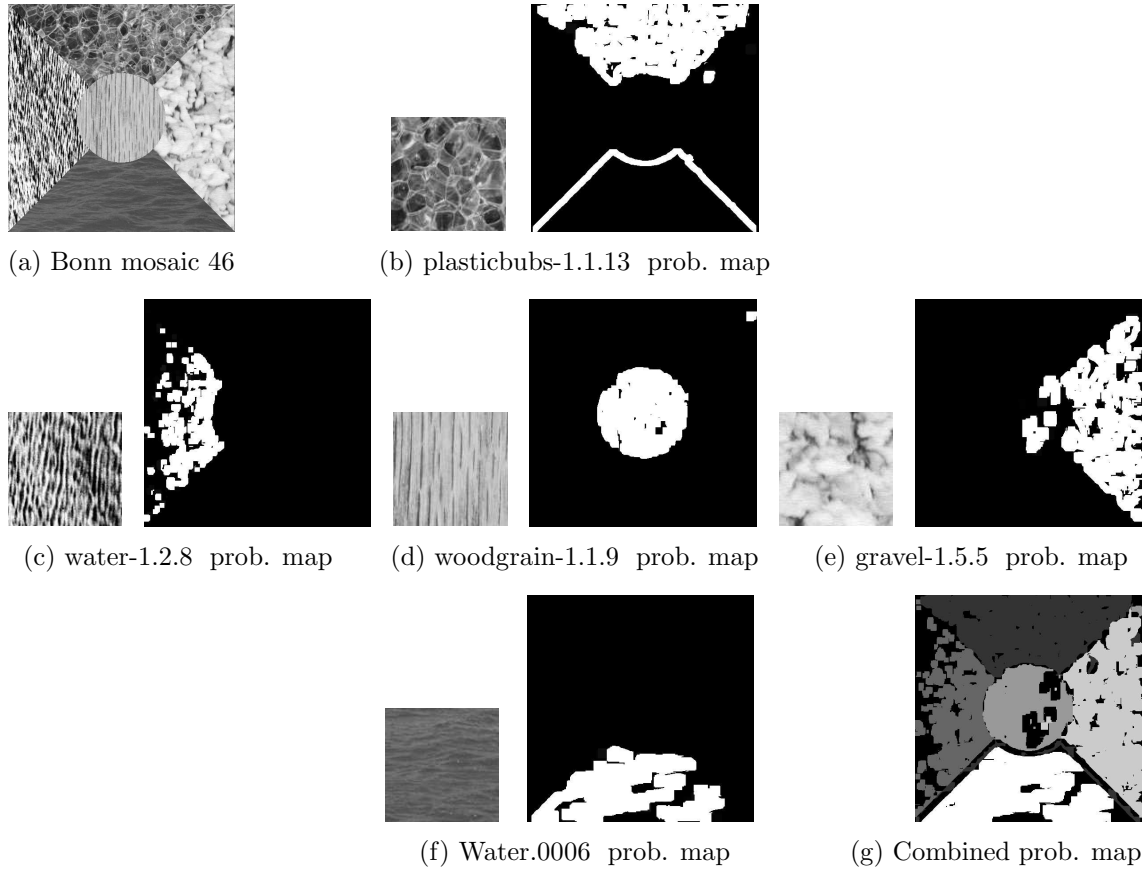
(a) Bonn mosaic 46   (b) plasticbubs-1.1.13 prob. map

(c) water-1.2.8 prob. map   (d) woodgrain-1.1.9 prob. map   (e) gravel-1.5.5 prob. map

(f) Water.0006 prob. map   (g) Combined prob. map

Figure C.17: Open ended texture classification of Bonn mosaic 46: (a) original
512×512 image; (b–f) probability maps with respect to a 128×128 image of training
texture; (b) probability map with respect to training texture plasticbubs-1.1.13; (c)
probability map with respect to training texture water-1.2.8; (d) probability map
with respect to training texture woodgrain-1.1.9; (e) probability map with respect
to training texture gravel-1.5.5; (f) probability map with respect to training texture
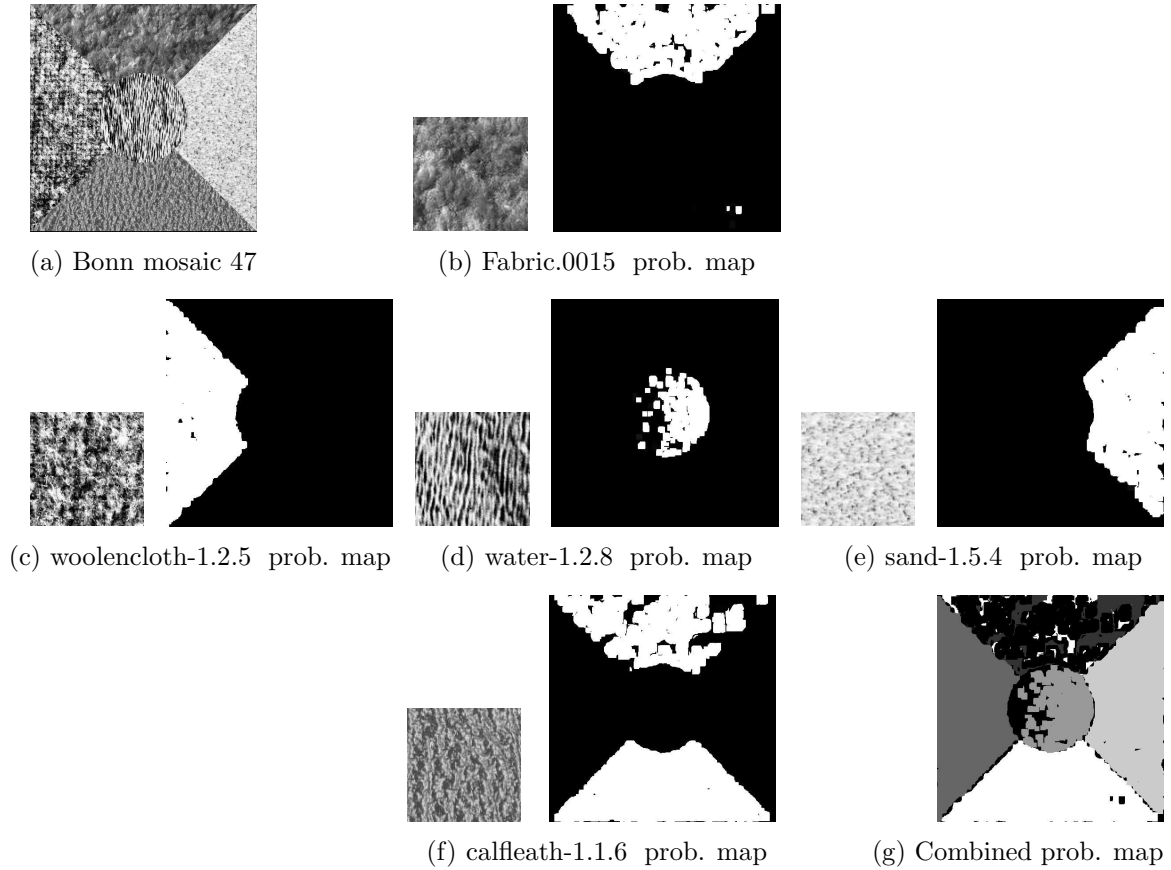Water.0006; (g) combined probability map.

(a) Bonn mosaic 47

(b) Fabric.0015 prob. map

(c) woolencloth-1.2.5 prob. map

(d) water-1.2.8 prob. map

(e) sand-1.5.4 prob. map

(f) calfleath-1.1.6 prob. map

(g) Combined prob. map

Figure C.18: Open ended texture classification of Bonn mosaic 47: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture Fabric.0015; (c) probability map with respect to training texture woolencloth-1.2.5; (d) probability map with respect to training texture water-1.2.8; (e) probability map with respect to training texture sand-1.5.4; (f) probability map with respect to training texture calfleath-1.1.6; (g) combined probability map.
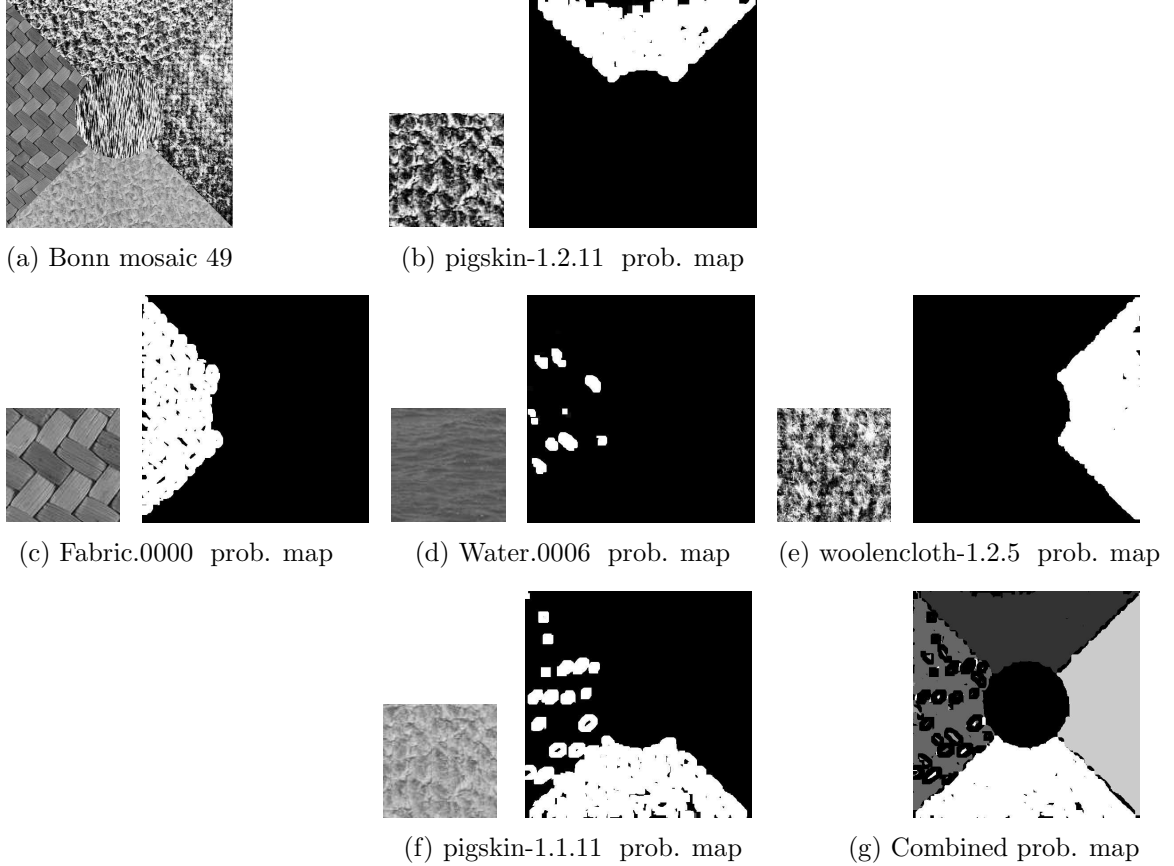
(a) Bonn mosaic 49   (b) pigskin-1.2.11 prob. map

(c) Fabric.0000 prob. map   (d) Water.0006 prob. map   (e) woolencloth-1.2.5 prob. map

(f) pigskin-1.1.11 prob. map   (g) Combined prob. map

Figure C.19: Open ended texture classification of Bonn mosaic 49: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture pigskin-1.2.11; (c) probability map with respect to training texture Fabric.0000; (d) probability map with respect to training texture Water.0006; (e) probability map with respect to training texture woolencloth-1.2.5; (f) probability map with respect to training texture pigskin-1.1.11; (g) combined probability map.
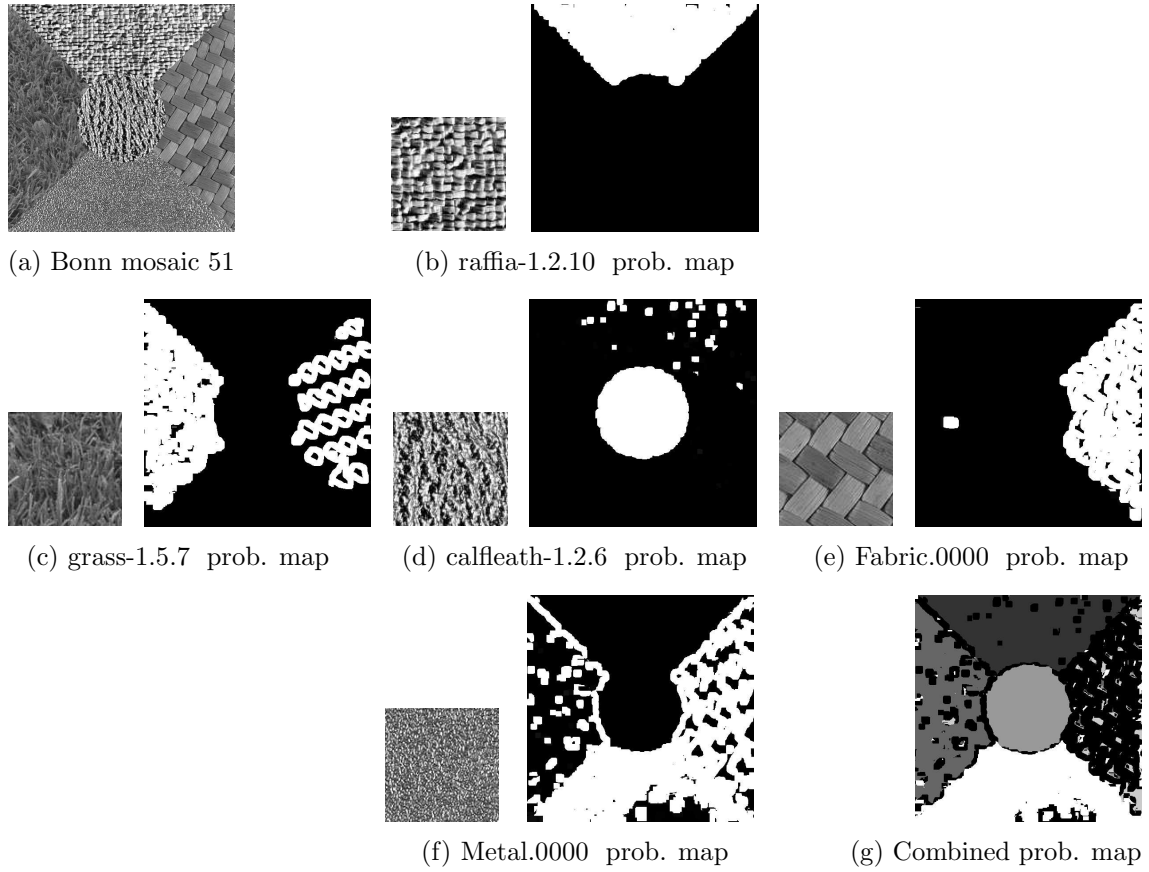
(a) Bonn mosaic 51

(b) raffia-1.2.10 prob. map

(c) grass-1.5.7 prob. map

(d) calfleath-1.2.6 prob. map

(e) Fabric.0000 prob. map

(f) Metal.0000 prob. map

(g) Combined prob. map

Figure C.20: Open ended texture classification of Bonn mosaic 51: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture raffia-1.2.10; (c) probability map with respect to training texture grass-1.5.7; (d) probability map with respect to training texture calfleath-1.2.6; (e) probability map with respect to training texture Fabric.0000; (f) probability map with respect to training texture Metal.0000; (g) combined probability map.
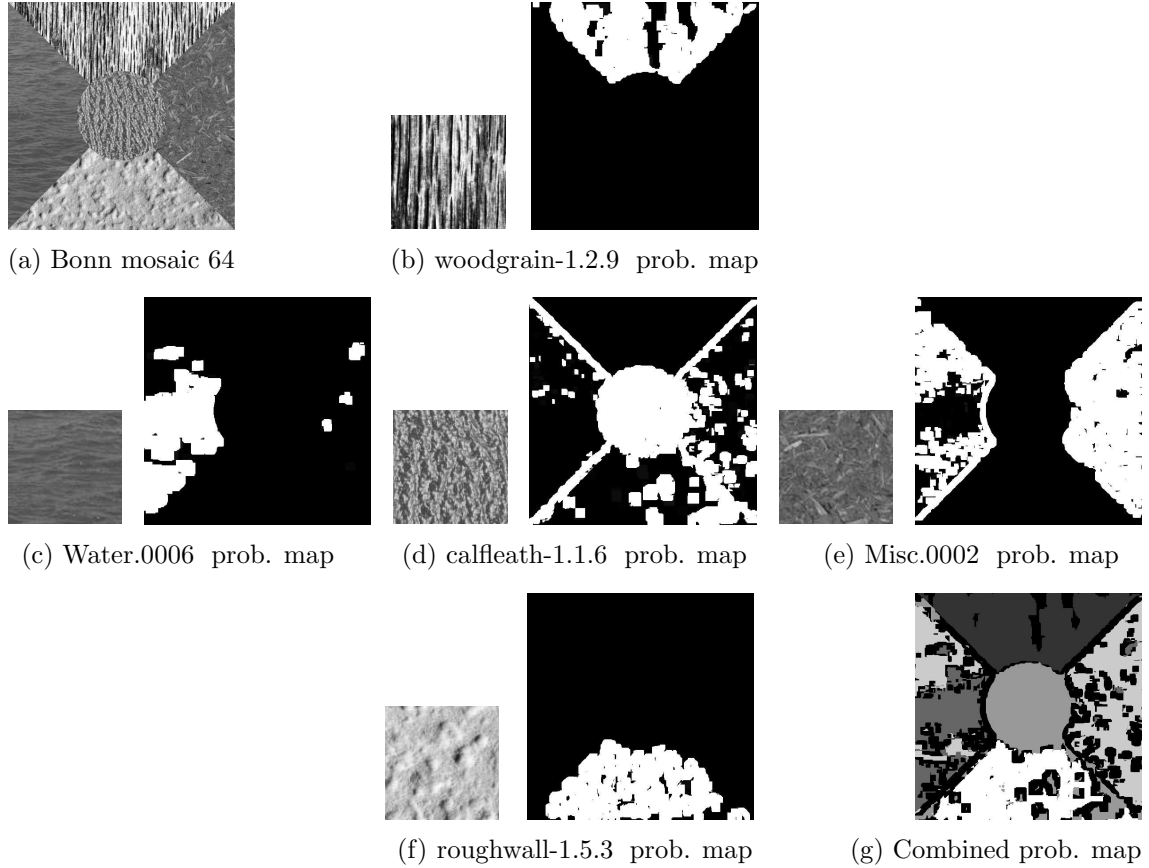
(a) Bonn mosaic 64

(b) woodgrain-1.2.9 prob. map

(c) Water.0006 prob. map

(d) calfleath-1.1.6 prob. map

(e) Misc.0002 prob. map

(f) roughwall-1.5.3 prob. map

(g) Combined prob. map

Figure C.21: Open ended texture classification of Bonn mosaic 64: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture woodgrain-1.2.9; (c) probability map with respect to training texture Water.0006; (d) probability map with respect to training texture calfleath-1.1.6; (e) probability map with respect to training texture Misc.0002; (f) probability map with respect to training texture roughwall-1.5.3; (g) combined probability map.
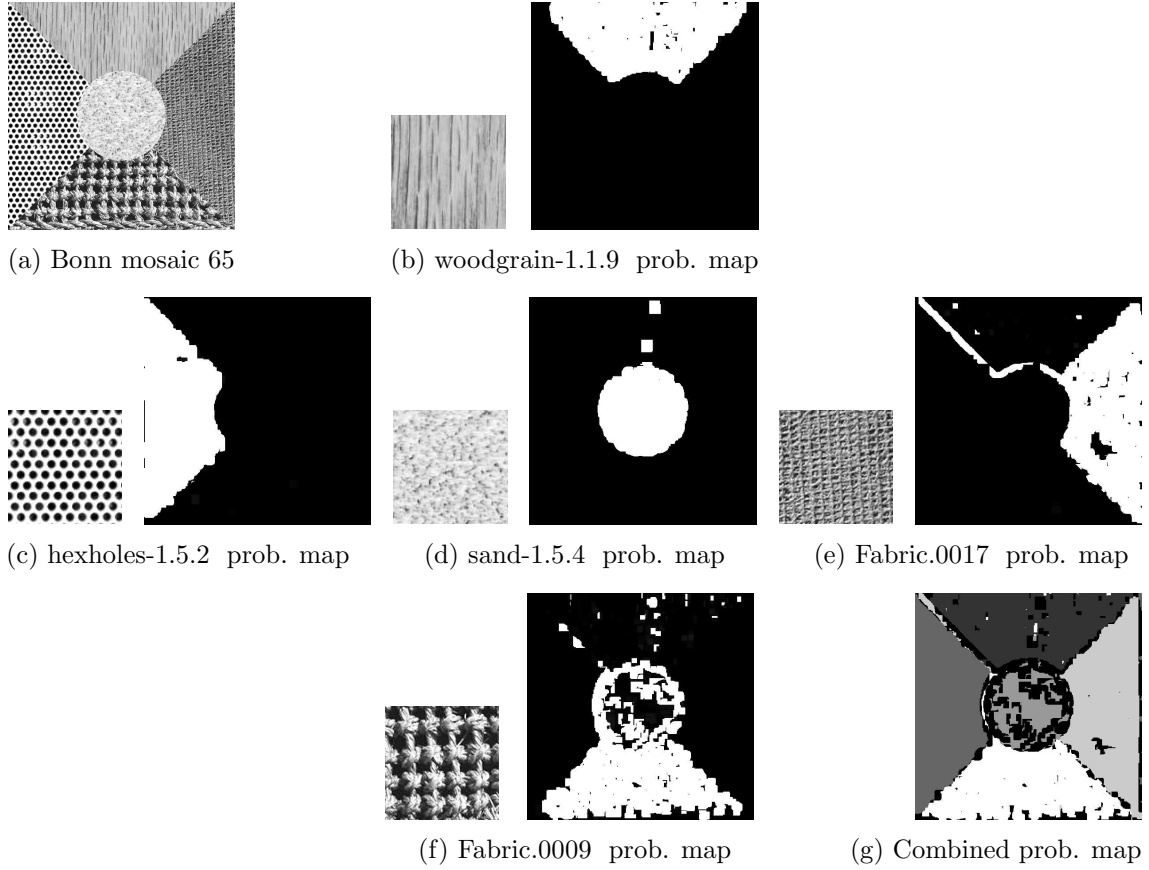
(a) Bonn mosaic 65

(b) woodgrain-1.1.9 prob. map

(c) hexholes-1.5.2 prob. map

(d) sand-1.5.4 prob. map

(e) Fabric.0017 prob. map

(f) Fabric.0009 prob. map

(g) Combined prob. map

Figure C.22: Open ended texture classification of Bonn mosaic 65: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture woodgrain-1.1.9; (c) probability map with respect to training texture hexholes-1.5.2; (d) probability map with respect to training texture sand-1.5.4; (e) probability map with respect to training texture Fabric.0017; (f) probability map with respect to training texture Fabric.0009; (g) combined probability map.
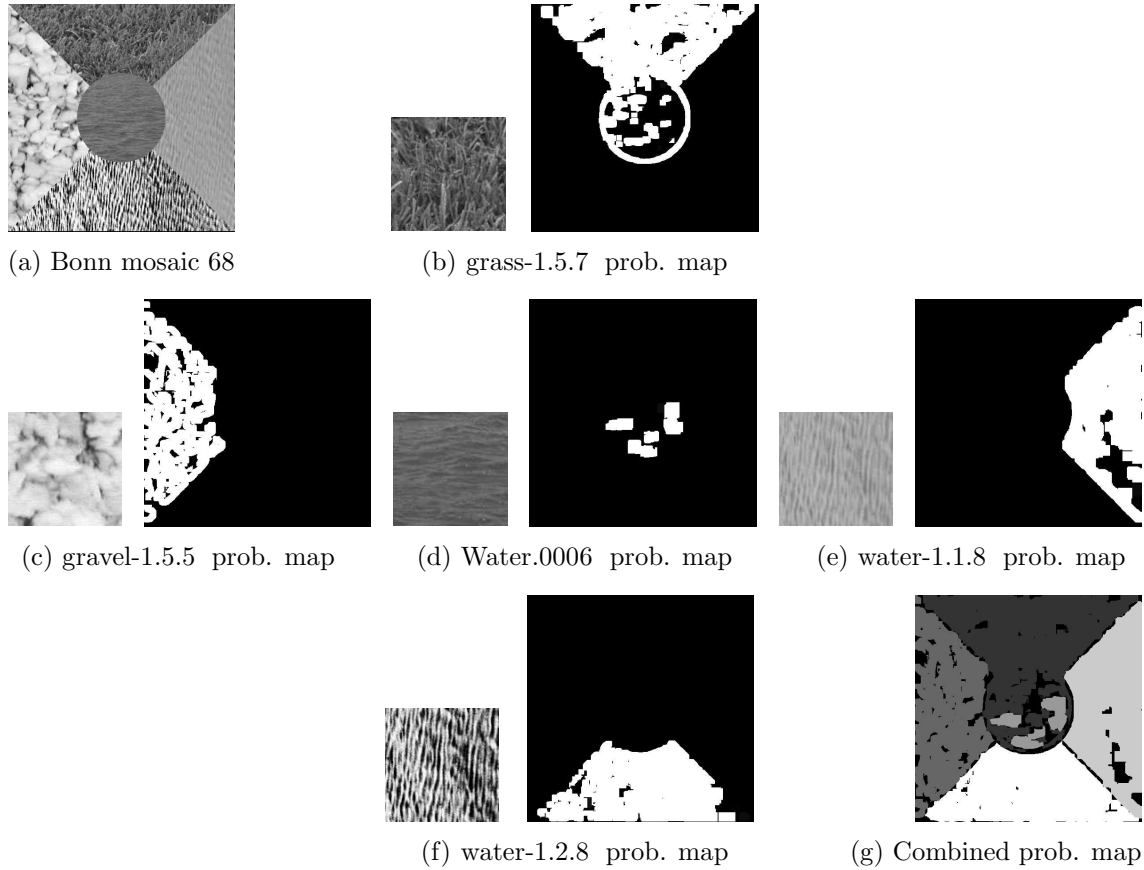
(a) Bonn mosaic 68   (b) grass-1.5.7 prob. map

(c) gravel-1.5.5 prob. map   (d) Water.0006 prob. map   (e) water-1.1.8 prob. map

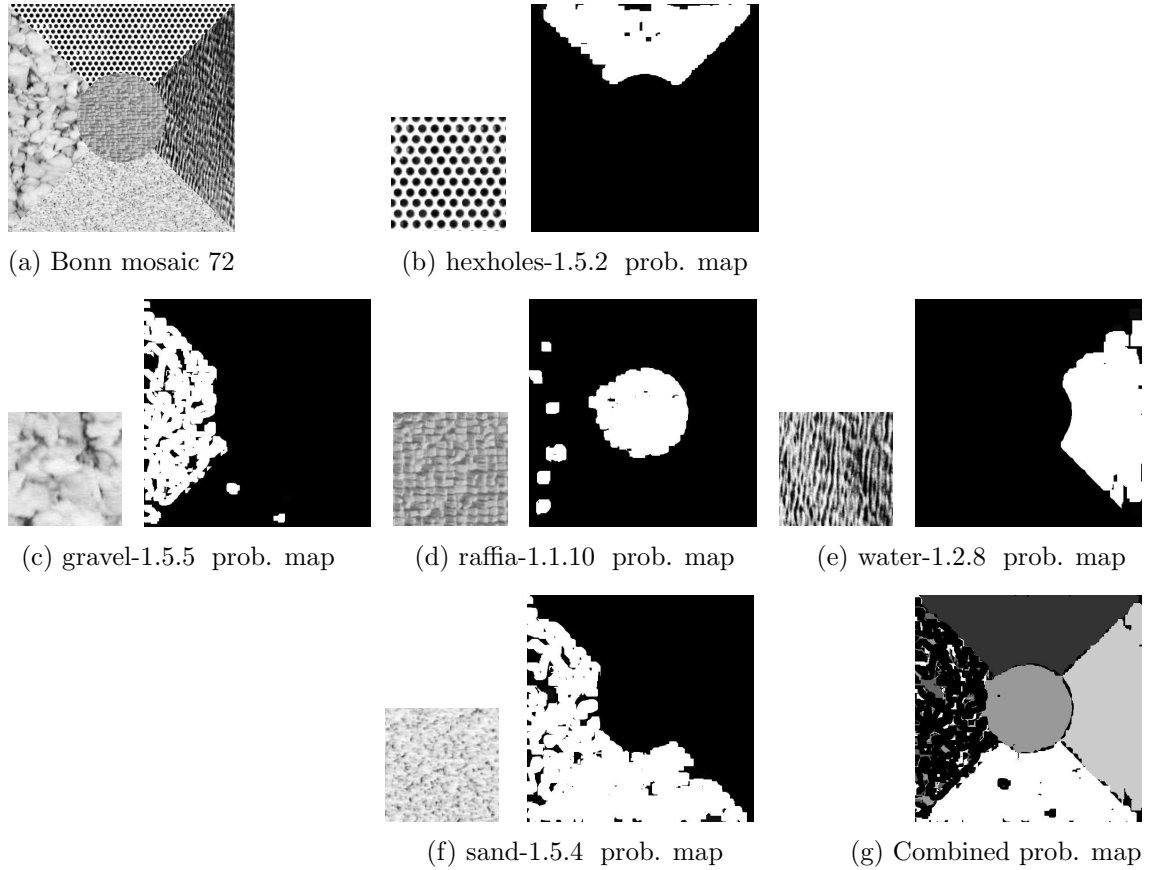(f) water-1.2.8 prob. map   (g) Combined prob. map

Figure C.23: Open ended texture classification of Bonn mosaic 68: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture grass-1.5.7; (c) probability map with respect to training texture gravel-1.5.5; (d) probability map with respect to training texture Water.0006; (e) probability map with respect to training texture water-1.1.8; (f) probability map with respect to training texture water-1.2.8; (g) combined probability map.
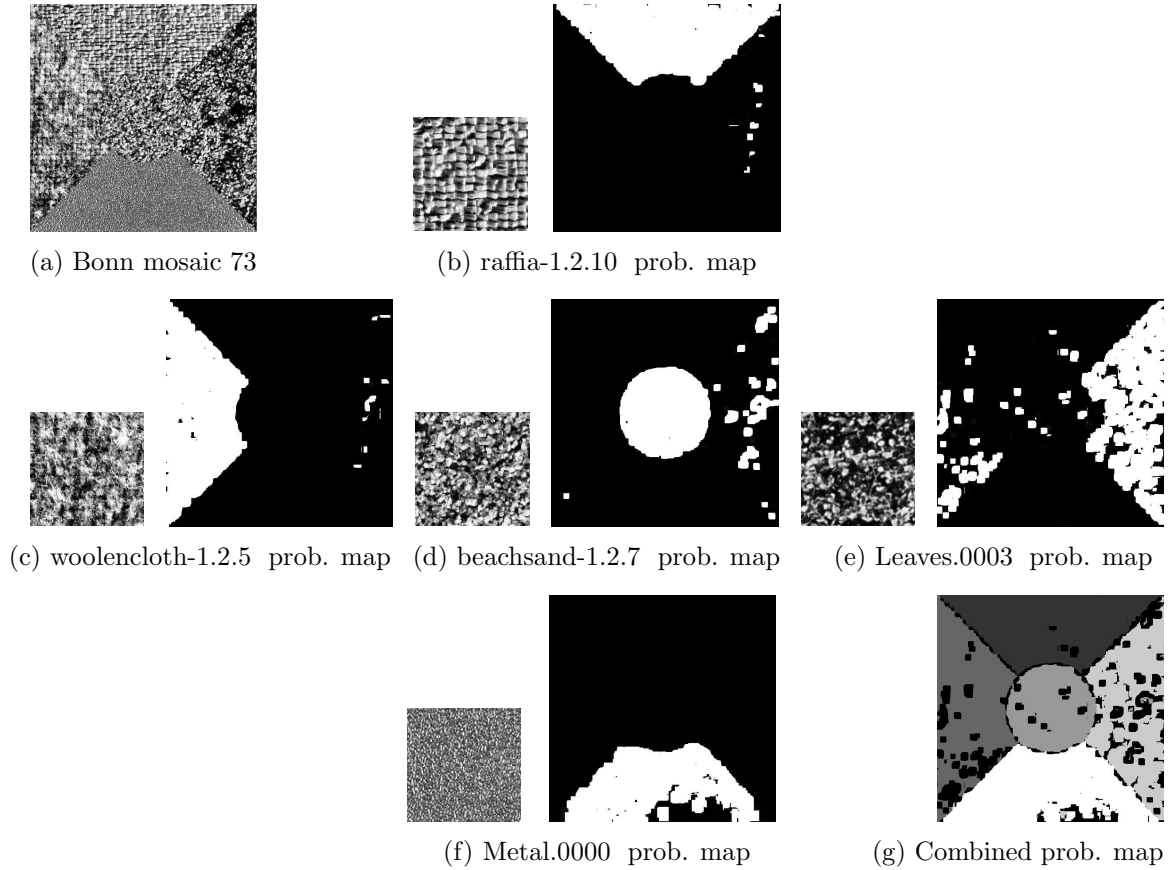
(a) Bonn mosaic 72

(b) hexholes-1.5.2 prob. map

(c) gravel-1.5.5 prob. map

(d) raffia-1.1.10 prob. map

(e) water-1.2.8 prob. map

(f) sand-1.5.4 prob. map

(g) Combined prob. map

Figure C.24: Open ended texture classification of Bonn mosaic 72: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture hexholes-1.5.2; (c) probability map with respect to training texture gravel-1.5.5; (d) probability map with respect to training texture raffia-1.1.10; (e) probability map with respect to training texture water-1.2.8; (f) probability map with respect to training texture sand-1.5.4; (g) combined probability map.

(a) Bonn mosaic 73   (b) raffia-1.2.10 prob. map

(c) woolencloth-1.2.5 prob. map   (d) beachsand-1.2.7 prob. map   (e) Leaves.0003 prob. map

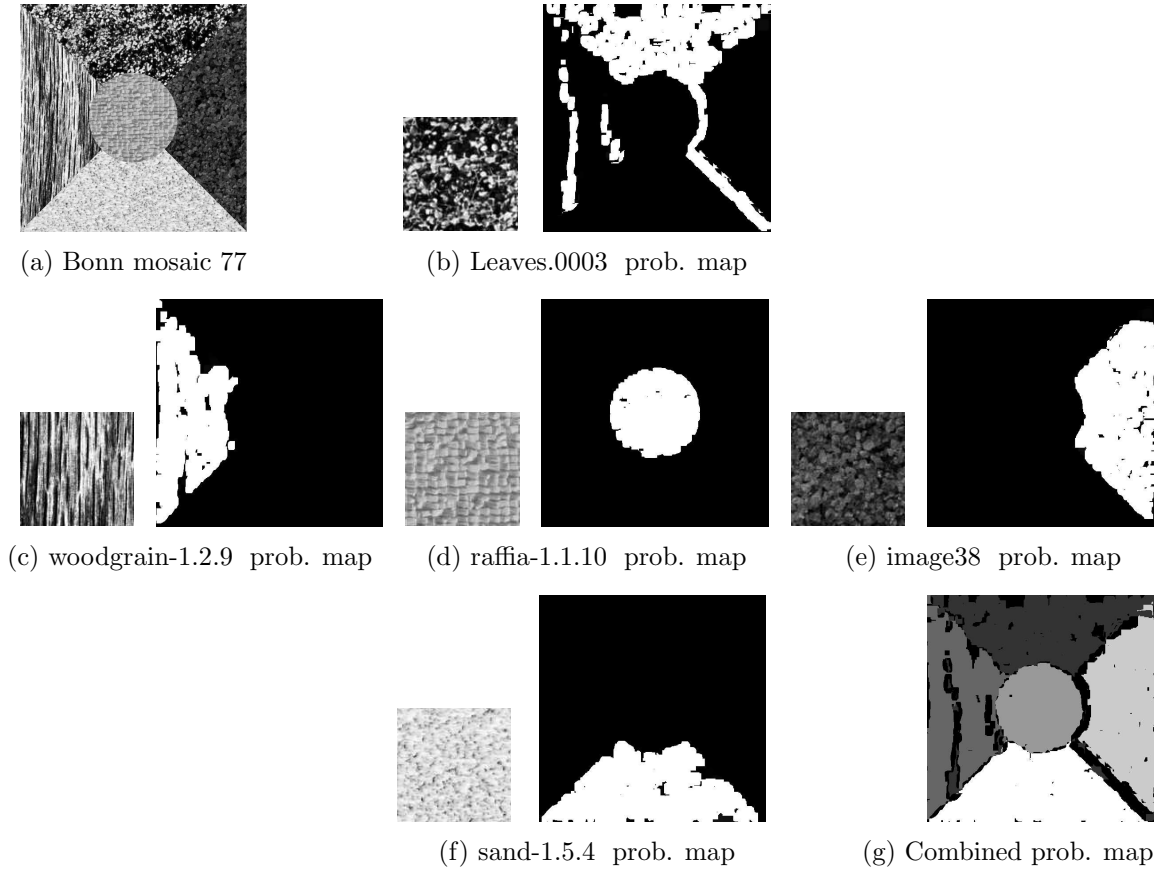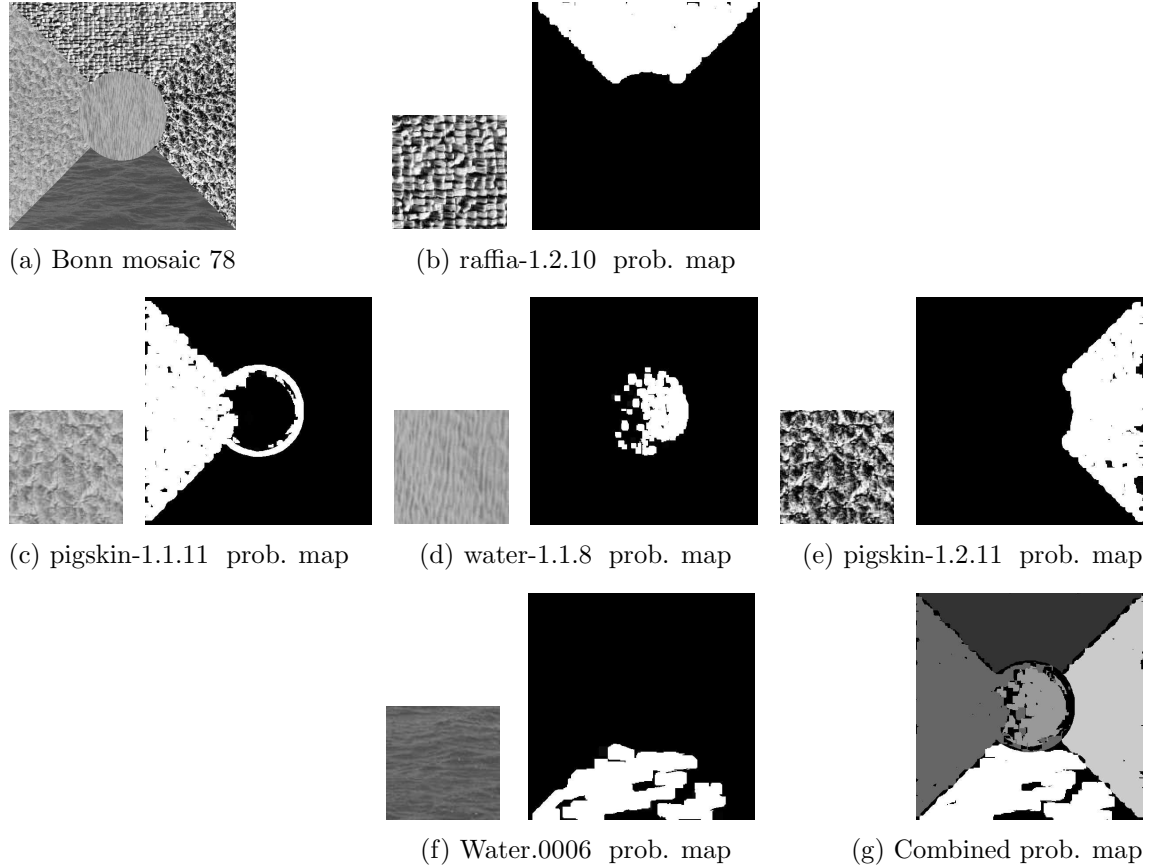(f) Metal.0000 prob. map   (g) Combined prob. map

Figure C.25: Open ended texture classification of Bonn mosaic 73: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture raffia-1.2.10; (c) probability map with respect to training texture woolencloth-1.2.5; (d) probability map with respect to training texture beachsand-1.2.7; (e) probability map with respect to training texture Leaves.0003; (f) probability map with respect to training texture Metal.0000; (g) combined probability map.

(a) Bonn mosaic 77

(b) Leaves.0003 prob. map

(c) woodgrain-1.2.9 prob. map

(d) raffia-1.1.10 prob. map

(e) image38 prob. map

(f) sand-1.5.4 prob. map

(g) Combined prob. map

Figure C.26: Open ended texture classification of Bonn mosaic 77: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture Leaves.0003; (c) probability map with respect to training texture woodgrain-1.2.9; (d) probability map with respect to training texture raffia-1.1.10; (e) probability map with respect to training texture image38; (f) probability map with respect to training texture sand-1.5.4; (g) combined probability map.

(a) Bonn mosaic 78

(b) raffia-1.2.10 prob. map

(c) pigskin-1.1.11 prob. map

(d) water-1.1.8 prob. map

(e) pigskin-1.2.11 prob. map

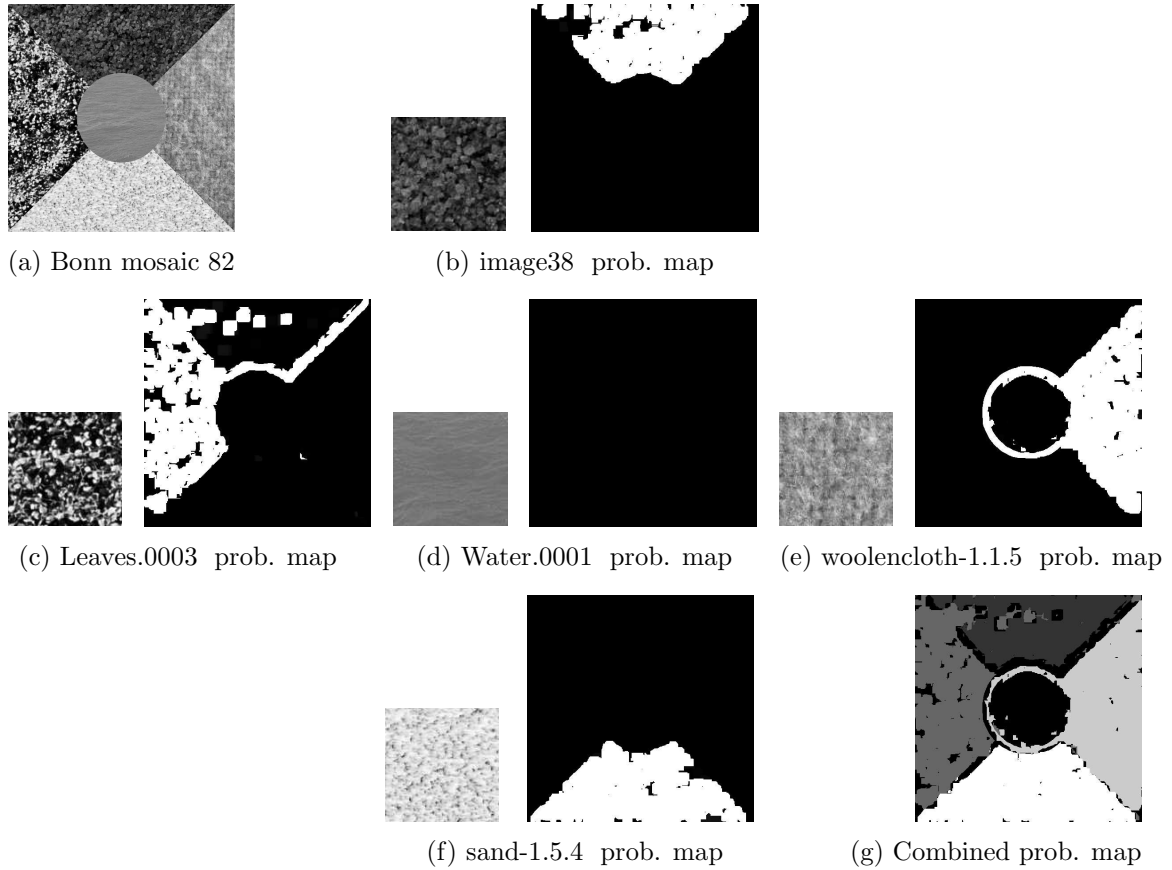(f) Water.0006 prob. map

(g) Combined prob. map

Figure C.27: Open ended texture classification of Bonn mosaic 78: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture raffia-1.2.10; (c) probability map with respect to training texture pigskin-1.1.11; (d) probability map with respect to training texture water-1.1.8; (e) probability map with respect to training texture pigskin-1.2.11; (f) probability map with respect to training texture Water.0006; (g) combined probability map.

(a) Bonn mosaic 82

(b) image38 prob. map

(c) Leaves.0003 prob. map

(d) Water.0001 prob. map

(e) woolencloth-1.1.5 prob. map
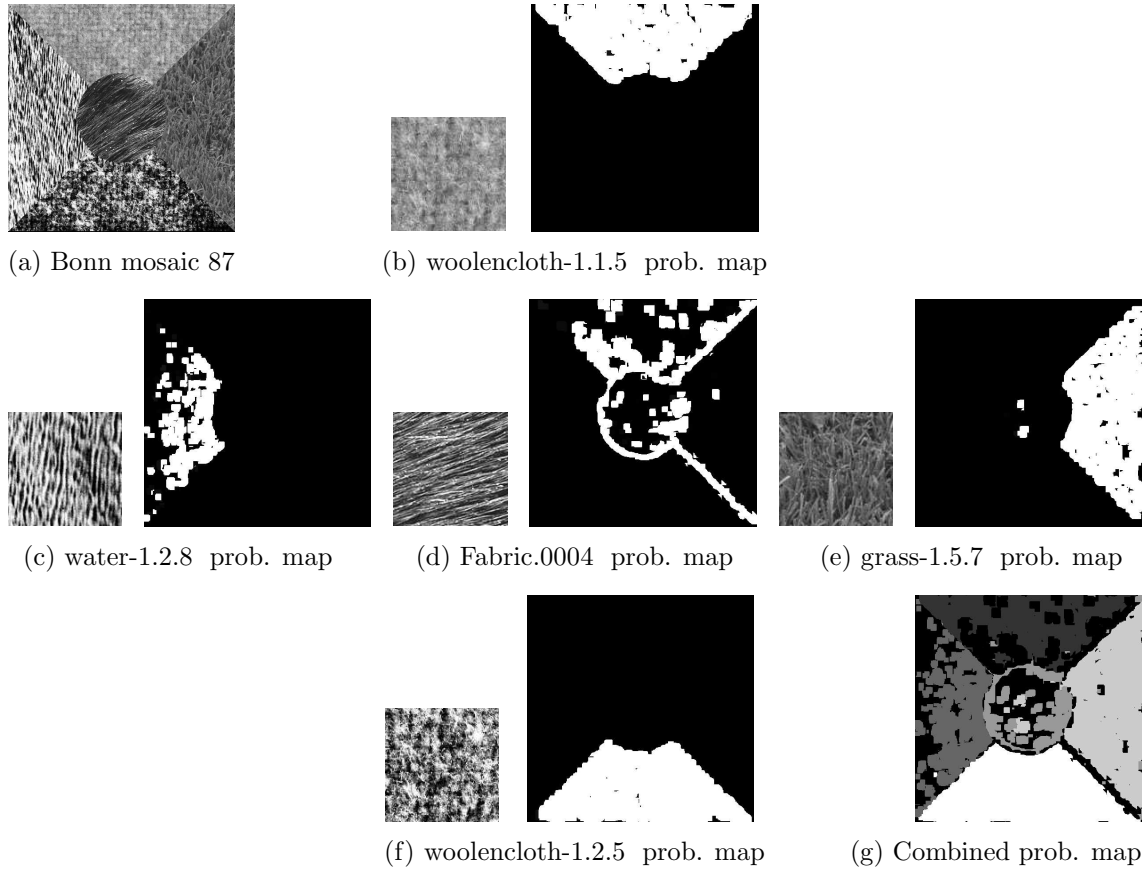
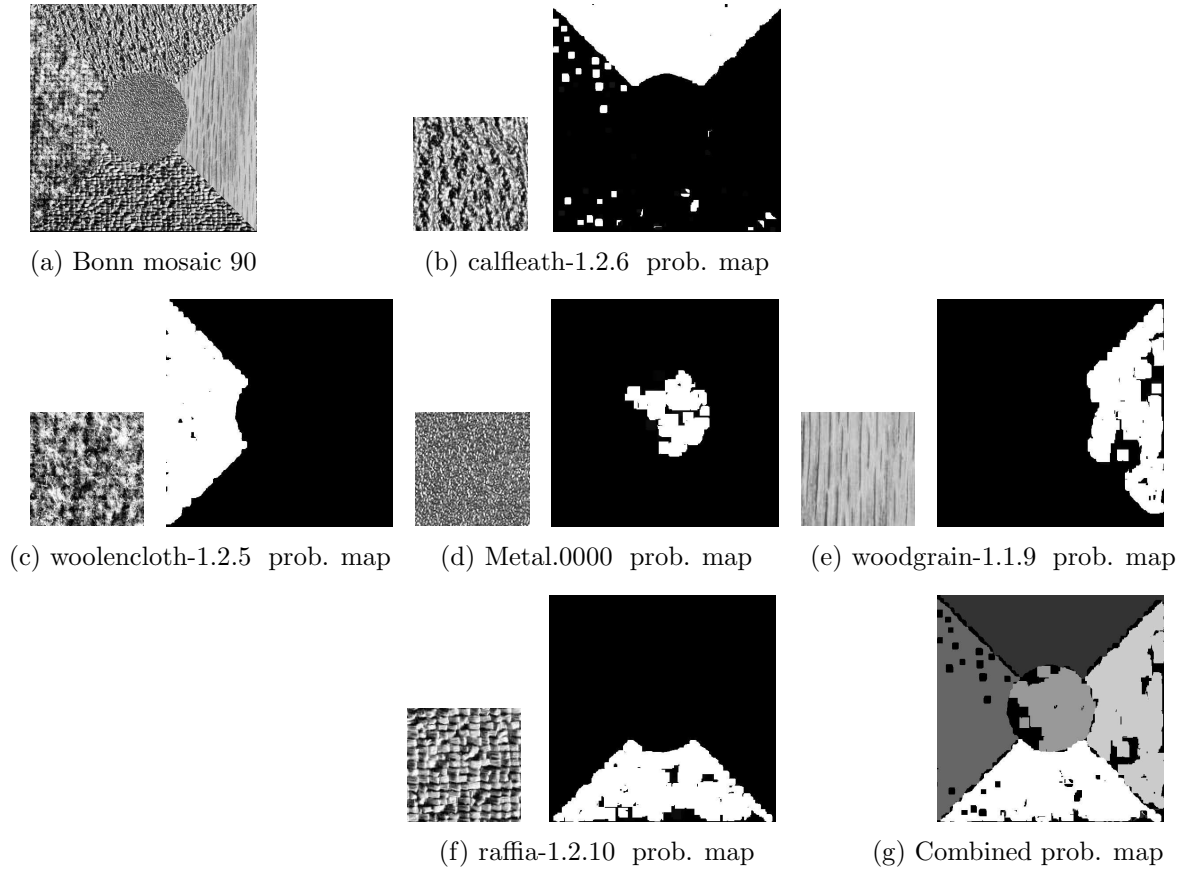(f) sand-1.5.4 prob. map

(g) Combined prob. map

Figure C.28: Open ended texture classification of Bonn mosaic 82: (a) original
512×512 image; (b–f) probability maps with respect to a 128×128 image of training
texture; (b) probability map with respect to training texture image38; (c) probability
map with respect to training texture Leaves.0003; (d) probability map with respect
to training texture Water.0001; (e) probability map with respect to training texture
woolencloth-1.1.5; (f) probability map with respect to training texture sand-1.5.4;
(g) combined probability map.

(a) Bonn mosaic 87

(b) woolencloth-1.1.5 prob. map

(c) water-1.2.8 prob. map

(d) Fabric.0004 prob. map

(e) grass-1.5.7 prob. map

(f) woolencloth-1.2.5 prob. map

(g) Combined prob. map
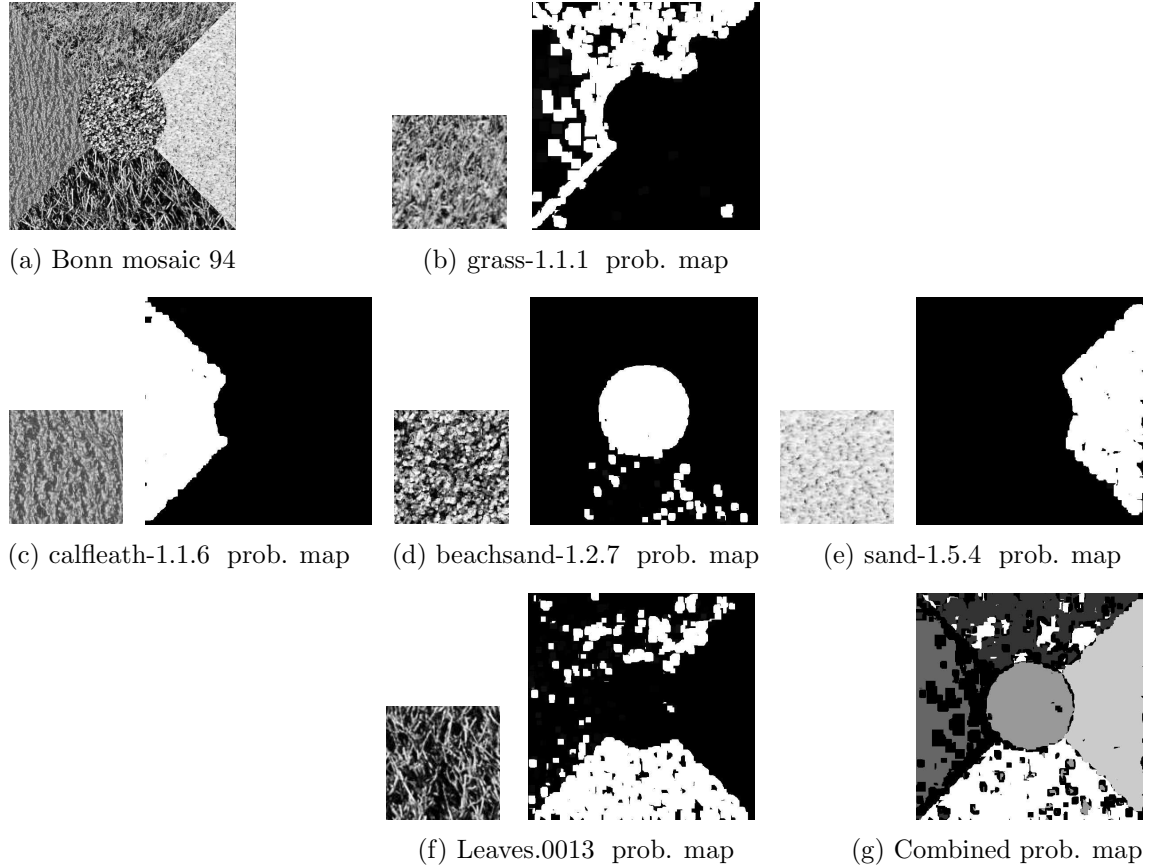
Figure C.29: Open ended texture classification of Bonn mosaic 87: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture woolencloth-1.1.5; (c) probability map with respect to training texture water-1.2.8; (d) probability map with respect to training texture Fabric.0004; (e) probability map with respect to training texture grass-1.5.7; (f) probability map with respect to training texture woolencloth-1.2.5; (g) combined probability map.

(a) Bonn mosaic 90

(b) calfleath-1.2.6 prob. map

(c) woolencloth-1.2.5 prob. map

(d) Metal.0000 prob. map

(e) woodgrain-1.1.9 prob. map
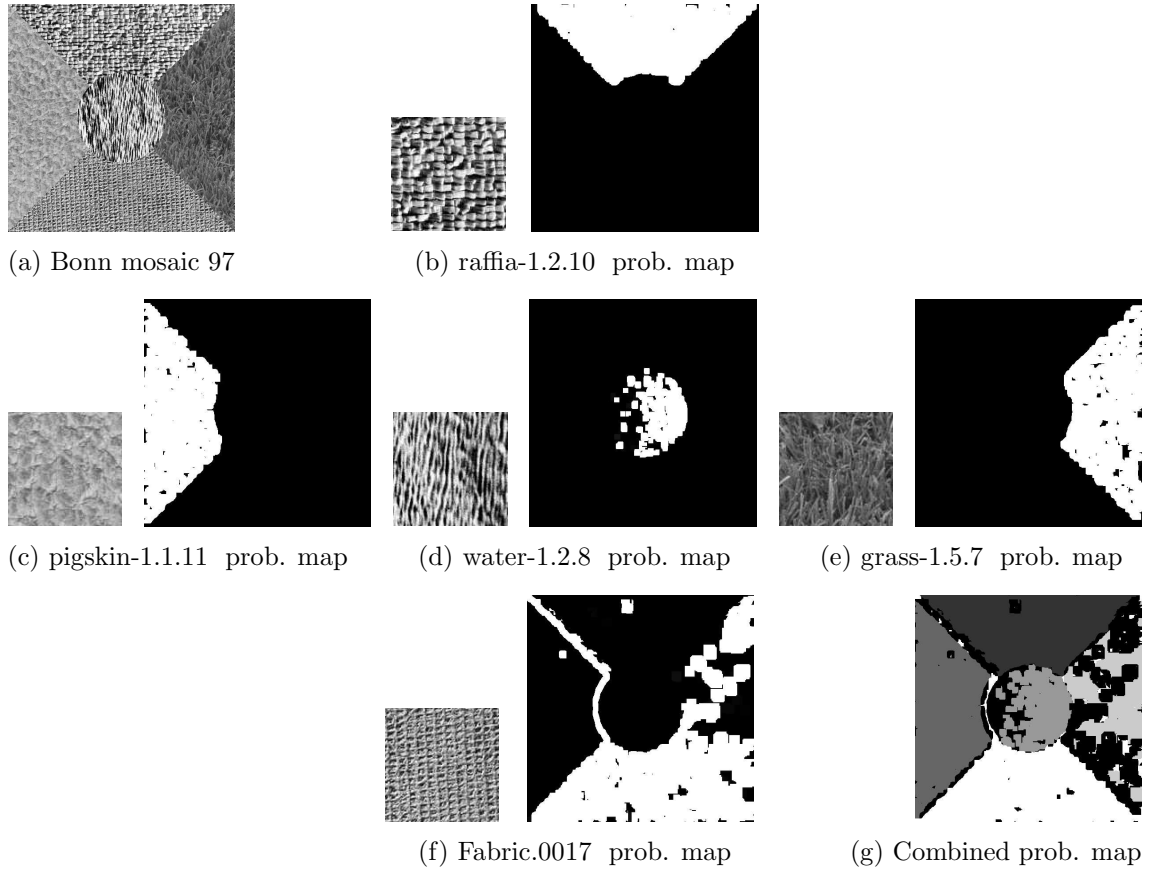
(f) raffia-1.2.10 prob. map

(g) Combined prob. map

Figure C.30: Open ended texture classification of Bonn mosaic 90: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture calfleath-1.2.6; (c) probability map with respect to training texture woolencloth-1.2.5; (d) probability map with respect to training texture Metal.0000; (e) probability map with respect to training texture woodgrain-1.1.9; (f) probability map with respect to training texture raffia-1.2.10; (g) combined probability map.

(a) Bonn mosaic 94

(b) grass-1.1.1 prob. map

(c) calfleath-1.1.6 prob. map

(d) beachsand-1.2.7 prob. map

(e) sand-1.5.4 prob. map

(f) Leaves.0013 prob. map

(g) Combined prob. map

Figure C.31: Open ended texture classification of Bonn mosaic 94: (a) original
512×512 image; (b–f) probability maps with respect to a 128×128 image of
training texture; (b) probability map with respect to training texture grass-1.1.1;
(c) probability map with respect to training texture calfleath-1.1.6; (d) probability
map with respect to training texture beachsand-1.2.7; (e) probability map with
respect to training texture sand-1.5.4; (f) probability map with respect to training
texture Leaves.0013; (g) combined probability map.

(a) Bonn mosaic 97

(b) raffia-1.2.10 prob. map

(c) pigskin-1.1.11 prob. map

(d) water-1.2.8 prob. map

(e) grass-1.5.7 prob. map

(f) Fabric.0017 prob. map

(g) Combined prob. map

Figure C.32: Open ended texture classification of Bonn mosaic 97: (a) original 512×512 image; (b–f) probability maps with respect to a 128×128 image of training texture; (b) probability map with respect to training texture raffia-1.2.10; (c) probability map with respect to training texture pigskin-1.1.11; (d) probability map with respect to training texture water-1.2.8; (e) probability map with respect to training texture grass-1.5.7; (f) probability map with respect to training texture Fabric.0017; (g) combined probability map.

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