Pyramidal Ice Crystals

In Chapter 8 we saw how to calculate halo radii from wedge angles. Then in Chapter 9 we saw how to calculate the wedge angles using crystallographic principles, much as Steinmetz and Weickmann had done. None of this would be convincing if the calculated halo radii were not consistent with the observed radii of real halos or if the calculated wedge angles were not consistent with the observed wedge angles of real ice crystals. And indeed not everyone was convinced by the results of Steinmetz and Weickmann. At that time, however, there were no photographs of odd radius halos and only a few photographs of pyramidal ice crystals. In Chapter 8, with the benefit of recent photographs, we examined several halo displays and found encouraging agreement between the predicted radii of the halos and the actual radii. Now we will look at some real pyramidal ice crystals. We will see that the real crystals do indeed look like the hypothetical crystal of Steinmetz and Weickmann.

In fact the resemblance is clear at a glance. Compare Figure 9.5, showing the hypothetical crystal, with almost any of the pyramidal crystals shown in the present chapter. Remember that the sizes of the crystal faces relative to one another are immaterial, so in Figure 10.4, for example, it is all right that one of the basal faces on the pyramidal crystal is small, and it is all right that half the pyramid faces are missing. What matters is the orientations of the faces relative to one another, and the orientations do indeed look right.

To get a more quantitative feeling for the resemblance between the hypothetical and the real, we need to introduce another angle, denoted by x'. Recall that angle x is the angle between the crystal axis and an inclined (i.e., pyramid) face. Angle x' is the angle between the crystal axis and an inclined *edge.* In the crystal photos it is normally x', rather than x, that can be measured. That is, no

pyramid face is apt to be seen edge-on, as would be necessary for measuring x. But if the crystal is lying on one of its prism faces, then the crystal axis and an inclined edge will both be parallel to the plane of the photo, so that x' can be measured. Angle x' is as good as angle x, in the sense that each determines all wedge angles of the crystal.

For our hypothetical crystal, with $x = 28°$, the theoretical value of x' turns out to be 31.5°. We have marked angles of 31.5° in the crystal photos in Figure 10.6. We stress that the 31.5° angle is the angle between the line segments in the photos, and that the line segments are not necessarily exactly parallel to the relevant crystal edges. However, in most cases we think the parallelism is nearly perfect and that therefore x' is indeed very nearly 31.5°.

So the agreement between the hypothetical crystal and the real crystals is quite good. You may be suspicious that the crystal photos came first, and that we then concocted the hypothetical crystal, but historically it was the reverse, or nearly so.

The pyramidal crystals of this chapter should be contrasted with the bullet crystals of Figure 2.7. The tapered surfaces of bullets are not true pyramidal faces and in fact are not even planar. Pyramidal crystals make odd radius halos, bullet crystals do not.

Large pyramidal crystals often come with some very strange looking company. Many of the crystals in that company nearly defy description, even in a good photograph, but there are others that we can make at least limited sense of. Figure 10.2 illustrates one type. There the left-hand crystal, a pyramid crystal, has shallow depressions in some of its faces, so that the faces are not perfectly planar. This gives a clue as to what is going on with the right-hand crystal. It, too, is a pyramid crystal, but the depressions now are veritable pits, nearly destroying the identity of the crystal. Nevertheless, the pits probably show where the pyramid faces would have been, had the crystal been better formed. Another example of this sort of pitted pyramid is the upper left crystal in Figure 10.12. Such crystals look at first like old crystals, badly deteriorated, perhaps blown up from the snow surface, but our experience is that they are not. Incidentally, we do not mean to imply that the pits have been somehow excavated in the faces. Rather the crystal growth in the centers of the faces simply cannot keep up with the growth along the edges.

It is clear from photos like Figure 10.2 that not all ice crystals have perfectly planar faces, and that the Miller index crystallography of Chapter 9 sometimes fails to describe real crystals. The failure can be only slight, as for the left-hand crystal, or it can be dramatic, as for the right. Of course you needn't go to pyramid crystals to see this failure. Ordinary column crystals often have indentations in their basal faces, and although in some crystals these indentations conform to

Miller index crystallography, as in the left center photo of Figure 2.6, where the indentation surfaces consist of stepped prism and basal faces, in other crystals the indentations are curved, as in the left center photo of Figure 2.5. Even the familiar stellar crystals often have curved basal "faces." This is obvious for the lower right crystal in Figure 2.1 and more subtle in the crystals of Figure 2.8. In the latter figure the basal face of the left-hand crystal is truly planar in the center, but then it tapers towards the edges, leaving tiny or non-existent prism faces. The basal faces of the right-hand crystal are truly planar nowhere.

Of the crystals shown in this chapter, those in the lower left photo of Figure 10.6 and in Figures 10.13–10.16 are from Fairbanks, Alaska, and the rest are from the South Pole. In many cases the Fairbanks crystals formed and grew in moisture from power plant plumes. Because of these special conditions, it is conceivable that the crystals themselves are somewhat special and not representative of crystals grown at normal cloud levels in the atmosphere. We do not think so—we are guessing that the pyramidal and more exotic crystals are due mainly to the low temperatures rather than, say, to contaminants in the plumes. But we may be wrong, and the possibility needs to be entertained that these crystals are special. If so, then the halos that they make might also be special.[1]

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[1] Low level halo displays in Fairbanks appear in Figures 8.3, 8.4, 8.5, 8.14, 8.16, 15.2, 15.3, 15.4, 15.10, 15.11, 15.12, 15.13, 15.17, 15.18, 15.20, 18.8.
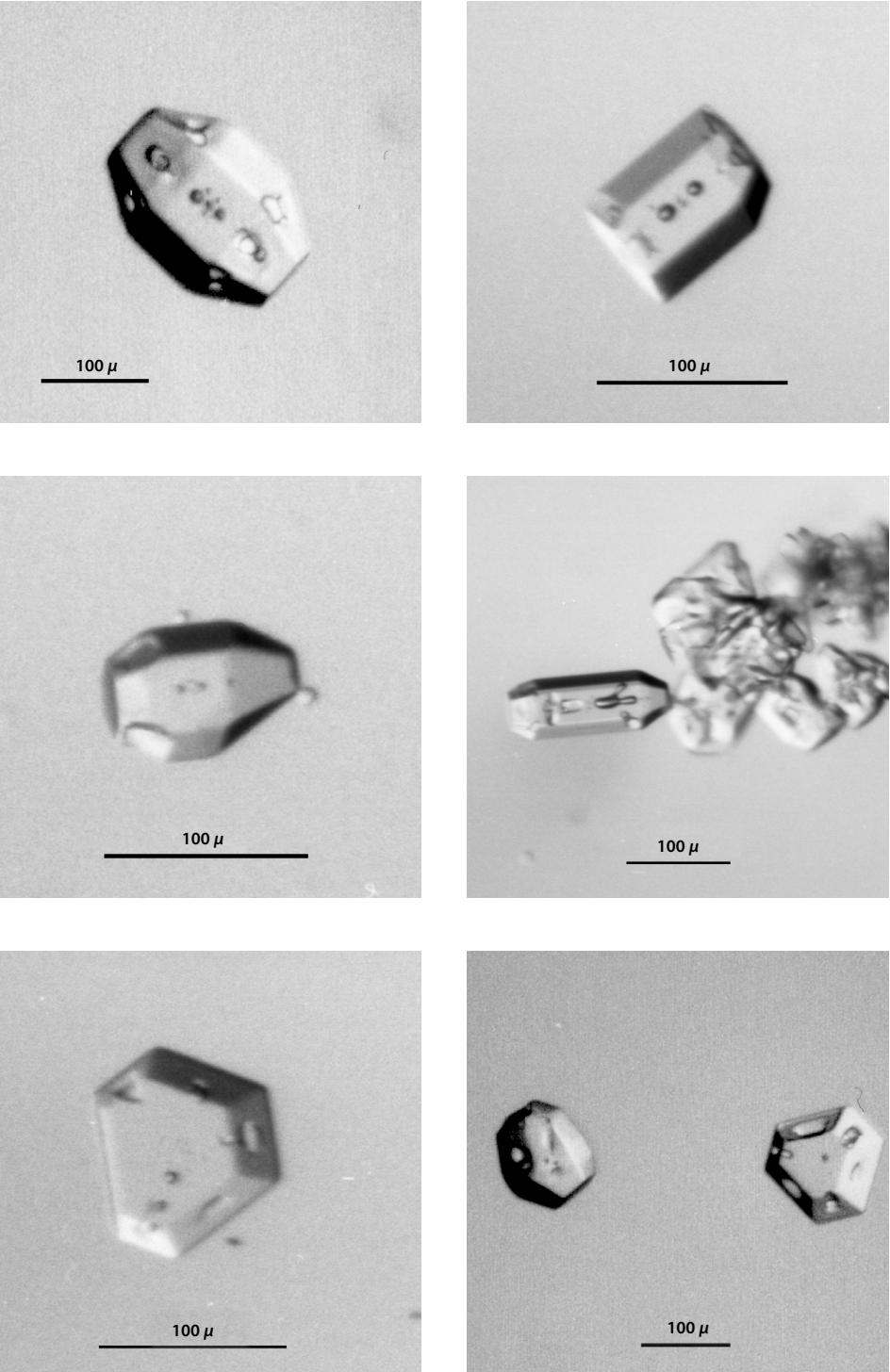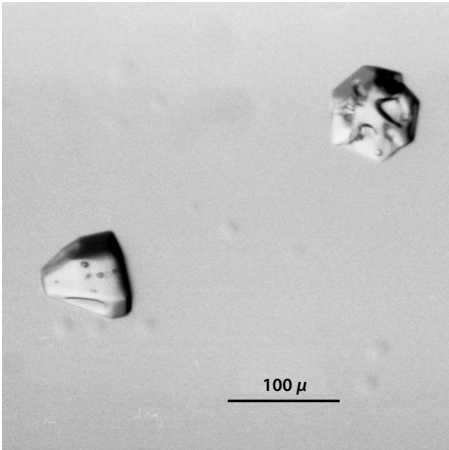
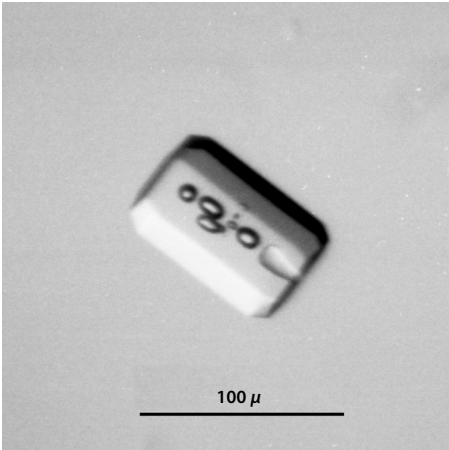**FIGURE 10.1**   Pyramid crystals.

FIGURE 10.2   Pyramid crystals.

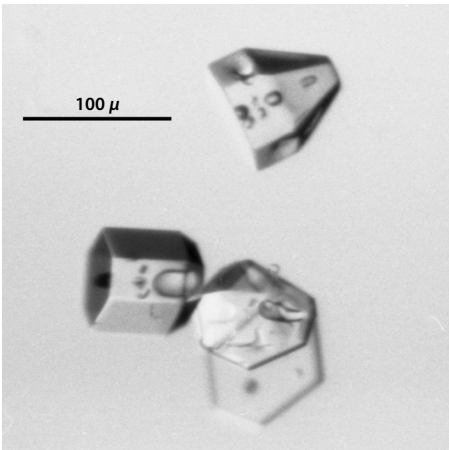**FIGURE 10.3**   Tiny pyramid faces.

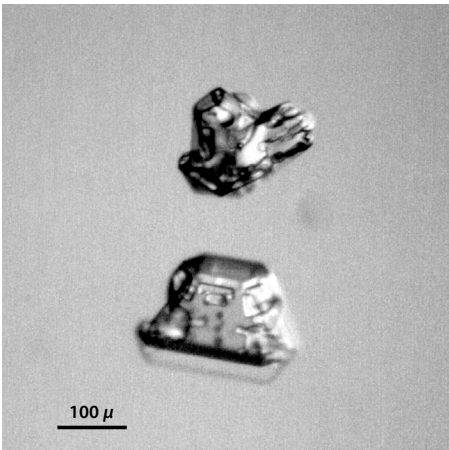**FIGURE 10.4**   Pyramid crystal above.
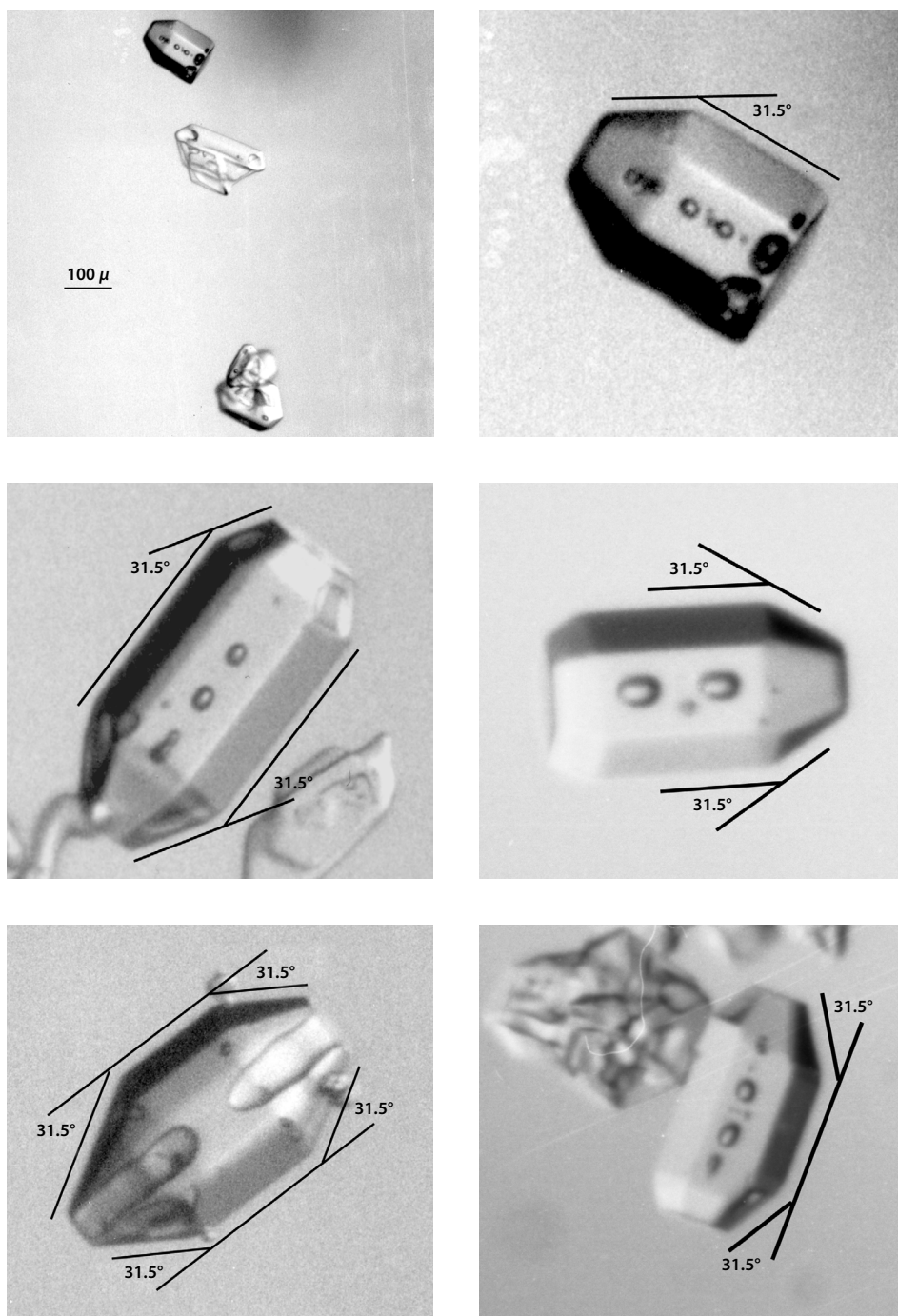

FIGURE 10.5   Pyramid crystal below.

FIGURE 10.6   Pyramid crystals. Line segments have been placed as nearly parallel as possible to crystal edges, but with the angle between line segments fixed at 31.5°. The value 31.5° is the theoretical value for the angle *x'* between appropriate *edges* on a crystal whose pyramidal faces are the {10$\bar{1}$1} faces. The crystals are from 100 to 180 microns in length.
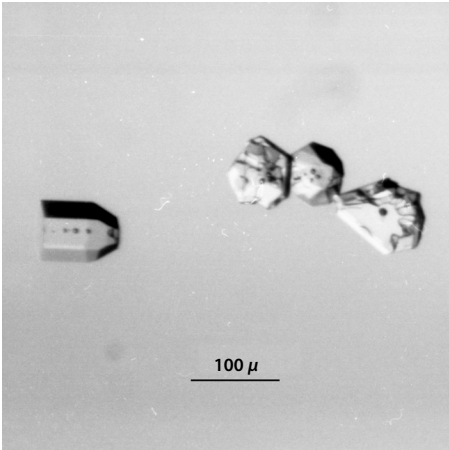
FIGURE 10.7   Pyramid crystal at left.
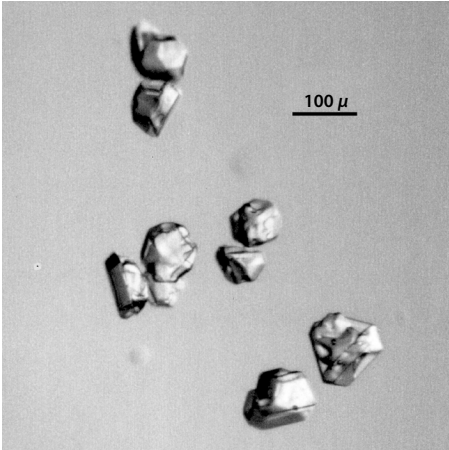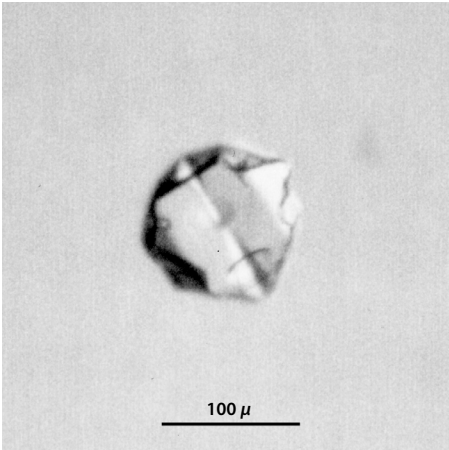

FIGURE 10.8   Complex crystals often assoc-
iated with pyramid crystals.

FIGURE 10.9   Twinned crystal? Such crystals
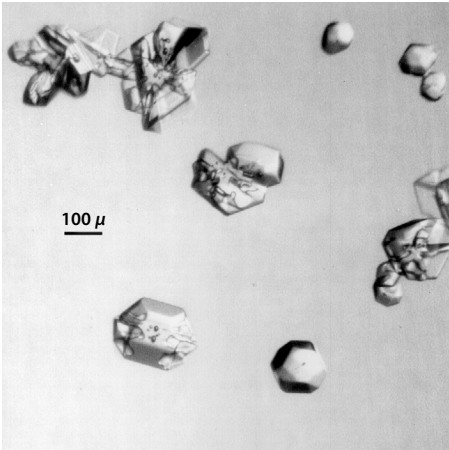often occur with pyramid crystals.

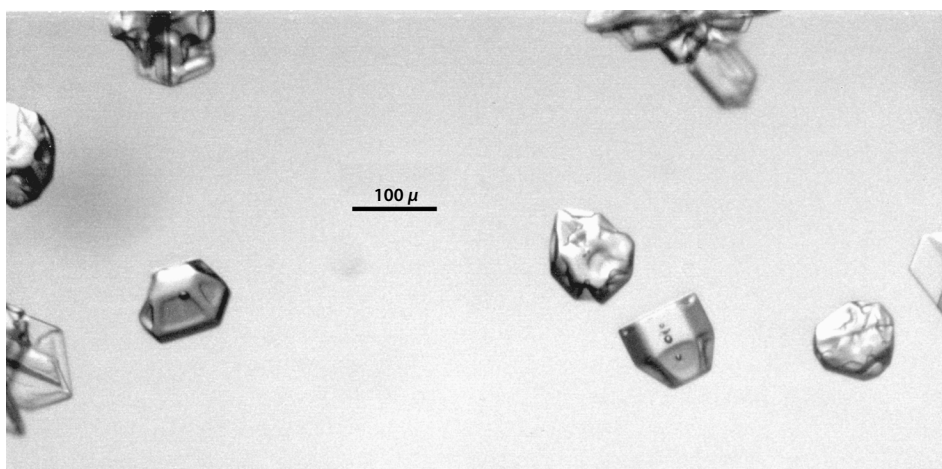**FIGURE 10.10**   Twinned crystal at lower left?

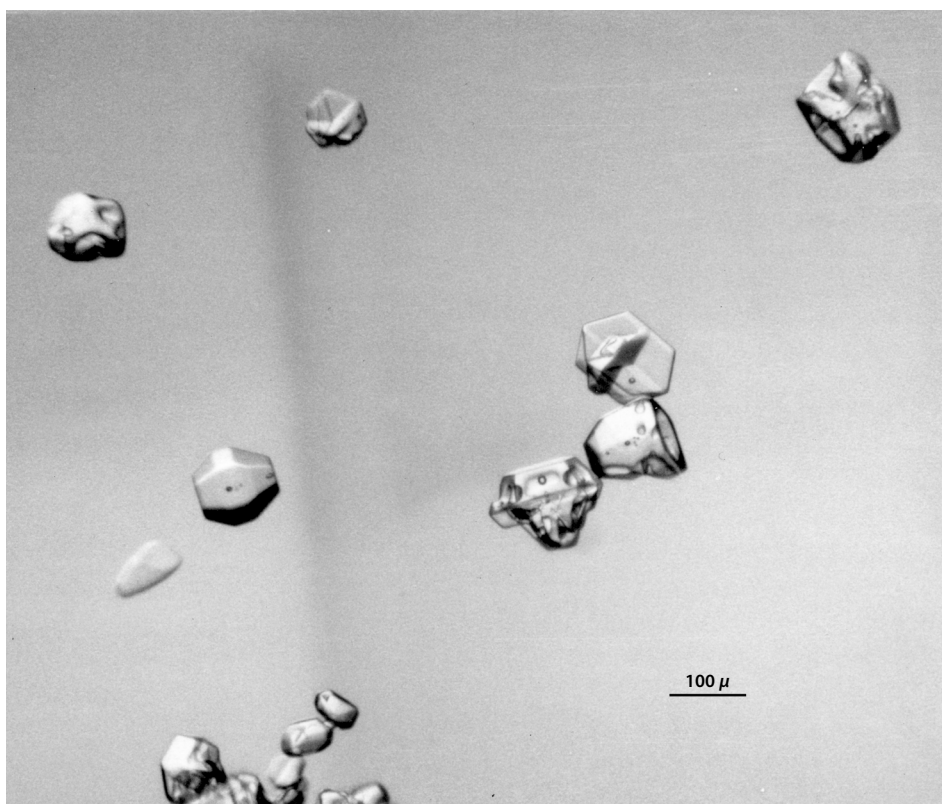**FIGURE 10.11**   Two pyramid crystals among more exotic crystals.

FIGURE 10.12   Well formed pyramid crystal among more exotic crystals.
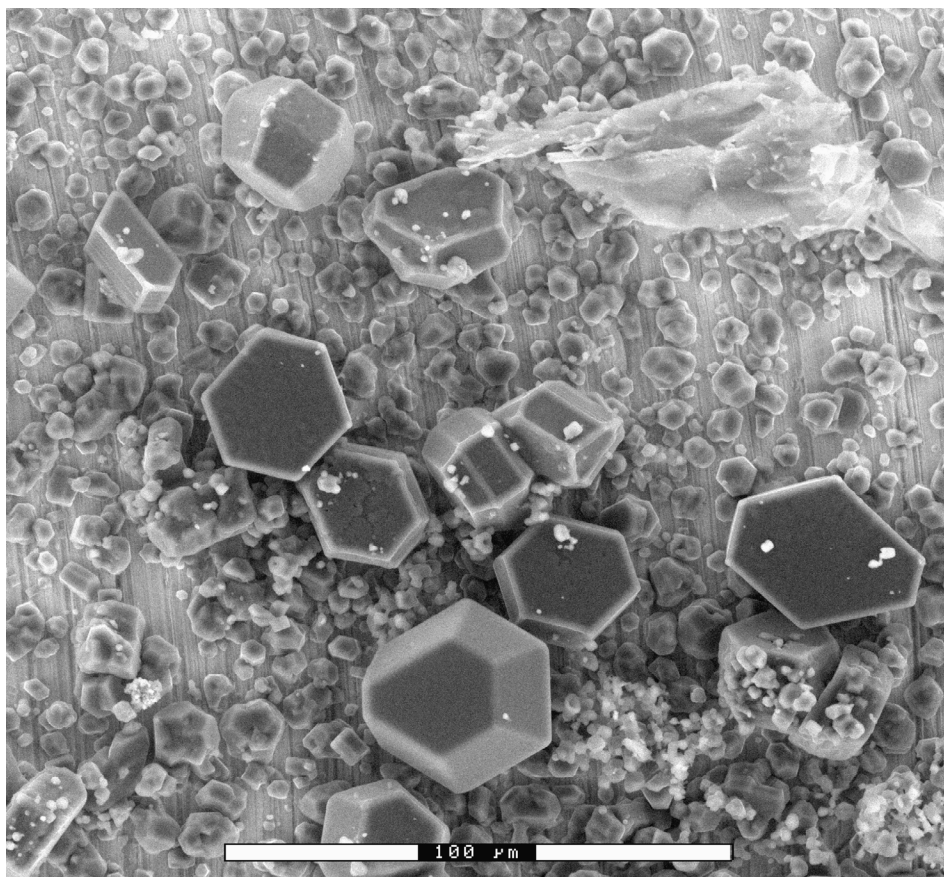
FIGURE 10.13 ESEM photo of atmospheric ice crystals collected in Fairbanks. Probably only the larger crystals here are big enough to make halos. The wispy object at upper right is extraneous. The 100μ label refers to the entire scale bar—black and white together. Photo © Kenneth P. Severin.
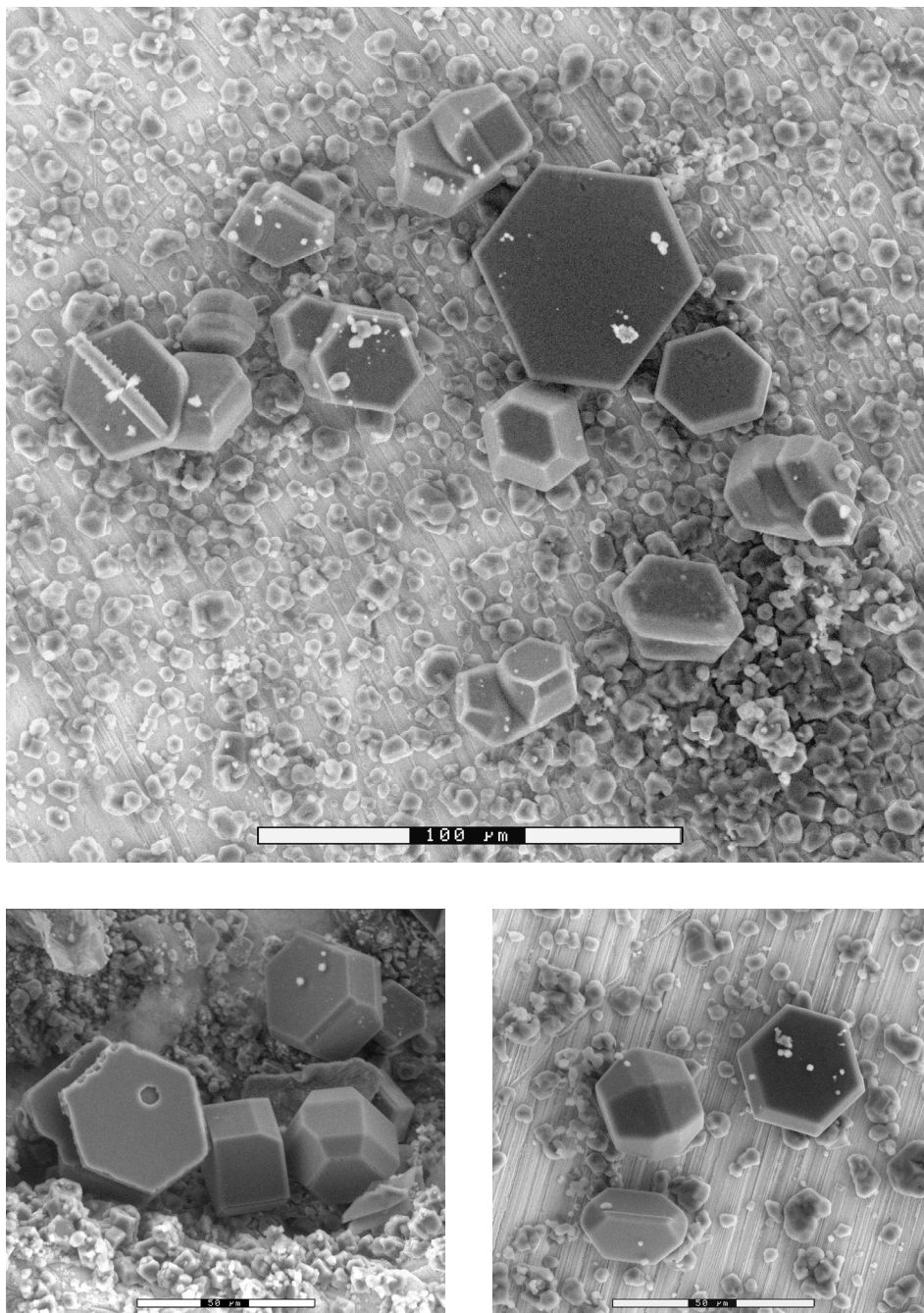
FIGURE 10.14 Crystals from the same crystal sample as in Figure 10.13. In the upper photo the black and white scale bar is 100μ, and in the lower photos, 50μ. The evident crystal damage is probably due to the electron beam. Photos © Kenneth P. Severin.
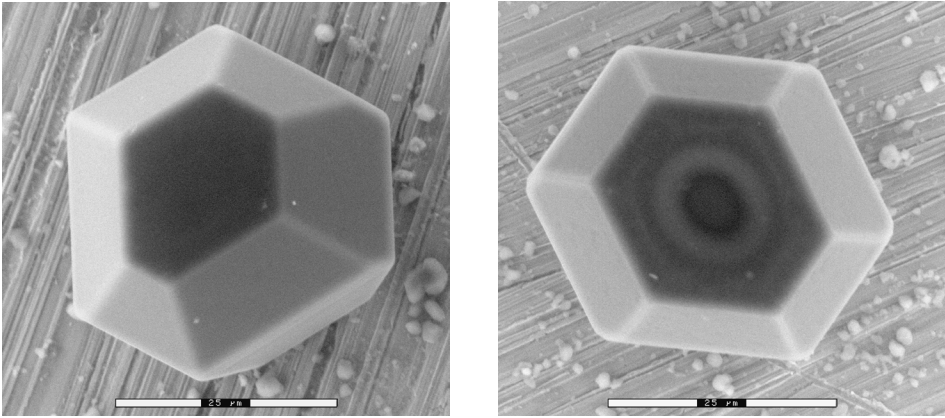
FIGURE 10.15   Pyramid crystals, both from the same crystal sample. At the right the view is looking directly down the *c*-axis. The black and white scale bar is 25*μ*. Photos © Kenneth P. Severin.
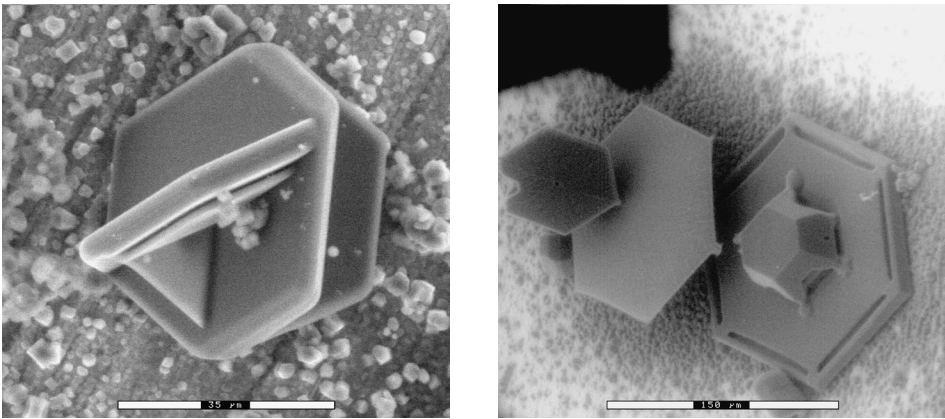

FIGURE 10.16   Crossed pyramidal plate crystal at left. Our experience is that most crossed plate crystals, when seen with the ESEM, turn out to be crossed pyramidal plates. The crystal with the pyramidal faces at the right is not a common type and will go unnamed. The black and white scale bar is 35*μ* at left, 150*μ* at right. Photos © Kenneth P. Severin.