



## Chapter 13

# Image-Processing Using Photoshop and Other Tools

[Of the lost detail in the darkest and lightest areas of a photograph due to the limited dynamic range of photographic film]: “strong shadows swallow up all timid lights within them, as her blazing lights obliterate all intrustive halftones across; and thus strong contrasts are produced, which, so far from being true to Nature, it seems one of Nature’s most beautiful provisions to prevent.”

— Lady Elizabeth Eastlake in her essay “Photography”, *London Quarterly Review*, pgs. 442–468 (1857); reprinted in *Classic Essays on Photography*, ed. by Alan Trachtenberg (ed.), Leete’s Books, New Haven (1980).

### 13.1 Introduction: Scientific Applications of Photoshop and Other Image-Processing Tools

1. Text, arrow, and other annotations of photographs.
2. Deleting unwanted background elements from photographs or scans.
3. Removing “stray light” damage from scans of books, journals or xerox copies.
4. Decolorizing a photo so as to create a black-and-white image that is cheap to publish.
5. Contrast enhancement.
6. Inverting images
7. Reducing the bits/pixel to make Web-publishable graphs.

### 13.2 Annotated Photo

Fig. 13.1 is a picture of Mars, taken on December 11, 1999 from the Mars Global Surveyor in orbit around the planet. For more than a year, the science team had noticed lots and lots of dark streaks on the planet’s surface. It is known that dust devils, which are miniature tornados made visible by entrained dust, are very common on Mars.

The desert-like conditions create convective instability; with even a modest amount of horizontal shear in the wind, the convective plumes can spin up into concentrated whirlwinds. But were dust devils really responsible for the streaks?

The figure answered their questions. The bright patch is a dust devil, photographed from almost directly above. The shadow shows its true columnar shape and the dark curve to the right of the dust devil is exactly the kind of streak that had been seen so often in earlier photographs.

However, without arrows and captions, the photograph is gibberish. The Mars Camera Science Team knew that, seen directly above from orbit, a whirling column of dust would look like a bright streak, but this is hardly obvious to the casual observer. Similar, the shadow is hard to tell from the streak. Only because this photograph was annotated by the Science Team using both arrows and text does the photograph become comprehensible. One can then immediately identify the key features and concentrate on the crucial question: Is the Science Team's interpretation reasonable?

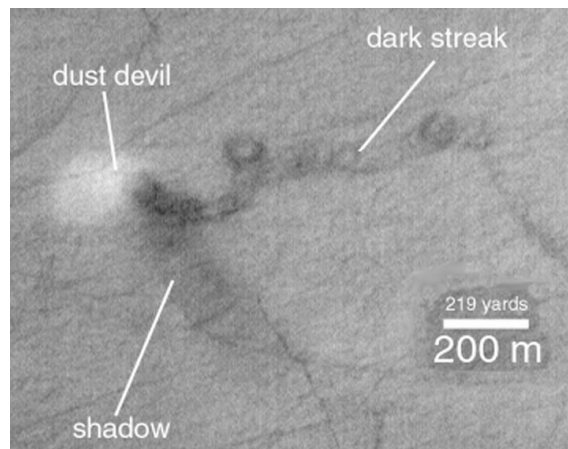


Figure 13.1: Annotated photograph of the Promethei Terra region of Mars, taken from Mars Global Surveyor. The dust devil is less than 100 meters (less than 100 yards) wide and the picture covers an area approximately (about 1 by 1 mile). The text annotations are by the Mars Science Team. The image was opened in Photoshop and cropped to a width of 1.3 km and height of 1 km from its original 1.5 by 1.7 kilometers size; the scale was moved to fit within the cropped image. Mars Orbit Camera (MOC) Team: M. C. Malin, K. S. Edgett, M. H. Carr, G. E. Danielson, M. E. Davies, W. K. Hartmann, A. P. Ingersoll, P. B. James, H. Masursky, A. S. McEwen, L. A. Soderblom, P. Thomas, J. Veverka, M. A. Caplinger, M. A. Ravine, T. A. Soulanille, and J. L. Warren, NASA's Planetary Photojournal (<http://photojournal.jpl.nasa.gov/>), MOC2-220-C.

### 13.3 Before and After Scientific Photos

Fig. 13.2 illustrates a cutaway of the earth's interior temperature which was made with a rather garish black background. It is easy to cut away the black in Photoshop. The "elliptical selection marquee" can be constrained to be a circle by holding down the shift key; it can be constrained to draw from the center of the globe by starting the drag at that point while holding down the Option key. The selection can then be inverted to select everything *outside* the globe by going to the **Select** menu and choosing **Inverse**.

Thus, the background outside the circle can be deleted in about thirty seconds, but the maneuver is so easy only because Photoshop has powerful selection tools (circle, draw-from-center, inverse).

### 13.3.1 Removing Unwanted or Irrelevant Graphical Elements

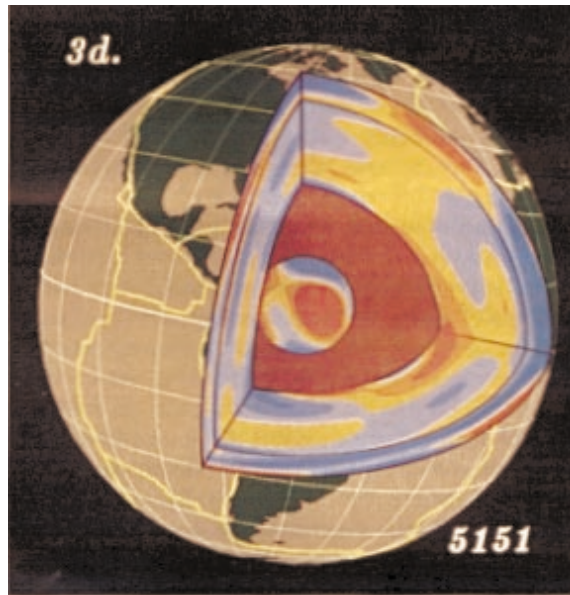


Figure 13.2: Cross-section from the outer mantle to the inner core. Blue areas are cold, dense, and transmit seismic waves at relatively high speeds. Red regions are hot and light. Plot generated by Adam Dziewonski and John Woodhouse.



Figure 13.3: Same as previous figure but with the black background excised in Photoshop.



Figure 13.4: A photograph taken through the Isaac Newton Telescope in the Canary Islands, showing a 1.5 million kilometer string of nuclei of Comet Shoemaker-Levy, 15 May '94, two months before its collision with Jupiter. (M. Irwin, A. Fitzsimmons and I. P. Williams).

Fig. 13.4 shows a telescope photo of Comet Shoemaker-Levy. Like most astronomical photographs, the raw image includes a vast amount of extraneous detail including many background stars. The simplified image was produced by

- Using the polygonal select to delete two large wedges of extraneous material.
- Selecting and then rotating the remaining image.
- Cropping the image using the crop tool, which is similar to the rectangular selection marquee (and can be obtained from it by dragging on the selection marquee item in the tool menu).
- Rubber stamping to eliminate some remaining disks that are *clearly* background stars.
- The contrast was moderately enhanced using a Contrast/Brightness Adjustment Layer.

Rubber-stamping has to be applied carefully; one should only eliminate elements that are clearly extraneous.

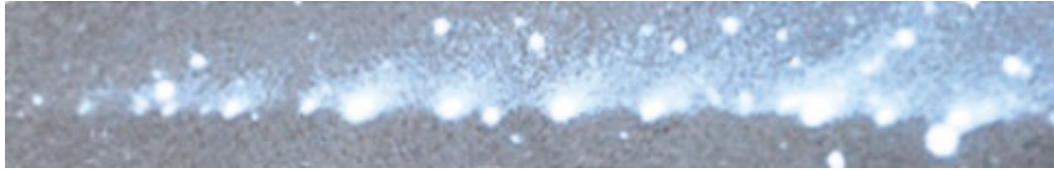


Figure 13.5: Same as previous figure except that extraneous parts of the image have been cut away, a few background stars have been removed by rubber-stamping, and the contrast was slightly enhanced.

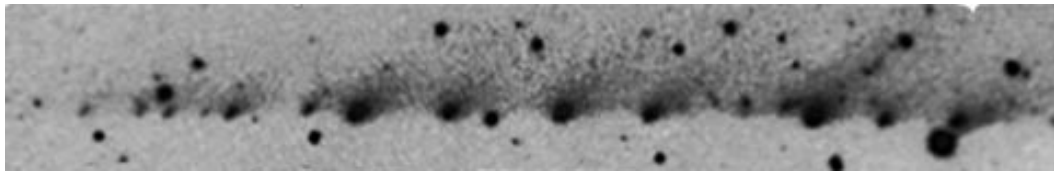


Figure 13.6: Same as previous figure except that black-and-white were inverted. The original image had a histogram that included only the upper half of tonal values. This was changed using an Adjustment Layer/Levels, and then the image made into a negative image through Adjustment Layer/Inverse.



Figure 13.7: Same as the previous negative image, but with Adjustment Layer/Threshold, which stores 1 bit per pixel. File size was reduced from 284 kilobytes to 95 kilobytes (EPS files). However, the tubular tail that extends from the leading nucleus back through the trailing fragments has been eliminated by thresholding. This image is good if one is focusing on nuclei, but disastrous if one wants to investigate the tail!

### 13.3.2 Removing “Stray Light” Damage

Fig. 13.8 shows the result of xeroxing a page of graphs from an ancient journal and then scanning. It is difficult to get good quality xeroxes of pages from a journal because it is impossible to close the cover of the xerox machine. A useful procedure in reducing the amount of stray light is to lay sheets of blank paper or other journal volumes on top of the glass next to the “target”. When the glass is completely covered, the amount of stray light reaching the xerox detector is reduced. If the xerox machine is near a wall, it may be impossible to completely block the wall side. The result is a xerox (and ensuing scan) which are contaminated by large blotches that are the image of stray light.

Photoshop is a good vehicle for removing the “stray light” damage because the damage can be simply erased. In cleaning up this figure, the “polygon-lasso” tool is quite helpful because one can click straight lines to bound the rather irregularly shaped blotches. The “magic wand” is not helpful because the entire image is black, so magic wand selects both the graphs and the noise. The ordinary “lasso” can be used, too, but it is slower because one must manually draw lines nearly parallel to the top and bottom of the page. The eraser is very useful for eliminating blotches that overlap lines of the graph, and thus have to be removed very carefully. Because the eraser has a “brushes” palette available, one can choose various eraser sizes as one works.

### 13.3.3 Contrast Enhancement

Fig. 13.10 shows a photograph from a fluid mechanics laboratory experiment. The contrast between the yellow-tinged vortices and the ambient reddish fluid is very poor. So, we enhanced this figure in Photoshop in the following ways:

- The black wedges in the corner and the outer wall of the tank were eliminated by using the elliptical selection marquee with Shift held down (to constrain it to a circle) and also Option held down (to draw from the center of the tank); the spacebar was held down to allow a slight adjustment of the center of the circle. Finally Select > Inverse was used to select the exterior of a circle centered on the tank, and this exterior was deleted.
- The contrast was enhanced by creating a new Adjustment Layer in the Layer menu, choosing the type of the new layer to be Brightness/Contrast and then adjusting these until the image seemed much clearer. (Adjustment Layer changes are previewed, but not actually applied to the image until “OK” is clicked.)
- The red color was replaced by first selecting the entire image, then Image > Adjust > Replace Color. This brings up a dialog box with a preview area and three eyedroppers. By clicking on the left eyedropper, one can pick a color to be replaced. The middle eyedropper (labeled with a plus sign) can be dragged to add more and more regions of color; the selected areas will be displayed in white in the preview box. One can then choose a new color to replace the old by dragging sliders that are also in the Color Replace dialog box. The red background of zero vorticity was replaced by blue.
- The rubber stamp was used to replace the black photoguide disks by ambient colors. The black disks in the blue regions, for example, were replaced by Option-click on a blue region and then clicking on top of a black disk. A black disk that intruded on a region of yellow streaked with a little orange was replaced by three bands of yellow, orange and yellow by using the rubber stamp with a smaller



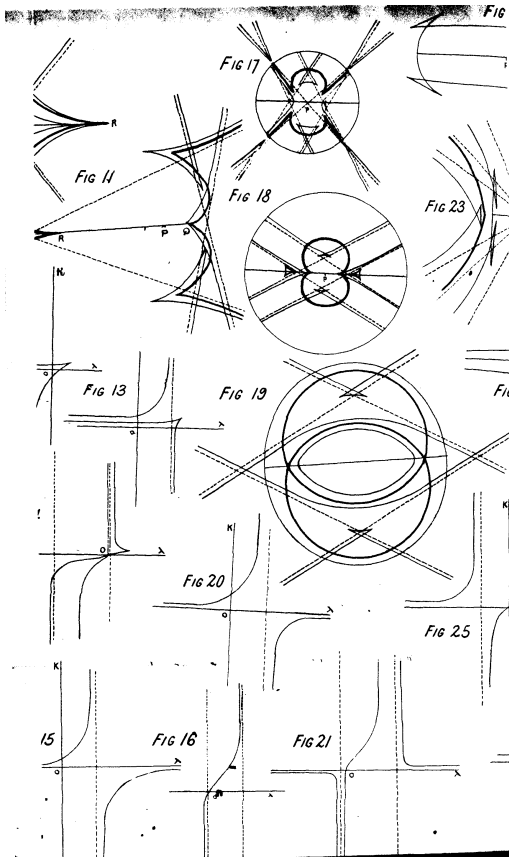


Figure 13.8: Scan of a collection of figures from an 1882 article by Henry M. Jeffrey, F. R. S. The scan was made from a xerox. Unfortunately, the xerox was contaminated by a lot of stray light because the fragile pages of the more-than-a-century old journal could not be easily manipulated without damaging them. The “stray light” damage was fixed in Photoshop as shown in the next figure. This figure is some interest independent of the stray light. First, Jeffrey’s article contained some 84 numbered figures; even in the 19th century, it was possible to use graphics extensively. Second, the figure shows how many graphs can be combined into a single page without loss of clarity, especially for line art. Third, the absence of captions is bad because the reader has to jump constantly between the text and the page with graphs. Fourth, in order to facilitate comparisons between different graphs printed on the same page and perhaps also to reduce the cost of the special printing plates for the graphs, the figures were printed on fold-out pages. These opened up to create pages much larger than the digest-size pages of the rest of the journal. Because all the graphs were crammed onto foldouts, individual figure captions had to be sacrificed.

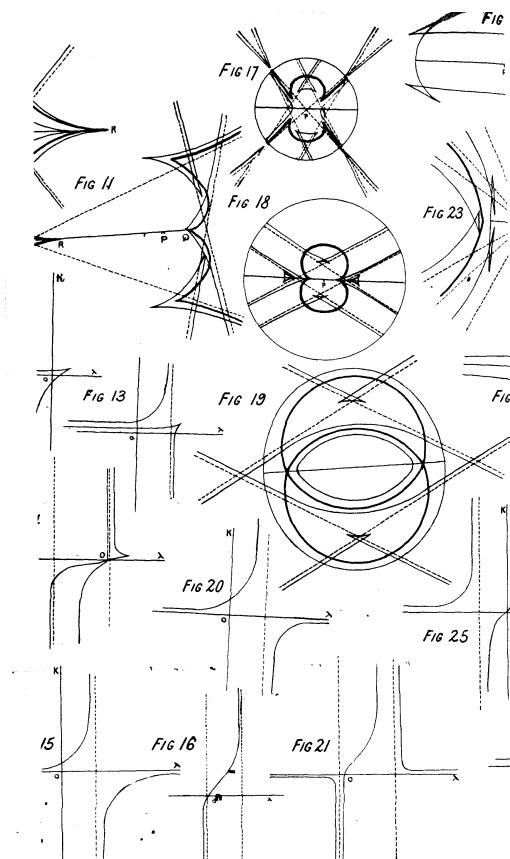


Figure 13.9: Same as previous figure except that the xerox imperfections have been erased using Photoshop.

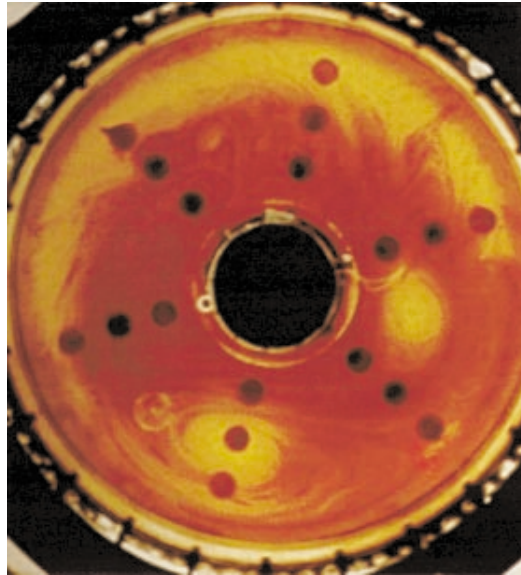


Figure 13.10: Scanned from a photograph of a laboratory fluid tank experiment by Harry Swinney of the University of Texas and collaborators. The yellow patches are vortices; the complete sequence of photos from which this has been taken illustrates the formation of vortices in a shear zone in a tank which is rotating on a turntable, and the subsequent merger of these vortices. The black disks are aids to the measurement of flow properties as the tank rotates and a camera and/or video camera photographs the tank from above.

brush size. Finally, the “stamped” areas were blended more smoothly into their background by applying the “smudge” tool.

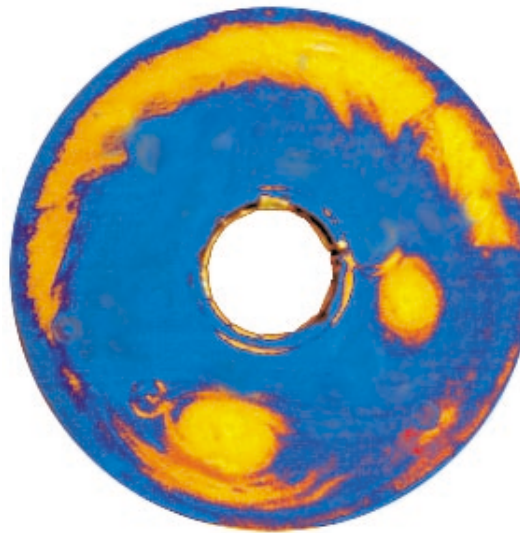


Figure 13.11: Same as previous figure, but “improved” in Photoshop

### 13.3.4 Decolorization

Fig. 13.12 shows a photograph of a laboratory experiment on the collision of two pairs of contra-rotating vortices. If one wanted to publish this photograph in black-and-white, such as would be useful in a theory paper that purported to explain these experiments, how could one do it?

Fig. 13.13 shows the result of converting the color image to a grayscale image. The grayscale image is not entirely successful. The contrast between shades of gray makes it difficult to see the green/orange differences of the original photograph — unfortunate since the colors indicated the origin of the vortices, which have exchanged partners by the time of this post-collision photograph. (In other words, the two green vortices have split up, each leaving the collision with a vortex of opposite sense of rotation from the other vortex pair, which was dyed orange.)

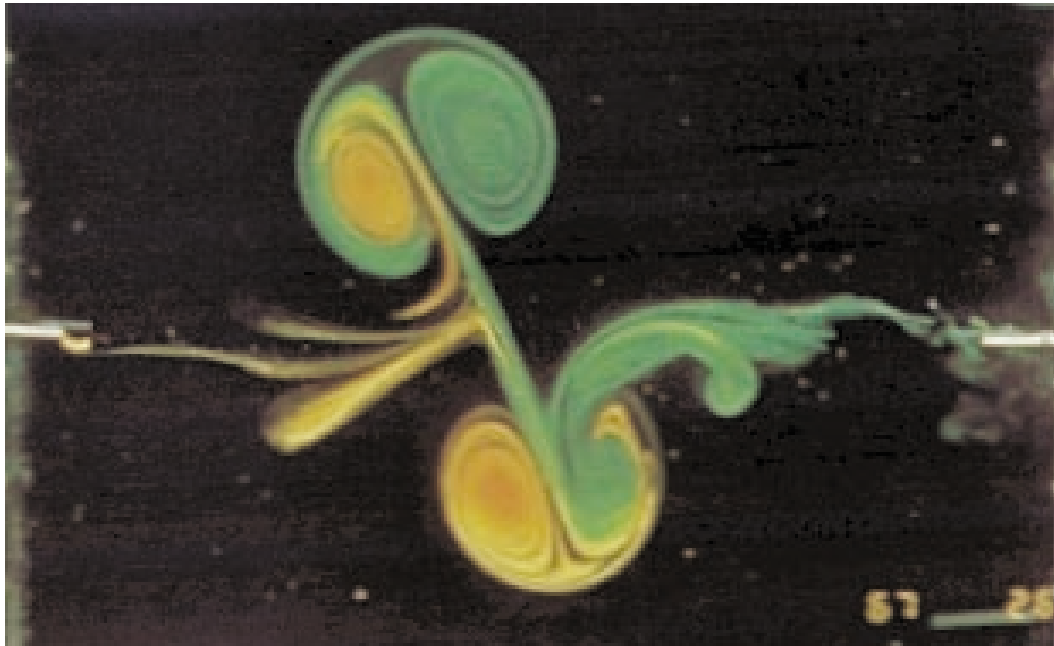


Figure 13.12: Colliding vortex pairs (modons) in a laboratory experiment by GertJan van Heijst and Jan-Bert Flor, published as Plate 18 by Ball(1999). The image was scanned from a photograph of the rotating tank; green and orange fluorescent dyes were used to mark each of the two initial vortex pairs, which have collided and exchanged partners at the time shown.

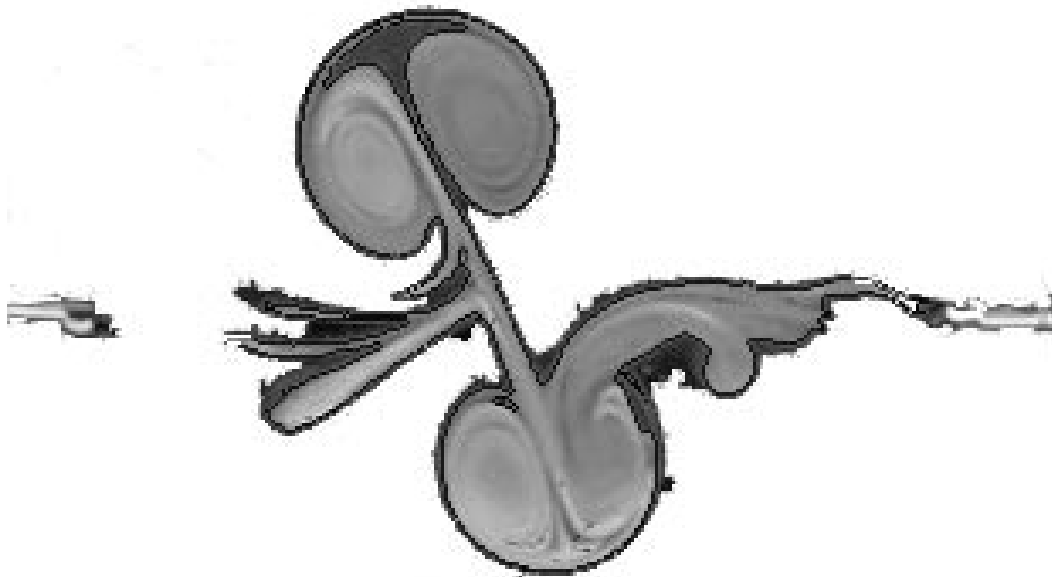


Figure 13.13: Same as previous figure, but converted to a grayscale image in Photoshop. The Trace Contour option was used to provide a black border around the main features of the vortex.

## 13.4 The Manipulated Photograph

A photo has always been regarded as strong evidence because “photos do not lie”. No professional photographer has ever believed this. In reality, photographs have manipulated visual reality from the very earliest experiments of Daguerre and Fox Talbot in the 1830’s.

One difficulty is that to quote Michell(1992): “the range of intensities in a visual field will often be very much greater than the range of tones than be captured and presented by a photograph. Pigments, inks and dyes can yield a ratio of tonal values, from darkest to lightest, of about forty to one, but the ratio from deep shadow to sparkling highlights in a sunlit field can be thousands to one. Thus the photographer must compress the intensity range of the scene with inevitable distortions and loss of detail”.

The *perceived* intensity of sound and light and other stimuli may not appear to have such a huge reason. However, human senses operate on a *logarithmic* scale, a fact which is known in physiology as Weber’s Law.

Photographers have developed a wide variety of strategies to cope with image problems. Deliberate overexposure or underexposure of an image is obvious. However, selective adjustments to parts of an image, known as “dodging” and “burning”, were developed in the nineteenth century. This eventually became elaborated into the Zone System, popularized by Ansel Adams, Minor White and other well-known photographers. “Dodge” and “burn” are two of the tools in Photoshop.

Colored filters are popular with photographers, too. Yellow filters are used to darken skies and bring out the detail of clouds. Red filters lighten foliage while also darkening skies even more than yellow filters. To dramatize building forms, architectural photographers have long been fond of covering their lenses with a red filter.

It is sometimes helpful to adjust the tone values of an entire image by either brightening or darkening. The “Claude glass” was a popular eighteenth century filter for darkening the view, which seems to make landscapes look more harmonious.

Photoshop allows one to dodge and burn, color filter, apply a Claude glass, and a wide range of other color and tone adjustments far more easily, and with far finer control, than similar adjustments with film and developer. Many of these adjustments are merely cosmetic, and therefore much more important to the photojournalist than to the photoengineer.

## 13.5 Common Boo-Boos

- When a tool fails to work, it is probably because one is in a **different layer** than one thinks.
- Another reason for tool failure is that the previous selection is still operating. One must make frequent use of **Deselect**, which is an item under the Select menu, or the keyboard shortcut Apple-D.
- When the Save menu does not allow an option such as Photoshop EPS, it is probably because the file needs to be **flattened**, that is, have all the layers combined into one, in order to be saved in EPS, or any other format that does not support layers.

## 13.6 Alpha Channel

Full-color RGB image files use 24 bits/pixel: 8 bits to specify 256 different intensity levels for each of the three additive colors. However, graphic designers found that this was not enough. What if one wanted to specify transparency properties, or other non-color properties at each pixel?

Some file formats, such as TIFF, Pict, and PNG, therefore support an “alpha channel”. This optional feature of a file is a place to store transparency information, etc. The concept of an “alpha channel” is a little bit fuzzy because there are potentially a lot of different additional properties that might be appended to a graphic file.

Adobe Photoshop allows a lot of alpha channels; some file formats support only one such channel. In any event, an alpha channel is a place to store properties of the pixels other than intensity-of-each-color.

## 13.7 Delayed Execution, History and All That

It is easy to reverse the drawing of a line in vector graphics simply by deleting the line. Reversion is more difficult in image processing because allowed operations include blending old and new colors together, diffusing features, and so. Blending and diffusion are much harder to cleanly reverse than the addition of a vector-graphics feature.

For this reason, “delayed execution” is a major theme in image-processing. Good software allows one to do all sorts of operations without changing the underlying image so that one can revert to an earlier state of the image.

Adobe Photoshop offers a rather bewildering array of tools for delay. Some important ones include the following:

1. layer masks
2. adjustment layers
3. history palette
4. history brush

### 13.7.1 Layer Masks

Artists often cut shapes out of paper or a material called “frisket” and fasten them to an illustration to block parts of the picture from the spray of an airbrush. Image-processing programs make it even easier to apply masks to confine various operations of painting, lightening, etc., to selected portions of the figure only.

Frequently, one only wants to apply adjustments to a portion of the image. For example, a flash photo may contain a picture of a person that is very bright (because the light from the flash could illuminate the subject) against a background that is extremely dark (because it was too far from the flash to be illuminated). One can create a layer mask by using all the standard painting tools to layer the label with white, black, or gray to indicate which pixels should allow an effect, prohibit an effect, or allow the pixel to average the effect with the original state of the pixel. Once the mask has been created, one can then apply effects with wild abandon only to the chosen area.

The alternative is to draw a selection border on the image and then apply the effect within the border. The trouble is that if the change needs to be altered later — coloring the sky a dark blue may need to be modified by adding in some clouds, for example



— then one has to painstakingly draw the selection border all over again. However, a layer mask is a permanent feature of the illustration, saved as part of the file whenever the image is saved in Photoshop format. One can apply, or not apply, a given layer mask very easily at any stage. The layer mask indefinitely delays the destruction of a selection border.

### 13.7.2 Adjustment Layers

Adjustments to brightness and contrast, saturation and hue, etc., can be made directly to the image, but are not easily undone. One can alternatively perform these same operations in a “layer mask”. The advantage is that the change can then be undone simply by deleting the layer. Furthermore, one can return to the layer at a later time to tweak the adjustments.

The adjustments are never closed, but are like a layer of paint that is allowed to remain indefinitely wet.

### 13.7.3 History Palette

This feature shows the names and snapshots of the last 20 graphical operations. (Changes to global preferences are not shown, but almost everything else is; the number of operations kept as “history” can be changed by the user, if the computer has enough memory to support a large number of “history” snapshots.)

By dragging items in the history palette to the little trash icon underneath the history palette, one can delete graphic operations that were not a success. In normal operation, deletion of a state also deletes all later states. However, at the expense of a little more memory and more thinking by the software, one can check an option called “Allow Nonlinear History”. When an operation in the middle of the “history” is deleted, only that operation goes away.

### 13.7.4 Snapshots

One may explicitly save an intermediate image state as a “snapshot” so that it will appear permanently in the history palette with its own name. This can provide a convenient visual anchor when doing (or undoing!) a complicated set of operations.

### 13.7.5 History Brush

Instead of brushing on strokes of a color, the history brush allows one to create by brushing sections where the image reverts to a previous state or snapshot. Thus, if one brightens the dark background of an image, and accidentally got some foreground pixels, one could use the history brush to revert those foreground pixels to their original state.

Alternatively, one can also apply the eraser with “Erase to history” option turned on. This reverts the chosen parts of the image to their appearance in the last SAVED version of the file.

## 13.8 Paths

Vector-graphics instructions, such as the walls of a polygon, are sometimes called “paths” in software manual. Photoshop allows one to draw “paths” using the pen tool

and its variants. The pen operates almost exactly as in Illustrator; it creates a curve controlled by Bezier polynomials. By using tools under the pen tool, one can add and delete anchor points, move segments bounded by two anchor points, move the direction arrows that radiate from anchor points and so on.

Paths can be used in two very different ways. First, just as in a drawing programs, paths can be given a “stroke” (the color/linewidth, etc. of the curve that defines the path) plus a “fill”, which is a color, color gradient or texture that fills the interior of the path. This use is simply a way to add vector-graphics items to a bitmap image.

The second use is that paths can be converted to selection borders. (Click the little triangle on the right of the “paths” palette to bring up a menu of options.) This allows one to draw very intricate selection borders, just the way you want them, when the square and elliptical selection marquee and the pixel-edge selection tools are inadequate.

## 13.9 Transformations

Just as in vector graphics, one can select an area of an image and apply rotation, shear, dilation, and other transformations to the selected block of pixels. Indeed, Photoshop has some three-dimensional transformations which can be very useful in modifying photographs of real, three-dimensional objects. Because of the similarity of these transformations to those in Illustrator and other drawing programs, these transformations will not be discussed in detail.

## 13.10 Organizing Images: Contact Sheets

A “contact sheet” is a collection of miniature images, all on a single page, which illustrates all the images in a single roll of film. Such contact sheets are very helpful in organizing graphics files because the thumbnail sketches allow one to easily identify a desired picture when the filenames alone are inadequate.

Photoshop has a command (under the Automate command under the leftmost main menu) which will automatically make a contact sheet showing all pictures in a given folder or subfolder. An example is shown in Fig. 13.14

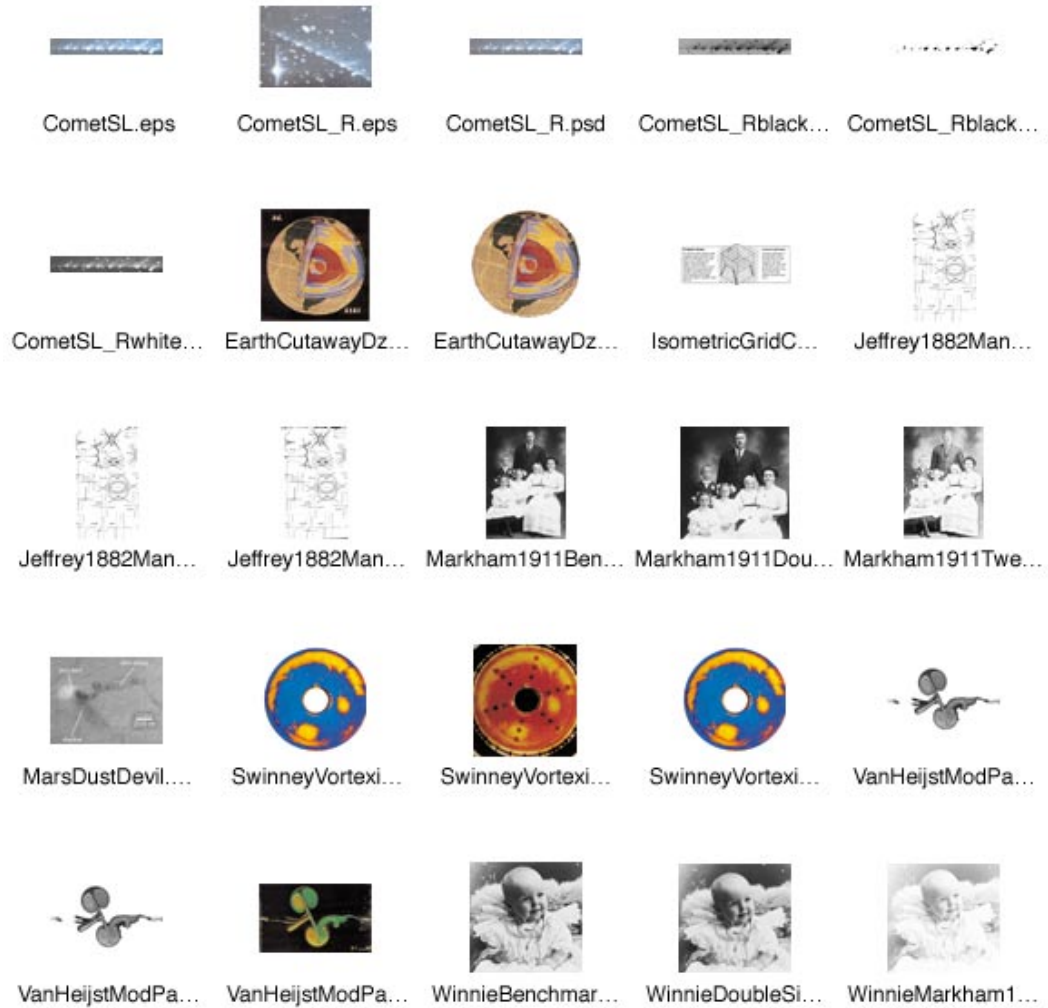


Figure 13.14: Contact sheet generated by Photoshop.