COLOR TABLES AND SEISMIC DATA

Soon after SEP developed color seismogram movies we learned how deceptive color can be. The reason is that there is no natural linear scale for color. Because color displays are thus intrinsically nonlinear, the eye tends to track interference patterns instead of the waves which are interfering. Color is suitable for 3-D migrated data where there should be no interfering waves. Generally we seem to prefer shades of gray for seismogram display. Atop the shades of gray many of us prefer red where data is clipped. Otherwise, we can sum up by saying that for viewing seismic data the principle of linear superposition applies so we don't like color.

FRACTAL PROGRAM

I won't hazard a definition of a fractal, but the first frame output from the following program reconstructed the cover of the August 1985 Scientific American. Subsequent frames zoom into an interesting area. I found that zooming in beyond about 2^{15} magnification required double precision to prevent graininess in the pictures. This is just what is to be expected of a 32 bit word with a 24 bit mantissa and an image size of 256 = 8 bits.

```
real data(500,500), x, y, size, delta, w
complex cc, cmplx, conjg, cz
n1=500;                n2=500
x=-1.25405;   y=.343;                  w = 4.
do i3 = 1, 15 {                        # make 15 frame zoom-in fractal movie.
        delta = w / n1
        do i2 = 1, n2 {                # scan (x,y)-plane
                do i1 = 1, n1 {
                        cc = cmplx( x + (i1-n1/2)*delta,  y + (i2-n2/2)*delta )
                        cz = 0.
                        do count = 1, 500 {
                                cz = cz*cz + cc
                                size = cz * conjg(cz)
                                if ( size > 4. ) break
                                }
                        data(i1,i2) = count
                        }
                }
        call snap("movie", n1, n2, data)       # output a data frame.
        w = w / 2.
        }
stop; end
```

Each point of a data frame is a count, i.e. a number from one to 500. The 500 is a practical limit. Higher values will be found in some parts of the (x, y)-plane, indeed, the count value *infinity* applies to some places in the plane. When the count goes to infinity it means the complex function defined by the recursion converges. The most interesting areas are just those surrounding the convergent region where the count is finite but high. So you can see that the statistics of the population are hard to describe. A description depends on the region selected—just like the statistics of seismic data.

FRACTALS SEEN IN SHADES OF GRAY

Fractals have application in theoretical rock physics. I am not aware of any applications in seismic exploration other than as a challenge to a graphics system. My first view of them was in the shades of gray that we typically use to display seismic data. Neither gray nor the the familiar color schemes popular with seismic contractors provided a view of the fractals that was as attractive (and informative) as that used by the magazine. I was reminded of coherence displays in variable density. You really have a hard time spotting the maximum of the coherency function. You can do it much better on a contour plot. I remembered several times we turned off the *most* significant bits of a display of a smooth function to give it a contoured look. It seems that our eyes have the ability to accomodate a wide range of lighting conditions, even within a single scene. The penalty we pay for this ability is our near inability to identify the most brightly lit location.

RANDOM COLOR TABLE

The basic seismogram color table relates seismogram amplitude linearly to brightness in some hue, often gray. I experimented with several color tables. I tried modulating the hue instead of the intensity. None of my initial ideas worked with fractals. I soon realized that my color tables were too smooth because I had assumed that the color table should give a unique mapping from the function value to the color. The uniqueness feature turned out not to be so important. More important was the need to readily distinguish constant levels such as contour lines. This requires a more rapidly changing color table. First I tried a random color table. For fractals the random color table worked better than any of the smooth-value-vrs.-color schemes. But the discontinuity was mildly distressing, and potentially confusing when viewing noisy geophysical functions, so I smoothed the random numbers to create more correlation. Smoothing over about 3-7 points seemed to give the most pleasing results. With such smoothing you could still make out the individual contours, but the display was less confusing where the contour lines came close together. I imagine the same considerations apply to examination of coherency to determine velocity.

RANDOM COLOR TABLES FOR SEISMIC DATA

I tried the random color tables on raw seismic data. Stepouts remained readily apparent. Amplitudes were more apparent than with shades of gray eliminating the need for AGC. So the random color tables had some advantage with seismic data, though I do not expect them to replace shades of gray.

The choice of a color scheme could be based upon the statistics of the function being displayed. I didn't try this yet, but one thing I saw suggested that the least populated function values should be displayed brighter. Randomly it happened that the seismically brightest region was small and not brightly lit, though I think it should have been. Likewise, the edges of the convergent regions of fractal planes, constitute a small but most interesting part of the plane.

SYSTEMATIC, RAPIDLY VARIABLE COLOR TABLES

Because random colors randomly gave unsatisfactory color schemes, I chose to make a systematic scheme that would allow some visual que of the absolute amplitude as well as changing rapidly with small changes in amplitude. Letting the variable *hue* vary from zero to 2π, I ended out with

$$\begin{aligned} red &= 1.3 + .7 \cos hue \\ green &= 1.3 + .7 \cos 8\, hue \\ blue &= 1.3 + .7 \cos 64\, hue \end{aligned}$$

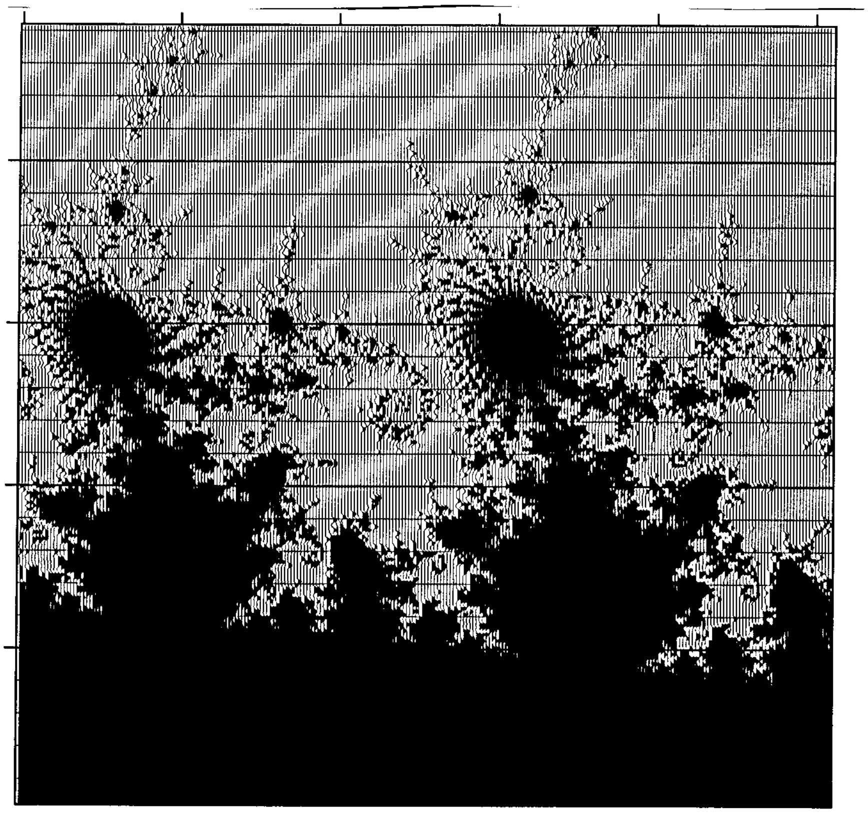
The number 64 is one quarter of the length of our color table. I suspect that triangle waves would be slightly better than cosines, but did not test that hypothesis.

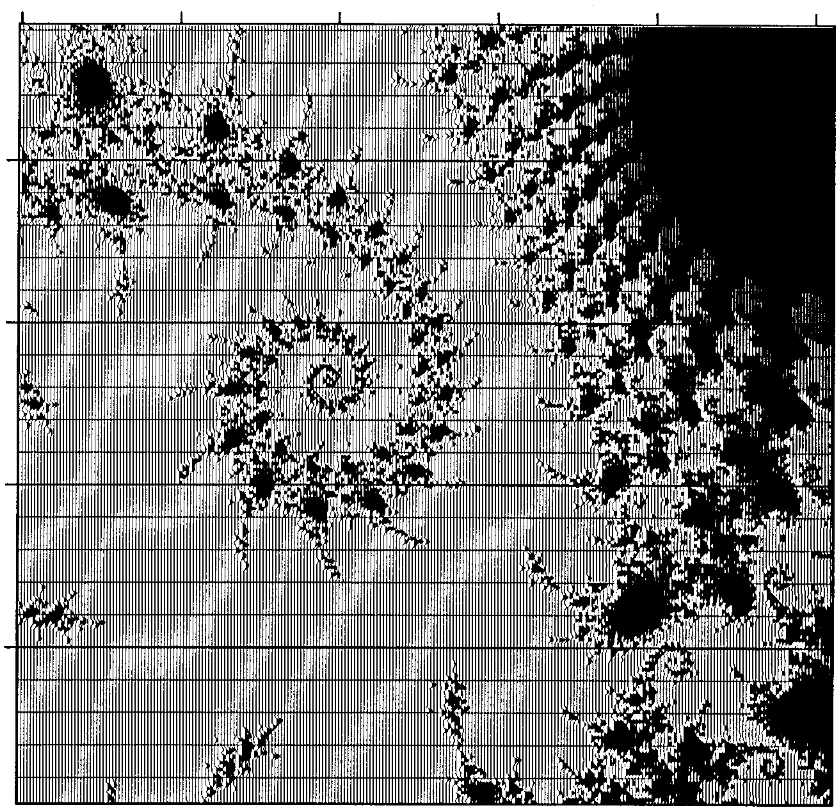
CONCLUSION

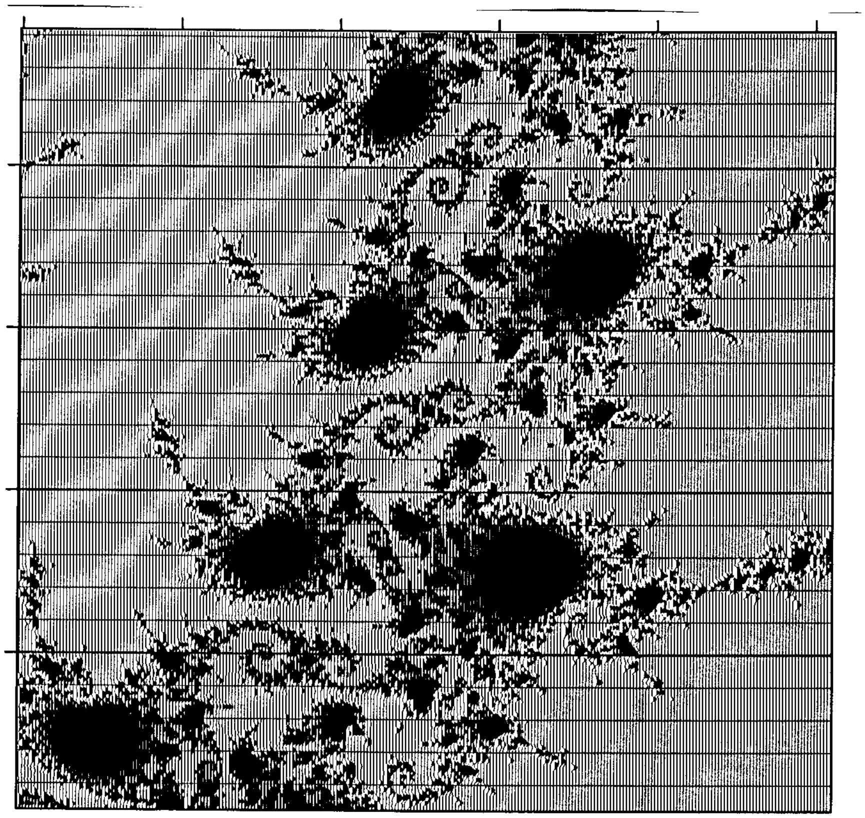
Color plotting programs should include at least one color scheme in which colors vary rapidly with function value.

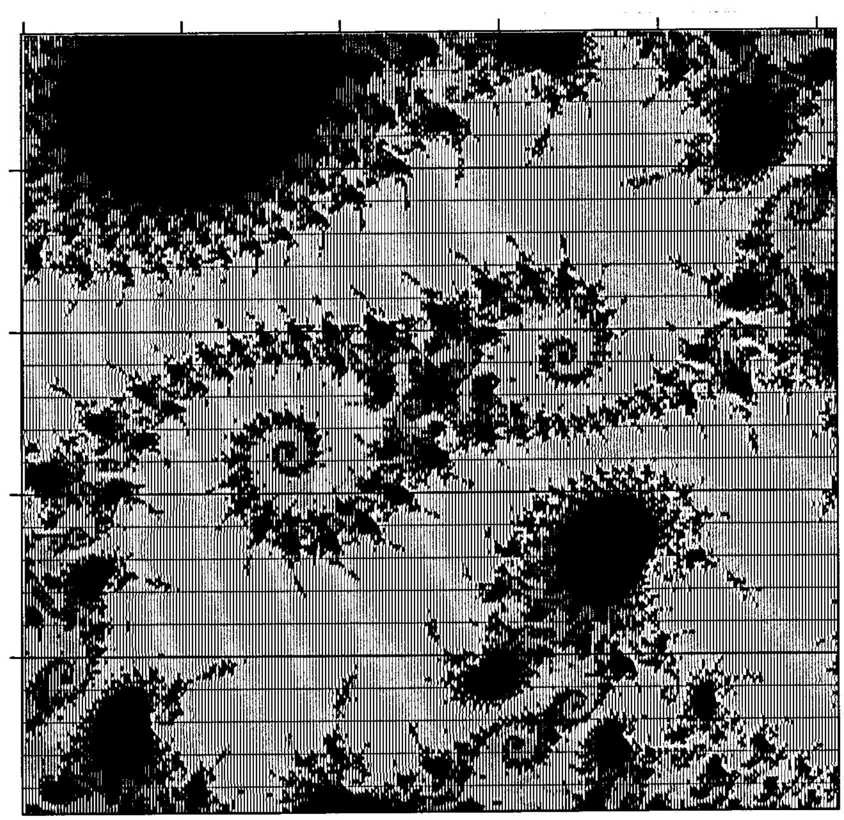
REFERENCES

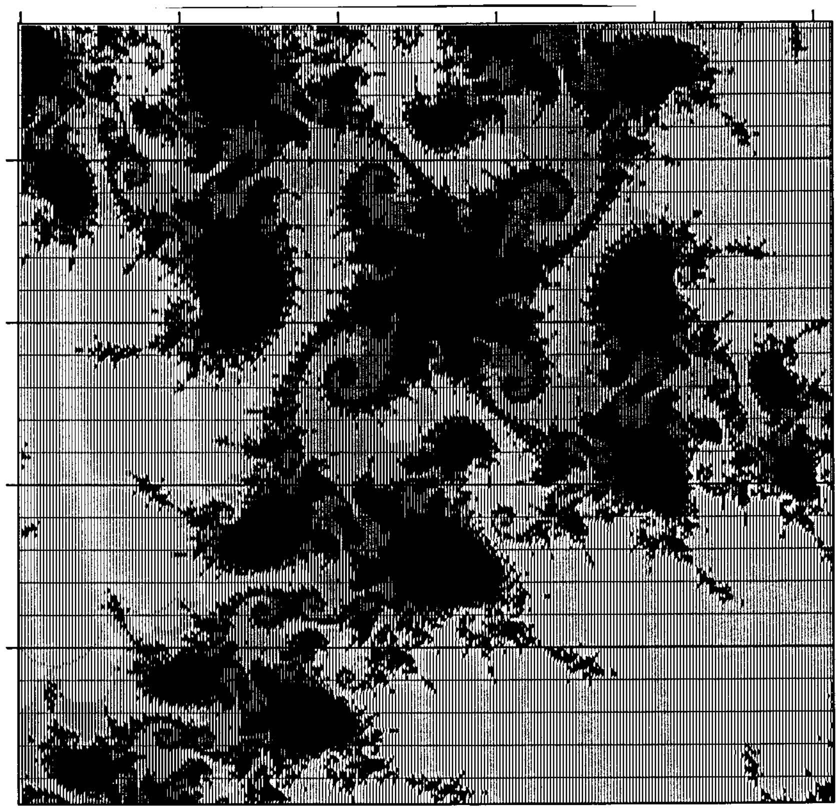
Dewdney, A.K., 1985, Computer Recreations: A computer microscope zooms in for a look at the most complex object in mathematics, Scientific American, August 1985, p. 16-20.

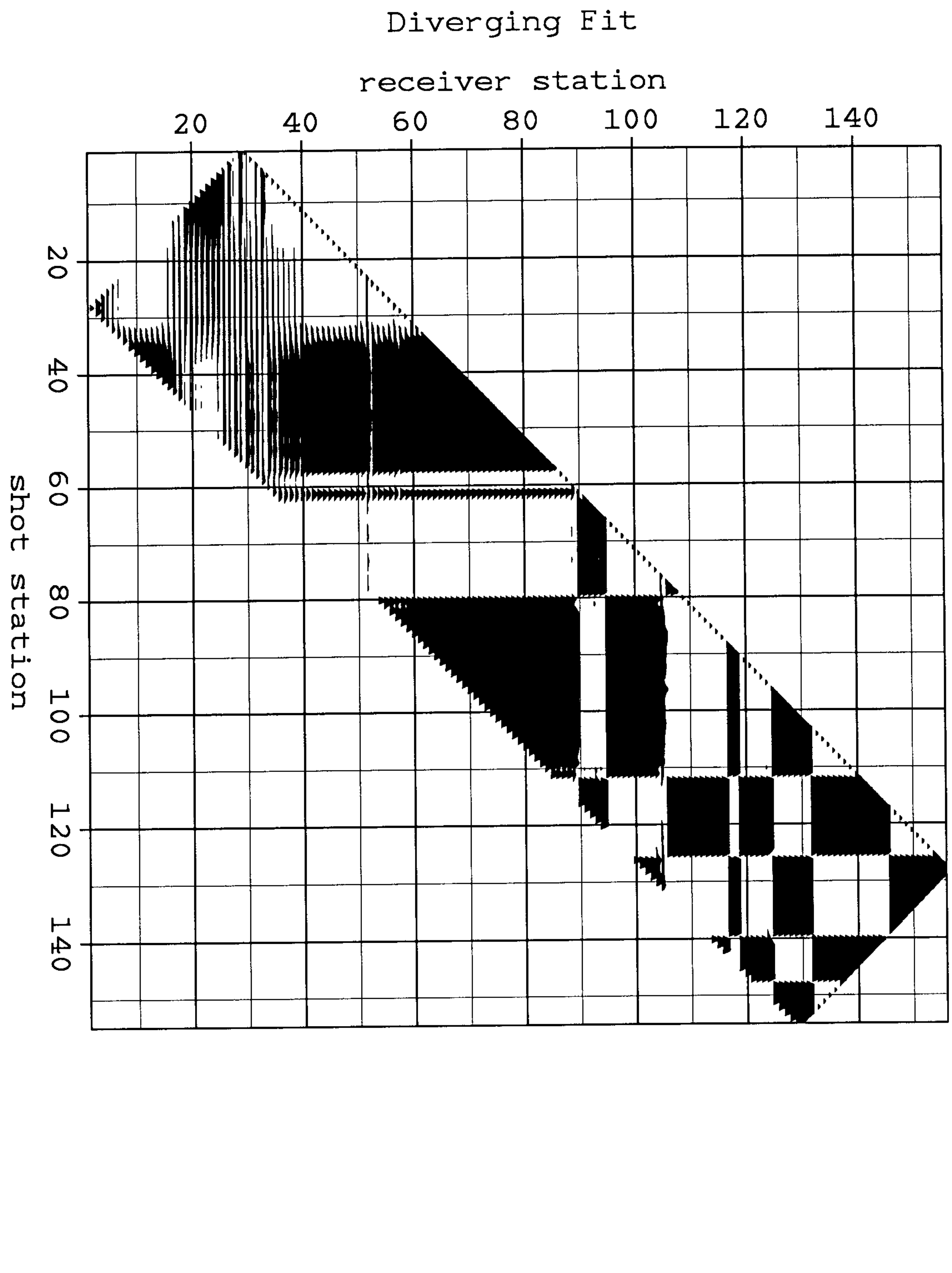








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