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# DISPLAY: AN INTERACTIVE PROGRAM TO CREATE COLOUR IMAGES OF SPATIAL DATA ON A PC

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## ABSTRACT

*A computer program has been written for the interactive, colour display of gridded datafiles on an IBM-PC (or close compatible) equipped with VGA or better resolution graphics. The program will display gridded datafiles having the storage formats of two popular PC-based gridding and imaging software systems. The gridded datafiles can be displayed as a variety of images on a VGA monitor, in order to extract the maximum information about the grid contents from the data.*

*In the most basic display mode, 'flat' images (similar to contour maps) are generated by representing the magnitudes of gridded data values by either 64 grey-scale intensities ranging from black to white or as 253 colour hues arranged in the natural order of the visible light spectrum with blues representing low intensities and deep reds representing the high intensities. The other image types that may be generated either in colour or as monochrome displays are shaded-relief, contour levels and shaded-contour levels. A provision to display the natural logarithm of gridded data values was specifically included for geochemical datafiles. Two images created from all or portions of two gridded datafiles may be generated in a split-screen display.*

*In addition to parameters that control the image type, the display parameters, which may be interactively selected from a simple menu and changed, are: the colour range, the file names, the direction and inclination of shading, the relief factor, and parameters controlling the portion of the grid to be imaged.*

## INTRODUCTION

During its early days of development, the motivation for writing the program DISPLAY was to provide a tool for rapidly viewing the contents of a gridded datafile as colour shaded-relief images on a desktop computer, and to allow the user the ability to interactively change the direction of false-illumination enhancement. The routine was developed in conjunction with an ongoing project to detect errors in the aeromagnetic profile data available for the province, to generate a contiguous set of gridded datafiles from that data (Kilfoil, *this volume*) and to release the error-corrected gridded datafiles as a digital Open File (Kilfoil and Bruce, 1990). Since many versions of gridded datafiles were generated in the process, the foremost design considerations for the program DISPLAY were speed and versatility in use. Many of the options now available within DISPLAY were added on, to increase versatility after many hours of use. Program DISPLAY was released as an Open File (Kilfoil, 1990) to assist in the interpretation of released gridded digital datafiles.

Although program DISPLAY was designed to generate colour, shaded-relief images from gridded geophysical data, images may be produced from any type of gridded data. For example, the contents of gridded datafiles might be various geochemical datafiles, digital elevation data, soil acidity, population density or forest resource value.

The software will only operate on IBM-compatible microcomputers configured with a combination of a graphics card and colour video monitor of VGA or higher resolution. Although DISPLAY will function with computer display boards of higher than VGA resolution (such as Super VGA), the program is not designed to take full advantage of this increased graphics resolution and its operation will appear as VGA. DISPLAY presently accepts the formats of gridded datafiles as output from GEOSOFT™ Inc.[1] and General Purpose Mapping System or GEOPAK™ Systems[2], two gridding and plotting software packages in common use throughout the geoscientific community in Canada.

In order to obtain the maximum effect of shaded-relief imaging, DISPLAY was designed to take full advantage of the 256 colours available under VGA resolution. However, to achieve the maximum colour resolution, the maximum spatial resolution was degraded to the 320 by 200 resolution from the 480 by 640 resolution available under 16-colour VGA mode. For program efficiency considerations, DISPLAY preforms a one-to-one mapping of grid cells to image pixels. Consequently, the values of only 320 by 200 grid cells can

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[1] (c) Copyright GEOSOFT Inc., Toronto, Canada.

[2] (c) Copyright GEOPAK Systems Software Resource, Toronto, Canada

**Table 1.** Example parameter menu, from program DISPLAY, used to generate dual images of a single datafile in a split-screen display mode. Note that these parameter settings will generate two grey-tone shaded-relief images from file 'mag_12a.grd': one with false illumination from the northeast, the other from the southeast. Plate 1c is a screen-capture print of the images that result from the parameter settings listed

| | | |
|---|---|---|
| Parameters are: | | |
| File names: | 'mag_12a.grd' | 'mag_12a.grd' |
| Size (NX,NY): | 745,558 | 745,558 |
| Origin: | 300,300 | 300,300 |
| Decimation: | 1 | 1 |
| Azimuth: | 45.0 | 135.0 |
| Inclination: | 45.0 | 50.0 |
| Relief factor: | 10.00000 | 10.00000 |
| Zmin/Zmax: | -600.0000, 1000.0000 | -600.0000, 1000.0000 |
| Hist equalized: | 1 | 1 |
| Colour: | 0 | |
| Enhanced: | 1 | |
| Shadows: | 0 | |
| Levels: | 0 | |
| RGB Background: | (45,20,10) Max=63 | |

Choose: 'File,Orig,Dec,Azi,Inc,Rel,Z-Ext,His,Col,Enh,Shad,Lev,Back' (X-Exit)

be displayed on the screen at one time. In the split-screen display mode, the display area available for each of the images is 160 by 200 pixels. A previously published grey-scale shading algorithm (Teskey and Broome, 1984) was adapted to the 64 levels of grey, ranging from black to white, available under VGA resolution for grey-tone shaded-relief image generation. The routine was further modified for the production of colour, shaded-relief images from the 256 colours available in a VGA palette. DISPLAY, written and compiled in FORTRAN (Microsoft, 1989), was optimized for the IBM-PC by a library of enhancement subroutines (Sutrasoft, 1989).

During the design of DISPLAY, the objective was to attain the maximum user-friendliness possible for the novice without creating a program that is too slow or cumbersome for the more experienced user. For this reason, and to keep the program trim and efficient, only a few basic image-generating functions have been included. However, the routine does have sufficient versatility that a quite thorough examination of a gridded dataset can be carried out.

For a detailed description of program usage, the reader is referred to the user's manual (Kilfoil, 1990). The description to follow is intended to summarize that document and provide some examples of images that can be created.

## INTERACTIVE CONTROL OF DISPLAY AND EXAMPLE IMAGES

DISPLAY uses two screens: a menu screen and an image display screen. The menu lists the parameters (Table 1) that control the generation of images on the display screen. When the menu screen, with the display parameters set as desired, is entered, the image is computed and appears on the display screen. The 'enter' key functions as a toggle between the two screens, allowing the display parameters on the menu screen to be adjusted and the resulting images inspected rapidly until the desired image display is obtained.

A portion of the gridded aeromagnetic datafile for NTS 12A, central Newfoundland (Kilfoil and Bruce, 1990), was chosen as the gridded dataset, from which example images were produced (Plates 1 and 2). This area was selected because a broad range of magnetic field strengths are represented. For reference, the town of Buchans is located just north of centre on each of these prints (a,b,c,d), and the semi-circular magnetic high situated along the northern boundary (just east of centre) is the southward-thrusted margin of the Topsails Complex to the north. Much of the area in the centre and to the southeast is underlain by volcanogenic sediments of the Buchans and Victoria Lake groups.

Plates 1 and 2 are printed copies of captured screen images in grey-level and colour, respectively. The images were generated by a HP Vectra PC on a VGA resolution graphics card and colour monitor, converted to printer plots by the Pizazz Plus (Application Techniques, 1989) image-capturing software, and printed at 1:250,000 scale on a HP Paintjet XL colour printer. Due to the pixel aspect ratio of the 256-colour VGA resolution, all images generated are slightly distorted (stretched in the Y- or north dimension). However, the scaling capability of Pizazz Plus has allowed distortion to be eliminated on Plates 1 and 2. As a result of this screen-capture process, the panels of Plates 1 and 2 are not as crisp as the images generated on the VGA monitor. As well, the colouring on the captured prints tends to be much darker than the on-screen images. The descriptions of menu parameters that

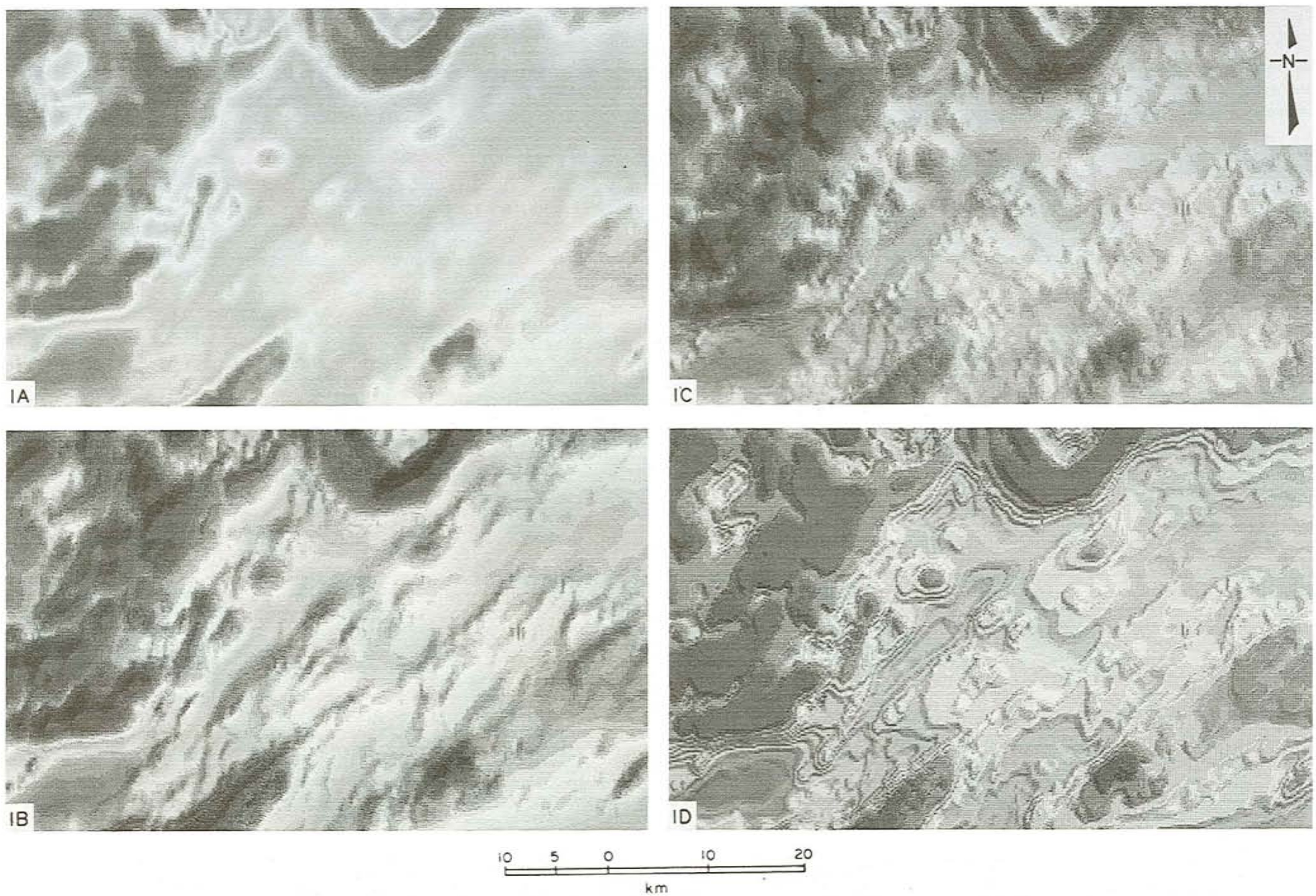


**Plate 1.** *Prints from various grey-tone images of corrected regional aeromagnetic data, Buchans area, NTS 12A, Nfld. a) 64 grey-level magnetic intensity image; b) shaded-relief image, false illumination from the southeast and inclined at 50°; c) split-screen, shaded-relief images for western half of 1a, image on left half illuminated from northeast at 45° inclination, image on right half illuminated as in 1b; d) shaded-relief, stepped levels image, illumination from the northeast inclined at 45°. Prints captured from a VGA monitor by Pizazz Plus software.*

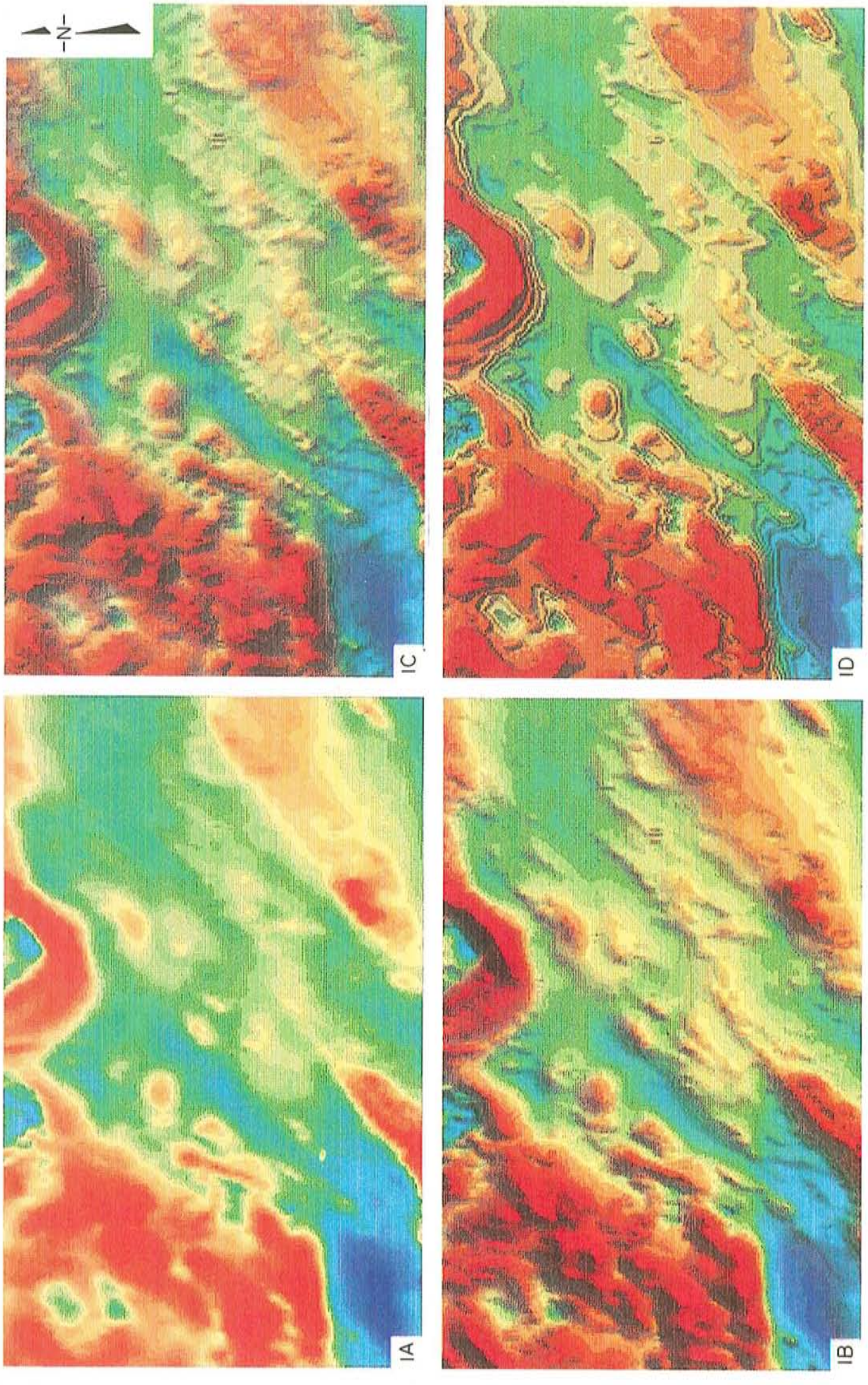


**Plate 2.** *Prints from various colour images of corrected regional aeromagnetic data, Buchans area, NTS 12A, Nfld. a) 253 rainbow colour magnetic intensity image; b) colour, shaded-relief image, false illumination from the southeast and inclined at 50°; c) colour, shaded-relief image, illuminated from northeast at 45° inclination; d) colour, shaded-relief, stepped levels image, illumination: Azimuth 045°, Inclination 45°. Prints captured from a VGA monitor by Pizazz Plus software.*

follows illustrate, through reference to these examples, the effects of display parameters on images generated.

When program DISPLAY is initiated, the names of a Sun control file and one or two gridded datafiles are included on the DOS command line. The Sun file sets a few initial display parameters so that they need not all be changed from the parameter menu. The contents of the Sun control file are arranged such that the same Sun file may be used to view the contents of all grid files of a specific type, such as aeromagnetic, VLF-EM, etc. The defaults for display parameters that are initialized in the Sun file, are (see descriptions below): image type, Azimuth and Inclination of false illumination, Relief factor, $Z_{min}/Z_{max}$ and control values used by the Levels option.

Four parameters control the type of image to be generated: Colour, Enhanced, Shadows and Levels. Since the various types of images selected involve colour palette changes, two different image types may not be plotted on the screen in the split-screen display mode. Therefore, the values of these menu parameters appear only once in the listing (Table 1), regardless of whether two image files are listed or not. Each of these parameters may be toggled to the 'on' state (1) or 'off' state (0) by typing the first letter. The initial state of each of these parameters is determined by values in the Sun control file (Kilfoil, 1990).

The Colour parameter determines whether a colour or grey-tone image will be generated. The panels of Plate 1 were captured from screen images generated with Colour turned off; those of Plate 2 are prints from images with the Colour parameter activated. Shaded-relief, grey-tone images are often useful for detecting linear features in gridded datafiles, as the observer is not influenced by the colour variations assigned to the absolute magnitudes of grid values.

When the Enhanced parameter is activated the image(s) generated will appear to have apparent relief, resulting from introduction of shadows caused by false illumination. If the Enhanced parameter is off, then grey-tone (Plate 1a) or colour rainbow (Plate 2a) images are generated from the scaled magnitudes of grid values. Shaded-relief images are generated in grey-tone (Plate 1b, c) or colour (Plate 2b, c) when the Enhanced parameter is turned on. Since the Azimuth, Inclination and Relief parameters control the orientation of enhancement, these parameters have no effect when the Enhanced parameter is inactive.

The Shadows parameter determines the emphasis of shadows on the image. When Shadows is turned off, all areas in shadow on a shaded-relief image will be black. With the Shadows parameter activated, half of the intensity range for grey-levels or colours are apportioned to each of the shaded and unshaded regions on the image, thereby allowing some detail to be extracted from areas in shadow. Shadows will have no effect on images when the Enhanced parameter is off. Generally, colour, shaded-relief images are brighter and more appealing when Shadows is on (Plate 2b to d), whereas grey-tone, shaded-relief images are more effective when Shadows is off (Plate 1b to d).

Activating the Levels parameter will map the range of possible grid values onto a series of stepped levels, which resemble the contours of a topographic relief map. The Levels parameter will cause such mapping irrespective of the values of the Colour or Enhanced parameters. The levels onto which the data is mapped and the emphasis or steepness of gradients between levels are determined by variables contained in the Sun control file, and can be edited by the user. Plates 1d and 2d are monotone and colour shaded-relief examples with the Levels parameter activated. As may be observed in these examples, the Levels option can be useful for emphasizing particular trends in the data. Images generated from lake-sediment geochemical data with the Levels command on have also proven useful for comparing gridded data to existing colour contour maps.

When the File-name parameter is selected from the parameter menu, the user is first asked if changes to the number of files to be displayed is desired; then for changes to the File name. Thus, the File-name parameter allows a switch from the single-file display to the dual-file display. The two file names can be changed independently in the split-screen display mode, or the same file name can be typed to obtain a dual image of the same data. The menu of Table 1 shows the menu-parameter listing of a split-screen display of single-gridded datafile. Plate 1c is a print of the image that results from these input parameters. Thus, the data from a single file may be viewed as images from two different illumination directions. Alternatively, using two different Decimation factors (see below), a large gridded datafile may be viewed on one side as an 'index map' (using large Decimation), while the origin of the other image (small Decimation) may be independently changed to view portions of the grid contents in greater detail.

The file Size parameter is included in the menu to provide the user information on the size(s) of any gridded datafile(s) selected, where NX is the number of grid cells (or pixels) per row and NY is the number of rows in the grid. It directly precedes the Origin parameter in the menu for reference when selecting an Origin for display, and is the only parameter in the menu list that cannot be changed. If a file Size of 0,0 appears when a new File name is entered, re-enter the File name before displaying the image.

Two menu parameters, the Origin and Decimation factor, determine the portion of input grid that will occupy the available plotting screen space when an image is generated. The Origin refers to the grid cell that will occupy the lower left pixel in the image window. The number of pixels available on the screen is 320 by 200 for a single-image display, and 160 by 200 for a two-image display. The default Origin, always quoted in grid coordinates, is **1,1** (origin of the grid). Interactive entries are to be integers in the order 'X,Y', referring to grid coordinates. If the entries input by the user are outside the range of possible coordinates for the grid, the grid-coordinate extreme values are taken as default. As example, if **0,0** is entered by the user, then the Origin is set to **1,1**. The X-coordinate of the Origin may be changed, say to 50, while leaving the Y-coordinate unchanged, by entering only **50** or **50,** at the prompt. Similarly, the Y-coordinate may be changed (to 50), by entering **,50**. The position (or absence) of the comma determines which coordinate the user is referring. The image Decimation bears similarity to the scale of a hardcopy plot. It refers to use of every $N^{th}$ grid cell in generating the image, where N is the Decimation factor. That is, if the Decimation factor is set to 2, then only every $2^{nd}$ grid cell in both the X and Y dimensions will be used to generate the image. The Decimation factor must be an integer greater than zero. By default, the image Decimation is set to **1** unless otherwise entered on the command line. A 'postage-stamp-sized' image of the grid contents can be generated by setting the Decimation factor to a large number, such as **10** or **20**. Compare the Origins with the grid-file Sizes listed in Table 1.

The amount of emphasis on shaded-relief images is controlled by three parameters listed in the menu: Azimuth, Inclination and Relief factor. Initial values for these parameters are taken from the first line of the Sun control file. The Azimuth and Inclination parameters define the angles, in degrees, at which a false illuminating sun is oriented with respect to the topographic representation of gridded data when generating a shaded-relief image. The Azimuth is the direction angle of the false sun, measured clockwise from a **0.0°** value at true North. Thus an Azimuth of **90.0°** is east; a west Azimuth can be obtained as **270.0°** or **-90.0°**. The Inclination defines the angle of the false sun or illuminating vector above the horizon, increasing with angle from zero at the horizon. An Inclination of **90.0°** defines a false sun source located directly 'above' the image (or from the viewer's perspective). Note that with the Inclination set to **90.0°**, the image will remain unchanged irrespective of the Azimuth setting. The best settings for Inclination, when using shading as a directional filter to enhance subtle structure in a gridded dataset, are in the range **30** to **60** degrees (above the horizon). The area in shadow on images increases with a decrease in sun angle. Therefore, the Inclination can be lowered to enhance particular trends, but only at the expense of overall loss of detail on the image. When the Azimuth of false illumination is perpendicular to the predominant grain of an image, as in Plates 1B and 2B, the Inclination should be increased slightly to de-emphasize the grain (Inclination parameter increased to **50.0** in listing on the right, Table 1).

The Relief factor refers to a scaling used to adjust the relative 'height' of the grid values when generating a shaded-relief image, and therefore determines the 'roughness' of the image. The initial setting should be in the range of the average difference in Z-values between adjacent valid grid cells. As a rough guide for choosing a Relief factor, divide the range of the Z-values ($Z_{max}$ minus $Z_{min}$) by 200. When displaying most aeromagnetic datafiles gridded to 200 m, a good colour-shaded image is generated with a Relief factor of about 10 (Table 1). Increasing the Relief factor decreases the image roughness when shading, and vice-versa. If shaded images appear 'flat', decrease the Relief factor, initially by an order of magnitude, and observe the difference in the displayed image. If a shaded image is too rough or 'noisy', increase the Relief factor. By adjusting the Relief factor and the false sun Inclination, an image can quite quickly be obtained, which optimally displays the features of interest in the gridded datafile.

The Z-extremes refer to the minimum and maximum Z-values to which the field values of the valid grid cells will be *linearly* stretched when assigning a representative colour scheme during creation of an image. $Z_{min}$ and $Z_{max}$ are really the extremes of a linear colour spectrum: grid Z-values near (or less than) $Z_{min}$ will be assigned the deepest blue colour, whereas Z-values near (or greater than) $Z_{max}$ will be assigned the deepest red colour; all other Z-values will be linearly stretched when assigning respective colours between these two extremes. This option is merely a means of allowing the user to alter the image colour scheme to locally emphasize a particular feature of interest. These values may be entirely different from the true extremes of actual values in the grid. The initial values of $Z_{min}$ and $Z_{max}$ are obtained from the second line of the Sun control file. The value of $Z_{max}$ should exceed that of $Z_{min}$; if $Z_{min}$ is greater than $Z_{max}$, the values are exchanged. The Z-extreme value settings will have no effect on images generated, if the Histogram equalization option is enabled.

The Histogram parameter controls linearizing or stretching of the Histogram of grid values when generating an image such that the colour values available for display (which represent field strengths in the grid) should occur in the image with nearly equal frequency. More simply stated, this option should assign equal weighting to each possible display colour in the image, and therefore produce the maximum dynamic range in the image colour scheme. If present, the histogram of grid values, from which the Histogram equalization is calculated, is written to the header of a GEOSOFT™ Version II format grid; the Histogram is appended as a footer line in GEOSOFT™ Version I and Geopak™ gridded datafiles. A value of **1** means 'on' or 'active', while a **0** means 'off' or 'inactive' and therefore a default to linear colour scaling between $Z_{min}$ and $Z_{max}$. If Histogram equalization is available (Histogram has been included) for a particular grid, then selecting this option will toggle between **0** and **1**. Plate 1a and all panels of Plate 2 were generated with Histogram equalized grey-tone or colour scaling.

The RGB Background refers to a series of three integer values, within the range 0-63, in the order: (Red, Green, Blue), that define the Background colour value for *grey-tone images only*. This option was added to allow choice of any aesthetic Background hue, which contrasts best with the grey-tone image(s) generated. The medium grey (value: 32,32,32) tone used as Background for colour images (which cannot be altered) would obviously not be a good choice for grey-scale images. The currently active value of the Background colour appears between brackets in the menu (Table 1). The default is **(45,20,10)**, a reddish-brown colour. As examples, a deep blue would be **(0,0,63)**; a deep green: **(0,63,0)**; an aquamarine: **(0,63,63)**; white **(63,63,63)**, etc.

The other option, not listed in the parameter menu, that is available with DISPLAY is the ability to generate images from logarithmically scaled grid values. However, this option can only be activated by selecting the appropriate image type in the Sun control file (for details, see Kilfoil, 1990).

### LIMITATIONS

As mentioned above, DISPLAY was not intended to be a fully fledged image-analysis system. At present, images can only be displayed on a VGA colour monitor; RGA graphics capabilities do not have sufficient colour resolution to do justice to a colour, shaded-relief image. The ability to overlay vector files, such as digital topographic data or digitized geology, has not yet been included, but future versions may well include this feature, as the lack of an image-referencing capability is the most obvious drawback to DISPLAY at present.

DISPLAY has been designed for optimal performance on IBM-PC's equipped with a math co-processor. The routine can be implemented on PC's that do not have a co-processor, but the floating-point calculations required for image colour scaling and shading significantly slow its speed of image generation.

The Histogram equalized colour option may only be available with GEOSOFT™ Version II grid formats because there is insufficient space in the grid headers of other grid formats to store a histogram of grid values. However, DISPLAY does accept a frequency histogram appended as a footer record to GEOSOFT™ Version I and Geopak™ format grids. The presence on the frequency histogram is indicated by the setting of a flag in the header of these grids formats. If a histogram of grid values has not been added to the grid, DISPLAY will revert to linear colour scaling. The ability to calculate a histogram of grid values on-line would be of benefit; however, this function should be optional as it would carry a high price in computer processing time.

At present, GEOSOFT™ or Geopak™ are the only grid-file formats that DISPLAY will accept. However, if the demands warrant, support for other grid-file formats may be added to future releases of DISPLAY. Although hardcopy support has not been incorporated into DISPLAY to date, support for certain colour printers in common use would be preferable to the screen capture utility used to print the images contained herein.

Program DISPLAY requires a Sun control file, which must be specified on the command line. This requirement could be eliminated if DISPLAY were programmed to inspect the contents of a each grid file and make 'intelligent guesses' at initial values to use in their display. To date, this option has not been implemented as the computation time required would slow the operation of DISPLAY considerably.

## ACKNOWLEDGMENTS

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