REPORT DOCUMENTATION PAGE

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1. Agency Use Only *(Leave blank).*	2. Report Date. August 1989	3. Report Type and Dates Covered.

4. Title and Subtitle.

Digital Terrain Elevation Data Compact Disk-Read Only Memory Prototype Evaluation

6. Author(s).

Jerry L. Landrum, James E. Braud, John L. Breckenridge, and Susan V. Carter

5. Funding Numbers.

Program Element No.	63704N
Project No.	01937
Task No.	300
Accession No.	DN257086

7. Performing Organization Name(s) and Address(es).

Ocean Science Directorate
Naval Ocean Research and Development Activity
Stennis Space Center, Mississippi 39529-5004

8. Performing Organization Report Number.
NORDA Report 192

9. Sponsoring/Monitoring Agency Name(s) and Address(es).

CNO (OP-096)
U. S. Naval Observatory
34th and Massachusetts Ave.
Washington, D.C. 20392-1800

10. Sponsoring/Monitoring Agency Report Number.

11. Supplementary Notes.

12a. Distribution/Availability Statement.

Approved for public release; distribution is unlimited. Naval Ocean Research and Development Activity, Stennis Space Center, Mississippi 39529-5004.

12b. Distribution Code.

13. Abstract *(Maximum 200 words).*

This report presents the Navy's evaluation of the Defense Mapping Agency's (DMA) prototype Digital Terrain Elevation Data (DTED) on Compact Disk-Read Only Memory (CD-ROM). The CD-ROM medium offers large savings in cost and in storage space, and is an appropriate on-line digital data base for mini- and micro-computers. A brief description of the CD-ROM technology is presented along with directions for reading the DTED data. Sample applications and results are described, and the evaluation team's recommendations are presented.

14. Subject Terms.

DTED, CD-ROM, product evaluation

15. Number of Pages.
47

16. Price Code.

17. Security Classification of Report. Unclassified	18. Security Classification of This Page. Unclassified	19. Security Classification of Abstract. Unclassified	20. Limitation of Abstract. None

Naval Ocean Research and Development Activity

August 1989

NORDA Report-192.

Digital Terrain Elevation Data Compact Disk-Read Only Memory Prototype Evaluation

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Foreword

This report summarizes the result of the Navy's prototype evaluation of the Defense Mapping Agency's Compact Disk-Read Only Memory as a distribution medium for the Digital Terrain Elevation Data. Twenty individuals participated in the evaluation. They were sent evaluation packages containing data samples and evaluation forms. The CD-ROM proved to be an excellent distribution media that offered large cost savings. The recommendations in this report are being incorporated into the production and will result in a more usable product for the Navy.

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Technical Director

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Commanding Officer

Executive Summary

This report presents the Navy's evaluation of the Defense Mapping Agency's prototype Digital Terrain Elevation Data (DTED) on Compact Disk-Read Only Memory (CD-ROM). The CD-ROM medium offers large savings in cost and in storage space, and is an appropriate on-line digital data base for mini- and micro-computers. A brief description of the CD-ROM technology is presented along with directions for reading the DTED data. Sample applications and results are described, and the evaluation team's recommendations are presented.

Acknowledgments

Contents

Digital Terrain Elevation Data Compact Disk-Read Only Memory Prototype Evaluation

1.0 Introduction

The Mapping, Charting, and Geodesy (MC&G) Division of the Naval Ocean Research and Development Activity (NORDA) is the Navy's lead laboratory for MC&G. The Oceanographer of the Navy tasked NORDA's Digital MC&G Analysis Program (DMAP) to coordinate the Navy's use and development of digital MC&G data.[1] The Commander, Naval Oceanography Command, has tasked DMAP to coordinate the Navy's evaluation of Defense Mapping Agency (DMA) prototype data bases.[2]

Compact Disk-Read Only Memory (CD-ROM) is an excellent medium for the distribution of large data sets, such as the Digital Terrain Elevation Data (DTED). DTED is used or is planned to be used in 45 Navy and Marine systems, which include aircraft mission planning, moving map cockpit displays, targeting, and navigation.[3] CD-ROM allows data organization through directories, subdirectories, and files, while offering either random or sequential access of data within a particular file. In addition to its potential as a distribution medium, it may serve as an on-line data base when speed of access is not a critical issue.

This report describes the CD-ROM technology, DTED file organization and structure, sample applications, responses to the evaluators' questionnaires, and recommendations.

2.0 DTED CD-ROM Overview

The CD-ROM technology uses laser optics and became commercially available in 1985. A CD-ROM weighs less than one ounce, and can be mass produced for about $2.00 per copy. Each CD-ROM holds as much data as about twenty 1600 BPI magnetic tapes. Since magnetic tapes weigh over 2 pounds and cost about $30.00 to produce and ship, tremendous savings of time, money, and space are obvious. Reader devices with software drivers for microcomputers are available for about $800.00 or less. Digital Equipment drives may be connected to Micro-VAXs either directly or to other machines via Ethernet Local Area Networks.

Currently there are two known information storage formats for CD-ROMs, the High Sierra de facto standard and the International Standards Organization (ISO) 9660. The format used is transparent to the user and application program as long as the correct software driver is installed. The prototype DTED CD-ROMs are in the High Sierra format, but DMA plans to use the ISO 9660 format for future distribution.

The proposed organization of the DTED Level 1 data set is shown on DMA's Proposed DTED CD-ROM Index. The worldwide distribution set is to consist of 85 CD-ROMs organized around Operational Navigation Chart (ONC) boundaries. Many of the CD-ROM areas have odd-shaped geographic limits to minimize the number of necessary CD-ROMs and to follow the ONC boundaries.

The DTED directory contains a number of subdirectories that correspond to each one-degree band of longitude. Each of these longitudinal directories contains the one-degree-square DTED files for that longitude band. Thus, a specific geographic coordinate may be used to construct a file specification for the retrieval of the DTED data for that coordinate. The format of the individual one-degree DTED cells is similar to the present magnetic tape distribution format.[4] (The difference is that on the CD-ROM all records are of fixed length, whereas on magnetic tape, records may vary in length, depending on data coverage.) Additionally each CD-ROM contains a gazetteer file to provide geographic positions for selected place names in the covered area.

3.0 Reading the DTED CD-ROM

A complete Microsoft MS-DOS file specification for a DTED cell on CD reader device D, located at 12°E and 48°N would be represented as shown:

D:/DTED/E0120000/N480000.DT1

Each cell file contains a 3508-byte series of descriptive ASCII headers followed by a latitude-dependent number of records. The number of records varies with latitude because the longitude post spacing of DTED increases with latitude to compensate for the convergence of the meridians at the poles. Each record

contains a series of 1201 two-byte binary elevation values for one column of longitude. On some computers, such as IBM-compatible PCs, it is necessary to swap the bytes in the elevation values. (Byte order used for binary data storage varies from computer to computer.) These records are completely described by the DMA product specifications for DTED and the information booklet packaged with the CD-ROMs.

The "C" function DATA (listed in Appendix A) illustrates a general-purpose reader providing random access to elevations for any geographic position on the CD-ROM, while supporting rapid sequential access by buffering one longitudinal column of elevations. To take full advantage of the speed offered by this reader, calls should be ordered by column and file. (One read is performed upon longitudinal column change. One file open and two reads are performed upon file change.)

4.0 Evaluation System Description

For sample applications, development, and testing, NORDA used an IBM-compatible PC (Zenith 248) with Enhanced Graphics Adapter and an Amdek Laserdrive CD-ROM reader with Hitachi Device Driver. The CD-ROM reader had an access time of 0.8 seconds. Programming languages used were Microsoft FORTRAN 3.2 and Microsoft "C" 5.0.

5.0 Sample Applications and Results

The "C" programs described in the following paragraphs are listed in Appendix A. The programs were written in order to assess the correctness of the digital representation on the CD-ROM, the general usefulness of the product, and to provide programming examples for product users. CONGEO plots a screen map of any geographic area contained on a single CD-ROM. CONSAMP plots a screen map of a file produced using program SAMPLE. CONTOUR plots a screen map of the southwest portion of a single DTED cell at full resolution. DATA is a function providing random geographic access to any point on the CD-ROM. SAMPLE creates a sampled file of any geographic area contained on a single CD-ROM. The FORTRAN 3.2 programs are not listed because this FORTRAN 77 subset implementation is not considered adequate for these applications due to the following deficiencies:
- lack of character substring function
- lack of graphics interface
- inability to open files in other than the default directory.

Later versions of Microsoft FORTRAN and FORTRAN 77 implementations generally do not have these deficiencies.

5.1 Application 1: Subsampling of a CD-ROM Coverage Area to a Disk File

The Microsoft FORTRAN 4.0 program provided by Mr. Jere Cadoret of the DMA Systems Center was most useful as an example of a DTED reader. Significant changes, however, were required to run under FORTRAN 3.2. File name restrictions prevented random access across directories. Access using FORTRAN was rather slow. It appeared that a small internal buffer caused a large read to be translated into a series of smaller reads, each taking a 0.8 second access time. Direct access to columns of data was awkward since the size of the DTED file header is not a multiple of the elevation data record size. It is strongly recommended that Microsoft FORTRAN users of this product upgrade to level 4.0. The "C" language proved to be more convenient and nearly twice as fast.

5.2 Application 2: Terrain Relief Map of DTED from CD-ROM

A simple pixel-based algorithm was implemented to render the terrain with color-coded Tanaka contours. The Tanaka contouring technique[5] uses a simulated direction of illumination to shade the contour lines. As the contour interval goes to zero, all pixels are turned on and the map becomes color filled with shaded relief. Programs were coded in FORTRAN 3.2 and "C" 5.0 to display a section of a DTED file at the file resolution of about 100 m. A program was written in "C" to display any rectangular region within a CD-ROM by subsampling the CD-ROM DTED files. The FORTRAN effort was limited by lack of a graphics interface (one had to be written in assembly language and was not completely debugged). Microsoft FORTRAN 4.0 and above are adequate and capable of using the "C" graphics interface.

Figures 1-6 were produced by running the "C" programs, then photographing from the Zenith 248 screen. On these figures the elevation data is color coded, with red being the highest elevation. The shading reveals the fine texture in the terrain data. Simulated illumination is from the north. CD-ROM numbers refer to the proposed DTED CD-ROM Index.

Figure 1 (CD-ROM #9, ONCs D-1, D-2, D-3) and Figure 2 (CD-ROM #15, ONCs E-1, E-2, E-3) were produced using program CONGEO to subsample and display the entire CD-ROM areas. The areas were stretched to the 640 × 350 screen resolution. Considerable distortion resulted, but the maximum data resolution possible on the evaluation system hardware was provided. Each took about 2 hours to plot, since the entire CD-ROM was sampled. To shorten display time, sampled files can be created using program SAMPLE; these can be plotted using program CONSAMP and will produce the same images in about 2 minutes. On Figure 2, the absence of the west coast of Denmark should be noted. This omission points out
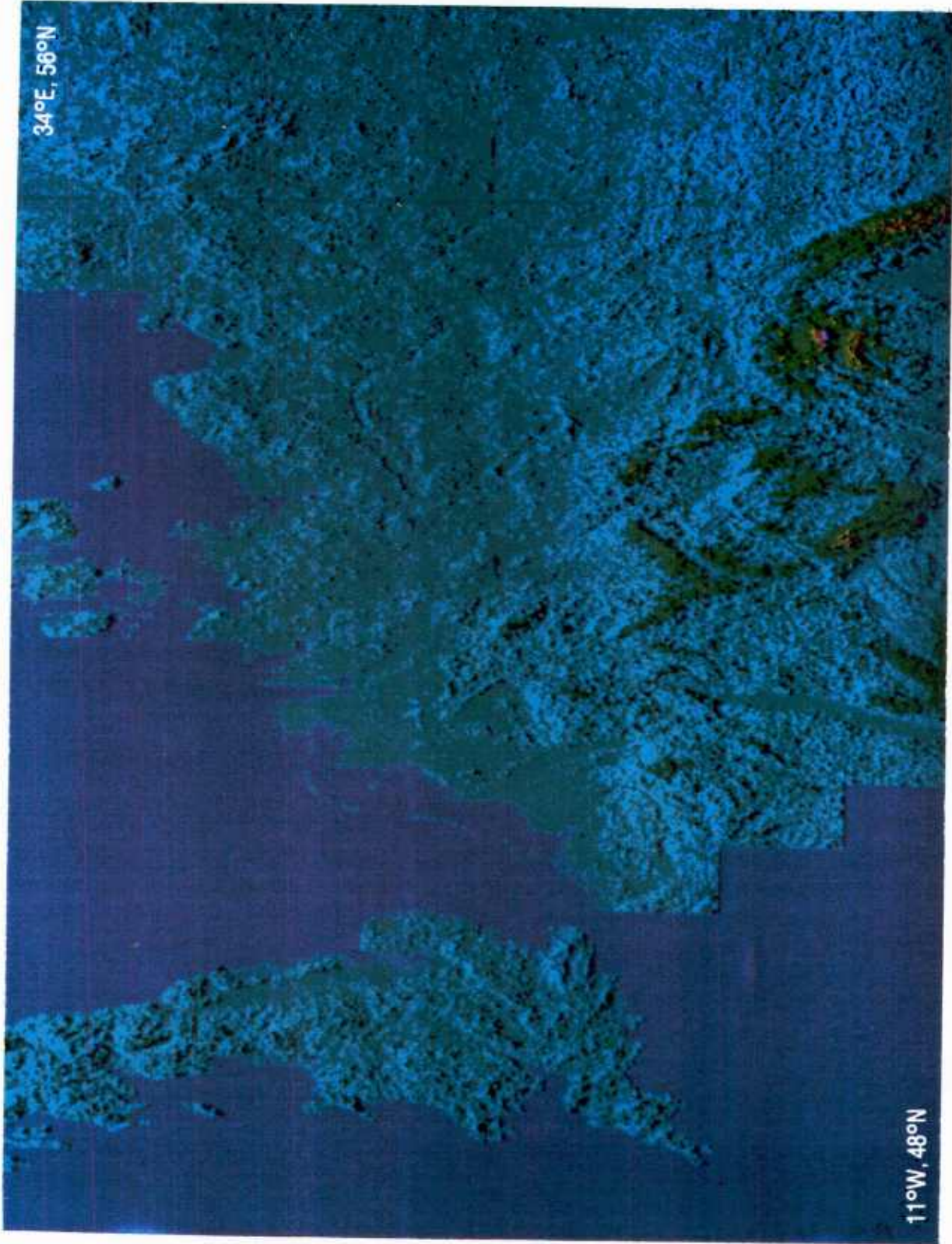
Figure 1. Prototype DTED CD-ROM #9.

3

Figure 2. Prototype DTED CD-ROM #15.

34°E, 56°N

11°W, 48°N

4

a discrepancy in the indicated data coverage. DTED cells for 8°E, 54°N and 8°E, 55°N were indicated to be present on the Location Diagram but were not present on the CD-ROM.

Figures 3 and 4 show the lower part of the one-degree cell at 7°E and 61°N using program CONTOUR at the DTED Level 1 resolution of about 100 m. Figure 3 uses a contour interval of 250 m, and plots in 3.5 minutes from CD-ROM or in 1 minute from the CD-ROM file copied to hard disk. (MS-DOS copy takes 30 seconds for files at this latitude). Figure 4 shows the same file at a contour interval of 0 m, resulting in the color-filled, shaded relief. Plotting time for Figure 4 was 6.5 minutes from CD-ROM and 3.5 minutes from hard disk.

Figure 5 (Southern Norway) and Figure 6 (Eastern Europe) show an intermediate level of resolution of about 1 km. The areas shown are 4° of latitude by 8° of longitude.

6.0 Evaluators' Responses to Questionnaire

DMAP's list of evaluators is included as Appendix B. This list was developed through responses to a call for evaluators in the *DMAP Newsletter*. Collated responses to DMA's evaluation questionnaire are included as Appendix C. DMAP distributed an additional questionnaire, which is included as Appendix D.

6.1 User Information

Most potential Navy users can accept the CD-ROM media in place of magnetic tape, but some do not have CD-ROM readers. Tape distribution may be phased out after the CD-ROM distribution is in place, and all users can read them.

Most users will be using both batch and interactive processing methods.

Table 1 lists the computer systems expected to use DTED from CD-ROM as drives and software drivers become available.

Table 1. List of the computer systems expected to use DTED from CD-ROM as drives and software drivers become available.

MICROVAX III	Intergraph Interview 360
IBM PC Compatible (Zenith 248)	Sun 3-160, 3-280
VAX 11-785	Silicon Graphics IRIS
VAX 11-750	AN/SYQ (V)
VAX 8550	COMPAQ 386/30 PC
Tektronix 4325, 4336, 4301	CDC Cyber 875

6.2 Packaging and Security

Most users considered the information booklet at least adequate, but the information on ISO 9660 drivers needs to be updated, since these are now available.

Most users considered the location diagram to be sufficiently detailed, but some want it to be larger, with the bounds of the covered area labeled, and with more latitude and longitude labels to avoid counting squares. Figure 7 is a copy of one of these location diagrams.

Most users felt the CD-ROM label contained enough information. Both the label and the package need a prominent CD-ROM number to help keep them together when several are in use.

No user had a problem with the physical security requirement.

6.3 Maintenance

Most users prefer annual updates. Some feel that a new CD-ROM should be produced when significant updates occur.

Users who do not have CD-ROM readers will continue to require updates on magnetic tape.

6.4 Ancillary Data

Only one user reported a requirement for the gazetteers.

6.5 CD-ROM Index

Most users considered the organization into 85 CD-ROM areas acceptable; however the Tactical Air Mission Planning System (TAMPS) evaluation (Appendix E) strongly recommends a breakdown by even multiples of 6° in latitude and longitude.

7.0 Conclusions

• The CD-ROM is an excellent distribution media for DTED in terms of cost and weight.

• Since CD-ROM reader devices are not widely available for mainframe computer systems, some users will continue to require magnetic tape distribution. A common solution is by networking a Personal Computer with a CD-ROM reader to the mainframe.

• Byte swapping of the 2-byte elevation records was required for the IBM PC evaluation system used at NORDA.

• The organization of the CD-ROM areas around Operational Navigation Charts does not suit the Navy's needs.

• Minor discrepancies in the data content (missing cells) were noted.

• Different record lengths for the header and data records made direct access using the FORTRAN language awkward.

• The organization of the 1° DTED cells into directories as separate files precluded random access

8°E, 61.5°N
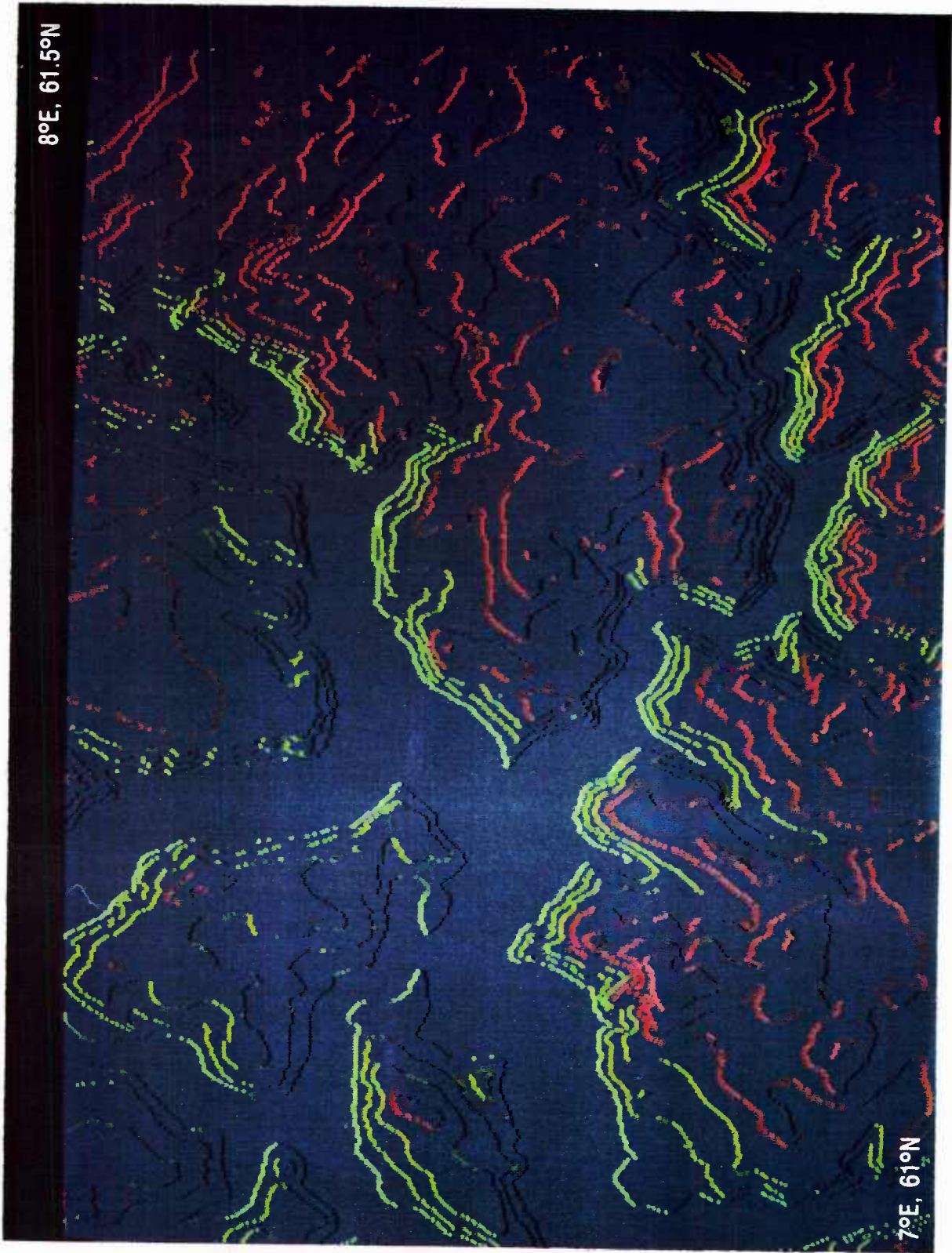
7°E, 61°N

Figure 3. 250-m shaded contour of partial DTED cell.

6
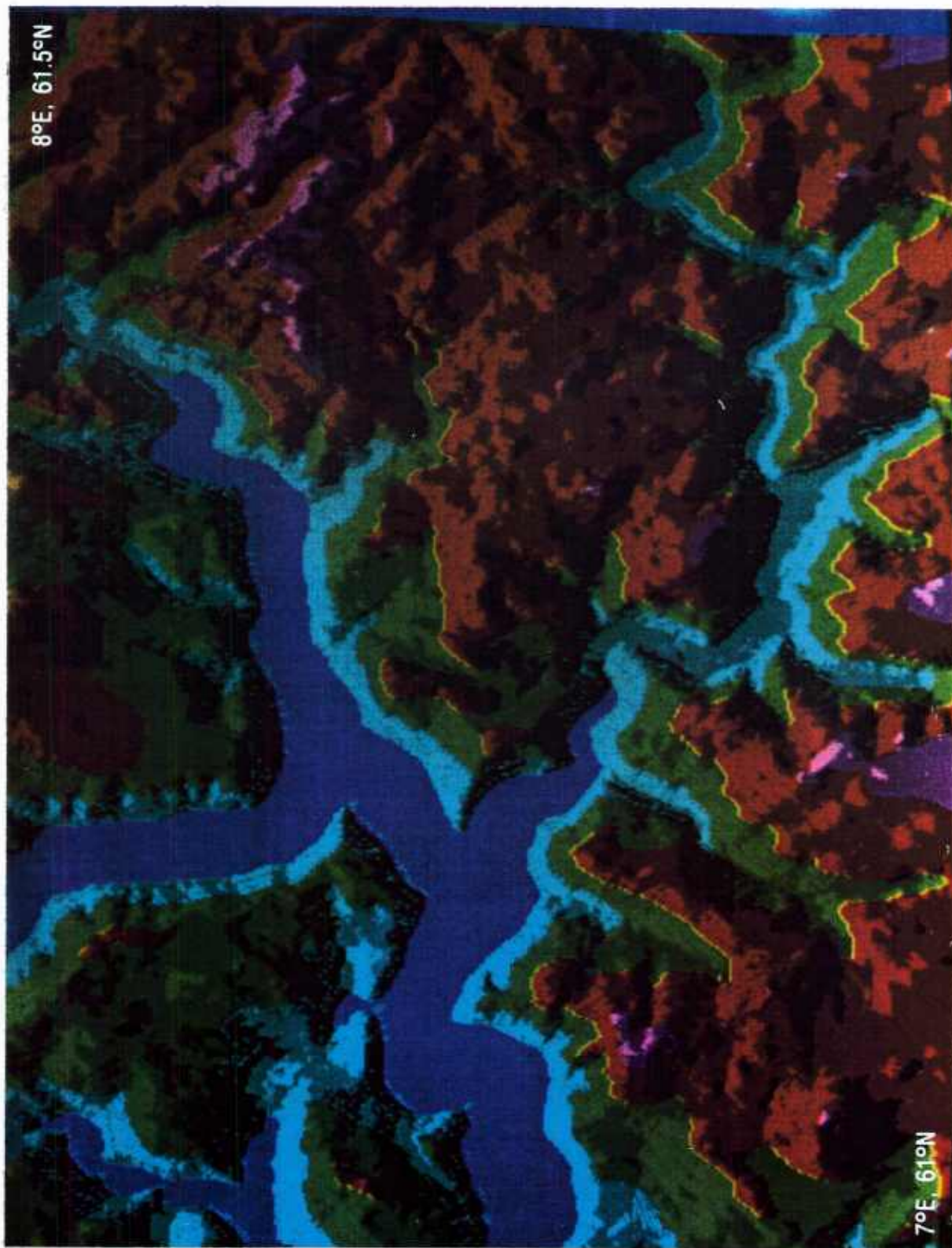
Figure 4. Color shaded relief of partial DTED cell.
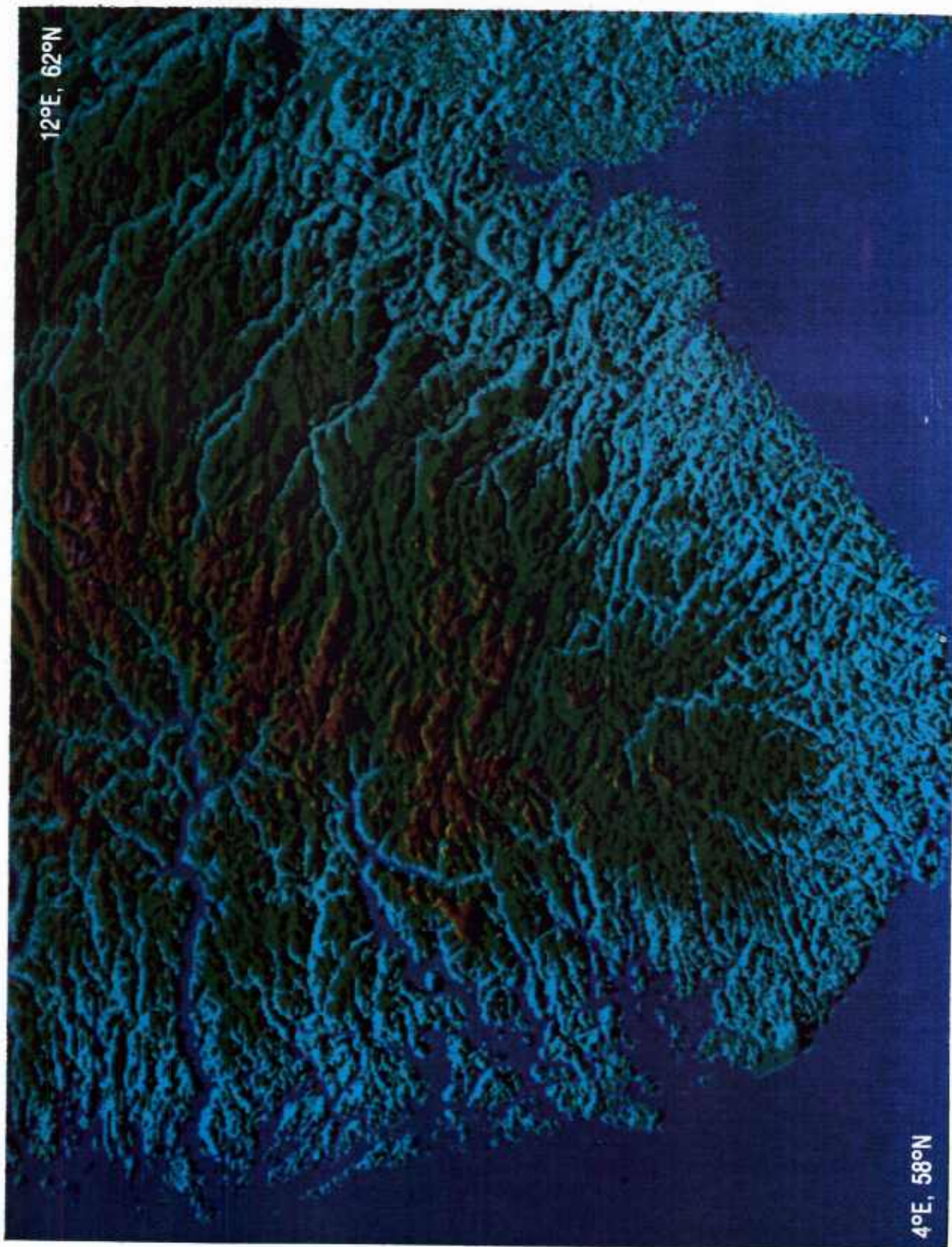
7

12°E, 62°N

4°E, 58°N
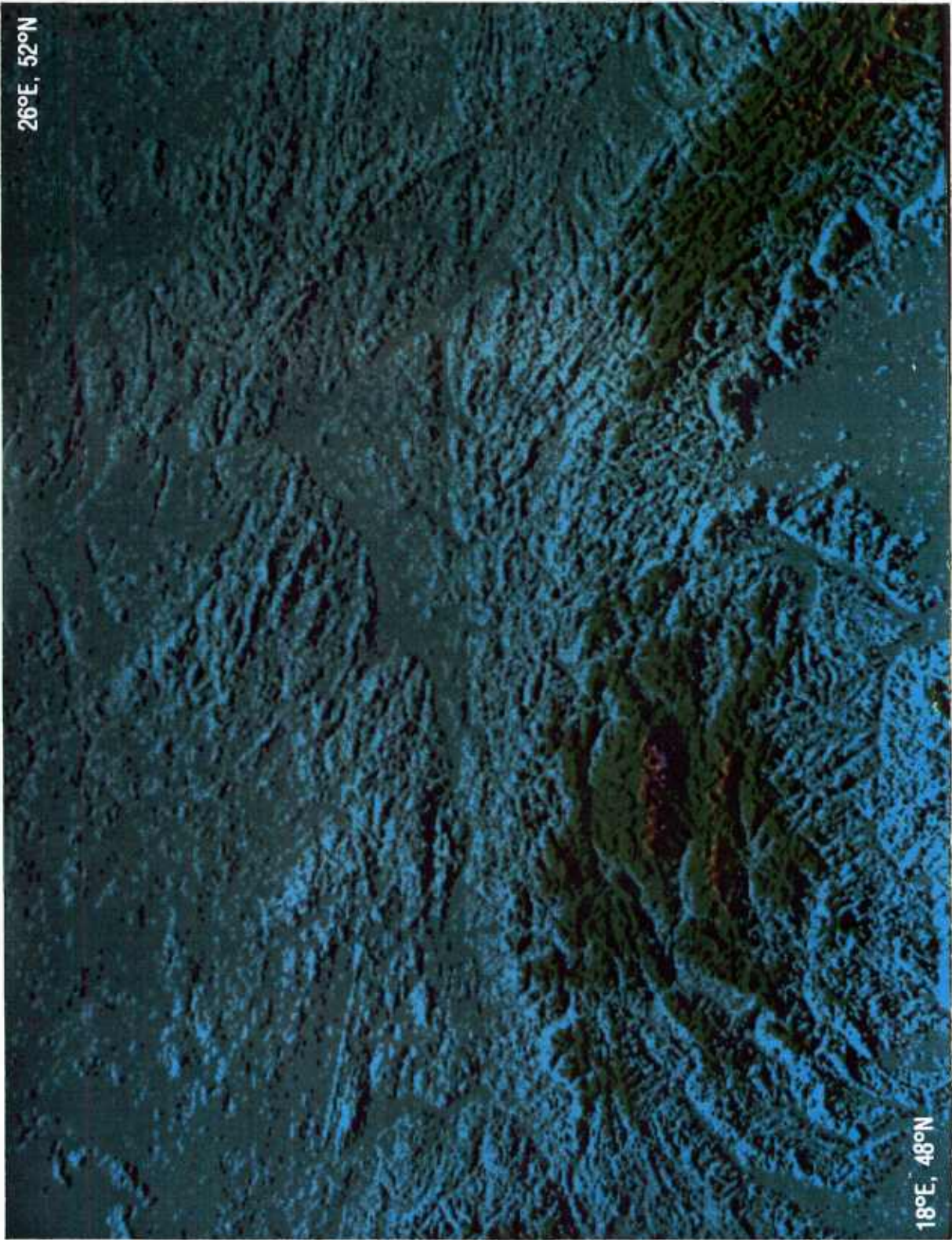
Figure 5. Southern Norway from CD-ROM #9.

8

Figure 6. Eastern Europe from CD-ROM #15.

9

LOCATION DIAGRAM
Geographic Coverage of ONC Areas:
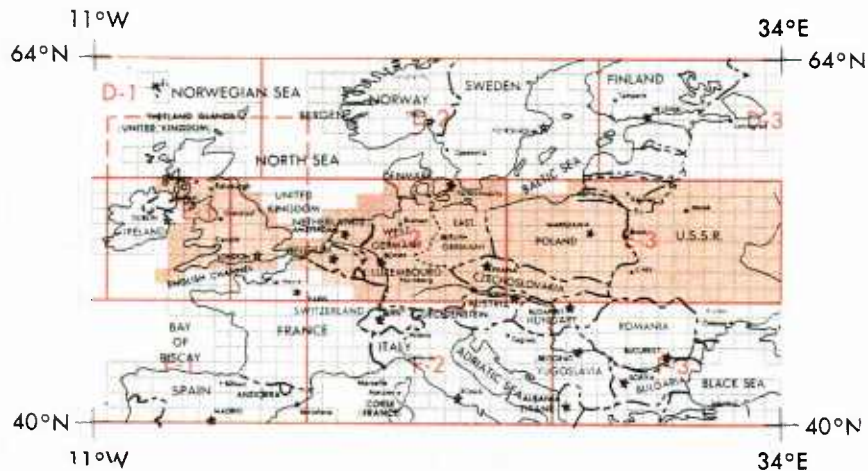48°00'N to 56°00'N
11°00'W to 34°00'E

Figure 7.

across files under the Microsoft FORTRAN 3.2 language but was possible under Microsoft "C" 5.1. and would be possible with Microsoft FORTRAN 4.0 and above.

• The Location Diagram supplied with the CD-ROMs is not adequate and needs to be reworked.

• The software supplied with the evaluation package was not adequate to perform a thorough evaluation.

8.0 Recommendations

8.1 Recommendations Not Affecting the DTED File Format

1. Reorganize the CD-ROM index into areas bordered by integer multiples of 6° in latitude and longitude. This reorganization would make the algorithmic determination of CD-ROM number from geographic position simpler. It would facilitate the use of CD-ROM as a worldwide, on-line data base. It would directly support the TAMPS application and would result in a less cluttered, easier-to-read index. The following are the desired characteristics; six-degree multiple boundaries, preferably square; full CD-ROM; and geographic and political features intact.

2. Insure that the location diagram accurately reflects the contents of the CD-ROM. Differences were noted on CD-ROM #9.

3. Enlarge the Location Diagram in the CD-ROM case. Use more latitude and longitude labels to reduce "counting the squares." This would be more readily accomplished if the areas were more square. Another solution would be to supplement it with a paper chart for each CD-ROM showing the covered areas in some sort of terrain relief, possibly similar to Figures 1 and 2,

but with lighter shades, a 1° labeled geographic grid, and selected place names plotted from the gazetteer. This method could also serve to automate the production of the location diagram, avoid discrepancies due to human error, and provide users with an overview of the topography.

4. Provide updates as significant changes occur via restamped CD-ROM. Any other update system would be awkward for an interactive user.

5. Place a prominent CD-ROM number on both the CD-ROM and case.

8.2 Recommendations Affecting the DTED File Format

While evaluation of the DTED file format is beyond the scope of this evaluation of the CD-ROM as a distribution medium, this may be a good time to reconsider the file format in light of the possibilities offered by the CD-ROM technology.

1. Include the maximum and minimum elevations in a DTED cell in the cell header to facilitate graphical applications where elevations are scaled into colors.

2. Make the length of the cell headers a multiple of the data record length to facilitate direct access using fixed record length. The elevation record length is 2414 bytes. The cell header length is now 3508 bytes. The header length should either be shortened to 2414 bytes or extended to 4828 bytes.

3. Consider data compression techniques to put more data on each CD-ROM.

4. A common Navy platform for reading the CD-ROM is the IBM-compatible PC, which requires byte swapping of the binary elevation records. This byte swapping should be done before creating the CD-ROM.

10
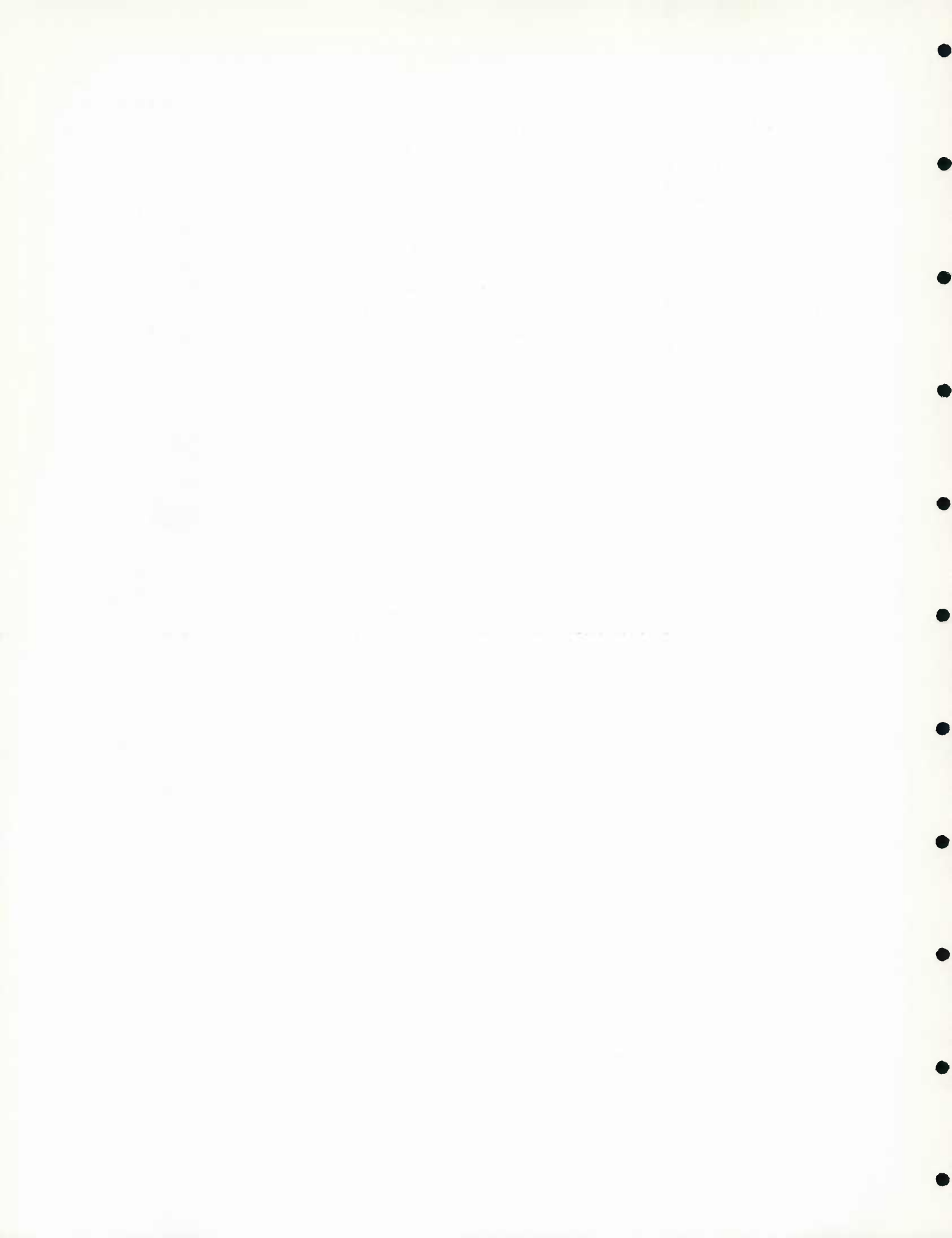
5. Consider possible reorganization to support rapid retrieval of data at various levels of resolution. An example would be a low-resolution grid containing elevation averages, as well as pointers to higher resolution grid files. These higher resolution grid cells could contain pointers to even higher resolution data. The CD-ROM technology offers many possibilities to exploit.

9.0 References

1. Chief of Naval Operations (1986). CNO Ltr Ser 098R/64353525.

2. Commander, Naval Oceanography Command (1983). Ltr Ser 952/3U349699.

3. Gebhardt, Kim and Susan Carter (1989). *Navy Requirements for Digital Mapping, Charting, and Geodesy Data*. Naval Ocean Research and Development Activity, Stennis Space Center, MS, NORDA Report (in preparation).

4. Defense Mapping Agency (1986). *Product Specifications for Digital Terrain Elevation Data*. Second Edition, Defense Mapping Agency Aerospace Center, St. Louis, MO, April.

5. Langran, Gail (1984). *Map Design for Computer Processing: Literature Review and DMA Product Critique*. Naval Ocean Research and Development Activity, Stennis Space Center, MS, NORDA Report 72, December.

Appendix A

"C" Program Listings

```c
/*
PROGRAM CONGEO - a pixel based contour algorighm                18-NOV-1988
Uses Microsoft C5.1 on IBM PC with EGA.
Produces the following displays of any rectrangular area contained within
    a single Digital Terrain Elevation Data Compact Disk:
    COLOR CONTOUR (contour interval > 0, shading threshold large),
    TANAKA SHADED CONTOUR (contour interval > 0, shading threshold small),
    COLOR FILLED CONTOUR (contour interval = 0, shading threshold large),
    COLOR SHADED RELIEF (contour interval=0, shading threshold small)

User inputs:
        backcol- short- background and data out of range color
        datmin,datmax- short- data outside this range will not be
                plotted. Hues will be scaled to this range.
        conint- short- contour interval in meters. Since the same code
                is used for contouring and filling if cint=0,
                a color filled map results.
        shade_threshold- short- the amount of elevation change in
                adjacent grid points that will result in the pixel
                being shaded light or dark. If very large, no shading
                will result. A negative value moves the illumination
                from the North to the South.
        rlonw,rlone,rlats,rlatn- double- geographic bounds of desired map

Routines called: Microsoft C 5.0 run time library
        data- short- returns an elevation from the CD-ROM for a geographic
        position.

Algorithm:
        for each x
          for each y
            if data is within desired range
              if contour interval not 0, compute contour number
                if contour interval is 0 or contour number has changed
                    from last point
                  scale the data value into a hue
                  compare slope against shade_threshold to get shade
                  compute color number from hue and shade
                  color the pixel

Limitations: The simple algorithm used results in missing pixels on
        vertical contour lines.

Author: Jerry Landrum, Naval Ocean Research and Development Activity
        Code 351, Stennis Space Center, Ms. 39522   phone (601) 688-4613
        AV 485-4613
*/
#include <stdio.h>
#include <stdlib.h>
#include <graph.h>
#define XMAXSC 640
#define YMAXSC 350

void main(void);
/*      Until a better way is found to set the palette, dark grey is used as
        the dark shade of all the hues.
        color map:    cyan    green   red     magenta
                      d m l   d m l   d m l   d m l                d=dark
```

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```
                                                                     m=medium
                                                                     l=light
                         | | |  | | |  | | |  | | |                    */

        short pal[12]={8,3,11,8,2,10,8,4,12,8,5,13};

void main(void)
{
        short data(double a, double b);
        short len,i;
        short    x=0,y=0;
        char line[80];
        char ok='n';
        short dat;
        float cscale;
        short color,hue,diff,datlas,shade,range,backcol;
        short datmin,datmax,shade_threshold;
        short conint,ic,iclast;
        short firstc=0;
        short nshade=3;
        short nhue=4;
        short xmax=XMAXSC;
        short ymax=YMAXSC;
        double rlonw,rlone,rlats,rlatn,rlon,rlat,rlonin,rlatin,geoinc;

/* get user input */
        input:;
        printf("Program PIXCON, hit RETURN to use default value in ()\n\n");
        printf("Enter background color number (9)\n");
                gets(line);
                if(sscanf(line,"%d",&backcol)<1) backcol=9;
        printf("Enter minimum data value? (1)\n");
                gets(line);
                if(sscanf(line,"%d",&datmin)<1) datmin=1;
        printf("Enter maximum data value? (2000)\n");
                gets(line);
                if(sscanf(line,"%d",&datmax)<1) datmax=2000;
        printf("Enter contour interval? (0)\n");
                gets(line);
                if(sscanf(line,"%d",&conint)<1) conint=0;
        printf("Enter shading threshold? (10)\n");
                gets(line);
                if(sscanf(line,"%d",&shade_threshold)<1) shade_threshold=10;
        printf("Enter geographic limits of area, west,east,south,north-real?");
        printf("     ( 41. 43. 56. 58. )");
                gets(line);
                if(sscanf(line,"%lf %lf %lf %lf",&rlonw,&rlone,&rlats,&rlatn)<4)
                        {rlonw=41.;rlone=43.;rlats=56.;rlatn=58.;}
        range=datmax-datmin;
        cscale= (float)nhue/(float)range;
        rlonin= (rlone-rlonw)/(double)XMAXSC;
        rlatin= (rlatn-rlats)/(double)YMAXSC;
        if(rlonin>rlatin) geoinc=rlonin;
                else geoinc=rlatin;
        printf("WESN: %lf %lf %lf %lf\n",rlonw,rlone,rlats,rlatn);
        printf("rlonin,rlatin: %lf %lf\n",rlonin,rlatin);
        printf("Any changes? (n)");
        scanf("%s",ok);
```

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```
            if(ok=='y') goto input;
/* one dummy call to function data so it prompts for CD drive before graphics m
        dat=data(rlonw,rlats);
/* set up terminal*/
        if (_setvideomode(_ERESCOLOR)==0)
        {
                printf("Graphics mode not available.\n");
                exit(-1);
        }
/* clear the screen */
        _setcolor(backcol);
        _rectangle(_GFILLINTERIOR,0,0,640,350);
/* outer loop in x, x coresponds to pixel position and data column */
        for(rlon=rlonw;rlon<=rlone;rlon=rlon+geoinc)
        {
                y=0;
                for(rlat=rlats;rlat<=rlatn;rlat=rlat+geoinc)
                {
                        dat=data(rlon,rlat);
                /*      printf("rlon,rlat,dat: %lf %lf %d\n",rlon,rlat,dat);*/
/* test for desired data range */
                        if((dat>datmin) && (dat<datmax))
                        {
                                if(conint !=0) ic=dat/conint;
                                if((conint==0)||(ic!=iclast))
                                {
/* compute hue, shade, and color */
                                        hue=(dat-datmin+conint/2)*cscale;
                                        diff=dat-datlas;
                                        shade=1;
                                        if(diff<-shade_threshold) shade=2;
                                        if(diff>shade_threshold) shade=0;
                                        color=firstc+shade+hue*nshade;
                                        iclast=ic;
/* color one pixel */
                                        _setcolor(pal[color]);
                                        _setpixel(x,350-y);
                                /*      printf("x,y,color: %d %d %d\n",x,y,color);*/
                                }
                        datlas=dat;
                        y++;
                } /* end of y loop */
                x++;
        } /* end of x loop */
/* end the program upon keyboard action */
        while(!kbhit()); /* Strike any key to continue */
        _setvideomode(_DEFAULTMODE);
}
```

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```
/*
PROGRAM CONSAMP - a pixel based contour algorighm. Input file of DTED produce
        using program SAMPLE. This program does not read the DTED distributio
        format.
Uses Microsoft C5.1 on IBM PC with EGA.
Produces the following displays of Digital Terrain Elevation Data
        read from a Compact Disk Read Only Memory file:
   COLOR CONTOUR (contour interval > 0, shading threshold large),
   TANAKA SHADED CONTOUR (contour interval > 0, shading threshold small),
   COLOR FILLED CONTOUR (contour interval = 0, shading threshold large),
   COLOR SHADED RELIEF (contour interval=0, shading threshold small)

User inputs:
        backcol- short- background and data out of range color
        datmin,datmax- short- data outside this range will not be
                plotted. Hues will be scaled to this range.
        conint- short- contour interval in meters. Since the same code
                is used for contouring and filling if cint=0,
                a color filled map results.
        shade_threshold- short- the amount of elevation change in
                adjacent grid points that will result in the pixel
                being shaded light or dark. If very large, no shading
                will result. Simulated light from the north.
        file- char- name of sampled elevation file produced by program
                SAMPLE.

Algorithm:
        for each x
          for each y
            if data is within desired range
              if contour interval not 0, compute contour number
                if contour interval is 0 or contour number has changed
                    from last point
                  scale the data value into a hue
                  compare slope against shade_threshold to get shade
                  compute color number from hue and shade
                  color the pixel

Limitations: The simple algorithm used results in missing pixels on
        vertical contour lines.

Author: Jerry Landrum, Naval Ocean Research and Development Activity
        Code 351, Stennis Space Center, Ms. 39522   phone (601) 688-4613
        AV 485-4613
*/
#include <stdio.h>
#include <stdlib.h>
#include <graph.h>
#define XMAXSC 640
#define YMAXSC 350

void main(void);
/*      Until a better way is found to set the palette, dark grey is used as
        the dark shade of all the hues.
         color map:    cyan   green  red    magenta
                       d m l  d m l  d m l  d m l                 d=dark
                                                                  m=medium
                                                                  l=light
```

```
                      | | |   | | |   | | |   | | |
*/
        short pal[12]={8,3,11,8,2,10,8,4,12,8,5,13};

        char file[30];
void main(void)
{
        short len,i;
        short   x,y;
        FILE    *fin;
        char line[80];
        float   header[8];
/* header[0]=rlonw, [1]=rlone, [2]=rlats, [3]=rlatn,
         [4]=lon spacing [5]=lat spacing [6]=width of grid [7]=height of grid*/
        short   data[YMAXSC];
        short dat;
        float cscale;
        short color,hue,diff,datlas,shade,range,backcol;
        short datmin,datmax,shade_threshold;
        short conint,ic,iclast;
        short firstc=0;
        short nshade=3;
        short nhue=4;
        short iw,ih;
        short xmax=XMAXSC;
        short ymax=YMAXSC;

/* get user input */
        printf("Program PIXCON, hit RETURN to use default value in ()\n\n");
        printf("Enter background color number (9)\n");
                gets(line);
                if(sscanf(line,"%d",&backcol)<1) backcol=9;
        printf("Enter minimum data value? (1)\n");
                gets(line);
                if(sscanf(line,"%d",&datmin)<1) datmin=1;
        printf("Enter maximum data value? (2000)\n");
                gets(line);
                if(sscanf(line,"%d",&datmax)<1) datmax=2000;
        printf("Enter contour interval? (0)\n");
                gets(line);
                if(sscanf(line,"%d",&conint)<1) conint=0;
        printf("Enter shading threshold? (10)\n");
                gets(line);
                if(sscanf(line,"%d",&shade_threshold)<1) shade_threshold=10;
        printf("Enter DTED sampled file spec? (%s)\n",file);
                gets(line);
                printf("len= %d",strlen(line));
                if(strlen(line) > 1) sscanf(line,"%s",file);
        while ((fin = fopen(file,"rb"))==NULL){
                printf("Error opening file: %s\n",file);
                printf("Enter another file spec?");
                scanf("%s",file);}
        len = fread(header,sizeof(float),8,fin);

/* extract the file width and height */
        ih=header[7];
        iw=header[6];
        if(ih<YMAXSC) ymax=ih;
```

```
        if(iw<XMAXSC) xmax=iw;
/* set up terminal*/
        if (_setvideomode(_ERESCOLOR)==0)
        {
                printf("Graphics mode not available.\n");
                exit(-1);
        }
/* clear the screen */
        _setcolor(backcol);
        _rectangle(_GFILLINTERIOR,0,0,640,350);
        range=datmax-datmin;
        cscale= (float)nhue/(float)range;
/* outer loop in x, x coresponds to pixel position and data column */
        for(x=0;x<=xmax;x++)
        {
/* read one column of DTED data */
                len=fread(data,2,ih,fin);
/* inner loop in y, y corresponds to pixel position and data row */
                for(y=0;y<=ymax;y++)
                {
                        dat=data[y];
/* test for desired data range */
                        if((dat>datmin) && (dat<datmax))
                        {
                                if(conint !=0) ic=dat/conint;
                                if((conint==0)||(ic!=iclast))
                                {
/* compute hue, shade, and color */
                                        hue=(dat-datmin+conint/2)*cscale;
                                        diff=dat-datlas;
                                        shade=1;
                                        if(diff<-shade_threshold) shade=2;
                                        if(diff>shade_threshold) shade=0;
                                        color=firstc+shade+hue*nshade;
                                        iclast=ic;
/* color one pixel */
                                        _setcolor(pal[color]);
                                        _setpixel(x,350-y);
                                }
                        }
                        else iclast=-1;
                        datlas=dat;
                } /* end of y loop */
        } /* end of x loop */
        fclose(fin);
/* end the program upon keyboard action */
        while(!kbhit()); /* Strike any key to continue */
        _setvideomode(_DEFAULTMODE);
}
```

```
/*
PROGRAM CONTOUR - a pixel based contour algorighm
Uses Microsoft C5.1 on IBM PC with EGA.
Produces the following displays of Digital Terrain Elevation Data
         read from a Compact Disk Read Only Memory file:
   COLOR CONTOUR (contour interval > 0, shading threshold large),
   TANAKA SHADED CONTOUR (contour interval > 0, shading threshold small),
   COLOR FILLED CONTOUR (contour interval = 0, shading threshold large),
   COLOR SHADED RELIEF (contour interval=0, shading threshold small)

User inputs:
         backcol- short- background and data out of range color
         datmin,datmax- short- data outside this range will not be
                 plotted. Hues will be scaled to this range.
         conint- short- contour interval in meters. Since the same code
                 is used for contouring and filling if cint=0,
                 a color filled map results.
         shade_threshold- short- the amount of elevation change in
                 adjacent grid points that will result in the pixel
                 being shaded light or dark. If very large, no shading
                 will result. A negative value moves the illumination
                 from the North to the South.
         file- char- file specification of DTED
                 elevation file, either on CD-ROM or copied to hard
                 disk.(runs faster from hard disk)

Algorithm:
         for each x
           for each y
             if data is within desired range
               if contour interval not 0, compute contour number
                 if contour interval is 0 or contour number has changed
                     from last point
                   scale the data value into a hue
                   compare slope against shade_threshold to get shade
                   compute color number from hue and shade
                   color the pixel

Limitations: The simple algorithm used results in missing pixels on
         vertical contour lines.

Author: Jerry Landrum, Naval Ocean Research and Development Activity
         Code 351, Stennis Space Center, Ms. 39522  phone (601) 688-4613
         AV 485-4613
*/
#include <stdio.h>
#include <stdlib.h>
#include <graph.h>
#define XMAXSC 640
#define YMAXSC 350

void main(void);
/*       Until a better way is found to set the palette, dark grey is used as
         the dark shade of all the hues.
           color map:    cyan     green   red      magenta
                         d m l    d m l   d m l    d m l           d=dark
                                                                   m=medium
                                                                   l=light
```

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```c
*/
        short pal[12]={8,3,11,8,2,10,8,4,12,8,5,13};

        char file[ ]="D:\\DTED\\E0080000\\N610000.DT1";
void main(void)
{
        short len,i;
        short   x,y;
        FILE    *fin;
        char line[80];
        unsigned char   header[3508];
        short           data[1207];
        short dat;
        float cscale;
        short color,hue,diff,datlas,shade,range,backcol;
        short datmin,datmax,shade_threshold;
        short conint,ic,iclast;
        short firstc=0;
        short nshade=3;
        short nhue=4;
        char iws[4],ihs[4];
        short iw,ih;
        short xmax=XMAXSC;
        short ymax=YMAXSC;

/* get user input */
        printf("Program PIXCON, hit RETURN to use default value in ()\n\n");
        printf("Enter background color number (9)\n");
                gets(line);
                if(sscanf(line,"%d",&backcol)<1) backcol=9;
        printf("Enter minimum data value? (1)\n");
                gets(line);
                if(sscanf(line,"%d",&datmin)<1) datmin=1;
        printf("Enter maximum data value? (2000)\n");
                gets(line);
                if(sscanf(line,"%d",&datmax)<1) datmax=2000;
        printf("Enter contour interval? (0)\n");
                gets(line);
                if(sscanf(line,"%d",&conint)<1) conint=0;
        printf("Enter shading threshold? (10)\n");
                gets(line);
                if(sscanf(line,"%d",&shade_threshold)<1) shade_threshold=10;
        printf("Enter DTED file spec? (%s)\n",file);
                gets(line);
                printf("len= %d",strlen(line));
                if(strlen(line) > 1) sscanf(line,"%s",file);
        while ((fin = fopen(file,"rb"))==NULL){
                printf("Error opening file: %s\n",file);
                printf("Enter another file spec?");
                scanf("%s",file);}
        len = fread(header,1,3508,fin);
        printf("%i %s\n", len,header);
/* extract the file width and height */
        for(i=0;i<4;i++) ihs[i]=header[i+441];
        for(i=0;i<4;i++) iws[i]=header[i+445];
        ih=atoi(ihs);
        iw=atoi(iws);
        if(ih<YMAXSC) ymax=ih;
```

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```c
            if(iw<XMAXSC) xmax=iw;
/* set up terminal*/
            if (_setvideomode(_ERESCOLOR)==0)
            {
                    printf("Graphics mode not available.\n");
                    exit(-1);
            }
/* clear the screen */
            _setcolor(backcol);
            _rectangle(_GFILLINTERIOR,0,0,640,350);
            range=datmax-datmin;
            cscale= (float)nhue/(float)range;
/* outer loop in x, x coresponds to pixel position and data column */
            for(x=0;x<=xmax;x++)
            {
/* read one column of DTED data */
                    len=fread(data,2,1207,fin);
/* must swap bytes on IBM */
                    swab((char *)data,(char *)data,sizeof(data));
/* inner loop in y, y corresponds to pixel position and data row */
                    for(y=0;y<=ymax;y++)
                    {
                            dat=data[y+4];
/* test for desired data range */
                            if((dat>datmin) && (dat<datmax))
                            {
                                    if(conint !=0) ic=dat/conint;
                                    if((conint==0)||(ic!=iclast))
                                    {
/* compute hue, shade, and color */
                                    hue=(dat-datmin+conint/2)*cscale;
                                    diff=dat-datlas;
                                    shade=1;
                                    if(diff<-shade_threshold) shade=2;
                                    if(diff>shade_threshold) shade=0;
                                    color=firstc+shade+hue*nshade;
                                    iclast=ic;
/* color one pixel */
                                    _setcolor(pal[color]);
                                    _setpixel(x,350-y);
                                    }
                            }
                            datlas=dat;
                    } /* end of y loop */
            } /* end of x loop */
            fclose(fin);
/* end the program upon keyboard action */
            while(!kbhit()); /* Strike any key to continue */
            _setvideomode(_DEFAULTMODE);
}
```

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```
/*      FUNCTION DATA   Microsoft C 5.0
Random access retreival of Digital Terrain Elevation Data from
Compact Disk- Read Only Memory

            inputs- double rlon- longitude in real degrees, positive for East,
                                        negative for West.
                    double rlat- latitude in read degrees, positive for North,
                                        negative for South.

            output- short data- elevation in meters read from CD-ROM. If no
                    data available at the position, a value of -9999 is returned.

            method- buffers one longitude column of data, thus it is much faster
                    if called for points in vertical order.

            algorithm- If desired point not in the currently open DTED file
                            construct new file spec and open.
                       If desired point not currently in the column buffer,
                            read the desired column.
                       Extract the desired point from the column buffer.

            by- Jerry Landrum, NORDA DMAP, AV 485-4613
*/
#include <stdio.h>
#include <stdlib.h>
short data(double rlon,double rlat)
{
FILE *fin;
static char file[30]="D:\\DTED\\E0000000\\N000000.DT1";
    /*                 01 23456 789012345 678901234567890 */
        short dat[1201];
        static long firste=3516;
        static long lencol=2414;
        long recnum;
        long i,lon,lat,lonsec,latsec,latindex;
        static long lonspc,latspc,column,lastcolumn=-9999;
        static int lastlon=9999,lastlat=9999;
        static short nofile=0,nodata=-9999;
        static int first=1;
        char lonc[4],latc[3],drive[1];
        long seek,len;
        double rlond,rlatd;
/* bias the lon with 360 and lat with 180 - this makes things easier
   since the addressing within a file is from the lower left corner. */
        rlond=rlon+360.;
        rlatd=rlat+180.;
/* extract integer degrees to construct file spec, and fractional part
   in seconds to compute position of elevation in the file. */
        lon=(int)rlond;
        lonsec=(rlond-(double)lon)*3600;
        lat=(int)rlatd;
        latsec=(rlatd-(double)lat)*3600;
/* if lat or lon of lower left corner has changed, must construct a file spec,
   close the currently open file and try to open the new one. */
        if((lon!=lastlon) || (lat!=lastlat))
        {
                lastlon=lon;
                lastlat=lat;
```

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```
                for(i=10;i<13;i++) file[i]='0';
                for(i=19;i<21;i++) file[i]='0';
                itoa(abs(lon-360),lonc,10);
                itoa(abs(lat-180),latc,10);
                for(i=0;i<strlen(lonc);i++) file[12-strlen(lonc)+i]=lonc[i];
                for(i=0;i<strlen(latc);i++) file[20-strlen(latc)+i]=latc[i];
                if(lon<360) file[8]='W';
                        else file[8]='E';
                if(lat<180) file[17]='S';
                        else file[17]='N';
/*  prompt for CD-ROM device letter on first call only */
                if(first==1)    {first=0;
                                printf("Enter CD-ROM drive letter(1 char)?");
                                scanf("%s",drive);
                                file[0]=drive[0];
        printf("file: %s",file);}
                        else fclose(fin);
                if((fin=fopen(file,"rb"))==NULL)
                        nofile=1; /* flag indicates file could not be opened*/
                else
                        {
                        nofile=0; /* flat indicates file sucessfully opened*/
/*  read and decode the lon and lat spacing (lonspc,latspc) from file header */
                        fseek(fin,(long) 100,SEEK_SET);
                        fscanf(fin,"%4ld%4ld",&lonspc,&latspc);
                        lonspc=lonspc/10;
                        latspc=latspc/10;
                        lastcolumn=-999;
                        }
        }
/*  if the needed file could not be opened, return the nodata value */
        if (nofile==1) return nodata;
/*  if the longitude column changed from the last call,
    must read a column of DTED*/
        column=lonsec/lonspc;
        if(column!=lastcolumn)
/*  recnum is the byte offset to the desired column of data */
                {
                recnum= firste + column*lencol;
                seek=fseek(fin,recnum,SEEK_SET);
/*  read one column of data */
                len=fread(dat,sizeof(short),1201,fin);
/*  on IBM must swap the bytes */
                swab( (char*)dat,(char*)dat,sizeof(dat));
/*  save longitude for test on next call */
                lastcolumn=column;
                }
/*  latindex is the index into the column of data for the desired latitude */
        latindex=latsec/latspc;
/*  return the desired elevation */
        return dat[latindex];
}
```

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```c
/*  PROGRAM SAMPLE  Microsoft C 5.0
  Produces a rectangular grid file on disk by regular sampling of DTED
        from CD-ROM.

        inputs(from terminal):
                outfil- char- output file spec
                iw,ih- short- desired output grid width and height
                rlonw,rlone,rlats,rlatn- double- west,east,south,north limits
                        of desired area.

        routines called- Microsoft C 5.0 run time library
                data- short- returns a data value for a geographic
                position from the DTED CD-ROM.

        method: compute sampling increment (geoinc) from inputs, retrieve
                the data column by column and write to output file.

        by: Jerry Landrum, NORDA DMAP, AV 485-4613.
*/
#include <stdio.h>
#include <stdlib.h>
#define XMAX 640
#define YMAX 350

void main(void);

void main(void)
{
        short data(double a, double b);
        double rlonw,rlone,rlats,rlatn,rlatin,rlonin,rlon,rlat;
        short iw,ih,ix,iy;
        static float header[8];
/*  buffer for one colunm of output data */
        static datout[YMAX];
        FILE *fout;
        static char outfil[30];
/*  get user input   */
        printf("Enter output file spec?");
                scanf("%s",outfil);
        printf("Enter desired output file size, x and y?\n");
                scanf("%d %d",&iw,&ih);
                if(ih>YMAX){
                        printf("File too big, reset YMAX in program SAMPLE");
                        exit(-1);}
        printf("Enter geographic limits(WESN)?\n");
                scanf("%lf %lf %lf %lf",&rlonw,&rlone,&rlats,&rlatn);
/*  rlonin is sampling increment in degrees lon */
        rlonin=(rlone-rlonw)/(double)iw;
/*  rlatin is sampling increment in degrees lat */
        rlatin=(rlatn-rlats)/(double)ih;
/*  form the output file header, open output file, and write out header */
        header[0]=rlonw;
        header[1]=rlone;
        header[2]=rlats;
        header[3]=rlatn;
        header[4]=rlatin;
        header[5]=rlonin;
        header[6]=(float)iw;
```

```
        header[7]=(float)ih;
        printf("%f %f %f %f %f %f %f %f\n",header[0],header[1],header[2],header
        fout=fopen(outfil,"wb");
        fwrite((char *)header,sizeof(float),8,fout);
        rlon=rlonw;
/*   begin loop for columns left to right */
        for(ix=0;ix<iw;ix++)
        {
                rlat=rlats;
/*   begin loop for one column bottom to top */
                for(iy=0;iy<ih;iy++)
                {
/*   function data returns one elevation for any point on the CD-ROM */
                        datout[iy]=data(rlon,rlat);
                        rlat=rlat+rlatin;
                }
/*   end of one column, write it to the output file */
                fwrite(datout,sizeof(short),ih,fout);
                rlon=rlon+rlonin;
        }
/*   end of column loop, close output file */
        fclose(fout);
}
```

Appendix B

Evaluation Team Members

Evaluator	Serial Number	Autovon	Commerical
CDR Chuck Miller, III NAVAIRSYSCOM Code 526W Washington, DC 20361	00068	222-3449	202 692-3449
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Evaluator	Serial Number	Autovon	Commerical
Mr. John M. Quinn NAVOCEANO Code GM SSC, MS 39522-5001	00060	485-5828	601 689-5828
Gary N. Richard NSWC Code N22 Dahlgren, VA 22448	00059		703 663-4229
Mr. Sam Smith NSWC Code K12 Dahlgren, VA 22448	00058	249-8159	703 663-8159
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Evaluator	Serial Number	Autovon	Commerical
Maura Lohrenz NORDA Code 351 Stennis Space Center, MS 39529-5004	00051	485-4611	601 688-4611
Jim Braud NORDA Code 351 Stennis Space Center, MS 39529-5004	00054	485-4422	601 688-4422
Jerry Landrum NORDA Code 351 Stennis Space Center, MS 39529-5004	00050	485-4613	601 688-4613

Appendix C

Collated Responses

Digital Terrain Elevation Data
Compact Disc-Read Only Memory (DTED CD-ROM)
Engineering Prototype Evaluation Form
Control Number _____

I. General:

DMA has prepared two engineeering prototypes of DTED produced on Compact Disc-Read Only Memory (CD-ROM). These engineering prototype DTED CD-ROMs are part of this evaluation package. Also enclosed in the package is a copy of the Product Specifications for DTED. The data on these Engineering Prototype discs conforms to DTED specifications with the exceptions noted in the CD-ROM Information Booklet. We suggest you carefully examine and familiarize yourself with the DTED Specifications and the exceptions noted in the CD-ROM Information Booklet prior to initiating your evaluation.

As a condition of acceptance of these DTED CD-ROMs, you are required to complete this form and forward it to DMASC/WG in the enclosed envelope. Your comments and suggestions will be combined with those Evaluation Forms we receive from other users and will form the basis for finalizing our CD-ROM design. These evaluation forms must be mailed no later than 18 November 1988 for your comments and suggestions to be considered for inclusion in our final DTED CD-ROM product design and production planning.

Enclosed in the evaluation package are 2 DTED CD-ROM indexes. Please annotate one of the copies with any changes or modifications you feel would be an improvement to the world-wide index. Send the annotated copy along with your evaluation form in the return envelope.

The following information in Sections II-VII is requested to help us provide a product that will support our users' needs. Please provide **UNCLASSIFIED** detailed answers where appropiate. Use additional sheets if necessary.

II. User Information:

1. DMA is considering no longer distributing DTED on magnetic tapes. The data will be provided on CD-ROMs only. Do you consider this

Acceptable __7__

Unacceptable (Please Explain) __2__

_____
_____
_____
_____
_____
_____

2. We consider our users to fall into two categories: Batch and Interactive. Batch users are users who transfer the DTED data from the CD-ROM to magnetic mass storage, then access the data from mass storage in a mini- or mainframe-computer environment. Interactive users are users who access the data directly from the CD-ROM in a micro- or mini-computer environment. Using these definitions, do you condiser yourself a Batch User, Interactive User, or Both?

Batch User _3_

Interactive User ____

Both _6_

3. Please describe the computer system(s) you plan on using to exploit the DTED

_____

_____

_____

_____

_____

4. How many copies of each DTED CD-ROM do you require? _____

5. Your Name _____

Title _____

Address _____

_____

_____

_____

Telephone Number Commercial ( ) _____ AUTOVON _____

III. Packaging and Security:

DMA plans are to provide future CD-ROMs with packaging and labeling similar to that of this Engineering Prototype. Each CD-ROM would come in the plastic case, and will include a location diagram on the back of the case, and an information booklet that slides in and out of the front of the case. The CD-ROM will be labeled with text indicating the contents of the disc, date mastered, classification and/or restrictions, stock numbers and other pertinent information.

1. Do you consider the information in the Information Booklet:

More than adequate _4_

Adequate _2_

Less than Adequate (Please Explain) _1_

Insufficient (Please Explain) _2_

_____

_____

_____

_____

2. The Location Diagram located on the back panel of the plastic case gives a graphic portrayal of the area contained on the CD-ROM.

Do you consider the detail of the Location Diagram

Too detailed _1_

Sufficiently detailed _7_

Lacking detail (Please Explain) _1_

_____

_____

_____

_____

3. Does the CD-ROM label contain:

More than enough information _I___

Enough information _7__

Not enough information (Please Explain) _I___

_____
_____
_____
_____
_____
_____
_____
_____

4.   Holders of DMA digital products are required to protect their holdings against misuse or loss. As a minimum, DMA recommends to users that whenever digital products are not under supervision of authorized persons, the data will be secured in a container or vault (e.g. 4-drawer safe) that provides physical evidence of unauthorized tampering or forced entry.

Does this requirement for a secure container or vault pose a problem?

No _9__

Yes (Please Explain) ____

_____
_____
_____
_____

IV. Maintenance:

DMA is considering providing periodic updates of DTED on CD-ROMs. These updates will be distributed and function similar to the DMA Chart Updating Manual (CHUM) and Notice To Mariner (NTM) maintenance system. For example, a maintenance CD-ROM will contain any new or modified cells produced since the issue of the original disc.

1. For your application, do you consider these updates necessary?

Yes _8_

No _1_

2. For your needs, should these updates occur:

Quarterly _1_

Semi-Annually _1_

Annually _4_

Other (Specify) _3_

_____
_____
_____
_____

3. Between the periodic maintenance CD-ROMs, DMA is considering no longer distributing DTED updates on magnetic tapes. For your application, would this be an impact?

No _8_

Yes (Please Explain) _1_

_____
_____
_____
_____

V. Ancilliary Data:

This question references the ancilliary data that will accompany the DTED data.

1.   The disc also includes gazetteers. Gazetteers give the user an opportunity to quickly define geo-coordinates for certain geographic features that have geographic names. The geo-coordinates can be used to extract DTED information for the feature and vicinity. For your application, is the gazetteer data:

Desired _1_

Required _2_

Not Required _4_

No Opinion _2_

Should not be on the disc _____

VI.   CD-ROM Index:

This question references the enclosed proposed DTED CD-ROM index. There are 85 areas that have been defined. Each disc will contain all filled 1 degree cells in the area. Efforts were made to define the index of the areas by ONCs and geographically.

1.   Do you consider the breakdown of the index into the 85 areas:

Acceptable _8_

Not Acceptable (Please Explain) _1_

_____

_____

_____

_____

VII. Suggestions and/or Comments:

Please use this area to express any concerns you may have that have not been addressed in this questionnaire.

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Appendix D

DMAP Questionnaire

Additional Questions for DMAP
Digital Terrain Elevation Data
Compact Disk-Read Only Memory (DTED CD-ROM)

1. Do you have a hardware system for reading the CD-ROM?

   If so:
   What kind?

   Were you able to read it?

   If not:
   Are you planning to get one?

   What kind?

2. Do you have a graphics system suitable for display of DTED?

   If so:
   Were you able to display it?

   What graphics system?

   What graphics software?

   What type of display? (contour, wireframe, shaded relief)

   If not:
   Are you planning to get one?

   What kind?

3. Do you now have software that uses DTED?

   If so:
   Were you able to interface the CD-ROM?

   What computer language is your software?

   What is your preferred language for supplied readers and demos?

   If not:
   Are you planning to develope software to use DTED?

   Please describe your plans.

Appendix E

Evaluation of Digital Terrain Elevation Data (DTED) on CD-ROM Tactical Air Mission Planning System (TAMPS) Application (Draft)

EVALUATION OF DIGITAL TERRAIN ELEVATION DATA ON CD-ROM TACTICAL AIR MISSION PLANNING SYSTEM APPLICATION

1. BACKGROUND

The Tactical Air Mission Planning System (TAMPS) currently utilizes the services of McDonnell-Douglas for the reformatting of Digital Terrain Elevation Data (DTED) cells that are initially distributed by the Defense Mapping Agency (DMA) on magnetic tape media. In the reformatting process, the 1-degree DTED cells are divided into as many as 64 subcells, each of which contain an 8-bit elevation matrix that is dimensioned as either (151.151) (151,101), depending upon the latitude. Scale factors are included with each subcell that allow for the 8-bit values to be expanded to the original 16-bit values with minimum loss of precision.

The reformatting process produces large files that contain all DTED and that are bounded by even multiples of 6 degrees of latitude and longitude. These files are called "load modules" and if fully populated, they can contain the equivalent of 36 DTED 1-degree cells. A single load module can represent nearly 52 million points for areas between 48 and -48 degrees latitude. Each subcell is written out as a fixed-length, 22884-byte record; when loaded, from tape to disk, it can be read by direct access. The load modules are numbered by four-digit integers, starting at number 0001, the southwest corner of which is at -90 latitude and -180 longitude. The numbering system results in 30-latitude bands of 60 load modules per band.

The load modules are distributed to the 84 planned TAMPS workstations via magnetic tape. Each tape typically contains 4 to 5 load modules, but may contain as many as 10. The size of the load module may depend on several factors, such as the latitude, percentage of completed cells, and the number of subcells that are over water at constant altitude.

With the 8-bit values that are used in the subcells, there is a possibility of 256 separate data levels. Of these, only 252 are actually used to store the elevation data. Although it is only speculation on my part, the additional four levels are likely used to support color overlays on the graphic display system that probably support 8-bit planes of color graphics. The 8-bit elevation data values are therefore used to support rapid rendering of DTED by the graphic display system. It is unclear at this point, however, how the simultaneous display of multiple subcells is handled. Since the scale factors will vary between subcells, there is a need to somehow normalize the elevations by applying the scale factors to the data prior to display. This could result in significant overhead during run-time and negate the advantage of using 8-bit data to directly feed the display processor when multiple subcells are displayed.

Perhaps an equally important reason that the DTED is stored as 8-bit values is the fact that the original TAMPS was severely limited in mass storage. The reformatted load modules require only half the storage that is required by the original 16-bit DTED data. This allowed for twice as much elevation data to be directly accessible as would have been allowed if 16-bit data values were used. The I/O transfer rate from disk to main memory is likewise doubled due to the use of 8-bit values.

2. DTED ON CD-ROM

The prototype of DTED on CD-ROM is distributed on two CD-ROM disks using the High Sierra standard format. All cells are on the World Geodetic System 1984 (WGS 84). The first disk contains 341 one-degree cells of Level 1 DTED in ONC areas D-1, D-2, and D-3. The second disk contains 275 one-degree cells in areas E-1, E-2, and E-3. This is the equivalent of between 7 and 9 load modules before reformatting. The DTED is written in fixed length data records and can be read directly as random access files. The directory structure and file-naming scheme allows for easy generation of the path and file name for any of the 1-degree cells.

Currently the High Sierra format is not supported by Digital Equipment Corporation (DEC). DEC will support the proposed actual distribution format ISO-9660 on the MicroVAX II and MicroVAX III using a Q-bus controller. These are the only DEC machines that currently support the addition of a CD-ROM reader as a peripheral. The only hardware/software configuration available at the Naval Ocean Research and Development Activity (NORDA) for the evaluation of a High Sierra formatted DTED CD-ROM consists of a Zenith 248, 8-MHz, AT compatible with floating point processor connected to an Amdek Laserdrive-1 CD-ROM reader.

3. OPTIONS

There are several options that could be considered as a mans of utilizing the CD-ROM distribution of DTED data by the TAMPS. For all of the options considered, TAMPS would benefit greatly if instead of using the ONC area as determining boundaries of data to be included on the distribution CD-ROM, even multiples of 6 degrees latitude and longitude were used. This would conform to the load modules' boundaries and would allow for complete load modules to be processed directly from CD-ROM without having to change CD-ROM disks. This is the strongest recommendation that should be made as a result of the TAMPS evaluation and should not result in a major impact on DMA at this early stage.

Option 1: Utilize DTED data directly from CD-ROM in its original distribution format.

To increase processing speed (CD-ROM is relatively slow compared to current magnetic disk technology). DTED data would be directly loaded from CD-ROM onto magnetic disk as required for mission planning areas.

The advantages of this option would be the elimination of the reformatting process completely. Data could be updated in more timely manner if direct distribution were done by DMA. Space and weight requirements would be reduced for CD-ROM distribution media versus magnetic tape.

The disadvantages would involve a possible major rewrite of existing software. If 8-bit data is truly needed by the graphic subsystem, the conversion from 16-bit to 8-bit data values must take place in real time with a degradation of graphic performance. Disk-to-memory transfer rate and available magnetic storage for on-line DTED storage is halved.

Option 2: Conversion or reformatting of CD-ROM DTED to TAMPS format at the TAMPS site as needed for mission planning.

Instead of the time required to mount and search magnetic tape sequentially for the load modules needed, the reformatting could take place directly on-line from the CD-ROM reader to the magnetic disk. This is the option that is presently being evaluated at NORDA.

Normally four load modules are required to be loaded for a mission planning session. These load modules require between 15 and 35 minutes to load from the magnetic tape. If the reformatting process could be completed in an equivalent amount of time, then all of the advantages of the direct distribution of DTED on CD-ROM by DMA could be gained without any performance loss or software rewrites.

The NORDA Digital Mapping, Charting, and Geodesy (MC&G) Analysis Program (DMAP) has developed software to perform the conversion on the PC configuration described above. The output listing that is included with this report reveals that the conversion from CD-ROM of load module 1415 required 1 hour and 30 minutes using this low-end configuration. The worst-case scenario (full load module located between -48 and 48 degrees latitude) currently would require about 2 hours and 16 minutes to convert using a PC.

This conversion process was also simulated using the VAX 8700 that is part of the Mass Data Formatting Facility (MDFF) located at NORDA. Preliminary results revealed an approximate 4 minutes and 15 seconds of CPU time and about 6 minutes of wall clock time required for the reformatting of load module 1535 (only half the size of a worst-case load module) using this configuration. Four load modules of this size were reformatted simultaneously allowing overlap of CPU and I/O

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time. The total wall clock time required to complete all four jobs was slightly over 20 minutes. This would indicate a worst-case clock time of 40 minutes for four full-coverage load modules at the lower latitudes using a VAX 8700.

According to DEC officials, the VAX 8700 performance is about 5 to 6.6 times that of a MicroVAX II. The VAXstation 3200, which is based on a MicroVAX III CPU, has a performance measurement that is 2.4 to 4.2 times that of a VAXstation GPX, which is based on a MicroVAX II. From these numbers, one could cautiously derive that the worst-case reformatting process for four full-load modules could take between 60 and 80 minutes of wall clock time. As indicated by these numbers, performance measurements can vary drastically according to mixes of instructions and I/O. It is unknown what type of measurements are used to generate these figures. The reformatting process is mostly compute bound and the actual transformation has been modified to utilize strictly integer arithmetic in order to speed up the processing. True indications of performance should be obtained through benchmarking prior to basing decisions on performance.

These preliminary results reveal that there could be a moderate loss of throughput if the reformatting or loading of the DTED is on the critical path (all other steps stopped while data are loaded) for mission planning.

Option 3: Reformatting of DTED at the TAMPS work-station as CD-ROM is received directly from DMA.

This may involve more training and bookkeeping for the TAMPS administrator. There would be no savings in space or weight because magnetic tape would be used as the primary storage media. All other elements of mission planning would remain the same. There would be a minimum software effort for NORDA to complete the conversion software.

Option 4: Use of NORDA MDFF as a reformatting facility using CD-ROM.

Hardware and software already exist. Estimate annual cost is $30K plus supplies (magnetic tapes, any hardware modifications, etc.).

Option 5: Use of CD-ROM at McDonnell-Douglas reformatting facility.

This should be more efficient than current tape methods because of the volume of data that can be directly accessed on a single CD-ROM cartridge.
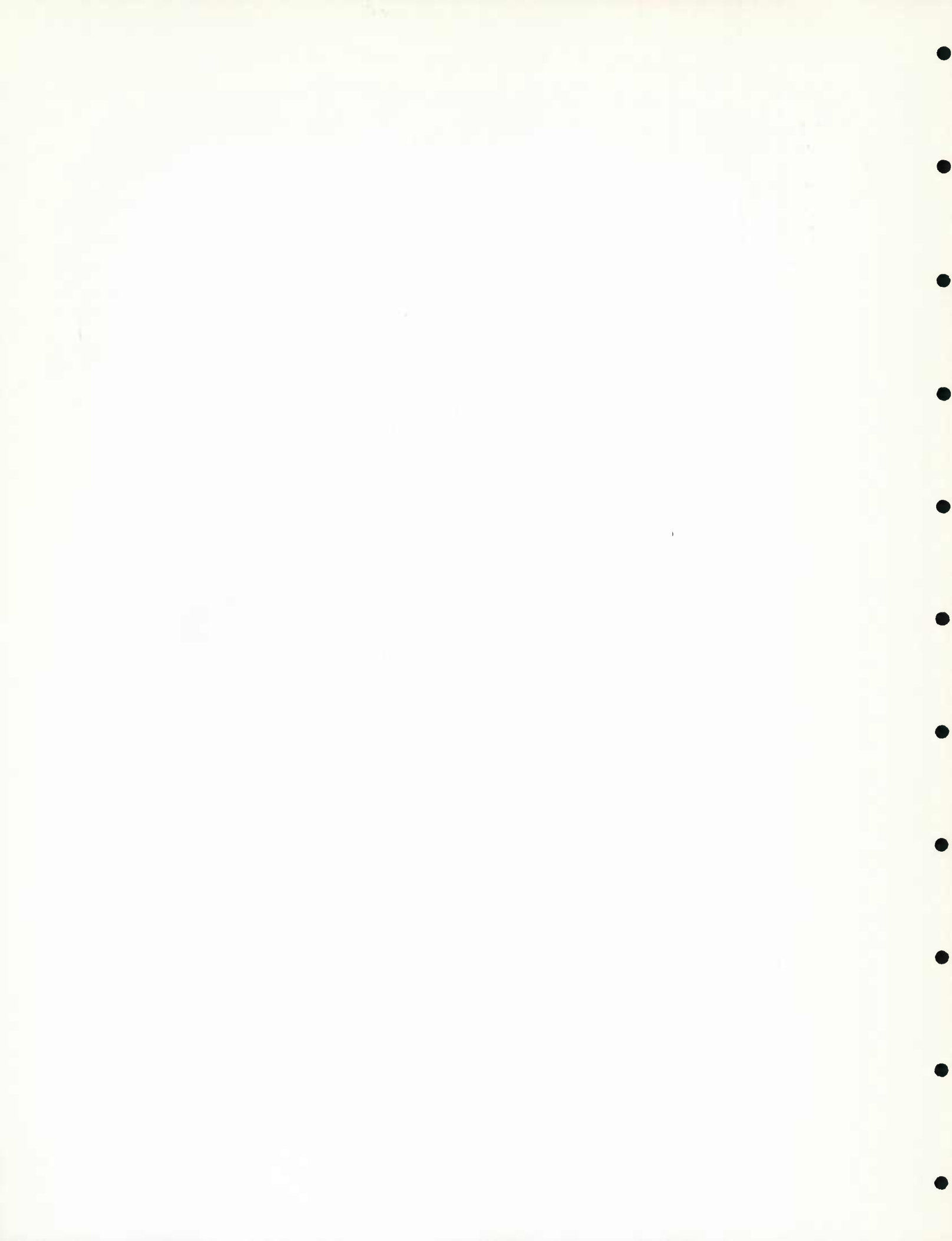
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