A RADIAL TREE-LOCATOR FOR USE IN A COMPUTER MAPPING SYSTEM

by

L. G. Brace

Résumé en français

DEPARTMENT OF FISHERIES AND FORESTRY
CANADIAN FORESTRY SERVICE
PUBLICATION NO. 1269
1970

ABSTRACT

A simple instrument designed for obtaining tree-mapping data in the field is described and the procedure for producing a tree map is outlined. The instrument and program provide a system for mapping, storage and retrieval of tree location and measurement data which is of particular advantage in research work.

RÉSUMÉ

Description d'un tachéomètre dendrométrique nouveau et du programme à suivre afin de confectionner la carte forestière qui en découlera. L'instrument et le programme permettent de cartographier, de conserver et d'avoir sous la main les données concernant la localisation et les dimensions des arbres; en recherche, voilà un avantage prononcé.

Published under the authority of the
Minister of Fisheries and Forestry
Ottawa, 1970

QUEEN'S PRINTER FOR CANADA
OTTAWA, 1970

Catalogue No. Fo. 47 - 1269

A RADIAL TREE-LOCATOR FOR USE IN A COMPUTER MAPPING SYSTEM

by

L.G. Brace[1]

INTRODUCTION

Maps showing the spatial distribution of trees on sample plots find considerable use in forestry both for illustration and as permanent records. Retrieval of mapped detail, in numerical form, is sometimes required for computation or for collation, reorganization, or revision of maps, but is not possible with most available tree-mapping methods.

A tree-mapping system that facilitates numerical retrieval has been developed for use on research plots at the Petawawa Forest Experiment Station and is described in this paper.

INSTRUMENT

An instrument for obtaining field data was designed and built. A general description of the instrument is given in Table 1, and Figure 1 is an assembly drawing of the components. The instrument is primarily a large graduated horizontal ring with a sighting device that moves around the circumference. It is mounted on legs and used in much the same way as a transit. The instrument can be disassembled for ease of transport and storage. The advantages of this instrument over a transit include:

1. Low magnification (less than 2X) and a wide viewing field (5 feet at 15 feet) that minimizes interference by brush and leaves and facilitates location of plot detail in forest conditions.
2. High illumination, which allows operation at light intensities as low as 5 per cent of full sunlight.
3. Rugged construction, which minimizes breakage and adjustment problems during field use.
4. An inexpensive, commercially available lens system.

---

[1]Research Scientist, Department of Fisheries and Forestry, Canadian Forestry Service, Petawawa Forest Experiment Station, Chalk River, Ontario.

TABLE 1. INSTRUMENT SPECIFICATIONS

Component	Material	Approximate dimensions	Approximate weight	Measurement
Horizontal circle	Aluminum alloy with brass fittings. Numbers photographed on sensitized aluminum	24" outside diameter 20" inside diameter 2" deep 1.5" wide	15 pounds 12 ounces	Scale reads to 30 minutes; can estimate to 15 minutes. Full 360-degree range.
Viewer carriage	Aluminum alloy body with brass wheels and stainless-steel vertical circle with etched numbers	9" long 1.5" deep 1.5" wide	1 pound 12 ounces	Scale reads to 1 degree over 40-degree range both sides of zero.
Viewer	Pentax* camera right-angle viewer (plastic and metal body) with modified objective lens assembly	1" outside diameter 3.5" long	11 ounces	
Legs	Tubular stainless steel with brass fittings	1" tube outside diameter 32" long unextended 60" long extended	5 pounds 4 ounces	
			23 pounds 7 ounces	

*The Pentax viewer, manufactured by the Asahi Optical Co. Ltd., Tokyo, Japan, is the basic lens system. A clear celluloid disk, scribed with a cross-hair, was inserted between the lenses at the joint in the viewer body, and a larger-diameter magnifying objective lens adapted.

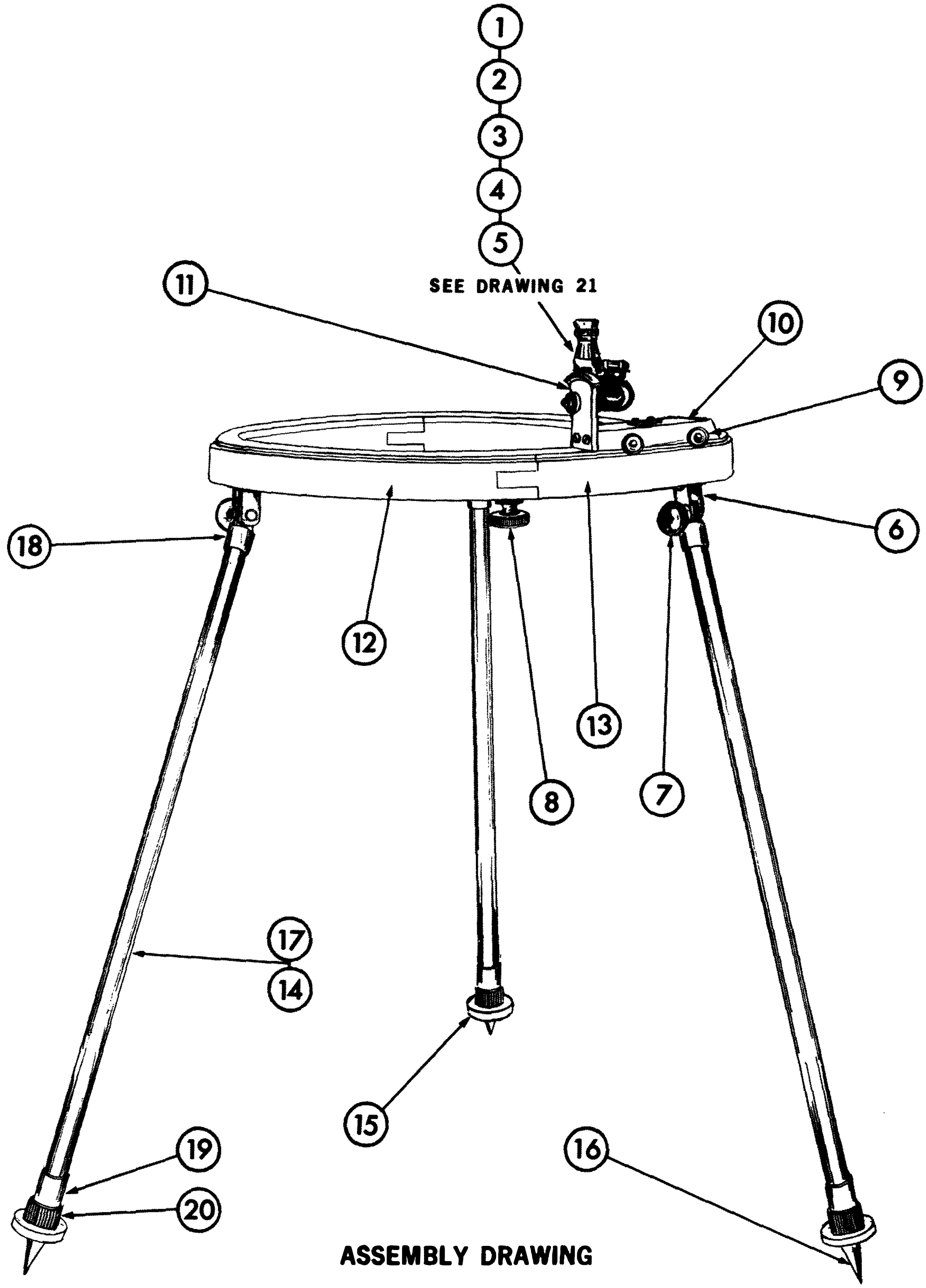

Figure 1. General view of components of radial tree-locator. Drawings of each component are available upon request.

MAPPING PROCEDURE

Field work

The instrument may be set up over a point on the ground or assembled so that the horizontal ring encircles a tree. The latter method is useful for plotting detail in relation to a given tree and simplifies relocation of the instrument position, but is limited by the ring diameter to trees 18 inches or less in diameter at breast height.

Alignment of the instrument with respect to true north is not critical, because an azimuth reading on true north can be used to derive the desired map orientation.

Each tree to be mapped is sighted through a right-angle viewer, and the azimuth of the tree is then read from the graduated horizontal circle and recorded.

Distance to the viewed tree is measured from the edge of the graduated ring with a tape, either as a horizontal distance or as a slope distance at a specified vertical angle when slope steepness dictates. The angle can be set on the vertical circle of the viewing apparatus. For the sake of simplicity, the vertical circle reads full degrees only and sightings are made with the indicator set at an even degree division.

Tree elevation at ground level relative to the height of the instrument can be obtained, if required, by sighting a levelling rod held at the tree being viewed.

Plot information is recorded to a prespecified format conforming to the format required in the computer program. Data specifications are:

Plot number	-	nearest whole number up to 999
Tree number	-	" " " " " "
Tree status	-	code 1 = living tree " 2 = cut tree " 3 = dead tree
Species	-	standard 3-digit codes
Height	-	nearest 0.5 foot
Diameter at breast height	-	" 0.01 inch
Elevation	-	" 0.1 foot
Azimuth	-	" 15 minutes (0.25 degree)
Distance	-	" 0.1 foot
Height to crown	-	" 0.5 foot
Crown width (two measurements at right angles)	-	" 0.5 foot
Slope angle	-	" degree

Computing and plotting

To obtain a top view of a plot, angle and distance data from field sheets are converted by computer to X, Y co-ordinates, which are plotted along with tree number, at a scale of 1 inch = 10 feet.

If a side view is desired, it can be produced as a cross-section through the plot showing the number, height, crown length, and elevation of each tree.

A map of top and side views of a fifth-acre plot is shown in Figure 2. The computer program, with notes on use, is shown in the appendix.

Circular areas up to 1 acre in size can be plotted on one map sheet. It is seldom possible to map an area larger than 1 acre from one instrument location in a natural stand because of restricted visibility. Plots of any shape can be mapped.

In mixed stands, different color codes for each species would be advantageous. Many plotters have this facility.

MAPPING TIME AND COST

The average field time to obtain map information with the tree locator for a fifth-acre plot in pine mixedwoods is given in Table 2. This does not include the time required to obtain tree heights and crown lengths necessary for plotting the side view. These measurements are ordinarily obtained with an abney hypsometer or haga altimeter.

Average times and costs for computing information and automatically plotting the same fifth-acre areas are shown in Table 3.

Mapping by this method is only about half as expensive as manual drafting.

MAPPING ACCURACY

Tests of accuracy were made by measuring intertree distances on the plots and on the maps and comparing them. Figure 3 shows results for two fifth-acre plots in natural pine mixedwood stands. Brush density was average (approximately 6,000 stems per acre, 4 feet high), and slope did not exceed 10 degrees.

Error was apparently not correlated with distance. The average location error between any pair of mapped trees, excluding the center tree in this case, was 0.3 foot. The location error between the center tree, where the instrument was situated, and any other tree, is taping error and should not exceed 0.2 foot. In a similar test on a plot where intertree distances were as large as 100 feet, similar errors were observed. All errors, from field work to final map, are included in this test of accuracy.

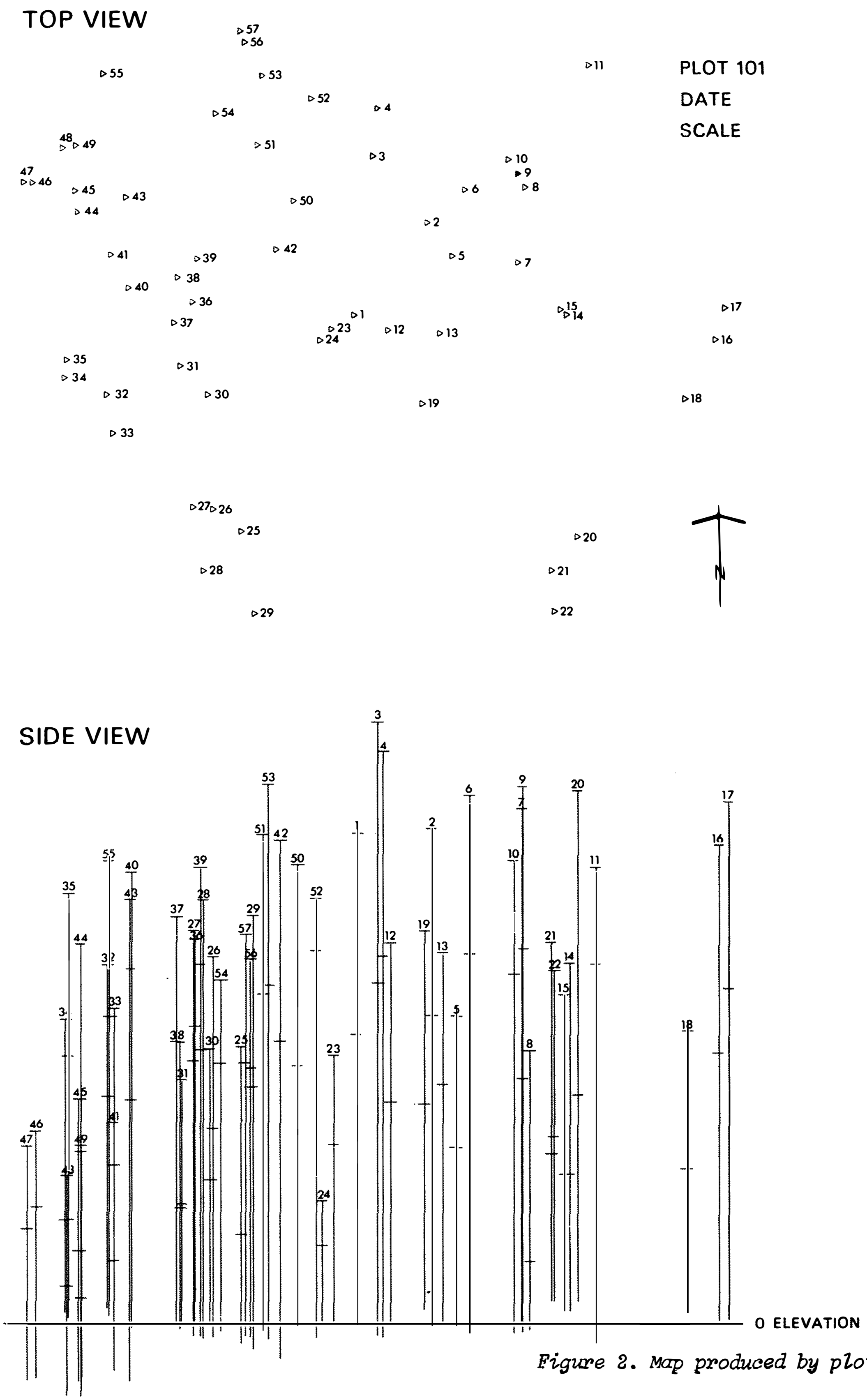

Figure 2. Map produced by plotter.

TABLE 2. FIELD TIME FOR TWO MEN TO MAP A FIFTH-ACRE PLOT*

Operation	Time (minutes)
Set up and level instrument	8
Measure and record data†	40
Take down instrument	4
	52

*Average of two plots; 57 trees per plot.

†Measure and/or record tree number, species, angle and distance and read and record elevation from a levelling rod.

TABLE 3. TIME AND COST FOR COMPUTING AND PLOTTING A FIFTH-ACRE PLOT*

	Top view		Top and side view	
Operation	Time (minutes)	Cost (dollars)	Time (minutes)	Cost (dollars)
Key punch and verify cards	60.00	2.05	60.00	2.05
Compute**	1.25	5.00	1.48	6.00
Plot†	5.00	2.50	14.00	7.00
Total††	66.25	$9.55	75.48	$15.05

*Average of two plots; 57 trees per plot.

**I.B.M. 360/65 computer.

†Calcomp 663 plotter.

††The greater the number of plots per run the lower the cost per plot because of fixed-cost reduction at both computing and plotting stages.

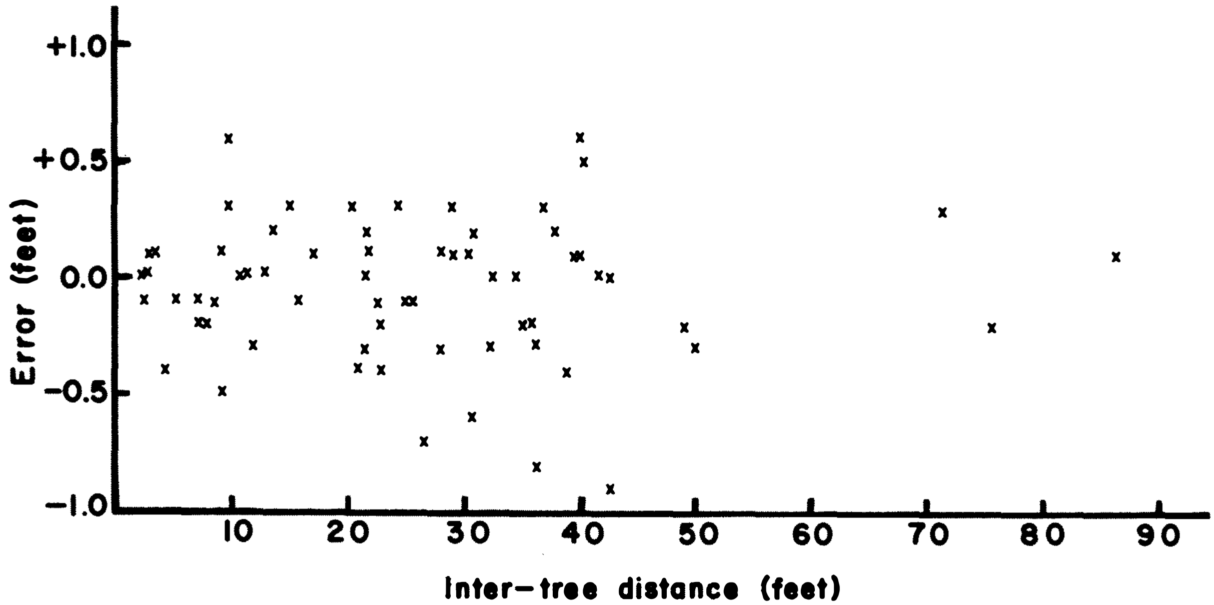

Figure 3. Mapping error.

Accuracy compares favorably with that of other instruments such as the plane table.

CONCLUSION

The computer-oriented mapping system described produces accurate tree maps at a reasonable cost. The instrument developed for the job is simple and relatively rugged. The system provides flexibility in map-data storage and retrieval. This flexibility is of particular advantage in research work and may well be useful for purposes other than tree-mapping.

ACKNOWLEDGMENT

Hans Zuuring of Biometrics Research Services prepared the computer program and provided time and cost data for the computing and plotting shown in Table 3.

APPENDIX

Program for Computing and Plotting Field Data

A. Notes on Program Use

1. Choice of Side View

The choice of a side view is optional and is made on the variable NØGØ. A side view is plotted if a positive integer (99 in the example included) is coded in card columns 79 and 80 on the card that follows END.

If no side view is required, code these columns 00.

2. Set-up of Card Following END Statement

This card must come immediately ahead of actual plot measurement data as shown in the example, and is coded as follows:

Card Column	Description
1 to 5	Number of trees on plot to be mapped
6 to 11	Azimuth of north position on plot (to 0.25 degree)
18 to 20	Plot number
35 to 46	Date (day-month-year)
79 to 80	Code for side view option (NØGØ)

3. Data Cards

Data cards follow the set-up card in order, after the END statement, and the last data card must be coded - 1 in column 80 to execute END (see example).

Crown-width data shown in columns 57 to 64 on the data deck were not used in this program.

B. Computer Program (see following pages).

```
C       PROGRAM WAS WRITTEN IN FORTRAN IV G FOR IBM 360 MODEL 65 COMPUTER
C       USING A CALCOMP 663 DIGITAL PLOTTER.
C       THE INSTRUMENT LOCATES ALL TREES RELATIVE TO ONE KNOWN PT. WITHIN
C       A RADIUS OF ABOUT 120 FT. BY MEANS OF AZIMUTHS AND DISTANCES
C       TAKEN HORIZONTALLY OR AT A MEASURED VERTICAL ANGLE.
C       DISTANCE MEASUREMENTS ARE MADE FROM THE EDGE OF THE RING MARKED
C       WITH DEGREES AND 1 FOOT IS ADDED TO EACH DISTANCE BY THE PROGRAM
C       AS IF THE MEASUREMENT HAD BEEN MADE FROM THE CENTRE OF THE INSTRUMENT.
C       BOTH A TOP AND SIDE VIEW OF EACH PLOT OF TREES IS SHOWN AT A SCALE
C       OF 1 INCH = 10 FT..
C       IN THE TOP VIEW TREE LOCATIONS ARE MARKED BY ONE OF 3 SYMBOLS
C       BASED ON THE STATUS OF THE TREE FOUND IN C.C.7.-
C                        1  FOR LIVING TREES (TRIANGLE SYMBOL)
C                        2  FOR CUT TREES (X SYMBOL)
C                        3  FOR DEAD TREES (CIRCLE SYMBOL)
C       IN THE SIDE VIEW THE BASE LINE IS THE ELEVATION RELATIVE TO  WHICH
C       ALL OTHER TREES ARE LOCATED.
C       THE CROWN LENGTH ON ALL TREES IS INDICATED BY TWO DASHES ON EACH
C       STEM LINE.
        DIMENSION DATA(4000),X(100),Y(100),TN(100),IT(100),Z(100),FT(100),
       1DA(100),FTD(100),H2C(100),FLAT(2),ALAT(3),BLAT(5),PLAT(2),CLAT(4),
       2 FUDG(100)
        CALL PLOTS (DATA(1),4000)
        Y(1) = 0.001
        MPX = 0
        ICR = 1
        IPR = 3
        CALL PLOT (15.0,15.0,-3)
C       HEADER CARD READ. NO. OF TREES(N),AZIMUTH ON NORTH(CF),SEVERAL
C       HEADINGS FOR PLOTTING IDENTIFICATION--
C           PLAT = THE WORD-PLOT- FOLLOWED BY THE PLOT NO.(8 PRINT POSITIONS)
C           FLAT = THE WORD-TOP VIEW- (8 PRINT POSITIONS)
C           BLAT =  THE WORD-DATE- FOLLOWED BY MONTH,DAY,YEAR(20 PRINT POSITIONS)
C           CLAT = THE WORD-SCALE  1''=10' (16 PRINT POSITIONS)
C           ALAT = THE WORD-SIDE VIEW-(12 PRINT POSITIONS)
      8 READ (ICR,100) N,CF,PLAT,FLAT,BLAT,CLAT,ALAT,NOGO
    100 FORMAT (I5,F6.2,1X,16A4,I4)
        IF (MPX)35,35,36
     36 IF (NOGO)7,24,30
     24 CALL PLOT (31.0,0.0,-3)
        GO TO 35
     30 CALL PLOT (16.0,13.0,-3)
C       DATA READ IN AT THIS POINT.TREE NO.(TN),TREE STATUS(IT),TREE HT.
C       (Z),TREE ELEVATION(FT),AZIMUTH(DA),DISTANCE(FTD),HT. TO CROWN(H2C)
C       AND VERTICAL ANGLE(FUDG).
     35 DO  9 I=1,N
        READ (ICR,101) TN(I),IT(I),Z(I),FT(I),DA(I),FTD(I),H2C(I),FUDG(I)
    101 FORMAT (3X,F3.0,I1,23X,F4.1,4X,F4.1,F6.2,2F4.1,21X,F3.1)
        IF (I.EQ.1) GO TO 9
        DB = 3.1415926 - (DA(I) - CF) * 0.01745329
        IF (FUDG(I))26,27,26
     26 FUDG(I) = FUDG(I) * 0.01745329
        FTD(I) = FTD(I) * COS(FUDG(I))
     27 FTD(I) = FTD(I) + 1.0
        X(I) = COS(DB) * FTD(I)
        Y(I) = SIN(DB) * FTD(I)
      9 CONTINUE
        CALL AXIS(-13.0,-13.0,1H ,1,26.,0.0,-130.,10.0,10.0)
        CALL AXIS(13.0,-13.0,1H ,1,26.,90.,-130.,10.0,10.0)
        CALL SYMBOL(-12.5,-1.0,.15,PLAT,90.0,8)
```

```fortran
      CALL SYMBOL(-12.0,-1.0,.12,FLAT,90.0,8)
      CALL SYMBOL(-12.0,8.5,.12,BLAT,90.0,20)
      CALL SYMBOL(-11.5,8.5,.12,CLAT,90.0,16)
      CALL NUMBER(0.0,0.2,.08,TN(1),90.0,-1)
      CALL SYMBOL(0.0,0.0,.08,2,0.0,-1)
      DO  11 I=2,N
      BLI = X(I) / 10.0
      BNE = Y(I) / 10.0
      BNA = BNE + 0.2
      IF (IT(I) - 2)14,15,16
   14 CALL SYMBOL(BLI,BNE,.08,2,0.0,-1)
      GO TO 17
   15 CALL SYMBOL(BLI,BNE,.08,4,0.0,-1)
      GO TO 17
   16 CALL SYMBOL (BLI,BNE,.08,1,0.0,-1)
   17 CALL NUMBER(BLI,BNA,.08,TN(I),90.0,-1)
   11 CONTINUE
      IF (NOGO)33,33,5
    5 CALL PLOT (32.5,-13.0,-3)
      CALL AXIS(0.0,0.0,1H ,1,26.,90.,-130.,10.,10.0)
      CALL AXIS(-16.0,26.0,1H ,1,16.,0.0,120.0,-10.0,10.0)
      CALL SYMBOL(-16.,12.,.12,ALAT,90.0,12)
      CALL PLOT (-4.0,0.0,3)
      CALL PLOT (-4.0,26.0,2)
      DO  12  I=1,N
      ALI = (FT(I) - FT(1) - 40.0) / 10.0
      IF (FUDG(I))21,22,23
   21 ALI = ALI - SIN(FUDG(I)) * FTD(I) / 10.0
      GO TO 22
   23 ALI = ALI + SIN(FUDG(I)) * FTD(I) / 10.0
   22 ANE = Y(I) / 10.0 + 13.0
      CALL PLOT (ALI,ANE,3)
      IF (H2C(I))12,12,20
   20 ALJ = ALI - H2C(I) / 10.0
      CALL PLOT (ALJ,ANE,2)
      CALL SYMBOL(ALJ,ANE,.2,13,0.0,-1)
      ALJ = ALI - Z(I) / 10.0
      CALL PLOT (ALJ,ANE,2)
      CALL SYMBOL(ALJ,ANE,.2,13,0.0,-1)
      ALJ = ALJ - .1
      CALL NUMBER (ALJ,ANE,.07,TN(I),90.,-1)
   12 CONTINUE
   33 MPX = MPX + 1
      GO TO 8
    7 CALL PLOT (0.0,0.0,999)
      STOP
      END
```

```
   57   4400 PLOT 101TOP VIEWDATE   10 - 06 - 68  SCALE    1''= 10'  SIDE VIEW    99
101  11                        020 7101096  32   4400 000 420 125  90           00
101  21                        600 720 972  35   8250 161 450 100 100           00
101  31                        600 8881075  48   5100 223 510 140 115           00
101  41                        600 8511090  54   5100 292 555 140 110           00
101  51                        020 450 561  36  10300 155 260  70  60           00
101  61                        600 780 951  46   8550 232 550 105 100           00
101  71                        710 7451060  31  11650 237 355 125 110           00
101  81                        130 405 796  41   9750 297 100 100  70           00
101  91                        600 7901052  44   9350 302 555 120  95           00
101 101                        600 685 799  46   8900 306 520 100  90           00
101 111                        600 690 672  62   8750 485 550  85  75           00
101 121                        020 550 494  31  15800  42 320  50  45           00
```

101	131	020	540	835	35	14600	115	350	95	90	00
101	141	020	505	833	15	13450	293	200	90	80	00
101	151	020	460	695	15	13300	285	200	75	65	00
101	161	600	6901137		30	13850	508	390	140	120	00
101	171	600	750	895	27	13350	520	480	100	95	00
101	181	020	410	655	18	14900	478	210	70	60	00
101	191	020	5501098		13	18750	150	300	140	120	00
101	201	020	7401488		00	18000	443	300	150	130	00
101	211	020	5201107		00	18750	455	215	120	105	00
101	221	020	480	710	00	19100	505	240	80	60	00
101	231	020	390	528	32	28500	28	260	75	65	00
101	241	020	180	364	33	27950	51	115	40	60	00
101	251	020	432	734	62	25200	342	160	80	70	00
101	261	600	552	716	52	26050	336	304	85	75	00
101	271	600	588	790	50	26450	350	400	85	75	00
101	281	600	636	857	54	25500	418	420	90	85	00
101	291	600	630	975	71	24300	445	410	105	75	00
101	301	020	410	842	43	28600	228	220	110	95	00
101	311	020	360	415	38	29850	250	180	55	45	00
101	321	020	500	560	12	29700	363	310	60	50	00
101	331	020	437	670	12	28850	375	210	75	55	00
101	341	020	430	424	21	30250	415	140	50	40	00
101	351	600	615	802	24	30600	407	380	105	80	00
101	361	600	560	776	35	32000	223	435	95	85	00
101	371	600	590	873	33	31250	248	410	90	70	00
101	381	020	416	608	40	32700	249	176	75	70	00
101	391	600	680	808	51	33500	230	540	100	· 90	00
101	401	600	660	907	38	32200	316	520	100	100	00
101	411	020	360	546	37	32900	355	160	65	60	100
101	421	600	750	925	56	35550	139	460	100	90	100
101	431	600	7001120		53	34250	365	410	145	120	100
101	441	600	630	715	39	33550	420	330	85	65	100
101	451	020	410	641	40	33900	436	190	70	70	100
101	461	970	360	366	25	33750	498	250	55	35	100
101	471	970	340	365	25	33700	510	220	50	40	100
101	481	020	320	428	53	34500	481	160	45	45	100
101	491	820	365	546	57	34650	465	144	60	55	100
101	501	600	675	830	42	1700	178	385	105	90	00
101	511	600	7201042		44	1550	273	490	120	105	00
101	521	600	640	691	56	3350	311	565	70	65	00
101	531	600	8051054		56	2400	362	515	120	120	00
101	541	600	515	823	49	1050	344	395	90	90	00
101	551	600	660	801	21	35900	492	435	85	80	00
101	561	710	550	818	53	2300	416	365	85	80	00
101	571	710	585	822	53	2300	435	400	100	90	00
											-1

1269-2-70-2.7M