PROGRAM STRATCOR (Version 1.6)

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FOR ZONATION AND CORRELATION OF FOSSIL EVENTS
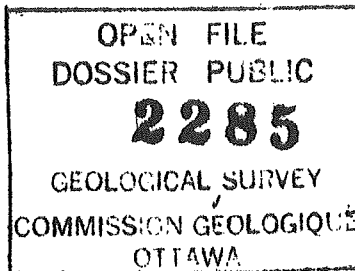
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BY

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INTRODUCTION

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The F77 program STRATCOR version 1.6 performs biozonation
and correlation of fossil events in sedimentary strata. Examples of
fossil events are the first, first common, last common or last
occurrence of taxa in samples of wells or outcrop sections, i.e. the
local stratigraphic range endpoints.
   STRATCOR is a "cross-plot" method that interpolates the record
in two wells or outcrop sections at a time; it may involve as few
as 2 or 3, or as many as 30 to 50 wells in a data set to be
analysed. The program comprises three modules:

1. PREP prepares the data; the user decides which taxa to include
or exclude from a run and also lists the order in which the wells
are to be interpolated, two at a time.

2. GRACOR consists of a Stage 1 that zonates the record and a
Stage 2 that correlates the zonation.

3. DENDRO displays the zonation (final composite standard) of
Stage 1 in GRACOR, and displays it in a visually attractive
dendrogram format.

   During stage 1 of GRACOR, the zonation stage, all well
sequences are composited in succession, two at a time to form a
Final Composite Standard. The method proceeds as follows:
   Firstly, the events in an assigned reference well
(number 1 for the program) are expressed as a function of the
events in common in well number 2. Only order of events is used

1.

in the event (well) sequences, not their depths in feet or meters. Thus, the event sequences have no scale, only an order. A best fit line is constructed for the scattergram of events in common using smoothing cubic splines. User controlled weights on the event positions may "steer" the fit such that it is stratigraphically satisfactory. Events not previously in the reference well are added to it at their interpolated positions. When an event in the reference well also occurs in the individual well, it has an interpolated position in the reference section. At this stage the user can select one of the following stratigraphic rules to calculate the newly interpolated position in the reference well (composite standard). The new position may be

a. the highest,
b. the lowest,
c. the unweighted average, or
d. the weighted average

of the previous and interpolated positions in the reference well. For more details on the method the reader is referred to the explanation below in the section on GRACOR.

Following the interpolation of well 2 in well 1, which creates a composite, the order of the individual record in well number 3 is cross-plotted with this composite, upon which interpolation again updates this composite record, etc. The final composite standard (= biozonation), uses the individual fossil record in all wells or outcrop sections.

The first two interpolation methods a and b, lead to deterministic zonations, methods c and d create probabilistic ones.

During stage 2, the correlation stage of STRATCOR, the composite standard is again cross-plotted with the fossil record in each individual well, now expressed in the original depth units of measurements. Again, the composite is expressed as a function of the individual record, using smoothing cubic splines, but now the composite is interpolated in each well to find the local depth of each composite event. The resulting correlation framework serves to draw detailed cross-sections between wells or outcrop sections.

The program STRATCOR consists of two interactive modules PREP.EXE and GRACOR.EXE. The first one is a pre-processor of input data; it converts standard RASC/CASC type of input data to the input format of GRACOR. More importantly, it allows the user to set a threshold for minimum event occurrence (similar to the parameter Kc in program RASC), to include rare events, and to determine the order in which the wells are interactively processed in GRACOR. GRACOR is the main program; it calculates a probabilistic or deterministic biozonation, depending on the choice of interpolation rule, and correlates the zonation through the wells.

An additional "bookkeeping-type" of program, DATLST version 2.0, written in QuickBasic 4.0 by M. D'Iorio (Ottawa) and Z. Huang (Halifax), converts the sequence-, depth-, and dictionary input files for PREP in a paleontological text file, with fossil occurrences listed per sample per well site. This conversion fascilitates error checking of the original input data.

Both PREP and GRACOR share the use of Lahey Fortran (F77L)

and the GSS Graphics Development Toolkit (see References) with
the burial and subsidence history programs DEPOR and BURSUB
version 3.5 (Gradstein et al., 1989).

PREP
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   PREP is an interactive data preprocessor. The program prepares
RASC/CASC type input files, i.e. a numerical dictionary, an event-
sequences file and a corresponding event-depths file, into a
computational and stratigraphic format suitable for use by GRACOR.
Using distributional data on the number of wells in which the
events occur, the user sets a threshold for the minimum number of
wells in which taxa should occur in order to participate in zonation
and correlation. Assigned "Rare events", with a frequency of
occurrence in few wells only, below the threshold kc, may be
allowed to participate in zonation. Also, the order in which wells
are processed and printed in the output of GRACOR is determined
by the user.

   There are 5 output files, four of which are for restart purposes
or input to GRACOR, and one, with the file name extension *.prl,
with PREP results. During execution of PREP, the user is prompted
for the master output file name. By default, each individual
output file name has its own, unique and fixed extension,
(see under "Output files to PREP").

Input files to PREP:

PREP input files are Ascii type files, that can be prepared with
a wordprocessor that produces ASCII output files, (e.g.
non-document mode of Wordstar, a memory resident ASCII
wordprocessor like Q-EDIT, or DOS text-file output of
Wordperfect). Files format is as in the RASC12 and CASC programs,
as explained below. No tabs or other "hard" wordprocessing type
characters are allowed, unknown in FORTRAN.

   1. Event dictionary: For this input file the user creates a listing
of taxa (or physical stratigraphic events), one per line. Names will
be used exactly as assigned in the dictionary. Author names to taxa
can be assigned if desired. The order of the entries in the
dictionary automatically corresponds to their unique dictionary
number, with the top entry assigned number 1 by the program.
The maximum number of entries allowed in the dictionary is
unlimited, but the three digit input format for the event-sequences
input file at present restricts the number of taxa to less than 999.
The word LAST or last must occur on the bottom line of the file,
but is not listed in output.

   A sample dictionary for 20 events looks as follows:

         Neogloboquadrina pachyderma
         Globorotalia inflata
         Tiliaepollenites sp.
         Neogloboquadrina acostaensis
         Log marker no. 4
         Uvigerina canariensis
         Globigerina praebulloides

```
        Deflandrea phosphoritica
        Asterigerina gurichi
        Flood of radiolarians
        Globoconusa daubjergensis
        Gyroidina girardana
        Coscinodiscus spp.
        Sigmoilopsis schlumbergeri
        Turrilina alsatica
        Coarse agglutinated foram spp.
        Uvigerina ex.gr. miozea-nuttali
        Areoligera semicirculata
        seismic horizon no. 3
        Ammosphaeroidina pseudopauciloculata
        LAST
```

During execution, PREP automatically creates an alphabetical
dictionary, and can print both the numeric and alphabetical
dictionaries in the output.

2. Event-sequence file: The user creates an "events in all wells"
file using a wordprocessor which saves files in ASCII format. In
exploration biostratigraphy listing will start at the top, instead of
the base of each well. In this version of STRATCOR, PREP is set
for 100 or less wells. The format of the event-sequence file for
PREP is the same as in the RASC12 program. Each well sequence
starts with a title of less than 40 characters, followed by lines
with coded events, using the unique dictionary number for each
event, in 20I4 format.This means each event occupies 4 spaces, with
20 events per line; coeval events are connected by a hyphen; each
well sequence ends with -999. On the last line of the file must be
the word Last or last.

A sample event-sequences file looks as follows (the numbers used
in this example do not correspond to taxa in the above example,
but normally must do so):

```
well 1
  38 -87-103  15 102 -10  69   9 111   8  50  60 112  18 -53  13
 115  11  17  62  85  61  68  82  43 -34  99 -72  98 -21  40  20
  81  49  27 -95 -96 107  39  59 106  80  79  44  37  29  45 -55
  66-110-109  58  70 114-121  71 -33 -92  78  77 -28 -31 -93-116
 -30-999
well 2
  38  87-102  15  86  83 100  -7 -89 -50-104  -8-111 -56  63 -91
  17  73 -43 -60  62  82  35  20  95  40 -34  99  59  94  96  49
  81-114  27  41  -3  65 -25 -26-107  47  14 -39  67  80  79  44
 -37  29 109  78
-999
well 3
  38 -87 -32-103  15  -1  -3  86   4-102 101  35  42  89 -52  -8
 111 -10  18  83  17  56  61 -16 -73 -43  82 127 -96-113  95 -97
  49  98  34  20 -74  81  99-107 -27  23 -25  40  22 106  14  39
  80  79  66  37  59 109  24  29  46 -31 -28-105  30  93 -12
-999
LAST
```

There is no limit to the number of events per well, but GRACOR
is limited to 100 events in common between wells. The minimum

number of events in common is set at 10, but this may be changed
in the parameter file   STRATCOR.PAR.

   3. Event-depth file: Each event, or groups of coeval events in
the event-sequence file has a corresponding depth in the event-
depth file. The format of this file is as in the CASC program.
Following the well title line, which must be identical to that
for the corresponding well title in the event-sequence file,
the second line has the rotary table height above sealevel
preceded by f or m (capitals allowed) to indicate feet
or meters units for all depths in the well. After the rotary
table height follows the local water depth. The next lines
contain the successive event depths in FORTRAN format 13F6.1.
This means each depth can be a 5 digit number followed by a
period; there are 13 events per line. Each well in the
event - depth file must have the same number of lines,
which means that 00000.0 values or blanks are added as needed.
The last line of the file must contain the word LAST or last.

   A sample event-depth file that matches the sample event-
sequence file, shown previously, is listed below:

well 1

f030.001330.0
01330.01390.01500.01776.01780.01786.01840.01870.01900.02230.02260.02530.02550.
02680.02710.02770.02800.03040.03070.03159.03580.03880.04210.04280.04380.04429.
04510.04810.04840.05309.05310.05470.05531.05850.05910.05940.05970.06060.06120.
06150.06310.06343.06505.06591.06665.00000.00000.00000.00000.00000.00000.00000.
well 2
m010.000200.0
00850.00870.00890.00900.00907.00920.01000.01040.01080.01260.01275.01330.01450.
01460.01490.01500.01510.01570.01600.01690.01805.01875.01885.01895.01905.01935.
01945.01950.01993.02005.02015.02055.02320.00000.00000.00000.00000.00000.00000.
00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.
well 3
f035.000880.0
01250.02090.02110.02320.02385.02410.02700.02950.02980.03400.03704.04000.04090.
04580.05025.05100.05200.05250.05643.05665.05671.06923.07060.07069.07103.07296.
07354.07375.07402.07411.07572.07694.07903.07940.07958.08460.08480.08623.08924.
08990.09025.00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.00000.
LAST

Output files to PREP:

   The program PREP produces 5 output files, based on a master
file name assigned by the user, and different, fixed extensions:
For the example below we assume the master output file name is
TEST1. The 5 output file names, by default are assigned as follows:

working dictionary file   TEST1.DCX
well summary file   TEST1.SUM
well sequence file   TEST1.SEQ
PREP restart file   TEST1.RST
PREP printout file   TEST1.PR1

The user is only concerned with TEST1.PR1, which includes tables
with frequencies of event occurrences, listings of included (for use

in GRACOR) and/or excluded events in alphabetical and/or
numerical order, and listing of order and selection of well sites
(for use in GRACOR).

To route TEST1.PR1 to your printer during execution,
issue the following DOS command before starting the program:
                        SET TEST1.PR1=device
where "device" is the DOS name for the printer (usually LPT1 or
PRN). The printed output will give you details about each well
while the data are being processed. If instead you want to put the
output into a disk file for printing later,but do not want to use the
current directory of the current drive, replace "device" in the
above command by the path and name of the relevant file.
    At the end of processing, delete this setting from the
environment by the DOS command:
                        SET TEST1.PR1=
These changes will be made automatically if the two SET commands
are included in the parameter file as initial and terminal DOS
commands, respectively.

Re-starting a halted run:

    When you re-start a halted run, the program resumes the job
described in the file named TEST1.RST, with reference to the
files TEST1.DCX, TEST1.SUM and TEST1.SEQ. All these files must
be present for proper execution of the program.

Execution of PREP.EXE

    PREP.EXE calls on COMMAND.COM, SORT.EXE and ANSI.SYS
(DOS versions 3.2 or 3.3) to execute. It will look for these files in
the default (= root) drive of the computer system (e.g. A: or C:¥).
When the computer system is booted from A: with the STRATCOR
boot disk, PREP will look for these files on the A: drive.

                        GRACOR
                        ======

    The program GRACOR executes in two stages:

    Stage 1 calculates the biozonation (composite standard); it is
entirely ordinal,and only uses the order of event occurrences in the
wells, without reference to the event depths in meters or meters.
Stage 1 may be repeated (cycled) 99 times, until the composite
stabilizes.

    Stage 2 takes the zonation obtained in Stage 1, and calculates
the interpolated depths of the zonation events for each well. The
user controls if the zonation obtained in stage 1 is deterministic or
probabilistic, using the manner in which events are interpolated in
the composite standard (see below under updating of reference
well).

GRACOR input files:

    After GRACOR has been loaded, the program prompts the user
for the master output files name in PREP, which in this case (see
above) is TEST1. Next, GRACOR by default looks for the standard
output files of PREP, including:

        - Event dictionary for the well data, e.g. TEST1.DCX
        - System standard well summary file,   e.g. TEST1.SUM
        - System standard well data file,   e.g. TEST1.SEQ

GRACOR output files:

    The user output of GRACOR is in 4 printable files:

        Stage 1 (zonation) results:

            - Final composite standard file,   TEST1.PR2

            - Intermediate output in all wells +
              Final Composite Standard   TEST1.PR3

        Stage 2 (correlation) results:

            - Interpolated depth of composite
              standard events in all wells,   TEST1.PR4

            - Intermediate output in all wells,   TEST1.PR5

The events in the individual and reference wells are
reported in the TEST1.PR3 and TEST1PR4 files, before the data
are plotted; and the biostratigraphic updating of the reference
well (stage 1) or the interpolated depths of the zonal composite
(stage 2) are reported as soon as the processing of an individual
well has been completed. GRACOR permits you to stop zonation
(stage 1) or correlation (stage 2) at the end of any well and
to resume later at the point where you left off. For this purpose,
two special output files are created:

            - The re-start file, called   TEST1.RST

            - The composite well file, called   TEST1.CWL

The re-start file contains a permanent record of the way in which
your results were obtained.   The composite well file contains the
data of the current reference well. The file TEST1.PR2 may be
submitted to program DENDRO for a dendrogram display of the
Final Composite Standard results.

Headers SOURCE and WELLS

In the print-out of "Events reported in Reference well" in the
TEST1.PR3 and TEST1.PR5 output files of GRACOR two headers are used
to keep track of running tallies for the events listed,
SOURCE and WELLS.

SOURCE is the input sequence number (from PREP) of the last well used to update the composite.

WELLS is the number of wells used to update the composite, and corresponds exactly to the tabulations in TEST1.PR1 of PREP that report the number of wells in which all dictionary events occur.

Fitting of smoothing cubic spline functions:

GRACOR finds the sequence of events in common between the current reference and individual wells; the details, together with a list of all events in the wells, are printed in two tables. A cubic spline function is then fitted to these common events in accordance with your choice of a smoothing factor (the program will display the minimum and maximum possible values). The spline fit always is monotonic, which means it increases in both x and y directions, and cannot return on itself (= negative sedimentation rate). The minimum, maximum and average spline fits are plotted on the screen with a scatter diagram of the common events, and you may revise the smoothing factor until you are satisfied with the fit; at that point the function is used for interpolation.

Weighting of events (function key F6 in the fitting menu) allows detailed control over the path of the spline fit, for geological purposes. Weights vary between -1 and +1. A weight of -1 for an event ignores that event when calculating a spline fit; a weight of +1 forces the spline through the event.

Cross-validation is a semi-automated, and mathematically objective manner to find the smoothing factor that minimizes the deviations to all points. Cross-validation (function key F7 in the fitting menu) toggles on/off. Once on, it stays on for next wells, until toggled off again. For a mathematical discussion of the smoothing cubic spline and cross-validation for use in stratigraphy, see Agterberg and Gradstein(1988).

Updating of reference well:

In stage 1, event positions in the reference well (i.e. the well assigned in PREP to be number 1) are interpolated for events in the individual well number 2. Events not previously in the reference well are added to it at the interpolated position. The position of common events is updated according to the method specified by you at the beginning: it may be the highest, the lowest, the unweighted or the weighted average of the previous and interpolated positions.

Formally this is expressed as follows: Let y be the individual section, x be the reference section, x1 the original position of an event in the reference well and x2 the interpolated one, when y is expressed as a function of x. The four options for interpolation of the reference well in STRATCOR are as follows:

   a. An event position only changes if the newly calculated position in the composite y is higher (younger) than the old position of the event in the composite

$$y = x2$$

b. An event position only changes if the newly calculated
position in the composite y is lower (older) than the old position
of the event in the composite

$$y = x1$$

c. An event position in y is based on the average of the old
and newly interpolated positions

$$y = (x1 + x2) / 2$$

d. An event position in the composite is based on the weighted
average of the old and newly interpolated positions

$$y = (n.x1 + x2) / (n + 1)$$

where n is the number of wells used sofar to update the
interpolated position of x in the composite standard.

A table is printed of all events in the individual well, showing
their interpolated position and how the reference well has been
updated. Under the heading WELLS a running tally is kept how
many times an event in the composite was updated.
When all wells have been incorporated into the reference well,
a table of the final composite sequence is printed (*.PR2 file).
At this point you may choose to move to stage 2 or to
carry out another cycle of stage 1, untill the composite
stabilizes; if you choose the latter, you may specify a method of
updating the reference well that is different from the previous
cycle. Stage 1 can be repeated 99 times.

Obtaining depths for composite standard (stage 2):

  In stage 2, depths in the individual well are interpolated for
events in the composite standard.   A table of the interpolated
depths is printed in file *.PR4. When this has been done for all
wells, the program ends.

Error messages:

   Any messages about errors causing the abandonment of the
program will be displayed on the monitor, but they will also be
saved in the file STRATCOR.ERR for your inspection.

DENDRO
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Program DENDRO is a separate executable module in Quick Basic

4.0 that reads the output file *.PR2 (e.g. TEST1.PR2) of
GRACOR which contains the Final Composite Standard, and displays
the composite inter-event distances in a conventional
dendrogram format. The succession of stratigraphically successive
"clusters", may be interpreted as interval or assemblage zones.

PARAMETER FILE
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The parameter file for PREP and GRACOR, called STRATCOR.PAR
contains run-time instructions of a stratigraphic, computational, or
computer technical nature.

File structure:

All information in a record after an exclamation mark ("!") is
treated as comment and ignored.   Any records which are blank or
contain only comment are also ignored. The data values in a
record are in free format, separated by a comma or one or more
blanks.   Null values are specified by typing two successive
commas instead of a value.   If all remaining values in a record are
tobe null, they may be omitted entirely.

 The parameter file consists of successive blocks of records of
different types:
     (1) Documentation records: documentation about the file
optionally presented to the user at the console.
     (2) Initial DOS command records: DOS commands to be carried
out before any data are processed.
     (3) Terminal DOS command records: DOS commands to be
carried out at the end of the program.
     (4) Computational parameters.
     (5) Printer code records: control codes to set the printer to
the desired mode for printing the output file.
     (6) Plotting device records: specification of the devices
available   for plots of the data.

The end of a block of records is signalled by the symbol "%%%";
all data in a record after this symbol are ignored.

Documentation:

   The first record in the parameter file identifies it, and is
displayed on the monitor whenever the file is read by STRATCOR.

 All other records have a maximum length of 74 characters and are
documentation of the contents of the file; they are displayed on
the monitor at the user's request.

DOS commands:

   Initial DOS commands, listed in the parameter file are executed
before the program processes any data; they can be used, for
example, to initialise plotting devices.

Terminal DOS commands are executed immediately before the
program ends; for example, environmental variables can be
automatically returned to their normal values. Each record in
either of these blocks contains a DOS command, exactly
as it would be typed at the console. The commands must
not be more than 77 characters in length. The number of initial
DOS commands is unlimited, but there may not be more than 10
terminal DOS commands.

Computational parameters:

     The computational parameters block in the Parameter file
consists of records containing the following:

a) The index of the independent variable for spline functions:

                    (i) in Stage 1;
                   (ii) in Stage 2.

When this index is 1, reference well position (y) will be fitted to
individual well position (x). When this index is 2, the direction of
fitting is reversed, individual well position (y) will be fitted to
reference well position (x). The latter is the stratigraphically
preferred option in STRATCOR.

b) The minimum number of events an individual well must have in
common with the current reference well before any spline functions
will be fitted; individual wells with less than this minimum will
be ignored. The maximum number in common is 100.

c) The accuracy of fitted spline functions. If this value is k, a
fitted spline function will have a value of i within qk of the target
value. The current versions of subroutine SMOOTH and function
FINDSP do not permit this to be less than 10**-6 or greater than
0.5.

d) The accuracy of inverse interpolation with a spline function. If
this value is k, the value of x obtained will be within qk of the
true value. The current version of function PPVINV does not
permit this to be less than 10**-8.

Printer codes:

     All printer record codes in the parameter file have a maximum
length of 20 characters and are specified as a numerical sequence
consisting of the decimal equivalents of ASCII characters. For
example, the code "<ESC>@<SI>" is specified by the sequence
"27,64,15".

Printer record 1 is the control code used to initialise the printer.
This code is the first item in the output file.

Printer record 2 is the control code used to reset the printer. This
code is the last item in the output file.

Printer record 3 is the code for a form-feed on the printer; it is
issued at the start of each table in the output file.

Printer record 4 is the number of columns available on a printed
line after the code in record 1 has been received by the printer.

Plotting devices:

The plotting devices record in the parameter file refers to a
plotting device. The program allows for a maximum of 5 devices.
The data in a record are:
   a) Logical name of the device. The name has a maximum
      length of 8 characters and must be enclosed in quotes.
   b) Height in VDC units required for graphics text with this
      device.
   c) Size in VDC units required for polymarkers with this device
      when scatterdiagrams are drawn.

The first device is the computer's console, which is used to present
menus and to obtain keyboard input; it may also be used for plots.
It must be a CRT device, must have 6 different choice indicators,
must be capable of string input, and must have cursor movement
keys. The remaining devices are only used for plots.
The logical name of a device is defined by the Graphics Software
Systems device driver, by your CONFIG.SYS file and by the DOS
command SET (see p. A-10 of the programmer's guide for the
Graphics Development Toolkit). If the height of graphics text or
the size of polymarkers is not specified, STRATCOR
calculates a default height or size internally.

HOW TO OBTAIN AND HOW TO EXECUTE STRATCOR
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Program STRATCOR version 1.6 can be obtained free of charge. For
compiled, executable modules only, send one 3.5" diskette (720K)
or two 5.25" diskettes (360K) to the author; if source code is
desired send two 3.5" diskettes or three 5.25" diskettes. Test
data files are included with the program.

The (Fortran 77) computer program STRATCOR is interactive on PC
operated under DOS, with a mathematical co-processor (!) and a
graphics card installed, like Hercules, EGA, VGA etc.
Results can also be directed to a plotter or printer output device.

For the program to operate, users must have the co-processor hardware
installed. Also, the commercially available graphics drivers software
must be present, depending on the specifications of the users PC.

Specific volumes of these graphics drivers for display device support
on PC can be obtained for about 100.- USD from

                    Graphics Software Systems, Inc.
                    9590 SW Gemini Drive
                    Beaverton, Oregon 97005
                    USA
                         tel 503-641-2200
                         fax 503-643-8642

For the information of users that have the STRATCOR source code, compilation of this source code was accomplished with the commercial language package from Lahey Fortran.

> Lahey Computer Systems, Inc.
> P.O.Box 6091
> Incline Village, Nevada 89450-6091
> U.S.A.
> > telephone 702-831-2500

Compile instructions are provided in the file README.DOC on the STRATCOR diskettes.

During execution, PREP.EXE calls on COMMAND.COM, SORT.EXE and ANSI.SYS (DOS versions 3.2 or 3.3) to execute. It will look for these files in the default (= root) drive of the computer system (e.g. A: or C:). When the computer system is booted from A: with a STRATCOR boot disk, PREP will look for these files on the A: drive.

Also, during execution, GRACOR.EXE calls on the specific display device driver from Graphics Development Systems, Inc., and ANSI.SYS from DOS, to graphically display (or plot) the cross-plots and best fit lines. Instructions for installation of this software in connection to the STRATCOR software is in the file README.DOC on the STRATCOR diskettes.

REFERENCES
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