INSTRUCTIONS FOR USING SLOPEAGE:
A COMPUTER PROGRAM FOR MORPHOLOGIC DATING OF SCARPS

David Nash
Department of Geology
University of Cincinnati
Cincinnati, Ohio 45221-0013

INTRODUCTION

SLOPEAGE determines tc for a scarp (the morphologic age of the scarp, t, multiplied by diffusivity, c) by matching its profile with a profile produced by a simple linear diffusion model. The program will display the observed scarp profile and the best fit model profile and, if desired, plot it on an HP-7475 or compatible pen plotter. Plot commands are sent to COM1: which must be opened from DOS using the MODE command. The batch file OPENCOM1.BAT is included on the SLOPEAGE disk but you must copy MODE.COM from your DOS disk to the SLOPEAGE disk before it can be used.

ASSUMPTIONS AND LIMITATIONS

1. Only scarps that satisfy the following criteria should be analyzed:
2. The crest line of the scarp should be straight in map view. Particular care should be taken not to profile a scarp in a reentrant carved by a gully or on a salient between two gullies.
3. The program assumes that the initial profile of the scarp was simple, consisting of a a straight scarp face separating a straight base and crest.
4. The scarp should not be degraded by slope wash. Although it is generally difficult to assess the effectiveness of slope wash, when a scarp's surface is sparsely vegetated and heavily rilled, when its profile has a significantly more extensive and rounded basal concavity than crestal convexity, and when there is an accumulation of debris on the upslope side of obstructions such as vegetation and boulders, slope wash is probably significant.
5. The material underlying the profile should be relatively cohesionless (i.e., sand and gravel). Cohesive materials such as clay do not have an angle of repose so no assumptions may be made about the initial morphology of scarps underlain by these materials.

ALGORITHM

Determining Initial Morphology:

With the assistance of the user, SLOPEAGE estimates the initial profile of the scarp. The user must define the crest and base (when profiling a scarp, the profile must be extended beyond the limits of the curvature of the basal concavity and crestal convexity) and determine the angle of repose for the underlying material.

SLOPEAGE finds the straight line intersections of the user defined scarp crest, base, and midsection. The scarp midpoint is defined as the point lying midway between the intersection of the base and midsection and the intersection of the midsection and crest. If the base and crest are inclined at approximately the same angle then, according to the diffusion model, the location of the scarp midpoint does not shift with time so the present center of the scarp was also the center point of the initial profile. The program extends a straight line, with a gradient equal to the user defined angle of repose, through the scarp midpoint. The program assumes that the simple initial profile of the scarp is defined by this line and the crest and base lines.

Modeling the Degradation of Scarp Morphology:

The initial profile is approximated with a number of line segments spaced at a fixed horizontal interval and the diffusion model is solved by explicit finite differences. Using the maximum stable time step, the initial scarp morphology is degraded by steps. After each time step, r^2, the coefficient of correlation (r^2 = explained variance / total variance) between the model profile morphology and the scarp morphology measured in the field is determined. The degradation of the model profile is continued until a time step causes r^2 to decrease at which point the morphology of the model profile at the previous time step is restored and the time step is reduced to one tenth of its previous value. Degradation of the model profile is continued until a time step once again causes r^2 to decrease. This process is iterated three times until the time step is one thousandth of its initial value (the size of the final time step may either be decreased or increased by the user). The program then displays the morphologic age of the scarp, the observed profile, the best fit model profile, and r^2.

Parameters Determined by the Program:

In addition to determining the morphologic age of the observed profile, the program makes a number of other measurements. If the user specifies that the initial crest and base were horizontal or that they were inclined at the same angle, the program will determine the scarp offset (the perpendicular distance separating the base and crest). The program also determines the slope angle of the midsection of the observed profile. The areas of material removed from above, and deposited below, the scarp midpoint are also calculated. If the area removed from the crestal convexity differs significantly from the area deposited at the base, it suggests that the program is not appropriate for dating the scarp (i.e., it may have been degraded by processes that can not be modeled with the diffusion model). The program also uses the "inverse solution" method proposed by Andrews and Hanks (1985) to calculate another value for morphologic age (their $\tau\kappa$).

INSTRUCTIONS FOR USING SLOPEAGE

A compiled copy of the SLOPEAGE program (written in TURBO Pascal) is on the SLOPEAGE diskette along with another version of the program, SLOPE-87 which uses the math coprocessor chip (the computer must have an 8087 or 80287 chip). The diskette also includes a file containing a "raw" (i.e., unprocessed) profile that was generated with the diffusion model (tc = 20 m^2). In order to use SLOPEAGE it is necessary to have:

1. An IBM or IBM-compatible PC with at least 256K of RAM and an IBM or IBM-like graphics card. SLOPEAGE is unable to use the Hercules or Hercules-like high resolution graphics cards.
2. An ASCII text editing program such as WordStar (EDLIN, the text editor supplied with MS-DOS will work but is awkward and difficult to use).

The program creates a large random access file in which it stores observed slope profiles. It searches this file for the profile specified by the user. If the file is on a floppy disk, this search may take a while. It is recommended instead that the profile file be copied to RAM or memory disk (created with a program such as VDISK on later versions of MS-DOS or similar programs supplied with the AST Six Pack, or QUADRAM boards). Note : SLOPE-87 can not read data files created by SLOPEAGE nor can SLOPEAGE read data files created with SLOPE-87.

If a prompt ends with a colon, after typing the response, the return key (henceforth referred to as "<ENTER>") must be pressed. If a prompt ends with "(y/n)" type "y", "Y", or "1" for an affirmative response or "n", "N", or "0" for a negative response and do not press <ENTER>.

Preparing a Data set Containing Observed Profiles:

Observed profiles containing up to 100 profile points can be processed by SLOPEAGE. A data file must be created with an ASCII text editing program such as WordStar (if WordStar is used, be certain to edit using the "N" rather than the "D" command). Each profile should contain:

Line 1: A profile label (less than or equal to 10 characters in length).

Line 2: A description of the profile (less than or equal to 80 characters in length) which may contain any information of interest to the user.

Line 3: The number of profile points comprising the observed profile (less than or equal to 100). This number must be an integer (i.e., do not use a decimal point).

Line 4: The x and y Cartesian coordinates of the first point of the observed profile.

.

.

.

Line n: The x and y coordinates of the last point of the observed profile.

Data for the next profile should follow on the next line (do not insert an intervening blank line). The Cartesian coordinates of an actual observed profile are given below:

```
Sample #1
A description for sample #1 could be placed here.
 14
   0.00   0.00
   4.14   0.08
   9.42   0.15
  15.14   0.30
  17.27   0.61
  18.97   0.91
  21.10   1.52
  23.11   2.13
  25.32   2.74
  26.39   3.05
  28.38   3.35
  32.53   3.61
  36.47   3.73
  43.61   3.76
```

Starting a Program Run:

Put the SLOPEAGE diskette into the default disk drive and type:

```
slopeage<ENTER>
```

A disclaimer will be displayed. Press

```
<ENTER>
```

to continue. The program will prompt:

```
Number pad must be enabled. Check it and press <ENTER>:
```

Make certain that the "Num Lock" is on. Pressing the key labeled "5" on the numeric key pad should result in a "5" being displayed following the colon of the prompt. If a "5" is not displayed, press the "Num Lock" key.

When <ENTER> is pressed,

```
Enter the name of the file containing processed profiles:
```

will be displayed. Enter the name of the data set containing the processed files (Default: SLOPEAGE.DAT or SLOPE-87.DAT). Try creating a new data set, type:

SAMPLE.DAT<ENTER>

The program will next prompt for the name of the file to which the output statistics should be written,

```
Enter the name of the output file:
```

Enter the name of the file to which the output statistics should be written, for example:

SAMPLE.OUT<ENTER>

(Default: SLOPEAGE.OUT). The program will check to see if the file exists. If it does exist, the new output data will be appended to the end of the existing file. If the file does not exist, it will be created.

The program will next check to see if the specified file for the processed profile data exists. If the file does not exist it will prompt:

```
Enter the name of the file containing raw profiles:
```

A sample raw profile is in the file SAMPLE.RAW on the SLOPEAGE disk, type:

SAMPLE.RAW<ENTER>

(a raw observed profile data set could be created using the procedure discussed in the "Preparing a Data set Containing New Observed Profiles" section above). The program will display the labels as it reads in each new profile. A display of any directory may be requested at any prompt for a file name by typing a question mark. The program will respond

```
Directory:
```

type the directory you wish to have displayed and press <ENTER>.

After reading the raw field data or if the processed profile file does exist, the program will prompt:

```
Type

  1) to read in new data
  2) to process existing data
```

If "1" is specified, the program will prompt for the name of the file containing the raw observed profiles. The new profiles will be added to the profiles already in the file. If "2" is specified, execution continues (Default: "2").

Defining the Initial Profile:

The program will next prompt:

```
Enter the PROFILE label to be processed (type "quit" to quit):
```

As discussed below, various default values can be reset at this point by typing "SETDEFAULT". A listing of all the profile labels in a file may be obtained by typing "SHOWLABELS". If you are using the sample raw data supplied with the SLOPEAGE disk, type:

```
tc=20<ENTER>
```

otherwise, enter the label of the observed profile to be dated. Make certain to type the label exactly as shown. If the profile label is not typed correctly, no matching profile label will be found in the data set and the program will display:

```
{profile label} not found (press <ENTER> to continue)
```

When the profile label has been entered correctly, the observed profile will be displayed. If it is a profile that has already been processed (i.e., the initial morphology of the profile has already been established in a previous program run (not the case for this example), the initial profile will also be drawn and the prompt:

```
Is this okay (y/n)
```

will appear in the upper right corner of the screen. If an affirmative response is given, the procedure to establish the initial profile will be omitted (skip to "Fitting the Observed Profile with the Model Profile" section below). If this is the first time the profile has been processed or if the user responds "n", "N", or "0" to the previous prompt, a prompt will appear in the upper left corner of the screen:

```
Enter START point of base
```

Use the “4” and “6” keys to move the cursor arrow to the left and right respectively until it points to the starting point of the base. Press the “5” or <ENTER> key to select the point. The next prompt will be:

```
Enter STOP point of base
```

Move the cursor to the last point of the base (make certain that this point is beyond the downslope extent of the basal concavity). The program will similarly prompt the user to define the scarp midsection and crest. Make certain that the base, midsection, and crest do not overlap. If they do, the program will display:

```
Something is wrong... try again (press <ENTER> to continue)
```

and the user will be asked to repeat the process.

When the base, midsection, and crest have been successfully defined, the program will ask the user to

```
Type

  1) If initial base and crest are to be set equal
  2) If initial base and crest are not to be set equal
  3) If initial base and crest are to be set to zero
```

If "1" is selected, the length weighted mean of the gradient of the base and crest will be calculated and the base and crest of the initial profile will be set equal to this mean gradient. If "2" is selected, the measured values of the base and crest gradients will be used for the initial profile (and the program will not calculate the scarp's offset). If "3" is selected, the gradients of the base and crest will be set equal to zero.

The program will next prompt:

```
Enter the initial angle of the midsection:
```

Enter the angle of repose of the underlying material and press <ENTER> or press <ENTER> without typing anything and the default midsection slope angle (reset using the SETDEFAULT command discussed below) will be used. If you are using the raw sample data set supplied on the SLOPEAGE disk, type:

```
30<ENTER>
```

If an initial midsection slope angle less than the angle of the observed profile midsection is specified, the program will determine some descriptive parameters for the scarp but will not attempt to match the observed profile with a model profile. If the initial slope angle is greater than the midsection angle of the observed profile, the program will display the observed profile, superimpose the generated initial profile on it and prompt

```
Is this okay (y/n)
```

If “n”, “N”, or “0” is entered, the process of defining the initial profile will be repeated. If “y”, “Y”, or “1” is specified, execution will continue (Default: “Yes”).

Fitting the Observed Profile with the Model Profile:

The program will display the observed profile and prompt:

```
Enter fit START point
```

Move the cursor arrow to the start of the range of points to be matched with the model profile. Press "5" or <ENTER> to enter the point. The program will next prompt:

```
Enter fit STOP point
```

Move the cursor arrow to the last point of the range of points to be matched with the model profile. When "5" or <ENTER> is pressed, the program will start fitting the model profile to the specified range of points on the observed profile (if you are using the profile in file SAMPLE.RAW, specify the first and last points of the profile). For a young scarp, the fit should take no more than a few seconds. For a very old scarp, the fitting process may take a minute or so. At regular intervals, the program will display the morphologic age of the model profile it is currently comparing with the observed profile. When the program has determined the age of the model profile that most closely matches the range of points on the observed profile, it will superimpose the model profile on the field data and write the morphologic age and other parameters to the previously specified output file and will prompt

```
Press <ENTER> to continue
```

in the upper right corner of the screen. When <ENTER> is pressed, various morphologic parameters and the morphologic age of the scarp (calculated using the best fit profile and, if the slope of the crest and base are equal, with the Andrews and Hanks (1985) "inverse solution" method) will be displayed. The program will again prompt:

```
Press <ENTER> to continue
```

If in resetting the default values (discussed below), you indicate that an HP-7475 plotter is attached to COM1: (unless instructed otherwise when resetting defaults, the program assumes a plotter will not be used), when <ENTER> is pressed, you will be asked

```
Do you want the results plotted (y/n)?
```

If an affirmative answer is given, the program will plot the profile and statistics for that profile if the HP7475 plotter is connected to COM1:. The plotter must be attached to COM1: and have a broad (0.7mm) black line pen in position #1, a fine (0.3mm) black line pen in position #2, and a fine red line pen in position #3. The program will prompt:

```
Enter vertical exaggeration:
```

You may either enter a value or use the default of five times vertical exaggeration by pressing <ENTER> without typing anything. You will next be prompted

```
If a specific scale is desired, enter it:
```

Generally you should just press <ENTER> but if you want to plot several profiles at the same scale, enter the number of meters per inch to be used.

After the profile has been plotted, if in resetting the default values (discussed below), you indicate that the Cartesian coordinates of the observed and model profiles are to be written to an ASCII file then you will be asked:

```
Do you want to record profile coordinates (y/n)?
```

If you answer affirmatively, the profile coordinates will be recorded. Finally, the program will prompt for the label of the next profile to be analyzed. Another profile label can be entered or program execution can be terminated by entering "quit" or "QUIT".

Changing Default values:

When prompted

```
Enter the PROFILE label to be processed (type "quit" to quit):
```

If you type:

```
SETDEFAULT<ENTER>
```

(note that there is no space between "SET" and "DEFAULT"), the program will prompt you for values to be used for various parameters. In most cases the default values for these parameters are appropriate. Pressing <ENTER> without specifying any value for a particularly parameter will leave its current value unchanged.

If the model profile does not extend to the ends of the original profile (which can cause serious errors), either increase the number of model profile points (do not exceed 100) or decrease the number of profile points used to model the initial scarp face (see below). Increasing the number of profile will increase computation time. Enter the number of profile points when prompted

```
Number of points in model profile (default: 31):
```

The size of the final time step can be decreased thus increasing the accuracy of the value of tc by increasing the number of solution iteration loops. If the default value of three is used, the size of the final time step is one thousandth of the size of the maximum permissible time step (see discussion in "Algorithm" section above). When prompted

```
Number of solution iteration loops (default: 3):
```

enter an integer number.

If the model profile is not smooth (i.e., it appears to be made up of long line segments rather than being a smooth curve), it can be smoothed by increasing the number of points used to represent the initial scarp face (generally no more than nine points are necessary). When the program prompts

```
Number of profile points in scarp face (default: 3):
```

enter the number of points used to represent the initial scarp face. For older scarps, three points should be sufficient but younger scarps may require more points.

Although the user is always prompted for the initial slope angle of each scarp processed, pressing <ENTER> without typing anything else will enter a default value for

this angle. The default value may be changed from 33.5^o by entering a different value when prompted

```
Default initial midsection slope angle (default: 33.5^o):
```

A five times vertical exaggeration is used when displaying the field and model profiles on the computer screen. This may be changed by entering a different value when prompted

```
Vertical exaggeration of profile (default: 5):
```

This vertical exaggeration is used only for plotting on the screen. The vertical exaggeration used by the plotter (if one is attached) is set separately.

If an HP-7475 or compatible plotter is attached to COM1:, when the prompt

```
Is an HP-7475 plotter attached (y/n)?
```

appears, answer affirmatively. The default is no plotter.

If you wish to produce an ASCII file containing the Cartesian coordinates of the observed and modeled profile, when the prompt

```
Are profile coordinates to be written to a file (y/n)?
```

appears, answer affirmatively and you will be prompted

```
Enter the name of the file for output profiles:
```

Enter the name of the file to which the profiles are to be written. If the file does not exist, it will be created. If the file does exist, the new data will be appended.

ADVANTAGES OF SLOPEAGE OVER OTHER MORPHOLOGIC DATING METHODS

A many procedures have been proposed for morphologic dating of scarps including Nash (1980,1984), Colman and Watson (1983), Hanks *et. al*. (1984), Andrews and Hanks (1985). All dating techniques should yield nearly the same age for a scarp. The principle advantages of SLOPEAGE are:

1. It is easy to use
2. It makes no assumptions about the inclination of the base and crest
3. It can date all, or any portion of the observed profile.

REFERENCES

Andrews, D.J., and Hanks, T.C., 1985, Scarp degraded by linear diffusion: inverse solution: *Journal of Geophysical Research*, v. 90, p. 10193-10208.

Colman, S.M., and Watson, K., 1983, Ages estimated from a diffusion equation model for scarp degradation: *Science*, v. 221, p. 263-265.

Hanks, T.C., Bucknam, R.C., Lajoie, K.R., and Wallace, R.E., 1984, Modification of wave-cut and faulting-controlled landforms: *Journal of Geophysical Research*, v. 89, p. 5771-5790.

Nash, D.B., 1980, Morphologic dating of degraded normal fault scarps: *Journal of Geology*, v. 88, p. 353-360.Š

Nash, D.B., 1984, Morphologic dating of fluvial terraces scarps and fault scarps near West Yellowstone, Montana: *Geological Society of America Bulletin*, v. 95, p. 1413-1424.