Council for Geoscience

# GEODATE FOR WINDOWS VERSION 1: ISOTOPE REGRESSION AND MODELLING SOFTWARE

*by*

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# Introduction

This manual documents the operation of GEODATE for Windows (version 1.3), a 32-bit program for the regression and modelling of isotope data. The software has been written for use on microcomputers using Windows 95/98/2000/NT and compatible operating systems.

Since this package is supplied free of charge, we request that its use be acknowledged when publishing. Correct reference is:

Eglington, B.M. and Harmer, R.E. (1999). GEODATE for Windows version 1: Isotope regression and modelling software. Council for Geoscience Open-file report 1999-0206 O, 24pp.

## *Options available*

The program is capable of regressing and processing simple X-Y data, Rb-Sr, Sm-Nd, U-Pb, Pb-Pb, Th-Pb, Lu-Hf, La-Ce, radiogenic U-Pb (Wetherill and Tera-Wasserburg approaches), Re-Os, K-Ar, Ar-Ar, evaporation Pb-Pb and Lu-Hf data with errors in both ordinates. Correlation between the errors can also be considered. Regression is based on the techniques of York (1969), Williamson (1968) and Titterington and Halliday (1979). Age, initial ratio and epsilon/gamma values, and their uncertainties, are calculated following the techniques of Ludwig (1980, 1990), Roddick (1987), Harmer and Eglington (1991) and Eglington and Harmer (1993). Concordia dates for radiogenic U-Pb data are calculated following the procedure documented by Ludwig (1998).

Routines are included to maintain and edit data files, and to generate on-screen plots of the regressions, weighted averages and concordia dates. It is also possible to import and export Microsoft Excel spreadsheets and to store the results of geochronological calculations in a separate database which may be queried using the DateView software of Eglington (1999). A copy of DateView is provided and installed with GEODATE for Windows.

# Program requirements

### *Files required*

The primary application executable, titled GDW1, was written in Delphi (currently version 4.0). The software comprises the file GDW1.EXE, various ActiveX components, the Borland Database Engine (BDE) and various Paradox data tables used for handling the data. Legal copies of all these files are automatically installed by the InstallShield software. The file GDW1.INI (in the Windows directory) is automatically created the fist time the program is run. This ASCII text file contains many of the parameter definitions e.g. decay constants utilised within GEODATE for Windows and may be edited by the user, as detailed elsewhere in this documentation.

By default, data are stored in random access files, separate files being used for each isotopic technique. These files all have the extension ".YK?" where "?" is a numeral in the range 0 to 9 or letter from A to H, corresponding to the analytical codes used in the program. The default versions of these codes are:

0 – general (no isotope system)
1 - Rb-Sr
2 – Sm-Nd
3 - Pb-Pb
4 - $^{238}$U-Pb
5 - $^{235}$U-Pb
6 - Th-Pb
7 - Lu-Hf
8 – radiogenic U-Pb (Wetherill concordia approach)
9 - La-Ce
A – radiogenic U-Pb (Tera-Wasserburg approach)
B – K-Ar
C – Ar-Ar
D – Ar reverse
E – K-Ca
F – Re-Os
G – La-Ba
H – Kober type zircon evaporation lead

These files are compatible with earlier DOS versions of GEODATE (e.g. Eglington and Harmer, 1991).

Record zero of each file contains a title for the data set whilst the data is stored in record 1 ... MaxSamples. The maximum number of samples permitted is usually 200, but can vary according to the version provided. The data record structure is as follows:

```
DataRecord      = record
    case integer of
     1 : (Sano      :  string[10];
        XElemConc, YElemConc, XRatio, XPrecis,
        XError, YRatio, YPrecis, YError, Correl                 :  6 byte real;
        AnTyp      :  char;
        ErTyp      :  char;
        RFlag      :  char;
        PFlag      :  char;
        ZRatio, ZPrecis, ZError                 :  6 byte real);
     2 : (Tit       :  string[80];
       NRep : integer;
        sparefield :  array[1..45] of byte);
    end;
```

Most of the fields constituting these records are self explanatory, those which might require some explanation are:

| | |
|---|---|
| AnTyp - analytical type (0 .. 9, A..H) | |
| ErTyp - error type (1 .. 4) | 1 = % X error and % Y error<br>2 = % X error and actual Y error<br>3 = actual X error and % Y error<br>4 = actual X and Y errors |
| RFlag – regress flag | Y = include for regression<br>N = exclude from regression |
| PFlag – plot flag (affects screen plotting output and export files) | Y = include for plots<br>N = exclude from plots |
| ZRatio, ZPrecis and ZError are extra variables needed in some of the isotope systems. For instance $^{207}Pb/^{206}Pb$ and its uncertainty is required in the Pb-Pb and concordia systems in order to calculate the error correlation coefficient (see later). | |
| NRep is the number of replicates used or assumed to define the analytical uncertainties and F cutoff value. Usually this will be 999 (an approximation for infinity). | |

### *Installing GEODATE for Windows*

Installation of GEODATE for Windows is easy. Simply follow the normal Windows 95/98/2000/NT approach for adding new software from the Windows Control Panel. Setup options are controlled by the InstallShield package which provides a professional interface for selecting the various options available to the user. Most users should accept the default options provided during this installation process. This process will also install and register all the software components required for the software to function in the Windows 95/98/2000/NT environment.

## Differences between the DOS version of GEODATE and the Windows version

There have been a number of improvements and changes made since the original DOS version of this software. The main changes are:

- GEODATE now runs in a 32-bit Windows environment.
- GEODATE now uses one F cut-off file, a Paradox table. The number of replicates used for each data set is now stored with the data in the .YK? file or defaults to 999. This modification increases the flexibility of GEODATE since analytical precisions for the various isotope systems and rock suites analysed are frequently defined at different confidence levels.
- Model confidence limits are presented at 95% confidence, not 1 sigma as in early DOS versions of GEODATE. The approach used is the same as for GEODATE (DOS) version 2.2. Remember that these confidence limits are directly related to the number of replicates used to assess analytical uncertainties.
- Model $^{238}U/^{204}Pb$ values and model Pb-Pb dates can be calculated for either one date supplied by the user or for individual dates specified in the 'Extra' field of each data record..
- Weighted averages can be calculated for a variety of variables.
- Histograms can be drawn for a variety of variables, including Nd model dates and model $^{238}U/^{204}Pb$ values.
- Data defining all screen graphics may be exported to Microsoft Excel spreadsheets for subsequent high quality plotting using packages such as GRAPHER for Windows (R).
- On-screen graphs may be modified or sent to a printer by right-clicking the image and selecting the appropriate options. Alternatively, they may be saved as metafiles or bitmap images.
- GEODATE can now perform constrained regressions.
- In addition to the GEODATE file structure used by DOS versions of GEODATE, it is now possible to access Microsoft Excel spreadsheets. The column order for individual isotope systems is stored in the .INI file so that, if one continually uses the same file structure, it is not necessary to define which column matches which variable each time a data set is imported. Users may thus use spreadsheet files rather than the .YK? files for all their data entry if they so desire.

- GEODATE for Windows can now also process radiogenic data using the Tera-Wasserburg approach (Tera and Wasserburg, 1972) and can convert data from this format to the Wetherill format or *vice versa*.
- A number of additional isotope systems have been implemented, including Ar-Ar in various formats.
- Weighted concordia dates (Ludwig, 1998) may now be calculated for zircon and other radiogenic U-Pb data.
- Various geochronological information calculated by GEODATE may now be directly exported to DateView (Eglington, 1999) database files.

## Program operation

On starting the program, the user is provided with a screen, as illustrated in Figure 1. Menu items available are: File, Edit, Regress, Model, Average, Options and Help. Some of the most commonly used menu items may also be accessed via speed buttons on a tool bar below the menu.

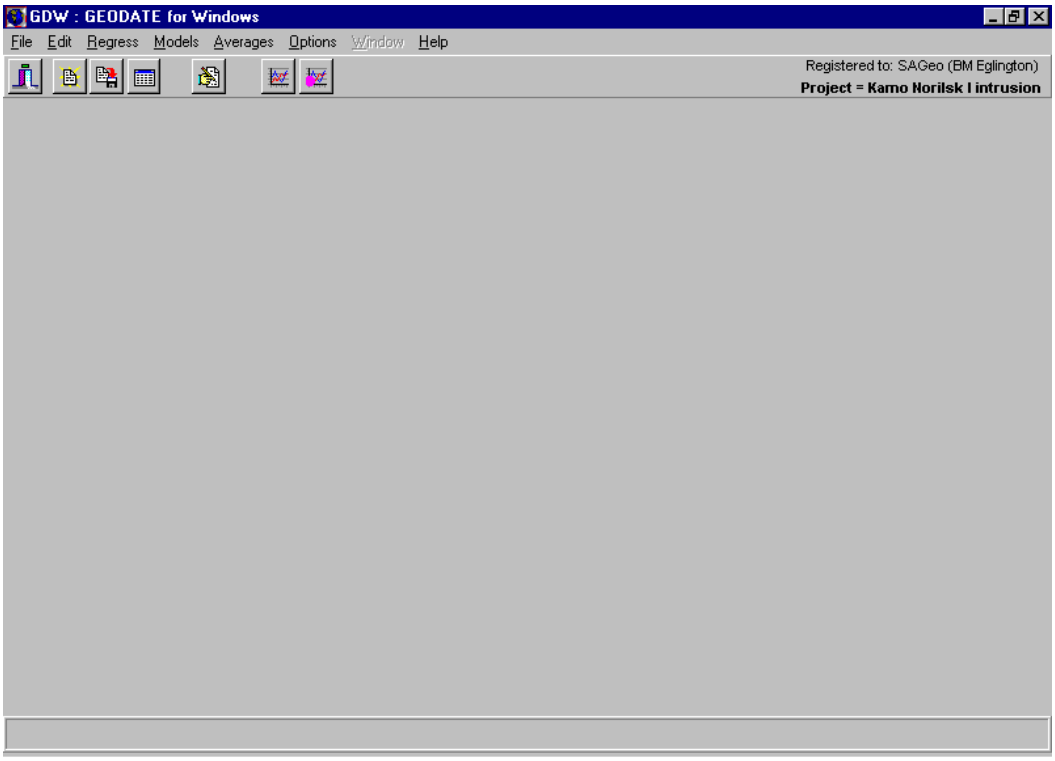



*Figure 1. Main window for GEODATE for Windows.*

## *Data input and editing*

Data may be input from any one of three sources: the keyboard, a GEODATE data file or a Microsoft Excel spreadsheet (Excel 5 or Excel 97).

### *Entering new data from keyboard*

Keyboard entry first requires one to define the isotope system used and the general form of the uncertainties. One also needs to type in all the sample numbers at this stage. The dialog for this process is illustrated in Figure 2.

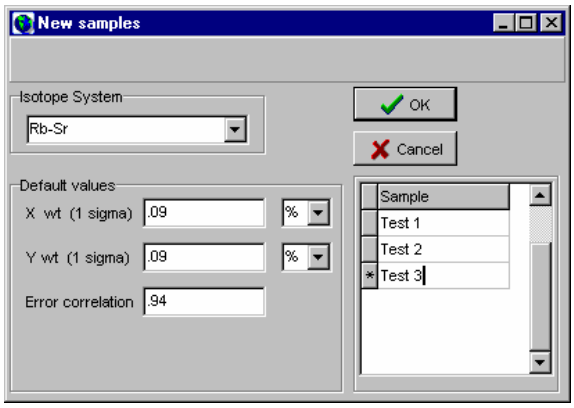



*Figure 2. Initial keyboard entry window for defining blanket uncertainties (if applicable) and sample numbers.*

Once this process has been completed, a new window is displayed (Figure 3) and the user may enter and edit the numeric data for each record.

*Editing data*

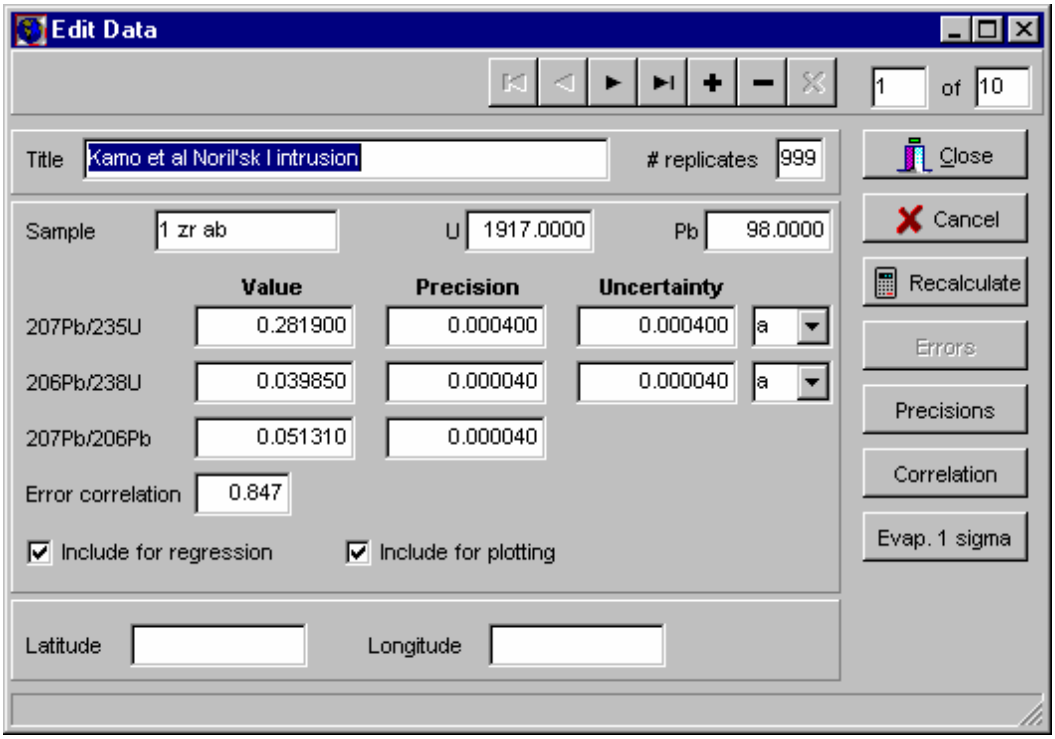



*Figure 3. Window for editing of data. All editing is held in memory and the original data file is not automatically updated. The user should save changes as necessary.*

For some isotope systems (e.g. Rb-Sr) the operator may choose to have the program calculate the relevant X/Y atomic ratio for each sample. X/Y atomic ratios are calculated as follows:

$^{87}Rb/^{86}Sr = Rb/Sr_{ppm}$ $(2.692948 + 0.283040*^{87}Sr/^{86}Sr)$
$^{147}Sm/^{144}Nd = Sm/Nd_{ppm}$ $(0.531497 + 0.142521*^{143}Nd/^{144}Nd)$
$^{176}Lu/^{177}Hf = Lu/Hf_{ppm}$ $(0.134399 + 0.025983*^{176}Hf/^{177}Hf)$
$^{138}La/^{142}Ce = La/Ce_{ppm}$ $(0.00811)$

These, and other, values are based on the atomic masses provided by Wapstra and Bos (1977), but may be changed in file GDW1.INI in the Windows folder.

The program expects all analytical uncertainties to be expressed as one sigma values, either as % or actual, according to the procedure used at one's laboratory. Blanket uncertainties may be chosen during data input. The uncertainties specified will be used for each of the samples and can thus reduce the amount of typing required. Obviously, this option would only be used if all the samples do, in fact, have the same uncertainties, expressed in the same way.

If the concentrations are changed during editing, the operator may choose to have the program recalculate the relevant X/Y atomic ratio (using formulae such as those presented above) by clicking on the 'Recalculate' button. The operator will be asked whether to accept the new value or not if it is significantly different from that already available.

Analytical uncertainties for regressions, weighted averages, etc may be derived from the precisions associated with each X and Y measurement. This is of paarticular use when importing SHRIMP U-Pb data from the spreadsheets typically used for reporting. In this case, a dialog (Figure 4) is presented, prompting the user to select the variable concerned and the nature of the original precision. This process needs to be done for each individual record in the data set.

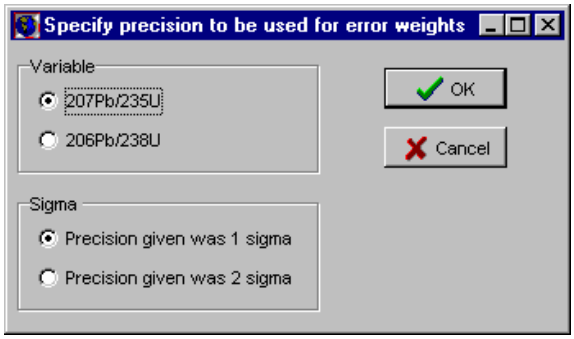



*Figure 4. Dialog for calculating analytical uncertainties from precisions.*

It is also possible to calculate the error correlation for radiogenic U-Pb and Pb-Pb data from the precisions and values provided if appropriate variables are stored in the 'Extra' variable and its precision. For Pb-Pb and Wetherill-type radiogenic U-Pb data this should $^{207}Pb/^{206}Pb$. Calculation follows the formulation of Ludwig (1980, 1998).

It is sometimes possible to obtain within-run precisions for zircon evaporation data which are significantly better than between-run precisions. It is thus possible to specify a minimum permissible percentage uncertainty for these data by clicking on the *Evap. 1 sigma* button in the Edit Data window. The user is then prompted for a minimum value, as illustrated in Figure 5

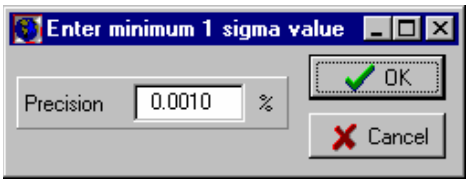



*Figure 5. Dialog for specifying the minimum percent analytical uncertainty allowed for zircon evaporation results.*

Data may be included or excluded from the regression by means of the 'Regress Flag' option in the Edit Menu. Any point excluded from a regression will not be deleted from the file but will appear separately on the printout.

Once keyboard entry is complete, the operator is prompted for the name of a GEODATE type file in which to store the data. Thereafter, if changes are made, it is up to the operator to save the modified file. ***Changes are not automatically updated in the file!***

### *Importing data from spreadsheets*

Data may also be easily imported from Excel spreadsheets. Figure 6 illustrates the dialog provided when one chooses to import data from an Excel spreadsheet. Once a spreadsheet has been opened (click on the *Open* button at the top of the window and select the file you want), the user needs to specify which rows to import and the columns in which the various fields will be found. One must also specify the isotope system so that GEODATE knows what to call each column. Once one is happy with the specifications, click the *Import* button, data is imported and is presented in the standard Edit Data window. Thereafter, the user is prompted for the name of a GEODATE file in which to store the data.

The column specifications for each isotope system are stored in the GDW.INI file. If one uses the same format for other data sets, then it is not necessary to respecify the column setting when performing subsequent imports. The ease of operation of this option now makes it feasible to use spreadsheets as the primary data file in place of the customised GEODATE files.

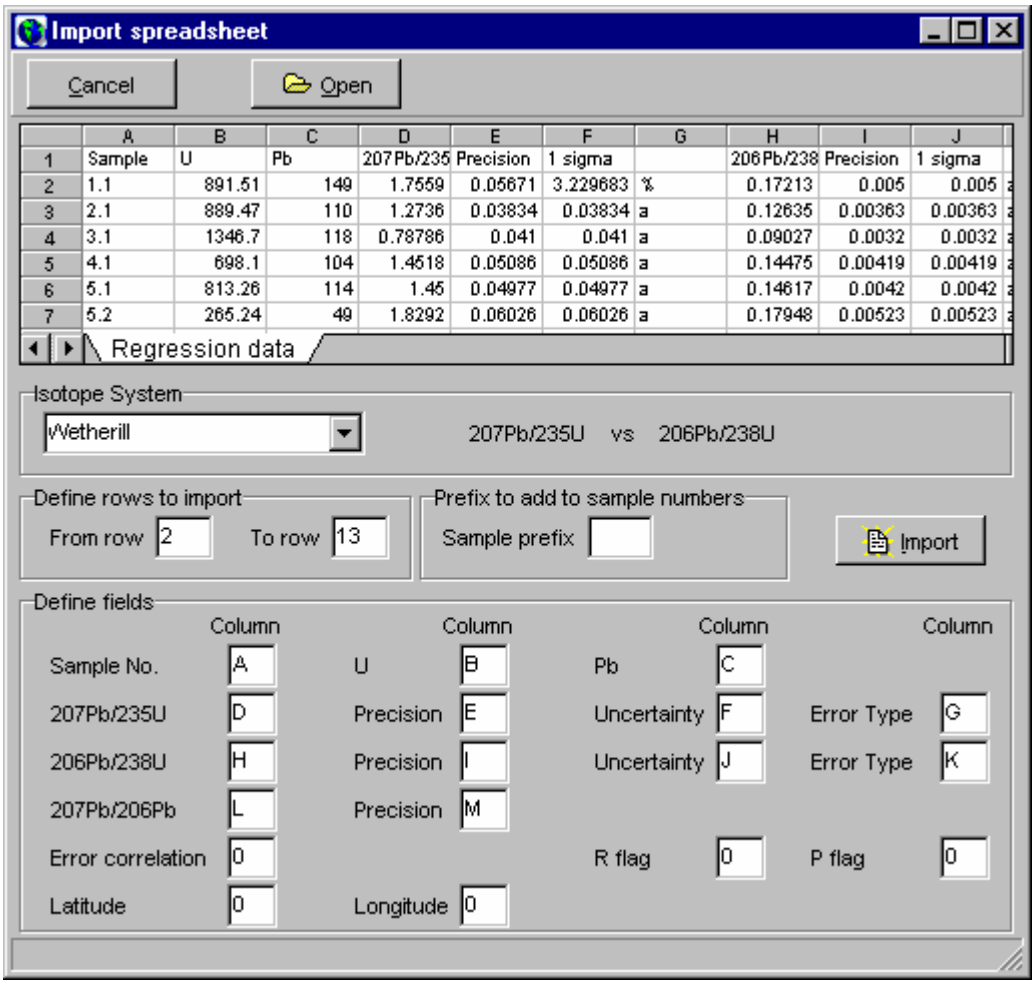



*Figure 6. Spreadsheet import window. After opening an Excel spreadsheet, one selects the appropriate isotope system and then defines the starting and ending rows to be imported and the columns in which the various data are stored. These column settings will be remembered for future use so as to minimise user input requirements if the same spreadsheet layout is used for other data.*

## *Calculation of regression dates*

Regression of data in this software follows the techniques of York (1969), Williamson (1968), Titterington and Halliday (1979) and Ludwig (1980, 1990). Uncertainties in the "X" and "Y" ordinates, together with their error correlation, are taken into account. Error correlation in U-Pb studies should be consistent with the equations of Ludwig (1980). The procedure cycles until the difference between two successive slopes is less than 0.000001 or the number of iterative cycles exceeds 200.

Dates for standard isochron type techniques (e.g. Rb-Sr, Sm-Nd), derived from the best-fit line, are calculated by substitution of the slope of the line into the equation:

$$t = \frac{\ln(\text{slope} + 1)}{\lambda}$$

Pb-Pb dates are determined by Newton's iterative technique, following regression. Iteration continues until two successive dates differ by less than 20 000 years.

Default decay constants used are:

$^{87}Rb = 1.42 \times 10^{-11}\ a^{-1}$
$^{147}Sm = 6.54 \times 10^{-12}\ a^{-1}$
$^{238}U = 1.55125 \times 10^{-10}\ a^{-1}$
$^{235}U = 9.8485 \times 10^{-10}\ a^{-1}$
$^{232}Th = 4.9475 \times 10^{-11}\ a^{-1}$
$^{177}Lu = 1.940 \times 10^{-11}\ a^{-1}$
$^{138}La = 2.58 \times 10^{-12}\ a^{-1}$

These, and other values, may be changed in the GDW1.INI file in the Windows folder.

Radiogenic U-Pb data (Wetherill aand Tera-Wasserburg concordia approach) may be regressed according to three methods. The operator may choose the standard technique where weighting is identical to that used in the Rb-Sr system, or may choose to augment the errors according to the degree of discordance of the points relative to the upper or lower concordia intercepts. In these cases the data are augmented following the formulation of Ludwig (1990) but with "p" initially held to a value of 0.2 (Eglington and Harmer, (1993). Figure 7 illustrates the dialog used to select the weighting approach for these situations.

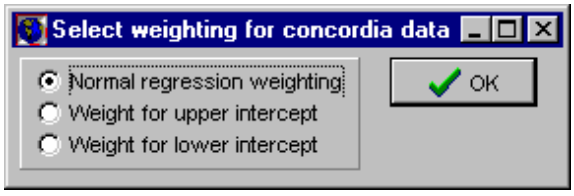



*Figure 7. Dialog used to specify the regression weighting approach to be used for radiogenic U-Pb data.*

Concordia intercept dates are derived following the approach of Ludwig (1980). Here too, successive dates must differ by less than 20 000 years before the procedure used returns a value.

Typical regression results for isochron data and radiogenic U-Pb data are illustrated in Figure 8 and Figure 9, respectively. It is also possible to calculate regressions constrained to pass through some point specified by the user. The approach used to calculate this form of regression is to use the X and Y values

of the constraining point be the centroid of the line. The regression uncertainties obtained in this way are believed to be more realistic than those calculated by 'adding' and extra precisely-defined point since this latter methodology increases the spread in the data and thus artificially reduces the regression uncertainties (Harmer and Eglington, 1991).

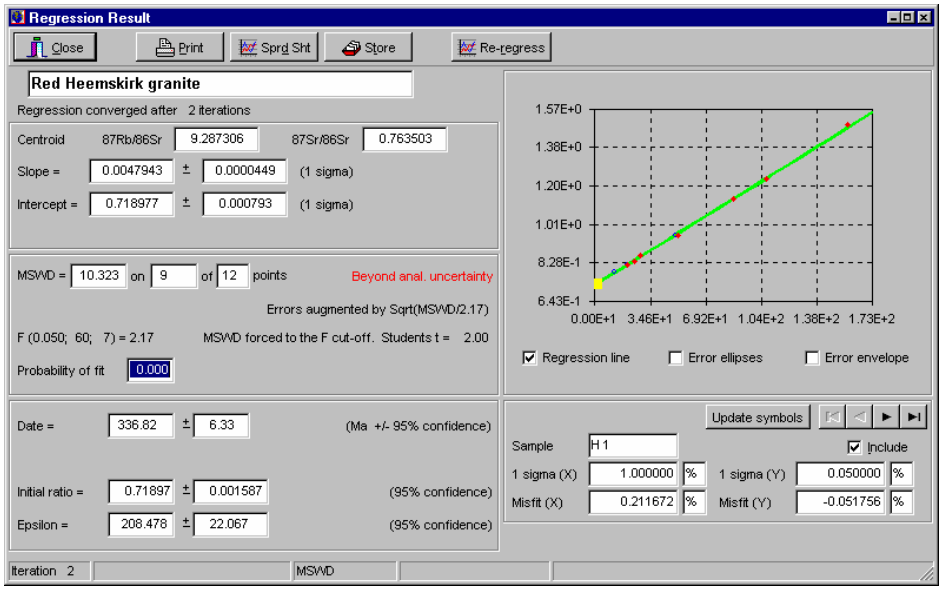



*Figure 8. Regression result window for typical isochron data, in this case Rb-Sr. Data are illustrated graphically (red symbols for points included in the regression and blue symbols for those excluded). The user may step through the data by clicking on the navigator bar below the graph. The current sample is highlit in a large yellow square. Results may be printed, saved in an Excel spreadsheet or stored in a DateView database.*

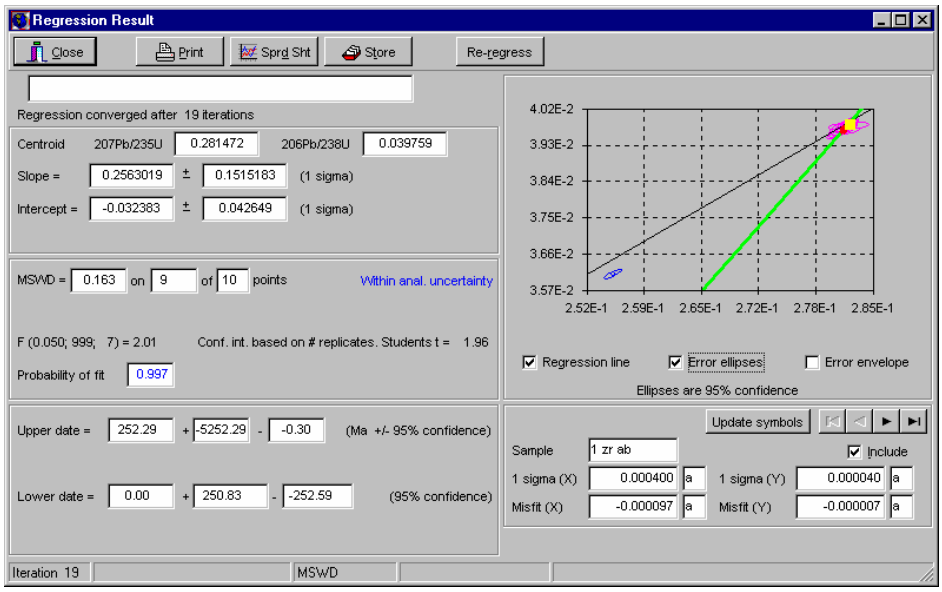



*Figure 9. Regression result window for Wetherill type radiogenic U-Pb data. Data are illustrated graphically (red symbols with magenta error ellipses for points included in the regression and blue symbols and ellipses for those excluded). If the user requires that the spreadsheet also contain the co-ordinates of the error ellipses, then the 'Error ellipse' check box beneath the graph must be checked prior to saving to spreadsheet.*

## *Calculated uncertainties*

Errors calculated for isochrons by GEODATE are based on the approach of York (1969) but, where the MSWD exceeds the specified Critical F value, the operator is prompted to choose one of a number of models with which to treat the data, as illustrated in Figure 10.

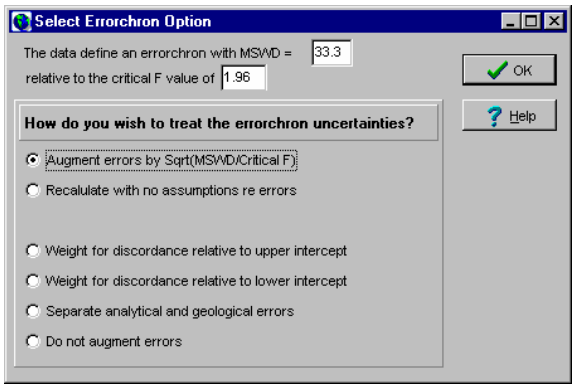



*Figure 10. Dialog used to select the errorchron enhancement approach to be used when MSWD > F.*

Options are:

- augment uncertainties by the square root of MSWD/Critical F. Mathematical details of this approach have been summarised by Harmer and Eglington (1991). The Student's t multiplier for 95% confidence estimation is derived (formula from Ludwig, 1983,1990) from the number of replicates utilised to define the analytical uncertainties.

- follow Ludwig's (1983) Model 2 approach in which no assumptions are made as regards analytical uncertainties and error correlation is assumed to be 0.0. This technique, as implemented here, forces the MSWD to a value of 1.0. The Student's t multiplier for 95% confidence estimation is derived from the number of samples regressed, not from the number of replicates utilised to define the analytical uncertainties.

- an option based on Model 3 of Ludwig (1983,1990) and is only available for standard isochron decay schemes (e.g. Rb-Sr, Sm-Nd). Excess scatter is assumed to be due to normally distributed variation in the initial ratios of the samples, in addition to their analytical uncertainties. The model requires the assumption that the sample initial ratios were not correlated with the parent/daughter ratios. The Student's t multiplier for 95% confidence estimation is derived from the number of samples regressed, not from the number of replicates utilised to define the analytical uncertainties. Calculation iterates until MSWD is forced to the chosen Critical F value.

- Ludwig's (1990) model 4 approach for radiogenic U-Pb (concordia) data in which analytical uncertainties are continually augmented relative to the discordance of the point until MSWD is equal to the Critical F value. This is achieved by increasing the value of "p". The Student's t multiplier is derived from a weighted sum of the number of samples regressed ($n_r$) such that this sum will always be less than $n_r$.

- an option proposed by Harmer and Eglington (1991) as being intuitively more appropriate for isochron type decay schemes. This model assigns separate analytical and 'scatter' components contributions to errorchron regression errors according to the following formulae:

  $\sigma^2(\text{excess}) = \sigma^2(\text{analytical}) * (\text{MSWD/F critical} - 1)$

- where uncertainties are not augmented to account for scatter in excess of that explained by analytical uncertainty. 95% confidence intervals are based on a Student's t value derived from the number of replicates used to define the analytical uncertainties. This approach will always provide an underestimate of the calculated uncertainties for errorchrons.

For the standard isochron techniques, age errors are determined using the same equation as that used for the calculation of the age. Concordia intercept age errors are determined by means of the equations presented by Ludwig (1980). Pb-Pb age errors are determined by substitution of the adjusted (plus or minus) slopes into equations similar to those used to derive concordia intercept uncertainties.

Source Pb-Pb growth-curves are calculated assuming either a single stage (starting at 4.57 Ga) or Stacey and Kramers (1975) two-stage model (3.7 Ga starting point). Details of the mathematics are presented in Appendix E. The user may select the model to be used from the Options Menu. Errors associated with these curves are calculated using the error envelope approach of Ludwig (1980), as explained in Appendix E. All these procedures are iterative and two successive æ values must differ by less than 0.0002 before a value is returned to the calling routine.

### *Calculation of weighted averages and model dates*

These two menu items permit the calculation of model uniform reservoir; depleted mantle; initial ratio; epsilon/gamma or model source $^{238}U/^{204}Pb$ values, model $^{207}Pb/^{206}Pb$ and weighted averages for each of the three measurement variables provided. Several of the calculations may be performed for the same date or initial ratio for all records or for a date specified in the extra variable field. It is also possible to calculate weighted average concordia dates (Ludwig, 1998).

#### *Depleted mantle and uniform reservoir models*

Model depleted mantle and uniform reservoir evolution is described by equations of the form

$$ratio = at^2 + bt + c$$

where t is the age in years. The parameters a, b and c are specified in the GDW1.INI file for each decay system and may be modified by the user using any ASCII text editor..

Default $T_{DM}$ dates for Sm-Nd and Rb-Sr, etc are based on equations of the form Ben Othman et al. (1984) or De Paolo (1991) whereas $T_{UR}$ dates are based on the following constants:

$^{87}Rb/^{86}Sr = 0.0847$ $^{87}Sr/^{86}Sr = 0.7047$

$^{147}Sm/^{144}Nd = 0.1967$ $^{143}Nd/^{144}Nd = 0.51264$

$^{176}Lu/^{177}Hf = 0.0334$ $^{176}Hf/^{177}Hf = 0.28286$

$^{138}La/^{142}Ce = 0.00306$ $^{138}Ce/^{142}Ce = 0.0228527$

These, and other values, may also be changed in the GDW1.INI file in the Windows folder.

### *Lead isotope evolution models*

The user may specify up to three lead isotope evolution systems in the .INI file. One is assumed to represent a single stage model, another a two stage model and the third may be any user defined model which matches the simple formulation:

ratio = initial ratio + 238U/204Pb ($e^{\lambda t} - 1$)

for $^{238}U$ decay and similarly for $^{235}U$ and $^{232}Th$.

### *Weighted averages*

Weighted averages are automatically calculated for all models selected and are presented in a window such as that illustrated in Figure 11.

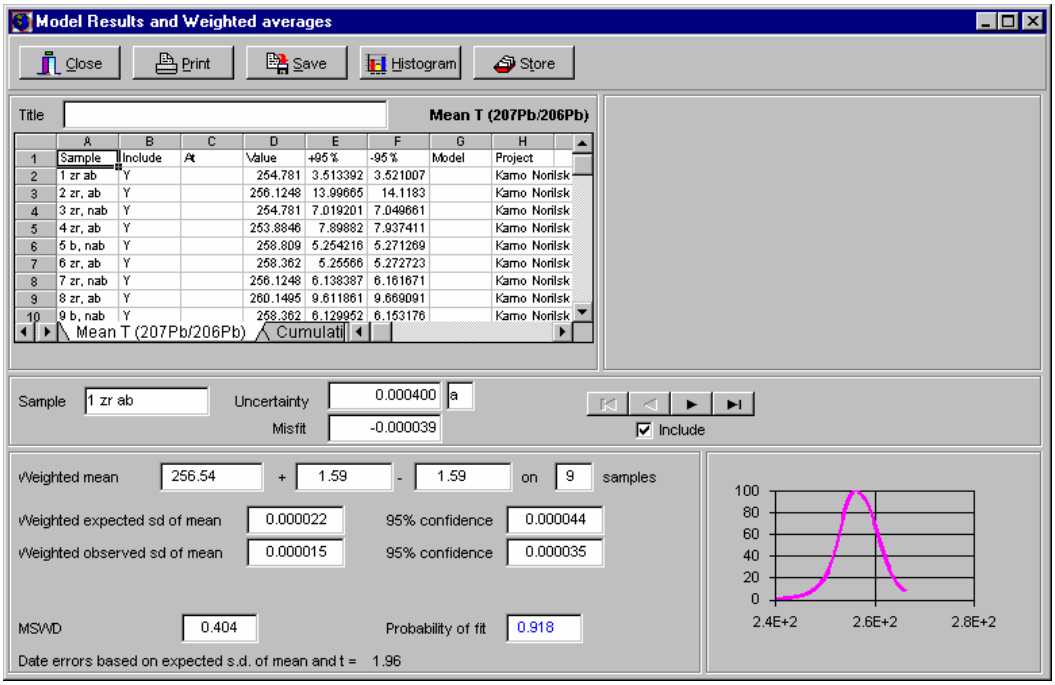



*Figure 11. Weighted average calculated for the model selected, in this case model $^{207}Pb/^{206}Pb$ for radiogenic U-Pb data. One may print the results, save individual records to spreadsheet or store the weighted average in a DateView database.*

Errors calculated for initial ratios or epsilon values (at a given age) are based on the error propagation formulation of Roddick (1987). A similar approach has been used to calculate the uncertainties for model dates when assuming some initial ratio.

In all cases, the pooled uncertainties for a number of "included" data points is calculated as the greater of the standard deviation of the values or the pooled standard error.Weighted averages for these parameters are calculated following the techniques of Claoue-Long (1989) and Eglington and Harmer (1993).

### *Concordia dates*

Concordia dates (Ludwig, 1998) may also be calculated for radiogenic U-Pb data. The results of these calculations are illustrated in Figure 12.

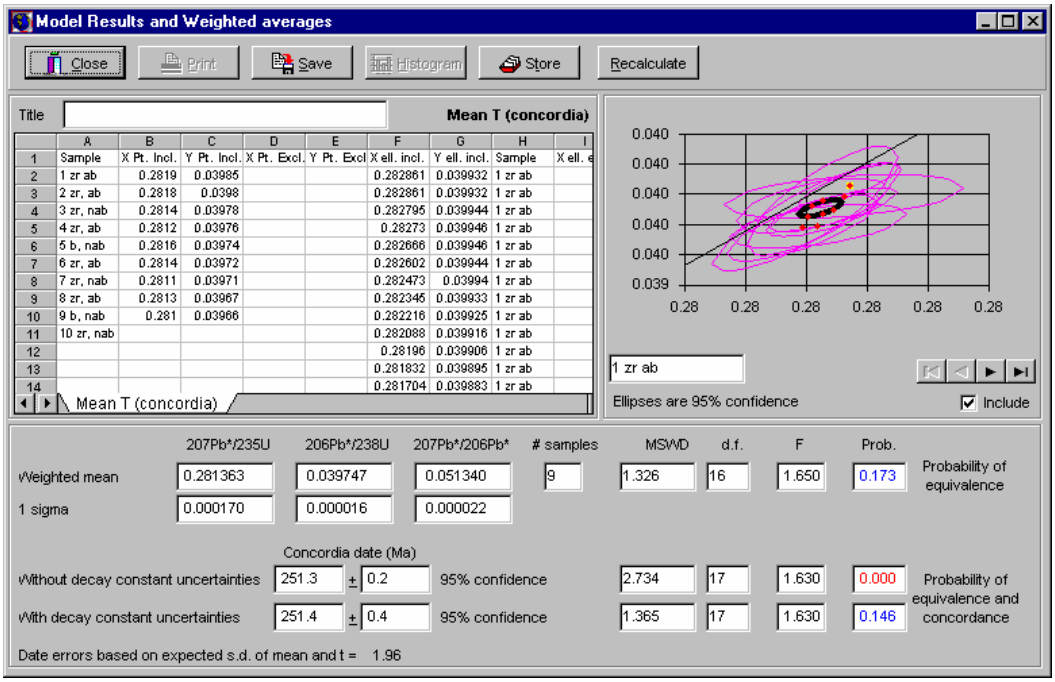



*Figure 12. Concordia date for the Noril'sk data of Kamo et al. (19??). These data are shown to be statistically equivalent (probability of equivalence = 0.172) but their weighted concordia date is not within error of the concordia curve if decay constant uncertainties are ignored.*

### *Screen graphics*

Graphical representations of the data are provided or may be created by the user after providing additional information e.g. for histogram plots. All graphs may be modified by right-clicking them and following the menu options provided. Default colours for the graphs may be changed in the GDW1.INI file.

### *Storing results in a DateView database*

Many of the geochronological results provided by GEODATE for Windows may be stored in a DateView database. In all such cases, the user is prompted to specify the area, stratigraphic unit, lithology, method, interpretation, equipment used and any additional comments before the data is added to this database.

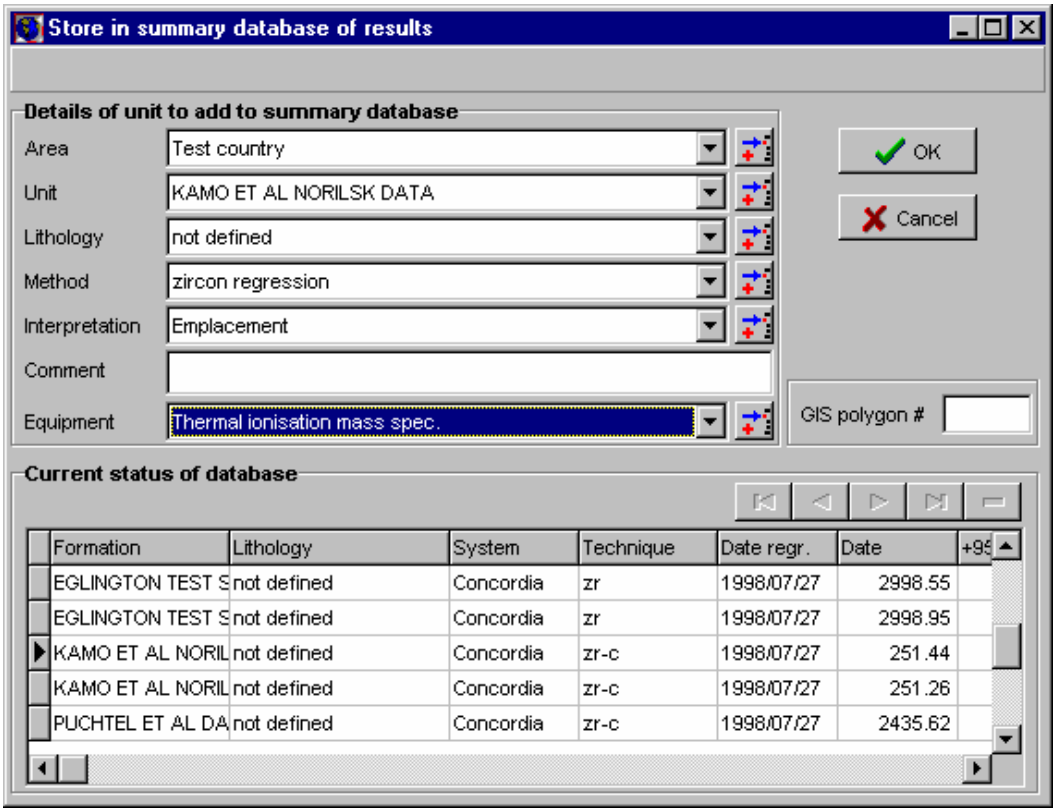



*Figure 13. DateView data storage window to transfer results from GEODATE for Windows to DateView.*

Most of the fields for which the user needs to supply information are lookup fields so as to avoid typing errors and the duplication of information. If the details are not already in the database, the user needs to add them to the database before completing the process and clicking the *OK* button in Figure 13. All appropriate fields for defining lookup values are accessed from one window, illustrated in Figure 14.

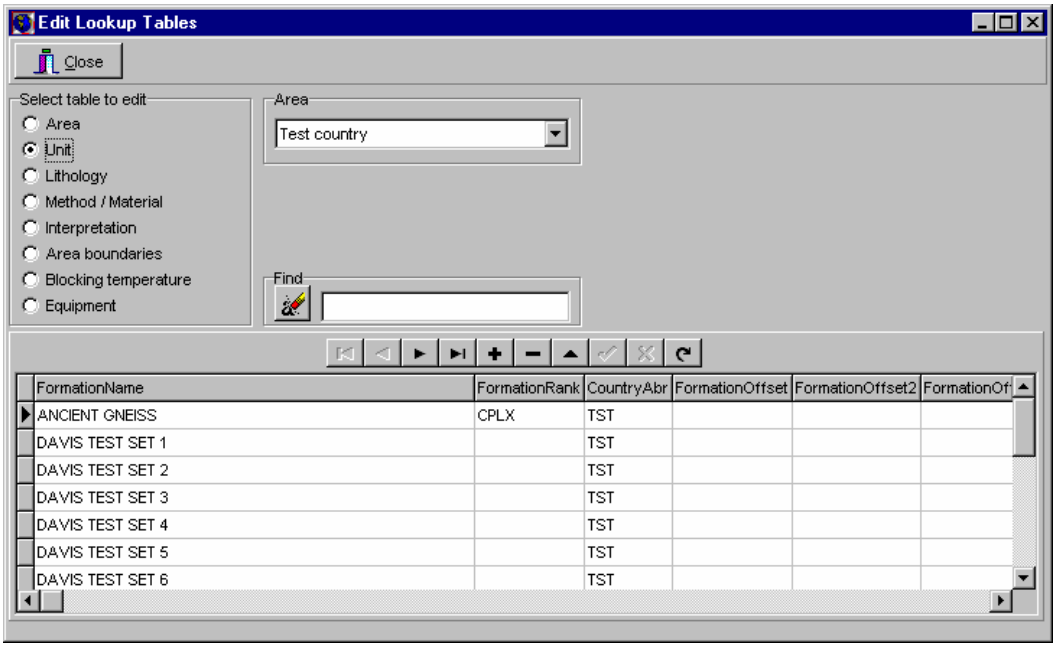



*Figure 14. Windows used to provide access for updating the lookup tables required for completion of data entry in Figure 13.*

## *Topics available via the Options Menu*

A number of default options may be set from this menu. These include:

### *Alpha level*

This sets the alpha level to be used for statistical tests, for instance alpha = 0.05 for a 5% level of significance which is normally taken as 95% confidence.

### *Concordia weight*

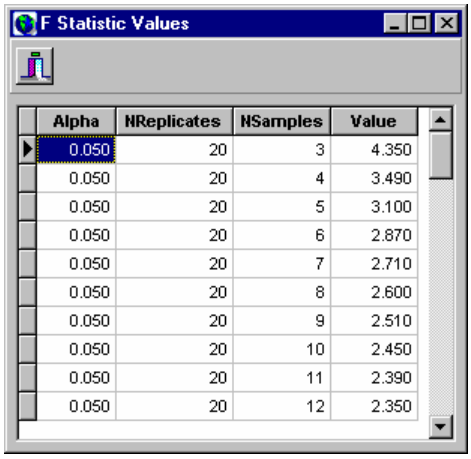
Here, one may specify the default concordia weighting option. It may be either Normal or Discordance.

*Ellipse magnification*

This option sets the magnification factor to be used for the graphing of data using ellipses. The user may select between 1 sigma or 95% confidence error ellipses.

*F table*

The F table provides the data for use in assessing whether scatter in regressions and weighted averages is within analytical uncertainty or not. One may have values in the table (illustrated in Figure 15) for various combinations of alpha level, number of replicates and number of samples. The specific alpha level to be applied is specified under the Alpha level sub-menu of the main Options Menu and is also read from the GDW1.INI file whilst the number of replicates defaults to 999 for new data and may be changed in the Edit Data window.




| Alpha | NReplicates | NSamples | Value |
|---|---|---|---|
| 0.050 | 20 | 3 | 4.350 |
| 0.050 | 20 | 4 | 3.490 |
| 0.050 | 20 | 5 | 3.100 |
| 0.050 | 20 | 6 | 2.870 |
| 0.050 | 20 | 7 | 2.710 |
| 0.050 | 20 | 8 | 2.600 |
| 0.050 | 20 | 9 | 2.510 |
| 0.050 | 20 | 10 | 2.450 |
| 0.050 | 20 | 11 | 2.390 |
| 0.050 | 20 | 12 | 2.350 |

*Figure 15. Dialog for specifying the F variate values for different combinations of alpha level, number or replicates and number of samples.*

*Pb models*

This specifies the default lead isotope evolution model to use. It may be one of either: Single stage, S+K 2 stage (Stacey and Kramers, 1975 two-stage model), or some other user defined model.

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