MonaziteAge©

Program for Calculating Monazite Ages

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1.0 - Introduction

Monazite age dating has become an invaluable tool in geology. Even though monazite is typically only an accessory mineral, it can be found in many rock types, making it possible to readily establish the ages for a variety of rocks. Monazite is a rare-earth phosphate, which can contain appreciable amounts of thorium. Because of the high thorium content, the mineral will typically contain enough lead, even in relatively young rocks, to be measurable using an electron microprobe.

The MonaziteAge program follows the dating procedure outlined by Suzuki and Adachi (1991, 1994), and Suzuki and others (1994). It can be used on both Th-rich phases and more U-rich phases, such as zircon or xenotime. It allows the user to calculate the age of a monazite grain from a single analytical point or from a set of analyses. When multiple analyses are used to determine a single age, the software will correct for non-radiogenic lead and for lead leaching that may have taken place. The program can also be used to create age maps from calibrated element maps of ThO_2, UO_2 and PbO, or from quantitative analysis data.

1.1 Method of Age Determination

The relationship between the weight percents of ThO_2, UO_2, and PbO in thorium-rich or U-rich minerals and the mineral's age can be defined by Equation (1) below [Suzuki and Adachi (1991, 1994) and Suzuki, and others (1994)]. It can be solved using an initial guess for the age, and then calculating the corresponding amount of PbO. A new, better age estimate is then made, and a new PbO value is determined. This iterative process continues until the estimated PbO value is within 0.001 weight percent of the measured value.

$$\frac{PbO}{W_{Pb}} = \frac{ThO_2}{W_{Th}} \left\{ \exp(\lambda_2\, t) - 1 \right\} + \frac{UO_2}{W_U} \left\{ \frac{\exp(\lambda_5\, t) + 138\ \exp(\lambda_8\, t)}{139} - 1 \right\} \quad (1)$$

(for monazite)

$$ThO_2{}^* = ThO_2 + \frac{UO_2\ W_{Th}}{W_U \left\{ \exp(\lambda_2\, t) - 1 \right\}} \left\{ \frac{\exp(\lambda_5\, t) + 138\ \exp(\lambda_8\, t)}{139} - 1 \right\} \quad (2)$$

$$PbO = m\, ThO_2{}^* + b \quad (3)$$

$$T_s = \frac{1}{\lambda_2} \ln(1 + m)\, \frac{W_{Th}}{W_{Pb}} \quad (4)$$

(for zircon & xenotime)

$$UO_2{}^* = UO_2 + \frac{139\, ThO_2\ W_U \left\{ \exp(\lambda_2\, t) - 1 \right\}}{W_{Th} \left\{ \exp(\lambda_5\, t) + 138 \exp(\lambda_8\, t) - 139 \right\}} \quad (5)$$

$$PbO = m\, UO_2{}^* + b \quad (6)$$

$$m\, \frac{W_{Th}}{W_{Pb}} = \frac{\exp(\lambda_5\, T_s) + 138 \exp(\lambda_8\, T_s)}{139} - 1 \quad (7)$$

Figure 1. Formulae for age calculations.

where:
⇒ *W* is the molecular weight of each oxide,

W_{Th} = 264
W_U = 270
W_{Pb} = 224 (for monazite)
= 222 (for zircon and xenotime)

⇒ λ is the decay constant of each isotope,

(232) $\lambda_2 = 4.9475 * 10^{-11}$ / year,
(235) $\lambda_5 = 9.8485 * 10^{-10}$ / year,
(238) $\lambda_8 = 1.55125 * 10^{-10}$ /year

⇒ *t* is the apparent age determined from each analysis.
⇒ ThO_2* is the equivalent amount of ThO_2 that would be required to produce the measured amount of PbO, if there was no UO_2 in the mineral.
⇒ UO_2* is the equivalent amount of UO_2 that would be required to produce the measured amount of PbO, if there was no ThO_2 in the mineral.
⇒ *Ts* is the age determined from the slope of PbO versus ThO_2* (or UO_2*).
⇒ m is the slope of the least square fit curve in Figure 2.
⇒ b is the intercept of the least square fit curve.

Figure 1. Continued

Using the above approach, an estimated age can be determined for each analysis. If many analyses are made, an average of the results can be used to estimate the average age for the rock. However, these calculations are based on a number of assumptions. First, it is assumed that the monazite grains contain no non-radiogenic lead. If the monazite formed with a measurable quantity of lead, then the age determined by the above described method will be older than is actually the case. Likewise, the method assumes that all of the lead that formed in the mineral grain stayed within the grain throughout its geologic history. Any leaching of the lead will produce younger ages than is actually the case. To account for the possibility that there may have been either a loss in PbO or some initial PbO, Suzuki and Adachi (1991, 1994) proposed an isochron method for determining the final age of the sample.

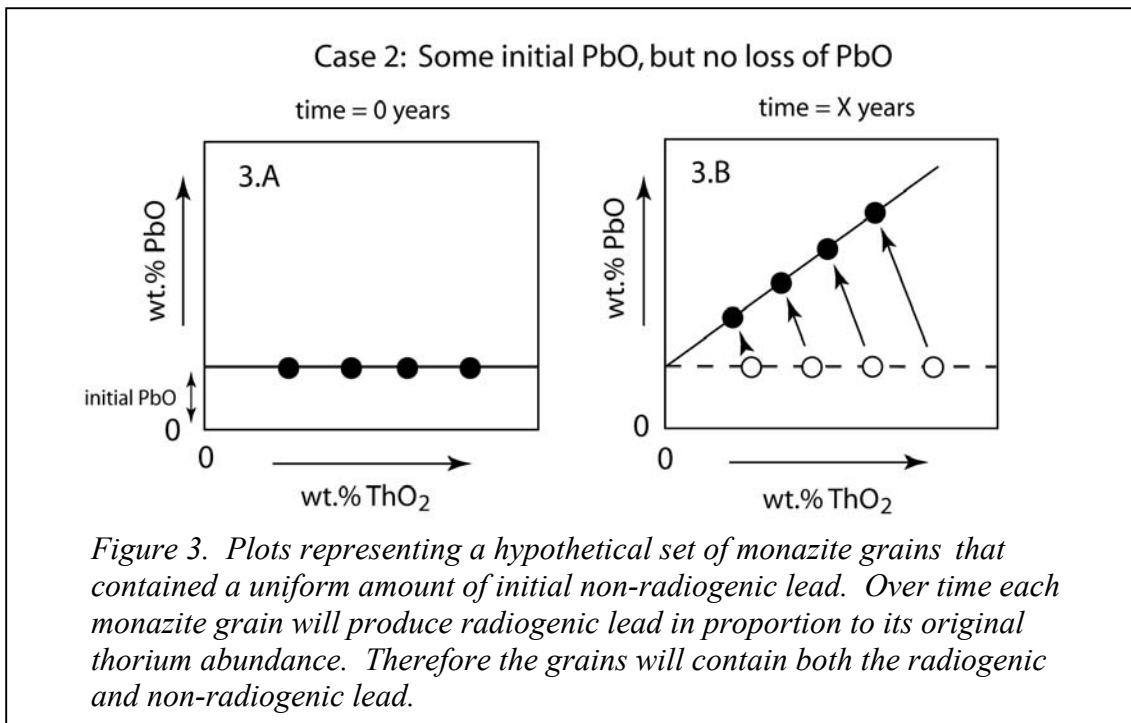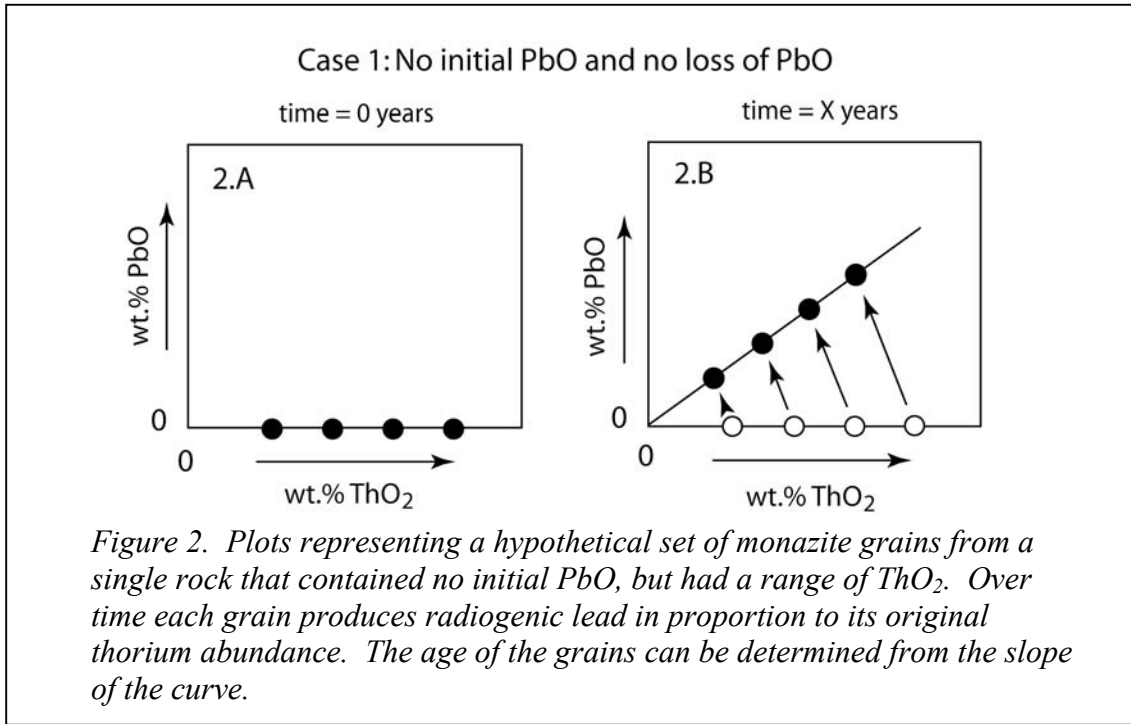If we look at a hypothetical case where the mineral grains contain,

a) no initial PbO,
b) only thorium as the radioactive element in the system, and
c) experienced no subsequent loss of lead,

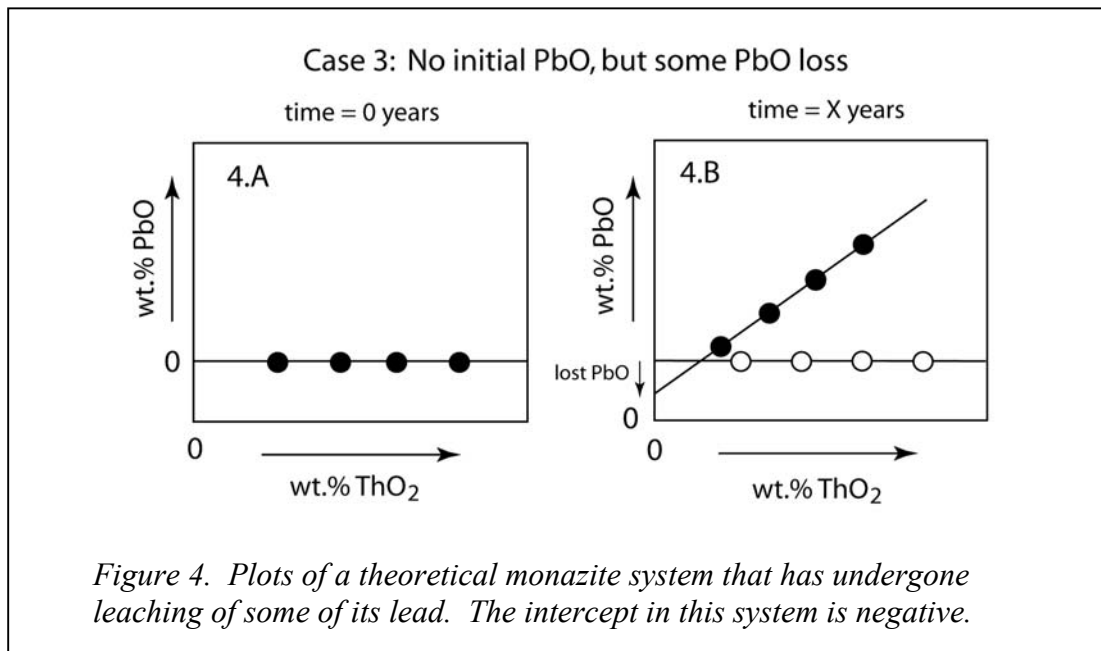the grains could be represented by the plots in Figure 2. At the time the grains formed, there would be no lead in the system, but the amount of thorium may have varied from one monazite grain to another. As such, the monazite grains would all plot along the X-axis, as illustrated in Figure 2A. Over time the PbO would increase in each grain due to the radioactive decay of the thorium. The amount of PbO accumulated would differ

depending on the amount of initial ThO$_2$, but the ratio of ThO$_2$ / PbO would be constant from grain to grain. Therefore all of the analyses should plot along a line, and the slope of the line would be a function of the age of the mineral grains (Fig. 2B).

Figure 2. Plots representing a hypothetical set of monazite grains from a single rock that contained no initial PbO, but had a range of ThO$_2$. Over time each grain produces radiogenic lead in proportion to its original thorium abundance. The age of the grains can be determined from the slope of the curve.

Figure 3. Plots representing a hypothetical set of monazite grains that contained a uniform amount of initial non-radiogenic lead. Over time each monazite grain will produce radiogenic lead in proportion to its original thorium abundance. Therefore the grains will contain both the radiogenic and non-radiogenic lead.

It is possible that the monazite grains originally contained some non-radiogenic lead (Fig. 3A). Over time, the radiogenic lead will be added to the non-radiogenic lead. Since these two lead isotopes are indistinguishable using an electron microprobe, calculated ages based solely on the total amount of thorium, uranium, and lead will result in an overestimate. However, the amount of non-radiogenic lead can be estimated from the plot in Figure 3B. The non-radiogenic lead is equal to the Y-intercept of the least square fit line to the compositional data, and the true age of the sample can be calculated from the slope.

A third possibility is that some of the lead was leached from the mineral grains. In this case, the age will be underestimated. Suzuki and Adachi (1991, 1994) and Suzuki and others (1994) discuss this possibility, and have made some estimates as to the leach rates that might be expected. If the monazite grains are all nearly uniform in size, then the plot in Figure 4 will reasonably represent the system. In this example, approximately equal amounts of PbO were leached from each grain, and therefore the intercept of the least square fit line becomes negative (Fig. 4B). However, the true age can again be determined from the slope. If the leach rate was not uniform, then a more complicated model would have to be applied to the system.

Figure 4. Plots of a theoretical monazite system that has undergone leaching of some of its lead. The intercept in this system is negative.

To simplify the calculations, the less abundant radioactive element is eliminated by calculating the equivalent amount of the primary radioactive element that would be required to produce the measured lead content. For monazite, one calculates the amount of ThO_2 that would be required to produce the measured amount of PbO if there was no UO_2 present in the mineral grain. This can be carried out using Equation (2) in Figure 1. However, in order to complete this calculation, the age of the mineral must be known.

Therefore these calculations require an iterative process, and the following procedure is used (for monazite):

1) Use Equation (1) to calculate an age from each analysis point.
2) Calculate ThO_2* (the equivalent required ThO_2, if there had been no UO_2 present, to produce the measured PbO) for each analysis using Equation (2) and the original estimated age.
3) Determine a least square fit to the data PbO versus ThO_2*.
4) Use the slope of this line and Equation (3) to determine a new age for the system.
5) Use this new age to recalculate the ThO_2* content for each analysis.
6) Repeat steps 3-5 until the calculated age converges.

A similar process is used for minerals with a higher uranium than thorium content; then Equations 5, 6 and 7 are used.

2.0 - Individual Ages

The program MonaziteAge makes it easy for users to process their analytical data and to extract ages from them. The compositional data can be entered into the program in one of three ways. The user can enter the data manually, one point at a time, if there are only a few analytical points to run. However in most cases, the user will want to input data from a file. The MonaziteAge program is capable of reading both JEOL Quantitative Analysis files and plain text files. Once the data have been input, the program will calculate an age for each individual point. Then the user has the option of calculating an age from the entire data set using the slope isochron method described above. The results from each operation are output to the main window **Monazite Age Dating** (Fig. 5). The results can then be edited, printed or stored.
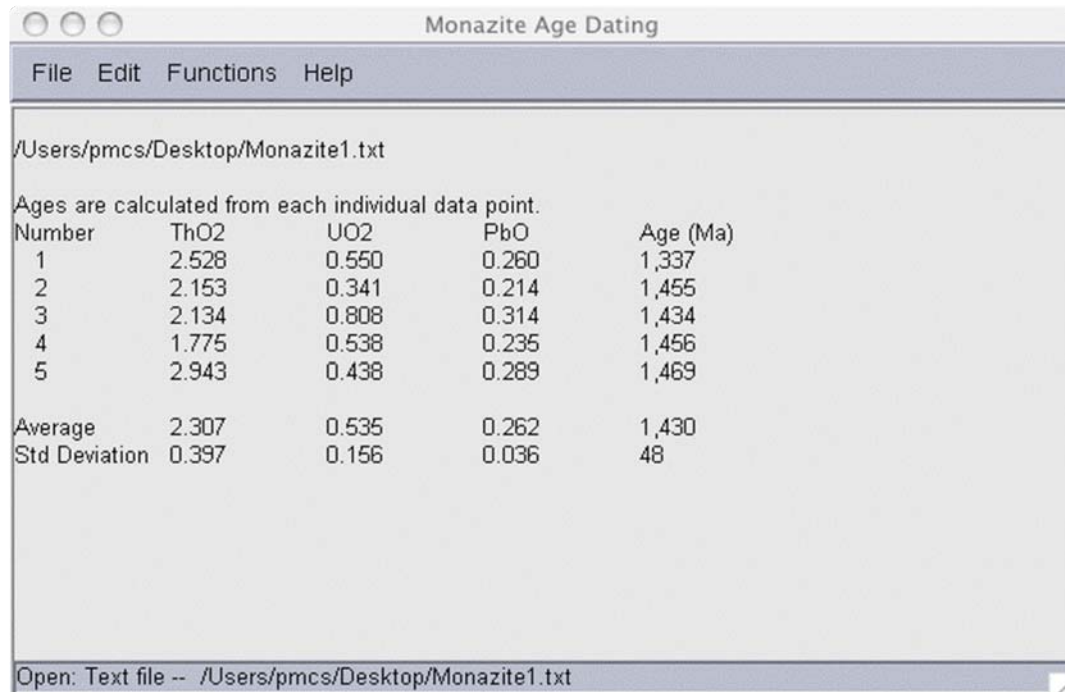

*Figure 5. MonaziteAge main window showing the results
from a group of analyses from one file.*

2.1 Entering Data Manually

Data can be entered into the program one data point at a time. By going to the menu item **Functions >> SinglePt**, the window shown in Figure 6 will open and the user can enter the weight percent ThO_2, UO_2, and PbO from the analyses. When the **Calc Age** button is used, the calculated age is displayed both in the **Single Point Analysis** window and in the main **Monazite Age Dating** window.

Using the Tab key allows the user to jump between fields. When the cursor is in one of the fields, hitting the return or enter key will select the entire content of that field. This helps in speeding up the data entry. When data entry is complete, the **Close** button will remove the window. The contents of the main **Monazite Age Dating** window can be saved, printed or edited.
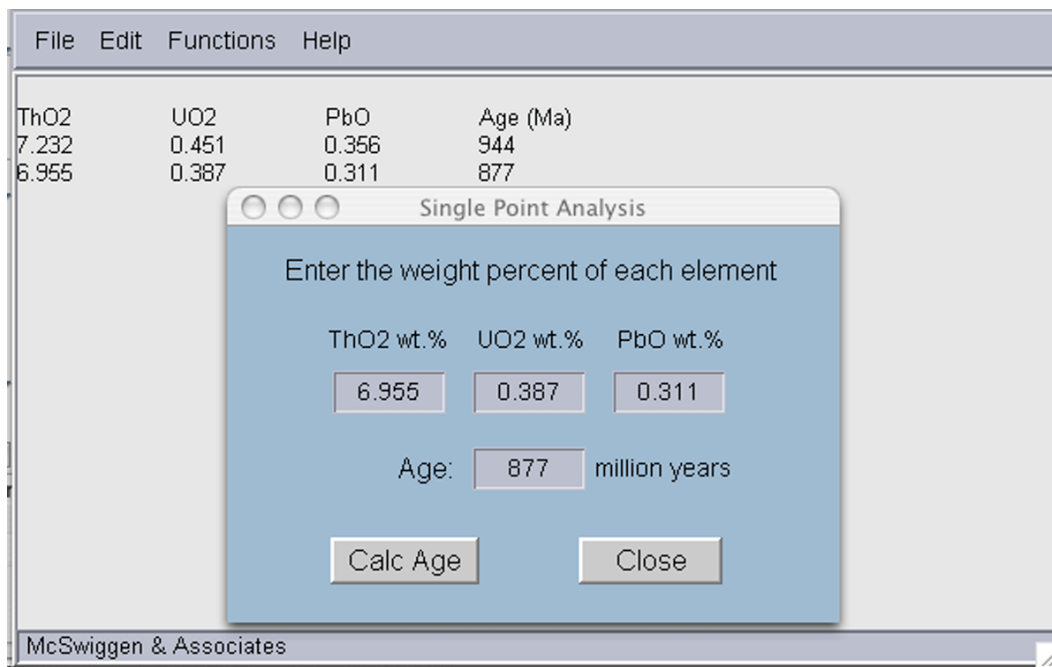
*Figure 6. The **Single Point Analysis** window allows the user to enter the weight percent ThO_2, UO_2, and PbO from an analysis one point at a time.*

2.2   Entering Data from a Text File

When large sets of data need to be processed, it is clearly more efficient to load them from a preexisting file. By going to the menu item **File >> Open >> Text Qnt**, a file dialog box will open allowing the user to select the desired file. Once the file has been selected, the contents of the text file will be loaded into the window shown in Figure 7. This window allows the user to inspect the content of the file and to specify which data elements to use. The data must be in the form of columns of weight percent ThO_2, UO_2, and PbO. Other columns of data can also be present, and there are no limitations on the number of header lines present in the file. However, there cannot be any additional lines of text below the data at the end of the file.

Using the window shown in Figure 7, the user must specify the number of header lines that need to be skipped and the column number of each oxide to be read. Clicking on the **Read** button imports the data into the program and automatically calculates an age for each data point. The results are output to the main **Monazite Age Dating** window.
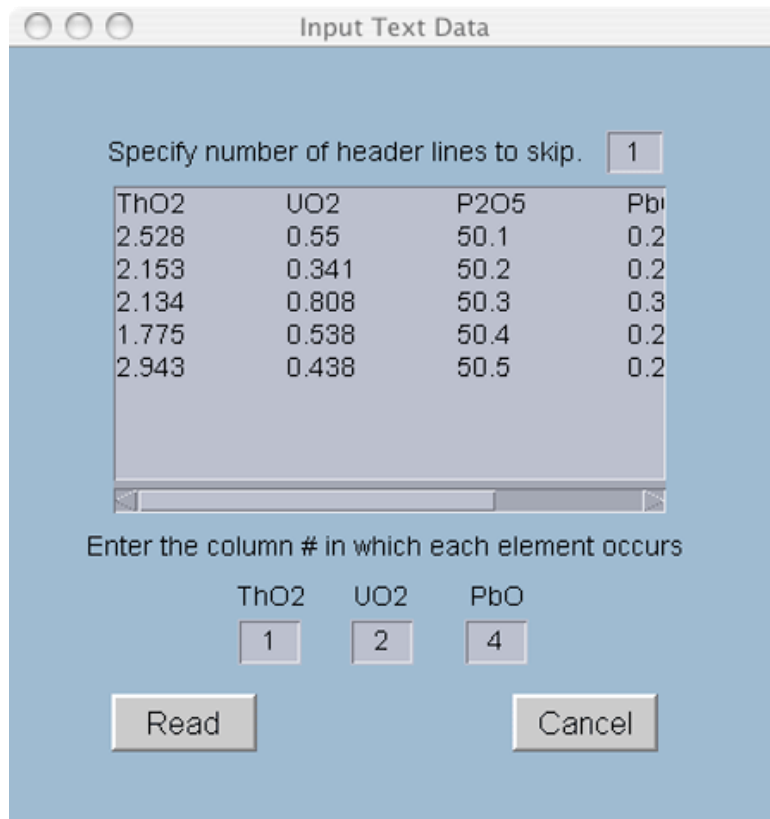

*Figure 7. The **Input Text Data** window allows the user to specify the number of header lines to skip and the column in which each oxide occurs. In this example, the PbO data is in column 4, and the P_2O_5 data in column 3 have been skipped.*

2.3   Entering Data from JEOL Quantitative Analysis Files

JEOL Quantitative Analysis files can be read directly into the MonaziteAge program through the menu item **File >> Open >> JEOL Qnt.** The **Import JEOL Data** window (Fig. 8) allows the user to select the JEOL Group and Sample in which the data are stored. When the window is first opened, it will display only those Groups that contain quantitative analyses of ThO_2, UO_2, and PbO. Once a Group has been selected, the Samples within that Group that contain analyses of these oxides will be displayed. The option to display only Groups and Samples containing analyses of ThO_2, UO_2 and PbO can be turned off by going to **Menu >> Options**.

The Apply button will open the **Select Stage Positions** window (Fig. 9) allowing the user to select the stage positions of interest. Individual stage positions can be selected
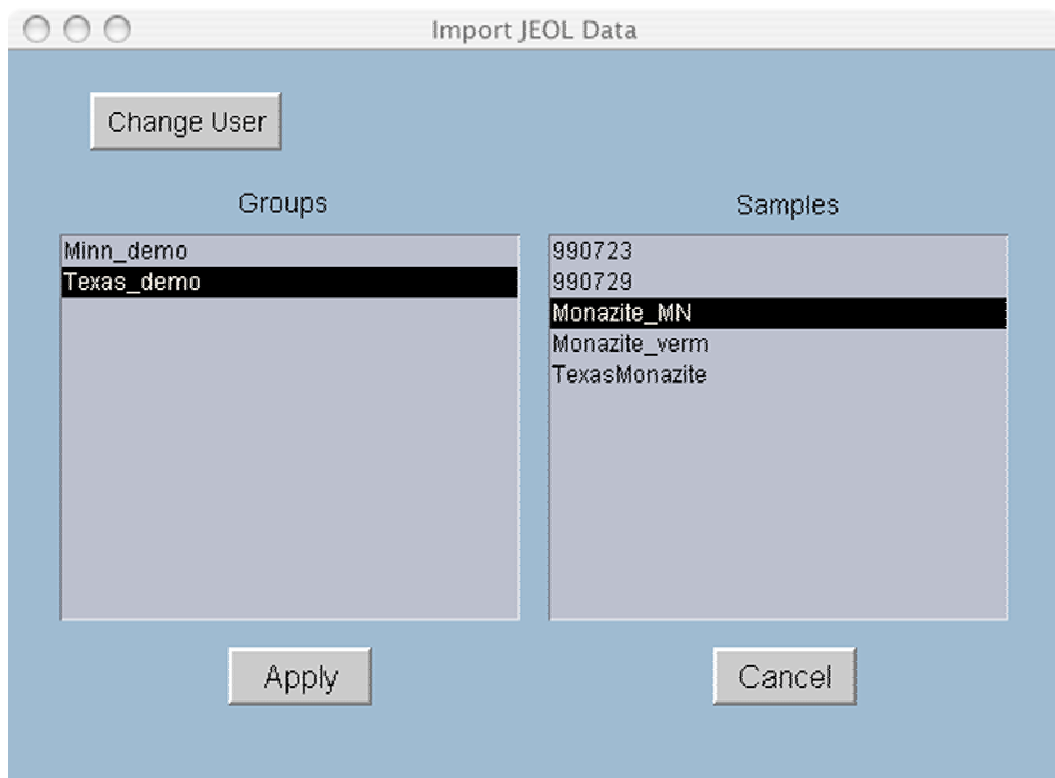

*Figure 8. **Import JEOL Data** window allows the user to select
the JEOL Group and Sample containing the quantitative data of interest.*

or unselected using mouse clicks. Multiple stage positions can be selected or unselected using <control> <shift>, or by using the **Select All**, **Select**, **Clear All** and **Unselect** buttons.

*Figure 9. **Select Stage Positions** window allows the user to choose which analyses are to be processed.*
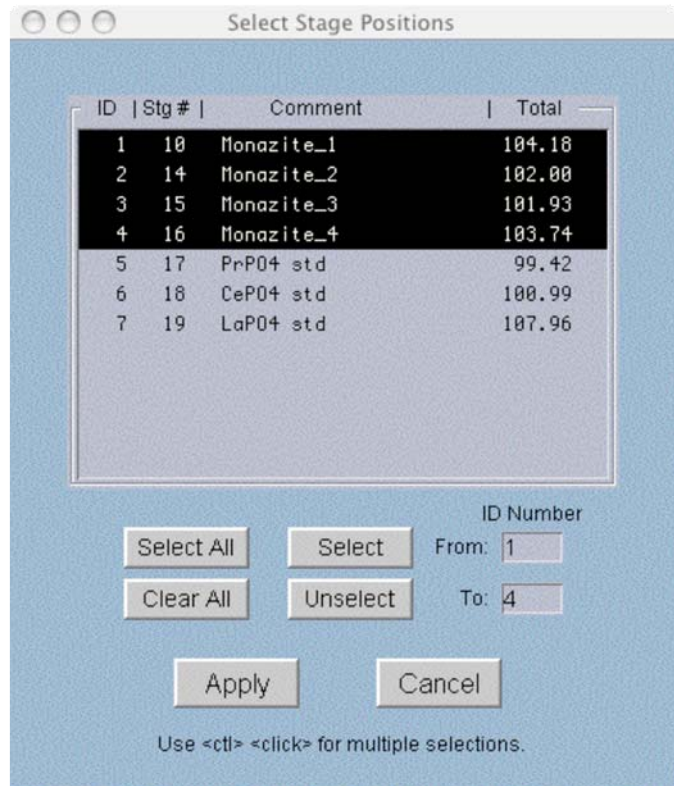
The user directory can also be changed from the window shown in Figure 8 (**Change User** button). The resulting **Select New User Directory** window (Fig. 10) allows the user to navigate through the file system and switch into a different user directory.

The user can move up through the file structure using the up arrow button or by using the pull down menu. Moving down deeper into the file structure can be achieved by selecting a directory and then by using the down arrow or the **Open** button.

Once the new user directory has been located, it needs to be selected using the **Select** button.

*Figure 10. **Select New User Directory** window allows the user to change to a different user directory.*

2.4 Using an Isochron Slope to Determine the Age

Once the data have been imported into the program from a file, an age can be determined from the slope of the data as described above. By selecting the menu item **Functions** >> **Slope Method**, the data are plotted; a least square fit curve is calculated, and from this the age is determined. The resulting plot looks like that shown in Figure 11.
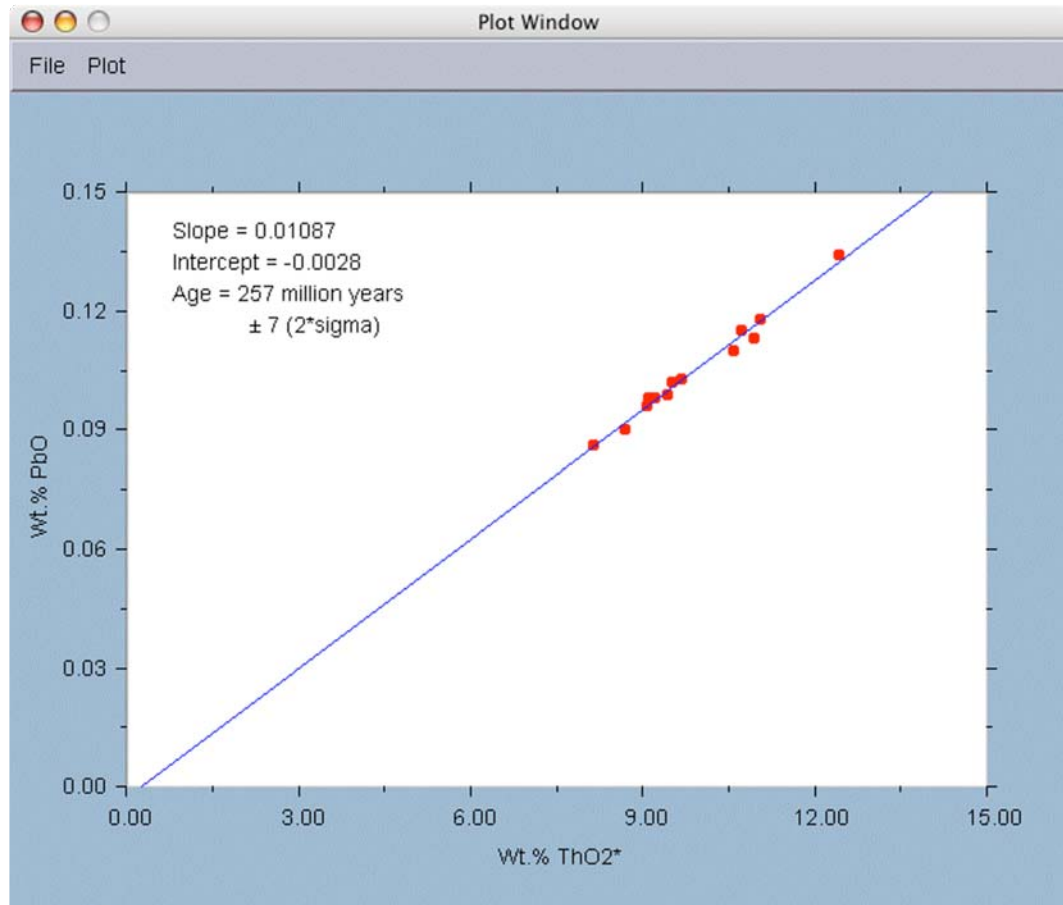

Figure 11. A plot of the data obtained from **Functions >> Slope Method.**
(Data from Suzuki and Adachi, 1994)

The slope and intercept of the least square fit line is displayed in the upper corner of the plot along with the age and the error of the age determination. The error was calculated from the spread of the individual age calculations. It does not include any of the analytical errors.

In the example above (Fig. 11), the data clearly define a linear relationship indicating that the individual analytical points are from material with a single age, even though they exhibit a range in ThO_2* contents. The negative intercept in this case is significant and suggests that there was a uniform amount of PbO leached from the monazite. This is in contrast with the data displayed in Figure 12.
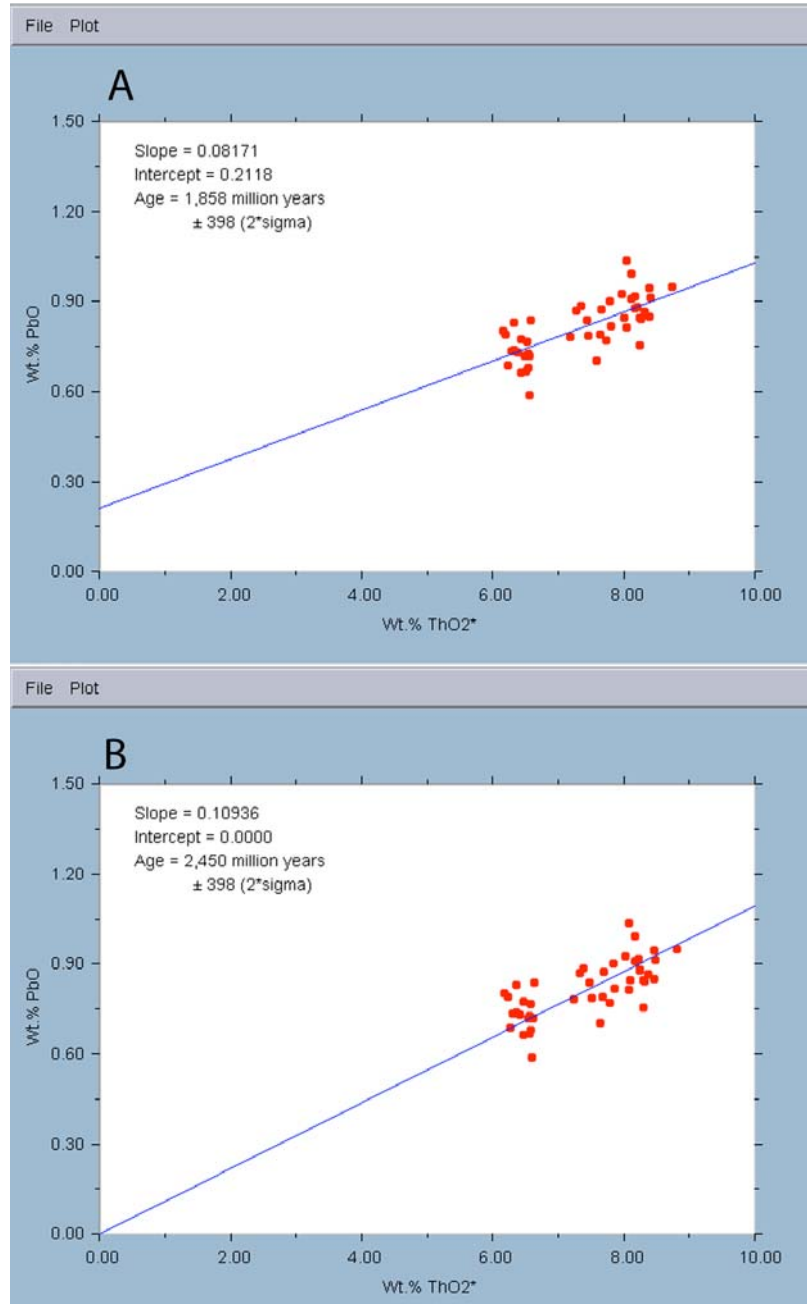

Figure 12. Plots of monazite analyses from a single sample showing a wide scatter in the data. The intercept in plot A was determined by a least square fit of the data. In plot B, the intercept was fixed at the origin. As a result, very different ages are calculated.

Figure 12 shows a set of monazite analyses from a granitic terrain containing rocks dated between 2.5 and 2.7 billion years old. The plots show significant scatter in the data. A simple least square fit line to the data produces an intercept of 0.21 weight percent PbO, suggesting significant non-radiogenic lead in these samples. However the larger scatter in the data and the small range in the ThO2* content indicate that the least square fit line is not well anchored. As a result, there is a significant error in the calculated slope of this line and the age calculated from it. For data sets of the type shown in this example, where there is significant scatter, it is better to assume that all of the lead is radiogenic and that there has been no loss of lead from the monazite grain. In which case, the intercept should go through the plot's origin. For just such data sets, the MonaziteAge program allows the user to fix the intercept at the plot's origin. This can be done using the menu item **Plot >> Modify**.

2.5 Modifying, Saving and Printing Isochron Plots

Isochron plots can be modified by selecting the menu item **Plot >> Modify**. This will open the **Modify Plot** window, which allows the user to change the minimum and maximum values displayed on the axes of the plot, the number of divisions to be used on each axis, and the colors used for the least square fit line and data points. It also allows the user to add a title to the plot and to control whether the least square fit line will be forced to intersect the y-axis at the origin.
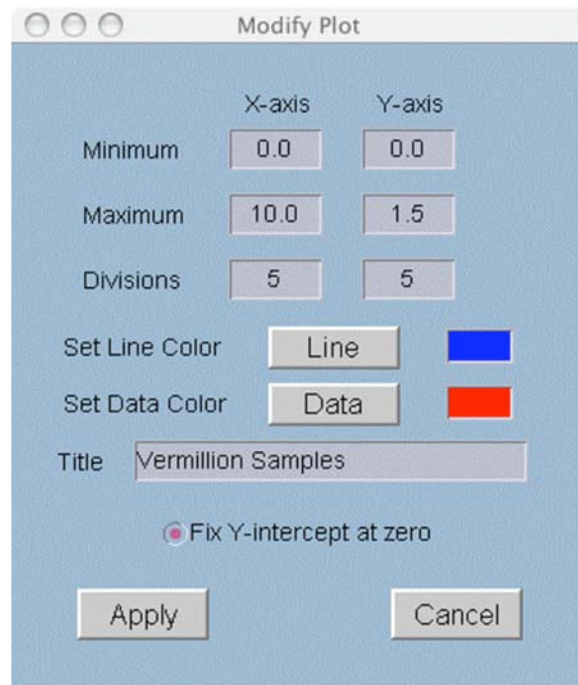

*Figure 13. **Modify Plot** window.*

To change the colors of the displayed line or data points, click on their respective buttons. This will open the dialog box shown in Figure 14, allowing the user to select a new color.
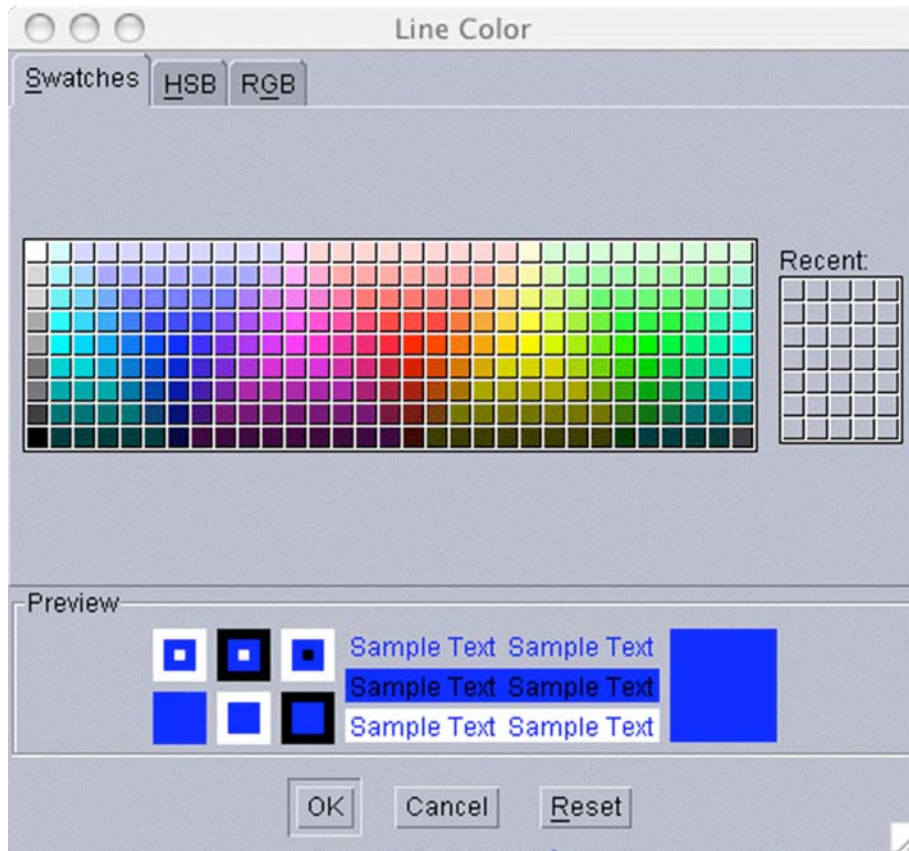

Figure 14. Dialog box for changing the colors used to display the least square fit line and analytical data points.

After the plot has been satisfactorily modified, it can be printed or saved. There are three file format options for saving the plots — encapsulated postscript (.eps), JPEG (.jpg), and PNG (.png). Both the JPEG and PNG formats are pixel formats; encapsulated postscript is a vector format. Plots stored as encapsulated postscript can be more easily modified than the others, since each item is stored as a separate element. Fonts, line widths, scale, and labeling can all be modified in other programs that handle postscript.

2.6   Editing, Saving and Printing Text Data

      Most of the results from these age calculations are automatically output to the main text window shown in Figure 5. This output can be edited using the normal editing functions listed in the **Edit** menu. The calculated ThO_2* or UO_2* values are not automatically output to the text window, but can be displayed using the **Plot >> Output Text** menu item. This command will output the measured concentrations (ThO_2, UO_2, PbO) and the calculated values (age, plus ThO_2* or UO_2*) for the data set currently being worked on.

      The contents of the main text window can be either saved as a text file using the **File >> Save** or **File >> Save As…** commands, or it can be sent to the printer using the **File >> Print** command.

3.0 - Age Mapping

It is not uncommon for monazite minerals to be fairly heterogeneous. This leads to the question of whether the mineral grains formed during a single event, or whether the grains had a history of mineral growth at different episodes over time. Age dating using an electron microprobe makes it possible to unravel these possibilities. Age mapping of a single monazite grain will help to ensure that multi-age grains are not misinterpreted as having an averaged, single age.

The MonaziteAge program can use two types of data to produce an age map. Either semi-quantitative element maps or a grid of quantitative analyses can be converted into an age map.

3.1 Using Semi-Quantitative Map Data

An age map can be made from a set of JEOL element maps of ThO_2, UO_2 and PbO. However in order to make an age map from these element maps, it is required that the ThO_2, UO_2 and PbO maps be already calibrated.

JEOL element maps are calibrated through the **Calibration Factor** window (Process >> Map Analysis >> Operation >> Calibration Factor) in the JEOL EPMA software. Either standard or quantitative analyses can be used for calibration purposes. For the best results, after the maps have been collected, it is recommended that the two areas of the grain with the largest compositional difference be analyzed quantitatively. These two analyses can then be used to convert the X-ray intensity maps into maps that display the weight percent of each element.

The JEOL EPMA software also allows the user to collect data for a single element on multiple spectrometers. For example, a user may use two spectrometers to map for Pb as a way to get a better signal to noise ratio. Once the two maps have been collected, the user can process the data using the JEOL Map Analysis program. First one needs to calibrate the maps, using the **Calibration Factor** window. Second, the user needs to add the maps together, using the **Map Add** function (… Operation >> Map Calculation >> Map Math >> Map Add). Third, the average values must be determined by using the **Div** function (… Map Math >> Div) to divide each value by 2. Finally, the user must store the resulting combined map, using the **Result Store** function (… Map Calculation >> Results Store). The **MonaziteAge** program can handle either measured or the calculated element maps.

In order to create an age map in **MonaziteAge**, the desired element maps must be selected. By selecting the menu item **File >> Open >> JEOL Map**, the **Import JEOL Map Data** window will open (similar to that shown in Fig. 8), allowing the user to select the JEOL Group and Sample of interest. The Groups and Samples that are displayed will either be all of the Group/Samples that contain map data, or only those Group/Samples that contain ThO_2, UO_2, and PbO maps. This option can be set by the user by going to the menu item **Help >> Options.**
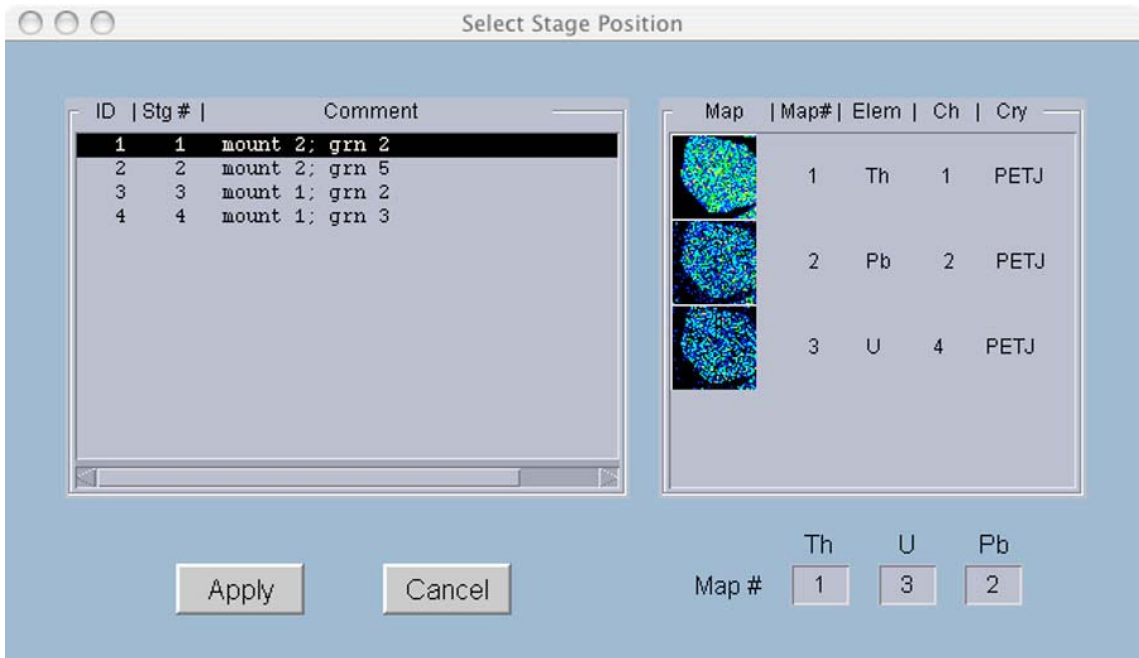
*Figure 15. **Select Stage Position** window. This window allows the user to select the stage position of the maps to be used to create an age map.*

After the Group and Sample has been selected, the **Select Stage Position** window (Fig. 15) will open. This window displays all of the stage positions in that Sample that contain ThO_2, UO_2 and PbO maps. Once a stage position has been selected, all of the individual maps that were collected at that position will be displayed in the panel at right. The software will display (in the lower right corner of the window) the default ThO_2, UO_2 and PbO maps that it identified in the directory. If there is more than a single map in this directory for any of the three elements, and the user wants to use one of the alternative maps, the map number can be entered in the appropriate box.

Once the desired stage position has been selected, the three element maps will be read in and an age will be calculated for each pixel. The resulting age map will be displayed in the **Age Map** window shown in Figure 16.
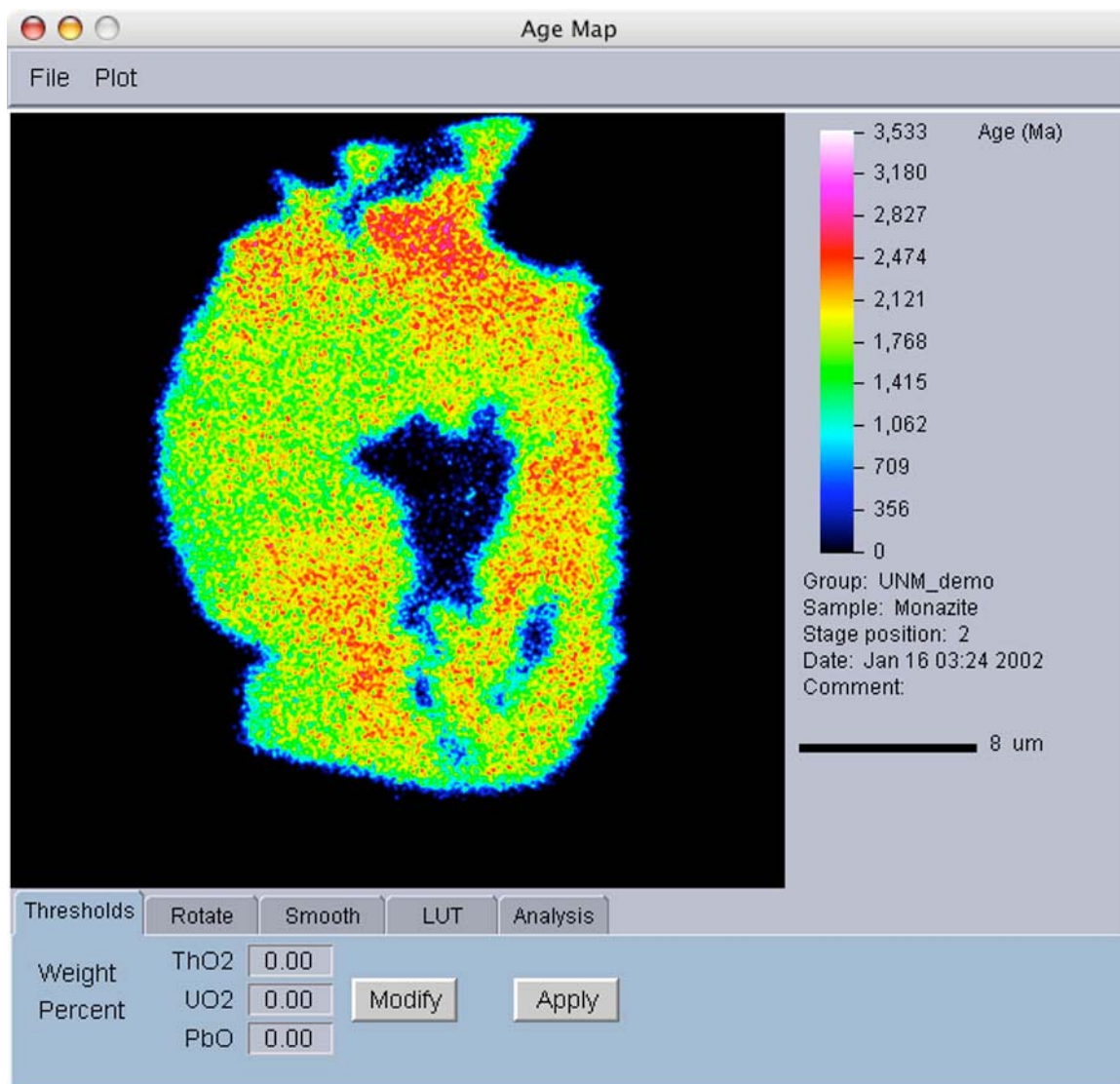
*Figure 16. **Age Map** window.*

The **Age Map** window has three panels. The left panel contains the age map itself. The right panel contains the scale bars and information about the map, and the bottom panel is a tabbed-panel for processing the image. A detailed discussion of the image processing functions follows in Section 3.3.

3.2 Quantitative Age Mapping

An alternative way to make an age map is to use quantitative analysis data that were collected in a grid. This type of data has an advantage over element maps in that it has been background-subtracted and matrix-corrected; thus the compositional values may be more accurate than those generated from element maps. However, quantitative data sets take longer to collect, and the JEOL Quantitative Analysis program limits the number of analyses to 10,000 points per sample.

To create a quantitative age map, the desired Group and Sample are opened using the **Open >> Qnt to Map** menu item. Once the Group and Sample have been selected, the **Select Stage Positions** window (Fig. 17) will open. The user can now select which stage positions are to be used to create the map. Only stage positions from a single grid can be used in the map. The stage positions must have been generated using the
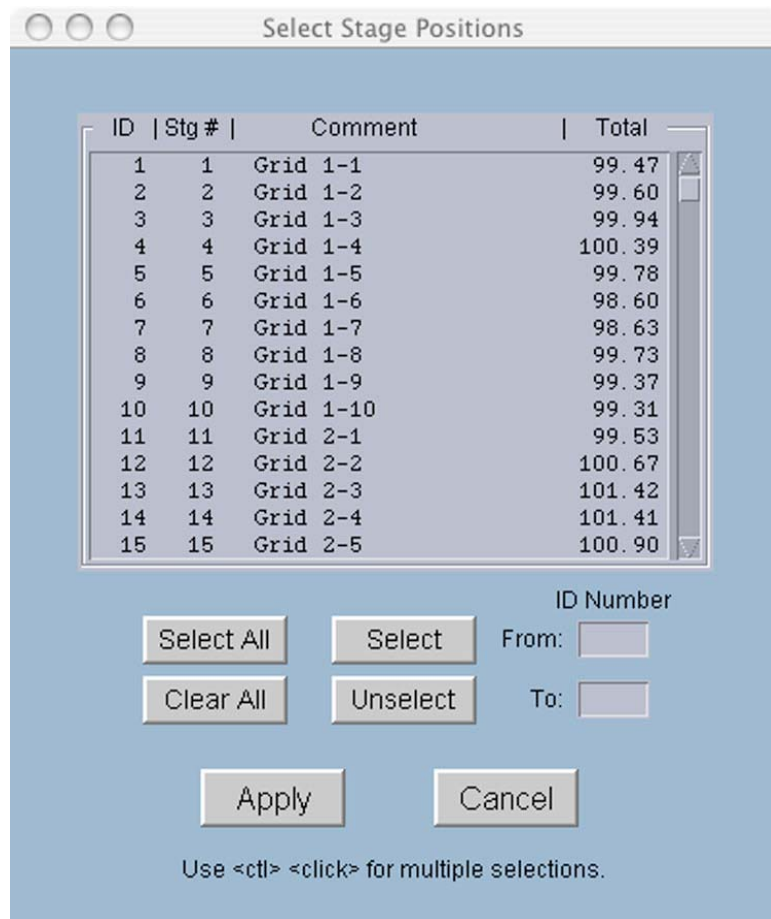

Figure 17. **Select Stage Positions** *window.*

Line Set command in the **Stage Conditions** window from the JEOL Quantitative Analysis program. If points from more than a single grid are selected, the program will give the user an error message.

The stage positions can be selected either individually by clicking in the list, or a range can be selected by typing in the beginning and ending values, and then by clicking on the **Select** button. All of the stage positions in the Sample can be selected by clicking on the **Select All** button. Positions can be unselected in a similar manner using the **Clear All** and **Unselect** buttons.

Once the stage positions have been selected and the **Apply** button clicked on, the program will read all of the quantitative data and calculate an age for each point. The results are then displayed in the **Age Map** window, such as shown in Figure 18. These maps will inevitably appear very pixilated since they will have relatively few data points.
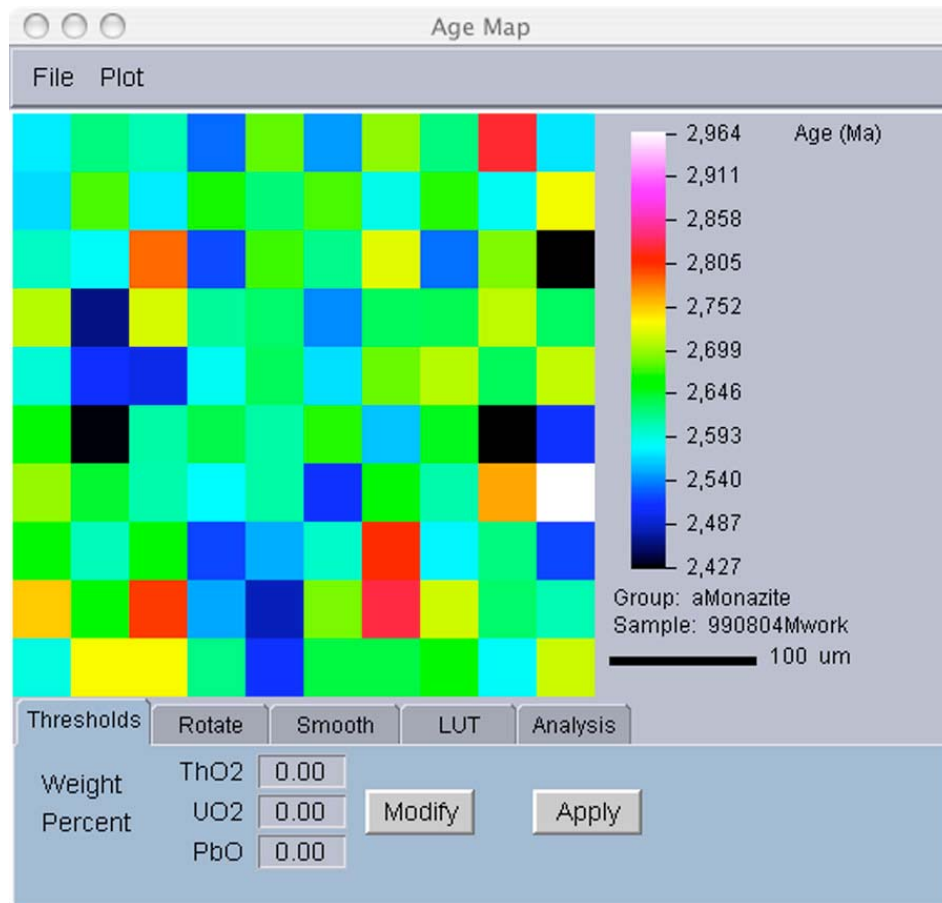

*Figure 18. **Age Map** window shows a map determined*
from a 10x10 grid of quantitative analyses points.

3.3   Image Processing

There are a number of ways that the images can be processed to better display the age data. These are outlined below.

3.3.1   Thresholds

The age of a monazite is calculated from the ratios of ThO_2, UO_2, and PbO. Because ratios are being used, it is very possible to calculate an age from background noise that looks identical to an age calculated from legitimate analyses. Therefore when working with maps which may extend beyond the monazite grain, where the measured values may be just background noise, it is imperative to have a way to eliminate ages calculated from those points. The **MonaziteAge** program offers the user a method to set a threshold for each element. If a pixel has less than the threshold value for that element, the age is set to zero. The threshold value of each element can be set in two ways. First, the value can be typed into the appropriate box in the **Thresholds** panel (Fig. 19). However, typically it is difficult to know what a reasonable threshold should be without
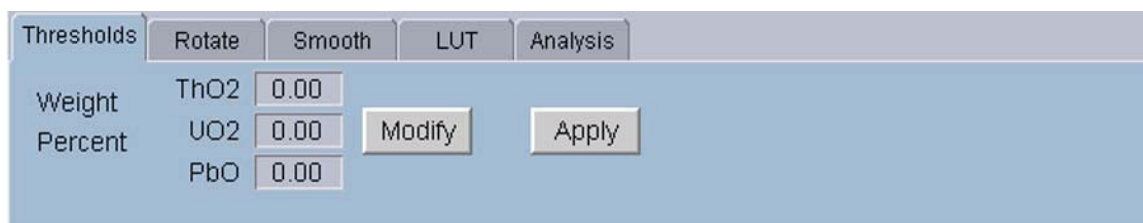

Figure 19.   Thresholds panel.

actually seeing the range of compositions for that element. Therefore the user has a second option. Clicking on the **Modify** button will display a histogram of the compositional data for that map (Fig. 20). When the window first opens it will display the ThO_2 data. This can be switched to one of the other elements by clicking on the appropriate buttons at the top of the window.

The up and down arrows on the left side of the histogram allow the user to change the intensity-scale of the plot. The sliders below the histogram allow the user to set the upper and lower limits. The lower limit will define the threshold when the **Set** button is clicked. Both the upper and lower limits are used if the **Zoom** button is clicked. In that case, the upper and lower limits will define the new range of the histogram to be displayed. Once the thresholds have been set, the window can be closed using the **Close** button.
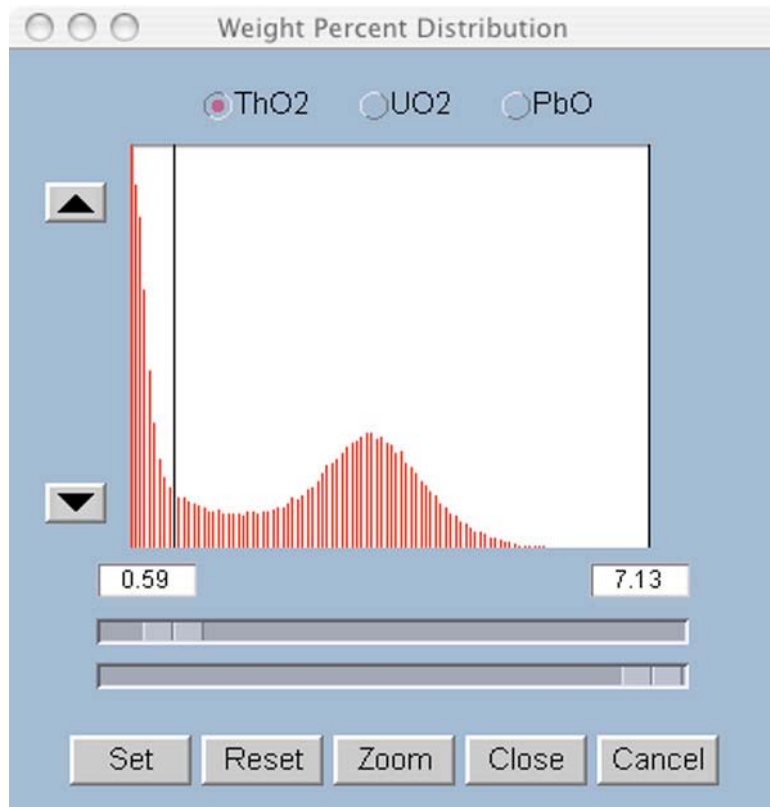
*Figure 20. **Weight Percent Distribution** window showing a
histogram of the ThO$_2$ compositions for the map. The user
can use the lower limit slider to set the threshold for that element.*

Even though one can set a threshold for each element, typically it is not necessary.
Once a threshold has been set for the major radioactive element, this is usually enough to
eliminate pixels that are due to the background noise.
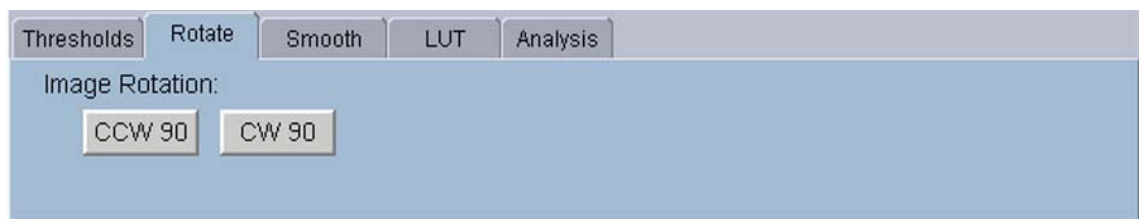
3.3.2 Rotate

*Figure 21. **Rotate** panel.*

The **Rotate** panel allows the user to rotate the image in either a clockwise or counterclockwise direction (Fig. 21). Each time the **CCW 90** or **CW 90** buttons are selected, the image will rotate 90° in one of the two directions.

3.3.3 Smooth

The user can apply a Gaussian smooth function to the image from the **Smooth** panel (Fig. 22). There are three filter sizes — three, five and seven, that can be used. Each time one of the buttons is clicked the image is processed with that Gaussian filter. The image data are NOT set back to the original values before the image is processed again. To reset the image back to its original values, use the menu item **Plot >> Reset**.
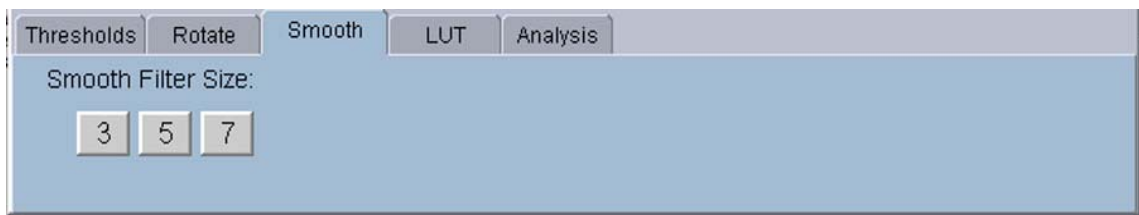

*Figure 22. **Smooth** panel.*

3.3.4 Look-Up-Table (LUT)

The images can be displayed in one of three color schemes using one of three look-up-tables (LUT). The choices are the default JEOL rainbow colors, the "Thermal" LUT (colors ranging from black to red to white), or a grayscale. The color scheme can be chosen by going to the **LUT** panel (Fig. 23) and clicking on the button associated with the LUT of interest.
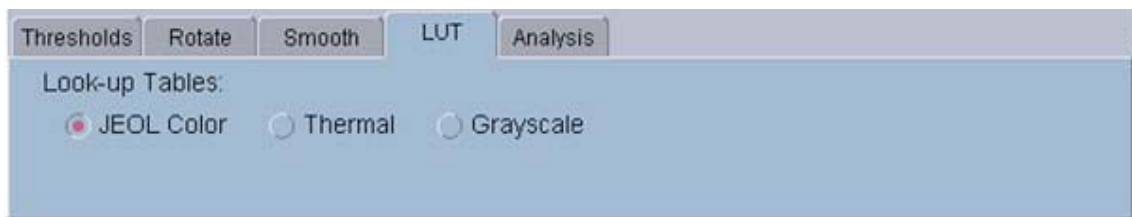

*Figure 23. **Look-Up-Table (LUT)** panel.*

3.3.5 Analysis

The **Analysis** panel allows the user to determine the specific age of a point, or an average age of a region on the map (Fig. 24). If the user selects the **1pt** option, clicks on a pixel on the map, and then clicks the **Apply** button, the age associated with that pixel will be displayed on the map. If the user had selected the **9pt** option, the average of a 3x3 array of pixels around that point would be displayed. If the user selects the **Area** option, he can click and drag over a specific rectangular shaped area on the map; when applied, the software will calculate the average of the entire selected area.

The **Clear** button will remove all of the analyzed points on the map. Likewise, any displayed analysis point will be removed, if the map is subsequently smoothed, rotated, or has its thresholds changed.
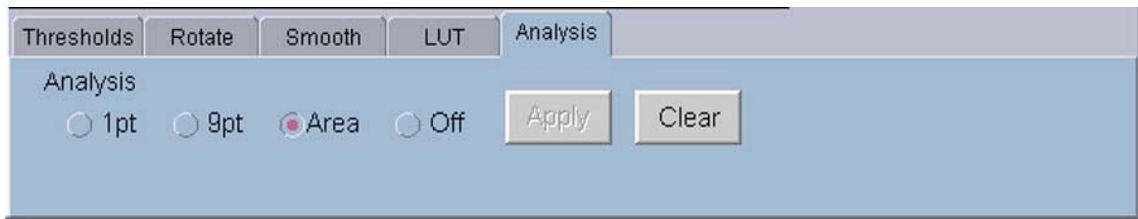

*Figure 24. **Analysis** panel.*

3.3.6 Brightness and Contrast

The brightness and contrast of the age map can be changed through the menu item **Plot >> Brightness / Contrast**. This will open the histogram shown in Figure 25. The user can adjust the brightness and contrast by sliding the upper and lower limits and then clicking on the **Apply** button. On some systems, the image is not immediately updated when the **Apply** button is selected. If the image is not immediately updated, point the cursor at the image and it will be updated.
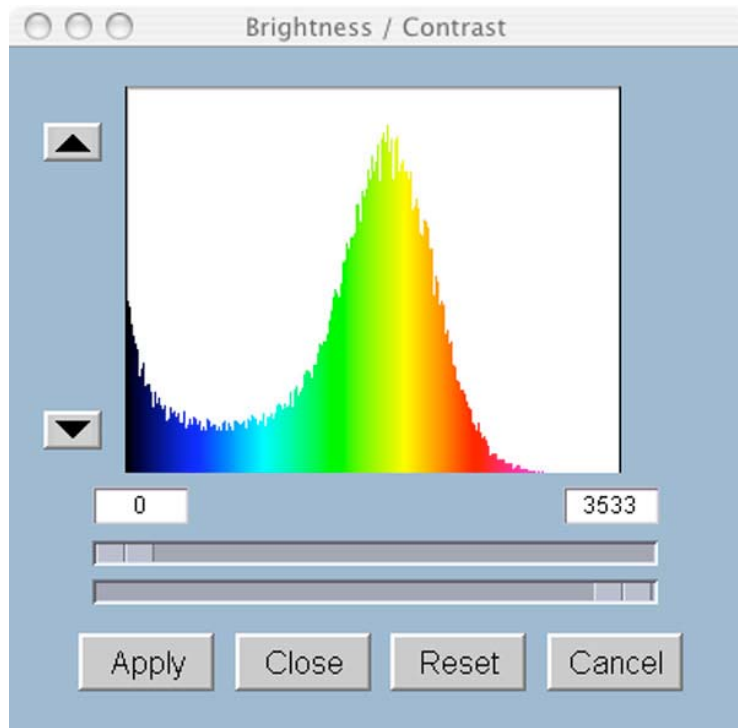
Figure 25. **Brightness / Contrast** *window.*
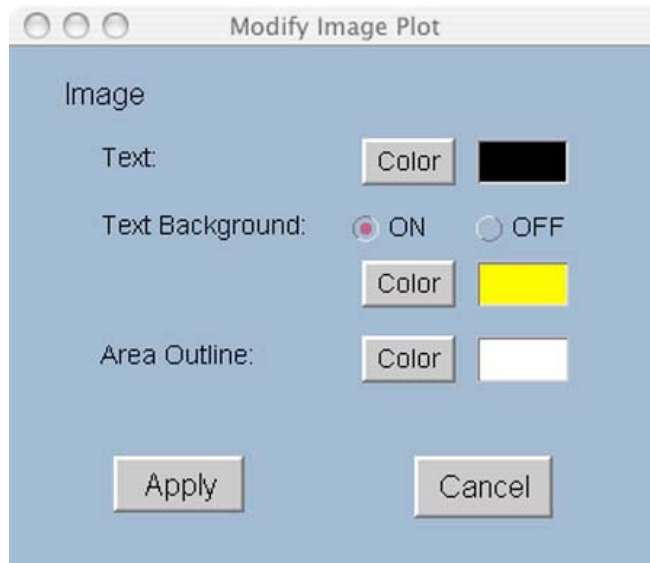
3.3.7 Modifying Display Colors

Figure 26. **Modify Image Plot** *window.*

The text and lines displayed on a map may not be as visible as the user would like, depending on the look-up-table used. The default colors can be changed from the menu item **Plot >> Modify Colors …**. The colors used for the text, the text background, and the area outlines can be changed by clicking on the appropriate button and selecting a new color.

3.3.8 Map Reset

The age map can be reset to its original values by selecting the menu item **Plot >> Reset.**

3.4   Saving Age Maps

The age map produced by this program can be saved in a number of different formats. By going to the menu item **>File >> Save As …** , the standard file save window will open (Fig. 27). In the filter box (arrow), the user can select one of four file formats in which to save the image:
1) encapsulated postscript (.eps),
2) JPEG (.jpg),
3) PNG (.png), or
4) Text (.txt).

The first three options (eps, jpg, and png) will save the image as it is displayed. The fourth option, txt, saves only the age data.

*Figure 27. **Save As… Plot Format** window.*

3.5 Saving Age Map Data

As mentioned above, the calculated map ages can be stored in a text file by going to the menu item **File >> Save As …**. The individual values will be saved in a tab-delineated format which can be imported or opened by other programs for additional data processing.

The map data can also be exported into the JEOL file system by selecting the **File >> Export JEOL**. The data will automatically be stored in the JEOL Group and Sample from which the original data had been imported, and will be stored in a format that can be read by the JEOL Map Analysis program.

4.0 - References

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Suzuki, K., and Mamoru Adachi, 1994, Middle Precambrian detrital monazite and zircon from the Hida gneiss on Oki-Dogo Island, Japan: their origin and implications for the correlation of basement gneiss of southwest Japan and Korea. Tectonophysics, vol. 235, p. 277-292.

Suzuki, K., M. Adachi, and I. Kajizuka, 1994, Electron microprobe observations of Pb diffusion in metamorphosed detrital monazites. Earth and Planetary Science Letters, vol. 128, p. 391-405.