Demagnetization Analysis in Excel (DAIE)

An open source workbook in Excel for viewing and analyzing demagnetization data from paleomagnetic discrete samples and u-channels

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User manual *(Version 1.0 of 30 November 2012)*

The DAIE workbook is a composite tool for viewing and analyzing stepwise demagnetization data of both discrete and u-channel samples; it is designed for an interactive operability and all the commands and choices can be entered by sliding menus associated to single cells. The standard demagnetization diagrams (Zijderveld orthogonal projection diagrams, stereographic projection of unit vectors, variation of the remanence intensity during the demagnetization treatment) are shown on the same worksheet including selectable parameters and User's choices. In addition, various other common demagnetization parameters (MDF, ΔGRM) are computed. The remanence characteristic components may be computed by principal component analysis (PCA) on a selected interval of demagnetization steps. Saving of the PCA data can be done both sample by sample, or in automatic by applying the selected choices to all the samples included in the file. The whole workbook is free both for use and editing.

The workbook is organized in 10 worksheets, with assigned distinct colors indicated in parenthesis:

1. OriginalData (yellow)
2. Command_plots (yellow)
3. PCA_Output (blue)
4. OutputPlots (blue)
5. SelectedSample (red)
6. CoordSystems (red)
7. PCA (red)
8. Zijderveld (red)
9. Stereo (red)
10. MDF_DGRM (red)

The yellow worksheets are those where the measured data are entered (OriginalData worksheet) and where the user can make any choice concerning the analysis of the data (Commands_Plots worksheet). The main demagnetization diagrams for each specimen are in the Commands_Plots worksheet .

The blue worksheets are those in which the output of the demagnetization data analysis are stored, either listed as values for distinct parameters (PCA_Output worksheet) or shown in bi-plots as a function of the specimen ID or stratigraphic depth (OutputPlots worksheet).

The red worksheets are those in which all the computations are made. They should not be edited and modified unless the User wants to make change to the design and operation of the whole workbook.

The individual worksheets will be described in the following.

"OriginalData" worksheet – The demagnetization data must be copied from the original measurement file and pasted in columns A to I.

Column A includes the specimen ID (in case of discrete samples) or the stratigraphic depth or position (in case of u-channels);

Column B includes the demagnetization steps (for alternating field or thermal treatment)

Columns C, D and E include the measured magnetic intensities along the X, Y and Z specimen's coordinates respectively. These intensities are in the output of each software running measurement cycles of rock magnetometers and are computed from the measured magnetic moments along the three orthogonal axes of the specimen, normalized by the specimen volume in the case of discrete samples, or by the volume felt by the SQUID response functions in the case of u-channels.

The convention for the specimen coordinates is as follow:

X is along the "reference arrow" drawn on the upper base of a cylindrical sample, Y is on the upper base of the cylinder too and Z is along the physical axis of the cylinder.
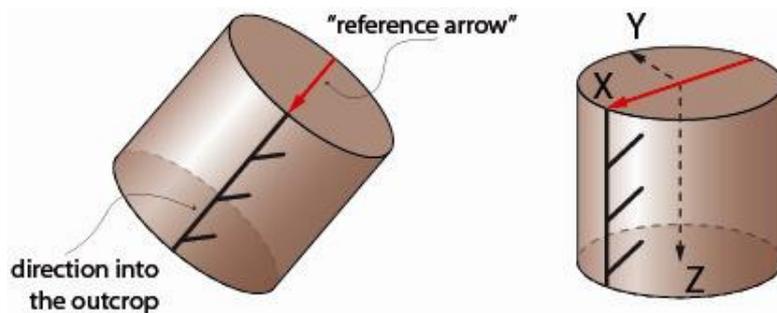
The samples, both cylindrical or cubic discrete samples and u-channels, are then measured such as the axes of specimen coordinate system will correspond to those of the magnetometer coordinate system.
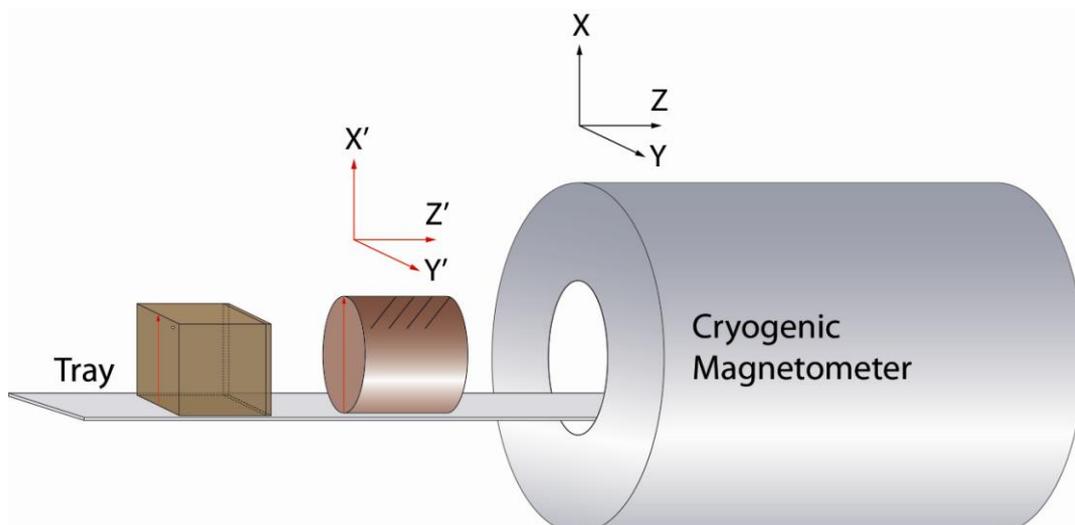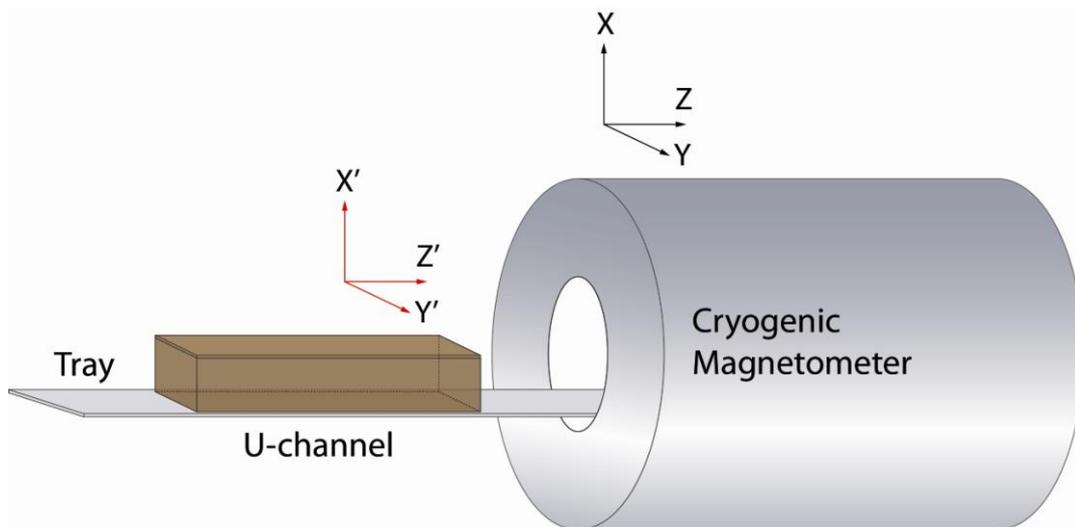
Columns F, G, H and I include the specimen orientation parameters, namely Sample Azimuth, Sample Dip, Formation Dip Azimuth, Formation Dip.

The data in columns A to I should be ordered according to column A.

Columns K to V should not be edited. They list the data relevant to the selected specimen only, according to the choice done in the "Command_plots" worksheet. Cells for selected data are active up to row 3001. Orientation parameters in the R, S, T and U columns are listed according to the convention P1=12, P2=0, P3=12, P4=0 (see notes concerning the orientation parameters in the "Command_plots" worksheet). These values are those used for the computations.

"Commands_plots" worksheet – This is the main worksheet where all the available choices are made by the User and where the demagnetization diagrams and analysis outputs for the selected specimen are shown.
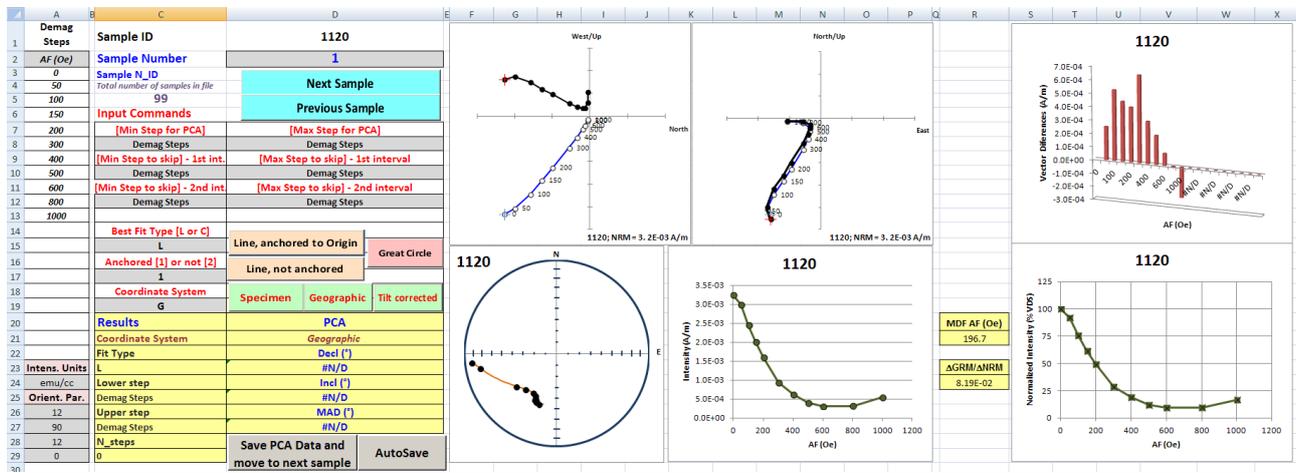
Columns A-D list all the possible choices and User's inputs, as well as the outputs of the principal component analysis for each individual specimen, according to the selected parameters and settings.

All the possible settings and choices (Input commands) are selected in the grey cells. The available choices are listed in the sliding menus connected to each of these cells. In columns Z-AAW all the codes used in the sliding menus are listed.

The outputs and results are listed in the cells colored in yellow.

The colored buttons are associated to the macros for selecting and scrolling through the samples in the file ("Next Sample" and "Previous Sample"), as well as for choosing the type of best fit on the selected demagnetization steps ("Line, anchored to Origin", "Line, not anchored" or "Great Circle"), and the coordinate system ("Specimen", "Geographic" or "Tilt corrected").

The grey buttons are associated to the macros for saving the results of the principal components analysis (PCA, Kirschvink, 1980) in the "PCA_Output" worksheet. The button "Save PCA Data and move to next sample" saves the output data for each single specimen according to the selected parameters; the button "Autosave" automatically saves the output data using the same selected parameters for all the specimens in the file.

Cell D2 lists the progressive number assigned to the selected specimen. The specimen can be selected directly typing its specific number on the cell, or by using the buttons "Next Sample" and "Previous Sample". The total number of specimens in the file is shown in cell C5. The list of all the specimens included in the file can be seen by scrolling the sliding menu associated to cell C3, which refers to cells AW2-AW151; this sliding menu does not modify the selection of the specimen, which is done only operating on the cell D2 or on the buttons "Next Sample" and "Previous Sample".

Demagnetization steps are listed in cells A3-A22. The present version of this workbook is designed for a maximum of 20 demagnetization steps. This number can be increased at wish by incrementing the "operational" rows in each of the red worksheets. The demagnetization type is listed in cell A2 and can be selected according to three choices: "AF (Oe)", "AF (mT)" and "Temp (°C)". The sliding menu is associated to cells AA2-AA4.

Cell A24 lists the magnetization intensity units used for data in columns C-E of the "OriginalData" worksheet. This parameter may be switched between SI (A/m) and CGS (emu/cc) units. The sliding menu is associated to cells AO2-AO3.

Notes on the version without macros ("DAIE no macro" file)

Macros could not work in old Excel versions. Therefore, a DAIE workbook without macros is also proposed, that can be run on such old Excel versions. In the "DAIE no macro" file, the colored buttons are not present and all the possible settings and choices should be entered by using the sliding menus associated to the grey cells only. The saving of the PCA data is done according to the code in cell D29. If "Y" is selected, each time a specimen is selected by means of the sliding menu associated to cell D3, the corresponding data are saved in the "PCA_Output" worksheet, according to the parameters and choices made on the grey cells. In order not to save the PCA data for the selected sample, no demagnetization steps should be selected in cells C8 and D8. Caution: If "N" is selected in cell D29, the data in the "PCA_Output" worksheet will be deleted for all samples.

Cells A26-A29 list the conventional codes for the orientation angles and follow the P1-P4 codes defined by AGICO (AGICO Print n. 6, available at http://www.agico.com/). They are briefly summarized below:

P1 is clock value of the direction of the fiducial mark drawn on the frontal side of cylinder. This arrow is X1 axis of the specimen coordinate system.
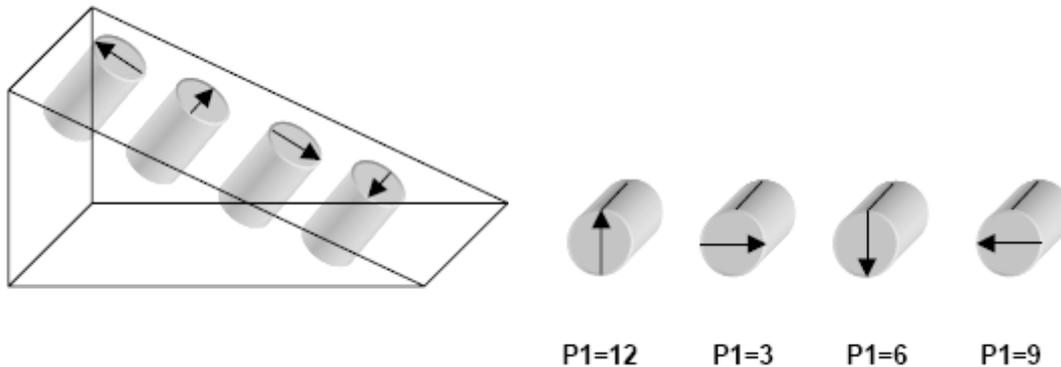
P2 value is 0 or 90.

P2=0 if the dip of the frontal side is measured. P2=90 if the plunge of the cylinder (drilling) axis is measured.

P3 is clock value of the direction (sample azimuth) which is measured in the field.

P4 value is 0 or 90.

P4=0 Value zero means that azimuth of dip and dip of mesoscopic foliation are measured. P4=90 Value 90 means that strike (right oriented) and dip are measured.

The sliding menus in cells A26-A29 are associated to the values reported in cells AD2-AD4 (for P1 and P3) and AE2-AE3 (for P2 and P4).

Cells C8 and D8 list, respectively, the minimum and maximum values of the demagnetization steps selected for PCA. They include sliding menus whose values are taken from cells A1-A22. The default value is cell A1 = "Demag Steps", which implies no PCA.

Cells C10 and D10 list the minimum and maximum values of the demagnetization interval to be skipped (discarded) from view and analysis. They include sliding menus associated to cells A1-A22. Default value is cell A1 = "Demag Steps", which implies that no step is discarded. For a correct use, the upper step of the interval to be discarded should be entered before of the lower step. If the upper and lower steps coincide a single step is discarded.

Cells C12 and D12 list the minimum and maximum values of the second demagnetization interval to be skipped (discarded) from view and analysis. They include sliding menus associated to cells A1-A22. Default value is cell A1 = "Demag Steps", which implies that no step is discarded. For a correct use, the upper step of the interval to be discarded should be entered before of the lower step. If the upper and lower steps coincide a single step is discarded.

Cells C15 and C17 indicate the type of fit chosen for the PCA analysis. Possible choices in C15 are "L" and "C", to indicate a best-fit line or great circle, respectively. The options are listed in a sliding menu associated to cells AJ2-AJ3. In the case of a best-fit line, cell C17 allows the choice to anchor it to the origin (1) or not (2). The options are listed in a sliding menu associated to cells AL2-AL3. The same choices may be done by using the command buttons colored in orange (for the two types of linear best-fit) or in pink (for the great circle).

Cell C19 indicates the selected coordinate system. There are three options (S, G and T) for the Specimen, Geographic and Tilt-corrected coordinate systems, respectively. The codes associated to the C19 sliding menu are listed in cells AH2-AH4. The same choice may be done by using the green command buttons.

The results of PCA are indicated in cells C20-C29 and D20-D27. C23 indicates the selected fit type (L = line anchored to the origin, L* = line not anchored to the origin, G = great circle). C25 indicates the lower step selected for PCA, C27 indicates the upper step selected for PCA, C29 indicates the numbers of step selected for PCA. D21 indicates the selected coordinate system, D23 indicates the declination of the best-fit line or of the great circle pole, D25 indicates the inclination of the best-fit line or of the great circle pole, C27 indicates the maximum angular deviation (MAD) for the selected fit.

For every sample, cells F31 to P52 list a table with declination and inclination values computed at each demagnetization step, in specimen, geographic and tilt corrected coordinates.

| 5320								
AF (Oe)	Intensity (A/m)	Decl Spec	Incl Specimen	Decl Geo	Incl Geo		Decl Tilt_c	Incl Tilt_c
0	2.72E-04	39.5	-27.1	39.5	-27.1		39.5	-27.1
50	3.26E-04	54.7	-26.8	54.7	-26.8		54.7	-26.8
100	6.39E-04	101.3	-62.9	101.3	-62.9		101.3	-62.9
150	9.41E-04	128.0	-70.0	128.0	-70.0		128.0	-70.0
200	1.01E-03	137.6	-71.8	137.6	-71.8		137.6	-71.8
300	7.00E-04	137.8	-72.0	137.8	-72.0		137.8	-72.0
400	3.90E-04	132.7	-71.2	132.7	-71.2		132.7	-71.2
500	1.63E-04	123.5	-64.4	123.5	-64.4		123.5	-64.4
600	6.31E-05	111.2	-36.8	111.2	-36.8		111.2	-36.8
800	3.44E-05	97.2	33.6	97.2	33.6		97.2	33.6
1000	3.94E-05	63.2	53.0	63.2	53.0		63.2	53.0
				#N/D	#N/D		#N/D	#N/D
				#N/D	#N/D		#N/D	#N/D
				#N/D	#N/D		#N/D	#N/D
				#N/D	#N/D		#N/D	#N/D
				#N/D	#N/D		#N/D	#N/D
				#N/D	#N/D		#N/D	#N/D
				#N/D	#N/D		#N/D	#N/D
				#N/D	#N/D		#N/D	#N/D
				#N/D	#N/D		#N/D	#N/D

The demagnetization diagrams shown in this worksheet include:

- Orthogonal projection diagrams (or "Zijderveld diagrams") of vectors measured at each demagnetization step, with projection on the North-South or East-West vertical planes (Zijderveld, 1967; Dunlop, 1979). Black circles indicate projection on the horizontal plane, white circles indicate projection on the vertical plane. When demagnetization steps are selected for PCA, the corresponding symbols turn to red (for horizontal projection) and to light blue (for the vertical projections). The symbols referring to the natural remanent magnetization (NRM) are marked by a

cross superimposed on the circles. The NRM intensity is indicated in SI units (A/m) at the bottom right of the plots, together with the sample N_ID. The numbers close to the symbols for the projections on the vertical planes indicate the corresponding level of stepwise demagnetization (cells A3-A22). Please be aware that the scale and the tick units may be different for the two projection axes. Values for these plots are computed in the "Zijderveld" worksheet.
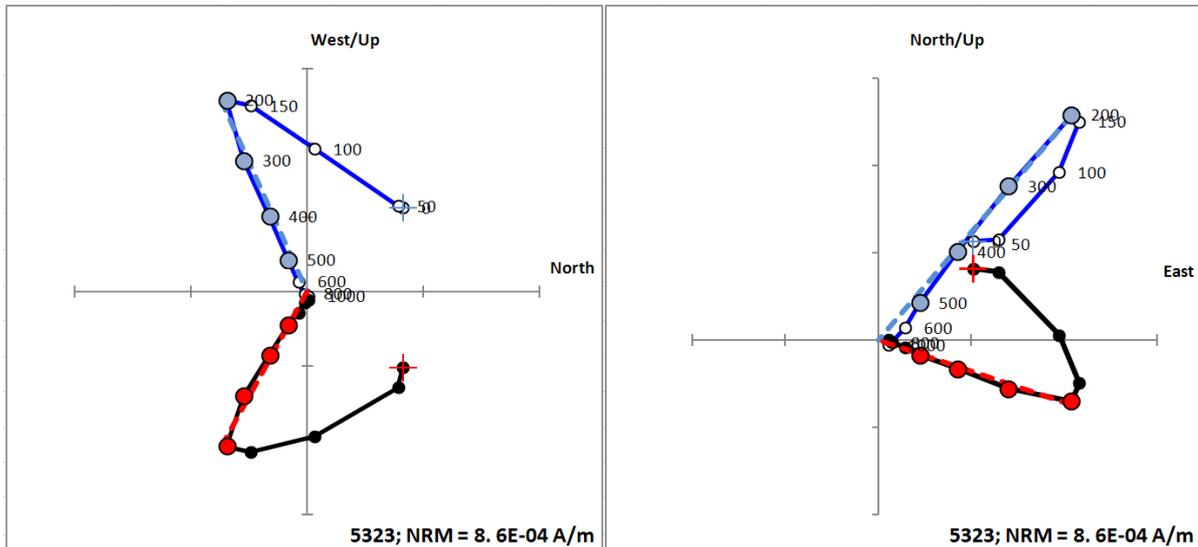

- Stereographic (equal area) projection of unit vectors defined at each demagnetization step (Dunlop, 1979). Black (white) circles indicate projection on the lower (upper) hemisphere. When demagnetization steps are selected for PCA, the corresponding symbols turn to red (for the lower projection) and to light blue (for the upper hemisphere projections). The symbols referring to the natural remanent magnetization (NRM) are marked by a cross superimposed on the circles. Values for these plots are computed in the "Stereo" worksheet.
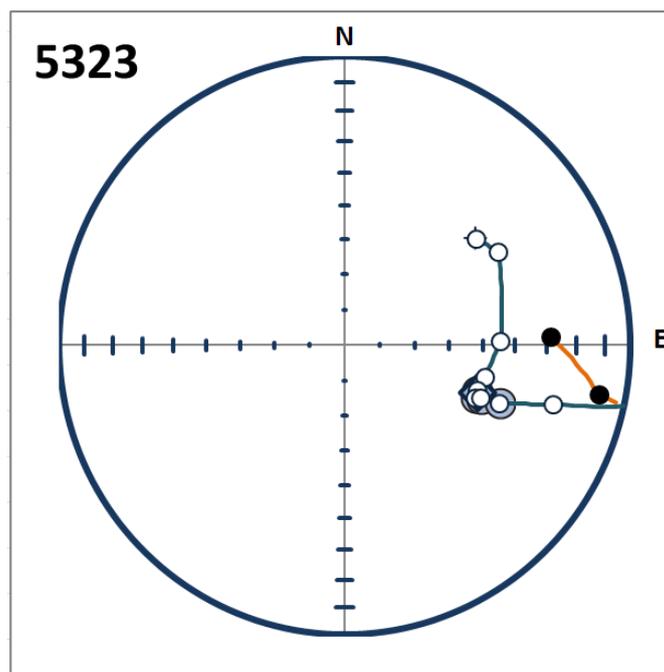
- Three plots for the variation of the NRM intensity as a function of the demagnetization steps. The first plot shows the absolute remanence intensity values in SI units (A/m) and the steps selected for PCA are shown by red circles. Values for this plot are listed in the "Zijderveld" worksheet.
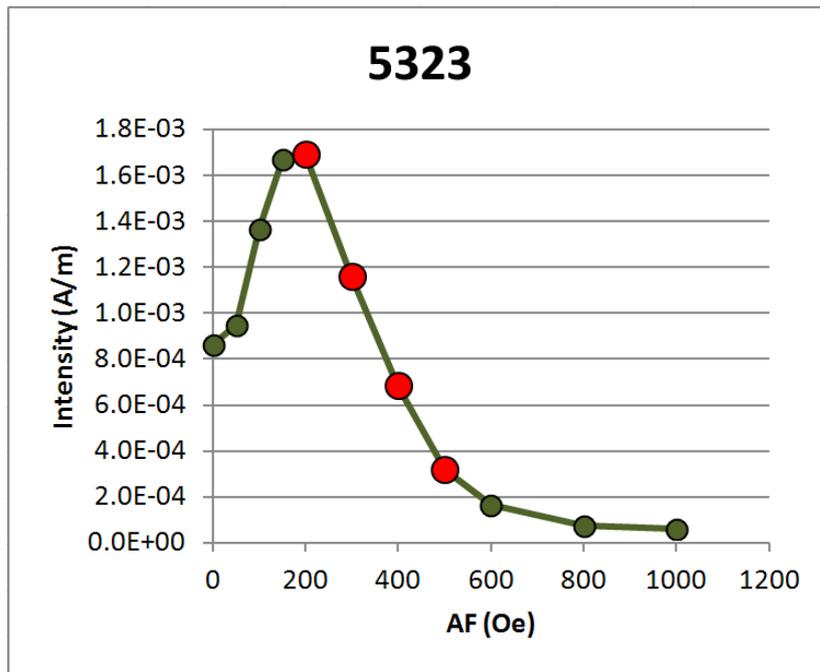
- The second plot shows the intensity differences (in A/m) between consecutive demagnetization steps. Vector differences are positive if the intensity decreases and negative if the intensity increases. Values for the second and third plots are listed in the "MDF_DGRM" worksheet.
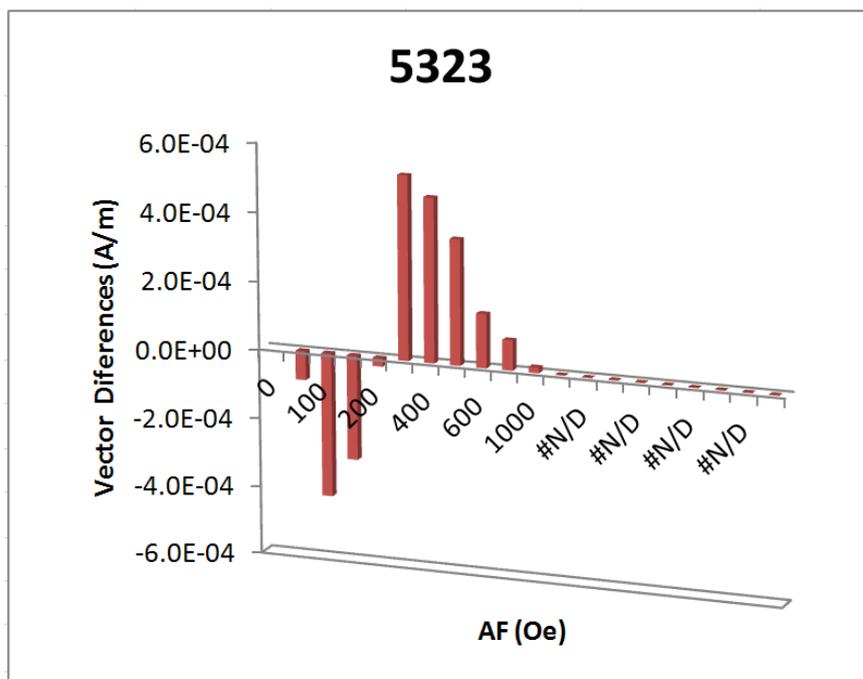
The third plot uses the sum of vector difference magnitudes (VDS, following Gee et al., 1993) between successive demagnetization steps and shows the remanence intensity decay as a percentage of the NRM initial value. In order to avoid the effect of possible gyromagnetic or spurious remanences acquired at high demagnetization steps, the computation of the VDS is limited to all the demagnetization steps preceding the minimum intensity value reached during the whole demagnetization treatment.
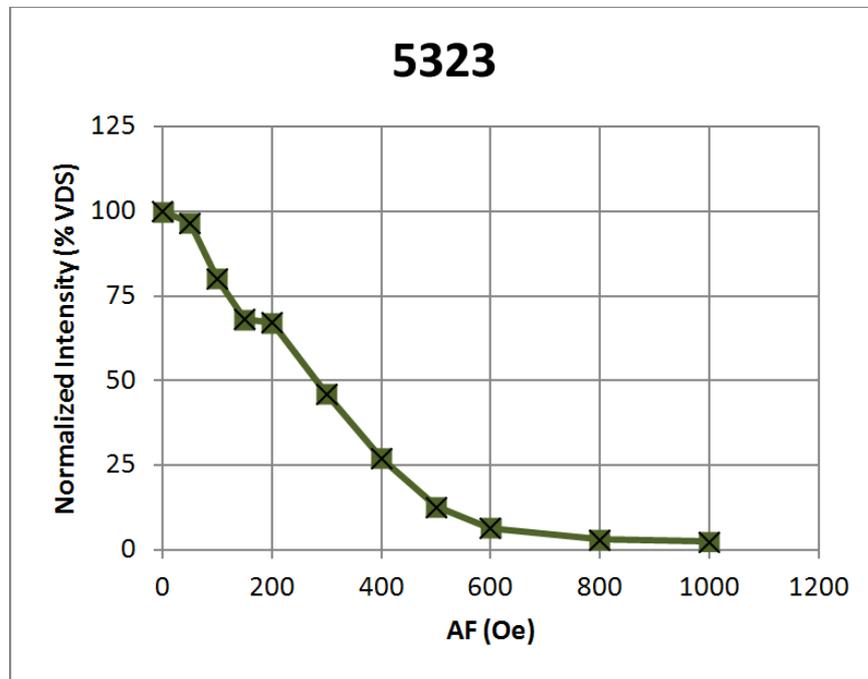
In the case of AF demagnetization, the median destructive field (MDF) and the ΔGRM/ΔNRM parameters are computed from the intensity data and listed in cells R21 and R24 of the "Commands_plots worksheet", respectively.

The MDF is the field necessary to reduce the remanent magnetization intensity to half of its initial value. The MDF value is computed from the VDS values, in order to take into account the possible removal of antipodal components during the first steps of AF demagnetization. The AF steps characterized by the acquisition of a gyromagnetic remanent magnetization (GRM) are also not taken into account in the computation of the MDF parameter.

The ΔGRM/ΔNRM is a parameter introduced by Fu et al. (2008) with the aim to quantify the acquisition of a GRM during the AF treatment. Defining MV as the intensity minimum value during the whole AF treatment, ΔGRM represents the difference of the final intensity value (FV) measured at the last AF step and MV, whereas ΔNRM represents the difference of initial intensity value(IV) and MV:

$$\frac{\Delta \text{GRM}}{\Delta \text{NRM}} = \frac{(FV-MV)}{(IV-MV)}$$

Both the MDF and the ΔGRM/ΔNRM values are computed in the "MDF_DGRM" worksheet.

"PCA Output" worksheet – This worksheet lists all the outputs of the principal component analysis (PCA) for each sample. It includes:

- Sample Number

- Sample ID

- Fit Type

- Coordinate System

- Declination from PCA

- Inclination from PCA

- Maximum angular dispersion (MAD)

- The lower step selected for PCA

- The upper step selected for PCA

- The number of steps selected for PCA

- The NRM intensity (in A/m)

- The MDF (in case of thermal demagnetization it lists the temperature at which the NRM intensity reaches half of its initial value)

- The ∆GRM/∆NRM parameter

and, finally

- The four orientation angles (Sample azimuth, Sample dip, Formation dip azimuth and Formation dip), according to the 12, 0, 12, 0 convention.

The values in this worksheet should be cleared before starting the analysis of a new file. Clearing of the cells content in this worksheet is done automatically with the "Autosave" option.

"OutputPlots" worksheet – This worksheet includes the output plots from the PCA analysis. All the parameters are plotted as a function of the sample ID (or stratigraphic depth). These plots are particularly useful in the case of u-channel samples to visualize the variation of the magnetic properties through the stratigraphic section.
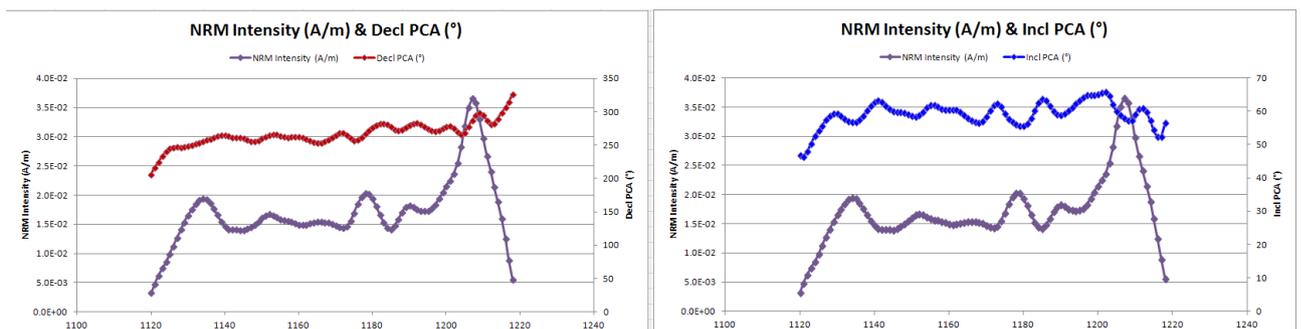
This worksheet shows:

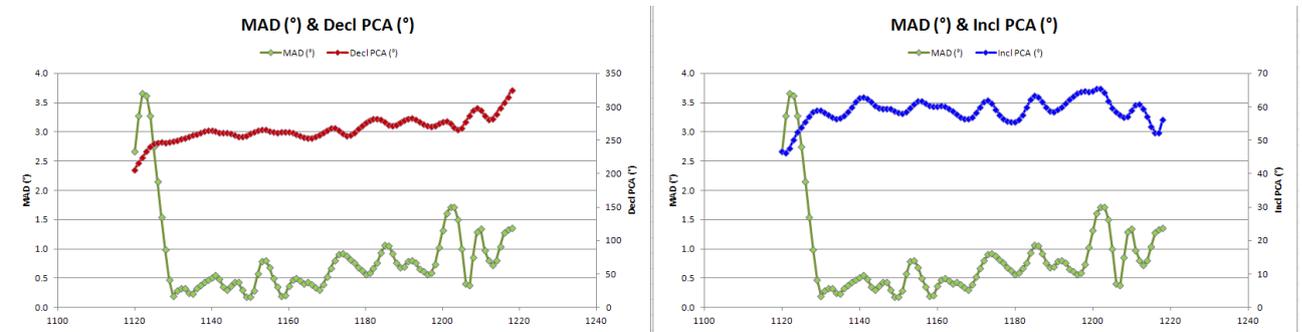- the variation of the PCA declination and inclination
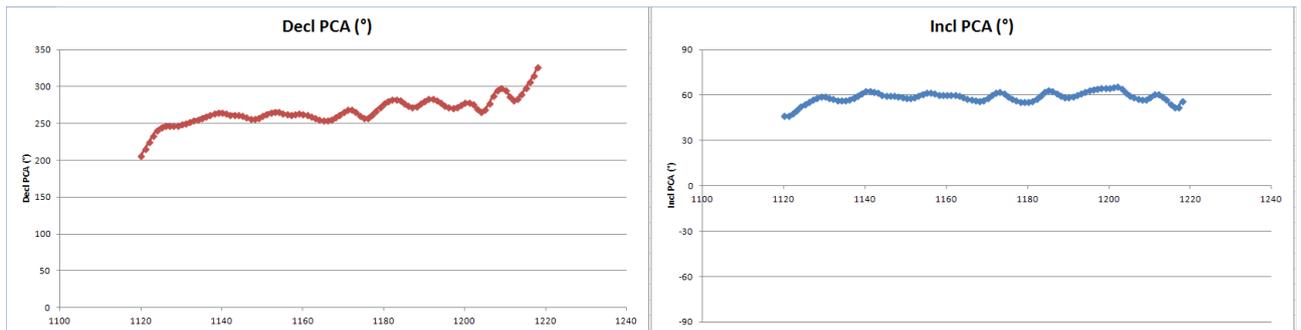
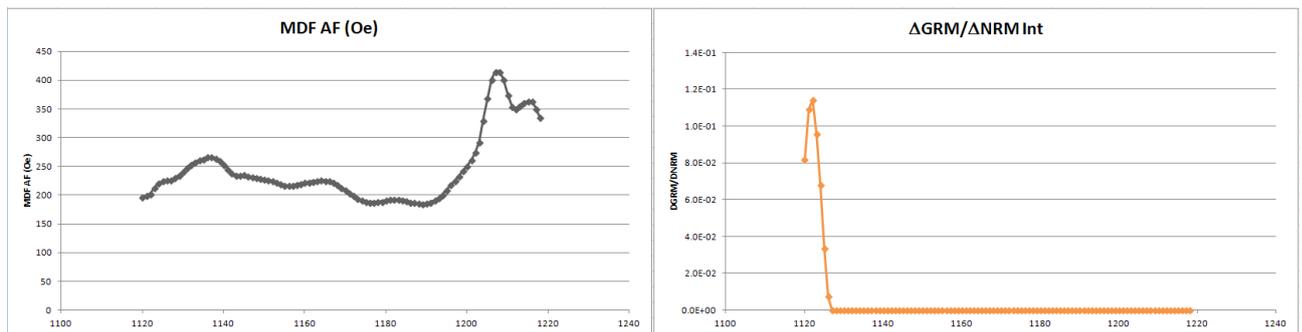- the variation of MAD and NRM intensity
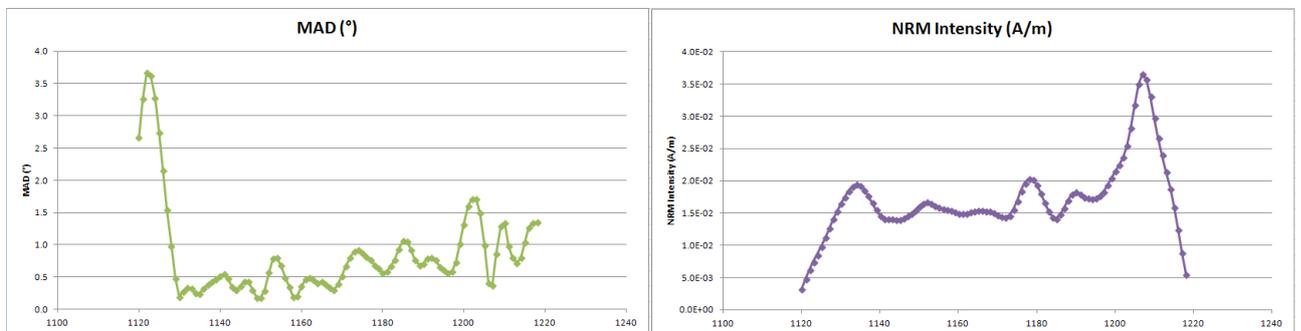
- the comparison of the plots for the NRM intensity and the PCA declination and inclination

- the comparison of the plots for the MAD value and the PCA declination and inclination

- the variation of the MDF and of ΔGRM/ΔNRM parameters

Red worksheets

These worksheets includes all the computations employed by the workbook and should not be edited unless it is intended to modify the "DAIE software" as a whole.

"SelectedSample" worksheet – It includes all the main original data for the selected sample. These data are automatically extracted from the "OriginalData" worksheet by making use of array formulas.

"CoordSystems" worksheet – It lists and computes the data (X, Y, Z, Declination, Inclination) for the selected sample in all the three different coordinate system (specimen, geographic and tilt corrected). Input data are in columns A-I. Computations and output data are in columns K-AK.

"PCA" worksheet – It includes all the computations used to calculate the principal component analysis parameters according to Kirschvink (1980). Input data are in columns A-I. Computations are in columns K-AQ. Output data are in columns AS-AV.

"Zijderveld" worksheet – It includes all the data needed to draw orthogonal vector plots of the demagnetization data and the best-fit line through the demagnetization steps selected for PCA. Input data are in columns A-H (demagnetization data) and T-AB (for PCA parameters). Computations and output data are in columns J-R. Values in columns AD-AQ are used for an optimal drawing of the plots.

"Stereo" worksheet – It includes all the data needed to draw stereographic (equal area) projection of the demagnetization data. Input data are in columns A-G (demagnetization data) and X-AC (for PCA parameters). Columns H-L are used for skipping steps eventually discarded from the view and the analysis of the demagnetization data. Computations are in columns L-V and AE-AI. Data for drawing the stereonet are in columns AK-AZ. Data for drawing great circles are listed in columns BB-CD (for the best-fit great circle computed from PCA) and CG-CZ (for great circle intervals connecting the projection points between consecutive demagnetization steps).

"MDF_DGRM" worksheet – It includes all the data and computations employed to calculate the MDF and ΔGRM/ΔNRM parameters. Input data are in columns A-C. Columns F-J are used for skipping steps eventually discarded from the view and the analysis of the demagnetization data. Computations are included in columns L-S and U-V. Outputs are listed in columns W-X (MDF) and Z-AA (ΔGRM/ΔNRM).

References

Dunlop, D.J. (1979), On the use of Zijderveld vector diagrams in multicomponent paleomagnetic studies. Physics of the Earth and Planetary Interiors, 20, 12–24.

Gee, J., H. Staudigel, L. Tauxe and T. Pick (1993), Magnetization of the La Palma Seamount Series: Implications for Seamount Paleopoles, Journal of Geophysical Research, 98, 11743-11767.

Fu, Y., T. von Dobeneck, C. Franke, D. Heslop and S. Kasten (2008), Rock magnetic identification and geochemical process models of greigite formation in Quaternary marine sediments from the Gulf of Mexico (IODP Hole U1319A), Earth Planet. Sci. Lett., 275, 233–245, doi:10.1016/j.epsl.2008.07.034.

Kirschvink, J.L. (1980), The least-squares line and plane and the analysis of paleomagnetic data, Geophysical Journal of the Royal Astronomical Society, 62, 699–718.

Zijderveld, J.D.A. (1967), A. C. demagnetization of rocks: analysis of results, in Methods in Palaeomagnetism, edited by D.W. Collinson, K.M. Creer, and S.K. Runcorn, pp. 254–286, Elsevier, Amsterdam, New York.