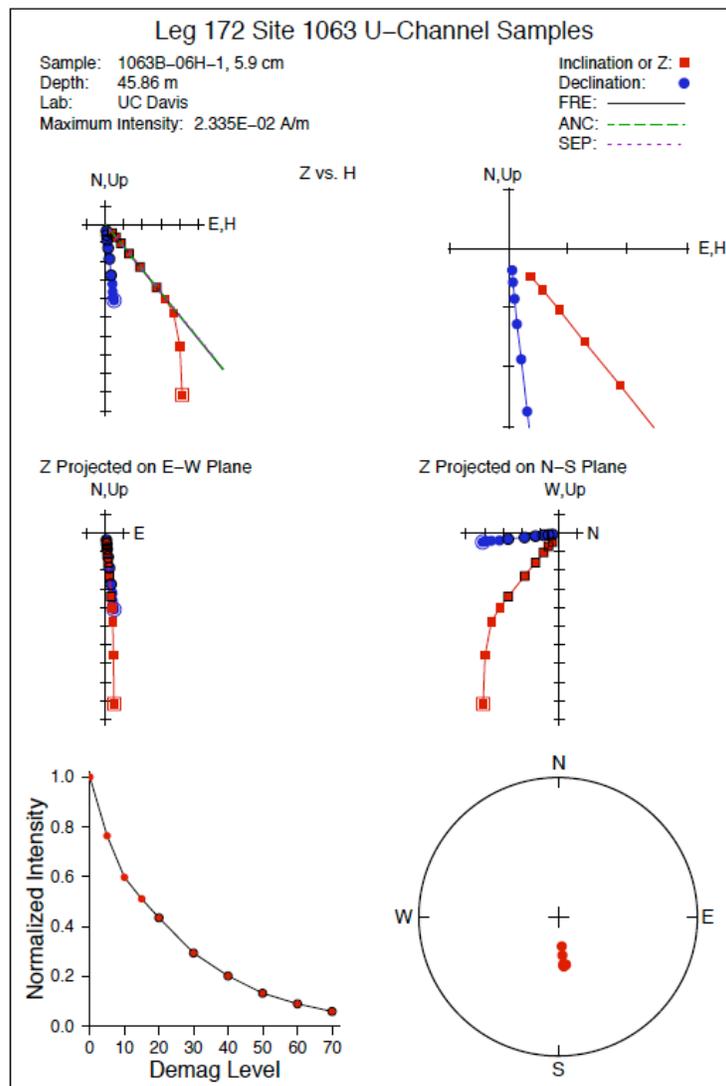# ZPLOTIT Software Users' Guide

Gary Acton
One Shields Avenue
Department of Geology
University of California, Davis
Davis, CA 95616

ZPLOTIT Software Users' Guide (Version 2011-01): A description of how to install and use ZPLOTIT, which produces vector demagnetization diagrams, intensity-decay plots, and stereonets and computes the principal component analysis (PCA) from paleomagnetic data sets.

Copyright Information

Citation Information

If you use the software to generate figures for publications, I would appreciate a citation to:

Acton, G., ZPLOTIT Software v2011-01. Downloaded from http://paleomag.ucdavis.edu/software-Zplotit.html, *DATE DOWNLOADED*.

> *or cite the user guide:*

Acton, G., ZPLOTIT Software Users' Guide Version, version 2011-01, Downloaded from http://paleomag.ucdavis.edu/software-Zplotit.html, *DATE DOWNLOADED*.

Table of contents

Introduction

This document is intended to be a quick reference guide for installing and using program ZPLOTIT, which produces

- *vector demagnetization diagrams*,
- *intensity decay diagrams*, and
- *stereonets*, and does
- *principal component analysis (PCA).*

Figure 1 and the cover image of this document show examples of the graphical output of ZPLOTIT for a single sample. ZPLOTIT reads paleomagnetic data sets that contain the magnetic remanence data (inclination, declination, and intensity) for many samples (tens, hundreds, or even thousands) measured after multiple demagnetization treatments or steps.

ZPLOTIT is executed from a standard Unix terminal window. The plots generated are merged into a single PDF file and the PCA results placed in a tab-delimited text file. The ZPLOTIT software package was designed to be similar to the FORCIT software package (Acton et al., 2007). If you are already running FORCIT to generate FORC diagrams, then installing and using ZPLOTIT should be intuitive.

Vector Demagnetization Diagrams

I use the term *vector demagnetization diagram* to describe the various plots that originated from Zijderveld (1967) and that include a modified version. These plots go by various names including vector component demagnetization diagrams, Zijderveld diagrams, modified Zijderveld diagrams, vector component diagrams, vector end-point diagrams, orthogonal vector plots, orthogonal projections, etc.

Vector demagnetization diagrams are 2-D plots of the projection of the end-points of the 3-D remanence vectors onto horizontal and vertical planes (e.g., Zijderveld, 1967; Dunlop, 1979; Chapter 5 of Butler,1998; Chapter 3 of Tauxe, 1998). The remanence vectors are generally the natural remanent magnetization (NRM) vectors measured after each step for a sample that is subjected to progressive step-wise demagnetization. Each vector is typically given by a declination (D), inclination (I), and

intensity (J), which can be decomposed into north (N), east (E), vertical (Z), and horizontal components, where

$$N_i = J_i \cos I_i \cos D_i$$
$$E_i = J_i \cos I_i \sin D_i$$
$$Z_i = J_i \sin I_i$$
$$H_i = J_i \cos I_i = \sqrt{N_i^2 + E_i^2}$$

For the horizontal projection in a vector demagnetization diagram, both Zijderveld and modified Zijderveld diagrams plot *N vs. E*. For the vertical component, modified Zijderveld diagrams plot *H vs. Z* where Zijderveld diagrams plot either *N vs. Z* or *E vs. Z*. Presumably, for a standard Zijderveld diagram, one could chose other vertical planes but whatever plane is chosen, it remains fixed within the diagram. In modified Zijderveld diagrams, the vertical plane always contains the vector. Thus, if the declination of the NRM changes as the sample is demagnetized, the orientation of the vertical plane changes. If the declination does not change, then the modified Zijderveld and Zijderveld diagrams are the same, except that few paleomagnetists ever use vertical planes other than the N-S or E-W planes in Zijderveld diagrams.

While I use various forms of the vector demagnetization diagrams, I am surprised at how much grief one can get for using a modified Zijderveld diagram rather than a Zijderveld diagram and vice versa. Each diagram has advantages and disadvantages. The Zijderveld diagrams sometimes are better at separating multiple components but can be confusing for general audiences when, for example, the North axis changes its orientation from one plot to the next or a sample with a shallow inclination projects onto the vertical plane as being steep. Modified Zijderveld diagrams have a constant orientation for the North axis and convey the true inclination and intensity but do not always separate the individual components for complexly magnetized rocks as well as do Zijderveld diagrams. I typically use modified Zijderveld diagrams when addressing large audiences that include non-paleomagnetists because I think they can be grasped more readily. Feedback from audiences previously exposed to vector demagnetization diagrams has been relatively positive … as in "I had hoped to never see another one of those diagrams but now I see why paleomagnetists use them". As with geographical maps, the user needs to decide what transformation conveys the intended message. Should one use the modified Zijderveld or

Zijderveld diagram and, if he or she uses the Zijderveld diagram, which vertical plane should be used?

I have attempted to simplify this question and reduce the grief by upgrading ZPLOTIT to do all three versions of vector demagnetization diagrams on each plotted page (e.g., Figure 1a).

Versions

The previous release (version 2009-10 as in October 2009) did only modified Zijderveld diagrams (Figure 1b). ZPLOTIT version 2011-01 produces vector demagnetizations with vertical plane projections that are *H vs. Z* (modified Zijderveld diagrams) as well as *N vs. Z* and *E vs. Z* (Zijderveld diagrams). The latest version also outlines (in black) data used in the PCA, which allows the user to identify which data were used in the automated PCA versus those that were excluded.

Background

ZPLOTIT is a combination of Fortran77 code, Unix shell scripts, and GMT commands, all of which are available free of charge. The main work is done by program zplotgmt.f. I wrote the graphical part of this Fortran77 program to take advantage of GMT's interface. The guts of the PCA subroutine come from USGS programs provided to me by Jack Hillhouse in the late 1980's. These are stored in the directory (or folder) called PCA, which is part of the ZPLOTIT distribution package. The main PCA routines (called LINES.F and LINE3D.F by the USGS) appear to have been written by Jon Hagstrum and Sheman Gromme, and are based on the PCA method of Kirschvink (1980). I have altered the routine numerous times since 1987, but the basics remain the same as in LINES.F. The latest version is now called *pcasub.f* and includes calls to several plate tectonic subroutines, which originated from Richard Gordon, Alan Cox, myself, and others. These are stored in the folder called lplate, which is also part of the ZPLOTIT distribution package. These routines can be used for a number of other applications: finding angular distances or azimuths between points on the globe, rotating points on a globe, find transform azimuths, and much more.

The initial version of ZPLOTIT was written for my own use and was not even remotely user friendly. I wrote it to combine the capabilities of a program called Zplot v2.5.3 (written by Steve Hurst in 1997) and a PCA

program that I had constructed to handle large data sets. Zplot had a very user-friendly GUI interface that let the user scroll through a paleomagnetic data set (Figure 2). The on-screen graphics were ideal for assessing the data, although exporting a large number of images in a printable form or into an electronic document was extremely tedious. Zplot also allowed the user to do PCA for individual samples using demagnetization steps selected by the user for each sample. The PCA results were shown on the screen but were not exported to a file. While this works well for a few samples, the PCA-part of the program was inadequate for use with large data sets. The final straw for Zplot as my primary viewing tool for vector demagnetization diagrams was when the MacIntosh operating system (OS) switched to MacOS X. Zplot was written for the Mac classic OS (MacOS 9 and earlier) and does not run natively under MacOS X. It can be run through an emulator such as SheepShaver (see http://sheepshaver.cebix.net/), and so I still do occasionally use it as a secondary tool.

After getting several requests from other paleomagnetists to use my user-unfriendly program, I decided to make a version available that is somewhat user friendly, particularly if one is familiar with Unix, shell scripts, Fortran77, and Generic Mapping Tool (GMT; Wessel and Smith, 1998, 2004). I make no guarantees that the ZPLOTIT software will be easy to install or will run on multiple platforms, although it should install and run on any computer running Unix.
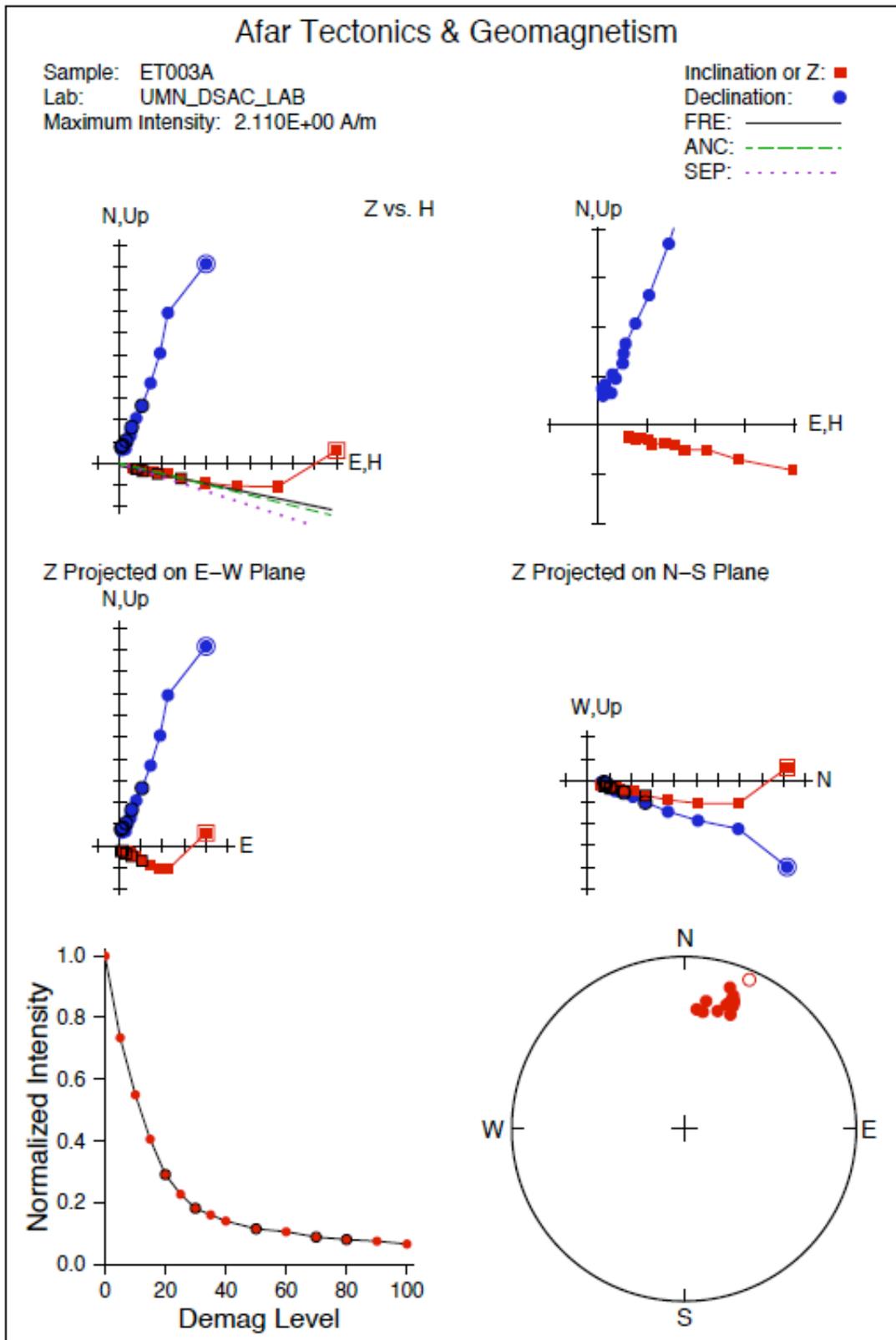
Figure 1a. Typical output from ZPLOTIT v2011-01 is shown for a single sample.
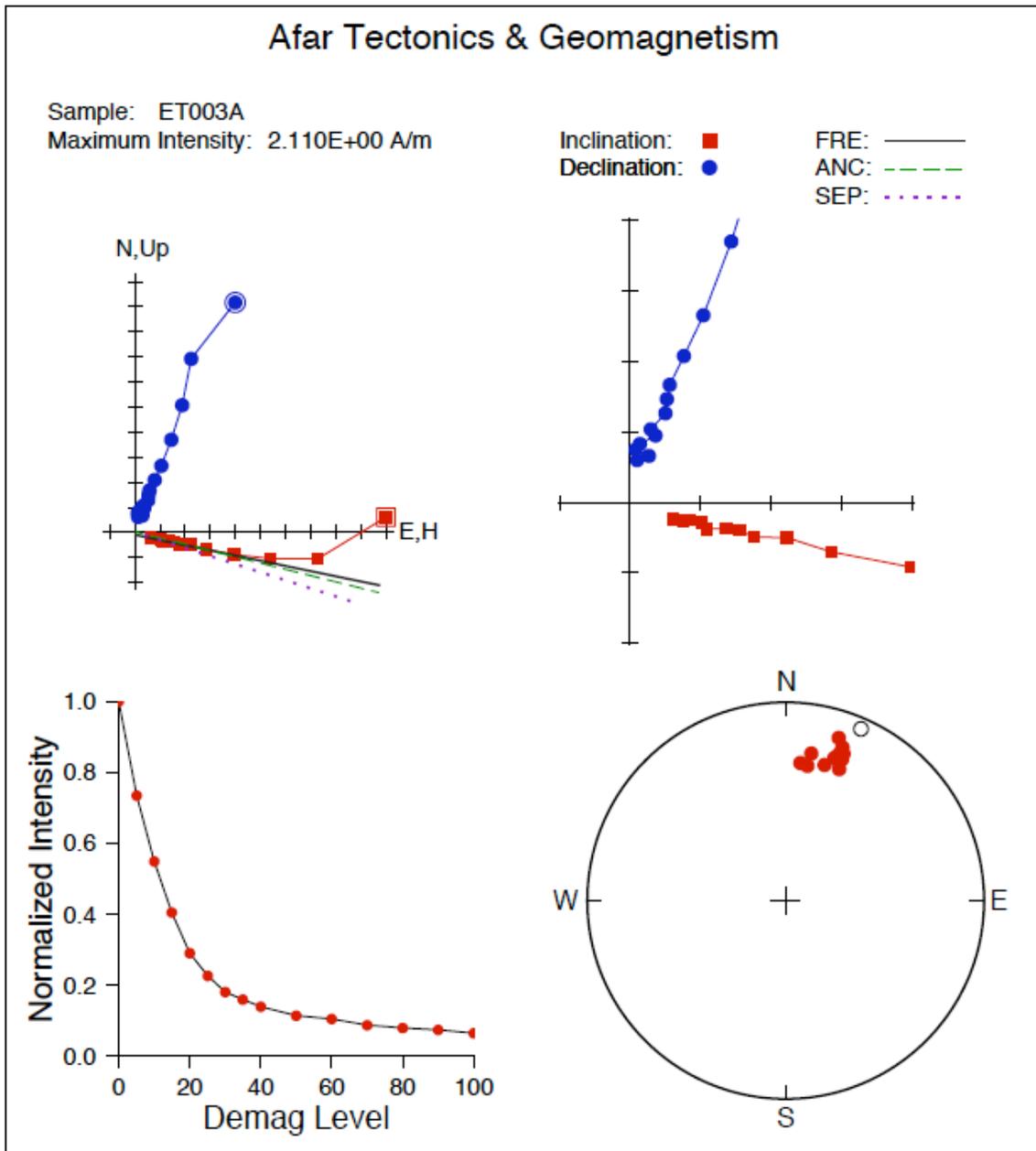
Figure 1b. Typical output from the previous version of ZPLOTIT (v2009-10), for comparison with the new version in Figure 1a.

File Name : 1062E-excursion.zplot   Date : Tuesday, September 29, 2009
User Name : Gary Acton
Sample Code : 39.0 mbsf
3

■ N,E

J/J max   Jmax= 7.00e-3

N,Up

E,H

0   Demag Level   70
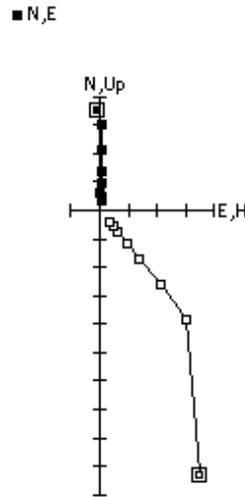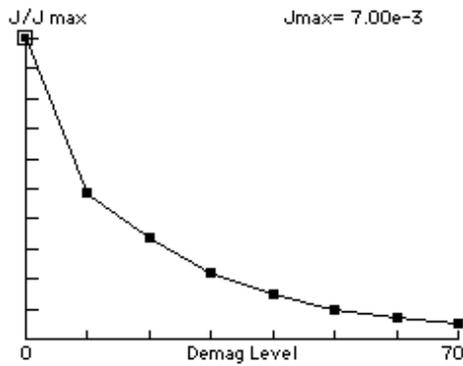
Demag	Decl	Incl	Intens
0.0	358.5	69.4	7.00e-3
10.0	360.8	51.9	3.40e-3
20.0	362.1	50.5	2.36e-3
30.0	363.2	51.6	1.54e-3
40.0	362.5	51.3	1.06e-3
50.0	362.5	50.7	7.00e-4
60.0	364.4	48.6	5.13e-4
70.0	369.4	50.0	3.48e-4

N

W   +   E

Equal Area   S
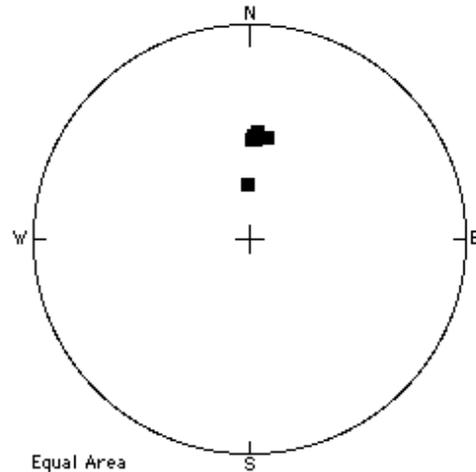
Figure 2. Example of the Zplot graphical user interface from a screen captured image. The location of plots on the screen and the type of vector demagnetization diagram can be modified within Zplot and saved in a user preference file.

Installing ZPLOTIT and Associated Software

Before ZPLOTIT can be installed it is necessary to have associated software installed. The installation is described for Mac computers with Mac OS X but can be extended to any Unix platform. This version of ZPLOTIT was tested on a MacBook Pro running Mac OS 10.6.6, with GMT version 4.5.5, and Fink version 0.29.17. Many geoscience departments have Unix workstations that have GMT and Fortran compilers already installed. In that case, installing ZPLOTIT is simple, as described below.

The first part of the installation instructions is aimed at getting Unix functionality on a Mac. You will need to have administrator privileges on the Mac you are using in order to install Unix Developer Tools, Fink, GMT, and Fortran compilers.

Installing Unix Developer Tools (Xcode)
When Mac OS X (10.1 through 10.6) is installed, most of the Unix applications that are typically part of Unix computers are not included. Instead the user needs to download and install what is referred to as "Developer Tools", which currently are in a package called Xcode. The Developer Tools are also commonly included on the installation disk that comes with new Mac computers. The applications include awk, grep, make, and many more applications along with c compilers. To find out more about Developer Tools and Xcode, see the Web sites at:

> http://developer.apple.com/technology/
> http://developer.apple.com/tools/xcode/

To download the latest version of Xcode, you will probably be required to become a member of the Apple Developers Connection (ADC). For either of the web pages listed above, you can login or become a member by clicking on the "Member Center" menu at the top of the web page.

The latest version of Xcode as of September 2009 was Xcode3.1.4 for MacOS 10.5 and Xcode 3.2.1 for MacOS 10.6. As of January 2011, Xcode 3.2.5 was available but I have not upgraded to it. The Fink project has recommendations for the latest version that is most compatible with the many Fink software packages. This generally follows slightly behind the latest Xcode releases.

To find the Xcode software, you may need to surf the web site a bit. As of January 2011, I found Xcode 3.2.5 following the links from "Member Center" to "Resources" and then to "Development Center" or devcenter.

Once you have downloaded Xcode, install it by double clicking on the xcode*.dmg file (where the * will depend on the version you downloaded), if it hasn't already opened automatically. If you still have problems mounting, use DiskImageMounter or the Disk Utility in the /Application/Utilities folder. You will be required to give a computer administrator password to install Xcode.

The whole installation process will take about 10 minutes.

Installing Fink

Fink is a project aimed at providing Unix software for Macs. See the Fink homepage at http://fink.sourceforge.net/ for more information. As of January 2011, both an Intel and PowerPC version are available. The versions are updated frequently. Below I give examples for downloading a recent version. If a newer version is available, get it instead. Currently, I am running Mac OS 10.6.5 and using the 64-bit Intel version of Fink.

Click on the Download link to get the latest version of the Fink software.
  Source location = http://fink.sourceforge.net/
          or http://www.finkproject.org/download/

Current versions I am using:
  File name = Fink-0.9.0-Intel-Installer.dmg
  Package as of 2010-12-25: 0.29.10

If you already have an earlier version of Fink installed, go to
  http://www.finkproject.org/download/upgrade.php
to learn how to quickly update your Fink. For example, the instructions at this web site for the case where you have not upgraded to a new operating system are to type the following in a terminal window:
  % fink --version   ← Determine your current version
  % sudo apt-get update
  % sudo apt-get dist-upgrade
  % fink selfupdate   ← This step will take about 30 seconds
                                to 15 minutes, depending on how
                                much upgrading is needed.

If you are upgrading Fink from a Mac OS 10.5 or earlier system, see the instructions at:
http://www.finkproject.org/download/10.6-upgrade.php?phpLang=en

Note, the above version is for Mac OS 10.6. Other versions of Fink can be used for older versions of Mac OS. The Fink homepage gives the pertinent information.

If you are installing Fink for the first time, once the file Fink-0.9.0-Installer.dmg has been downloaded, it will open automatically. To install, simply double click on Fink 0.9.0 Installer.pkg. This will create a directory /sw with the pertinent files.

The whole installation process will take you about 15 minutes.

Installing pdftk
The pdftk toolkit is used by ZPLOTIT to merge the individual pdf files that are created for each sample into the "merged.pdf" file. It has many other applications, which are described at http://www.accesspdf.com/pdftk/. This site also contains the downloadable version of pdftk for MacOS X at http://www.pdflabs.com/docs/install-pdftk/.

The NEW VERSION of pdftK (January 2011)
            pdftk-1.44-osx10.6.dmg
Click on the link, download, and install by clicking on the pdftk1.44_ox10.6.dmg file and then clicking on pdftk1.44_osX10.6.pkg.

OLD VERSION of pdftk (September 2009)
            pdftk1.12_OSX10.3.dmg.gz
Click on the link, download, uncompress, and install by clicking on the pdftk1.12_OSX10.3.dmg and then clicking on the pdftk1.12_OSX10.3.pkg.

Installing TextWrangler
TextWrangler is a free text-editing program with a lot of power. It is similar to BBEdit and it is free. You will likely need to use it unless you can edit with vi or some other text editor in a Unix terminal window.

Download the latest copy

Source Location = http://www.barebones.com/products/textwrangler/download.shtml
File name = TextWrangler_3.0.dmg (as of September 2009)

To install TextWrangler, you simply follow the instruction and drag the TextWrangler icon to the directory of your choice (I typically keep it in the Applications folder). The download and installation will take <5 minutes.

Downloading ZPLOTIT

The program ZPLOTIT, its subroutines, the Unix Makefile, and this document are in a file called Zplotit.tar.gz or Zplotit.sit. These files are available at the Web site

http://paleomag.ucdavis.edu/software/Zplotit/

Simply download either of them from the web page (Option click for Macs). The file will likely automatically uncompress if you are using a Mac. If it does not automatically uncompress, then uncompress it using Stuffit Expander or the gunzip command in a terminal window by typing:

% gunzip Zplotit.tar

If you are unfamiliar with terminal windows, then see the next section (Opening a terminal window). Next, extract the folders in "Zplotit.tar". On a Mac, you can simply double click on "Zplotit.tar". Alternatively, you can extract the folder from a terminal window by typing:

% tar –xvf Zplotit.tar

You should end up with three folders:
Zplotit
PCA
lplate.

Opening a terminal window

Program ZPLOTIT is run from a terminal window. If you have never used the Unix terminal application, it's a great time to start. The terminal application is located in the /Application/Utilities folder for Mac OS X. In the following and above, I assume the terminal window has a prompt of %. Commands are typed into the terminal window after the prompt (%).

After you have opened a terminal window, you will likely get a prompt ($), which is the prompt for the bash shell. I mainly use the csh and tcsh and so the following discussion will be based on using either of those Unix shells from the terminal application. You can switch shells from the default Mac OS 10.5 shell, which is the bash shell, in two ways. You can do a temporary switch by opening a terminal window and typing either /bin/csh or /bin/tcsh. Either shell is fine. If you want a more permanent switch, open the Terminal → preferences window. Click on the "Execute this command (specify complete path):" button and type either /bin/csh or to /bin/tcsh over the existing /bin/bash. Finally click the red button to close the preferences window. The next terminal window you open will be in the shell of your choice.

Creating a .cshrc profile

After opening a terminal window using the csh shell or tcsh shell, a file called .cshrc is read. This file must reside in your home directory. The .cshrc contains the paths (path = the directory where something exists) for executable programs, libraries, and manual pages, along with aliases and other user-defined preferences.

To create a .cshrc profile, first open a terminal window. Make sure you are using the csh (type /bin/csh). List the contents of your home directory. Because the terminal window automatically opens in your home directory, you only need type:

    % ls –a

Your home directory (which is /Users/acton for me) will need to have a file called .cshrc, which it will not have if you have never used the terminal application. If you commonly use terminal window and already have a .cshrc file, then you will understand how to edit your .cshrc file to include the lines listed below. If you have don't have a .cshrc, I have included a file in the zplotit folder, called zplotit-cshrc. Copy the zplotit-cshrc file to your home directory and then type:

% mv zplotit-cshrc .cshrc

To activate your .csrhc file, which you should do now and after the rest of the software is installed, type:

        % source .cshrc

Note, any time you open a terminal window in the csh or tcsh shells, it automatically sources (reads) the contents of the .cshrc file. If you ever make a change to the .cshrc file, you need to run "source .cshrc" from the terminal window while in your home directory.

You can list the contents of the .cshrc file by typing:

        % more .cshrc

or you could open it with TextWrangler (use "Open Hidden" from the File menu). The example .cshrc file is shown in Figure 3.

```
# @(#)Cshrc
####################################################################
#       .cshrc file
####################################################################

source /sw/bin/init.csh
set path = (. /bin /sbin)
set path = ($path /sw/bin /sw/sbin /usr/bin /usr/sbin)
set path = ($path /usr/local/bin)
set path = ($path /usr/local/lib)
set path = ($path /usr/libexec)
set path = ($path /Applications/Local/bin)
set path = ($path /Applications/Local/lib)

setenv MANPATH .:/sw/share/man:/usr/share/man:/usr/local/man:/usr/local/share/man
setenv INFOPATH
/sw/share/info:/sw/info:/usr/local/share/info:/usr/local/lib/info:/usr/local/info:/usr/share/info

####################################################################
#My personal favorite aliases, etc. - Gary Acton  ########
####################################################################
set history=40                  # save last 40 commands
.
.
.
and so on
```
Figure 3. Example .cshrc file for Unix csh shell.

In the above, the paths of the Fink software, GMT, compilers, etc. are listed (they reside in /sw/bin and the other /sw directories). WARNING: Below, I also discuss upgrading GMT outside of the Fink software, in which case you will need to upgrade your .cshrc file as discussed below. The source for ZPLOTIT is assumed to be placed in /Applications/Local/src/Zplotit. The executable version "zplotit" is in this directory also, and it will be also copied into /Applications/Local/bin automatically when ZPLOTIT is compiled. If you place the source or binary code in some other folder, then you will need to change the path or add an additional path. Below the paths, I have included some examples of setting aliases in the .cshrc file.

Installing GMT and Fortran77 Compilers on Mac OS X

Now that you have the developer tools and Fink, you can install GMT and Fortran compilers. These can be compiled in three different ways, not all of which work for all versions of MacOS or for all versions of GMT. Prior to 64-bit Intel processors and Snow Leopard (MacOS 10.6), installing Fink and using Fink versions of GMT worked relatively flawlessly. Fink is now stable for MacOS 10.6, but GMT 4 has some features that differ between what is available through Fink versus that directly from the GMT web site. Thus, I will describe three ways in which I have installed GMT, all of which have worked at various points for MacOS 10.4, 10.5, or 10.6. The first few steps are the same for all 3 methods

METHODS 1, 2, and 3
1. Open a terminal window.
2. Type the following
   % /bin/tcsh
3. Type
   % /sw/bin/pathsetup.sh
   This command fixes the paths in your .cshrc file, which actually should already have been done when you created the .cshrc profile above.
4. Type the following commands (and be prepared to enter the root or superuser password for your computer):
   % sudo fink update
   % sudo fink self-update
   % sudo fink update-all
   The fink commands seem somewhat redundant but they work, and as you will see after typing the first command, fink basically

tells you what to type next.

5. Now install the Fortran compiler by typing
   % sudo fink install fort77
   Depending on whether you have previously installed fort77 or not, you may get the message that there is nothing new to install or the package will install. Other Fortran77 compilers should work but I prefer to use the fort77. Other compilers such as the g77 compiler can be a bit finicky.

METHOD 1

6. To install GMT from the main GMT homepage,
   a. Go to http://gmt.soest.hawaii.edu/
   b. Click the "Download" link on the left
   c. Click on the "INSTALL FORM" link within the text on the right under the section entitled "Fast-track for (repeat) Unix/Linus/OSX users"
   d. Under the section entitled "A. Basic Requirements", click on install_gmt.sh and download this to the directory in which you want GMT to be stored, e.g., /Applications/Local/src. You could also download this file by going directly to:
      http://gmt.soest.hawaii.edu/gmt/install_gmt.sh
   e. Below the install_gmt.sh link, you should see the Install Form. The install form will be displayed with buttons pre-selected for the default options of the install form. I only changed a couple of these. My preferences are shown below for the few categories where I did not use the defaults:

   1. Select the appropriate netCDF library option:
   ○ netCDF 3.6.x is already installed
   ● Please get and install the latest netCDF 3.6.x
   ○ I already have the netcdf.tar.Z archive, just install it for me
   Give full pathname to the netCDF directory: [   ]

   I did this because I do not follow the various updates of netCDF nor do I care to. Instead, I just get whatever the GMT page thinks is the newest version.

   ----
   3. Select the components you want (bzip2 sizes indicated):
   ☑ GMT source code (1.1 Mb, the main GMT programs, REQUIRED)
   ☑ GMT Shared Data (0.04 Mb, shared run-time files, REQUIRED)
   ☑ GMT Documentation (24 Mb, PDF & HTML versions of Cookbook, Tutorial and Man pages, examples)
   ☑ GMT Supplemental Programs (3.9 Mb, see section C.10 below for details)
   ☑ GSHHS Low-resolution Coastlines (3.9 Mb, Basic-resolution (CLI) GSHHS coastlines, REQUIRED)
   ☑ GSHHS High-resolution Coastlines (9.3 Mb)
   ☑ GSHHS Full-resolution Coastlines (29.0 Mb)

   I wanted to have all the coastline data files, etc., and so I checked all the boxes.

----

11. Select supplemental packages to install:
- ☑ DBASE: Extracting data from NGDC DEM and other grids
- ☑ GSHHS: Global Self-consistent Hierarchical High-resolution Shoreline tools
- ☑ IMGSRC: Extracting grids from global altimeter files (Sandwell/Smith)
- ☑ MECA: Plotting special symbols in seismology and geodesy
- ☑ MEX: Interface for reading/writing GMT grdfiles for ⦿ Matlab or ◯ Octave
- ☑ MGD77: Programs for managing and plotting MGD77 data
- ☑ MGG: Programs for making, managing, and plotting *.gmt data
- ☑ MISC: Manipulate PostScript, create bit-patterns, extract netCDF columns
- ☑ SEGYPROGS: Plot SEGY seismic data files
- ☑ SPH: Spherical triangulation, Voronoi construction and interpolation
- ☑ SPOTTER: Plate tectonic backtracking and hotspotting
- ☑ X2SYS: Track intersection (crossover) tools (REQUIRES MGG and MGD77)
- ☑ X_SYSTEM: MGG-specific Track intersection (crossover) tools (REQUIRES MGG)
- ☐ XGRID: X11 graphical editor for netCDF-based .nc files (REQUIRES Xlibs)

Note: The selected packages will only be installed if you also selected the supplemental tar archive above.
package, the mex package requires Matlab or Octave, and xgrid requires various X11 libraries.

---

11. Additional information for MEX (Matlab or Octave):

Enter head of the Matlab system directory if you selected Matlab above: [   ]
Note: You can leave the path blank under OS X or if $MATLAB is defined in your environment and points t
Enter directory for *.m files for the GMT/Matlab-Octave interface: [   ]
Enter directory for *.mex files for the GMT/Matlab-Octave interface: [   ]

> I use Matlab occasionally, so I also selected the Mex box and the Matlab button. I have not used Mex before, but maybe I will in the future

    f. To download the form, click on the "Get Parameters" button at the bottom of the web page. Next you need to save it to your computer by using RIGHT CLICK on the mouse OR LEFT CLICK and hold the control key

        i. THEN select "This Frame --> Show only this frame" from the popup menu

        ii. NEXT save the file, which should have the name GMTparam.txt

7. Make sure that the GMTparam.txt file and the install_gmt.sh file are in the same directory where you want to install GMT

8. Within the terminal window and while in the directory that contains install_gmt.sh, type:

```
% chmod a+x install_gmt.sh
% sh install_gmt.sh GMTparam.txt
```

The script will download the tar files it needs and then start compiling the programs. This may take several minutes, so be patient.

The install script has failed for various reasons in the past, although the last couple installation were fast and easy. The most common reason for prior difficulties were due to errors that occur during installation of the "Mex" package. Thus, you may not want to install Mex if you have trouble.

After successful installation, you may want to clean up the /Applications/Local/src directory by deleting the tar files:
GSHHS_high.tar.bz2
GSHHS_full.tar.bz2
GSHHS_coast.tar.bz2
GMT_suppl.tar.bz2
GMT_src.tar.bz2
GMT_share.tar.bz2
GMT_doc.tar.bz2

9. Edit your .cshrc file
   a. Add the three lines below as shown in Figure 4.
      setenv NETCDFHOME /Applications/Local/src/netcdf-3.6.3
      set path = ($path /Applications/Local/src/GMT4.5.5/bin)
      append_path MANPATH /Applications/Local/src/GMT4.5.5/man

```
# @(#)Cshrc
###################################################################
#       .cshrc file
###################################################################

source /sw/bin/init.csh
setenv NETCDFHOME /Applications/Local/src/netcdf-3.6.3
set path = (. /bin /sbin)
set path = ($path /Applications/Local/src/GMT4.5.5/bin)
set path = ($path /sw/bin /sw/sbin /usr/bin /usr/sbin)
set path = ($path /usr/local/bin)
set path = ($path /usr/local/lib)
set path = ($path /usr/libexec)
set path = ($path /Applications/Local/bin)
set path = ($path /Applications/Local/lib)

setenv MANPATH .:/sw/share/man:/usr/share/man:/usr/local/man:/usr/local/share/man
append_path MANPATH /Applications/Local/src/GMT4.5.5/man
setenv INFOPATH
/sw/share/info:/sw/info:/usr/local/share/info:/usr/local/lib/info:/usr/local/info:/usr/share/info

#####################################################################
#My personal favorite aliases, etc. - Gary Acton  ########
#####################################################################
set history=40                    # save last 40 commands
.
.
.
and so on
```

Figure 4. Example .cshrc file for Unix csh shell with GMT compiled locally.

10.   Type
       % source ~/.cshrc
       % rehash   ← this will allow all recently compiled
              programs to be found when you attempt to execute them.

METHOD 2
   6. To install GMT from fink,
       % sudo fink install gmt   ← YES, you must install the associated
              packages (netcdf, etc.) when asked.
       % sudo fink install fort77
       % rehash   ← this will allow all recently compiled
              programs to be found when you attempt to execute them.

METHOD 3

7. Install the executable version of GMT from fink
   % sudo apt-get update
   % sudo apt-get install gmt   ← YES, you must install the
          associated packages (netcdf, etc.) when asked.
   % rehash   ← this will allow all recently compiled
          programs to be found when you attempt to execute them.

Installing ZPLOTIT

The last step is to compile ZPLOTIT. For the novice Unix user, please simply follow these commands exactly. The more experienced user may wish to change the directory in which the program and executables are installed. If you do that, then you must understand how to change path names in the .cshrc file and in the Makefile. If you don't want to hassle with that and you are using a Mac, do the following

1. Create a folder called "Local" in the main "Applications" folder.
2. Create a folder called "src" in the "Local" folder.
3. Create a folder called "bin" in the "Local" folder.
4. Create a folder called "lib" in the "Local" folder.
5. Move or copy the Zplotit, lplate, and PCA folders into the "/Applications/Local/src" folder.
6. In a terminal window, change directories by typing:
      % cd /Applications/Local/src/Zplotit
5. Compile the program by typing:
      % make
6. Rehash the list of executable programs
      % rehash

This should have installed various executables (ZPLOTIT and its subroutines) within a folder /Applications/Local/bin. Now you are ready to give it a test run.

If you want to install ZPLOTIT elsewhere and/or want to store the Zplotit folder and associated folders elsewhere, then you should change paths that are listed at the top of the following files:

      Makefile (change the BIN parameter to the appropriate directory)
      zplotit (change the ZPLOCAL parameter to the appropriate
            directory)

Units and Nomenclature

Magnetic units have become complicated by the required conversion from the cgs system often used in laboratories to the SI system used by journals and by the somewhat interchangeable usage of the magnetic induction field (**B**) and the magnetizing field (**H**) and of the magnetization polarization (**J**) and magnetization (**M**) (Shive, 1986).

The units used in ZPLOTIT for demagnetization steps for Alternating Fields (AF) are in milliTesla (mT) and for temperature are in °C. The intensity of magnetization is assumed to be in A/m. Input data sets should be converted to these units. Conversion from cgs units can be accomplished using method #2 describe by Shive (1986), in which the field in Oersted (Oe) is converted to mT, where 1 mT = 10 Oe, and the magnetization in emu/cm^3 is converted to A/m, where 1 A/m = 1E-03 emu/cm^3.

ZPLOTIT Input: Paleomagnetic Data Sets

Input data sets must be Unix text files. NOTE: a Unix text file differs from a PC or Mac text file mainly in the way carriage returns are handled. They are different, so convert your Mac or PC text files to Unix text files, which can be done by several programs. I use one called TextWrangler (freeware, with installation information above). I have also written a shell script called mactounix, which converts a Mac text file (e.g., the text file you get when you save an Excel file to a tab-delimited text file on a Mac) to a Unix text file. This script is included in the Zplotit folder.

The format for the ZPLOTIT input data sets (Figure 5) follows from that used in Zplot. The first six lines are comment lines, the purposes of which in Zplot are fairly obvious from the descriptive term at the beginning of each line. ZPLOTIT ignores the first 4 lines, so the user could put whatever information he or she might want in those lines. The fifth line should start with the phrase "Project: " followed by a project description. The program actually skips the first 9 characters on the fifth line and then reads the next 40 characters. Thus, keep your project description to 40 characters or less. This limit is necessary as the project description is plotted as the title for each plot and long titles will not fit. If you don't

have a specific project description, you may leave the project description blank or use some generic term such as the date or "Vector Demagnetization Diagram", etc. The sixth and seventh lines of input are also ignored, although the seventh line is the column descriptions, which should be tab delimited for general use.

The remaining lines are data. There should be no blank lines interspersed with the data or at the end of the data file. A line of data includes 7 primary columns:

1) Sample: This is a sample identification character string with up to 50 characters. The sample ID must be at least one character and presumably will be several. If the first character is an asterisk (*), then the line of data is ignored. Quote symbols (") are ignored.
2) Project or Labcode: This must be a character string that is 12 characters long. This is a somewhat meaningless column, which is a hold over from Zplot, where it was referred to as the "Project" column. I kept it in the format because I still use Zplot occasionally and so I wanted the ZPLOTIT files to be compatible with Zplot. For ZPLOTIT, I typically replace "Project" with "Labcode" as the column descriptor and then put in a character string that is 12 characters long that describes the lab and instrument. For example, data from the *JOIDES Resolution* have the code JR__LCDC_LAB, were the LCDC indicates the measurements were made with the LongCore magnetometer with DC SQUIDS. Similarly, data from the UC Davis lab have the code UCD_UCDC_LAB, where the UCDC indicates the measurements were made with the U-Channel magnetometer with DC SQUIDS. Feel free to put whatever code or words you like, just make sure it is 12 characters long, e.g., "ZPLOTIT-DATA".
3) Demag: This is the demagnetization step in mT or ℃. It can be an integer or real number. Because AF demagnetizers generate peak fields that are less than 200 mT, ZPLOTIT assumes that if the highest demagnetization is less than or equal to 200, the data are AF demagnetization steps. If the highest demagnetization is >200, the data are assumed to be thermal demagnetization steps. These assumptions are used in doing the automated PCA.
4) Declination: This is the declination, which can be given as an integer or real number. Ideally, it is a real number with precision in the tenths to hundredths of a degree.

5) Inclination: This is the inclination, which can be given as an integer or real number. Ideally, it is a real number with precision in the tenths to hundredths of a degree.
6) Intensity: This is the intensity of magnetization in A/m, which should be given as real number in scientific notation. Decimal (and integer) values can be read, but these are likely to truncate significant digits.
7) Depth: This is a depth, such as a depth in a drill hole or stratigraphic height. Alternatively, enter 0 if no depth is recorded. The value can be an integer or real number.

The eighth column is for a "Comment" and is not used by the ZPLOTIT. Similarly, additional columns can be included in the data file after the comment column, none of which will be read or used by ZPLOTIT.

EXAMPLE DATA SETS

Example data sets are provided in the folder Zplotit/Examples. These include Excel files and the text files derived from them (converted to Unix text files). The smaller data set (Afar-example-data.xls and its Unix text version Afar-example-data.txt) is in the sub-directory Afar-example. The data are for 21 samples, which is a small subset of a larger data set published in Acton et al. (2000). A larger data set (388 samples from below 700 mbsf) is provided in the ANDRILL-example folder, which is a data set published in Acton et al. (2008). The data file is an Excel file called ANDRILL-data-2008-12.xls, with its Unix text file version called ANDRILL-data-2008-12.txt. The top of this data set is given in Figure 4.

Sample	Labcode	Demag	Declination	Inclination	Intensity	Depth	Comment
AND-2A-0010.89A	UCD_UCDC_LAB	0	350.40	21.91	3.570E+00	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	100	344.53	19.60	2.680E+00	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	150	343.33	22.21	2.030E+00	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	200	340.48	28.07	1.330E+00	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	250	343.17	31.26	7.800E-01	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	300	357.34	31.91	3.490E-01	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	350	5.40	43.82	1.680E-01	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	400	5.20	45.46	9.950E-02	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	450	14.92	51.45	5.080E-02	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	500	43.25	74.49	2.110E-02	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	550	239.45	24.41	8.260E-03	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	600	231.57	82.45	2.160E-02	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89A	UCD_UCDC_LAB	650	268.33	66.78	2.540E-02	10.89	AND-2A-0010.89A basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	0	162.98	14.24	3.480E+00	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	5	161.77	14.36	3.516E+00	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	10	161.63	14.99	3.425E+00	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	15	161.60	15.35	3.075E+00	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	20	161.55	15.64	2.590E+00	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	25	161.58	15.74	2.152E+00	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	30	161.67	15.73	1.756E+00	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	35	161.73	15.56	1.451E+00	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	40	161.74	15.37	1.206E+00	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	45	161.71	14.75	9.802E-01	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	50	161.84	14.19	8.337E-01	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	60	161.54	13.00	6.690E-01	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	70	161.28	11.87	5.880E-01	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	80	160.97	10.88	5.260E-01	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	90	160.57	9.95	4.700E-01	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0010.89B	UCD_UCDC_LAB	100	160.76	8.88	4.510E-01	10.89	AND-2A-0010.89B basalt/volcanic breccia
AND-2A-0011.92A	UCD_UCDC_LAB	0	130.82	-27.01	1.030E+01	11.92	AND-2A-0011.92A basalt/volcanic breccia
AND-2A-0011.92A	UCD_UCDC_LAB	100	130.46	-24.57	8.920E+00	11.92	AND-2A-0011.92A basalt/volcanic breccia
AND-2A-0011.92A	UCD_UCDC_LAB	150	126.61	-22.35	7.820E+00	11.92	AND-2A-0011.92A basalt/volcanic breccia

Figure 5. Example of the data format for a ZPLOTIT data file.

The input file must have the following properties:
  * No more than 200,000 lines of data. This is the array size set within zplotgmt.f, which can be increased. Given that most samples will have no more than about 20 demagnetization steps, this allows up to about 10,000 samples to be plotted. It seems unlikely that anyone will want to store more than that many pages of plots in a single "merged.pdf" file.
  * No more than 100 demagnetization steps per sample. This is an adjustable array size in line3d.f and zplotgmt.f.
  * The data must be sorted by sample name and then by demag step.

ZPLOTIT Principal Component Analysis (PCA)

The characteristic remanent magnetization direction (ChRM) can be estimated from the paleomagnetic data using principal component analysis (PCA) (Kirschvink, 1980) and Fisher statistics (Fisher, 1953). For the PCA direction, ZPLOTIT finds the best-fit line that passes through the vector demagnetization data in two ways. First, it uses the "FREE" option of PCA in which the line is fit through the data free of the constraint that the line passes through the origin of vector demagnetization diagram. Second, it uses the "ANCHOR" option of PCA in which the line is fit through the data but is anchored to the origin of

vector demagnetization diagram. A third estimate of the ChRM is made from the Fisherian average of data from the highest two to four demagnetization steps used in the FREE PCA analysis, as discussed further below. We refer to this estimate as the Stable End Point (SEP), although it may not always be a true stable end point as the magnetization may still be decaying for the highest few demagnetization steps (see discussion below).

In the first two cases, ZPLOTIT uses an iterative search to find and delete data from demagnetization steps that are outliers, where an outlier is defined as a datum that degrades the fit of the line relative to all other demagnetization data used. ZPLOTIT requires that data from at least N steps are used to find the best estimates of the FREE and ANCHORED PCA direction, where N is given by the user. N must be at least 2, and one would ideally want four or more steps for a more robust fit. If the MAD < 1.5°, ZPLOTIT stops seeking better fits. This is an arbitrary cutoff but prevents data being tossed for minor improvements in the quality of the PCA fit. Ultimately, ZPLOTIT seeks to use as many steps as possible between *the user-supplied range of demagnetization steps* to find a best estimate of the ChRM direction. ZPLOTIT will only search within the user-supplied range. The user is "required" to supply the lowest and highest AF and the lowest and highest THERMAL steps over which the search is done (Sorry, but even if you only have AF or only have THERMAL data, you currently have to type a couple extra numbers … greater flexibility may occur in future versions if there is any demand). For example, to avoid contamination by low-coercivity or low-unblocking temperature overprints, one might NOT want to use NRM data from demagnetization steps <25 mT or <250°C in the PCA. The user might also want to avoid using noisy results such as when spurious ARMs are acquired during higher AF demagnetization step or when thermal alteration occurs at higher thermal demagnetization. Hence, one might give a range of 25 to 80 mT for the AF search and 250°C to 600°C for the THERMAL search. If you wanted all the data to be used, then you could use the full range of your data, e.g., 0 to 200 mT and 0°C to 800°C.

As an example, suppose you have a data set where each sample has been progressive AF demagnetized from 0 to 80 mT with 5 mT steps or increments. Lets say a common low-coercivity overprint was present, but could be removed in peak alternating fields of about 5 to 15 mT. Lets say that you also think in general, most of the 14 demagnetization steps between 15 and 80 mT were good data (very few spurious measurements

for any sample). You might demand that at least 10 steps be used in the PCA, between a range of 15 and 80 mT. If the spurious measurements were truly rare, ZPLOTIT would typically use all 14 of the demagnetization steps. It only throws out outliers and it stops seeking outliers once it reaches the user-defined limit (10 in this example).

The search algorithm has one other subjective criterion in that it will remove the lowest demagnetization step first, if it degrades the line fit and if there are at least 6 steps available for analysis. For example, if the line fit through the 14 demagnetization steps of a sample (with conditions similar to that described in the example above: demagnetization steps at 5 mT increments from 15 to 80 mT) gave a MAD of 5.5 but gave a MAD of 5.4 when the 15 mT step was excluded, then the 15 mT step would be considered an outlier *even if removing one of the other steps reduced the MAD value more*. This is done because the lowest demagnetization step is more likely to be contaminated by low coercivity or low unblocking-temperature overprints. One of the instances where this criterion may be enacted is when the demagnetization paths in vector demagnetization diagrams decay toward the origin but have slight curvature. Such behavior is not uncommon particularly when a primary (high coercivitity or high unblocking temperature) component has been slightly overprinted by a lower coercivity or unblocking temperature component, such as might be caused by recent field overprinting or drilling overprints. In such cases, the low coercivity/unblocking component may appear to be removed completely by lets say 15 mT or 250°C, but small curvature that is difficult to see may still exist at slightly higher levels of demagnetization. It would thus be beneficial to avoid including the lowest demagnetization step if they degrade the fit even slightly before considering other possible outliers, particularly when there are a sufficient number of data (~6) for determining the PCA line.

The stable end point (SEP) direction typically is the vector average of only data from the highest three demagnetization steps used in the PCA analysis. If the mean of these three directions has a precision parameter <200 (lower values indicate higher dispersion), then data from the fourth highest demagnetization step is included in an attempt to improve the average. If this new datum differs from the mean of the other three by more than 10° angular distance, then it is ignored also. ZPLOTIT then uses an iterative search to find and remove the direction that is the largest outlier of the 3 or 4 highest demagnetization steps. ZPLOTIT will remove one of the 3 or 4 directions, in which case the Fisherian average

may include as few as 2 directions. Comparison of the SEP with the PCA direction can be useful for indicating where magnetization components exist even after demagnetization or where progressive demagnetization has been ineffective in revealing linear demagnetization paths (such as when the demagnetization paths make great circles on the stereonets).

The output of the PCA includes two tab-delimited tables and a text file with the user-supplied PCA search criteria:

> pca-outliers-removed.txt ← results with outliers removed
> pca-outliers-included.txt ← results with no outliers removed
> search-criteria-YYYY-MM-DD.txt ← This contains the search criteria supplied by the user

The pca-outliers-removed.txt gives the preferred PCA results. The pca-outliers-included.txt file is included should one want to examine the data with no outliers removed. Both files can be opened and edited in Excel or other spreadsheet applications. An example table is shown in Figure 6, after being opened in Excel and formatted a bit to facilitate this discussion. The green columns show the PCA FREE results, the yellow columns show the PCA ANCHORED results, and the purple columns give the SEP results. The last column is the angular difference between the PCA FREE and SEP results. This would be near zero for a single vector component that decayed to the origin of the vector demagnetization diagram. In such cases, all three estimates of the ChRM would be virtually identical.

Sample	Inclination Free	Declination Free	MAD	Length	Deviation Angle	Steps	Low	High	Option	Inclination Anchored	Declination Anchored	MAD	Length	Deviation Angle	Steps	Low	High	Option	Inclination SEP	Declination SEP	Kappa	N	ANGDIS
ET002A	-4.8	198.1	0.81	2.60E+01	5.98	5	30	70	FRE	-5.4	192.3	1.49	2.87E+01	0	10	30	80	ANC	-5.5	190.4	3927.3	3	7.6
ET002B	-8.1	194.1	0.78	3.23E+01	0.43	7	30	80	FRE	-8.4	193.8	0.25	3.23E+01	0	7	30	80	ANC	-8.5	193.6	26546.2	3	0.6
ET002C	-11.4	193.3	0.99	3.02E+01	3.01	7	30	80	FRE	-8.9	191.5	1.05	2.45E+01	0	6	35	80	ANC	-7.2	190.4	1781.8	3	5.1
ET002D1	-9.7	189	0.68	3.62E+01	0.15	9	20	80	FRE	-9.8	188.9	0.27	3.62E+01	0	9	20	80	ANC	-10	188.8	15738.5	3	0.4
ET002D2	-11.4	193.3	1.29	3.26E+01	0.77	8	25	80	FRE	-10.7	192.9	0.52	3.76E+01	0	9	20	80	ANC	-10.4	192.6	54827.5	3	1.2
ET002E1	-9.5	191.5	0.41	2.97E+01	0.53	7	30	80	FRE	-9.8	191.2	0.23	2.97E+01	0	7	30	80	ANC	-10.1	191	164482.5	3	0.8
ET002E2	-5.1	195.9	8.35	3.77E+01	2.01	5	535	595	FRE	-6.4	196.2	5.22	3.77E+01	0	5	535	595	ANC	-5.4	197.3	299.9	3	1.4
ET002F	-12.5	190.4	0.61	4.03E+01	0.3	9	20	80	FRE	-12.6	190.6	0.25	4.03E+01	0	9	20	80	ANC	-12.8	190.7	204600.2	3	0.4
ET002G	-16.1	184.3	1.2	4.50E+01	0.23	7	30	80	FRE	-15.9	184.4	0.39	4.50E+01	0	7	30	80	ANC	-15.7	184.4	32140.3	3	0.4
ET003A	11.7	26.2	2.35	4.55E+00	10	5	20	80	FRE	14	20.5	1.39	3.93E+00	0	6	20	60	ANC	17.8	13.2	146.4	4	14
ET003B	16.4	10.7	1.45	3.30E+01	0.52	9	20	80	FRE	16.8	10.5	0.53	3.30E+01	0	9	20	80	ANC	17.3	10.1	27503.6	3	1.1
ET003C	8.8	25	3.72	3.73E+01	4.15	5	420	595	FRE	8.6	23.7	3.63	3.73E+01	0	5	420	595	ANC	-45.9	235.8	11.9	2	134.5
ET003D	23.2	8	1.17	2.44E+01	0.94	8	25	80	FRE	22.7	8.7	0.5	2.44E+01	0	8	25	80	ANC	22.3	9.4	16878.5	3	1.6
ET003E	22.5	0.3	1.05	2.51E+01	0.61	9	20	80	FRE	22	0.1	0.41	2.51E+01	0	9	20	80	ANC	21.3	359.8	12501.7	3	1.3
ET003F	28	356.4	1.08	2.85E+01	0.7	8	25	80	FRE	27.9	357.5	0.34	1.70E+01	0	5	40	80	ANC	27.8	357.5	18117.9	3	1
ET004A	21.8	359.3	1.14	2.55E+01	1.64	9	20	80	FRE	23	358.5	0.75	2.55E+01	0	9	20	80	ANC	24.2	357.5	3124.2	3	2.9
ET004B	18.1	13.5	0.76	3.44E+01	1.74	8	25	80	FRE	18.8	12.3	0.68	4.03E+01	0	9	20	80	ANC	20.3	9.3	891.5	3	4.6
ET004C	21.8	352.7	1.5	3.67E+01	1.51	5	420	595	FRE	21.7	353.2	1.4	3.67E+01	0	5	420	595	ANC	27.7	145.4	3.4	2	123.9
ET004D	21.9	0.6	1.07	3.31E+01	0.28	8	25	80	FRE	22.1	0.5	0.48	3.31E+01	0	8	25	80	ANC	21.9	0.2	17225.1	3	0.4
ET004E	14.2	2.1	1.41	1.73E+01	0.46	9	20	80	FRE	14.5	2.4	0.64	1.73E+01	0	9	20	80	ANC	14.9	3.1	1514.7	3	1.2
ET004F	28.1	1.6	1.36	1.98E+01	0.71	6	25	80	FRE	28.3	1	0.86	1.98E+01	0	8	25	80	ANC	27.2	0.2	1900	3	1.5

Figure 6. Example table generated by ZPLOTIT with the PCA results.

Columns in the table include:
MAD: Maximum Angular Deviation.
Length: Distance from origin of the vector demagnetization space to the centroid of the data used to find the best-fit line.

Deviation Angle: The angle between the best-fit line and a line that passes through the origin and the centroid.

Steps: Number of demagnetization steps used in finding the best-fit line.

Low: The lowest demagnetization step used in finding the best-fit line.

High: The highest demagnetization step used in finding the best-fit line.

Option: The PCA fitting option, which is either FRE = PCA FREE or ANC = PCA ANCHORED.

Kappa: The Fisherian precision (dispersion) parameter.

N: The number of directions averaged in the SEP estimate.

ANGDIS: The angular distance between the PCA FREE direction and the stable end point direction.

After running ZPLOTIT once (see "**Running ZPLOTIT**" below), you may scroll through the plots and see if the demagnetization range and other parameters that you set are appropriate. You may also see line fits that you do not agree with for one reason or another. If you want to "individualize" the fit for specific samples, you can either comment out certain steps within your master data file by placing an asterisk (*) in front of the data line, deleting the data line, or extracting only those steps you want used and moving them to a new data file. Rerun ZPLOTIT to incorporate your changes. Such individualization can be tedious for large data sets, but may be necessary for critical intervals.

The user should always beware of batch processing. The PCA table has enough columns of information to catch most types of aberrant results. As a check, I often plot the FREE, ANCHORED, and SEP results against each other to see where deviations occur. I also plot the MAD and ANGDIS downhole and see where noise or artifacts may be present. The idea behind automating the PCA is to make processing more objective and a lot faster (seconds versus weeks for large data sets). The caveat is that the automation can sometimes miss subtle changes in the magnetization direction that an experienced interpreter could note. The best results will occur when you use your paleomagnetism skills in conjunction with the ZPLOTIT automated PCA.

ZPLOTIT Plots

For each sample, a one page graphic is created that now includes six plots. The upper left plot is a vector demagnetization diagram of all the

data for a sample using the H vs. Z projection. It includes the declination (solid blue circles) and the inclination (solid red squares), with each successive data point connected with a blue and red line, respectively. In addition, three lines are shown that represent the PCA results. These are only shown for the inclination to avoid cluttering the plot. The solid very dark gray line is the free-fit PCA line (FRE), the dashed green line is the anchored PCA (ANC), and the dotted purple line is the stable endpoint (SEP) (see the section above for a description of these parameters).

The upper right plot is an enlarged or zoomed-in version of the vector demagnetization diagram (H vs. Z). ZPLOTIT first tests to see if three times (3x) magnification is needed. If none of the data have intensities <33% of the maximum intensity for the sample, then no plot is generated, as no magnification is needed. If even one data point has an intensity <33% of the maximum intensity, then a 3x magnified plot is created. If more than 25% of the data have intensities that are <10% of the maximum intensity, then a 10x magnification is used. The absolute spacing of the tic marks is the same as in the full-scale vector demagnetization diagram, which aids in comparing the results between the two plots.

The middle two plots are new to Zplot v2011-01. The left and right plots are vector demagnetization diagrams showing all the data for a sample using the H vs. E projection and the H vs. N projection, respectively.

The lower left plot shows the decay of the normalized intensity, where the normalization is relative to the maximum intensity for the sample.

The lower right plot is a Equal-Angle Stereonet (Wulff Projection). Symbols are hollow circles when the direction is in the upper hemisphere and solid circles when the direction is in the lower hemisphere. For more on projections, see Fisher et al. (1987).

For final publication quality figures, you may want to extract a plot, remove the PCA lines, or make other cosmetic changes. Any page in the PDF file can be extracted in Acrobat or edited in standard graphic programs. For example, I import the PDF file into Adobe Illustrator, select the page I want, and then edit as desired for publication.

Running ZPLOTIT

ZPLOTIT is run from a terminal window. If you have a paleomagnetic data file (lets assume a file exists and is named pmag-data.txt), simply change directories to where the file resides and type "zplotit". For example, if the file was on your desktop, you would type:

       % cd Desktop   ← if you were in your home directory or
       % cd ~/Desktop   ← does the same as above regardless of
                                 which directory you are currently in.

Then run ZPLOTIT
      % zplotit

The program will then ask you some questions. An example run is shown below for the example file Afar-example-data.txt. In the example, my input is given in red and the text that is output by the computer is in black.

```
% zplotit

 INPUT filename:              Afar-example-data.txt
 Number of Data  =  346
 Enter the minimum AF step to start the PCA
 For example, if you only want to use steps
 greater than or equal to 20 mT, enter 20.
20

 To further limit the search,
 Enter the maximum AF step to end the PCA
 For example, if you only want to use steps
 less than or equal to 60 mT, enter 60
80

 Enter the minimum THERMAL step to start the PCA.
 For example, if you only want to use steps
 greater than or equal to 200 deg C, enter 200.
400
 Enter the maximum THERMAL step to end the PCA.
 For example, if you only want to use steps
 less than or equal to 600 deg C, enter 600.
600

 Enter the minimum number of steps you would
 prefer the program to use. If the number of
 demagnetization data are less than or
 equal to this minimum value, then the program
 will not seek to remove outliers.
 **** Enter an INTEGER *****
 Typically, I use 4 or more
5

 Would you like the depth (in meters)
 included on the plot (y or n)?
n

 ET002A
 Current PCA limits: 20 80    Minimum # of steps to use:  5
 Number of steps measured for this sample:  21
 Number of Data remaining to plot =  325
```

```
ET002B
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  17
Number of Data remaining to plot =  308
ET002C
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  16
Number of Data remaining to plot =  292
ET002D1
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  17
Number of Data remaining to plot =  275
ET002D2
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  16
Number of Data remaining to plot =  259
ET002E1
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  17
Number of Data remaining to plot =  242
ET002E2
Current PCA limits: 400 600    Minimum # of steps to use:  5
Number of steps measured for this sample:  15
Number of Data remaining to plot =  227
ET002F
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  17
Number of Data remaining to plot =  210
ET002G
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  16
Number of Data remaining to plot =  194
ET003A
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  15
Number of Data remaining to plot =  179
ET003B
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  17
Number of Data remaining to plot =  162
ET003C
Current PCA limits: 400 600    Minimum # of steps to use:  5
Number of steps measured for this sample:  15
Number of Data remaining to plot =  147
ET003D
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  16
Number of Data remaining to plot =  131
ET003E
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  17
Number of Data remaining to plot =  114
ET003F
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  17
Number of Data remaining to plot =  97
ET004A
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  17
Number of Data remaining to plot =  80
ET004B
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  17
Number of Data remaining to plot =  63
ET004C
Current PCA limits: 400 600    Minimum # of steps to use:  5
Number of steps measured for this sample:  15
Number of Data remaining to plot =  48
ET004D
Current PCA limits: 20 80    Minimum # of steps to use:  5
Number of steps measured for this sample:  16
Number of Data remaining to plot =  32
ET004E
Current PCA limits: 20 80    Minimum # of steps to use:  5
```
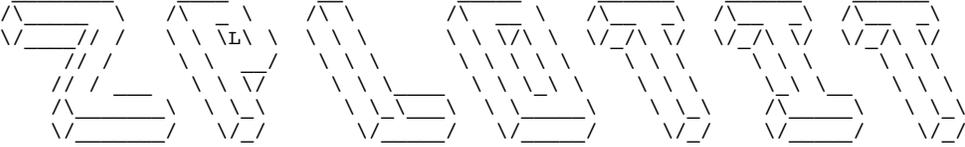
```
 Number of steps measured for this sample:  16
 Number of Data remaining to plot =  16
 ET004F
 Current PCA limits: 20 80    Minimum # of steps to use:  5
 Number of steps measured for this sample:  16
 Number of Data remaining to plot =  0

Beginning to make plots. BE PATIENT!

ZPLOTIT has made  10 figures made so far. Please be patient while the rest are completed.


*********************************************************************************
*                   Program zplotit processing completed.                     *
*********************************************************************************

Principal component analysis (PCA) results are in: pca.txt.
Orthogonal vector plots, demagnetization diagrams, and stereonets are in: merged.pdf.

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Processing Completed

%
```

On MacBook Pro computers with the Intel core duo processor, ZPLOTIT typically takes about 0.65 seconds/plot or about one minute to process and create diagrams for a single data file with about 100 samples. ZPLOTIT will create several files as it runs. When it is done, it cleans up its mess and stores all the graphic files in a single PDF file called "merged.pdf". The PCA output is in pca.txt. The PDF file can be opened with Acrobat or Mac preview and individual pages can be extracted and edited by most standard graphics program (I use Adobe Illustrator). The pca.txt file is a tab-delimited text file that can be opened in Excel.

Examples

To test that your installation worked, do the following:

        % cd /Applications/Local/src/Zplotit/Examples/Afar-example
        % zplotit

Then answer the questions as was done in the above example run. After the program is done, you can compare the images and pca.txt files that

you generated with the merged-archive.pdf and pca-archive.txt files that I generated when I ran the program.

Acknowledgments

References

Acton, G., Florindo, F., Jovane, L., Lum, B., Ohneiser, C., Sagnotti, L., Strada, E., Verosub, K.L., Wilson, G.S., and The ANDRILL-SMS Science Team, Palaeomagnetism of the AND-2A Core, ANDRILL Southern McMurdo Sound Project, Antarctica, *Terra Antartica, 15*, 2008. Available at http://paleomag.ucdavis.edu/research/acton/Publications/Preprint-Acton-ANDRILL_SMS_Paleomag.pdf.

Acton, G., A. Roth, and K.L. Verosub, 2007. Analyzing micromagnetic properties with FORCIT software, *Eos, 88*, 230.

Acton, G.D., Tessema, A., Jackson, M., and Bilham, R., 2000. The tectonic and geomagnetic significance of paleomagnetic observations from volcanic rocks from Central Afar, Africa. *Earth Planet. Sci. Lett., 180*, 225-241. Available at http://paleomag.ucdavis.edu/research/acton/afar.html.

Butler, R.F., 1998. **Paleomagnetism: Magnetic Domains to Geological Terranes**. Blackwell Scientific Publications, Electronic Edition, Available at http://www.geo.arizona.edu/Paleomag/book/.

Dunlop, D.J., 1979. On the use of Zijderveld vector diagrams in multicomponent paleomagnetic studies. *Phys. Earth Planet. Inter., 20*, 12-24.

Kirschvink, J.L., 1980. The least-squares line and plane and the analysis of palaeomagnetic data. *Geophys. J. R. Astron. Soc., 62*, 699-718.

Shive, P.J., 1986. Suggestions for the use of SI units in magnetism. *Eos 67*, 25.

Wessel, P. and Smith, W.H.F., 1998. New, improved version of the Generic Mapping Tools released. *Eos 79*, 579.

Wessel, P. and Smith, W.H.F., 2004. The Generic Mapping Tools (GMT) version 4 Technical Reference and Cookbook. Available at: http://gmt.soest.hawaii.edu/gmt/gmt_services.htmlSOEST/NOAA.

Zijderveld, J., 1967. A.C. demagnetization of rocks: Analysis of results. In: D.W. Collinson, K.M. Creer, and S.K. Runcorn (Editors), **Methods in Paleomagnetism**. Elsevier, New York, pp. 254-286.