

Chapter 1

Chapter 9 - Problems

1.1 Problems

Before you start, make sure you have the most recent distribution of the **PmagPy** software (see PmagPy website) and see instructions in Problem 2 in Chapter 5 for help in accessing the data files. Find the data files for these problems in the `Essentials_Examples/Chapter_9` directory.

Problem 1

The remanence vectors in the `Chapter_9` directory saved in `zijd_example.csv` were measured during the thermal demagnetization of a specimen. The first column is the specimen name. The second is the temperature to which the specimen was heated, before cooling in zero field. The next columns are intensity, declination and inclination respectively for each treatment step.

- Write a python program in a Jupyter notebook to make a Zijderveld diagram using python.

Follow these steps: 1) Read in the data. 2) Convert the vectors to x, y, z . 3) Plot x versus $-y$ using some solid symbol and then connect those dots with a line. This is the horizontal projection of the vector so x should be on the horizontal axis and $-y$ should be up. (Think about this! You are plotting a map view and Y is the East direction. So $+y$ should be to the right of x .) 4) Now plot x versus $-z$. Here again the projection is unusual because $+z$ is the down direction. Therefore it should be down. [It is $-z$ that is up!]

Use a different (open) symbol for these points and plot them on the same plot as your x, y data.

- b) The same data were saved without headers in a file named *zijd_example.dat*. Plot them using the program **ipmag.zeq**. [Hint: check the help message by typing **help(ipmag.zeq)** to figure out how...]. Compare your answer from Problem 1a with that produced by the PmagPy program **ipmag.zeq**. Rewrite your program until it is right; you can cheat by looking in **ipmag.zeq** and the two function modules **pmag.py** and **pmagplotlib.py** if you have to, but make your program “your own”.
- c) Assuming these data have already been converted to geographic coordinates ($x = N, y = E, z = V$), what is the approximate direction (e.g. NE and up) of the low stability component of magnetization? The high stability component of magnetization? What is the most likely remanence carrying mineral in this specimen? Thinking about what you learned about VRM in Chapter 7, for the low stability component to be a VRM acquired over the last million years, at what temperature would the rock have to have been held to acquire this component viscously over a million years?
- c) Run **ipmag.zeq** again, this time setting the `-begin_pca` and `-end_pca` flags to calculate best-fit lines through the two components and a great circle through all the data except the NRM and last steps. Look at these new images in your notebook. In a markdown code block explain which interpretation makes the most sense?

Problem 2

- a) Use the program **sundec.py** from the command line to estimate what the drilling azimuth was using the following sun compass information: You are located at 35° N and 33° E. The local time is three hours ahead of Universal Time, so we subtract -3 from local time. The shadow angle for the drilling direction was 68° measured at 16:09 on May 23, 1994.
- b) Now use the **pmag.dosundec** function from the **pmagpy.pmag** module to do the same thing. Note, you will have to import the **pmagpy.pmag** module with the notebook command:

```
import pmagpy.pmag as pmag
```

Problem 3

- a) The direction of NRM for these problem is given in geographic coordinates along with the attitude of dipping strata from which the site was collected:

$$D = 336^\circ, I = -2^\circ, \text{bedding dip} = 41^\circ, \text{dip direction} = 351^\circ.$$

Plot the NRM direction on an equal-area projection (see Appendix ??). Then using the procedures outlined in Appendix ?? (or slight modifications thereof), determine the “structurally corrected” direction of NRM that results from restoring the strata to horizontal.

Check your answer with the program **di_tilt.py**

- b) Now try the same problem using the pmagpy.pmag function `dotilt()` in a Jupyter notebook.

Problem 4

Now consider a more complex situation in which a paleomagnetic site has been collected from the limb of a plunging fold. On the east limb of a plunging anticline, a direction of NRM is found to be $I = 33^\circ, D = 309^\circ$. The bedding attitude of the collection site is $\text{dip} = 29^\circ, \text{strike} = 210^\circ$ ($\text{dip direction} = 120^\circ$, and the pole to bedding is azimuth = 300° , inclination = 61°). The trend and plunge of the anticlinal axis are trend = 170° , plunge = 20° . Determine the direction of NRM from this site following structural correction. To do this, first correct the NRM direction (and the pole to bedding) for the plunge of the anticline. Rotate the fold axis to horizontal first. Then complete the structural correction of the NRM direction by restoring the bedding (corrected for plunge) to horizontal. Use the function `pmag.dotilt()` in the **PmagPy** package to do your rotations in an Jupyter notebook.

Problem 5

Write a python program to convert $D = 8.1, I = 45.2$ into geographic and tilt adjusted coordinates. Use the geographic coordinates as input to the tilt correction program. The orientation of the laboratory arrow on the specimen was: azimuth = 347° ; plunge = 27° . The strike was 135° and the dip was 21° . (NB: the convention is that the dip direction is to the “right” of the strike). For this it would be handy to use the **numpy** module which

allows arrays, instead of simple lists. To make an array A of elements a_{ij} :

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix},$$

the command would be:

```
import numpy as np
A=np.array([[a11,a12,a13],[a21,a22,a23],[a31,a32,a33]])
```

The import command can be put at the beginning of the program as always. Use your programs to convert direction to cartesian coordinates and back again.

Compare your answer to the one given by **di_geo.py** and **di_tilt.py** that are callable from the command line in an interactive mode. Rewrite your code until you have it right. NB: **di_tilt.py** uses dip and dip direction instead of strike and dip. These are completely interchangeable, but dip and dip direction is unique, while strike and dip requires some convention like “dip to right of strike”).

Problem 6

An intrepid group called “the red team” sampled a lava flow on Bastille day in 2006. The team, the sampling sites and the notebook page are shown in Figure 1.1a,b and c respectively. In this problem we will look at some real data collected from this lava flow.

- a) Make a new directory in your homework directory for this problem. Do not include spaces in the directory name! Run the **Pmag GUI** graphical user interface by typing **pmag-gui.py** on the command line. [Note that PC users may have to omit the .py termination.] This problem does not use the Jupyter notebook!

Change directories into your new homework directory and fire up **pmag-gui.py**. Choose data_model 3



Figure 1.1: Paleomagnetic site NS034. a) Photo of the “red” team. b) Photo showing sample holes with labels. The picture was taken in an easterly direction (see look direction in notebook page.) c) Page from the notebook.

b) Convert your data files to the MagIC format. The measurements were made in the SIO paleomagnetic laboratory in the SIO lab format. Specimens were demagnetized using the AF and thermal methods and the data are in the Chapter_9 directory, named ns_a.mag and ns_t.mag respectively.

- Click on the button labeled ‘1. convert magnetometer files....’ and choose the ‘SIO format’ before clicking on ‘Import file’.
- Click on ‘add’ and select ns_a.mag to start. Check the ‘AF Demag’ box. If you open the file you will see that the specimen names have the format: ns034a1. The terminal number distinguishes this from the sample, ns034a and the terminal letter distinguishes the sample from the site, ns034. So choose the number of terminal characters.... to be ‘1’. The default sample-site naming convention of XXXXY is already correct. Now fill in the Location name to be ‘North Shore Volcanics’ and click on ‘OK’ at the bottom of the page.
- Repeat this procedure for the thermal demagnetization data. Be sure to click on the ‘Thermal (includes thellier but not trm)’ button instead of AF Demag.

- After clicking on ‘OK’, select ‘Next step’ and click on ‘OK’ to combine both measurement files into a single file.
 - Skip the panel ‘Step 3:’ by clicking on ‘OK’ to complete the conversion step.
- c) Click on the button labelled ‘2. Calculate the geographic/tilt-corrected directions’. Here you could fill out the form using the notebook information in Figure 1.1. But someone has typed in all the data you need for you. They are in the ‘Orientation file’ named ‘orient.txt’ in the Chapter_9 directory.
- Click on the button ‘Import Orientation File’ and select that file. This should fill in the most of the information for you. Note that the red team’s convention was to mark a sample with a ~ if it broke off before orientation and to put the method code ‘SO-GT5’ in the magic_method_codes column. All “sample_flag”s are set to ‘g’ (good) by default.
 - Click on ‘Save Orientation File’ and then ‘Calculate Sample Orientations’. These samples were oriented with a Pomeroy orientation device, so, select the first option under orientation convention.
 - The magnetic declination of the compass was set to 0 (notebook entry says “MagDec set to zero”)., so we need to correct all the information for magnetic declination. Select “Use the IGRF value at the lat/long and date supplied” option.
 - You will need to supply the hours to subtract from local time to get to GMT here because all the sampling times were in local time. The entry in the notebook page says that GMT is five hours ahead of local time, so enter “-5” here. Click on ‘OK’.
 - You can enter a number of sampling codes. Here, select field drilling, location with GPS, Pomeroy orientation device options.
 - There is only one bedding plane estimate, so skip the bedding averaging option.
- d) Look at the demagnetization data.

- Click on the ‘Demag GUI’ button. You should have a panel of plots including a Zijderveld plot, an equal area projection with all the demagnetization directions, a intensity decay curve, and a blank site level equal area projection.
- You will see a list of data to the left. You can toggle the orientation from geographic to specimen or stratigraphic (tilt corrected) by choosing the coordinate system. You can also change the declination for the horizontal axis of the Zijderveld diagram with the Zijderveld plot pull down menu. The default is to use the X=East direction.
- Calculate the best fit direction for this specimen by first clicking on the ‘add fit’ interpretation option and selecting data from the second demagnetization step to the end in the ‘bounds’ drop down menus at the top left of the panel. Choose the default to calculate a best-fit line by simply leaving the Interpretation Type set to ‘line’. You will see the data re-plotted with the best-fit line. Save the interpretation by clicking on the ‘save’ button.
- Step through all the data until you have interpreted all the specimens. If you set ‘Mean Options’ to Fit 1, how each interpretation shows up in the site window.
- Under the ‘File’ menu, select ‘Save MagIC tables’. Use the default age of 1100 Ma for these rocks. Calculate the site mean by averaging all the specimens with Fisher statistics. Then click on ‘OK’.
- Exit the program by selecting the ‘Quit Demag-gui’ option under the ‘File’ menu.

e) Explore the MagIC database tables that you have created.

- Look at the chapter on the MagIC database and file formats in the PmagPy cookbook.
- Click on the Pmag GUI’s button ‘3. fill Earth-Ref data’ and verify the relationship of the specimens to the samples. Click on ‘Save and continue’.
- Repeat this for Step 2.

- For Step 3, you must insure that site ‘ns034’ belongs to ‘North Shore Volcanics’, which you must add with the ‘Add a new location’ button. Then click on the cell below locations and select that.
- These were extrusive igneous rocks, so select those options for the site_class column.
- find ‘Basalt’ under the site_lithology column and ‘Lava Flow’ for site_type.
- Then click on ‘Save and continue’.
- Step 4 allows you to verify that everything you have done was propagated correctly to the site level. Click on ‘Save and continue’.
- For step 5, you must let the program know what type of location these samples were taken from, so select ‘Outcrop’ under that column. Then select ‘Save and continue’.
- Step 6 deals with ages. Fill in stratigraphic correlation for the geochronology method (GM-CC-STRAT), Ga for the age_unit and 1.1 for the age.
- Click on ‘Save and continue’ to finish.

You can explore your handiwork by looking at the files created in your homework directory with Excel or some other spreadsheet program.