Earth Science 1023a/2123a
Lab 3
Magnetics

Purpose: This lab will serve to demonstrate the use of a magnetometer, a device used to measure minute variations in the Earth's magnetic field. These variations can then be used to locate a body buried within the Earth if that body exhibits a magnetic variation from the surrounding material.

Theory and Applications: The Earth has a global magnetic field produced by internal processes within the Earth itself. On the surface of the Earth, this field is easy to detect (it causes a compass needle to point towards the *north magnetic pole*).

Being able to take precise measurements of the strength and direction of the magnetic field using a *magnetometer* is useful for a number of applications. In geophysical exploration, this is used in two primary ways, one as an exploration tool to locate minerals which may be magnetic (mostly magnetite or other minerals containing iron, but occasionally other metals and sulphides) or to produce regional maps of geologic structures that are covered by *overburden* (soil, swamps, etc.). Additionally, magnetic are useful in environmental, engineering and forensic applications where there is a need to locate a buried object that may be magnetic. In this lab, we will be attempting to locate a buried pipe, but this could also be used to locate unexploded ordinance, buried oil drums, ancient weaponry or sunken ships provided that these objects contain sufficient magnetic contrast to their surrounding material.

The Magnetic Field: The magnetic field is measured in terms of flux density, the details of which would be covered in a physics course. The important thing to know about the magnetic field is that we are measuring something that would normally be represented numerically as a *vector*. When you use a compass, you are only measuring the direction of the (horizontal component of the) magnetic field, and not its strength. With a magnetometer, you will either measure the strength of the horizontal component of the field (when working near the equator) or the vertical component of the field (when working closer to the poles). Within Canada, we usually measure the *intensity* (strength) of the vertical component only.

The magnetic field intensity is usually expressed in terms of a unit called the Tesla (T). Since one Tesla is very large compared to the strength of the Earth's field, we commonly use the nano-Tesla (nT) which is one-billionth of a Tesla (1 nT = 10^{-9} T). In some older literature, a nano-Tesla is also referred to as a gamma (γ), however in this lab we will use nT. Earth's field varies from approximately 30,000 nT at the equator to 60,000 nT at the poles (Reynolds, 1997).

Drift: For the sake of time constraints on this lab, we will be ignoring one important component of observing the Earth's field in that the field also varies with time. If you set up a magnetometer and record measurements over the course of a day, you might find variations of up to 200 nT. If you are doing a survey over the course of several days, and you are interested in variations of 10 nT, then this presents a problem. This problem is caused by diurnal variations of the Earth's field, as well as the interaction of the *ionosphere* (the upper layer of our atmosphere) with the *solar wind* (charged particles being ejected from the sun). A full treatment of this topic would take many weeks and much mathematics, so at this level it is usually sufficient simply to be aware of this phenomenon when performing magnetic surveys. It is generally a good idea to check the website http://www.spaceweather.gc.ca/sfst-2-eng.php before surveying to check the current conditions.

The simplest way to adjust for time variations within the magnetic field is to use a *base station* and do *drift corrections*. This involves returning to the same location periodically, known as a base station, to repeat the measurement in order to see how the magnetic field is varying with time. These data can then be used to correct your survey data to remove some of the effects of the time variations. We will do base station readings in this lab, but will not require a drift correction calculation.

Half-width: There is a useful technique employed during the processing of magnetic data that can help estimate the depth of the body being observed. This is known as the *half-width* estimation. This is best illustrated, as in Figure 1.

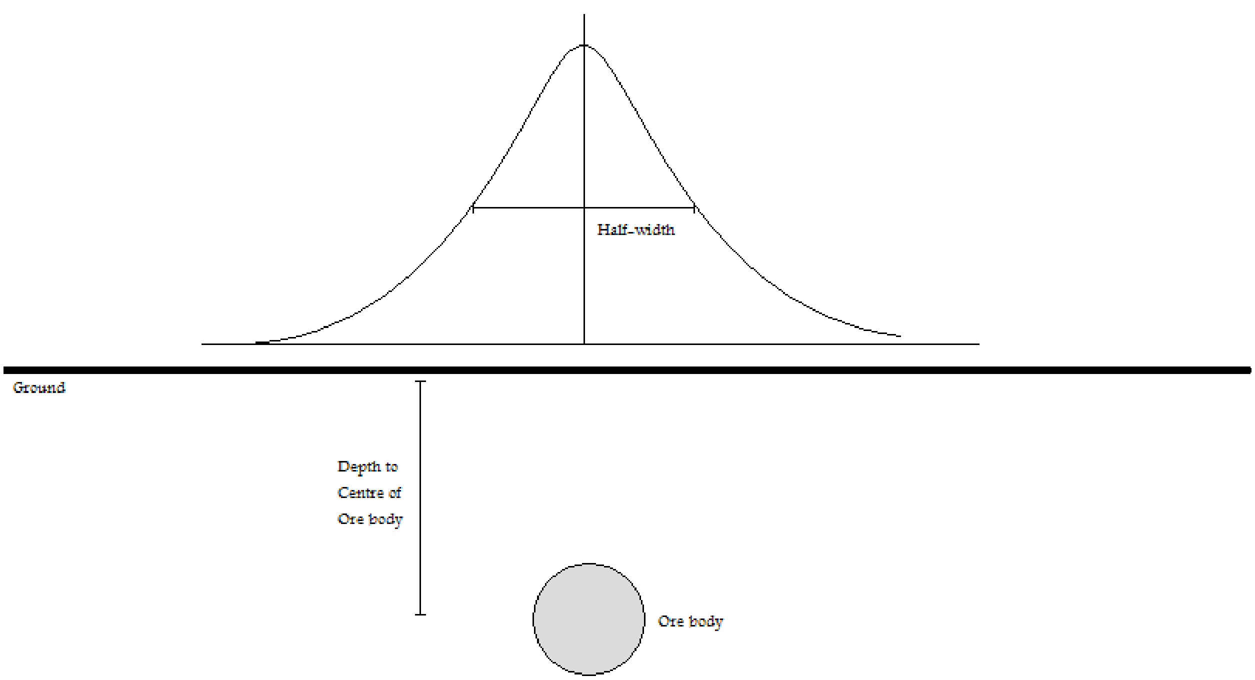

Figure 1: The half-width is the width of the plotted anomaly at half of the peak anomaly height.

The half-width is the width of the plotted anomaly at half of the magnitude of the total anomaly. For a buried sphere or horizontal cylinder, the half-width is roughly equal to the depth to the centre of the buried object. For a vertically oriented plate, the depth estimate is considered to be $^{3}/_{8}{}^{th}$ of the half-width to the top of the plate (Reynolds, 1997).

Method: In this experiment a flux gate magnetometer will be used to measure the vertical component of the Earth's magnetic field along a survey line at the back of the Visual Arts Building on campus. Along the survey line, you will pass over a buried metallic pipe. While the target today is a pipe, this same technique could be used on a localized, horizontally-oriented and magnetized intrusion. The measurements will be carried out at regular (0.5 metre) intervals along the survey line.

1. Using a tape measure and a compass, establish accurately the position of the survey line.
2. Collect the required data (survey position, magnetic reading at each survey position (station) and the time of each reading) during the field experiment. Record the position, reading, and time at each station. Also, collect data after every 10 meters for a drift observation, recording the reading and the time.
3. (Time permitting) Bring small metal objects (coins, keys, belt-buckles…) near the magnetometer to determine the effect of these items on the quality of the readings. Qualitatively determine how far away these objects need to be from the magnetometer to have little-to-no effect.

Treatment of Data:

1. Plot the readings of the magnetic field against the position along the line. This gives you a magnetic profile of the area.
2. Assuming that the anomalous magnetic field is entirely due to a buried pipe, use the half-width estimation to find the depth to the buried pipe.
3. Plot the base station readings versus time. This gives you an idea of how much drift occurred over the course of the survey.
4. Was the drift a significant source of error for the experiment? What other possible errors may have occurred during the experiment?
5. (Bonus) Perform a full drift correction on the data, and repeat questions #1 and #2.

Bibliography:

Reynolds, J.M. (1997) An Introduction to Applied and Environmental Geophysics, John Wiley and Sons, London. 796 pp.