

## GY 112 Lecture Notes Why Geologists Date

### Lecture Goals:

#### A) Why date?

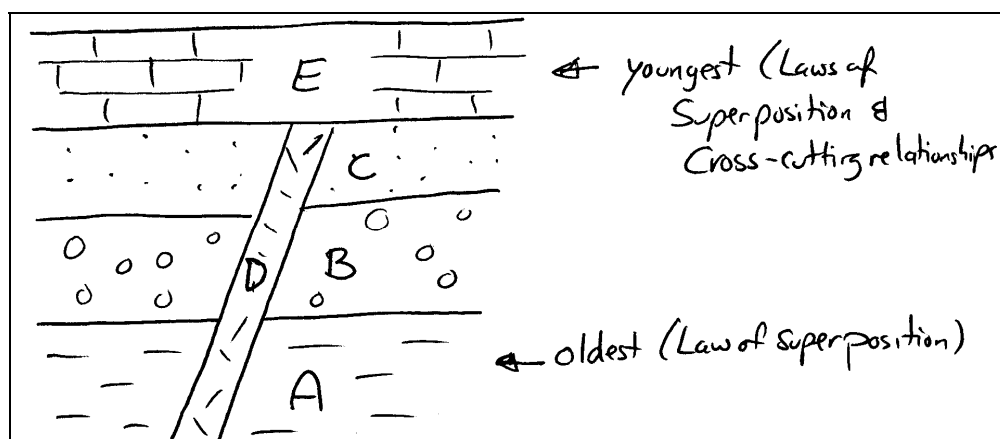
#### B) Absolute versus Relative Dating Techniques

#### C) Specific types of dating: Fission track, Paleomagnetism

*Textbook reference: Levin 7<sup>th</sup> edition (2003), Chapter 1; Levin 8<sup>th</sup> edition (2006), Chapter 2 and 3 (plus stuff from Doug's personal experience)*

#### A) Why Date?

Geologists date geological materials in order to sort out the sequence of events responsible for their formation. In other words, we *date to put a time frame on events in Earth history*. We have already started to do this in the GY 112 labs, specifically the Week 2 exercises. Using the principles that you used then, the cartoon below should be relatively easy to sort out:



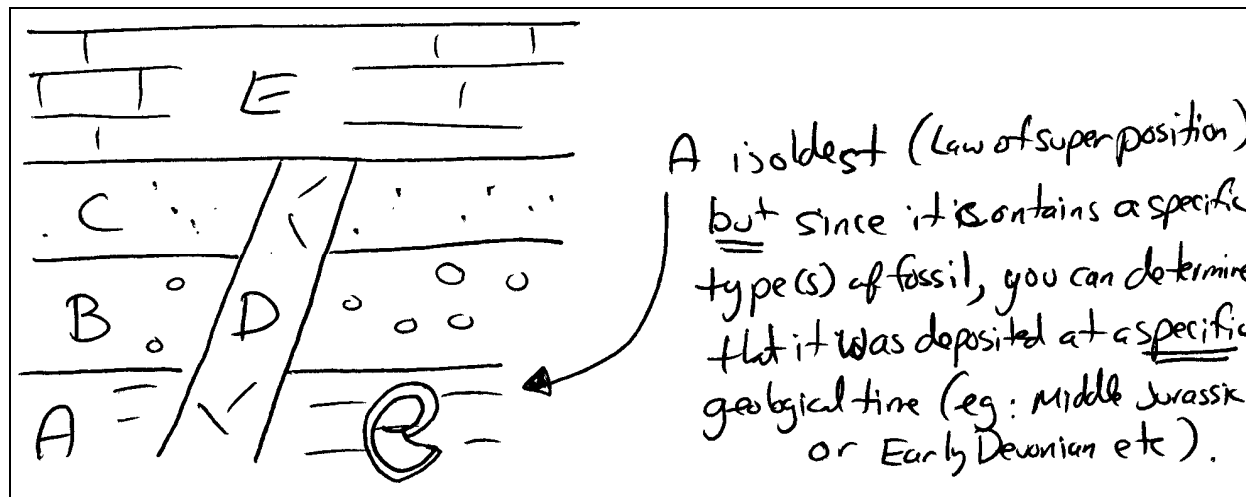
Both of these cartoons allow you to "date" the order of events, but only in a relative sense (e.g., A occurred before B which occurred before C etc). For this reason, this is considered to be a **relative dating** technique. In contrast, methods that provide an actual number for an age (e.g., 365.2 MA), are considered to be **Absolute dating** techniques.

#### B) Absolute versus Relative Dating

There are several relative dating techniques that geologists use (including the sequence of events approach above), but the most useful is **Paleontology** *the study of fossil life*. In fact, in this course, we will spend a considerable amount of time discussing paleontology (some would say way too much time). But this simply reflects the importance of "**beasties**\*" in Earth history.

\*Note: Dr Haywick, who is *not* a paleontologist regards all past and present living things as "beasties". This includes all fossils, all insects, all animals, most GY 112 students and anything else that either walked, crawled, swam, floated, flew etc. Other geologists (including my friend Dr Clark who *is* a paleontologist) probably find offence with my use of this term. Too bad.

We won't go into detail about paleontology just now (give it about a week), but here is how fossils can help you date rocks. Consider the following cartoon:



You will be able to determine that layer A is older than layer B and C, but that is all you can say. However, if layer A contains a specific type of fossil, say a snail, you may be able to put a better date on that layer. The argument goes, if a sedimentary rock contains a fossil, the sediment that comprises that rock must be about the same age as the fossil it contains. So if you can date the fossil, you can date the rock. Now most fossils cannot be absolutely dated with radiometric or other techniques (see the next section), but paleontologists have amassed a lot of data about the various beasts that have been around on this planet. They have a pretty good "sequence of fossils" that can allow geologists to date sedimentary rock layers relatively accurately (but not yet in an absolute sense). So let's go back to our cartoon. If layer A contains a snail, you can ask a qualified paleontologist (say Dr. Clark) about what it is and when it lived. If you're lucky, she/he will respond "*This gastropod is Species A and it lived in the lower part of the Devonian Period*". They can usually get more accurate than this (down to specific biochronozones), but even if this is as good as they can get, it is far better than simply concluding that layer A is older than layer B etc.

Now let's turn to the absolute methods of dating. These are methods that put an absolute date (e.g., 345 MA) on rocks and other geological materials. There are many different methods that can be used, but we will consider 4 in this class:

- 1) Radiometric Dating
- 2) Stable Isotope Stratigraphy
- 3) Fission Track Dating
- 4) Paleomagnetism

The first two will be examined in dedicated lectures; radiometric dating will be the subject of our next lecture; stable isotope stratigraphy the subject of the next lecture after that. We'll consider fission track and paleomagnetism shortly. But first, a comment about "absolute dates".

Absolute dating is generally considered to be **quantitative** which means that it gives you an accurate and generally reproducible data. Not all methods are as absolute as others. Radiometric dating and fission track dating give straight numbers, but stable isotope stratigraphy and paleomagnetism require a certain amount of human interpretation. You get quantitative data, but you have to match these numbers to some sort of previously interpreted stratigraphy. I guess this makes them **qualitative** absolute dates. You'll see what I mean in a few minutes.

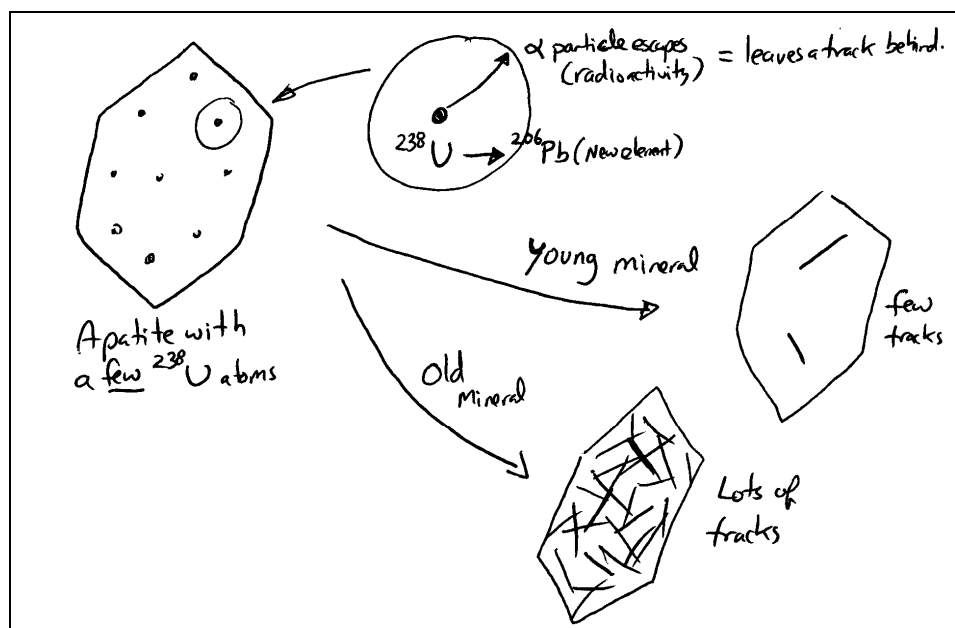
### C) Fission track dating



Fission track dating uses similar principles to radiometric dating, with a twist. Both methods rely on the presence of radioactive elements (**radioactive isotopes**) within some minerals and measure ages based upon the amount of **decay** that has occurred. We will spend a whole lecture talking about radiometric decay later and I don't want to repeat everything twice. If you can't wait, download the lecture on radioactive decay/radiometric dating. Otherwise, just assume that some isotopes (e.g.,  $^{238}\text{U}$ ,  $^{40}\text{K}$  etc.) decay over time.

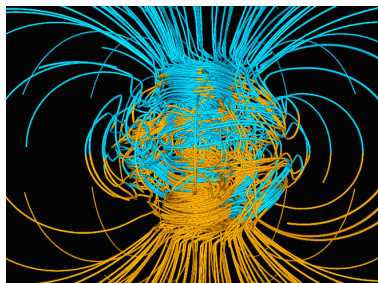
Fission track dating is especially useful for dating various types of volcanic sequences (e.g., ash beds) as they contain certain minerals as phenocrysts that contain some of these radioactive isotopes. There are many minerals that can be used, but since I have had some experience looking at apatite in ash beds in New Zealand, I'll focus on this mineral. Apatite  $[\text{Ca}_5(\text{PO}_4)_3(\text{F},\text{Cl},\text{OH})]$  is a phosphate mineral (number 4 on the Mohs' Hardness list) that can contain very minor amounts of radioactive isotopes such as  $^{238}\text{U}$ . This isotope is unstable, and will eventually break down (through **fission**) to produce a new element ( $^{206}\text{Pb}$ ) and **radioactivity**. The radioactivity is actually particles that are expelled from the nucleus at a great speed (again, we go into this in more detail tomorrow). Ask yourself, what would happen to the apatite crystal if one of these radioactive particles was expelled from a uranium isotope *within* the mineral? Well ultimately, the structure of the apatite is affected along the path the radioactive particle moved. A track is left behind (see photo of tracks within a crystal on the left), hence the term *fission track* dating. Now here is the important bit; *the longer the period of time that has passed, the larger the number of radioactive particles that have been expelled from unstable isotopes and hence, the more tracks you get.*

Sounds relatively easy doesn't it? Just count tracks in a few mineral grains and get an age. Well like all simple concepts, there is more to it than this. Simply extracting the mineral like apatite takes time and skill. You need to count tracks in many minerals, and since phenocrysts of the useful minerals may not be all that common, you often have to "pick" through a lot of rock before you get the sufficient number of minerals that you need. Then the crystals have to be prepared. The tracks are counted with the aid of a microscope, so all of the minerals have to be mounted to a glass slide, thinned, polished and finally etch in acids to reveal the tracks. You establish the age of the minerals through the use of simple physical equations, previously established rates of radioactive decay and a simple desktop computer. A glass of wine also helps.



### Paleomagnetism

You might recall paleomagnetism from GY 111 if you had that class before. Paleomagnetism is one of the major pieces of evidence supporting plate tectonics, but it's also a major tool of use in **stratigraphy** and dating.

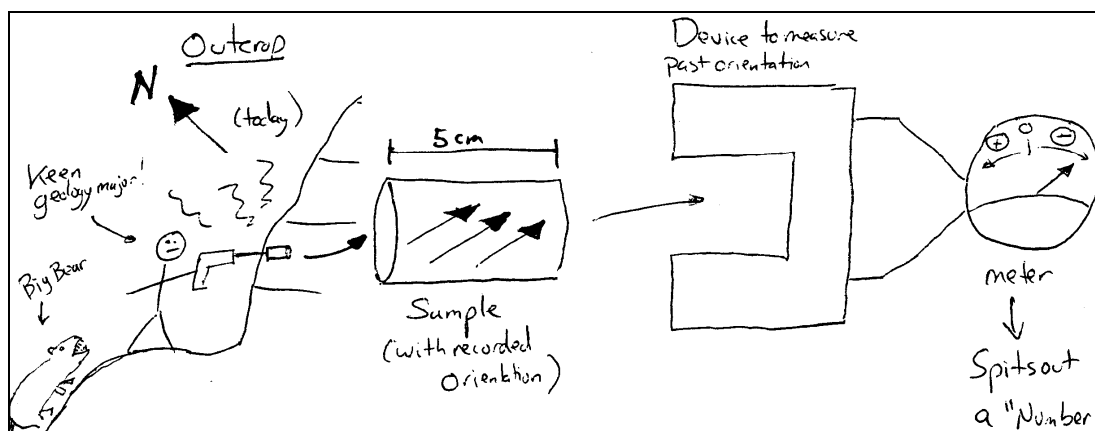


**Recap:** The Earth has a magnetic field and any substance that contains magnetic components (including minerals comprised of iron compounds) will preserve the orientation of that field. For reasons that are not yet clear, the Earth's magnetic field periodically flips and the poles reverse. North becomes south, south becomes north, dogs and cats start living together... (sorry, I always loved that bit in *Ghostbusters*). Anyway, minerals record these periodic reversals. When we were discussing plate

tectonics, we considered the orientation of magnetic minerals within molten rock. You get a similar effect in sedimentary rocks. Sediment may not have been molten, but if it sinks slowly, the iron-bearing particles may still settle preserving the orientation of the magnetic field. Fine grained sediments (shales, mudstones) are the best types of sedimentary rocks for paleomagnetic stratigraphy (**paleomagnetostratigraphy** or **magnetostratigraphy**).

In order to do this type of stratigraphy, you first have to extract samples of sediment or sedimentary rock. The sample must be orientated relative to the current magnetic field *before* it is extracted (this is necessary in order to measure the orientation and inclination of the past magnetic field; see sketch below). Geologists use a corer to extract the samples. It's heavy, it runs on smelly gasoline, it's noisy and it's just the type of thing to use in a National Park camp ground at 6:00 am in the morning.



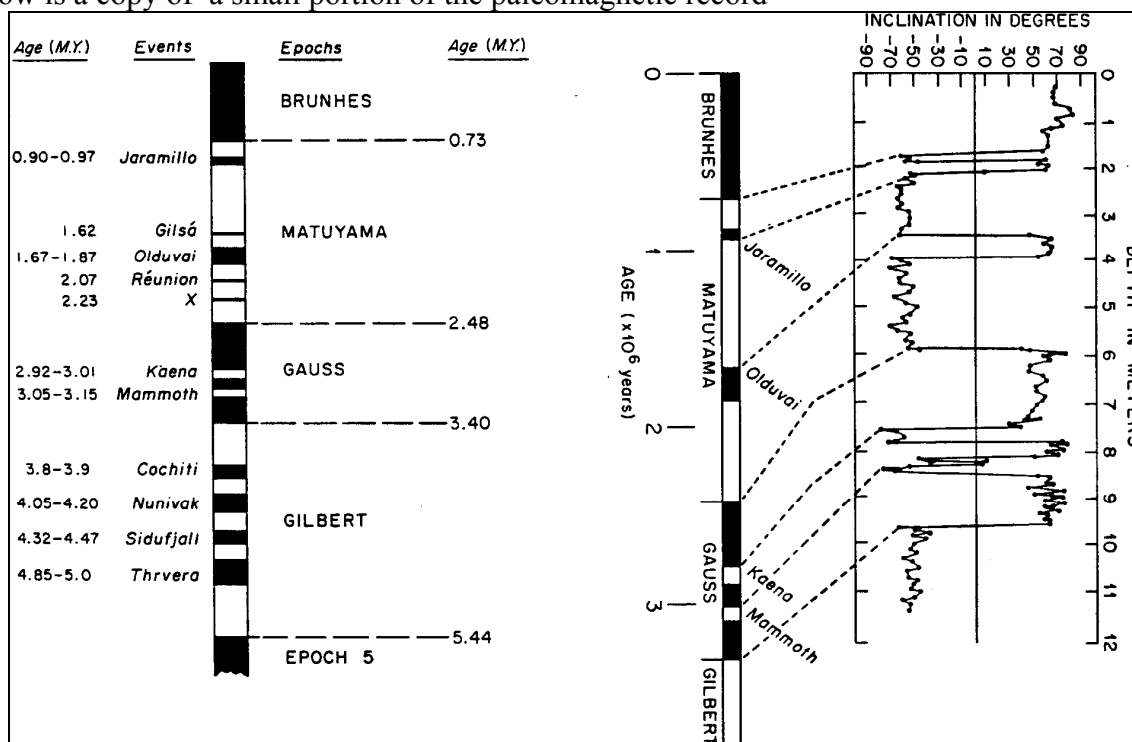


The samples are returned to the laboratory and placed in a machine that measures the orientation of the iron particle in the sediment (I have no idea how it does this, but a picture of the **magnetometer** from Otago University in New Zealand is shown below should you be interested in just what the machine looks like.). Eventually the magnetometer spits out numbers (orientation, declination etc.). These data are then used to date your samples.



Now I mentioned before that paleomagnetism as a means of dating was a *qualitative absolute* date. The reason that I said this was because you compare your data to a previously established magnetostratigraphy. In a way, this is like comparing the fossil content of a sedimentary rock to the previously established fossil record. The magnetostratigraphic record has been well established around the world and is considered to be pretty "absolute". In part, this is because there have been a lot of magnetic reversals. The more reversals you get, the better your resolution of time. Significant periods of time that are marked by consistent orientations of the Earth's magnetic field are called **epochs** (the same term used for the smallest division of the Geological time scale; e.g., Pliocene Epoch). Epochs come in two flavors; **normal** (normal **polarity** like today) and **reversed** (reversed polarity; dogs living with cats etc.). Most magnetic epochs last 1 to 5 MA, but there are lots of exceptions to this rule. There are also shorter-lived magnetic reversals that occur irregularly throughout the rock record. These are called **events**. Some lasted for several hundred thousand years, whereas others lasted such a short time that we just give them a single age. Most of the events and all of the epochs have specific names. You don't have to know what these names are in GY 112, but you may encounter them later in your academic careers in geology or other disciplines. For example, all you future archaeologists will study about our human ancestors. How do you think they dated the age of the bones that they found in Australia, Africa and Asia? Often, it was with paleomagnetism. In fact, some of the names of the magnetic reversals are derived from important archaeological sites. Olduvai springs to mind.

Below is a copy of a small portion of the paleomagnetic record



Above figure is from: Bradley, R.S. 1985. Quaternary Paleoclimatology. Allen and Unwin Publishing, London, 472 pp.

### Important terms/concepts from today's lecture

*(Google any terms that you are not familiar with)*

- relative dating
- absolute dating
- quantitative
- qualitative
- paleontology
- stratigraphy
- radiometric dating
- stable isotopic stratigraphy
- fission track dating
- fission
- paleomagnetism
- paleomagnetostratigraphy/magnetostratigraphy
- radioactive element/isotope
- radioactive decay
- epoch (magnetic variety)
- event (magnetic variety)
- normal polarity
- reversed polarity