

## GY 112 Lecture Notes Why Geologists Date

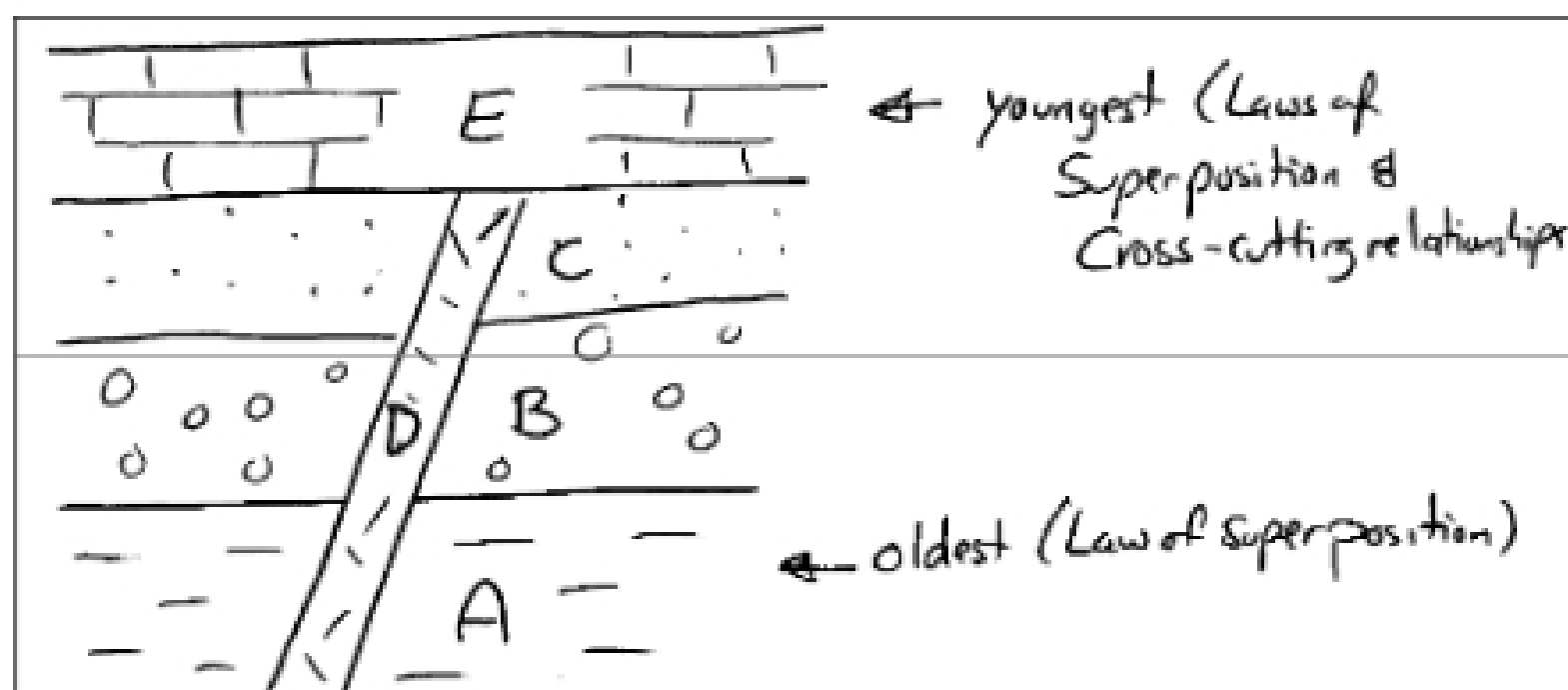
### Lecture Goals:

- 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:



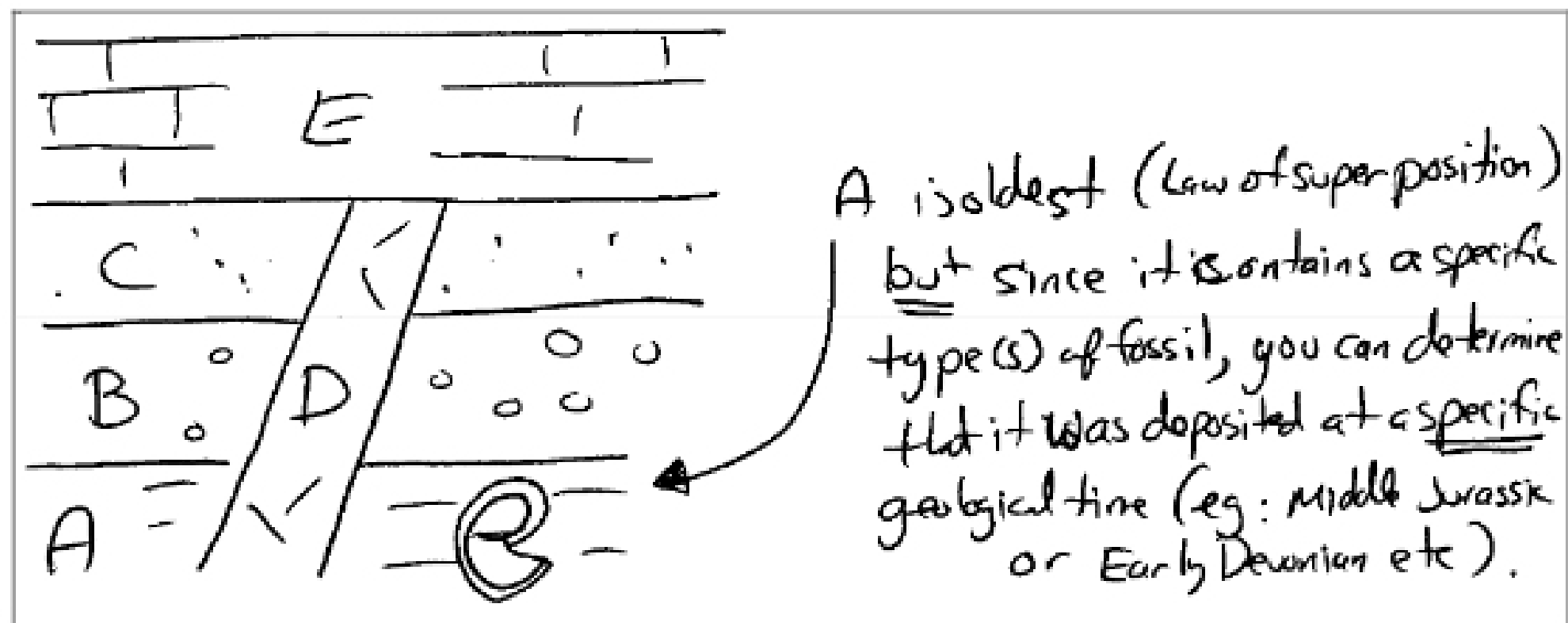
Both of these cartoons allow you to "date" the order of events, but only in a relative sense (e.g., A occurred before B which occurred before C etc). For this reason, this is considered to be a **relative dating** technique. In contrast, methods that provide an actual number for an age (e.g., 365.2 MA),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