§ graded beds
slidewords* graded beds

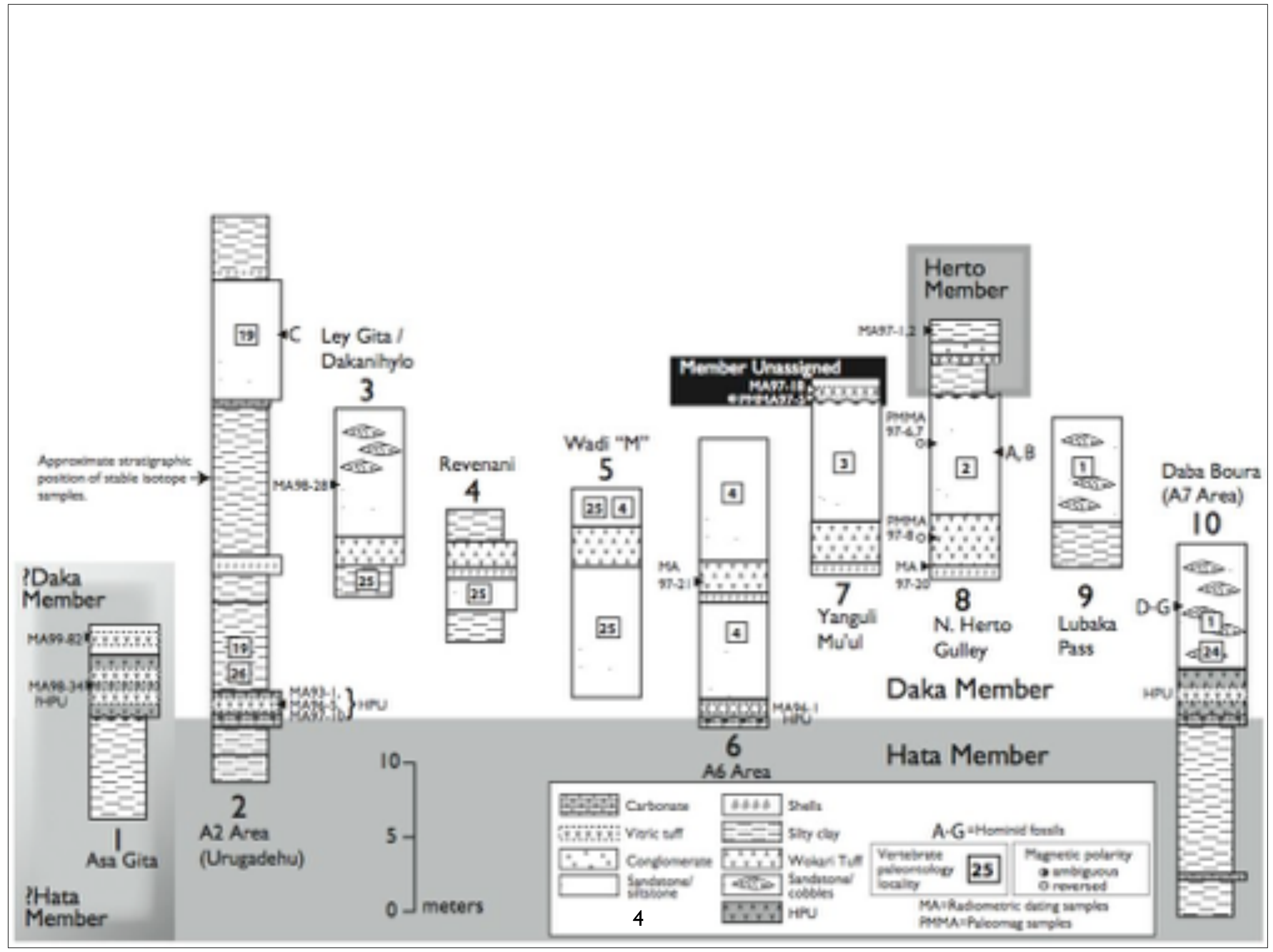
§Sand vs. sandstone
slidewords*Sand vs. sandstone

§ flint/chert
slidewords*Chert/Flint: Microscopic quartz crystals crow in Silica rich rocks in high temperature, high pressure aqueous solutions.

Concerning the terms "chert", "chalcedony" and "flint"

There is much confusion concerning the exact meanings and differences among the terms "chert", "chalcedony" and "flint" (as well as their numerous varieties). In petrology the term "chert" is used to generally refer to all rocks composed primarily of microcrystalline, cryptocrystalline and microfibrous quartz. The term does not include quartzite. Chalcedony is a microfibrous (microcrystaline with a fibrous structure) variety of quartz. Strictly speaking, the term "flint" is reserved for varieties of chert which occur in chalk and marly limestone formations. [1] [2] Among non-geologists (in particular among archaeologists), the distinction between "flint" and "chert" is often one of quality - chert being lower quality than flint. This usage of the terminology is prevalent in America and is likely caused by early immigrants who imported the terms from England where most true flint (that found in chalk formations) was indeed of better quality than "common chert" (from limestone formations). Among petrologists, chalcedony is sometimes considered separately from chert due to its fibrous structure. Since many cherts contain both microcrystaline and microfibrous quartz, it is sometimes difficult to classify a rock as completely chalcedony, thus its general inclusion as a variety of chert.

[edit]



4

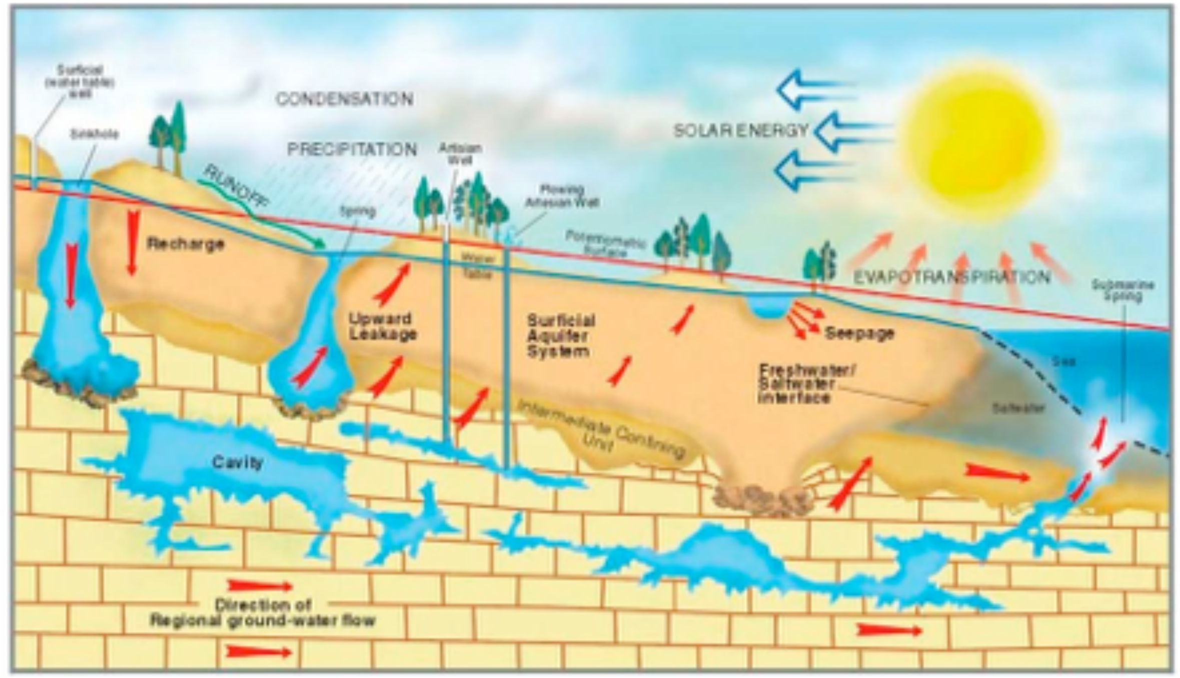
§ stratigraphic columns
slidewords* stratigraphic columns

Calcium Carbonate

Pedogenic

Limestone (non-pedogenic)

§ Calcium carbonate: pedogenic & non-pedogenic; limestone if silicified
slidewords* Calcium carbonate: pedogenic & non-pedogenic; limestone if silicified



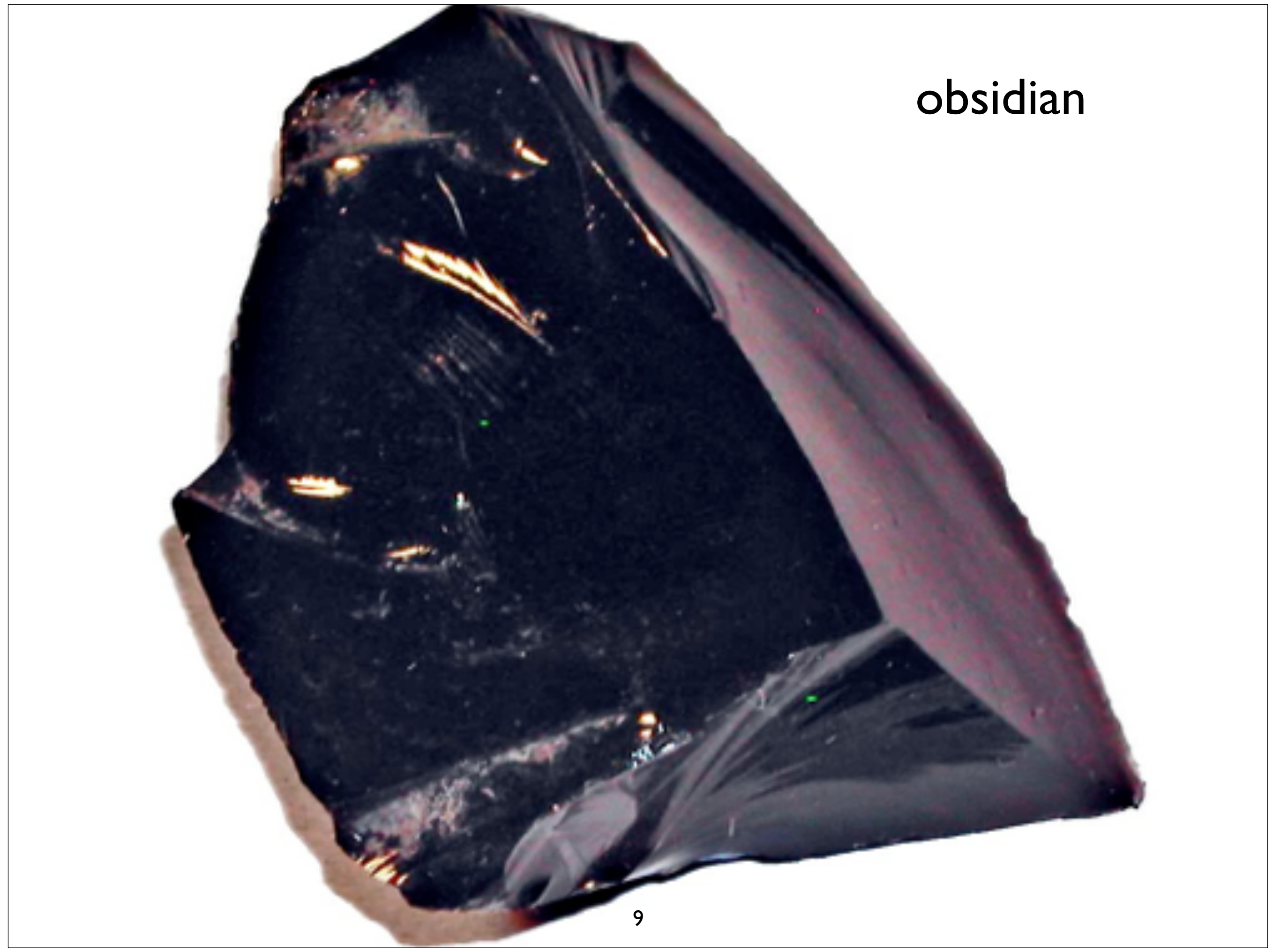
Karstic

§ Karstic landscape
slidewords*karstic landscape

§limestone breccia
slidewords*

Pyroclastic

§ erupting volcano
slidewords*pyroclastic



§obsidian flake
slidewords*obsidian

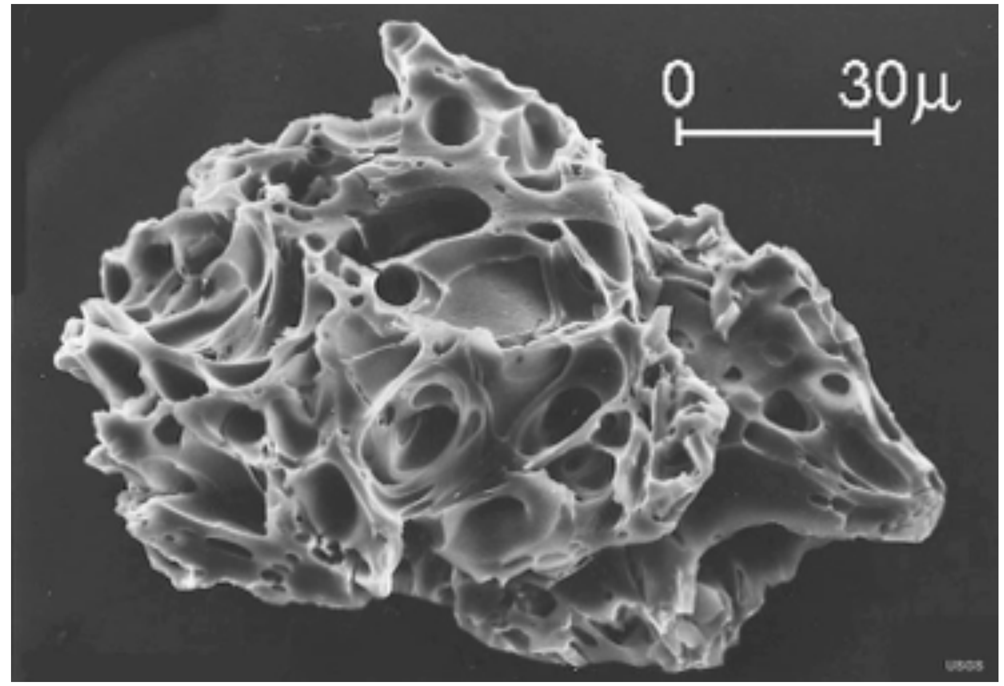
Lava

§ lava
slidewords*lava

§ flood basalt
slidewords*flood basalt

§ erupting volcano
slidewords*

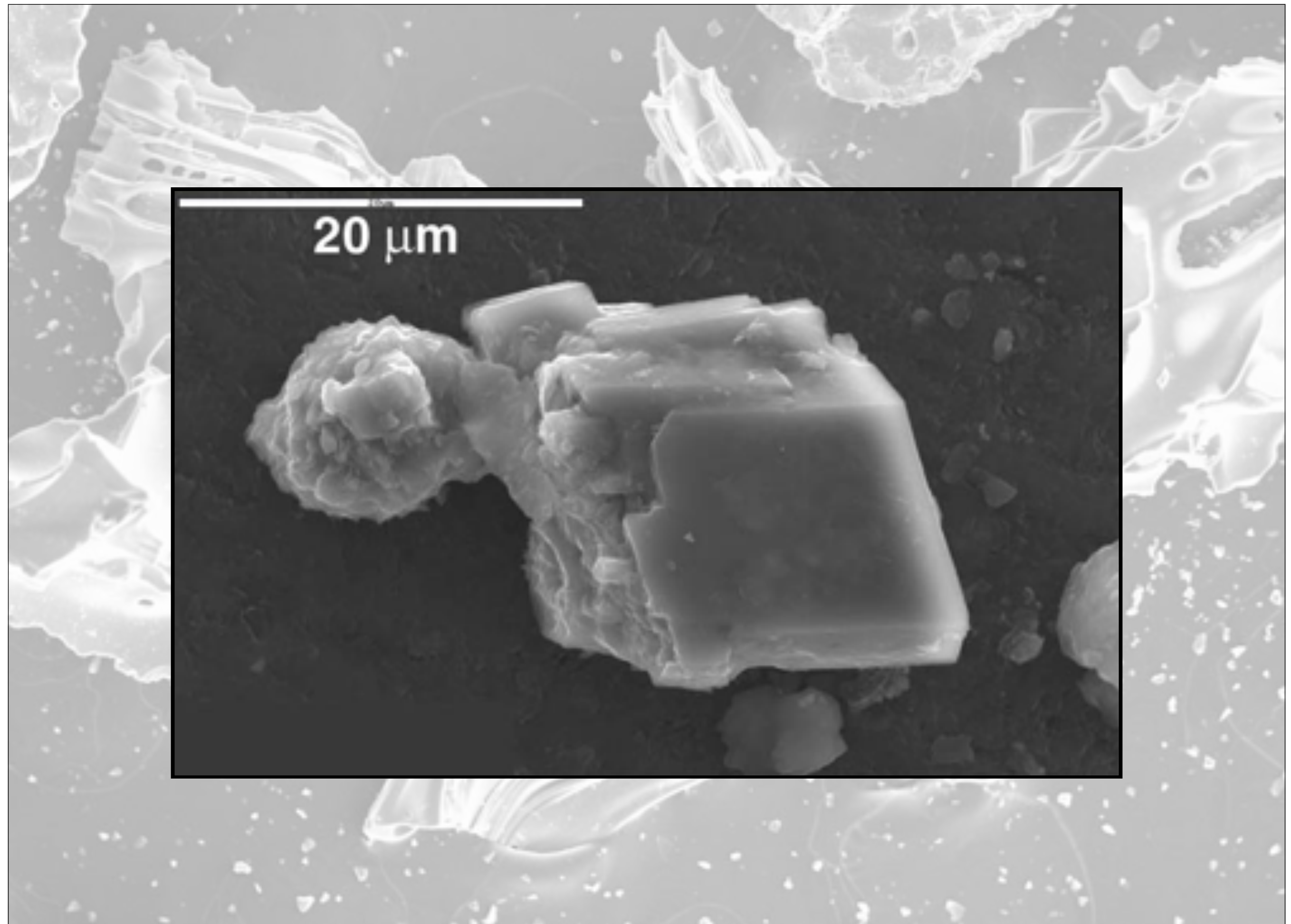
§Airfall ash
Ash flow
slidewords*



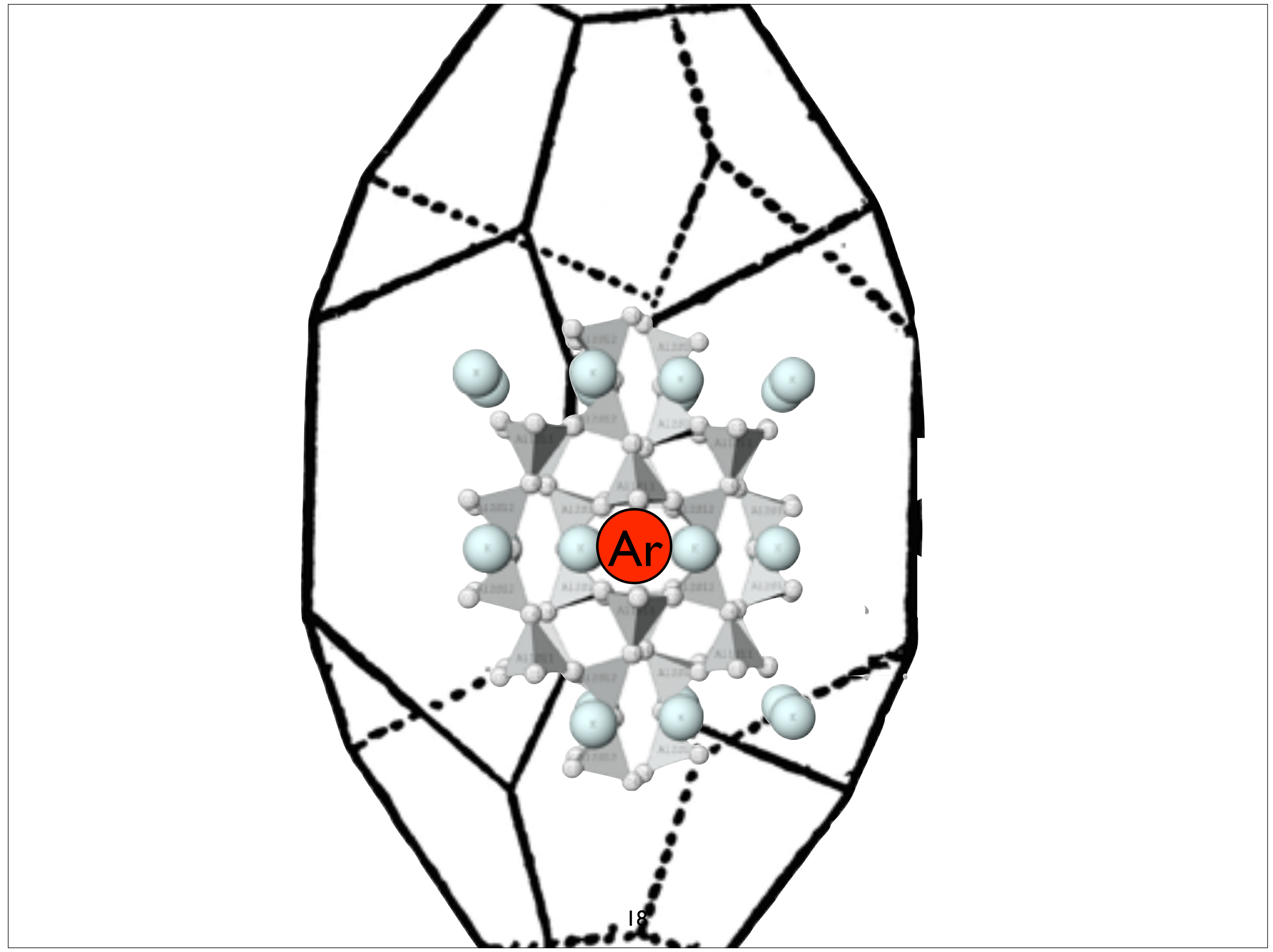
§ volcanic ash particle
slidewords*

§ volcanic ash
slidewords*

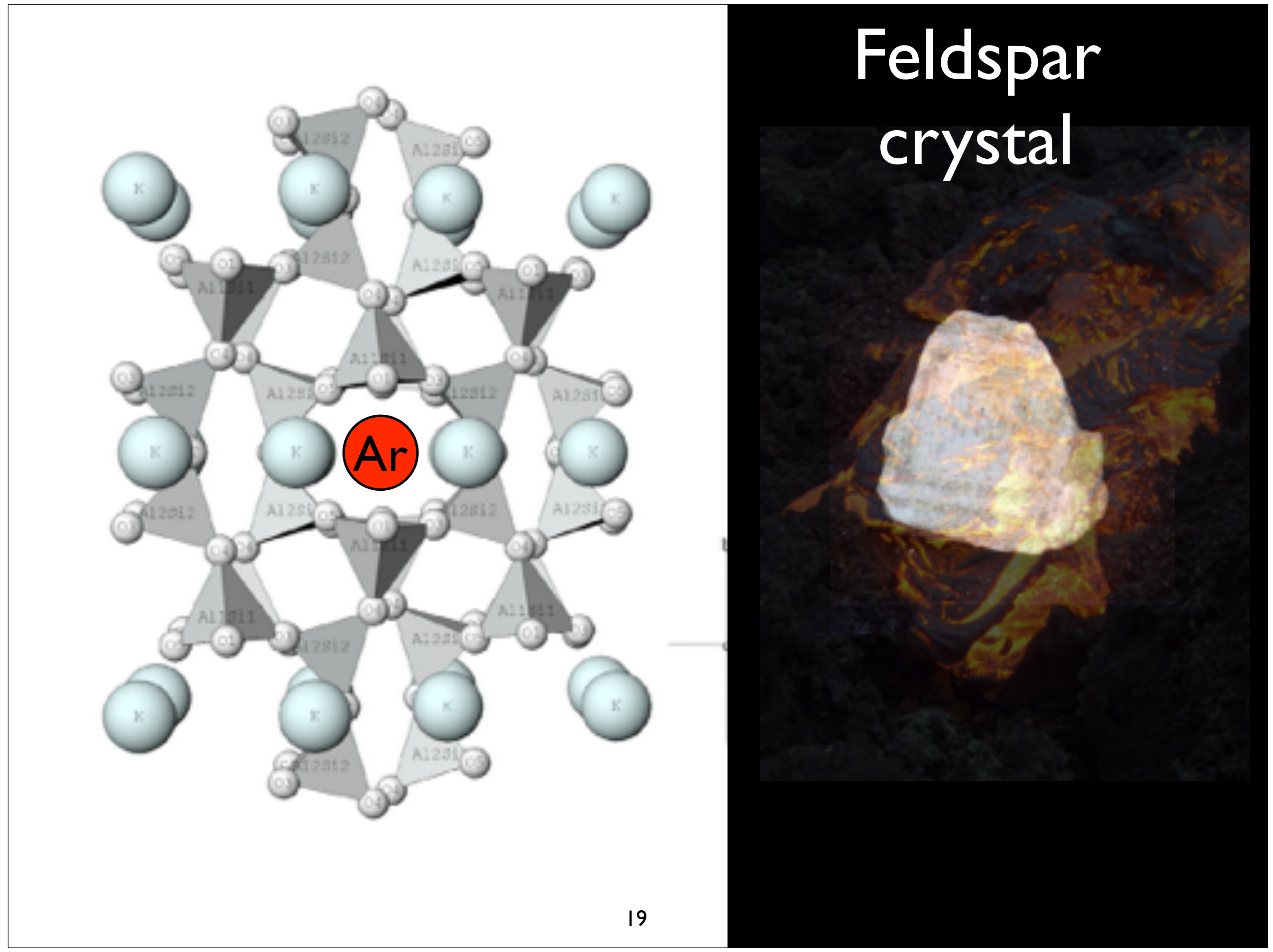
§Airfall ash
Ash flow
slidewords*Airfall ash
Ash flow



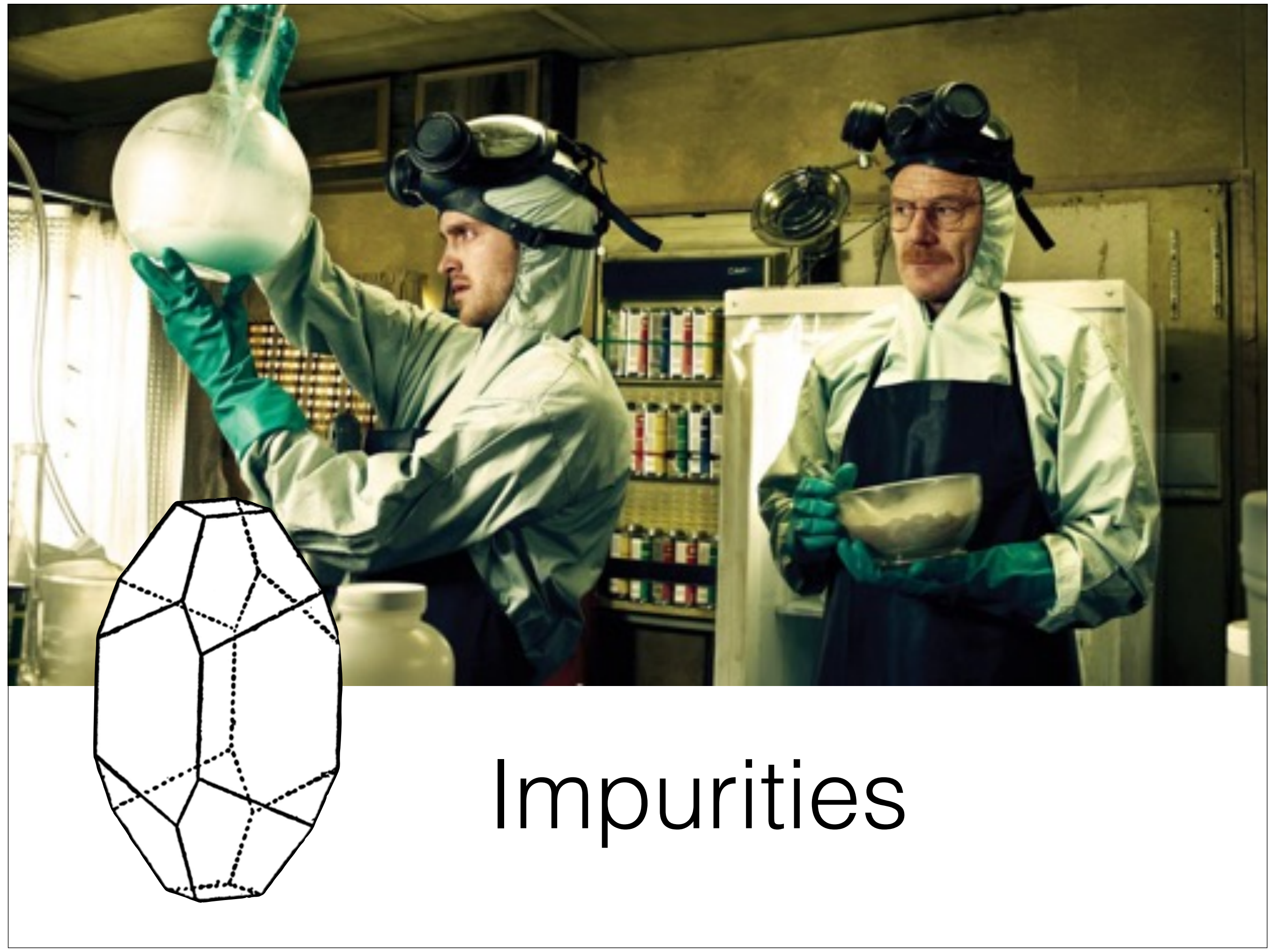
§ Feldspar
crystal
slidewords*



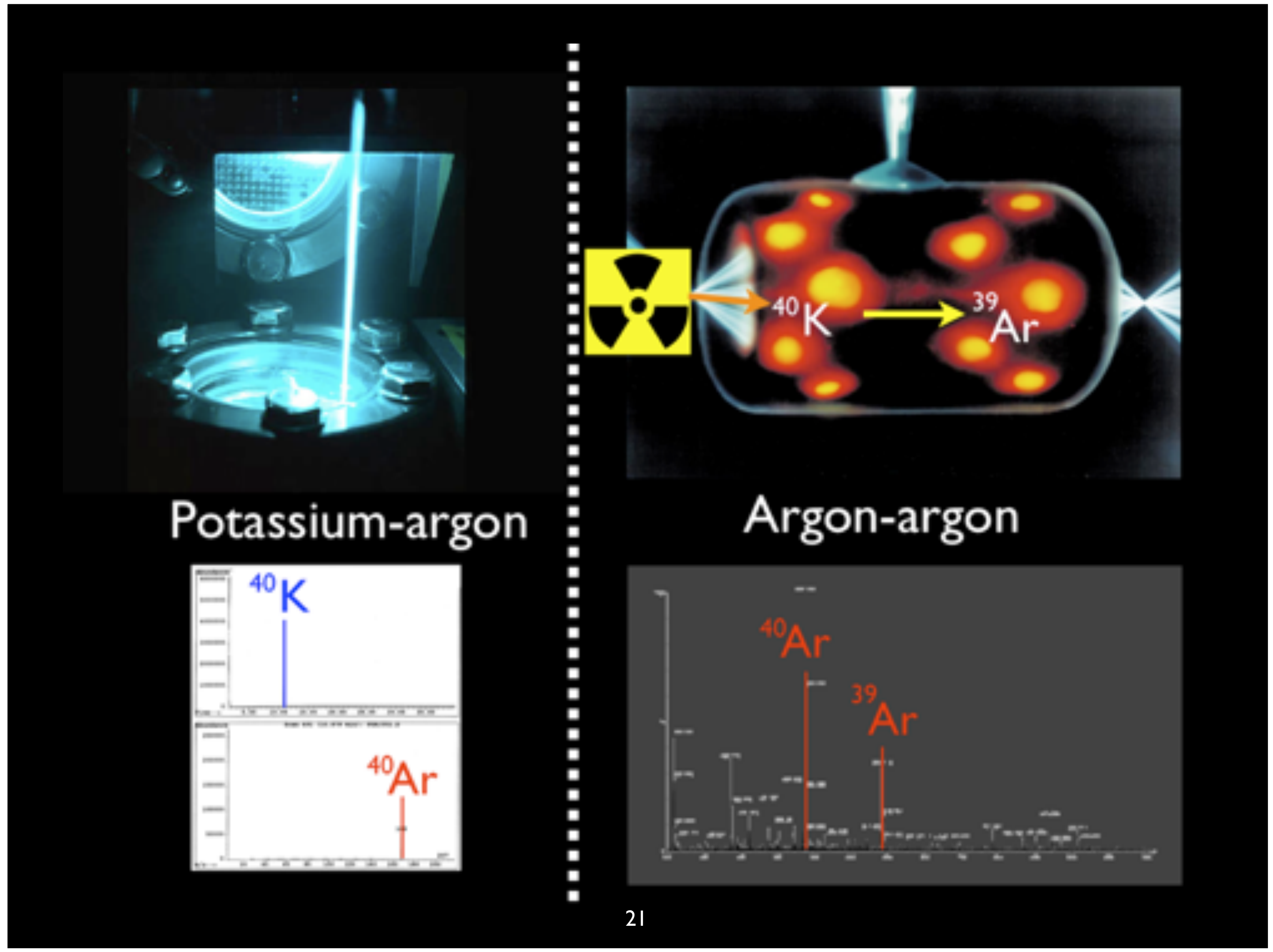
§Feldspar
crystal
slidewords*



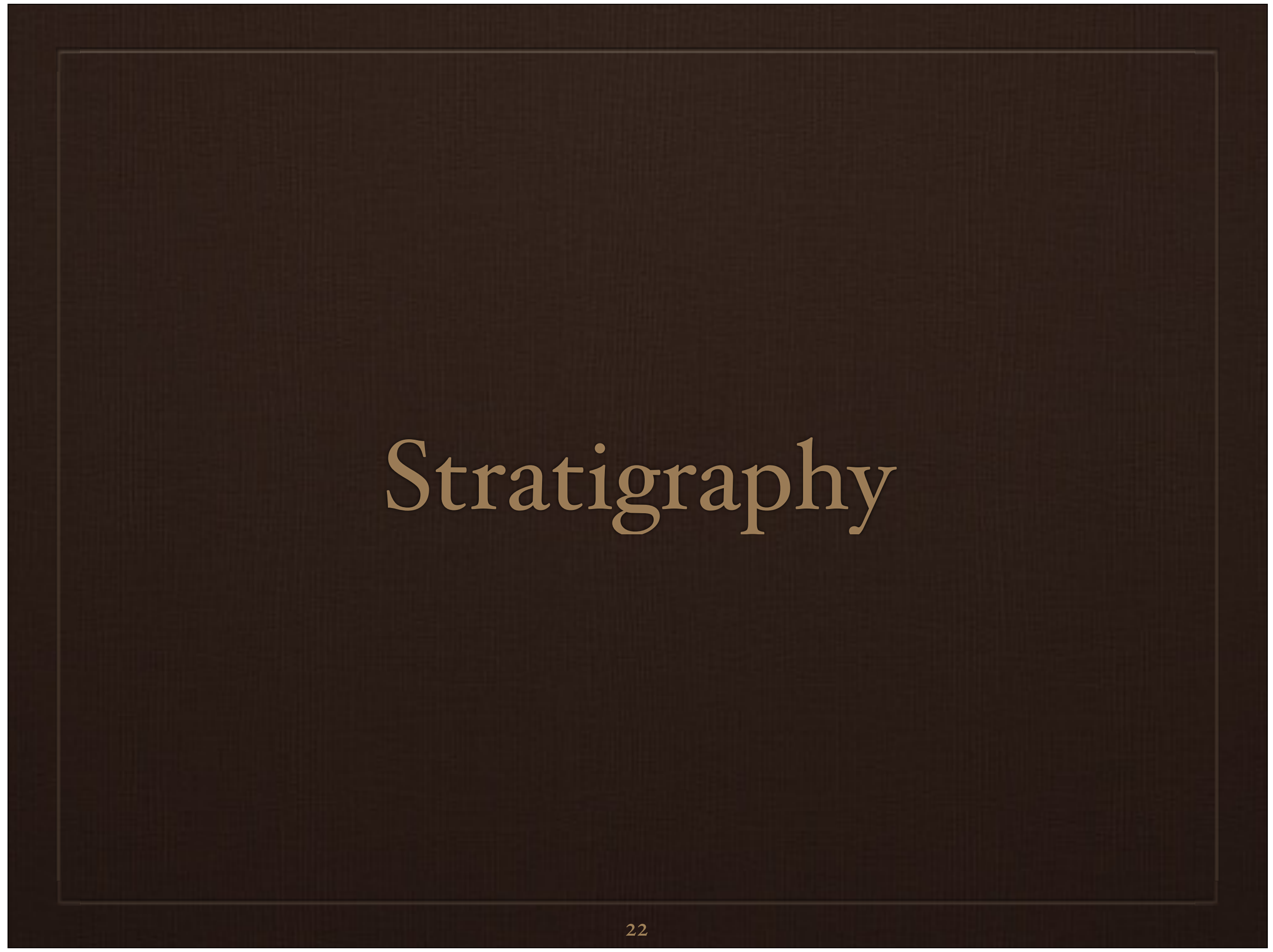
§ Feldspar
crystal
slidewords* Feldspar
crystal



§Breaking Bad cookin'
slidewords*impurities



§
slidewords* Potassium-argon; argon-argon



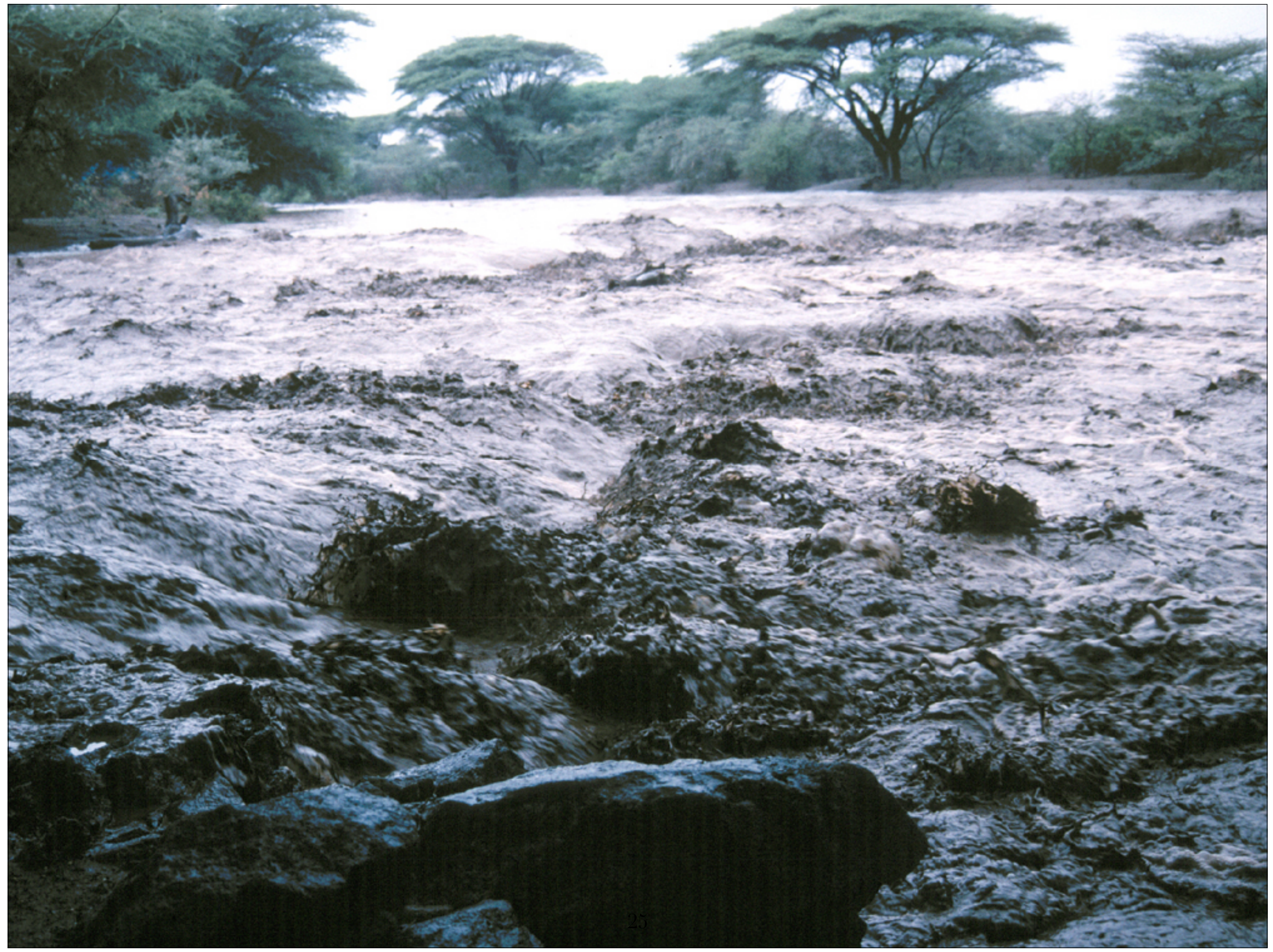
§
slidewords* Stratigraphy

Date shorthand

- Ma = mega-annum = million years
- ka = kilo-annum = thousand years

§
slidewords* Date shorthand
Ma = mega-annum = million years
ka = kilo-annum = thousand years

§
slidewords*

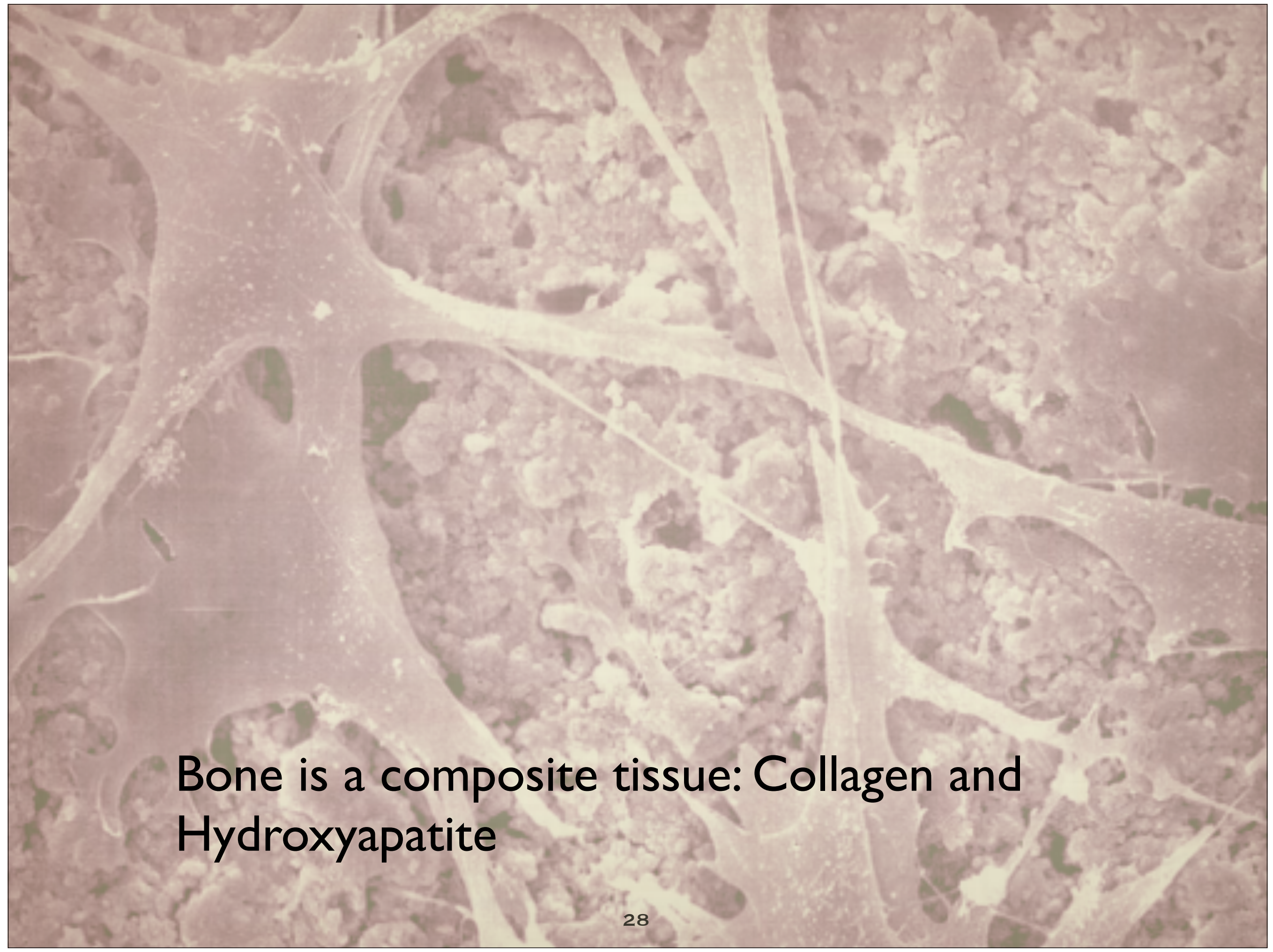


§
slidewords*

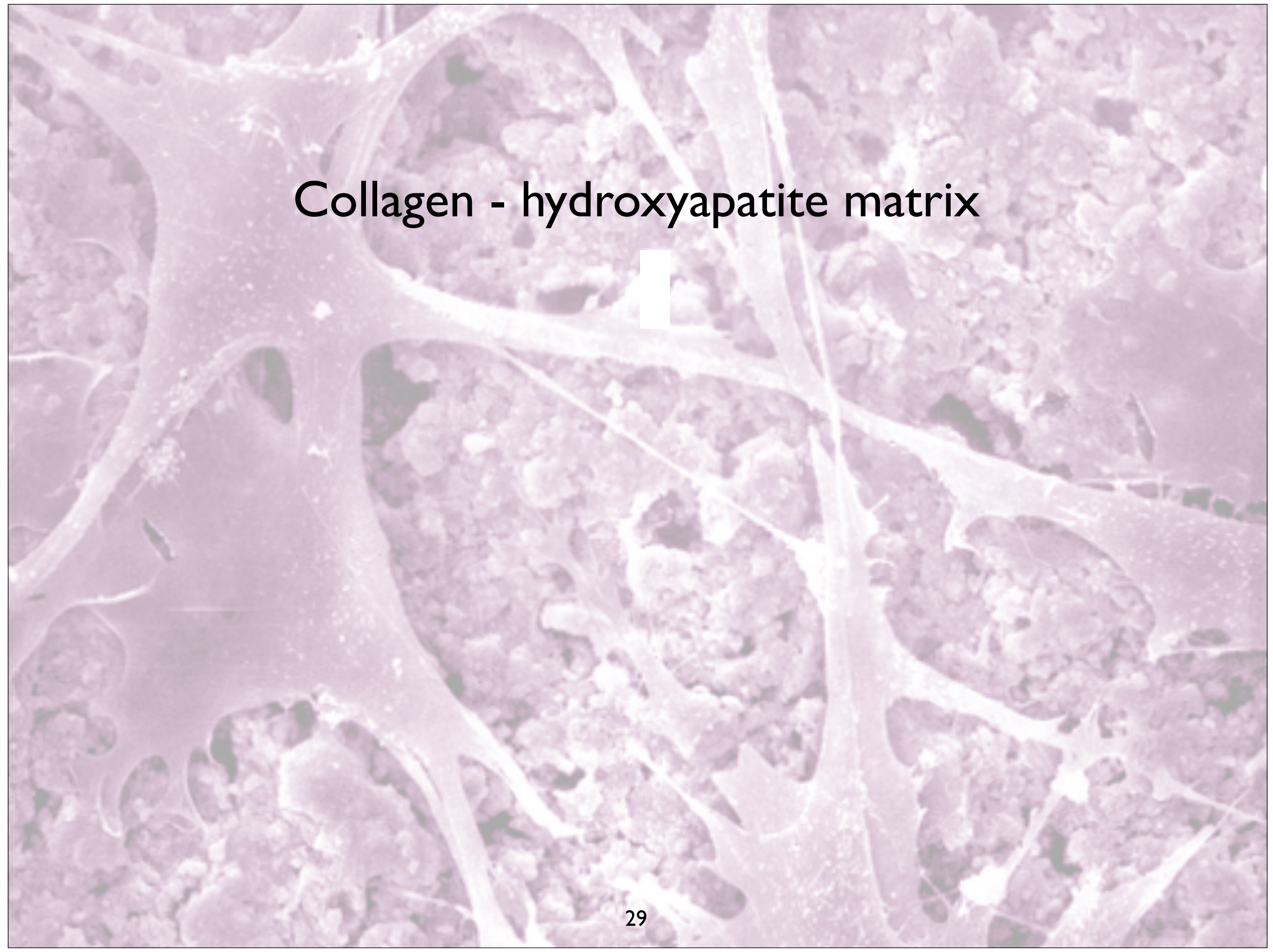
§
slidewords*

§ Professor finding fossils
slidewords*# Permineralized: most common mode of preservation of dinosaur body fossils!

* Pore space is filled in with ground water: some dissolved minerals precipitate in pores (probably some contribution by bacterial activity)
* Is the same process as going on in cementation of the sediment around it
* Original hard parts remain, but extra material added to pores
* Because the new material is added, fossil will break like rock and be colored like the mineral that filled in the poor space
* "Petrified" wood is actually permineralized wood
* In some cases, soft tissues can be permineralized, but this seems to be very rare



§Bone is a composite tissue: Collagen and Hydroxyapatite
slidewords* Bone is a composite tissue: Collagen and Hydroxyapatite



§ Collagen - hydroxyapatite matrix
slidewords* Collagen - hydroxyapatite matrix

Calcium Carbonate

Pedogenic

Limestone (non-pedogenic)

§ Calcium carbonate: pedogenic & non-pedogenic; limestone if silicified

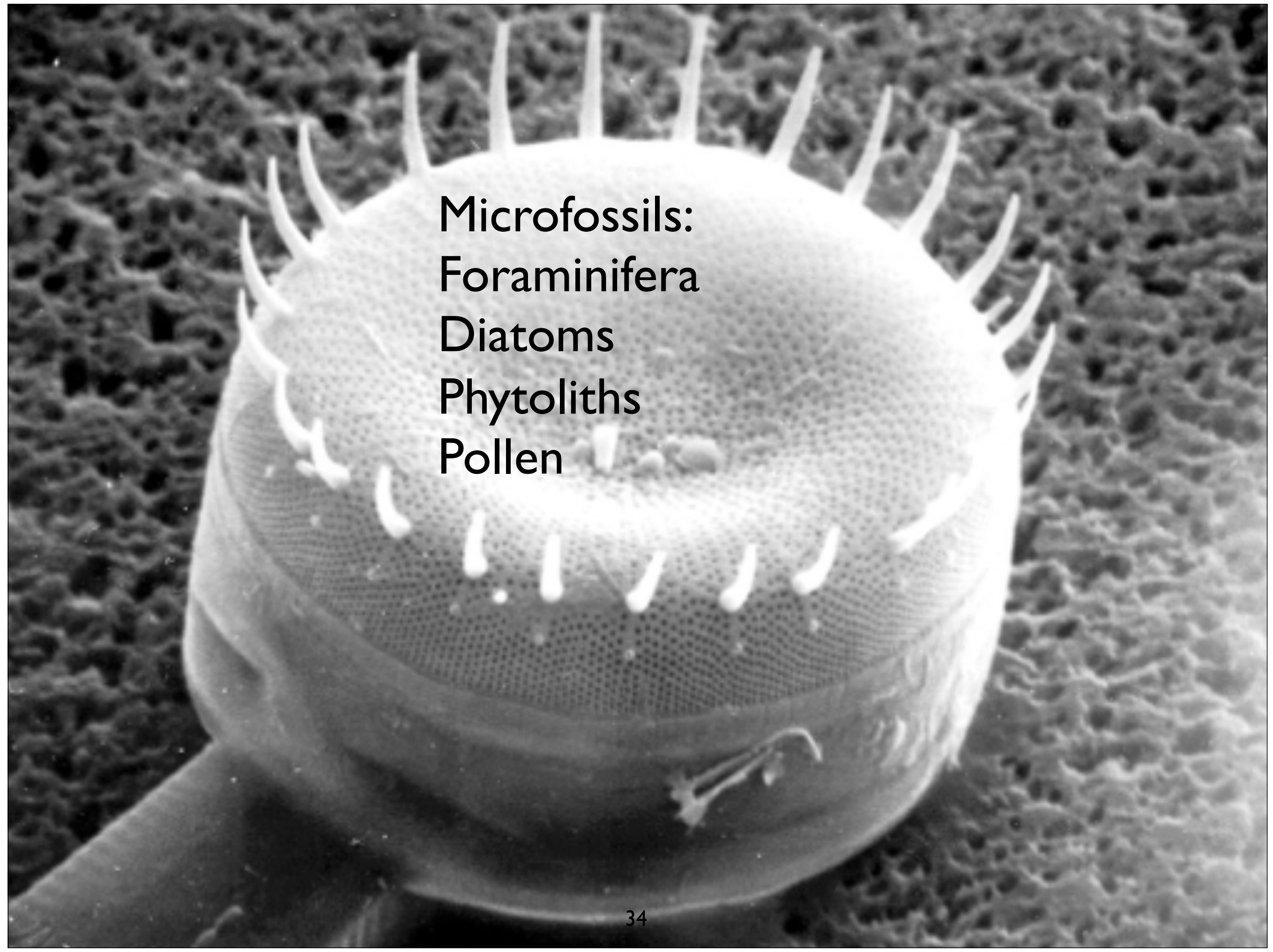
slidewords* Calcium carbonate: pedogenic & non-pedogenic; limestone if silicified

§ normal fossils in field
slidewords* Permineralization

Trace fossils

§ footprint fossils
slidewords* Trace fossils

§ ferm fossil
slidewords*Cast/mold fossils



§ pollen fossil
slidewords*Microfossils:
Foraminifera
Diatoms
Phytoliths
Pollen

§ *in situ* artifact
slidewords*

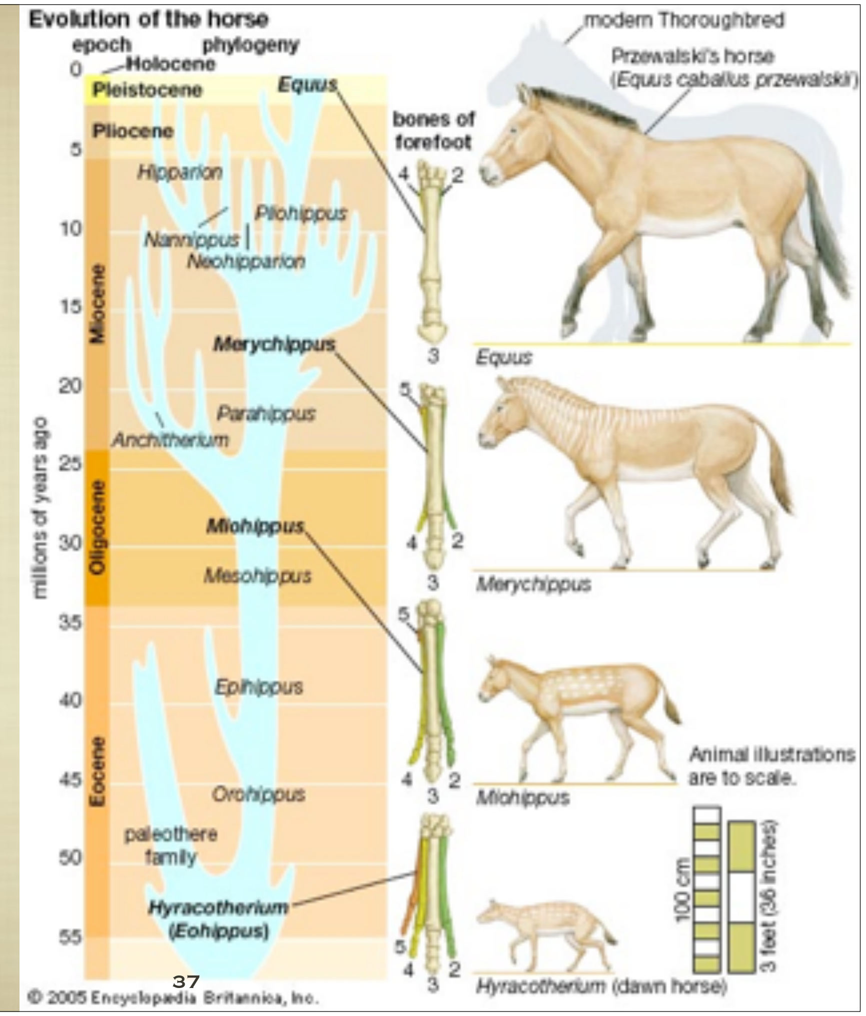
Dating the past

- Relative dating
- Absolute dating

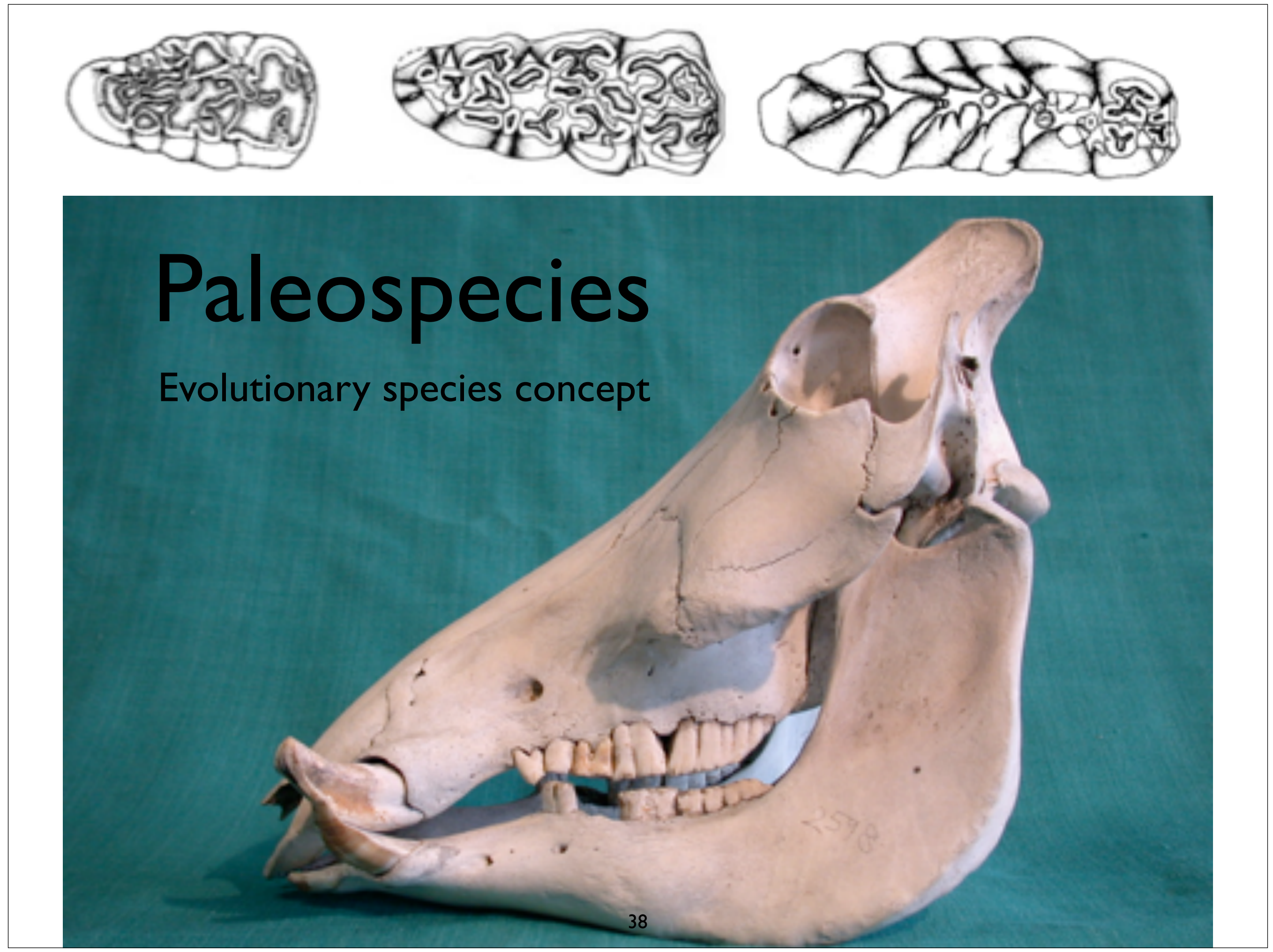
§
slidewords* Dating the past
Relative dating
Absolute dating

Relative dating

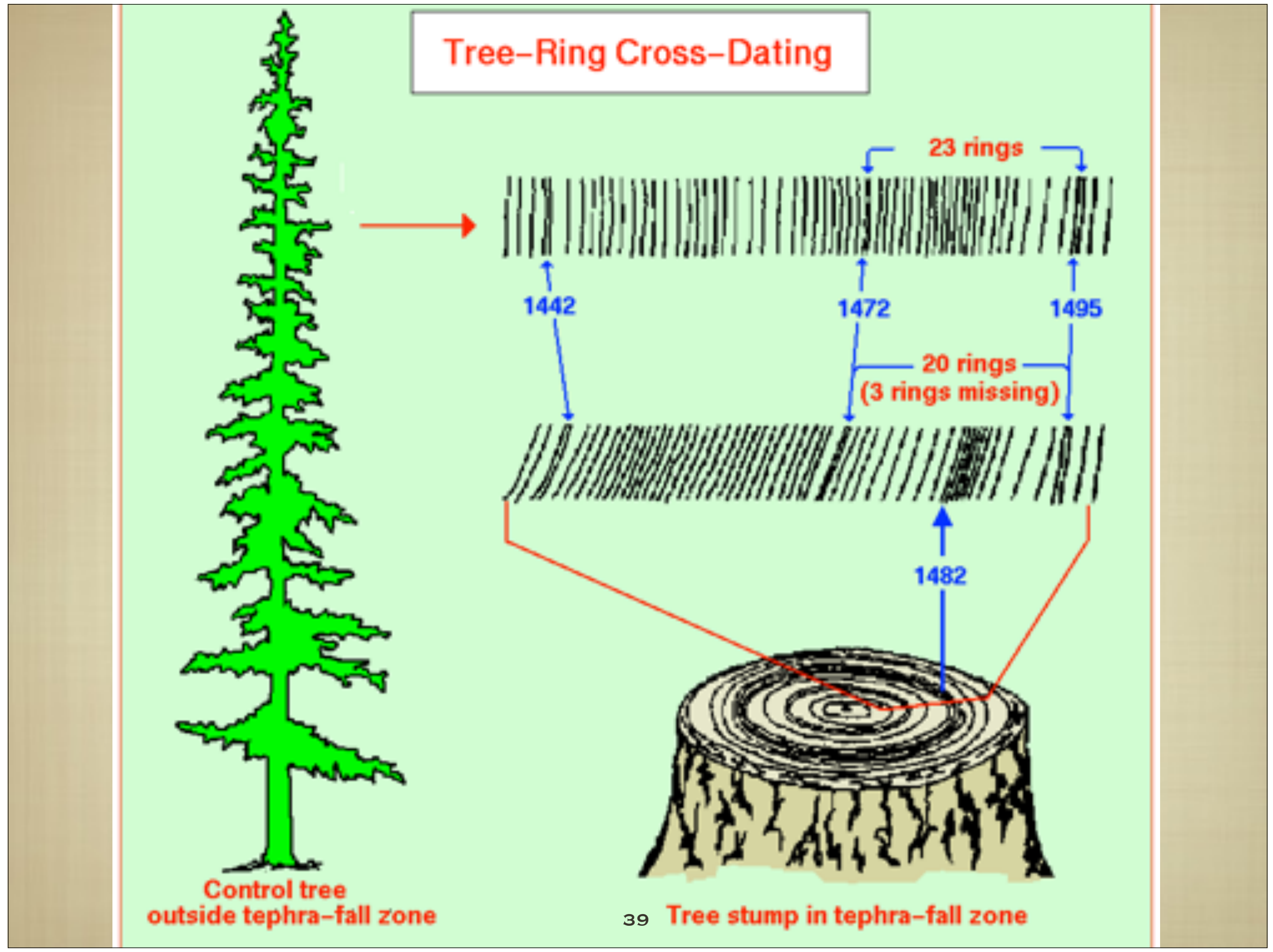
Biostratigraphy,
Floral series
&
Pollen series



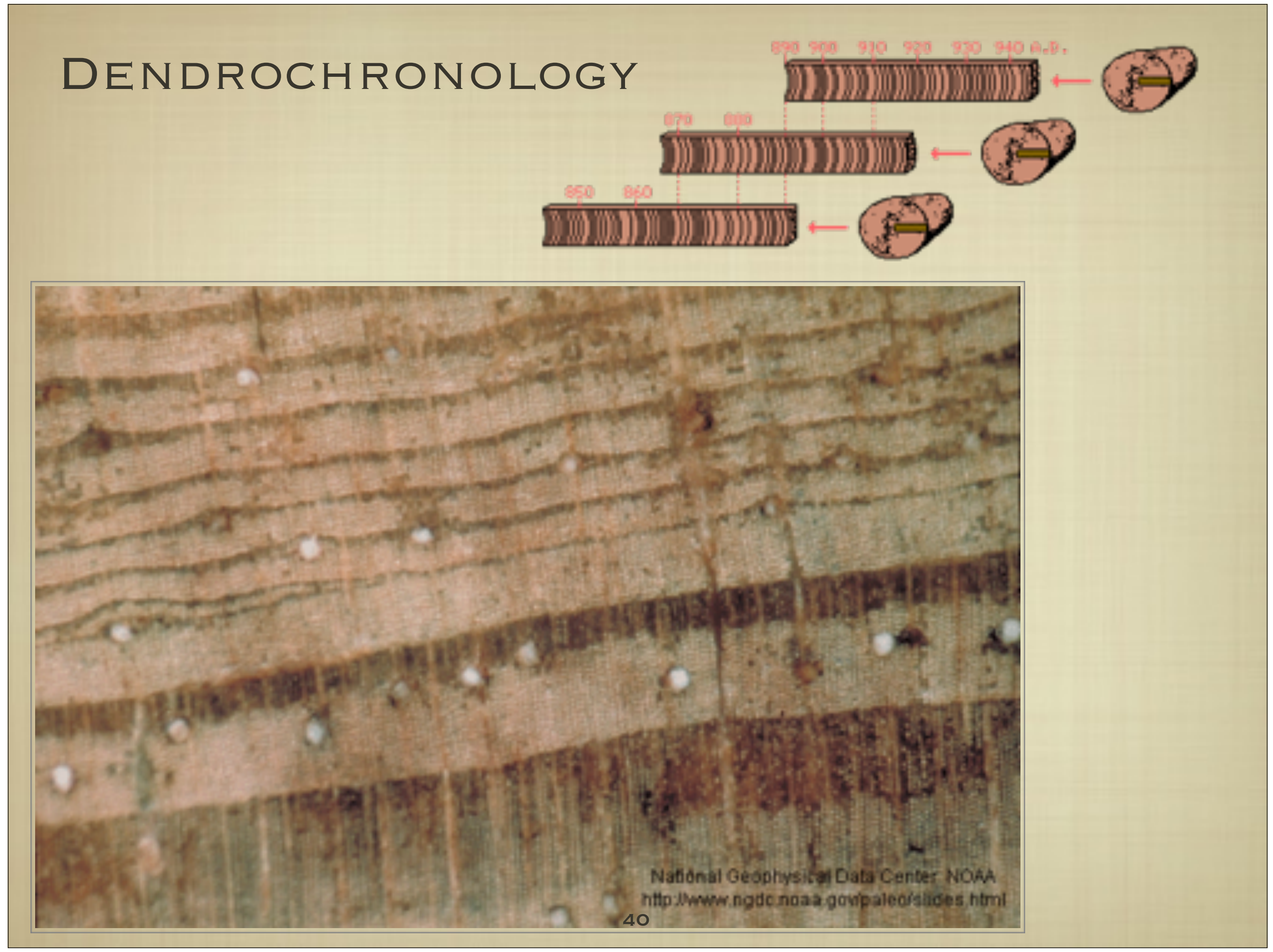
§ Horse evolution
slidewords* Biostratigraphy,
Floral series
&
Pollen series
Relative dating



§
slidewords* Paleospecies
Evolutionary species concept: The term paleospecies (or palaeospecies) indicates an extinct species only identified with fossil material. This identification relies on distinct similarities between the earlier fossil specimens and some proposed descendant, although the exact relationship to the later species is not always defined.

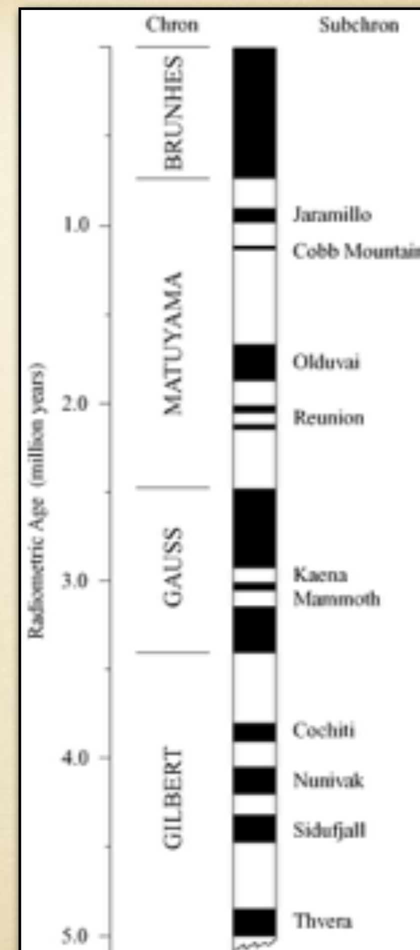


§
slidewords* den·dro·chro·nol·o·gy
the science or technique of dating events, environmental change, and archaeological artifacts by using the characteristic patterns of annual growth rings in timber and tree trunks.



§
slidewords* den·dro·chro·nol·o·gy
the science or technique of dating events, environmental change, and archaeological artifacts by using the characteristic patterns of annual growth rings in timber and tree trunks.

Paleomagnetism



§

slidewords* Paleomagnetism (or Palaeomagnetism in the United Kingdom) is the study of the record of the Earth's magnetic field in rocks, sediment, or archeological materials. Certain minerals in rocks lock-in a record of the direction and intensity of the magnetic field when they form.

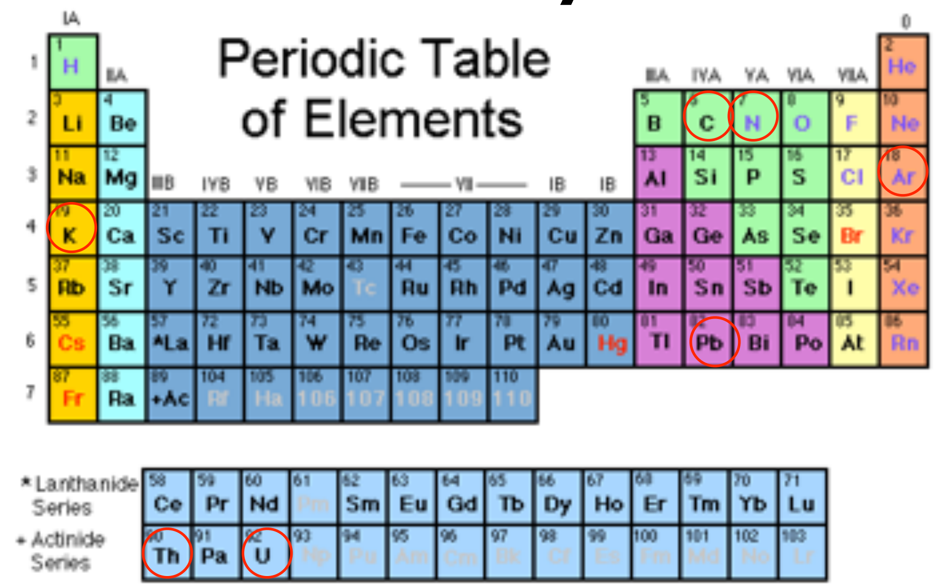
Radiometric dating

uses radioactive decay to determine age of substance

Open system vs. closed system

§
slidewords* Radiometric dating
uses radioactive decay to determine age of substance
Open system vs. closed system

Isotopes / radioactive decay



§Isotopes / radioactive decay: periodic table of elements

slidewords***Isotopes** are any of the several different forms of an element each having different atomic mass (mass number). Isotopes of an element have nuclei with the same number of protons (the same atomic number) but different numbers of neutrons. Therefore, isotopes have different mass numbers, which give the total number of nucleons—the number of protons plus neutrons.

Radiometric dating

the major methods

OLDER SAMPLES:
Potassium-argon and **argon-argon** compares amount of radioactive 40 K ("potassium 40") to the amount of it's daughter, 40 Ar ("Argon 40") to determine date. Initially announced in 1956 by Garniss Curtis, Joseph Lipson, and Jack Evernden. Effective on volcanic rocks from about 100,000 years old and earlier.

Uranium-lead relies on decay of uranium to lead through a series of intermediate steps. Used on the mineral Zircon, which incorporates uranium but rejects lead in crystallization. Lead is thus all from radioactive decay of Uranium. Works on zircon containing rocks older than about 1 Ma.

YOUNGER SAMPLES:
Carbon 14 compares about to radioactive Carbon 14 to stable Carbon 12 in a once-living sample of carbon to determine age since the sample stopped interacting with the atmosphere. Works well only on samples less than 50,000 years old.

Uranium-thorium (U series) compares the amount of uranium to daughter thorium. Uranium is water soluble, thorium is not, so the method is often applied to lake and ocean-bottom sediments that contain non-pedogenic precipitates like calcium carbonate.

LESS RELIABLE METHODS:
Fission track dating counts the tracks left by spontaneous fission of Uranium in a uranium containing mineral. Sometimes inaccurate due to the tendency for tracks to "erase" naturally under intense conditions.

Thermoluminescence dating is the determination, by means of measuring the accumulated radiation dose, of the time elapsed since material containing crystalline minerals was either heated (lava, ceramics) or exposed to sunlight (sediments).

§
slidewords* OLDER SAMPLES:
Potassium-argon and argon-argon compares amount of radioactive 40 K ("potassium 40") to the amount of it's daughter, 40 Ar ("Argon 40") to determine date. Initially announced in 1956 by Garniss Curtis, Joseph Lipson, and Jack Evernden. Effective on volcanic rocks from about 100,000 years old and earlier.

Uranium-lead relies on decay of uranium to lead through a series of intermediate steps. Used on the mineral Zircon, which incorporates uranium but rejects lead in crystallization. Lead is thus all from radioactive decay of Uranium. Works on zircon containing rocks older than about 1 Ma.

YOUNGER SAMPLES:
Carbon 14 compares about to radioactive Carbon 14 to stable Carbon 12 in a once-living sample of carbon to determine age since the sample stopped interacting with the atmosphere. Works well only on samples less than 50,000 years old.

Uranium-thorium (U series) compares the amount of uranium to daughter thorium. Uranium is water soluble, thorium is not, so the method is often applied to lake and ocean-bottom sediments that contain non-pedogenic precipitates like calcium carbonate.

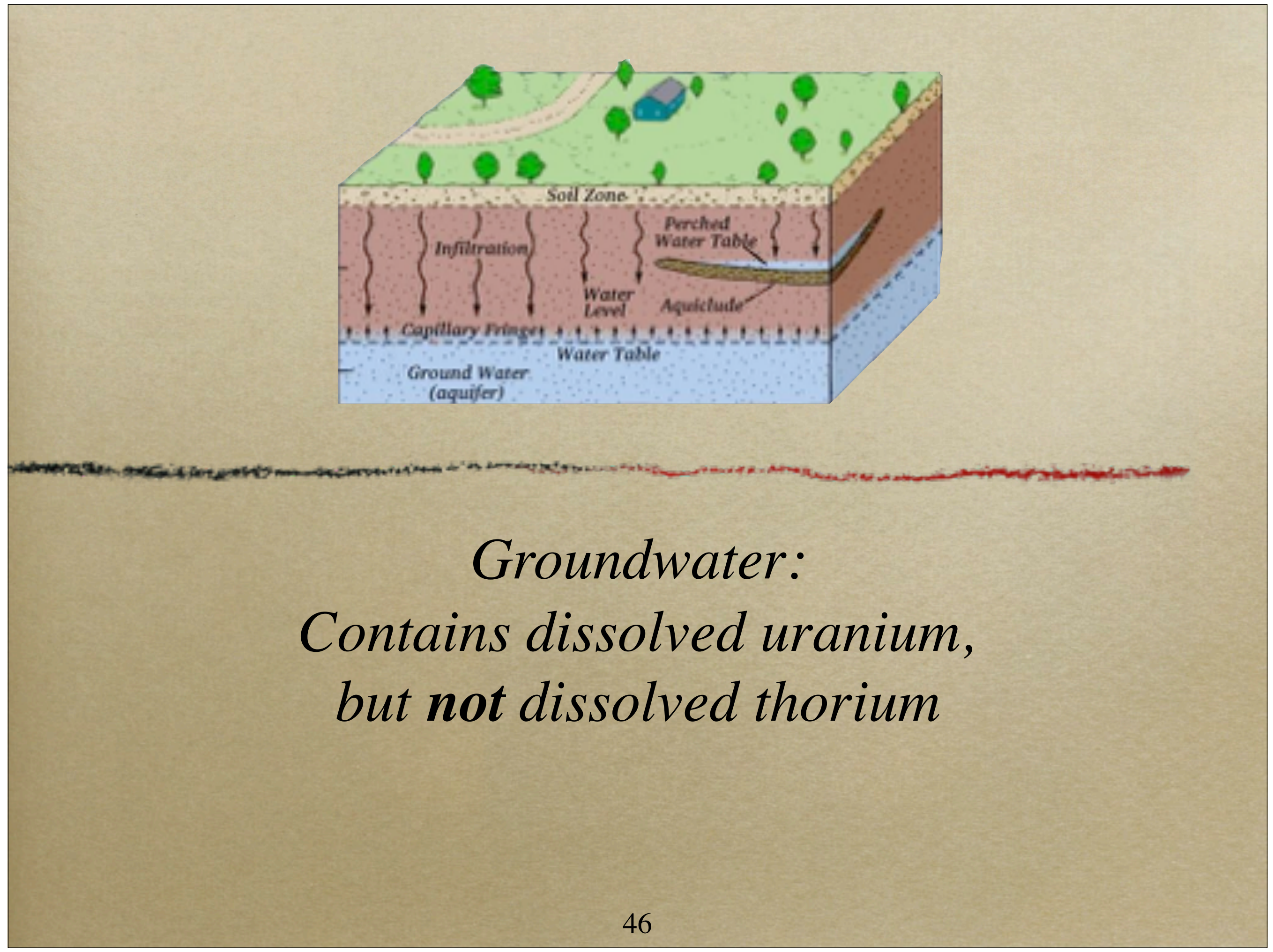
LESS RELIABLE METHODS:
Fission track dating counts the tracks left by spontaneous fission of Uranium in a uranium containing mineral. Sometimes inaccurate due to the tendency for tracks to "erase" naturally under intense conditions.

Thermoluminescence dating is the determination, by means of measuring the accumulated radiation dose, of the time elapsed since material containing crystalline minerals was either heated

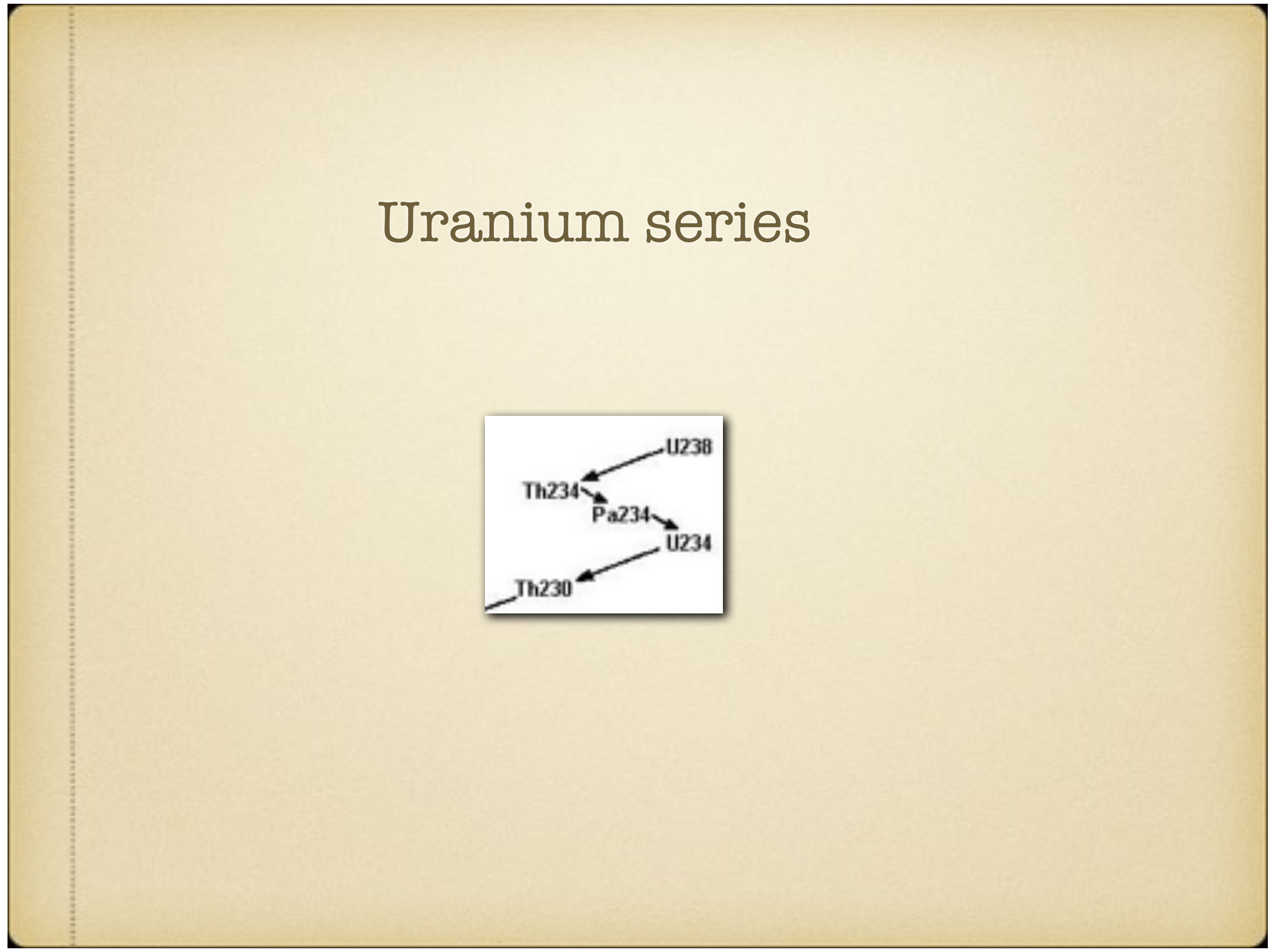
K-Ar dating first used in mid 1950's

1956 Curtis, Lipson, & Evernden publish the method

§
slidewords* K-Ar dating first used in mid 1950's
1956 Curtis, Lipson, & Evernden publish the method
Potassium-argon and argon-argon compares amount of radioactive 40 K ("potassium 40") to the amount of it's daughter, 40 Ar ("Argon 40") to determine date. Initially announced in 1956 by Garniss Curtis, Joseph Lipson, and Jack Evernden. Effective on volcanic rocks from about 100,000 years old and earlier.



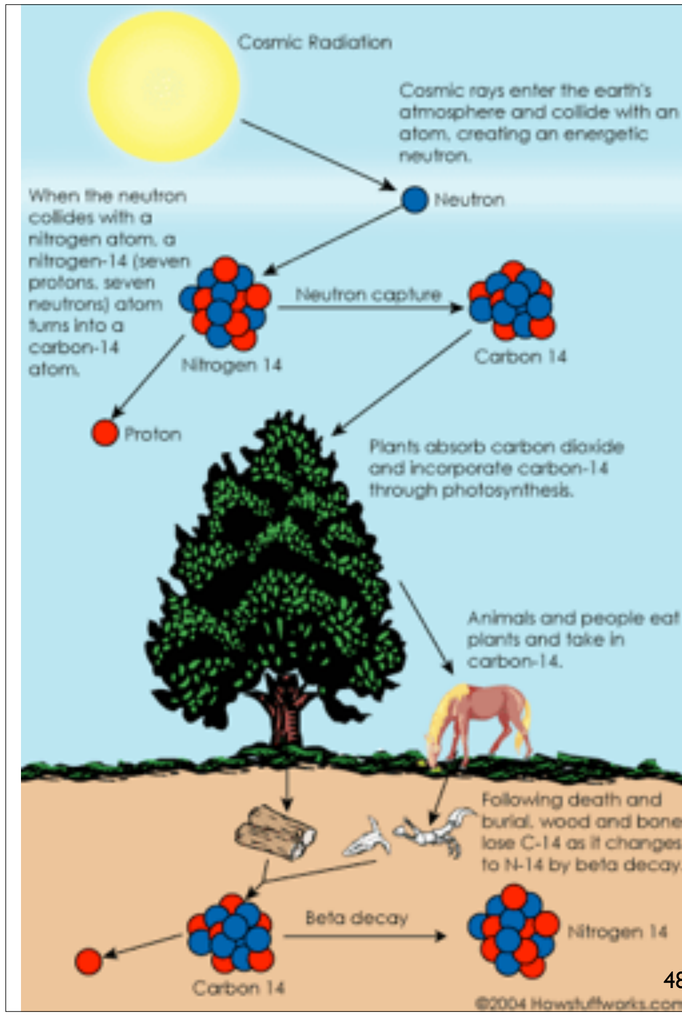
§
slidewords* Groundwater:
Contains dissolved uranium, but not dissolved thorium



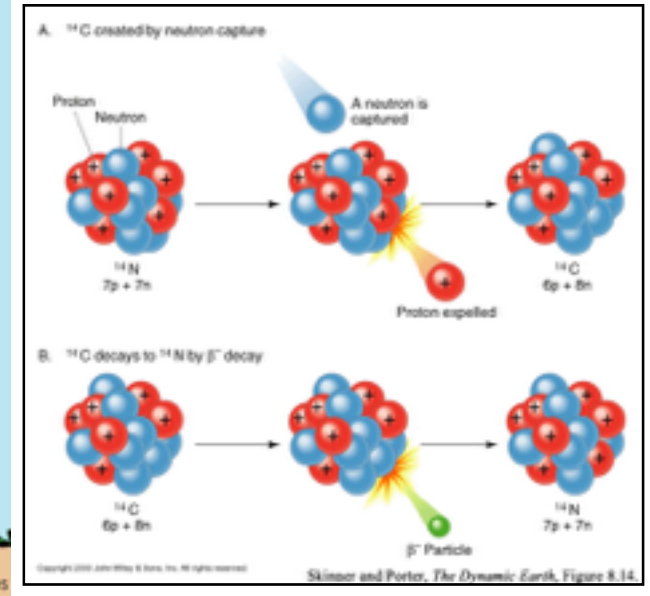
§

slidewords****Mass Spectrometric U-Series (MS/U-series) Dating of Calcite and Tooth Materials****:* This method is not based on radiation exposure, but rather on the decay of uranium into thorium over time. Changes in soil radioactivity or moisture content do not lead to uncertainties in ages calculated by this method. The difference between its use in calcite and on tooth materials is explained in Appendix 1.

Mass-Spectrometric Uranium Series Dating (MS/U-series) of Calcite and Tooth Materials: Calcites which are intercalated with archaeological layers are excellent time markers in the time range 1-400 ka. Natural calcite, a uniquely valuable material for precise age determinations, is formed by evaporation of calcium-rich waters which drip into archaeological contexts. Two different isotopes of uranium in the dripping water are incorporated into the newly-formed crystals, but without any of the daughter thorium atoms. The decay rates of these isotopes are well known. The mass spectrometric approach (Edwards et al., 1996) determines the parent-daughter ratios with much higher precision than the older technology of alpha spectrometry. Therefore, precise ages (± 1% 2s) can be obtained with MS/U-series dating. In the case of tooth enamel (see above), we obtain the average age of the uranium which may enter teeth slowly over time and in some cases be partially leached back out. Therefore the significance of the U-series "age" depends on the mode of U-uptake.

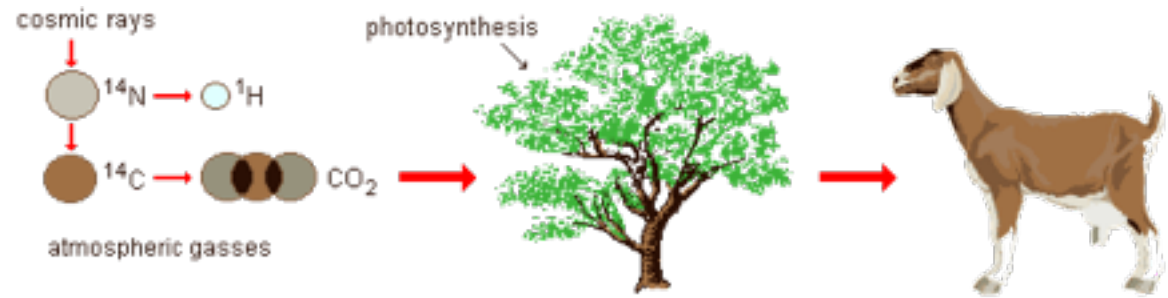


Radiocarbon Dating



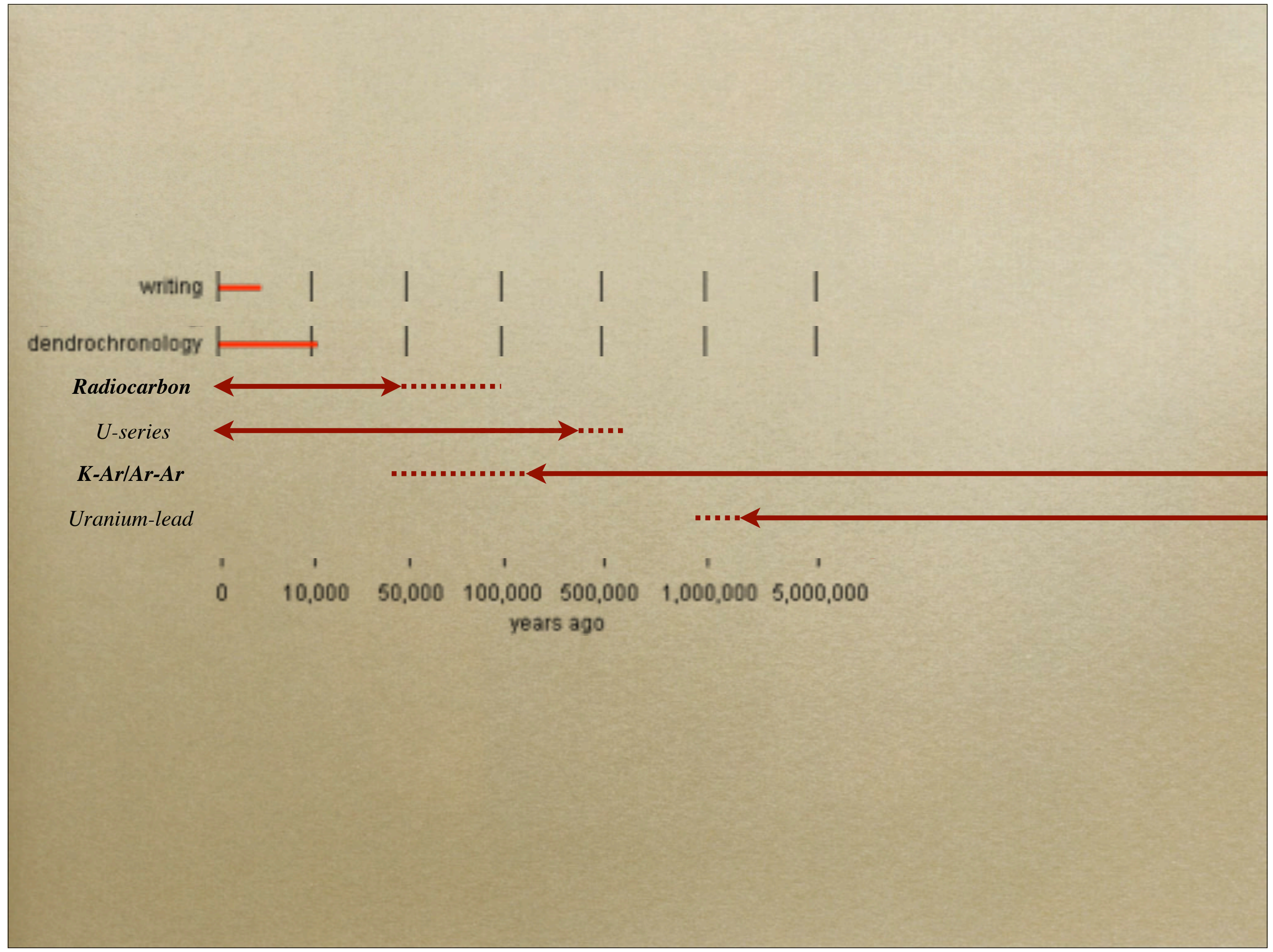
§
slidewords*Radiocarbon dating (also referred to as carbon dating or carbon-14 dating) is a method for determining the age of an object containing organic material by using the properties of radiocarbon (14. C), a radioactive isotope of carbon.

Radiocarbon dating



§

slidewords*Radiocarbon dating (also referred to as carbon dating or carbon-14 dating) is a method for determining the age of an object containing organic material by using the properties of radiocarbon (14. C), a radioactive isotope of carbon.



§
slidewords*comparative dating methods: OLDER SAMPLES:
Potassium-argon and argon-argon compares amount of radioactive 40 K ("potassium 40") to the amount of it's daughter, 40 Ar ("Argon 40") to determine date. Initially announced in 1956 by Garniss Curtis, Joseph Lipson, and Jack Evernden. Effective on volcanic rocks from about 100,000 years old and earlier.

Uranium-lead relies on decay of uranium to lead through a series of intermediate steps. Used on the mineral Zircon, which incorporates uranium but rejects lead in crystallization. Lead is thus all from radioactive decay of Uranium. Works on zircon containing rocks older than about 1 Ma.

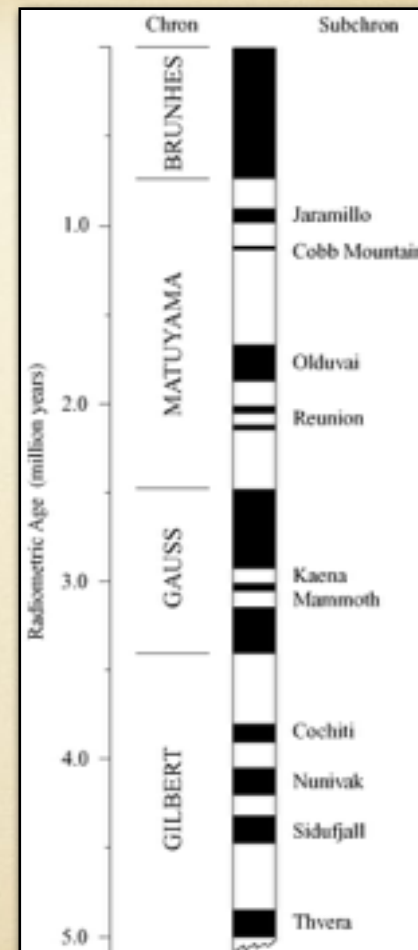
YOUNGER SAMPLES:
Carbon 14 compares about to radioactive Carbon 14 to stable Carbon 12 in a once-living sample of carbon to determine age since the sample stopped interacting with the atmosphere. Works well only on samples less than 50,000 years old.

Uranium-thorium (U series) compares the amount of uranium to daughter thorium. Uranium is water soluble, thorium is not, so the method is often applied to lake and ocean-bottom sediments that contain non-pedogenic precipitates like calcium carbonate.

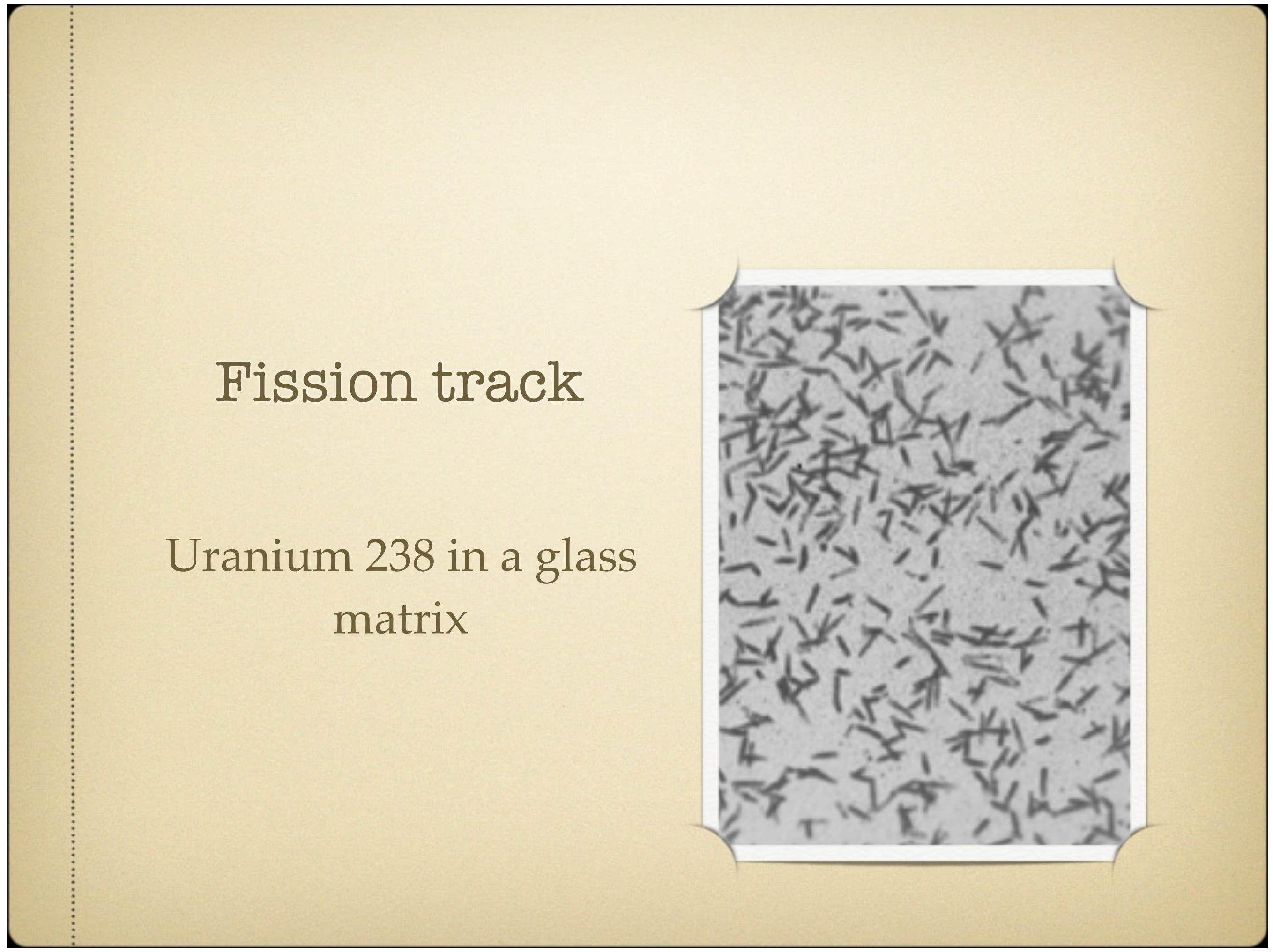
LESS RELIABLE METHODS:
Fission track dating counts the tracks left by spontaneous fission of Uranium in a uranium containing mineral. Sometimes inaccurate due to the tendency for tracks to "erase" naturally under intense conditions.

Thermoluminescence dating is the determination, by means of measuring the accumulated radiation dose, of the time elapsed since material containing crystalline minerals was either heated

Paleomagnetism



§
slidewords* Paleomagnetism (or Palaeomagnetism in the United Kingdom) is the study of the record of the Earth's magnetic field in rocks, sediment, or archeological materials. Certain minerals in rocks lock-in a record of the direction and intensity of the magnetic field when they form.



§

slidewords* **Fission Track Dating**

Another radiometric method that is used for samples from early human sites is **fission track dating**. This is based on the fact that a number of crystalline or glass-like minerals, such as obsidian, mica, and zircon crystals, contain trace amounts of uranium-238 (^{238}U), which is an unstable isotope. When atoms of uranium-238 fission, there is a release of energy-charged alpha particles which burn narrow fission tracks, or damage trails, through the glassy material. These can be seen and counted with an optical microscope.

Fission tracks in obsidian as they would appear with an optical microscope

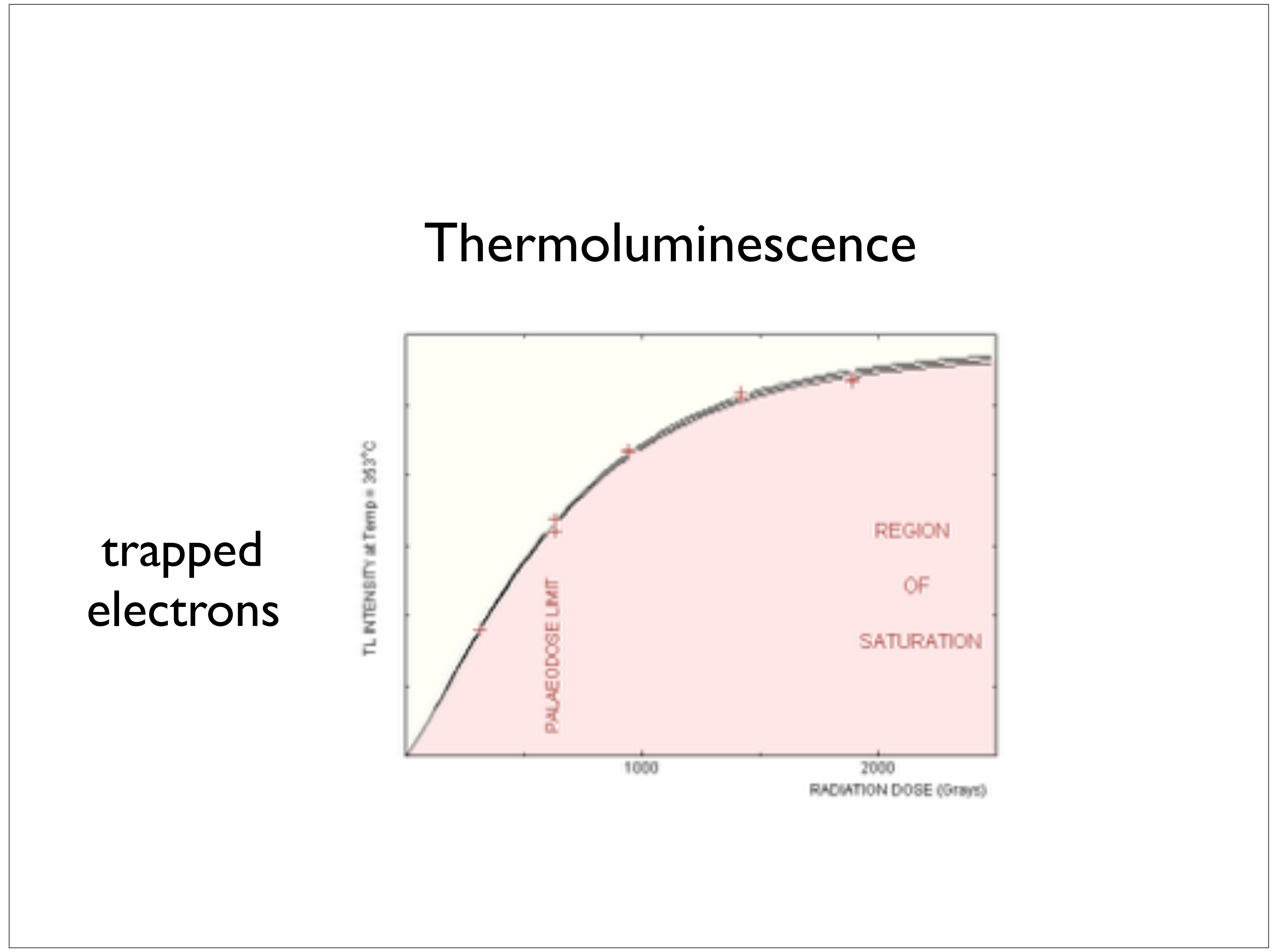
The number of fission tracks is directly proportional to the amount of time since the glassy material cooled from a molten state. Since the half-life of uranium-238 is known to be approximately 4.5 billion years, the chronometric age of a sample can be calculated. This dating method can be used with samples that are as young as a few decades to as old as the earth and beyond. However, paleoanthropologists rarely use it to date sites more than several million years old.

With the exception of early historic human made glass artifacts , the fission track method is usually only employed to date geological strata. Artifacts made out of obsidian and mica are not fission track dated because it would only tell us when the rocks cooled from a molten state, not when they were made into artifacts by our early human ancestors.

Fission track dating is a radiometric dating technique based on analyses of the damage trails, or tracks, left by fission fragments in certain uranium bearing minerals and glasses. Uranium-238 undergoes spontaneous fission decay at a known rate. The fragments emitted by this fission process leave trails of damage in the crystal structure of the minerals enclosing the uranium. Etching of polished surfaces of these minerals reveals the *spontaneous fission tracks* for counting by optical microscopic means. The number of tracks correlates directly with the age of the sample and the uranium content. To determine the uranium content the sample is annealed by heating and exposed to a barrage of thermal neutrons. The neutron bombardment produces an induced fission of the uranium-235 in the sample and the resulting new *induced tracks* are used to determine the uranium content of the sample as the U-235:U-238 ratio is well known. Alternatively, a uranium-free piece of mica, the *external detector*, is attached to the sample and both sample and mica are exposed to a barrage of thermal neutrons. The resulting induced fission of the uranium-235 in the sample creates new *induced track* in the external detector, which are revealed by etching. The ratio of *spontaneous tracks* to *induced tracks* is proportional to the age.

Apatite, sphene, zircon, micas and volcanic glass typically contain enough uranium to be useful in dating samples of relatively young age (Mesozoic and Cenozoic) and are the materials most useful for this technique. Additionally low-uranium epidotes and garnets may be used for very old samples (Paleozoic to Precambrian). Because heating of the sample above about 70 to 120 °C (for apatite - higher temperatures for other minerals) causes the fission damage tracks to heal over or anneal, the technique is useful for dating the most recent cooling event in the history of the sample. This *most recent* cooling event obviously may not coincide with the actual *formation age* of the mineral involved. This resetting of the clock can be used to investigate the thermal history of basin sediments, kilometer-scale exhumation caused by tectonism and erosion, low temperature metamorphic events, and geothermal vein formation.

The fission track method has also been used to date archaeological sites and artefacts. It was used to confirm the potassium-argon dates for the deposits at Olduvai Gorge.



§

slidewords* **Thermoluminescence Dating**

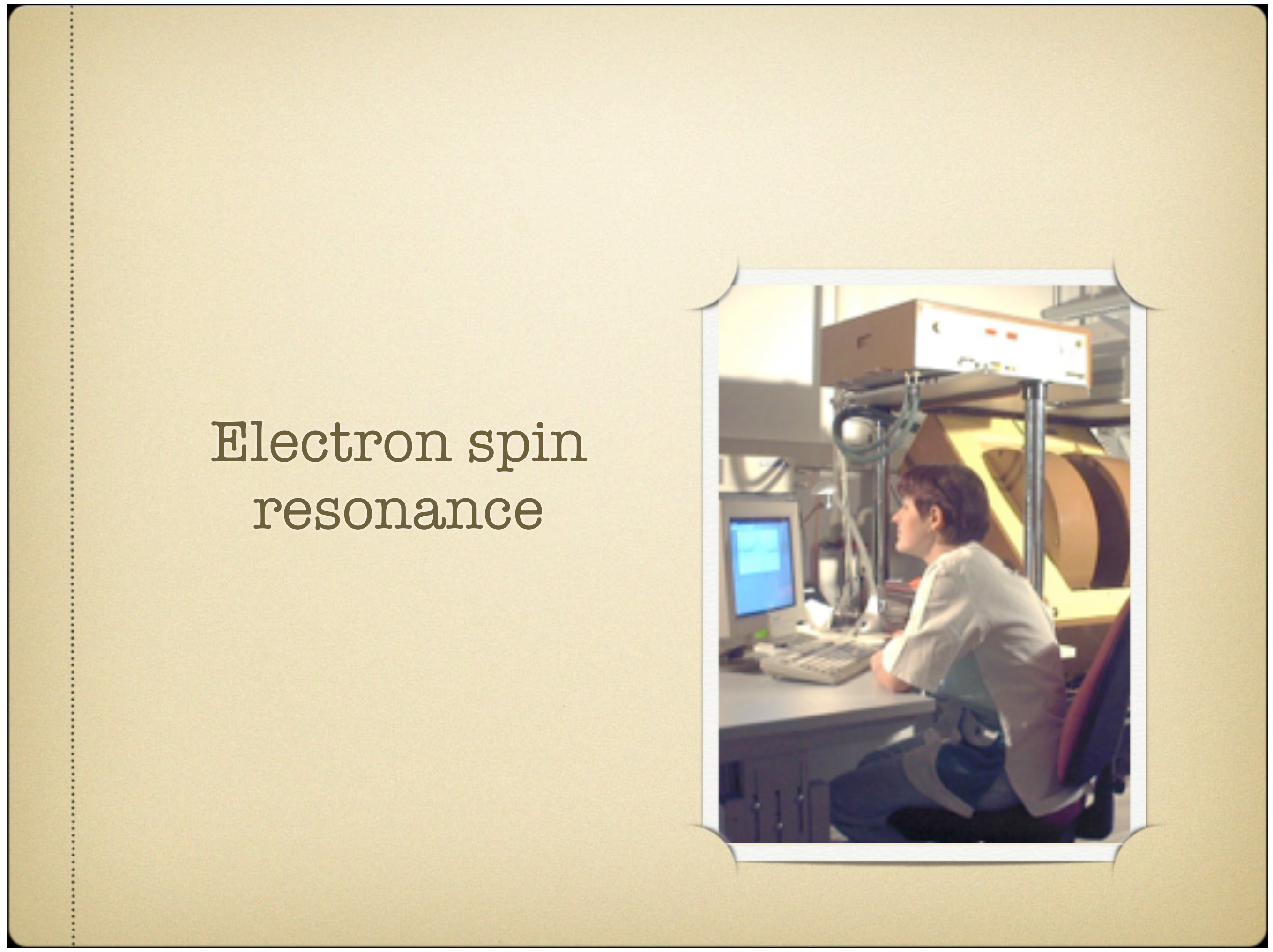
Thermoluminescence (TL) dating is a radiometric method based on the fact that trace amounts of radioactive atoms, such as uranium and thorium, in some kinds of rock, soil, and clay produce constant low amounts of background ionizing radiation. The atoms of crystalline solids, such as pottery and rock, can be altered by this radiation. Specifically, the electrons of quartz, feldspar, diamond, or calcite crystals can become displaced from their normal positions in atoms and trapped in imperfections in the crystal lattice of the rock or clay molecules. These energy charged electrons progressively accumulate over time. When a sample is heated to high temperatures in a laboratory, the trapped electrons are released and return to their normal positions in their atoms. This causes them to give off their stored energy in the form of light impulses (photons). This light is referred to as **thermoluminescence** (literally "heat light"). A similar effect can be brought about by stimulating the sample with infrared light. The intensity of thermoluminescence is directly related to the amount of accumulated changes produced by background radiation, which, in turn, varies with the age of the sample and the amount of trace radioactive elements it contains.

Thermoluminescence release resulting from rapidly heating a crushed clay sample

What is actually determined is the amount of elapsed time since the sample had previously been exposed to high temperatures. In the case of a pottery vessel, usually it is the time since it was fired in a kiln. For the clay or rock lining of a hearth or oven, it is the time since the last intense fire burned there. For burned flint, it is the time since it had been heated in a fire.

The effective time range for TL dating is now from a few decades back to about 300,000 years, but it is most often used to date things from the last 100,000 years. Theoretically, this technique could date samples as old as the solar system if we could find them. However, the accuracy of TL dating is generally lower than most other radiometric techniques.

Thermoluminescence dating **(TL)** of burned flint has gained wide acceptance as one of the most reliable dating methods for prehistoric archaeological sites (e.g. Mercier et al, 1995). It can be used over a time range from about 5 to 1000 ka. We are collaborating with N. Mercier and H. Valladas on TL dating of burned flint from sites in Israel and the Crimea, using their method for age determinations. Although burned flint is relatively rare in many archaeological sites, we have found that it is an invaluable tool for crosschecking our ESR ages. In sites that have plenty of teeth for ESR dating, but which show complex U-uptake histories, age estimates will have large uncertainties. These can be significantly reduced using burned flint, even if only a few samples are available.



§

slidewords* **Electron Spin Resonance Dating**

Another relatively new radiometric dating method related to thermoluminescence is **electron spin resonance (ESR)**. It is based also on the fact that background radiation causes electrons to dislodge from their normal positions in atoms and become trapped in the crystalline lattice of the material. When odd numbers of electrons are separated, there is a measurable change in the magnetic field (or spin) of the atoms. Since the magnetic field progressively changes with time in a predictable way as a result of this process, it provides another atomic clock, or calendar, that can be used for dating purposes. Unlike thermoluminescence dating, however, the sample is not destroyed with the ESR method, which allows samples to be dated more than once. ESR is used mostly to date calcium carbonate in limestone, coral, fossil teeth, mollusks, and egg shells. It also can date quartz and flint. Paleoanthropologists have used ESR mostly to date samples from the last 300,000 years. However, it potentially could be used for much older samples.

Electron Spin Resonance Dating falls into the group of dating methods that uses radiation exposure to date many materials found at archaeological sites. It is also known as a Radiometric Dating Method. This technique is mostly used to date minerals.It has been used to date such things as sedimentary quartz, fossilized teeth, flint, and calcium carbonate in limestone, coral and egg shells.

This method works by using radiation to cause electrons to separate from the atoms. These electrons then become trapped in the crystal lattice of minerals. This changes the magnetic field of the material at a rate that is predictable, allowing it to be used to date an item. It can be used to date when mineralization, sedimentation, or the last heating of minerals took place. It is often used to date quartz from meteorite strikes, and places where earthquake activity has taken place.

Unlike the other two methods of dating by radiation exposure, Thermoluminescence (TL), and Optically Stimulated Luminescence (OSL), Electron Spin Resonance dating can be repeated a number of times. This is because it is the only method that detects the paramagnetic centers and it does not destroy these centers when the measurement is made. Electron Spin Resonance dating is relatively new, some still consider it an experimental dating technique and is often used in combination with another dating method.

Electron Spin Resonance Dating (ESR): Fossil teeth are a ubiquitous component of prehistoric sites, and as a consequence, ESR dating of tooth enamel is very widely applicable in archaeology and palaeoanthropology. Since publication of the first papers on dating of sites in Israel (Schwarcz et al., 1988; Schwarcz et al., 1989) electron spin resonance (ESR) dating of tooth enamel has been recognized as a useful tool for chronometric dating in the time range beyond the 40 ka limit of radiocarbon and up to at least 2 Ma (Schwarcz et al. 1994). It takes its place alongside U-series and luminescence dating as one of the principal dating methods for this time range. General descriptions of ESR dating of tooth enamel are given by Grün et al. (1987), Grün and Stringer (1991), and Schwarcz and Grün (1992). Significant levels of uncertainty in the ESR age arise through problems associated with uranium uptake into the enamel, which in many cases can be reduced through additional dating of the teeth using MS/U-series dating. Here, the rate of change of radioactivity inside the tooth can be better understood, and