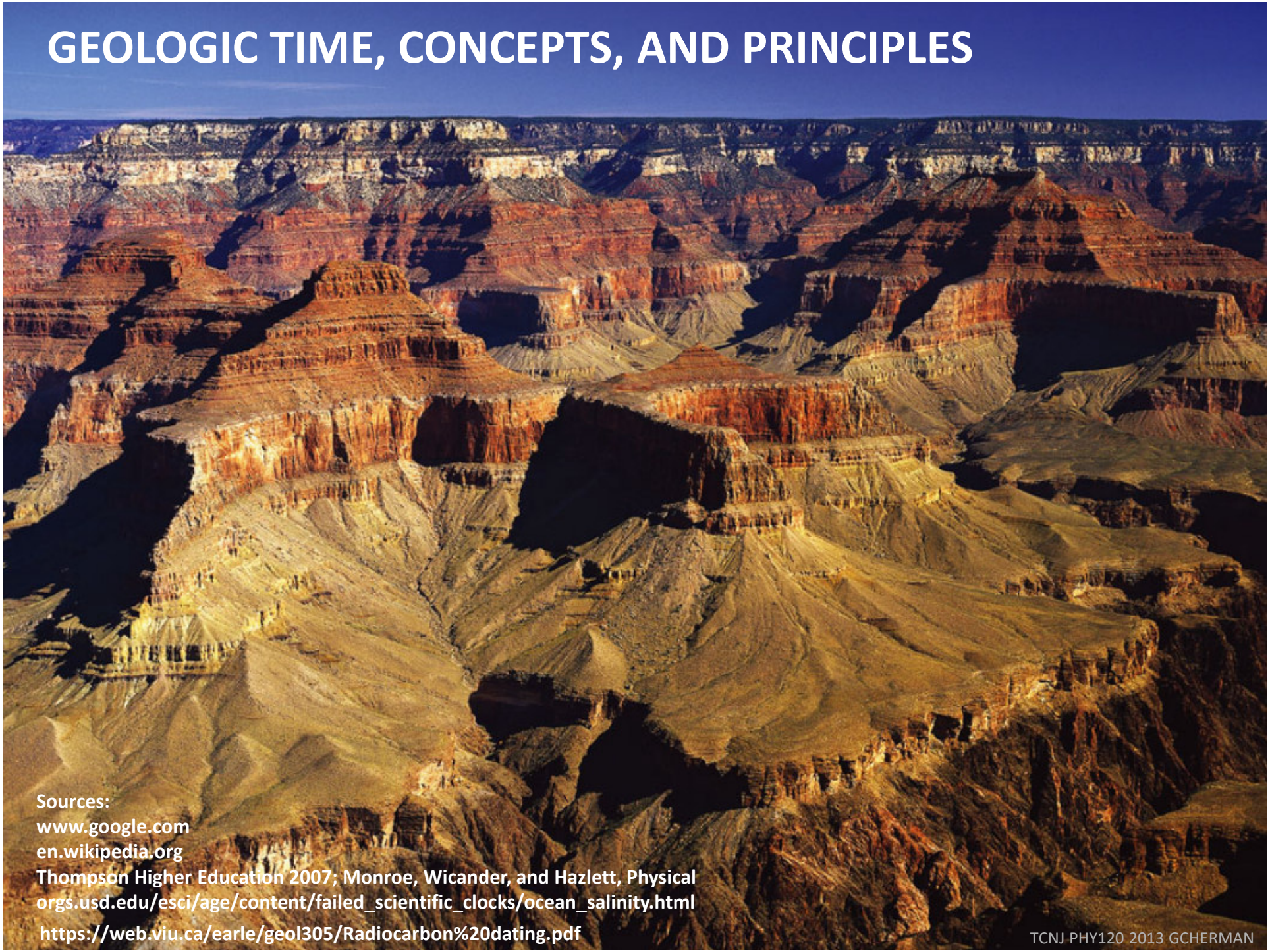
GEOLOGIC TIME, CONCEPTS, AND PRINCIPLES



Sources:
www.google.com
en.wikipedia.org
Thompson Higher Education 2007; Monroe, Wicander, and Hazlett, Physical
orgs.usd.edu/esci/age/content/failed_scientific_clocks/ocean_salinity.html
https://web.viu.ca/earle/geol305/Radiocarbon%20dating.pdf

GEOLOGIC TIME, CONCEPTS, AND PRINCIPLES

- **Early estimates of the age of the Earth**
- **James Hutton and the recognition of geologic time**
- **Relative dating methods**
- **Correlating rock units**
- **Absolute dating methods**
- **Development of *the* Geologic Time Scale**
- **Geologic time and climate**

•**Relative dating** *is accomplished by placing events in sequential order with the aid of the principles of historical geology*.

•**Absolute dating** *provides chronometric dates expressed in years before present from using radioactive decay rates.*

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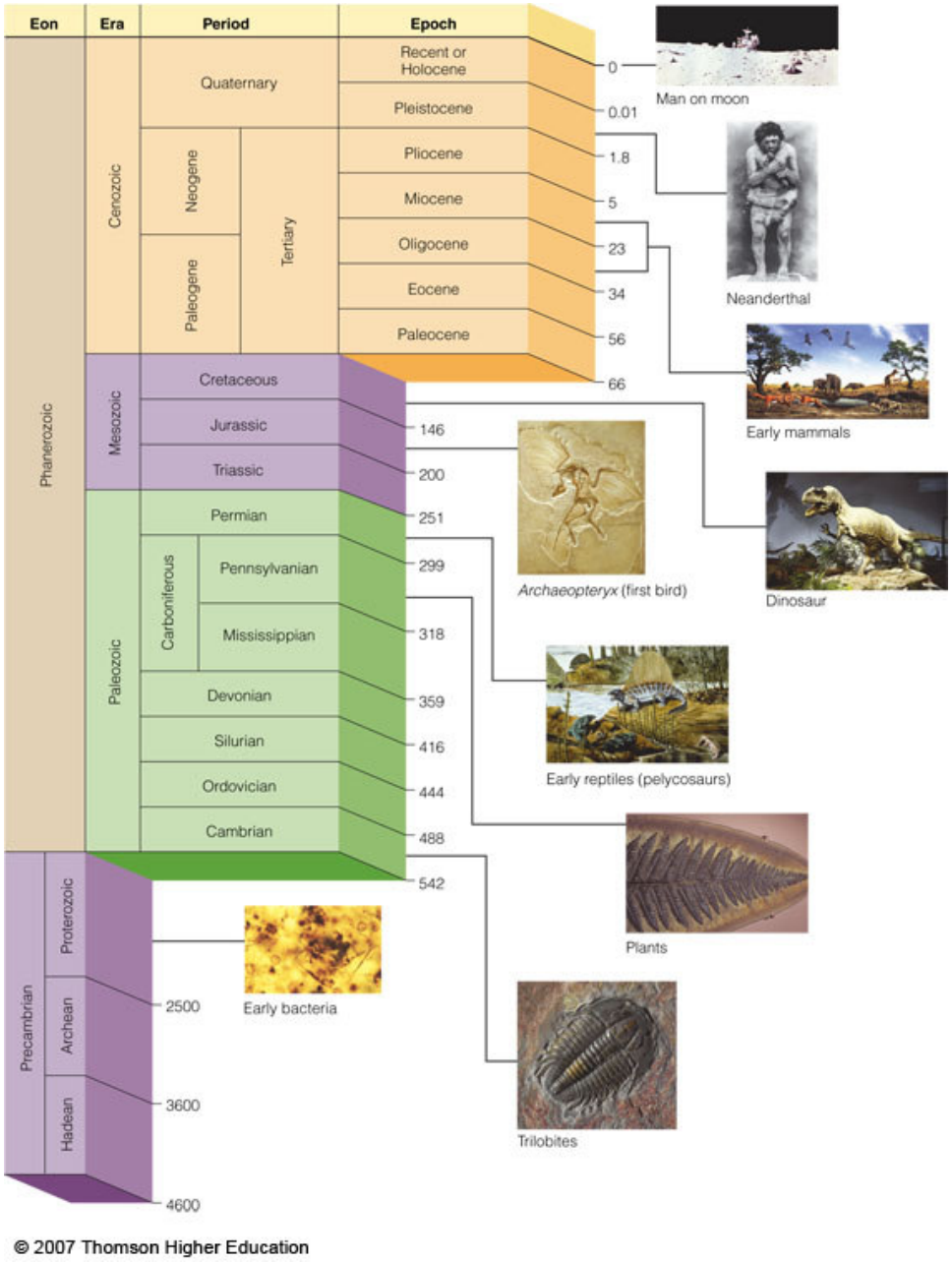

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Geologic time on Earth

• A world-wide relative time scale of Earth's rock record was established by the work of many geologists, primarily during the 19th century by applying the principles of historical geology and correlation to strata of all ages throughout the world.

Covers 4.6 Ba to the present

- Eon – billions to hundreds of millions
- Era - hundreds to tens of millions
- Period – tens of millions
- Epoch – tens of millions to hundreds of thousands

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EARLY ESTIMATES OF EARTH'S AGE

• Scientific attempts to estimate Earth's age were first made during the 18th and 19th centuries. These attempts all resulted in *ages far younger than the actual age* of Earth.

• Biblical account (1600'S)

James Ussher

James Ussher was Church of Ireland Archbishop of Armagh and Primate of All Ireland between 1625 and 1656. Wikipedia

Bishop Ussher Dates the World: 4004 BC
www.lhup.edu/~dsimanek/**ussher**.htm
Sir James Lightfoot improves that calculation to 9 AM Oct 3, 4004 BC.

1778 'Iron balls' Buffon
Georges-Louis Leclerc de Buffon

From *Measuring Eternity* by Martin Gorst

74,832 years old and that humans were relative newcomers.

www.**strangescience.net**/buffon.htm

1710 – 1910 'salt clocks'

26 – 150 Ma for the oceans to become as salty as they are from streams carrying low-concentrations of salt into an initially fresh-water ocean

THE FOUNDERS OF MODERN GEOLOGY

James Hutton is considered to be the founder of modern geology.

was a Scottish physician, geologist, naturalist, chemical manufacturer and experimental agriculturalist. His work helped to establish the basis of modern geology. Wikipedia

Born: June 14, 1726, Edinburgh

Died: March 26, 1797, Edinburgh

Books: The theory of rain ; Theory of the earth, or, An investigation of the laws observable in the composition, dissolution, and restoration of land upon the globe,

- Hutton first suggested that present day processes operating over long periods of time could explain all geologic features.

- Hutton's observations led to the establishment of the *principle of uniformitarianism*.

Sir Charles Lyell

was a British lawyer and the foremost geologist of his day. He is best known as the author of *Principles of Geology*, which popularised James Hutton's concepts of uniformitarianism – the idea that the earth was shaped by the same processes still in operation today. Lyell was a close and influential friend of Charles Darwin.

Born	14 November 1797 Kinnordy, Forfarshire, Scotland
Died	22 February 1875 (aged 77) Harley Street, London, England

1830 *Principles of Geology*

- Argued convincingly for Hutton's conclusions and *established the principle of uniformitarianism as the guiding principle of geology*.

PRINCIPLES OF UNIFORMITARIANISM

•This principle simply states that all investigations can assume that physical and chemical laws have operated through time, and the same processes which operate today (with allowance for varying rates), have also operated throughout Earth's history.

2.bp.blogspot.com/-7SOgPIJKhvo/UMdznlsQf5I/AAAAAAAAAIc/nM2_9XYf6e4/s1600/uniformitrariasim.jpeg

PRINCIPLES OF UNIFORMITARIANISM

Stephen Jay Gould (September 10, 1941 – May 20, 2002) was an American paleontologist, evolutionary biologist, and historian of science. He was also one of the most influential and widely read writers of popular science of his generation. He spent most of his career teaching at Harvard University and working at the American Museum of Natural History (NY). In the latter years of his life, Gould also taught biology and evolution at New York University.

Gould's most significant contribution to evolutionary biology was the ***theory of punctuated equilibrium***, which he developed with Niles Eldredge in 1972.

Gould argued that Hutton's interpretation of uniformitarianism actually included a cyclical series of events in which all of Earth history was repeated with "repair" of the earlier age, much as many primal societies view time as a cyclical, rather than linear, phenomenon.

Furthermore, the rates of geological processes were not required to be constant or gradual in either Hutton's or Lyell's concept of uniformitarianism.

Similarly, catastrophism was not originally linked to a sequence of "special creations" or similar total recreation of the world geology and life.

Instead, each sequence bounded by unconformities and containing a "new biosphere" was believed to be the result of a "revolution" which did not invoke any suspension of presently operating laws of nature.

FUNDAMENTAL PRINCIPLES OF RELATIVE DATING

•*Relative dating is accomplished by placing events in sequential order with the aid of the principles of historical geology*.

•Six fundamental principles:

1) **Superposition** – undisturbed strata are younger on top and older on the bottom

2) **Original horizontality** – strata are deposited as flat, horizontal layers

3) **Lateral continuity** – strata are laterally continuous until they pinch out

4) **Cross-cutting relationships** – younger features cross-cut older features

5) **Inclusions** – fragments contained in rocks are older than the rock

6) **Fossil succession** - stratigraphic layers of the same age contain the same fossils

3 of 6 PRINCIPLES OF RELATIVE DATING ESTABLISHED BY NICOLAS STENO

1) **Superposition** – undisturbed strata are younger on top and older on the bottom

2) **Original horizontality** – strata are deposited as flat, horizontal layers

3) **Lateral continuity** – strata are laterally continuous until they pinch out

Nicolas Steno (1 January 1638 – 25 November 1686

was a Danish Catholic bishop and scientist and a pioneer in both anatomy and geology. Steno was trained in the classical texts on science; however, by 1659 he seriously questioned accepted knowledge of the natural world. Importantly he questioned explanations for tear production, the idea that fossils grew in the ground and explanations of rock formation. His investigations and his subsequent conclusions on fossils and rock formation have led scholars to consider him one of the founders of modern stratigraphy and modern geology.

From Wikipedia, the free encyclopedia

Portrait of Steno as bishop

•Observed the burial of organisms on flooplains by gravity-settled sediment.

•Subsequent floods covered previous deposits.

•Layers are laid-down essentially horizontal, and

•Extend laterally until they either pinch out or terminate against the edge of the depositional basin boundary

FUNDAMENTAL PRINCIPLES OF RELATIVE DATING (cont.)

4) Cross-cutting relationships – younger features cross-cut older features

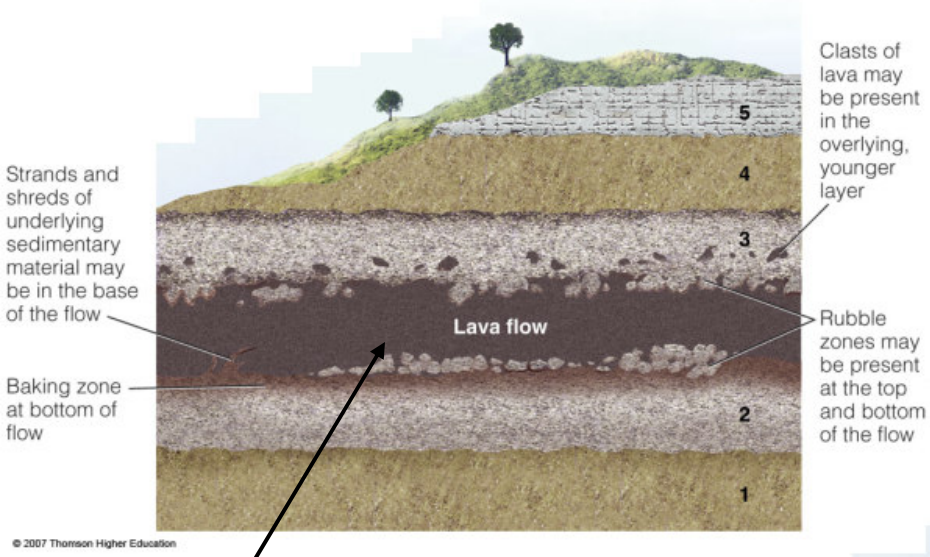
Basic dike cuts country rock and is therefore a younger structure

This principle is attributed to James Hutton who first realized the significance of unconformities at Siccar Point, Scotland

Fault cuts and offsets strata and is therefore a relatively younger structure

FUNDAMENTAL PRINCIPLES OF RELATIVE DATING (cont.)

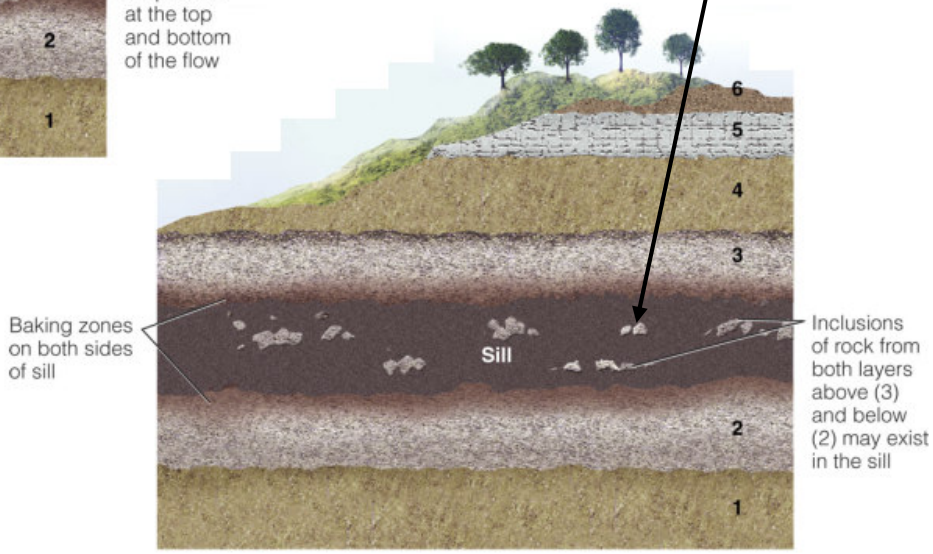
5) Inclusions – fragments contained in rocks are older than the rock



• Lava flows on Earth's surface and may have pieces ripped up and included in overlying detrital bed.

•Only the bottom contact is baked.

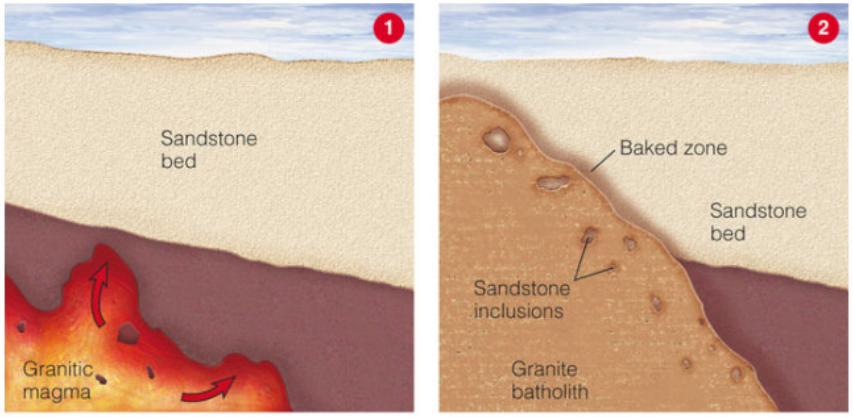
• Sills have two baked margins and may have inclusions from the bounding beds

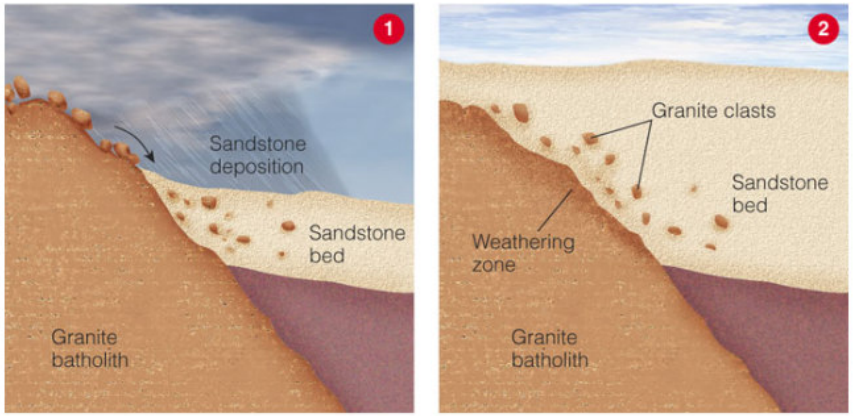


FUNDAMENTAL PRINCIPLES OF RELATIVE DATING

5) Inclusions – fragments contained in rocks are older than the rock

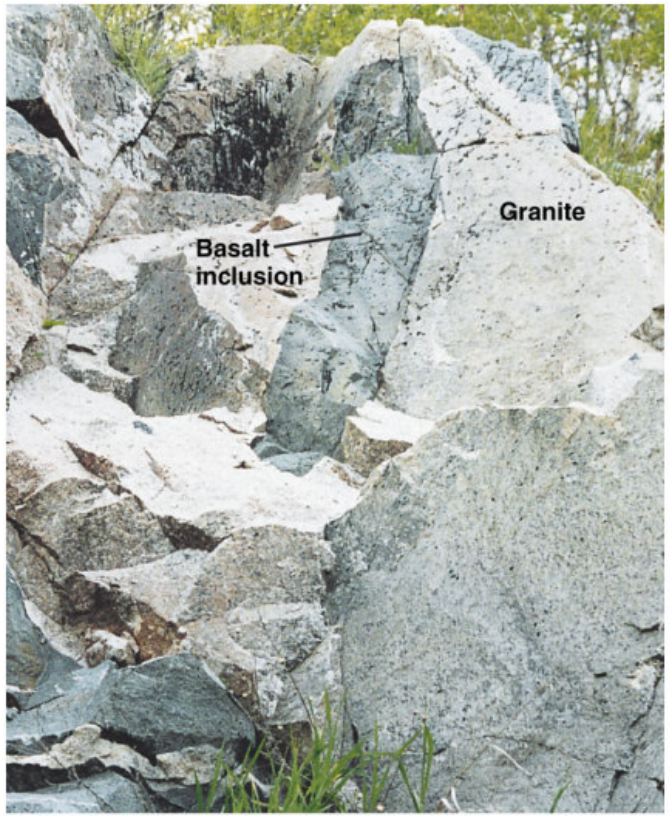
Top - SS older than igneous activity





Bottom - Granite older than SS

basalt inclusion in a granite from Wisconsin



FUNDAMENTAL PRINCIPLES OF RELATIVE DATING (cont.)

6) Fossil succession

•An English civil engineer noticed while building a canal in England independently recognized the principle of superposition by reasoning that fossils seen in the excavation bottom were older than those in overlying, leading to the principle of faunal and flora succession.

William Smith (geologist)

From Wikipedia, the free encyclopedia

William 'Strata' Smith (23 March 1769 – 28 August 1839) was an English geologist, credited with creating the first nationwide geological map. He is known as the "Father of English Geology" for collating the geological history of England and Wales into a single record, although recognition was very slow in coming. At the time his map was first published he was overlooked by the scientific community; his relatively humble education and family connections preventing him from mixing easily in learned society. Consequently his work was plagiarised, he was financially ruined, and he spent time in debtors' prison. It was only much later in his life that Smith received recognition for his accomplishments.

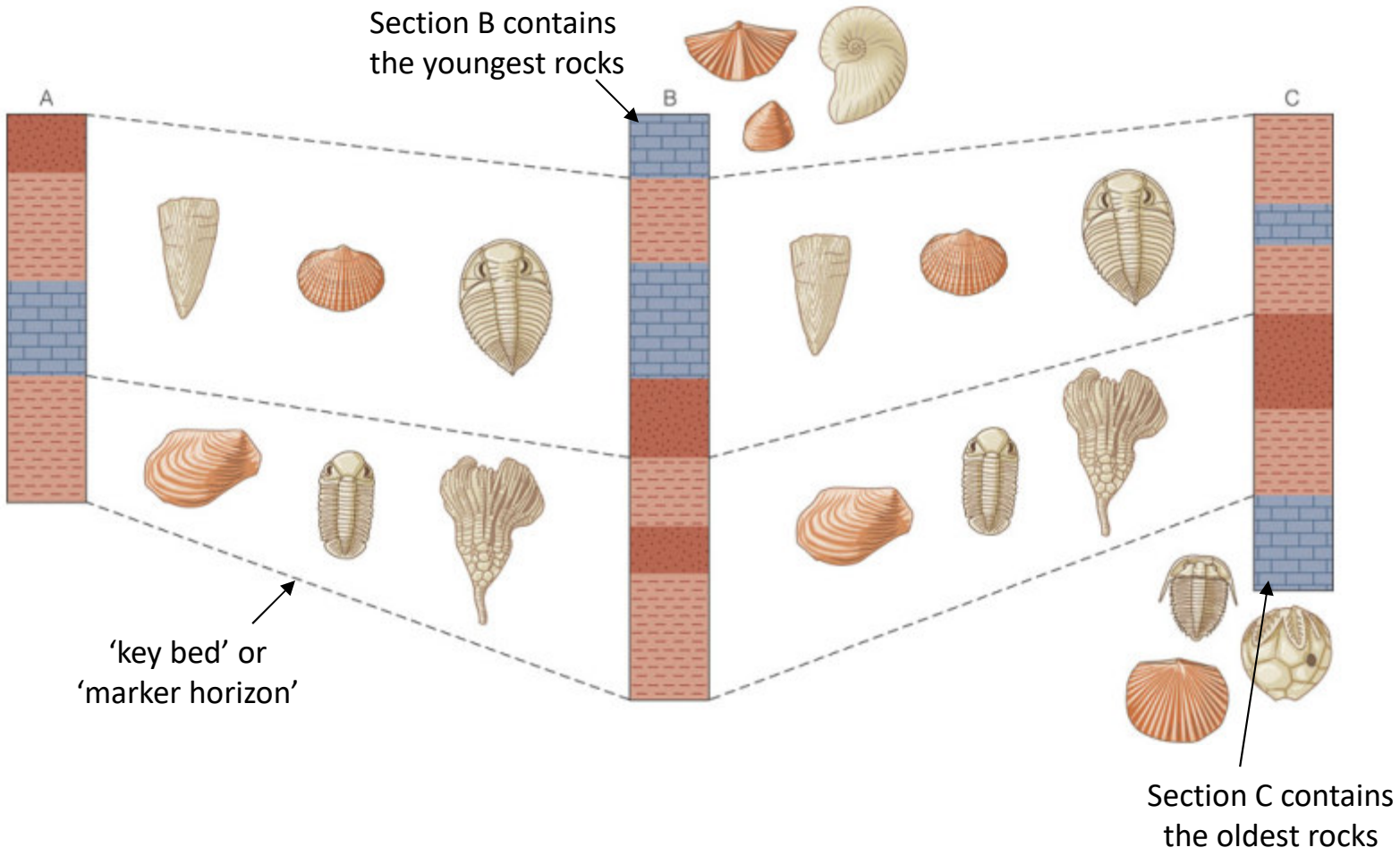
William Smith

William Smith

Born	23 March 1769 Churchill, Oxfordshire
Died	28 August 1839 (aged 70)
Nationality	English
Fields	Geology
Known for	Geological map

FUNDAMENTAL PRINCIPLES OF RELATIVE DATING

6) Fossil succession - Stratigraphic layers of the same age contain the same collection of fossils



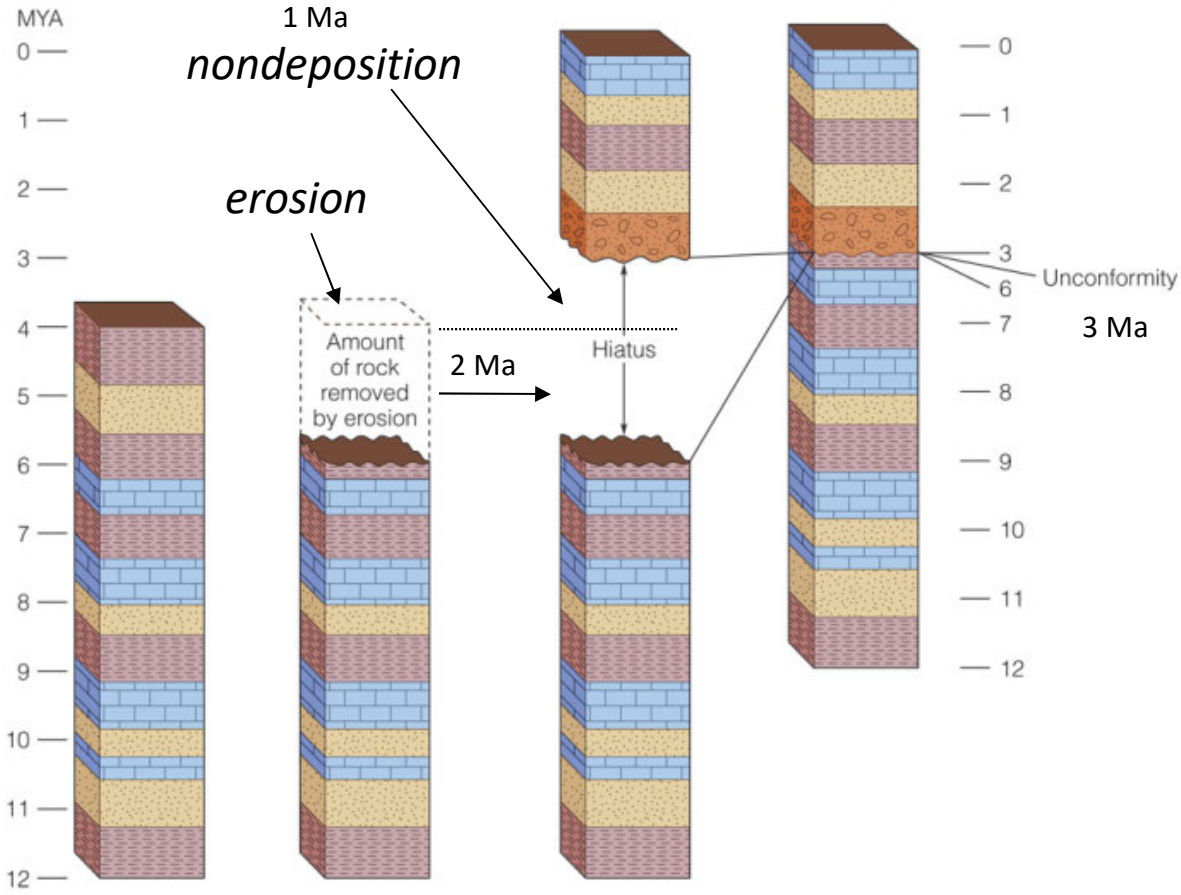
SUMMARY OF PRINCIPLES OF HISTORICAL GEOLOGY

•The principles of historical geology, *in addition to uniformitarianism*, are superposition, original horizontality, cross-cutting relationships, lateral continuity, inclusions, and fossil succession.

•These principles are used to determine the sequence of geologic events and to interpret them.

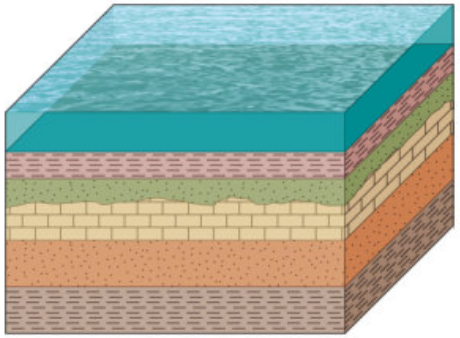
UNCONFORMITIES *are surfaces of discontinuity in the rock deposition sequence which encompass significant periods of time*.

- Unconformities may result from *nondeposition and/or erosion*.

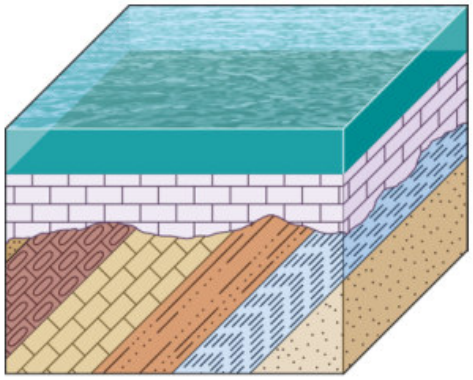


UNCONFORMITIES

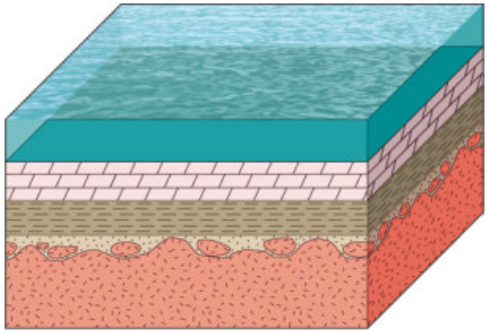
1) Disconformity – Surface separates parallel strata on either side



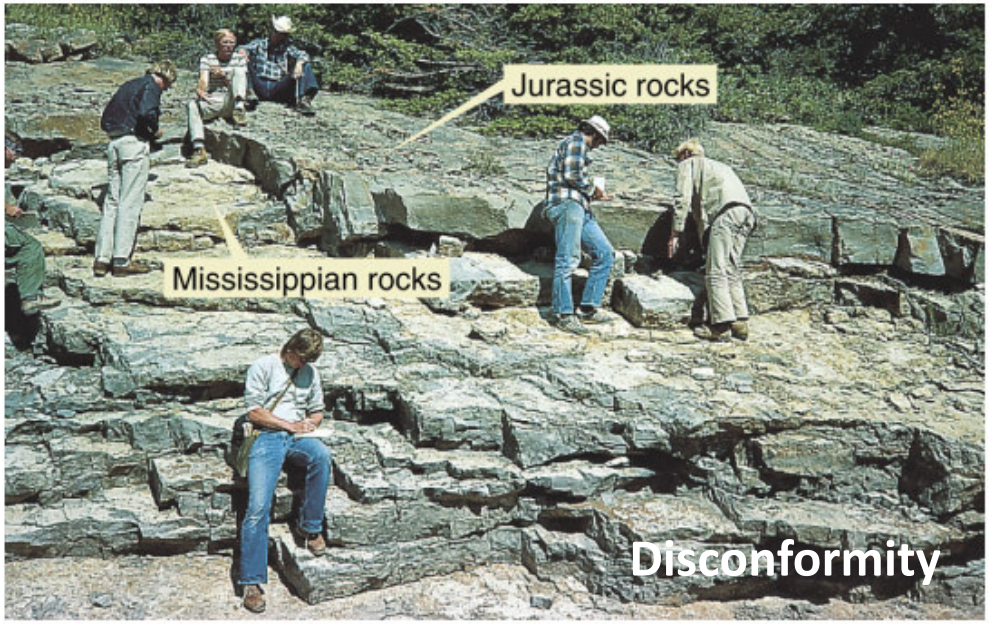
2) Angular unconformity – Surface separates strata tilted differently



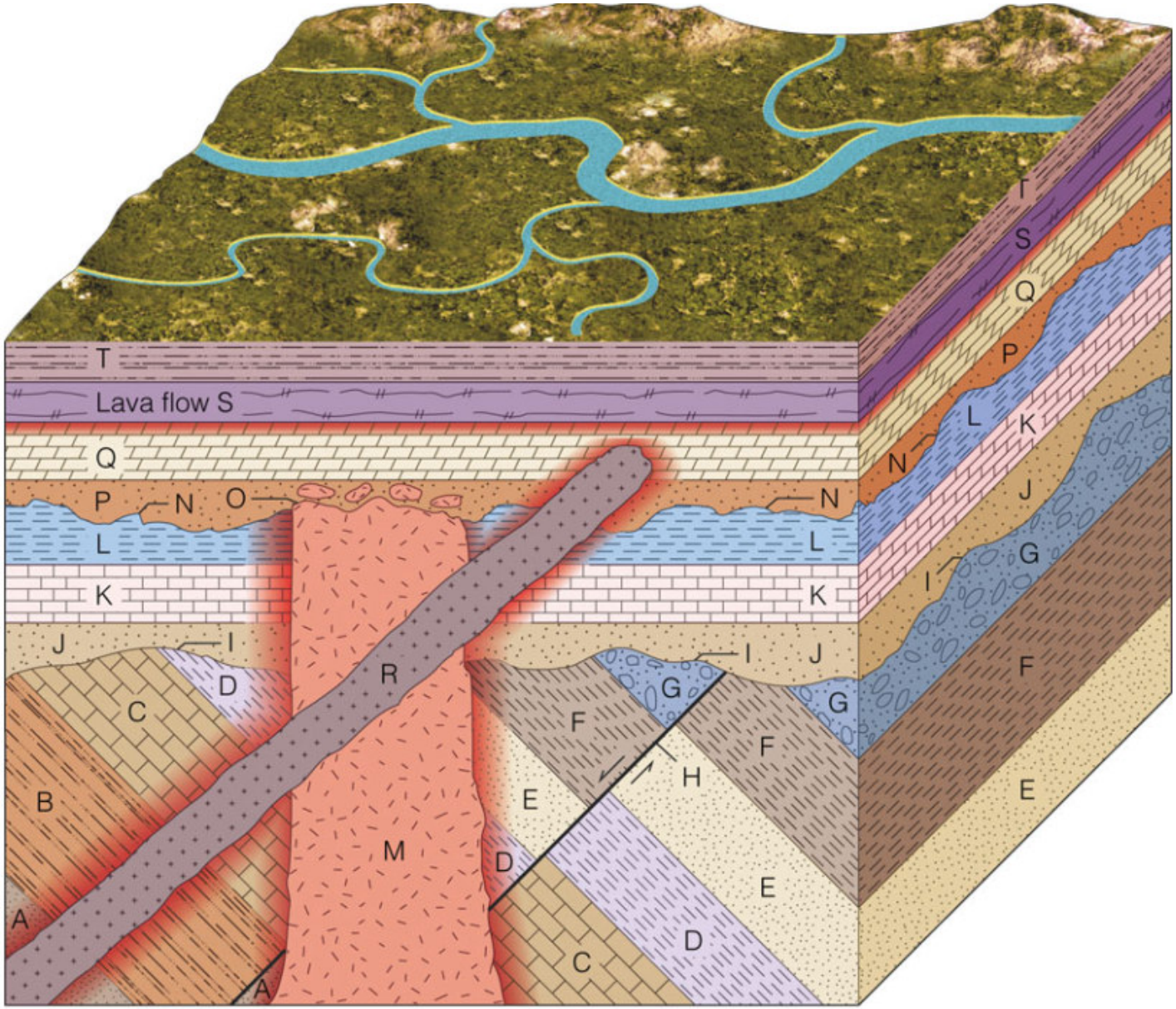
3) Nonconformity – Surface cut into crystalline (igneous and/or metamorphic) rocks, then covered by sedimentary rocks



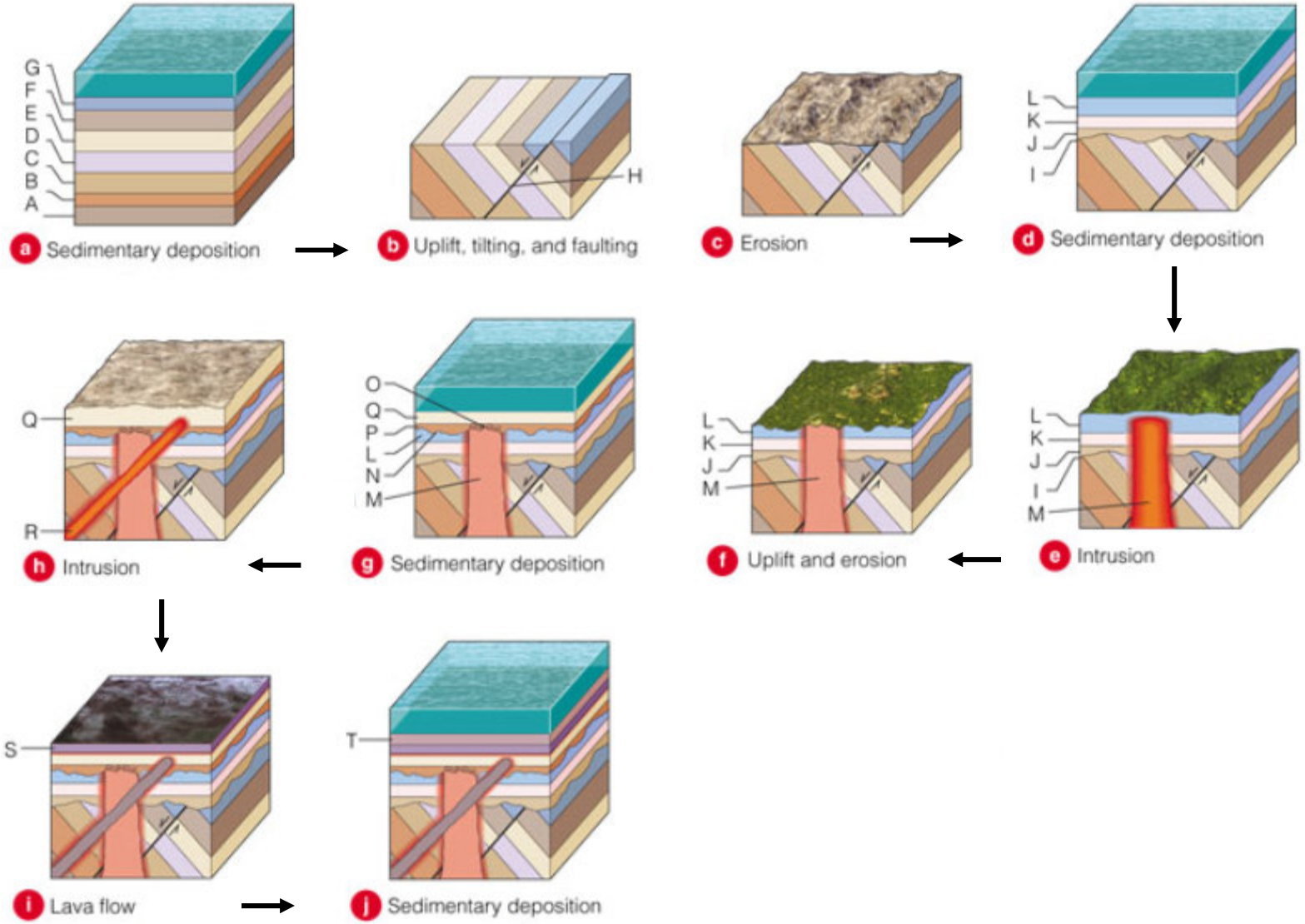
UNCONFORMITIES



RELATIVE DATING EXAMPLE

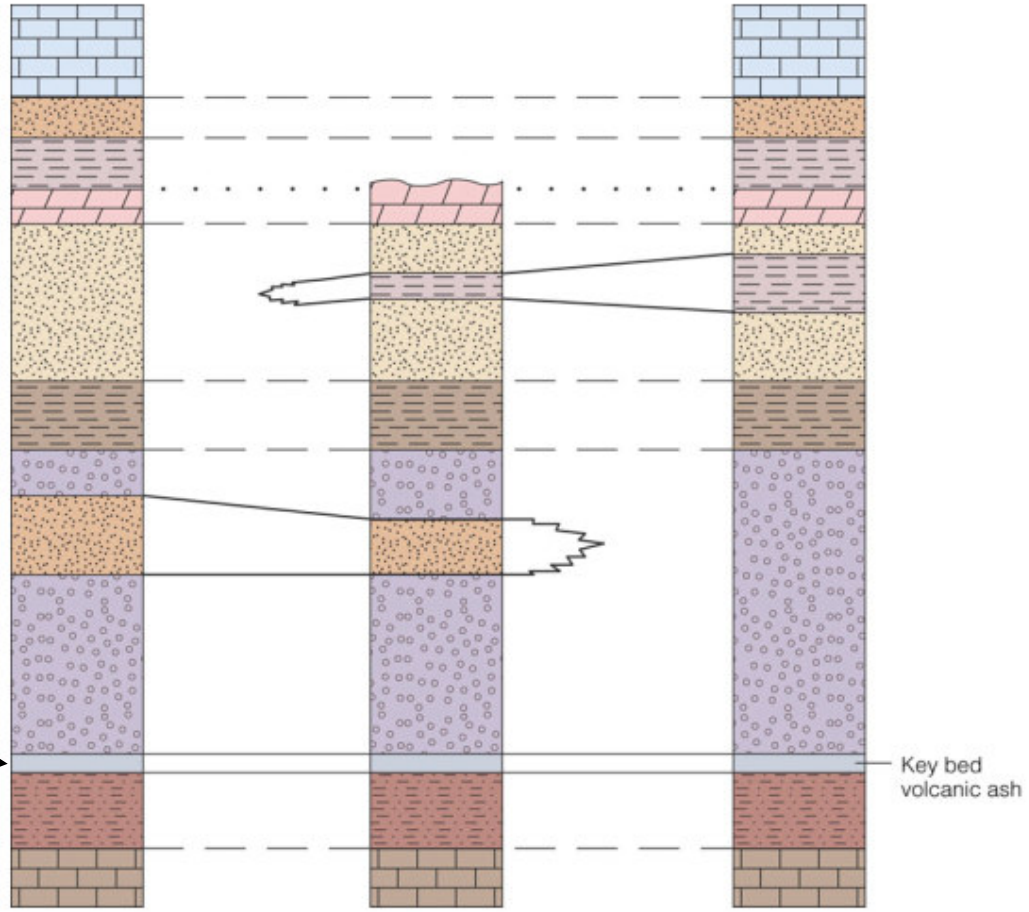


RELATIVE DATING EXAMPLE solution



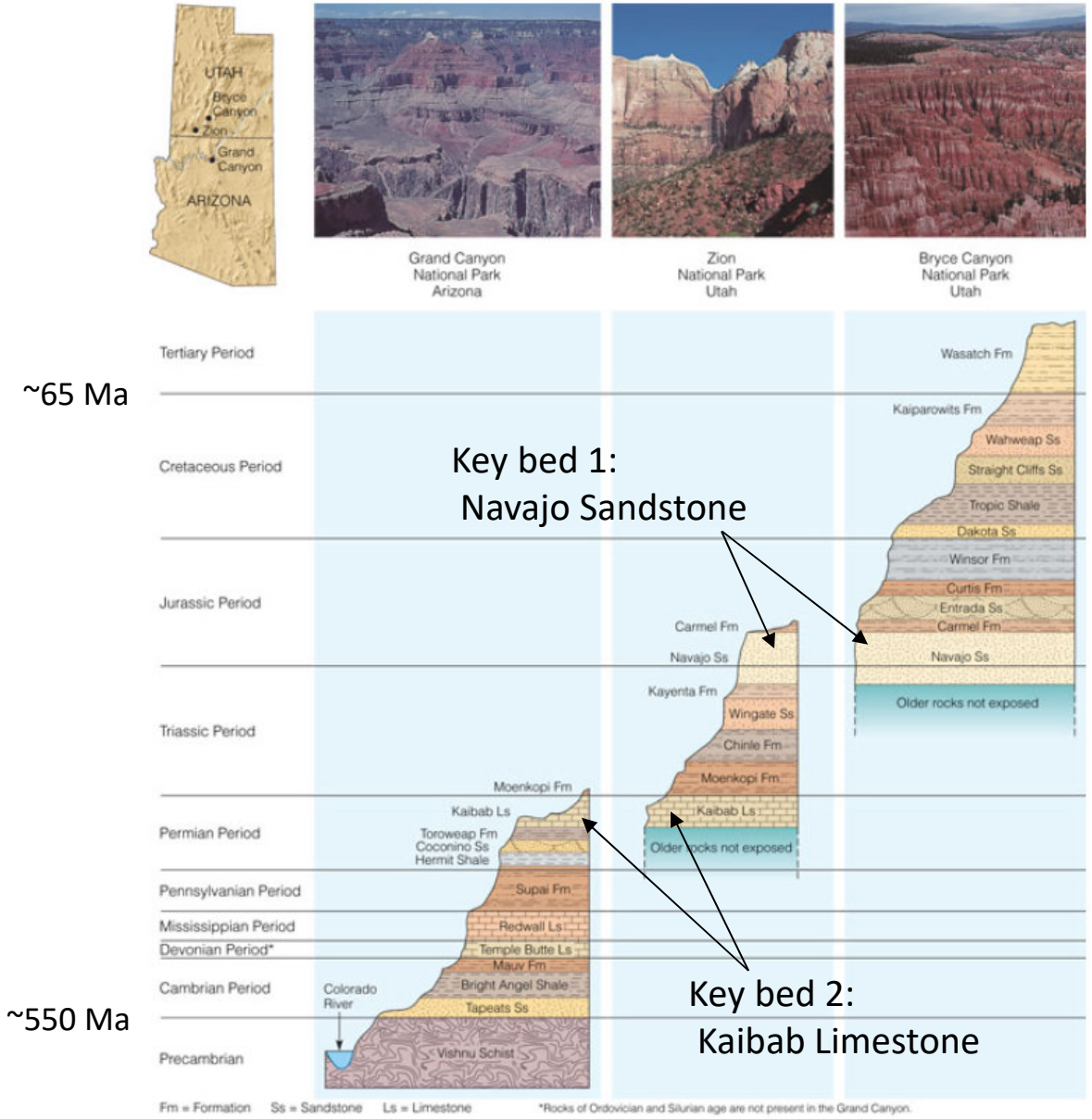
STRATIGRAPHIC CORRELATION is the demonstration of equivalency of rock units from one area to another.

Key beds are stratigraphic units such as coal beds or ash layers, that are sufficiently distinctive to allow identification of the same unit in different places or area.



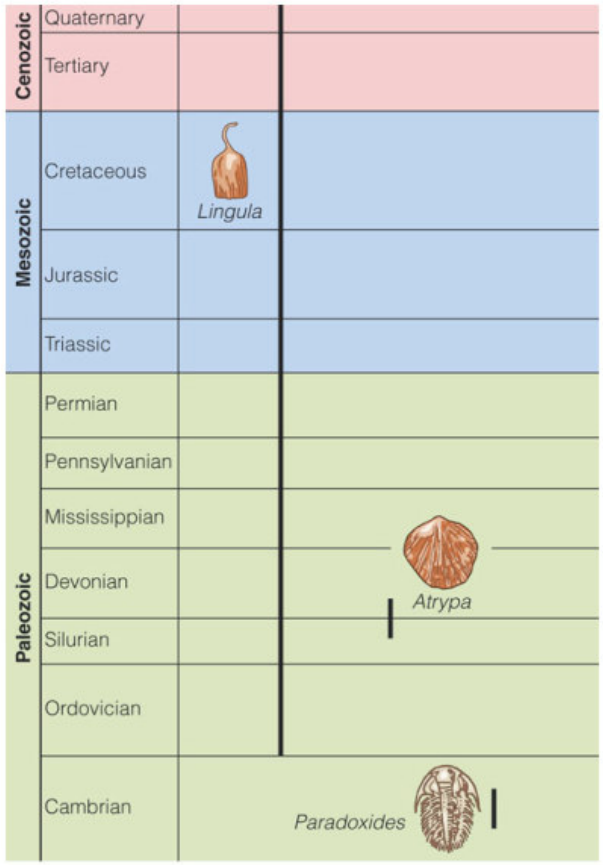
STRATIGRAPHIC CORRELATION

An example of **using** *key beds* to correlate stratigraphic sections from three National Parks in the southwest USA totaling over 400 Ma of rock succession

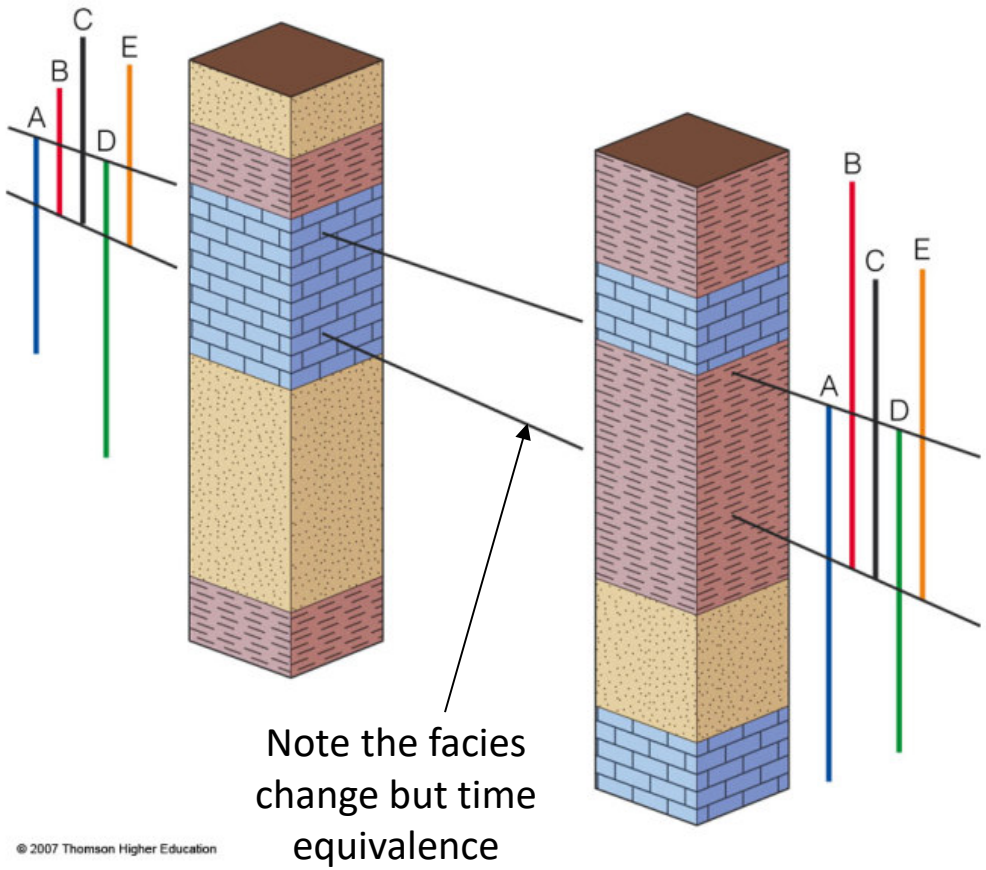


GEOLOGIC TIME, CONCEPTS, AND PRINCIPLES

- Good guide fossils have rather short intervals of existence



- Time equivalence is usually demonstrated by the occurrence of similar fossils (guide fossils) in strata.



Marker horizon

From Wikipedia, the free encyclopedia

Marker horizons or **chronohorizons** or **marker beds** are stratigraphic units of the same age and of such distinctive composition and appearance, that, despite their presence in separate geographic locations, there is no doubt about their being of equivalent age (isochronous) and of common origin. Such clear markers facilitate the correlation of strata, and used in conjunction with fossil floral and faunal assemblages and paleomagnetism, permit the mapping of land masses and bodies of water throughout the history of the earth.

Tephra horizons in Iceland

Palynology, the study of fossil pollens and spores, routinely works out the stratigraphy of rocks by comparing pollen and spore assemblages with those of well-known layers - a tool frequently used by petroleum exploration companies in the search for new fields. The fossilised teeth or elements of Conodonts are an equally useful tool.

The ejecta from volcanoes and bolide impacts create useful markers, as different volcanic eruptions and impacts produce beds with distinctive compositions. Marker horizons of tephra are used as a dating tool in archaeology, since the dates of eruptions are generally well-established.

One particular bolide impact 65 million years ago, Chicxulub, is controversially held to have led to a major extinction event and produced an iridium anomaly that occurs in a thin, global layer of clay marking the Cretaceous–Paleogene boundary. [1][2] Iridium layers are associated with bolide impacts and are not unique, but when occurring in conjunction with the extinction of specialised tropical planktic foraminifera and the appearance of the first Danian species, signal a reliable marker horizon for the Cretaceous–Paleogene boundary.[3]

Fossil faunal and floral assemblages, both marine and terrestrial, make for distinctive marker horizons. Some marker units are distinctive by virtue of their magnetic qualities. The Water Tower Slates, forming part of the Hospital Hill Series in the Witwatersrand Basin, include a fine-grained ferruginous quartzite which is particularly magnetic. From the same series a ripple-marked quartzite and a speckled bed are used as marker horizons.

On a much smaller time scale, marker horizons may be created by sedimentologists and limnologists in order to measure deposition and erosion rates in a marsh or pond environment. The materials used for such an artificial horizon are chosen for their visibility and stability and may be brick dust, grog, sand, kaolin, glitter or feldspar clay.[4]

Danian

From Wikipedia, the free encyclopedia

For the village in Iran, see Danian, Iran.

The **Danian** is the oldest age or lowermost stage of the Paleocene epoch or series, the Paleogene period or system and the Cenozoic era or erathem. The beginning of the Danian age (and the end of the precessing Maastrichtian age) is at the Cretaceous–Paleogene extinction event 65.5 ±0.3 Ma. The age ended 61.7 ±0.2 Ma, being followed by the Selandian age.[1]

Contents [hide]

1 Stratigraphic definitions
2 Palaeontology
3 References
  3.1 Notes
  3.2 Literature
4 External links

System	Series	Stage	Age (Ma)
Neogene	Miocene	Aquitanian	younger
Paleogene	Oligocene	Chattian	23.03–28.4
		Rupelian	28.4–33.9
	Eocene	Priabonian	33.9–37.2
		Bartonian	37.2–40.4
		Lutetian	40.4–48.6
		Ypresian	48.6–55.8
	Paleocene	Thanetian	55.8–58.7
		Selandian	58.7–61.7
		Danian	61.7–65.5
Cretaceous	Upper	Maastrichtian	older

Subdivision of the Paleogene Period according to the IUGS, as of July 2009.

Stratigraphic definitions [edit]

The Danian was introduced in scientific literature by German-Swiss geologist Pierre Jean Édouard Desor in 1847. It is named after the Latin name for Denmark. The Montian stage from Belgian stratigraphy (named after the city of Mons) is now considered a junior synonym and is no longer in use.

The base of the Danian is defined at the iridium anomaly which characterized the Cretaceous–Paleogene boundary (K–T boundary) in stratigraphic sections worldwide. A section in El Kef, Tunisia was appointed as a reference profile (GSSP) for this important boundary.[2] The Danian is the oldest age of the Paleocene, defined at its base by the K-Pg boundary. It is very important because the readily recognized iridium anomaly and primitive Danian planktonic foraminifers define the base of the Danian. Danian foraminiferans repopulated the Paleocene seas after the Cretaceous mass extinction (Olsson et al., 1996). The first replacement foraminiferan of the Paleogene is the Globigerina eugubina, which is used to define the base of the Danian Age (Stainforth et al., 1975). This foraminiferan replaced the Cretaceous genus Globotruncana.

The top of the Danian stage (the base of the Selandian) is close to the boundary between biozones NP4 and NP5 from marine biostratigraphy. It is slightly after the first appearances of many new species of the calcareous nannoplankton genus *Fasciculithus* (*F. ulii*, *F. billii*, *F. janii*, *F. involutus*, *F. tympaniformis* and *F. pileatus*) and close to the first appearance of calcareous nannoplankton species *Neochiastozygus perfectus*.

The Danian stage overlaps the Puercan and Torrejonian North American land mammal ages and the Shanghuan and lowest part of the Nongshanian Asian land mammal ages. It includes the oldest Mammal Paleogene zones, all included in the 1 - 5 group.[3]

THE K-T BOUNDARY MARKER HORIZON

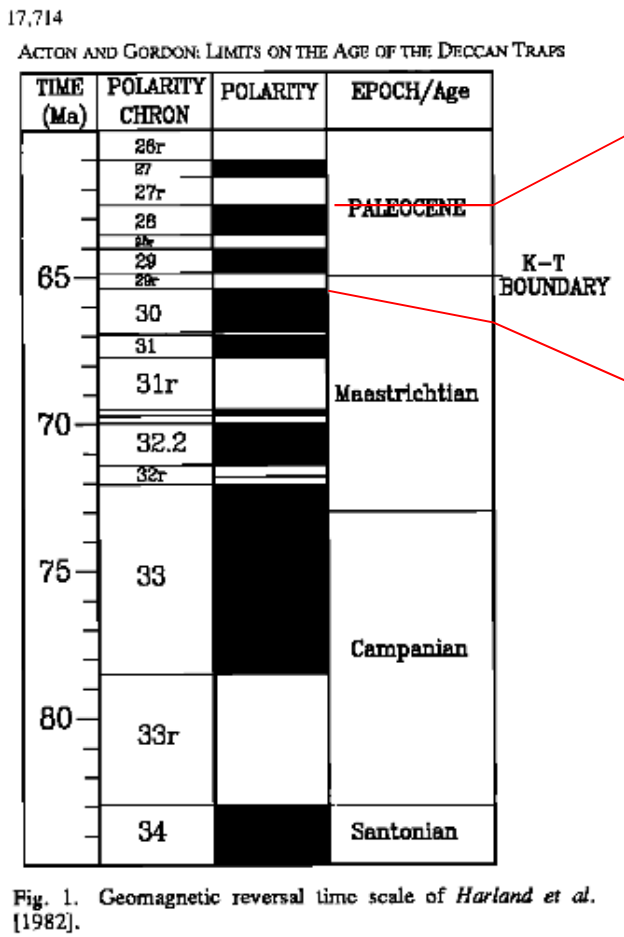
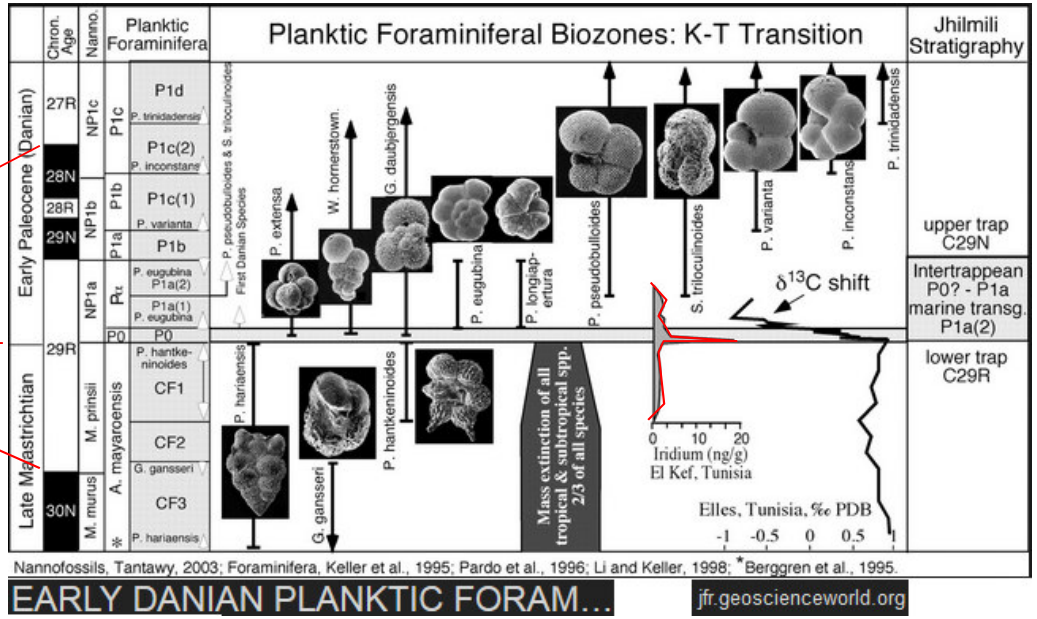


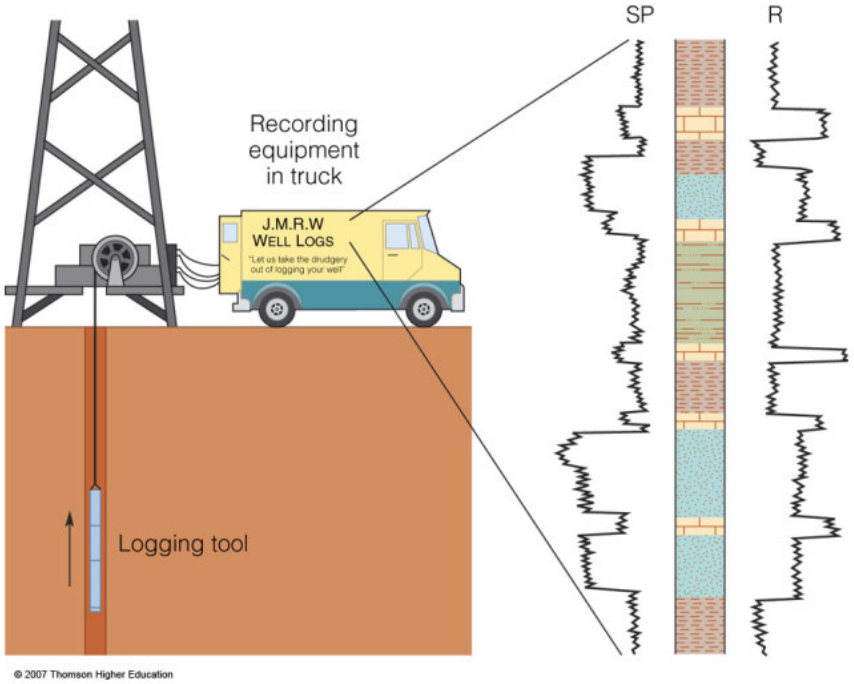
Fig. 1. Geomagnetic reversal time scale of *Harland et al.* [1982].

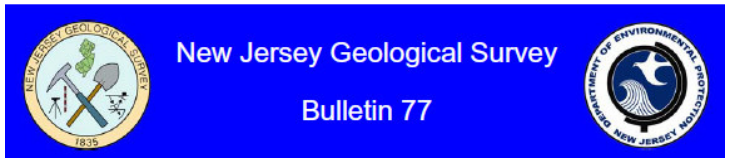


Cooling at this time is consistent with a global sea-level drop of ~40 m beginning in geomagnetic polarity chron 30n and ending in chron 28r, clearly spanning the K-T boundary.

This event followed closely on a sharp sea-level drop and subsequent rise of ~30 m, coincident with the highest $\delta^{18}O$ values recorded for the 30 My before or afterward, which occurred in the middle of chron 30n, ~1 My before the K-T boundary.

SUBSURFACE GEOPHYSICAL LOGS are commonly gathered and used to identify key beds and marker horizons



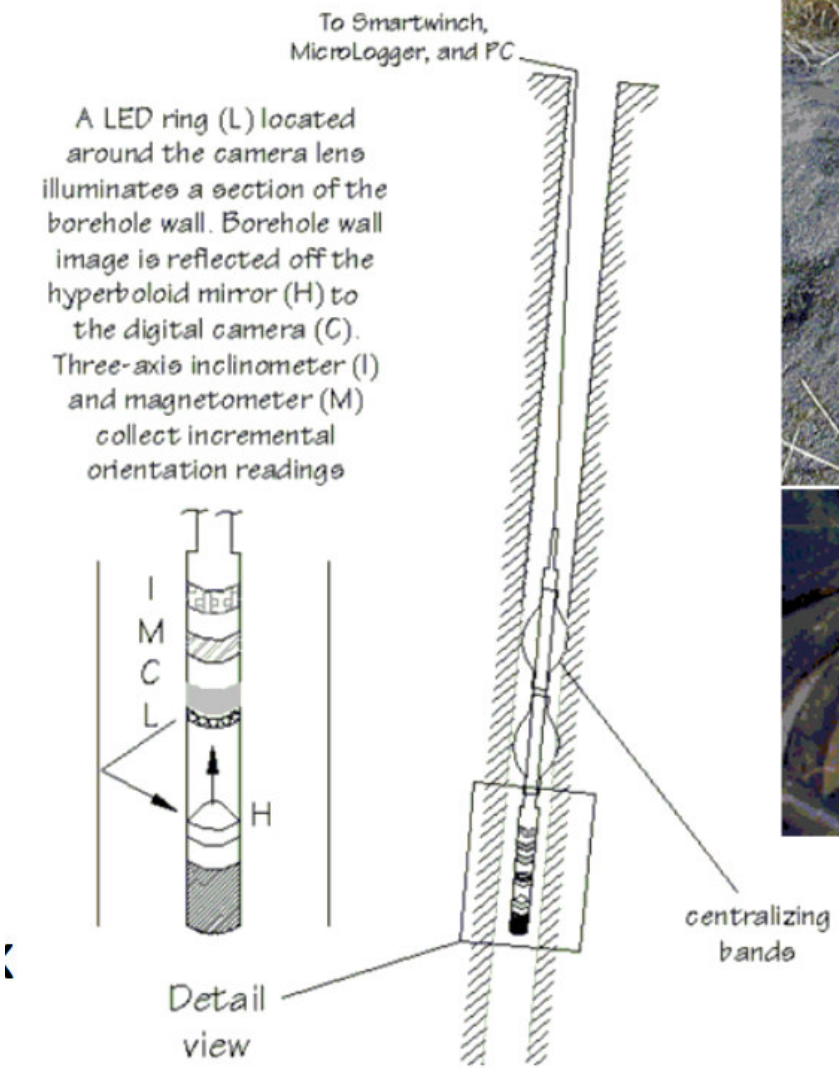


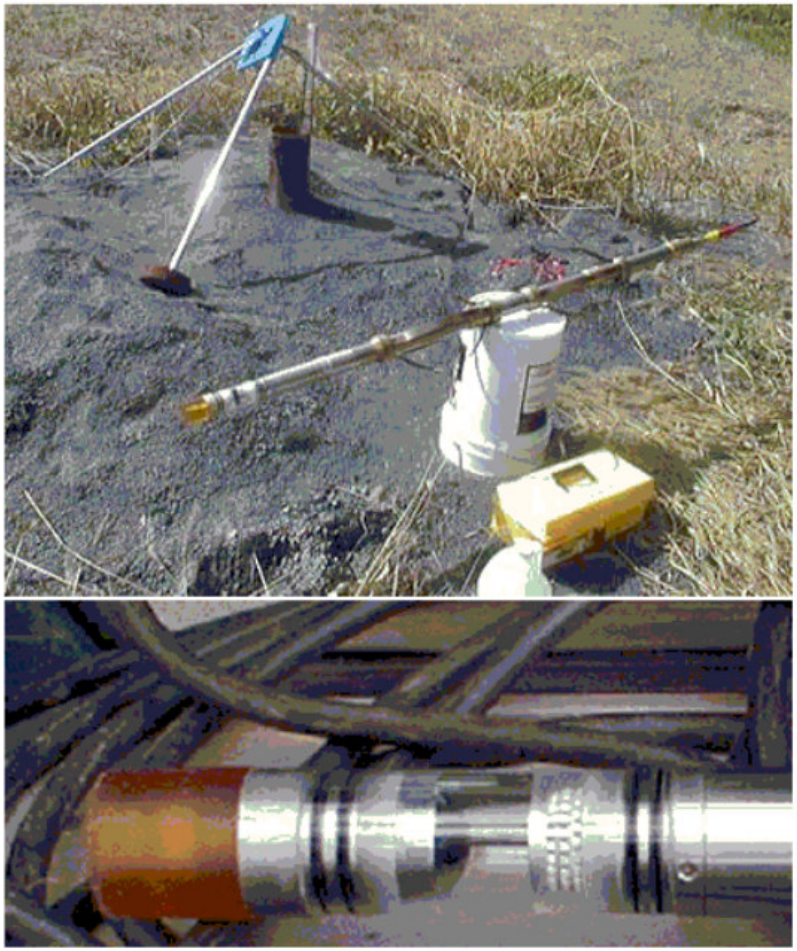
Contributions to the Geology and Hydrogeology of the Newark Basin

State of New Jersey
Department of Environmental Protection
Water Resource Management
New Jersey Geological Survey
2010

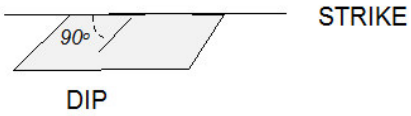
DOPTV

DIGITAL OPTICAL TELE-VIEWER

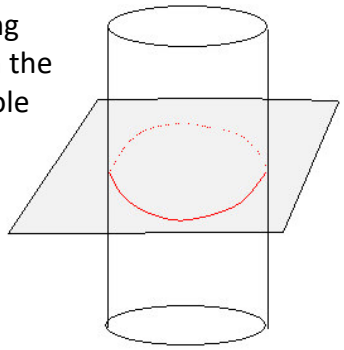




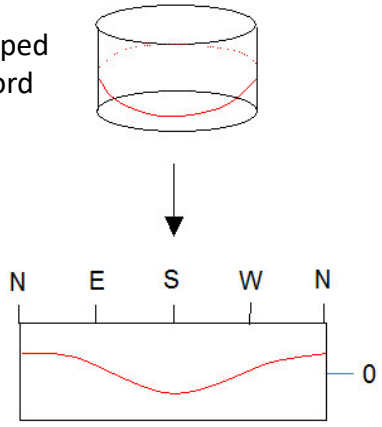
4-mm scan rings are stacked and aligned to form a composite borehole image



trace of dipping plane on the borehole wall

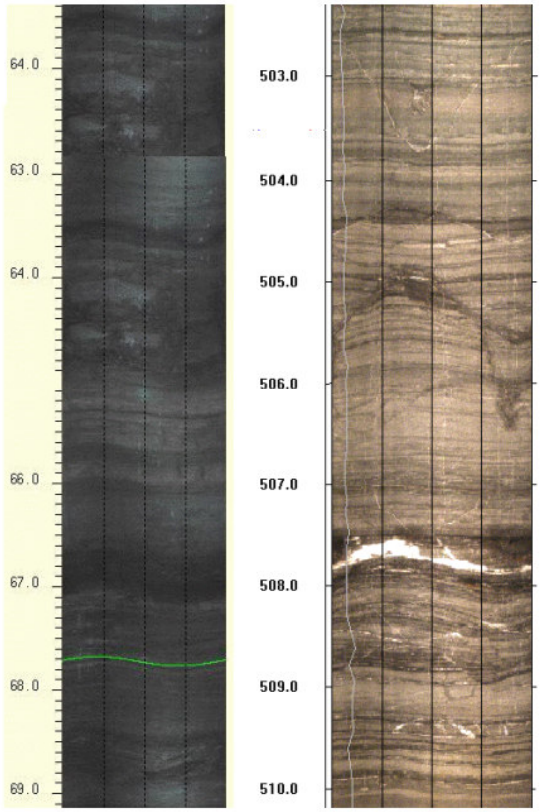


wrapped record

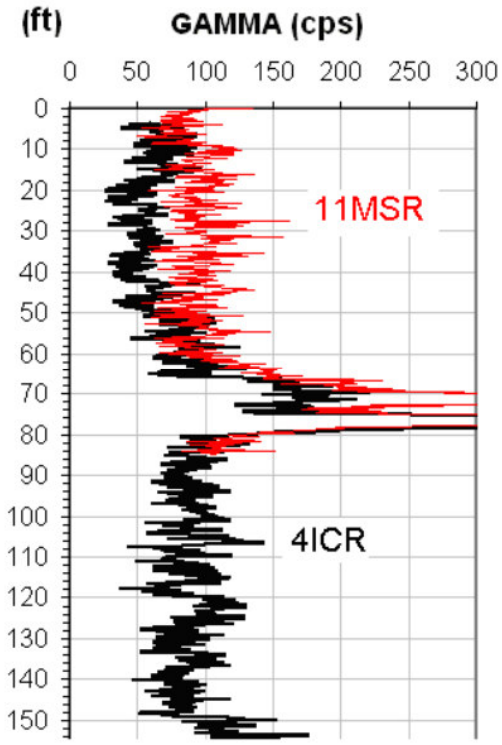


Elliptical trace unwraps into a sinusoidal curve

COMPARISON OF RG OPTV AND ALT-MT/SOPRIS OBI-40

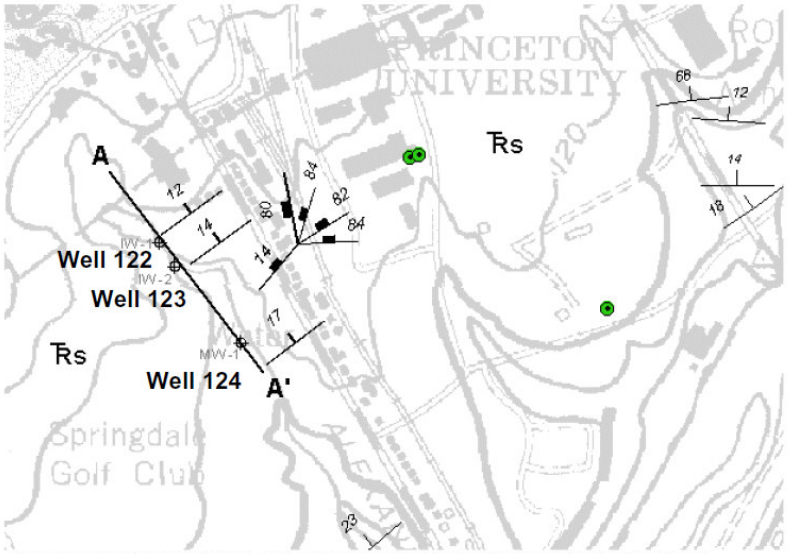


3 ft/min **9 ft/min**



THE USE OF ORDINARY MARKER HORIZONS

An example from the Triassic Stockton Sandstone at the Princeton University Springdale Golf Club, Mercer County, NJ



BASE MAP FROM US GEOLOGICAL SURVEY PRINCETON, NJ 7-1/2' TOPOGRAPHIC QUADRANGLE

EXPLANATION:

Well 122 — Well and ID

12 — Strike and dip of sedimentary bedding

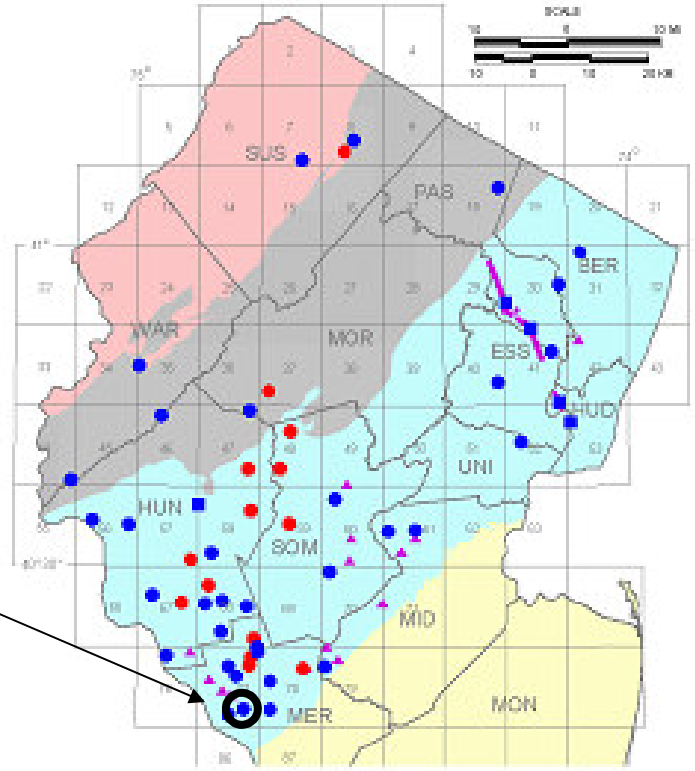
80 — Strike and dip of most-abundant fractures

82 — Strike and dip of less-abundant fractures

A / A' — Trace of hydrogeologic section

Core locations from U.S. Geological Survey Water Resources Investigation 95-4136

Trs — Triassic Stockton Formation



Well 124 – Stockton sandstone

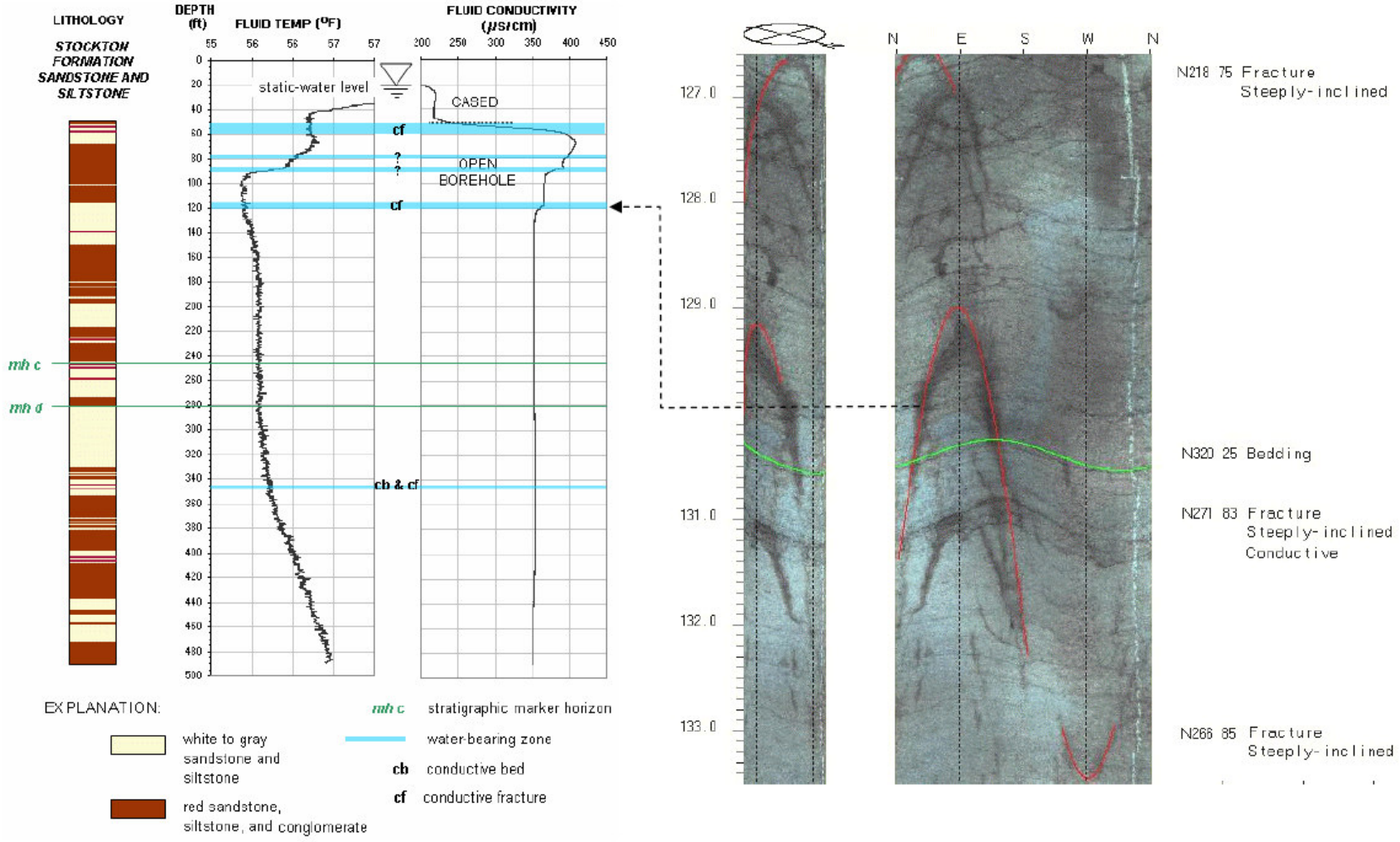


FIGURE 4F7. Hydrogeologic section based on geophysical logs (left) summarizing the distribution and types of hydraulically-conductive features in well 124 at the Springdale Golf Club, Princeton Twp., Mercer County, NJ. OPTV record of the 6-inch diameter well (right) shows geologic structures and hydraulically-conductive features in sandstone. Depth values are in feet below land surface.

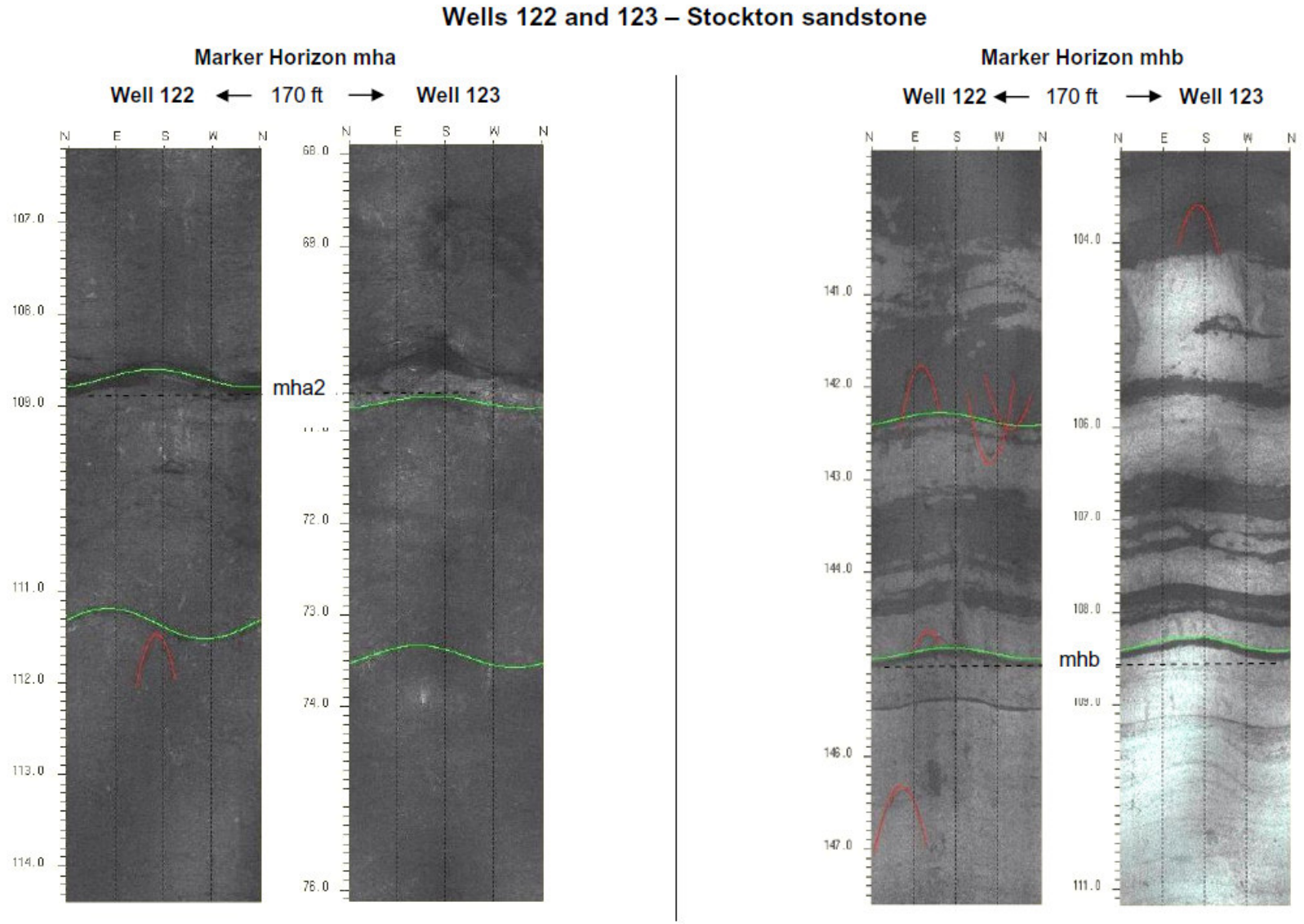


Figure 4F9. Stratigraphic correlation of wells 122 and 123 at the Springdale Golf Club, Princeton Twp., Mercer County, NJ based on OPTV records and showing stratigraphic marker horizons mha (left) and mhb (right). Depth values are in feet below land surface.

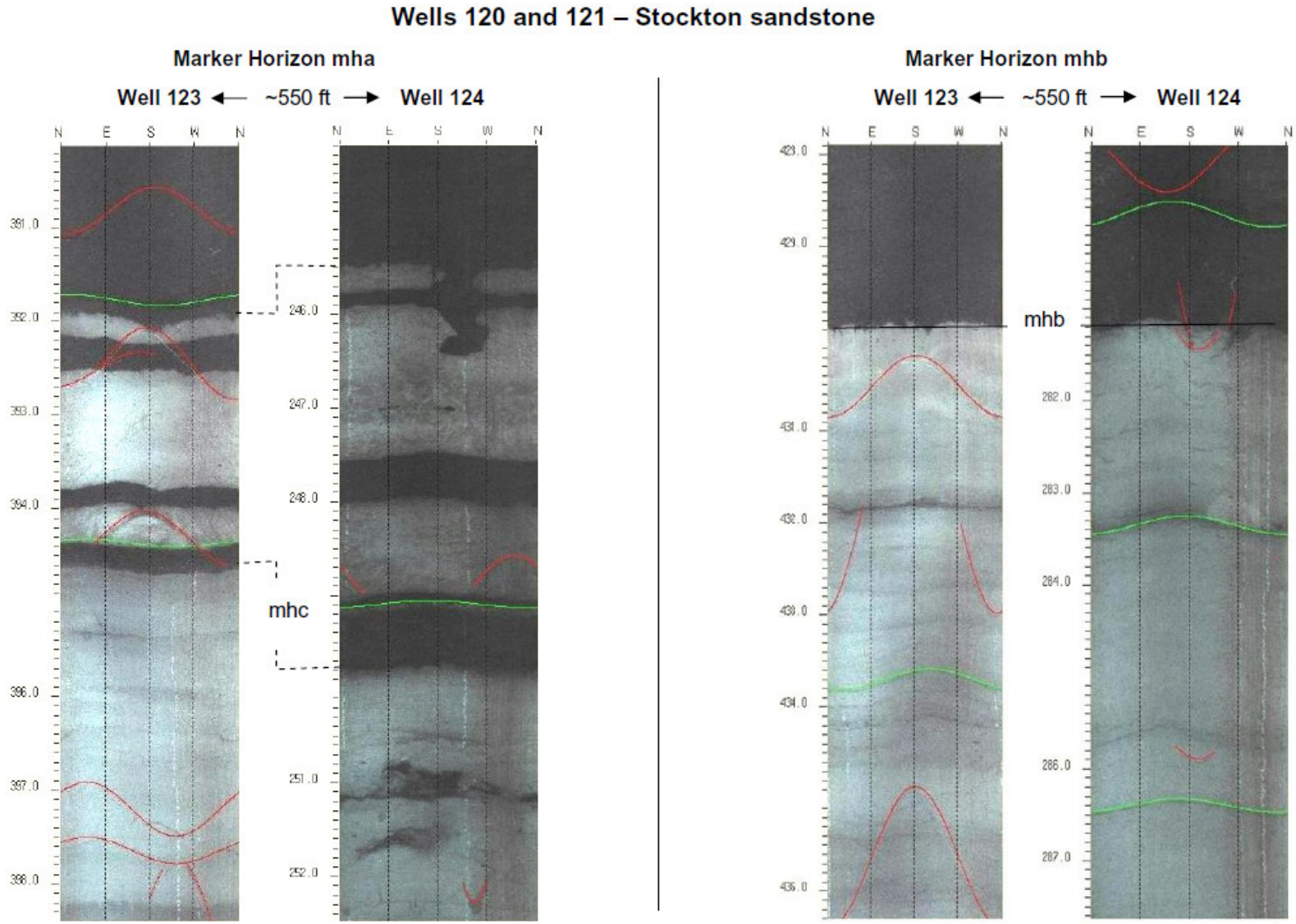


Figure 4F10. Stratigraphic correlation of wells 122 and 124 at the Springdale Golf Club, Princeton Twp., Mercer County, NJ based on OPTV records and showing stratigraphic marker horizons mhc (left) and mhd (right). Depth values are in feet below land surface.

Wells 122 to 124 – Stockton sandstone

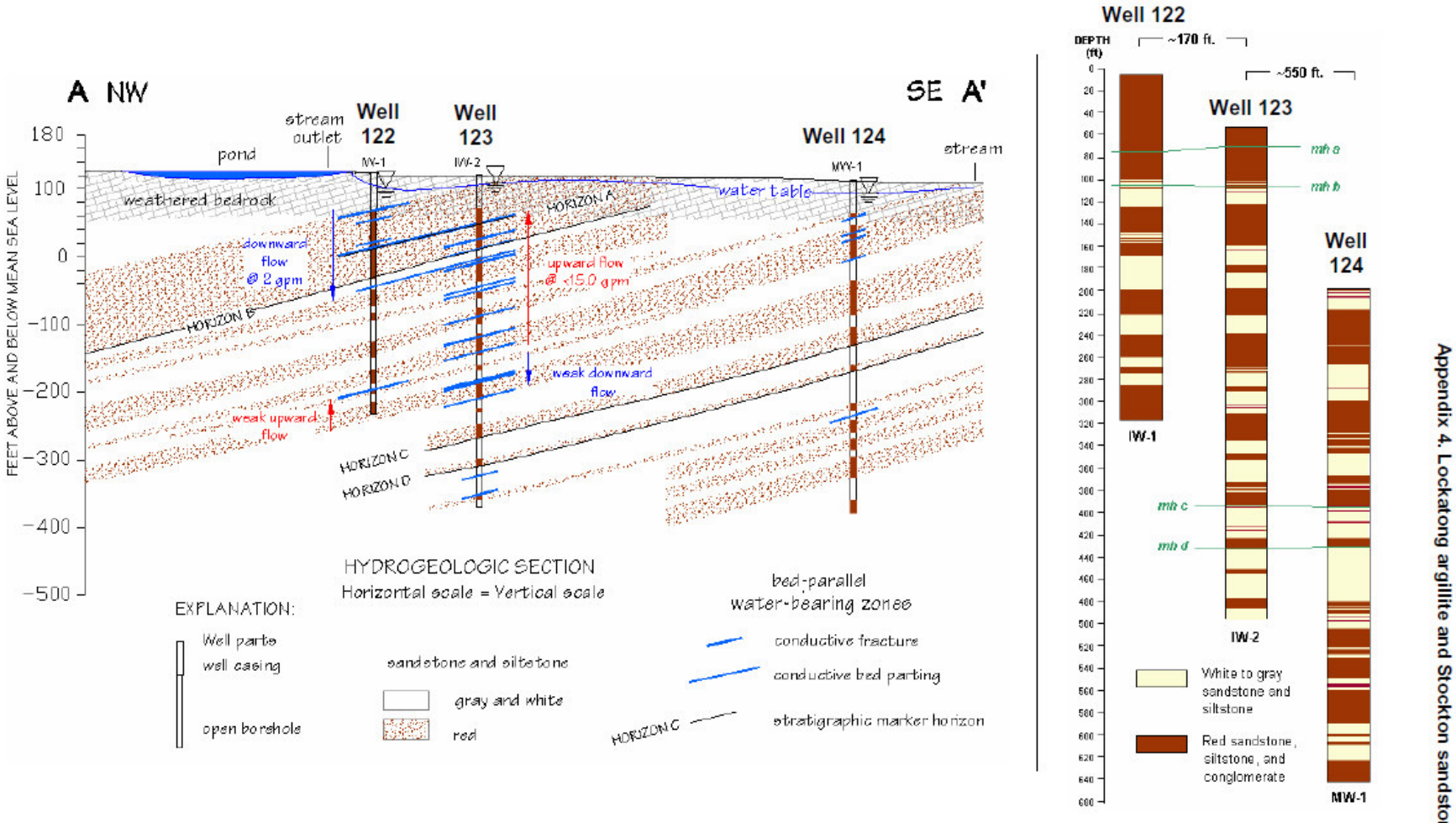


Figure 4F2. Hydrogeologic section (left) and stratigraphic section (right) showing stratigraphic correlation between wells 122 to 124 at the Springdale Golf Club, Princeton Twp., Mercer County, NJ. Depth valuyes for the sections on the right are in feet below land surface.

Wells 120 and 121 – Stockton sandstone

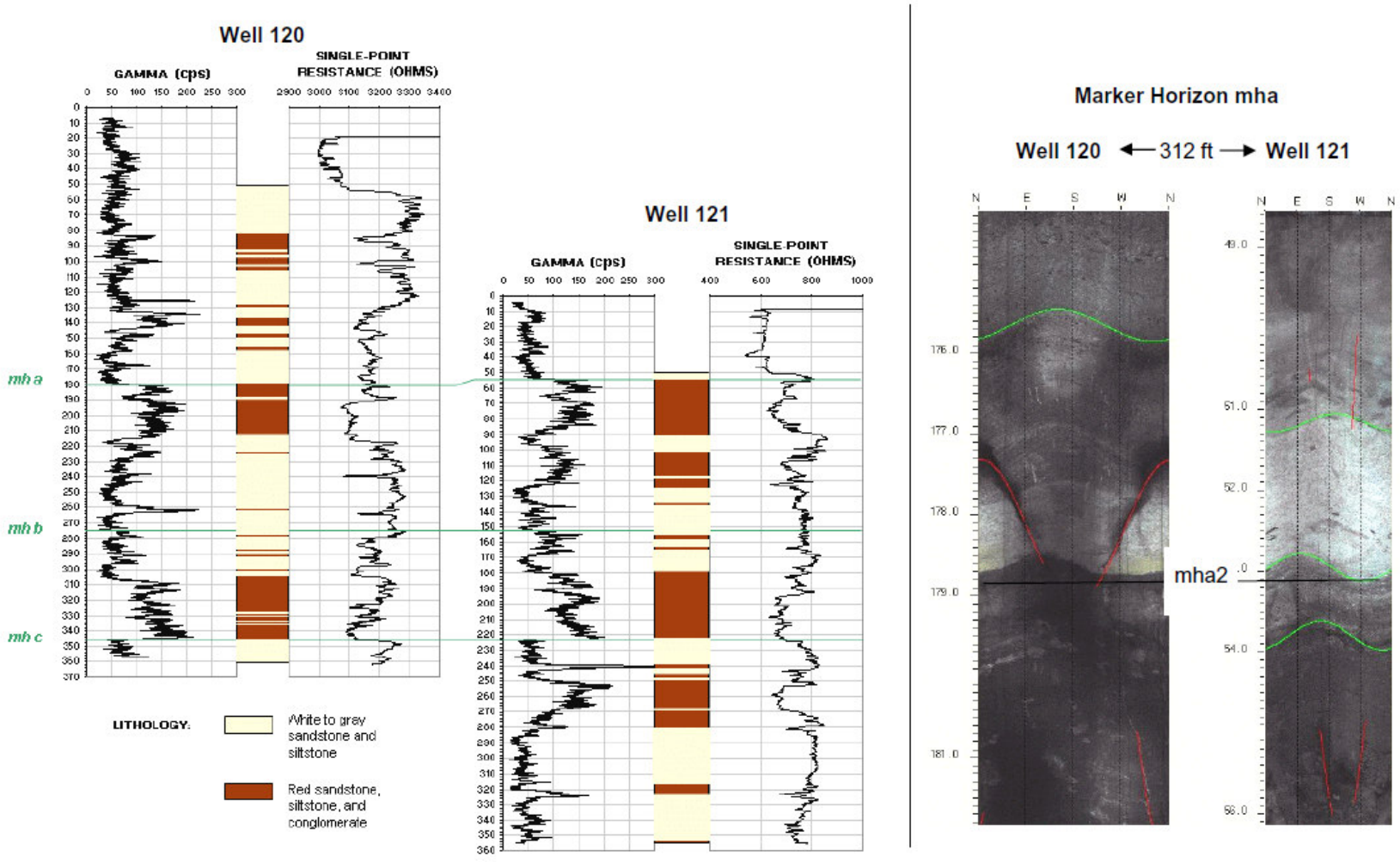
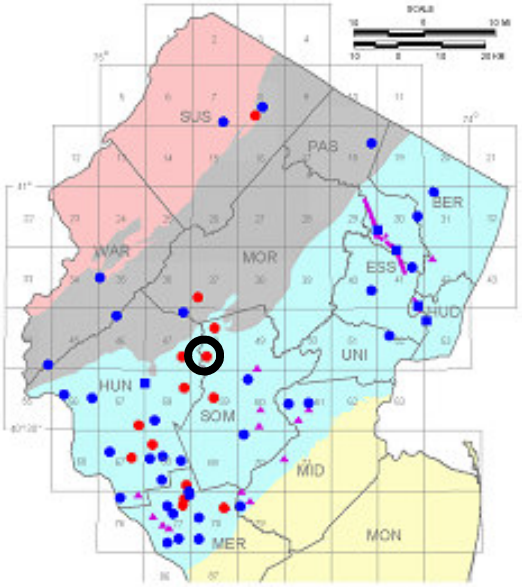


Figure 4E6. Stratigraphic correlation of wells 120 and 121 at the Greenacres Country Club, Rt. 206, Lawrence Twp., Mercer County, NJ based on natural gamma and electrical-resistivity logs (left) and OPTV records (right). Stratigraphic marker horizon mha is shown in both figures. Depth values are in feet below land surface.

THE USE OF ORDINARY MARKER HORIZONS

An example from the Triassic Passaic Formation mudstone and siltstone at Trump National Golf Course, Somerset County, NJ



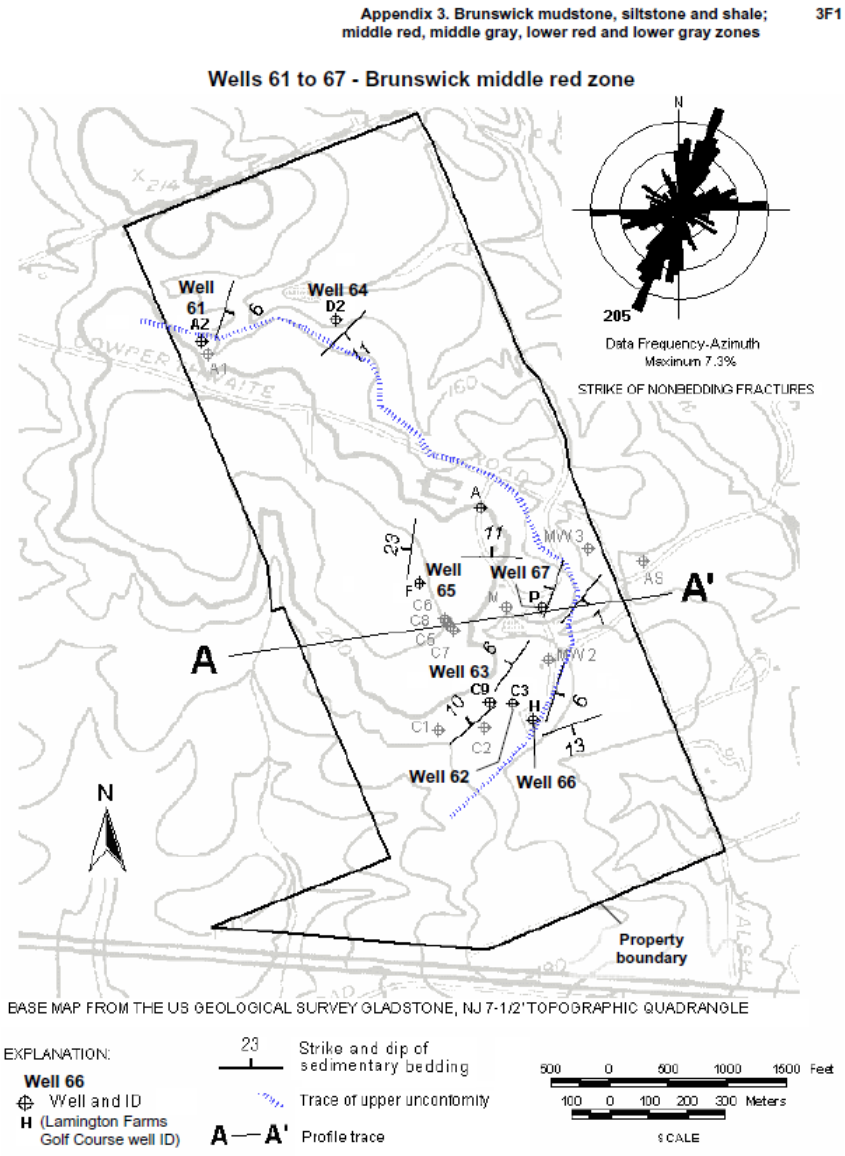
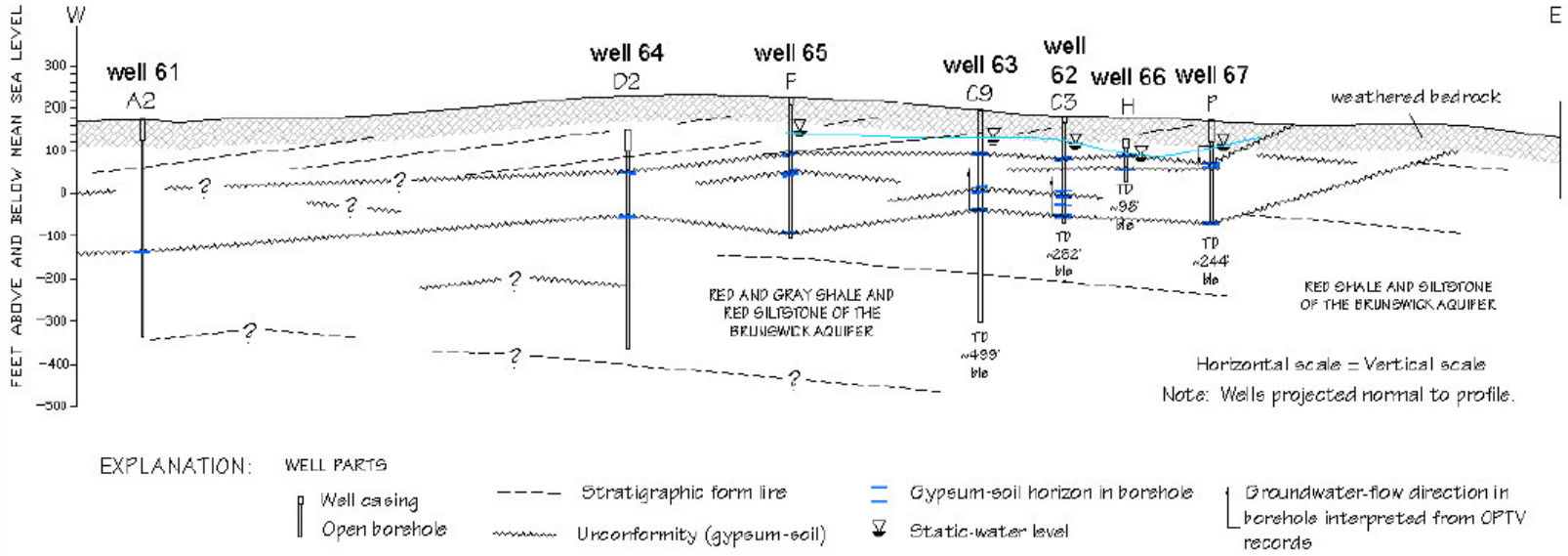


Figure 3F1. Map showing the location of wells 60 to 67 at Trump National Golf Course (formerly Lamington Farms Golf Course), Bedminster Twp., Somerset County, NJ.

UNCONFOMITIES AS MARKER HORIZONS

An example from the Triassic Passaic Formation mudstone and siltstone at Trump National Golf Course, Somerset County, NJ



Appendix 3. Brunswick mudstone, siltstone and shale; middle red, middle gray, lower red and lower gray zones

3F3

FIGURE 3F3. Hydrogeologic section based on seven wells at Trump National Golf Course, Bedminster Twp., Somerset County, NJ. Wells penetrate stratigraphic unconformities along extensive gypsum-soil beds. Stratigraphic sequences above and below the many unconformities dip in different directions.

KEY BEDS

Wells 62, 63 and 65 - Brunswick middle red zone

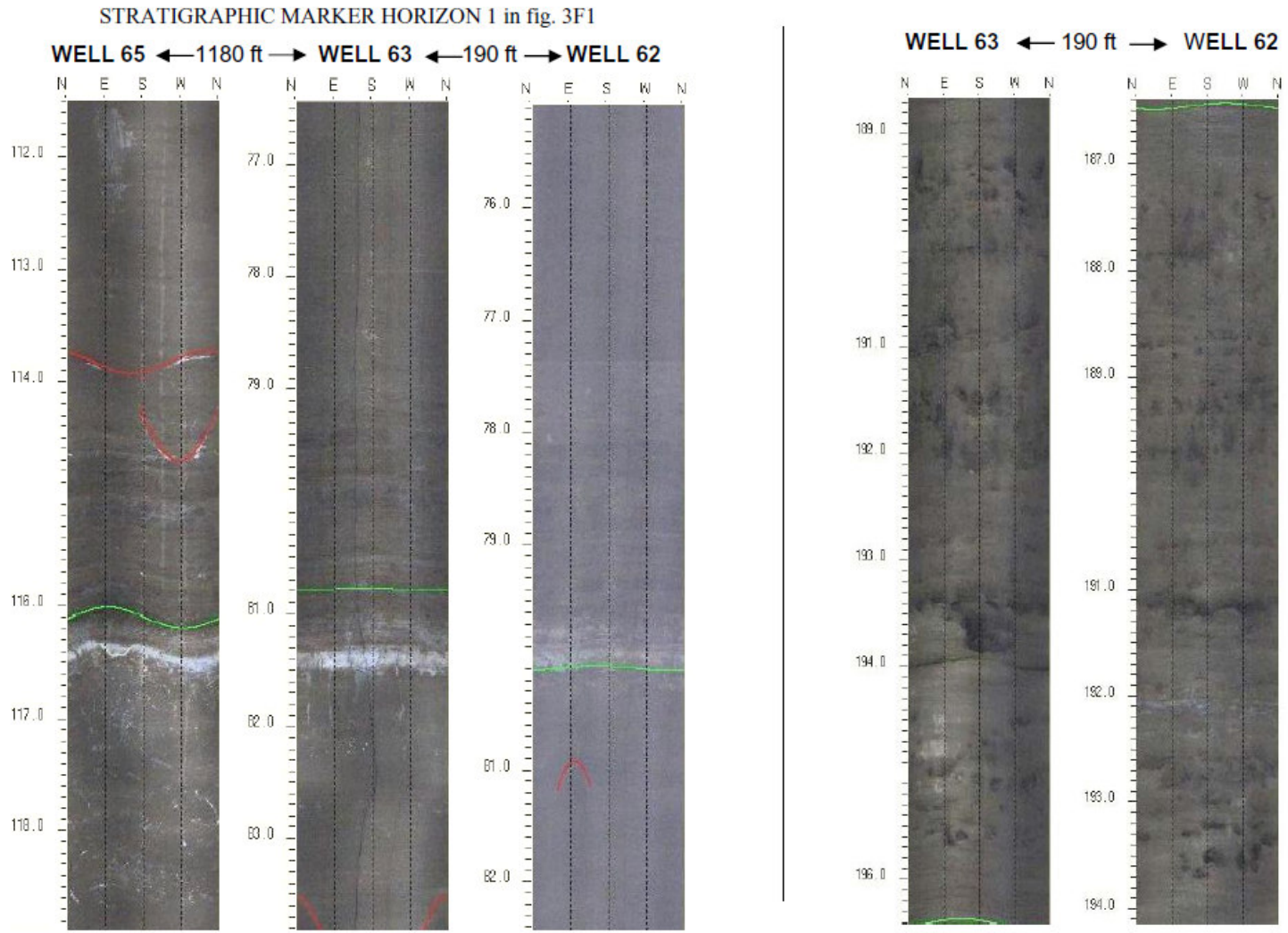
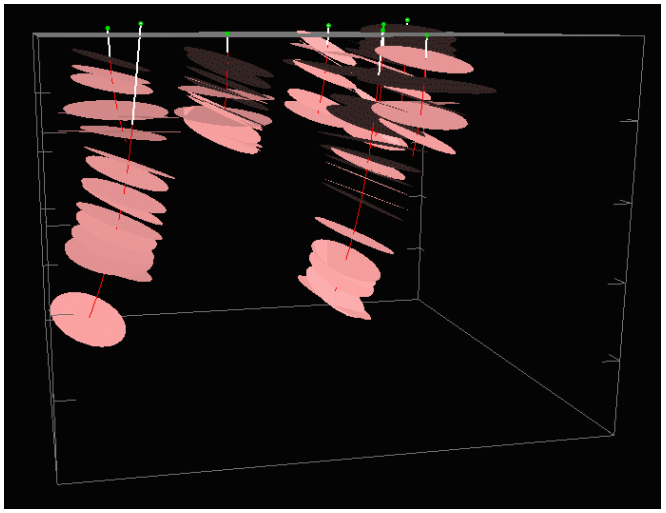
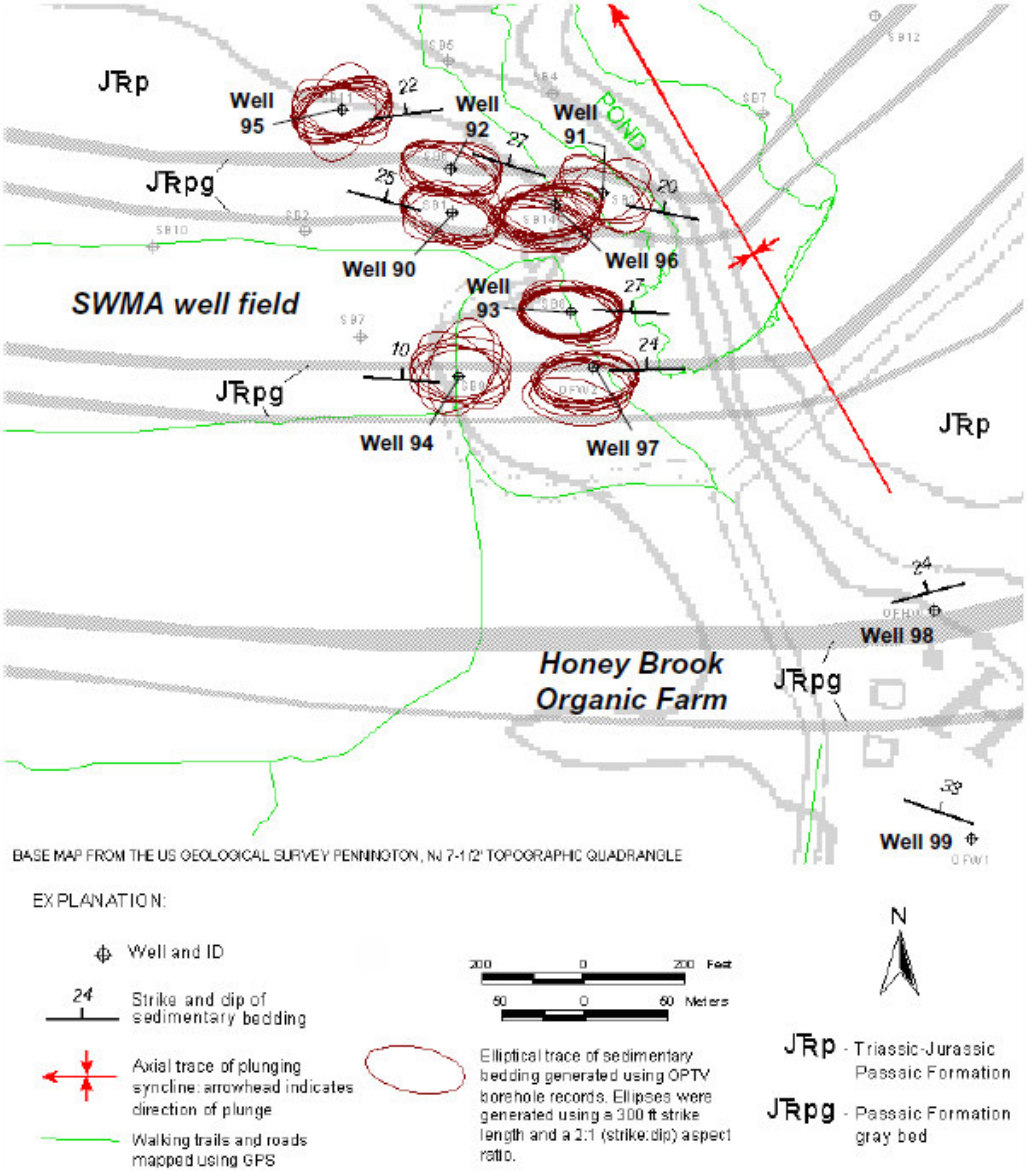


FIGURE 3F4. OPTV records for wells 62, 63 and 65 at Trump National Golf Course, Bedminster Twp., Somerset County, NJ showing stratigraphic marker horizon 1(left and fig. 3F2) and a correlation of a gypsum -soil horizon for wells 62 and 63 (right). Depth values are in feet below land surface.

KEY BEDS

An example from the Triassic Passaic Formation mudstone, siltstone, and shale at the Stonybrook-Millstone watershed preserve well field, Mercer County, NJ





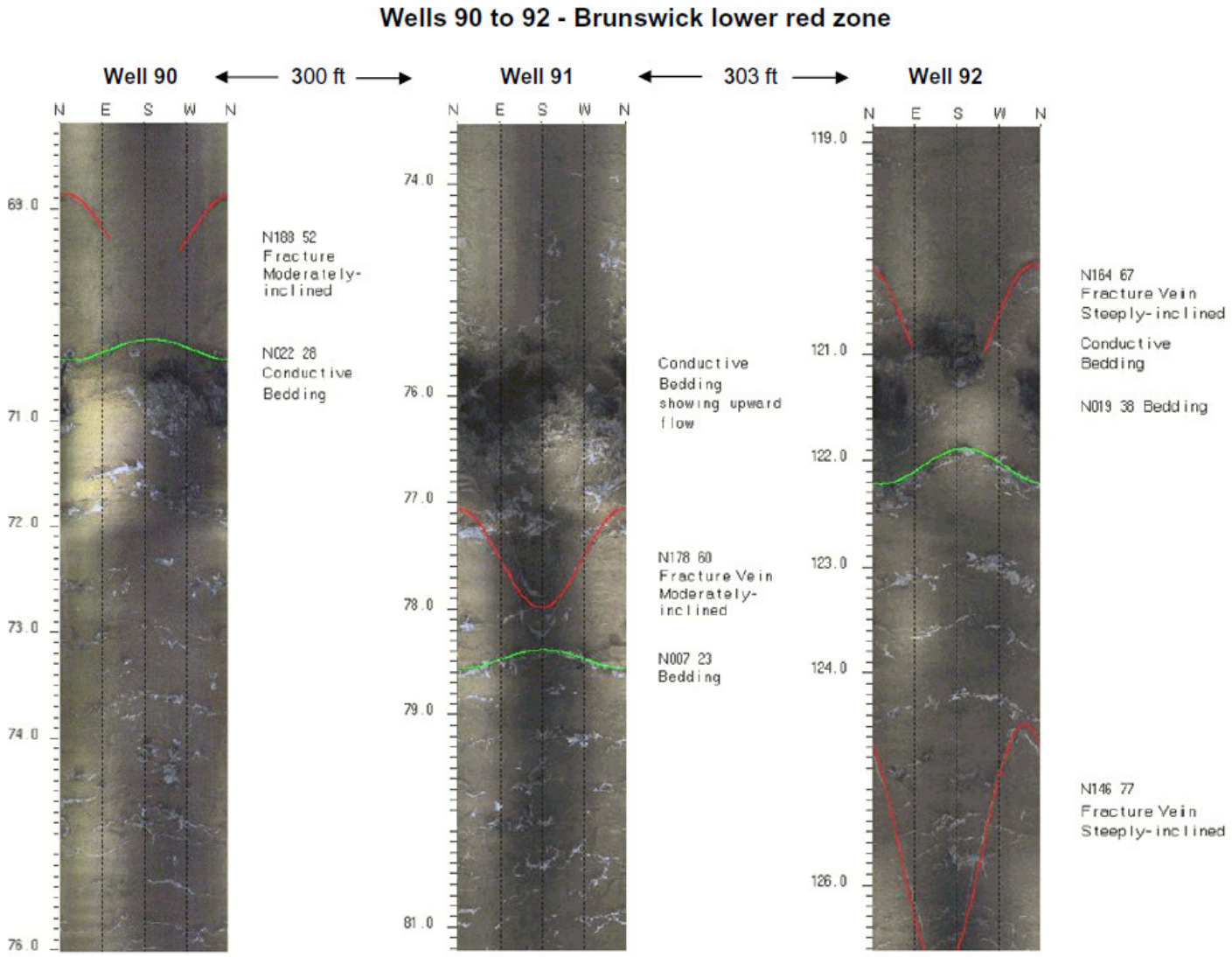
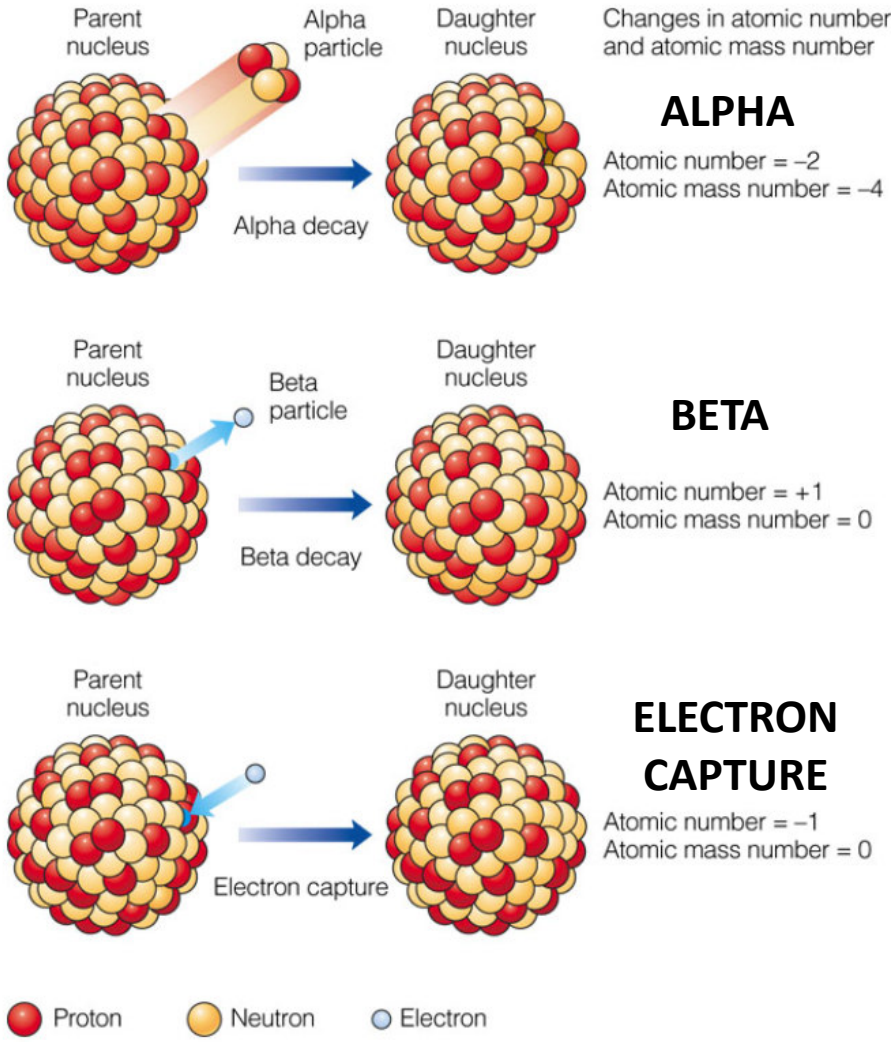


FIGURE 3M7. Stratigraphic correlation of wells 91 to 93 at the Stony Brook-Millstone Watershed Association well field based on OPTV records showing a major water-bearing zone in a gypsum-soil horizon and other geologic structures. Depth values are in feet below land surface.

ABSOLUTE DATING USING RADIOACTIVE ISOTOPE DECAY

- Soon after the discovery of radioactivity by Marie and Philip Curie during the late 19th century, geologists used radioactive-isotope decay to develop a method for determining absolute ages of rocks.

- Three types of radioactive-isotope decay are now recognized



RADIOACTIVE ISOTOPE DECAY

- Some elements undergo only 1 decay step in the conversion from an unstable form to stable form, whereas others undergo many.

multiple decay steps

1 decay step

Clocks in the Rocks

The following radioactive decay processes have proven particularly useful in radioactive dating for geologic processes:

Parent	Half-life (10^9 yrs)	Daughter	Materials Dated
^{235}U	0.704	^{207}Pb	Zircon, uraninite, pitchblende
^{238}U	4.468	^{206}Pb	Zircon, uraninite, pitchblende
^{40}K	1.251	^{40}Ar	Muscovite, biotite, hornblende, volcanic rock, glauconite, K-feldspar
^{87}Rb	48.8	^{87}Sr	K-micas, K-feldspars, biotite, metamorphic rock, glauconite

Note that uranium-238 and uranium-235 give rise to two of the natural radioactive series, but rubidium-87 and potassium-40 do not give rise to series. They each stop with a single daughter product which is stable.

Parent isotope (radioactive)	Daughter isotope (stable)	Half-life (Gy)	Decay constant ($10^{-11}yr^{-1}$)
^{40}K	$^{40}Ar^*$	1.25	5.81
^{87}Rb	^{87}Sr	48.8	1.42
^{147}Sm	^{143}Nd	106	0.654
^{176}Lu	^{176}Hf	35.9	1.93
^{187}Re	^{187}Os	43	1.612
^{232}Th	^{208}Pb	14	4.948
^{235}U	^{207}Pb	0.704	98.485
^{238}U	^{206}Pb	4.47	15.5125

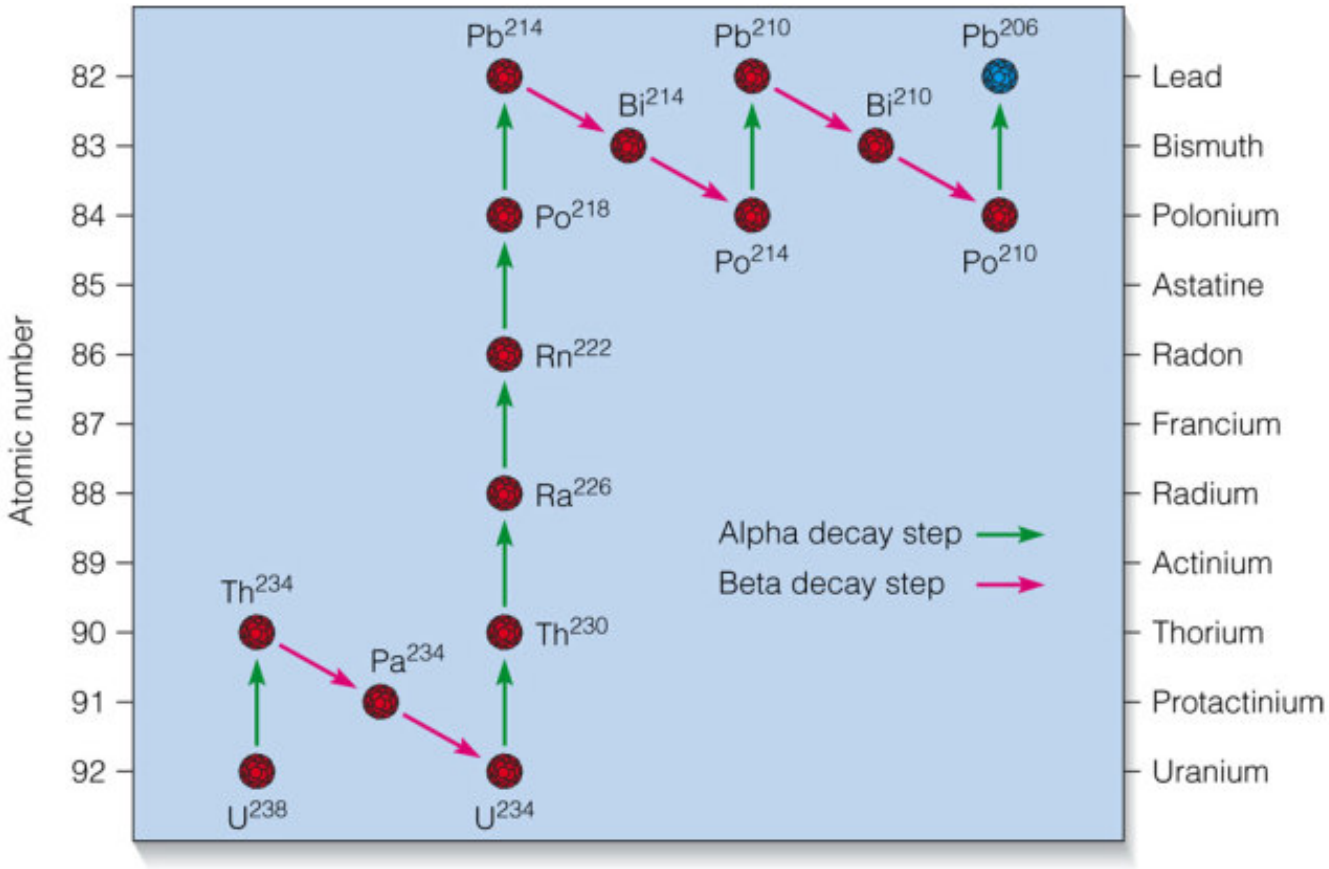
Lead isochrons are also an important radioactive dating process.

RADIOACTIVE ISOTOPE DECAY

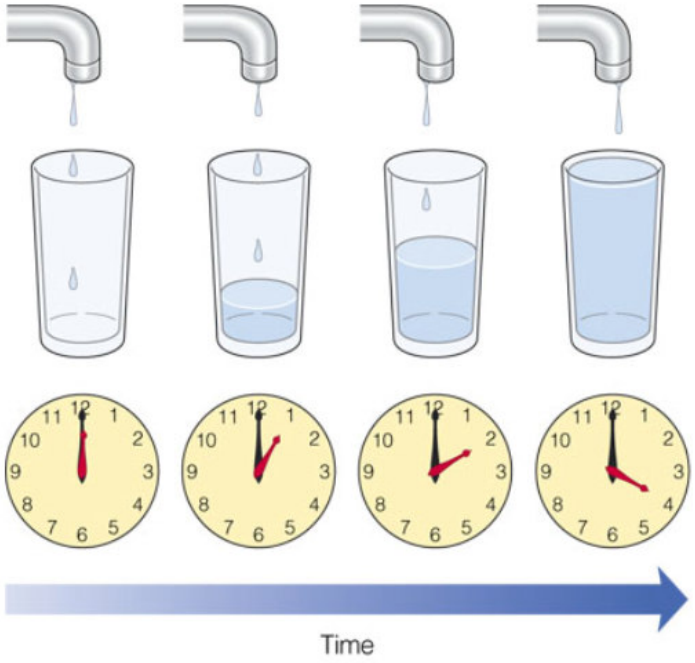
- $U^{238} \rightarrow Pb^{206}$

- An example involving 14 decay steps:

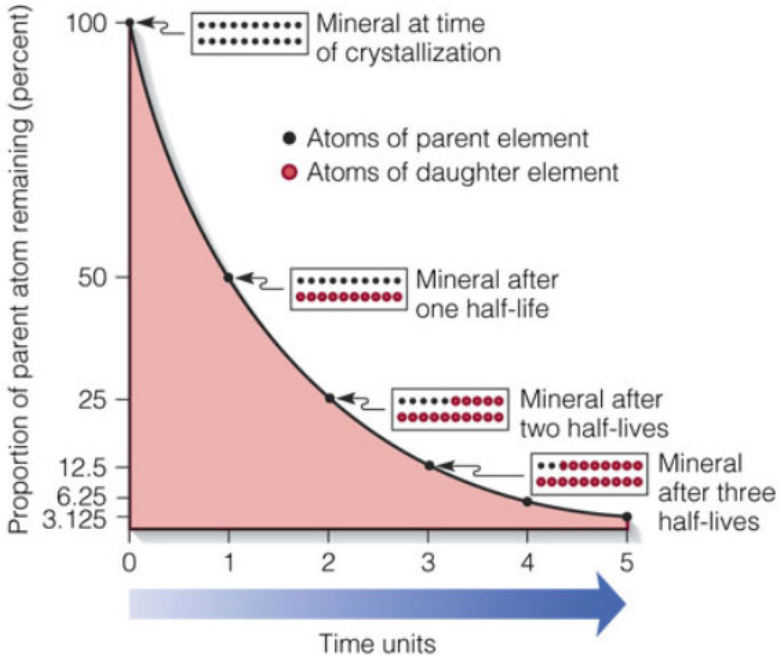
8 Alpha-decay steps and
6 Beta-decay steps



RADIOACTIVE ISOTOPE DECAY occurs at a *geometric rate* rather than a linear rate.



An example geometric radioactive decay curve



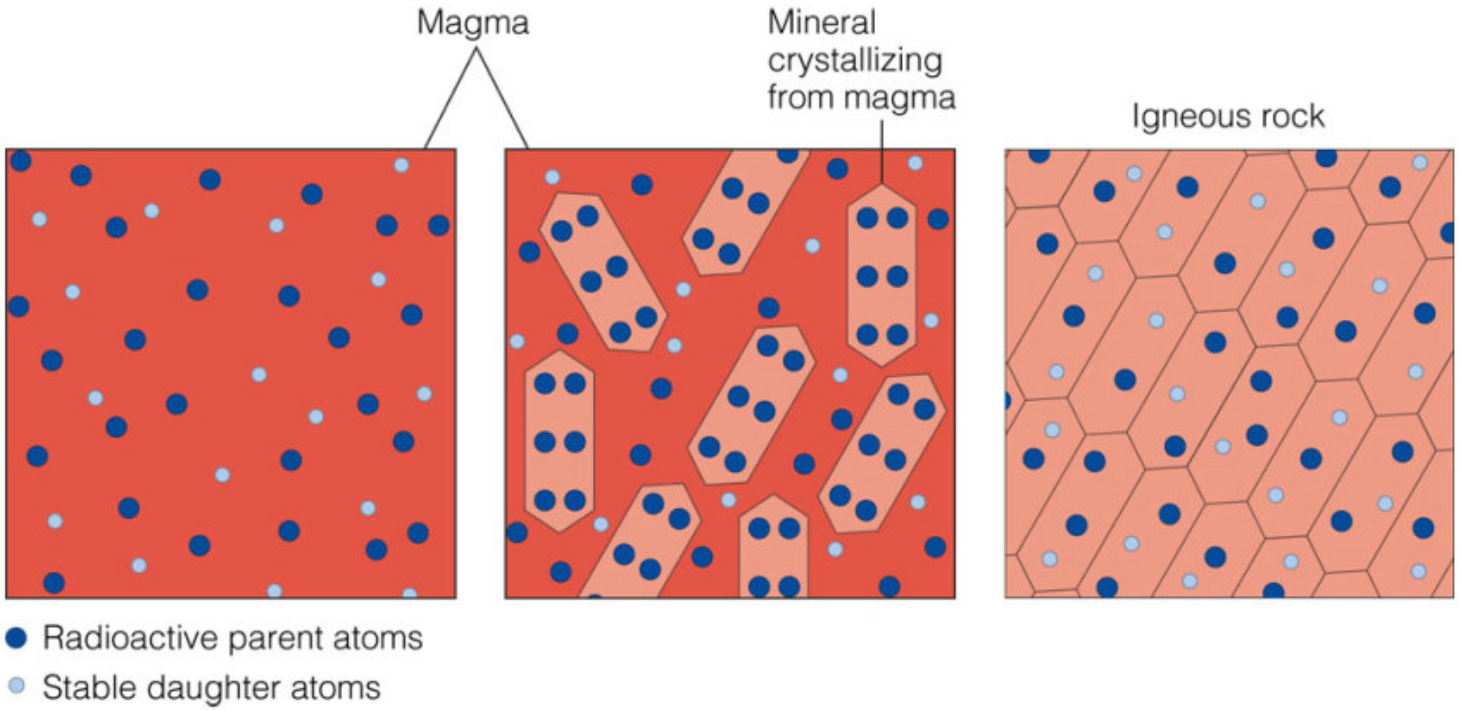
- A steady drip from a leaky faucet is an example of a linear rate that is a steady progression or decline.

- Radioactive decay occurs at a *geometric rate*.

•The h*alf-life of a radiometric element* is the amount of time required for a parent element within a new mineral to be reduced in volume by 50% from decay into a daughter element. In the example above, after two half-lives, only 25% of the parent element remains within the mineral, whereas the daughter is 75% of the volume

RADIOACTIVE ISOTOPE DECAY

• The most common method of determining an absolute age is by measuring the proportion of radioactive parent isotope to stable daughter isotope to obtain the number of half-lives which have elapsed since the parent isotope's incorporation within a mineral crystal.



RADIOACTIVE ISOTOPES

• Long-lived radioactive isotope pairs in igneous rocks provide the most accurate dates.

Five of the Principal Long-Lived Radioactive Isotope Pairs Used in Radiometric Dating

ISOTOPES		Half-Life of	Effective Dating	Minerals and Rocks That
Parent	**Daughter**	**Parent (years)**	**Range (years)**	**Can Be Dated**
Uranium 238	Lead 206	4.5 billion	10 million to 4.6 billion	Zircon
				Uraninite
Uranium 235	Lead 207	704 million		
Thorium 232	Lead 208	14 billion		
Rubidium 87	Strontium 87	48.8 billion	10 million to 4.6 billion	Muscovite
				Biotite
				Potassium feldspar
				Whole metamorphic or igneous rock
Potassium 40	Argon 40	1.3 billion	100,000 to 4.6 billion	Glauconite Hornblende
				Muscovite Whole volcanic rock
				Biotite

• Use of two isotope pairs from a single sample or site is the most reliable way to determine the absolute age of a rock.

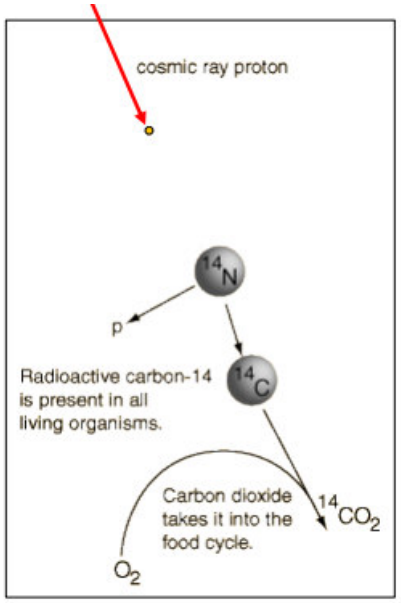
RADIOCARBON DATING uses Carbon 14, a short-lived radioactive isotope and this isotopic method is only applicable to organic material of less than 60,000 years of age.

- Radioactive carbon (^{14}C) is generated in the upper troposphere when a cosmic ray (typically a proton) hits the nucleus of an atom and produces a neutron (among other things) that is then captured by a nitrogen atom (14N)

- All Carbon isotopes (^{14}C, 13C, 12C) mix in the atmosphere mostly as $^{12}CO_2$, and thus are incorporated into living organisms. The proportion of ^{14}C to ^{12}C in living tissue is comparable with the proportion in the atmosphere (for terrestrial organisms), or to a water body for aquatic organisms. Animals get most of their ^{14}C dose from the food that they consume.

- When the organism (or a tissue) dies absorption of ^{14}C ceases, and the amount of ^{14}C gradually decays back to ^{14}N at a set rate.

- Measuring the ^{14}C to ^{14}C isotopic ratios provides a radiometric age of the time of the organisms passing.



Radioactive carbon (^{14}C) decays back to nitrogen (^{14}N) emitting an electron (e^-) and an antineutrino ($\bar{\nu}$) with no mass or charge.

$$^{14}_{6}C \Rightarrow {}^{14}_{7}N + {}^{0}_{-1}e^{-} + {}^{0}_{0}\bar{\nu}$$

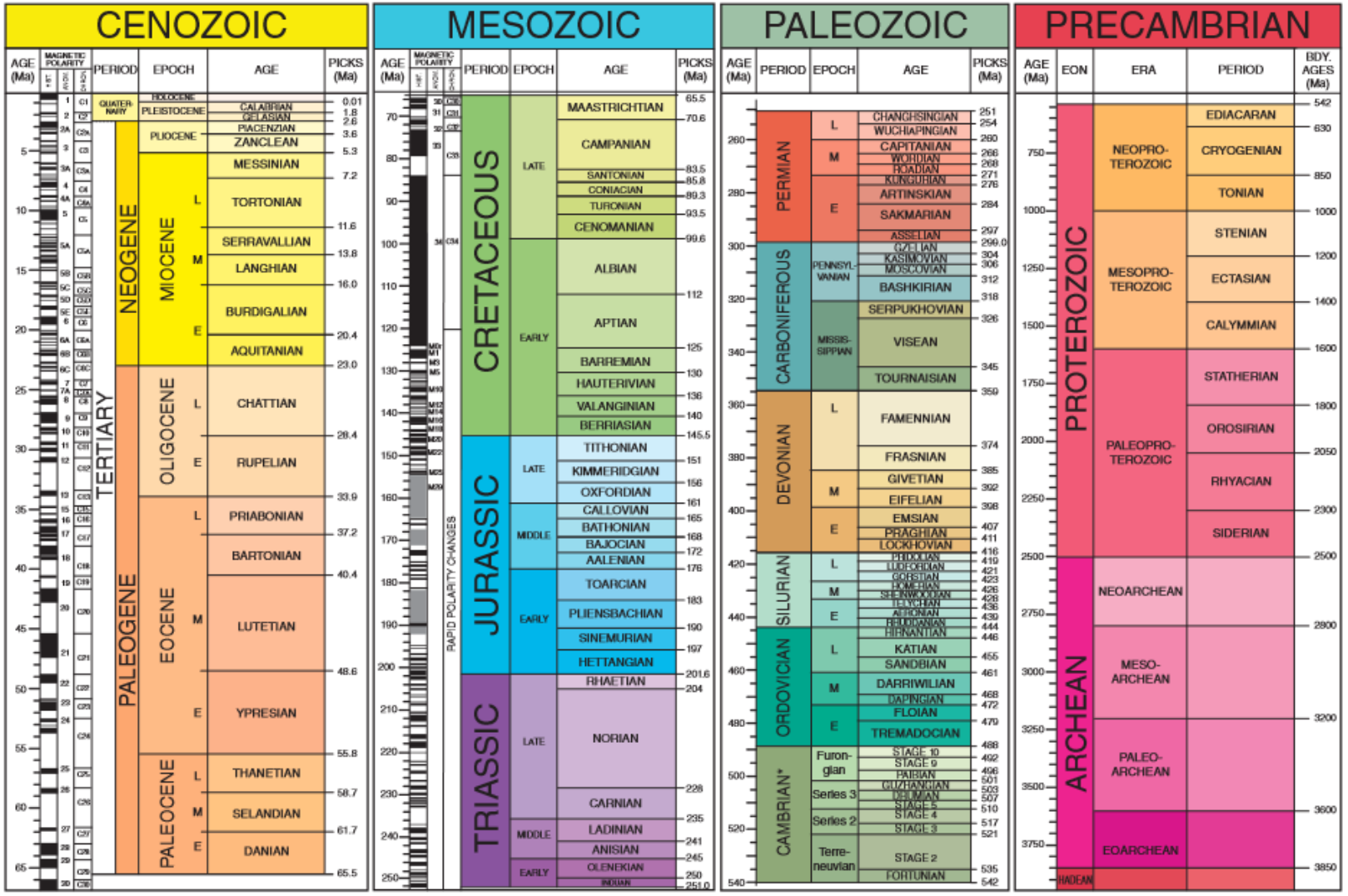
Ötzi

Born	*c.* 3300 BCE near the present village of Feldthurns (Velturno), north of Bolzano, Italy
Died	*c.* 3255 BCE (aged about 45) Ötztal Alps, near Hauslabjoch on the border between Austria and Italy
Cause of death	Exsanguination due to arrow wound on his shoulder[1]
Other names	Similaun Man; "Frozen Fritz" (by British tabloids)/Otzi
Known for	Oldest natural mummy of a Chalcolithic (Copper Age) European man
Height	1.65 m (5 ft 5 in)
Weight	50 kg (110 lb; 7.9 st)
Website	

South Tyrol Museum of Archaeology

- After about ten ^{14}C to ^{14}N half-lives (~57 thousand years (ka)) there barely any ^{14}C left in the tissue.

2009 GEOLOGIC TIME SCALE



THE GEOLOGICAL SOCIETY OF AMERICA®

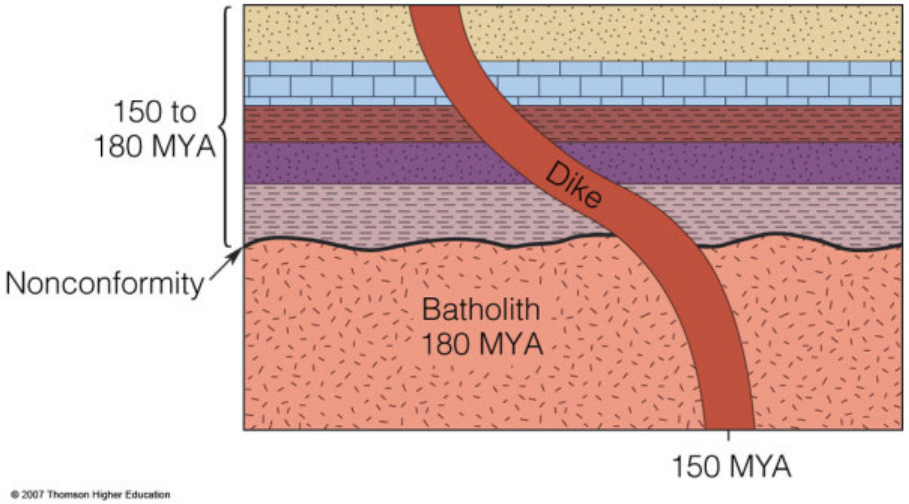
*International ages have not been fully established. These are current names as reported by the International Commission on Stratigraphy.

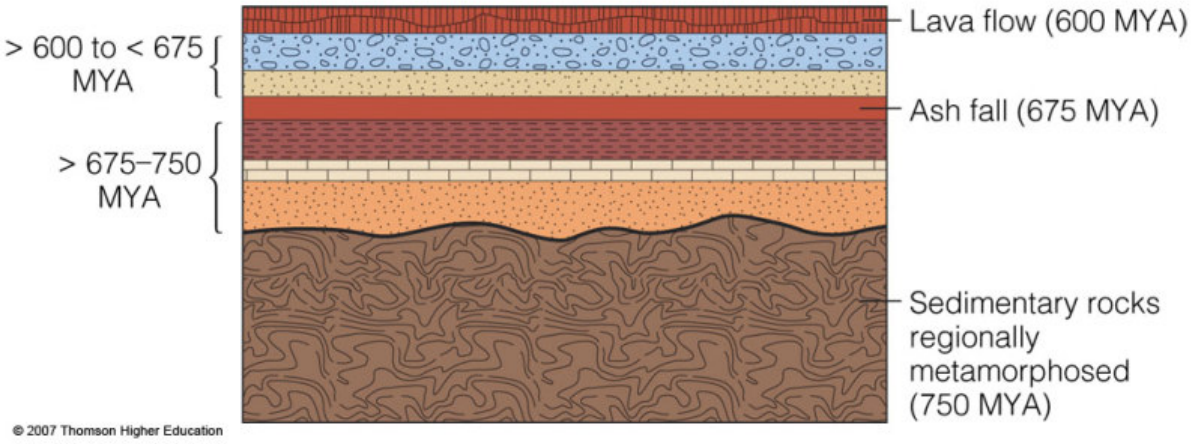
Walker, J.D., and Geissman, J.W., compilers, 2009, Geologic Time Scale: Geological Society of America, doi: 10.1130/2009.CTS004R2C. ©2009 The Geological Society of America.

Sources for nomenclature and ages are primarily from Gradstein, F., Ogg, J., Smith, A., et al., 2004, A Geologic Time Scale 2004: Cambridge University Press, 589 p. Modifications to the Triassic after: Furin, S., Preto, N., Rigo, M., Roghi, G., Gianolla, P., Crowley, J.L., and Bowring, S.A., 2006, High-precision U-Pb zircon age from the Triassic of Italy: Implications for the Triassic time scale and the Carnian origin of calcareous nannoplankton and dinosaurs: Geology, v. 34, p. 1009–1012, doi: 10.1130/G22967A.1; and Kent, D.V., and Olsen, P.E., 2008, Early Jurassic magnetostratigraphy and paleolatitudes from the Hartford continental rift basin (eastern North America): Testing for polarity bias and abrupt polar wander in association with the central Atlantic magmatic province: Journal of Geophysical Research, v. 113, B06105, doi: 10.1029/2007JB005407.

ESTABLISH ABSOLUTE AGES OF SEDIMENTARY ROCKS

- Absolute ages of most sedimentary rocks and their contained fossils are established indirectly by radiometric dating of igneous and metamorphic rocks associated with the sedimentary strata.

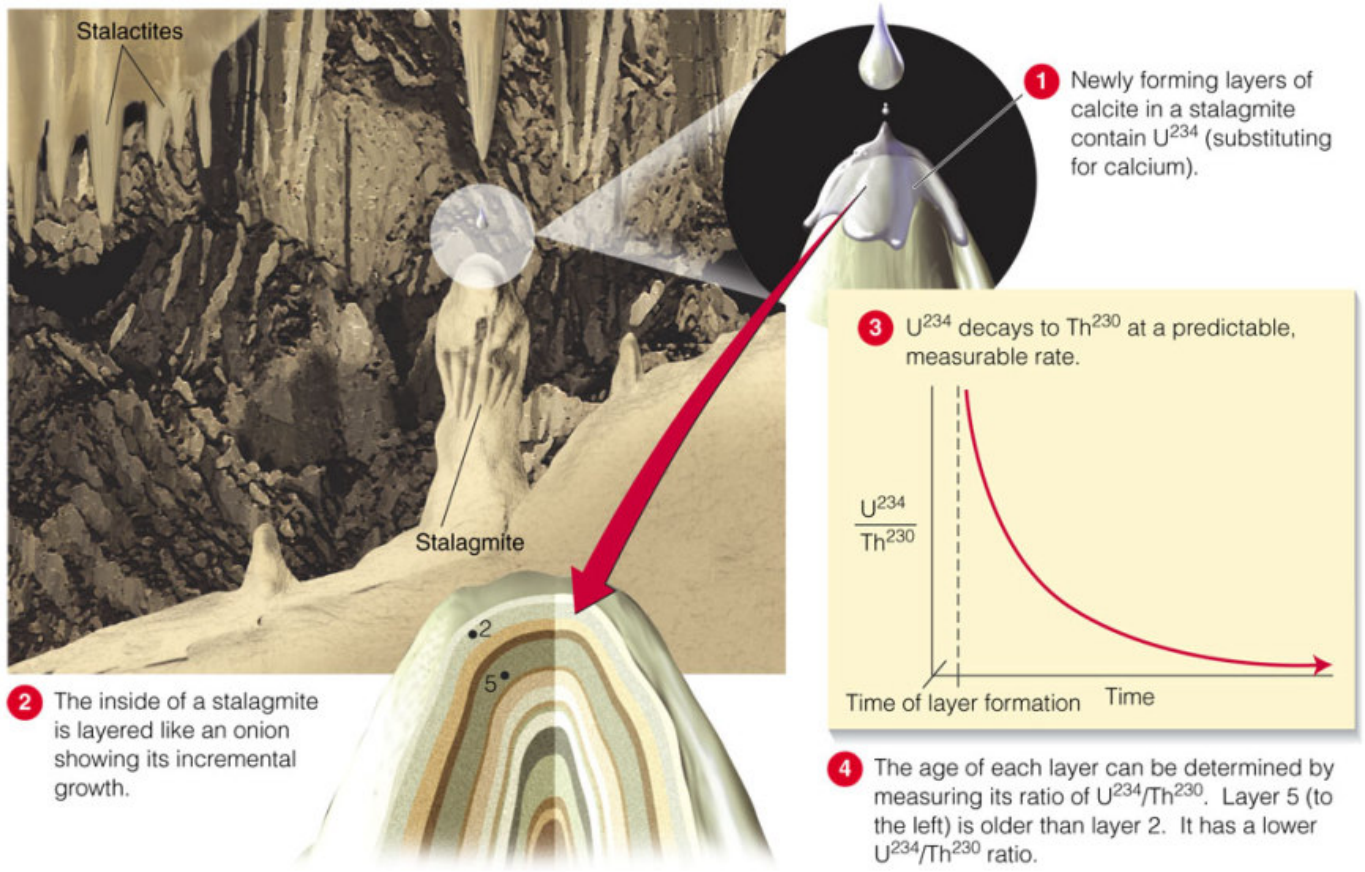




USING STALAGMITES FOR AGE-DATING AND CLIMATE STUDIES

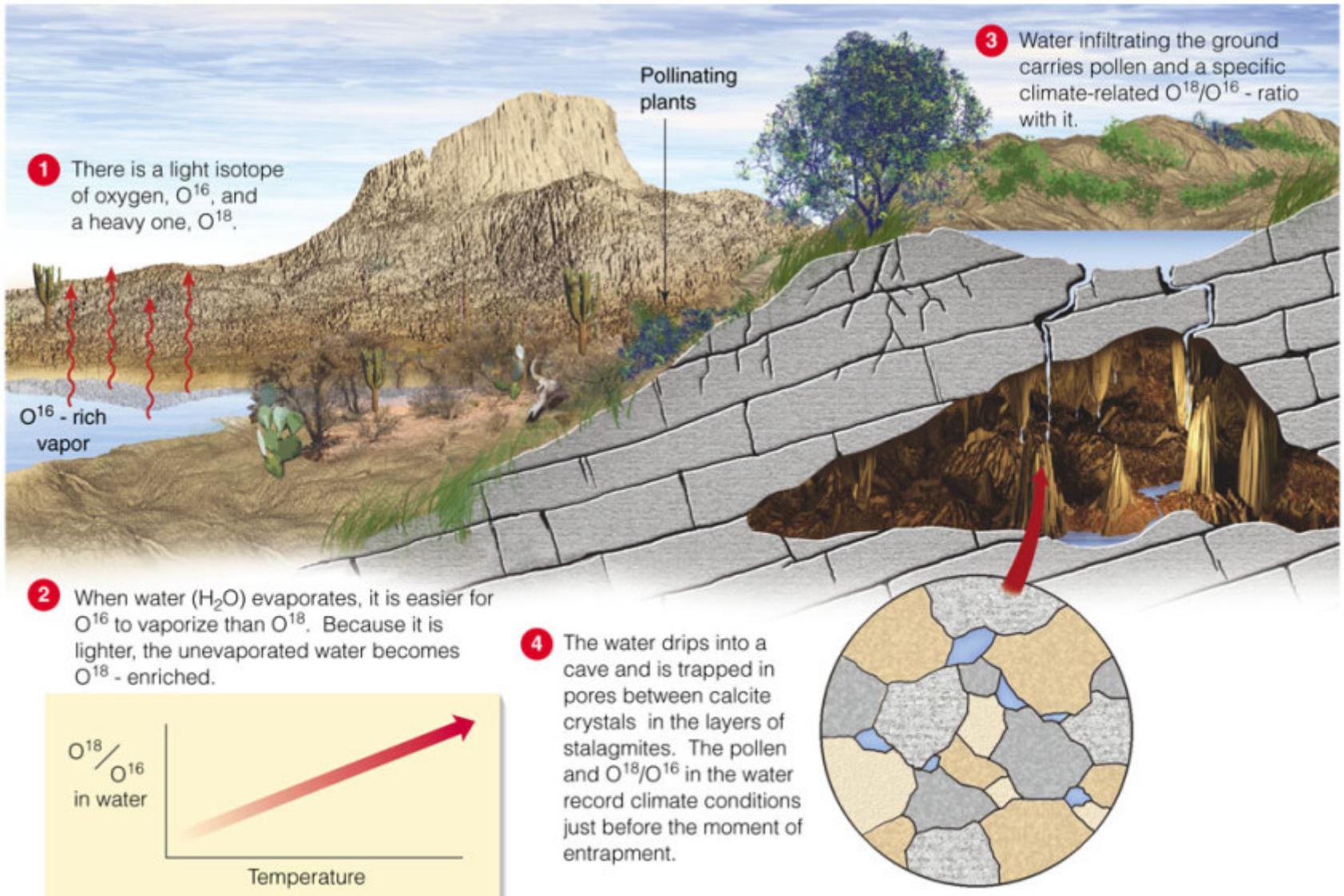
• Two different isotopes are gathered from the calcium carbonate that precipitated as stalagmites, slowly and continuously through time.

•U^{234}/Th^{230} is used to established the ages, and O^{18}/O^{16} is used to figure out if the climates were warm or cold.

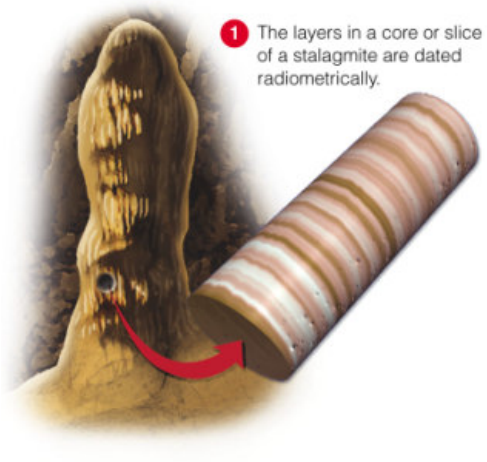


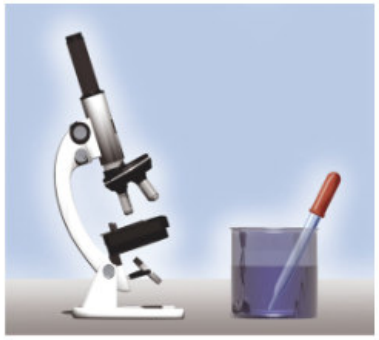
• O^{18} is heavier than O^{16} and therefore becomes selectively concentrated in water during warm times, because O^{16} vaporizes more readily than O^{18}

USING STALAGMITES FOR AGE-DATING AND CLIMATE STUDIES



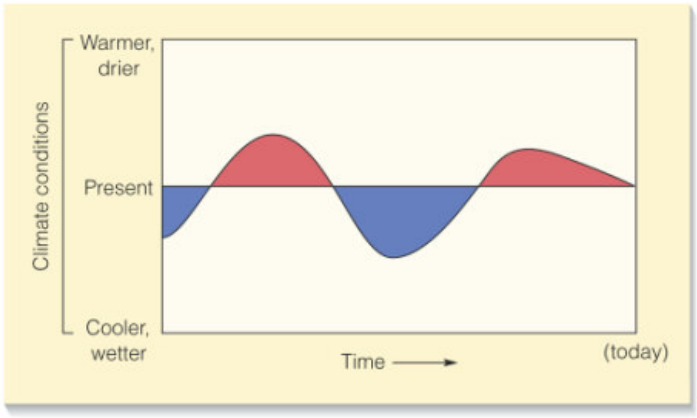
USING STALAGMITES FOR AGE-DATING AND CLIMATE STUDIES





2 The pore water is analyzed in each layer for O^{18}/O^{16} and species of plants (from the pollen).

3 A record of climatic change is put together for the area of the caves.



• Thus a detailed record of climate change for the area can be determined by correlating the climate results from using the Oxygen concentrations with the time period using the Uranium-Thorium ages

FISSION-TRACK DATING measures the number of microscopic, linear tracks left by the fission decay of Uranium-238 and is useful for dating samples from about 40,00 years to 1.5 Ma, a period of time for which other techniques are not always available

• Unlike other isotopic dating methods, the "daughter" in fission track dating is an effect in the crystal rather than a daughter isotope.

•Uranium-238 undergoes spontaneous fission decay at a known rate, and it is the only isotope with a decay rate that is relevant to the significant production of natural fission tracks; other isotopes have fission decay rates too slow to be of consequence.

•The fragments emitted by this fission process leave trails of damage (fossil tracks or ion tracks) in the crystal structure of the mineral that contains the uranium.

• Chemical etching of polished internal surfaces of these minerals reveals spontaneous fission tracks, and the track density can be determined.

•Because etched tracks are relatively large (in the range 1 to 15 micrometres), counting can be done by optical microscopy, although other imaging techniques are used.

GEOLOGIC TIME, CONCEPTS, AND PRINCIPLES

And the Days Grow-Longer?

• Results of recent studies confirm that Earth has been slowing down and taking longer to complete full rotations about its axis.

• Researchers studying tide-deposited sedimentary rocks in Utah, Australia, Alabama, and Indiana found evidence that the lunar cycle has been lengthening over the past 900 million years.

• The oldest sediments indicated Earth's days were just 18 hours long, which would have made for a year of 481 days. *Science, July 5*.

EXAMPLES OF RELATIVE AGE DATING

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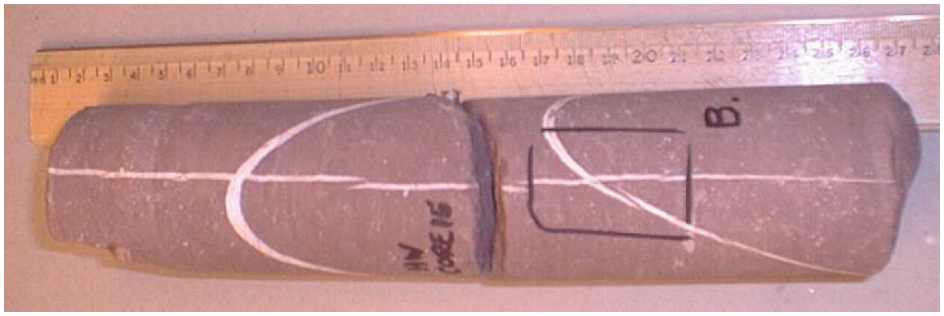
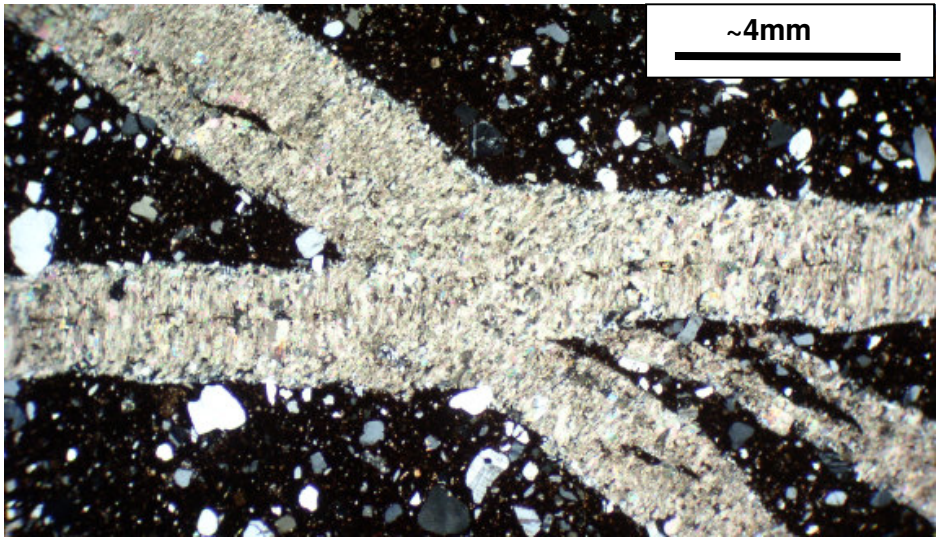
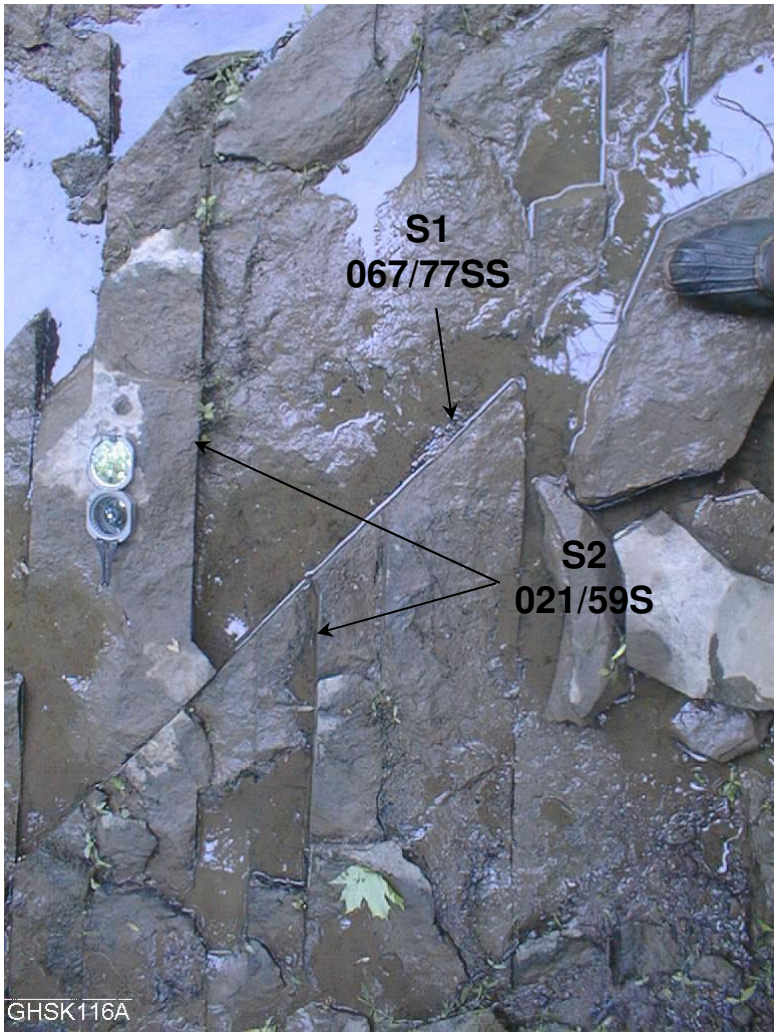
EXAMPLES OF RELATIVE AGE DATING







FOCUSED ON CROSS-CUTTING AND ABUTTING FRACTURE GEOMETRY AND MORPHOLOGY