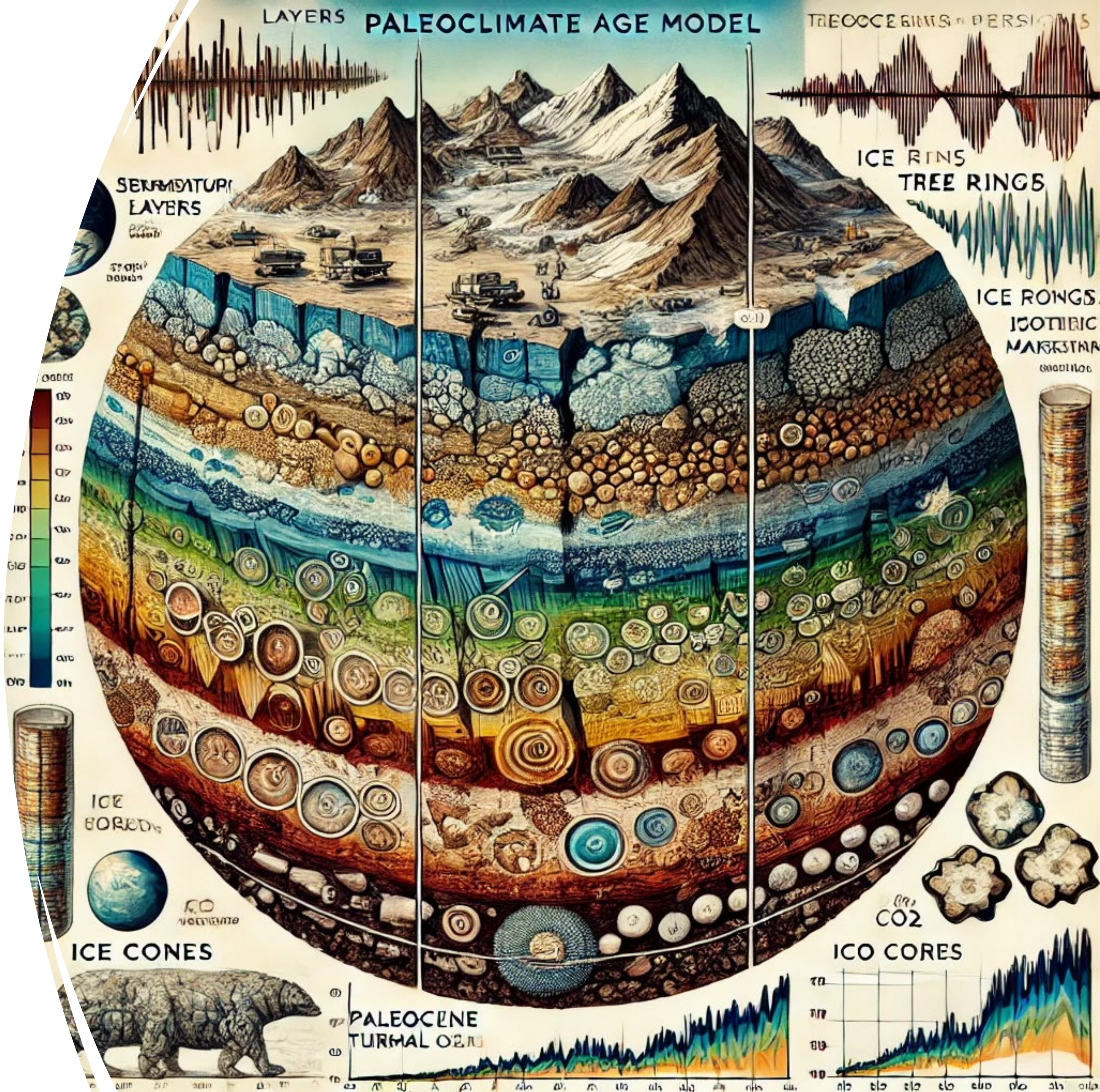
AGE MODELS

DEFINITION

An **age model** is a tool used in geology to estimate the age of sedimentary layers or geological events based on various dating techniques. It creates a relationship between the depth or position of a sample (such as sediment, rock, or ice core) and time, allowing geologists to assign ages to specific layers or events.



PURPOSE OF AGE MODELS IN GEOLOGY

1. **Dating Geological Events**: Age models help **assign specific ages to events** recorded in geological archives, such as volcanic eruptions, glaciations, or biological changes (e.g., extinction or migration of species).

2. **Constructing Timelines**: By creating a chronological framework, age models **enable the reconstruction of the sequence of events** in Earth's history. This helps in understanding how different processes unfolded over time.

3. **Correlating Data**: Age models allow geologists to **synchronize data from different locations**. For example, marine sediment cores, ice cores, and terrestrial records can be aligned chronologically, revealing connections between regional and global events, such as climate changes or tectonic activities.

In summary, age models are crucial for building a detailed, time-resolved understanding of Earth's history, facilitating the comparison and correlation of data across different regions and geological settings.

IMPORTANCE OF AGE MODELS IN GEOLOGY

1.Establish a temporal framework for geological events

•Age models provide a **precise timeline** for sedimentary deposits, allowing scientists to determine **when** different layers were formed.

•This is essential for creating a **chronological order** of geological and climatic events, without which it would be difficult to understand the sequence of Earth's transformations.

2. Reconstruct paleoclimate

•Age models help to **date past climatic events**, such as ice ages or global warming periods, and link them to changes in sediments or atmospheric gases.

•This is crucial for understanding **how and when** the climate changed in the past, and for identifying the factors that influenced these changes, like solar activity or volcanic emissions.

3. Decode sedimentary records

•Marine, lacustrine, and glacial sediments contain **natural archives** of climatic and environmental information. Age models place this information on a **time scale**, helping to interpret phenomena like variations in chemical composition or grain size of sediments.

•Without an age model, it would be difficult to distinguish **natural cyclical changes** from **sudden** or catastrophic ones.

4. Link geological and climatic events

•Age models allow scientists to connect specific geological events, such as volcanic eruptions or asteroid impacts, to subsequent climatic or biological changes.

•These temporal connections help explain **cause-and-effect relationships**, such as how a volcanic eruption might lead to a global cooling period.

IMPORTANCE OF AGE MODELS IN GEOLOGY

5. Understand geological and climatic cycles

•Age models help identify **natural cycles** that affect the Earth, such as glacial-interglacial cycles or Milankovitch cycles (orbital variations that influence climate).

•These models trace the evolution of climate and environmental conditions in response to natural forces over long time scales.

6. Compare data across different geographic regions

•By using age models, researchers can **compare data** from different parts of the world, synchronizing global events like mass extinctions or ice ages on a planetary scale.

•This is key to understanding how global climatic changes impacted different regions differently.

7. Predict future climate changes

•Age models provide a basis for **predicting future climate changes**. By studying past climate cycles, we can better understand **how** and **when** future changes may occur and what their **impacts** might be.

•These models are essential for identifying long-term trends and understanding how the climate system might respond to anthropogenic factors like increased CO_2 emissions.

8. Develop adaptation and mitigation strategies

•Reconstructing past climate changes helps modern societies develop **adaptation strategies** for new climate conditions, as age models show how the climate has naturally fluctuated and how it might change again.

•They provide insights into **feedback mechanisms** that could accelerate or slow down climate change.

In summary, age models are fundamental to understanding the **geological** and **climatic past**, correlating global events, and making projections about the future climate.

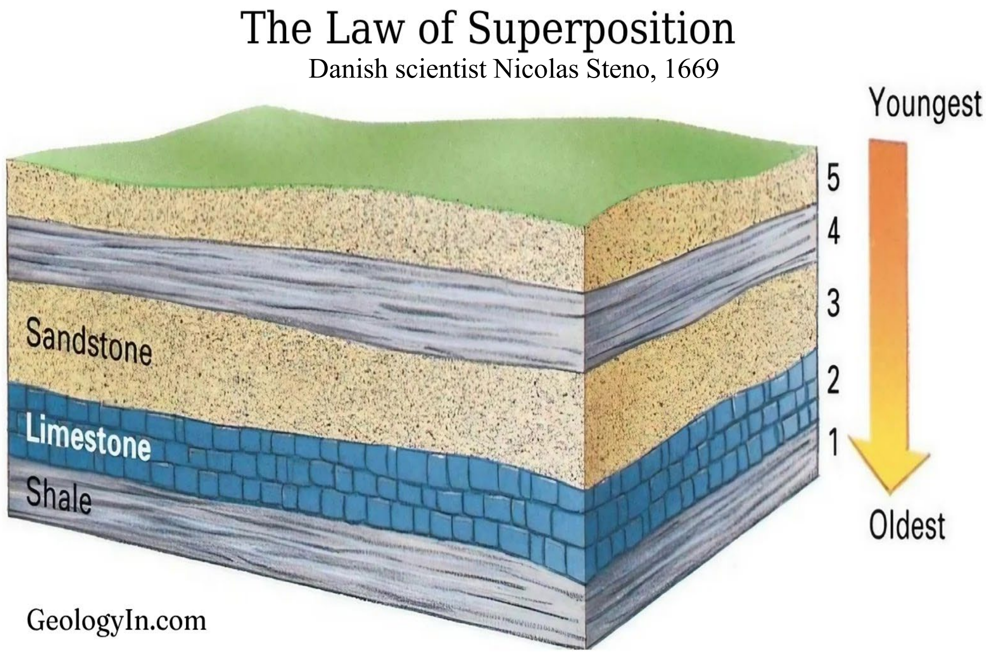
TYPES OF AGE MODELS – relative dating

When constructing **age models**, there are two main types of dating techniques: **relative dating** and **absolute dating**.

1. Relative Dating

A. **Stratigraphy**.
B. **Biostratigraphy**
C. **Magnetostratigraphy**:

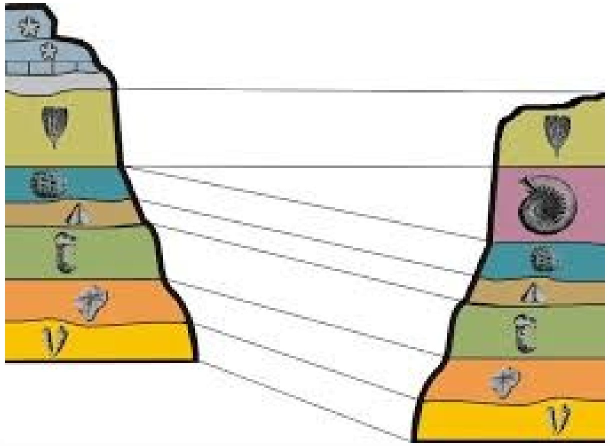
A. **Stratigraphy**: This method relies on the principle of superposition, where layers of sediment or rock are ordered by their relative positions—**older layers** are found beneath **younger layers**. It doesn't provide exact dates but helps establish the sequence of events.



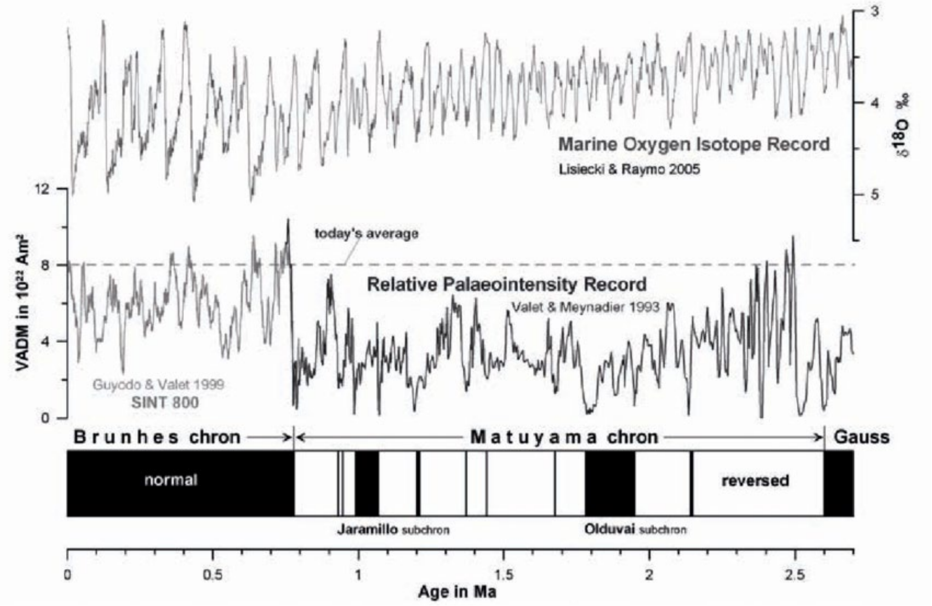
TYPES OF AGE MODELS – relative dating

1.Relative Dating

A. **Biostratigraphy**: Uses fossils (biohorizons) within sediment layers to determine their relative ages, based on the known time ranges of specific species.



B. **Magnetostratigraphy**: Based on the changes in Earth's magnetic field recorded in rocks, helping to date layers by comparing them to the “reference” global geomagnetic polarity time scale.



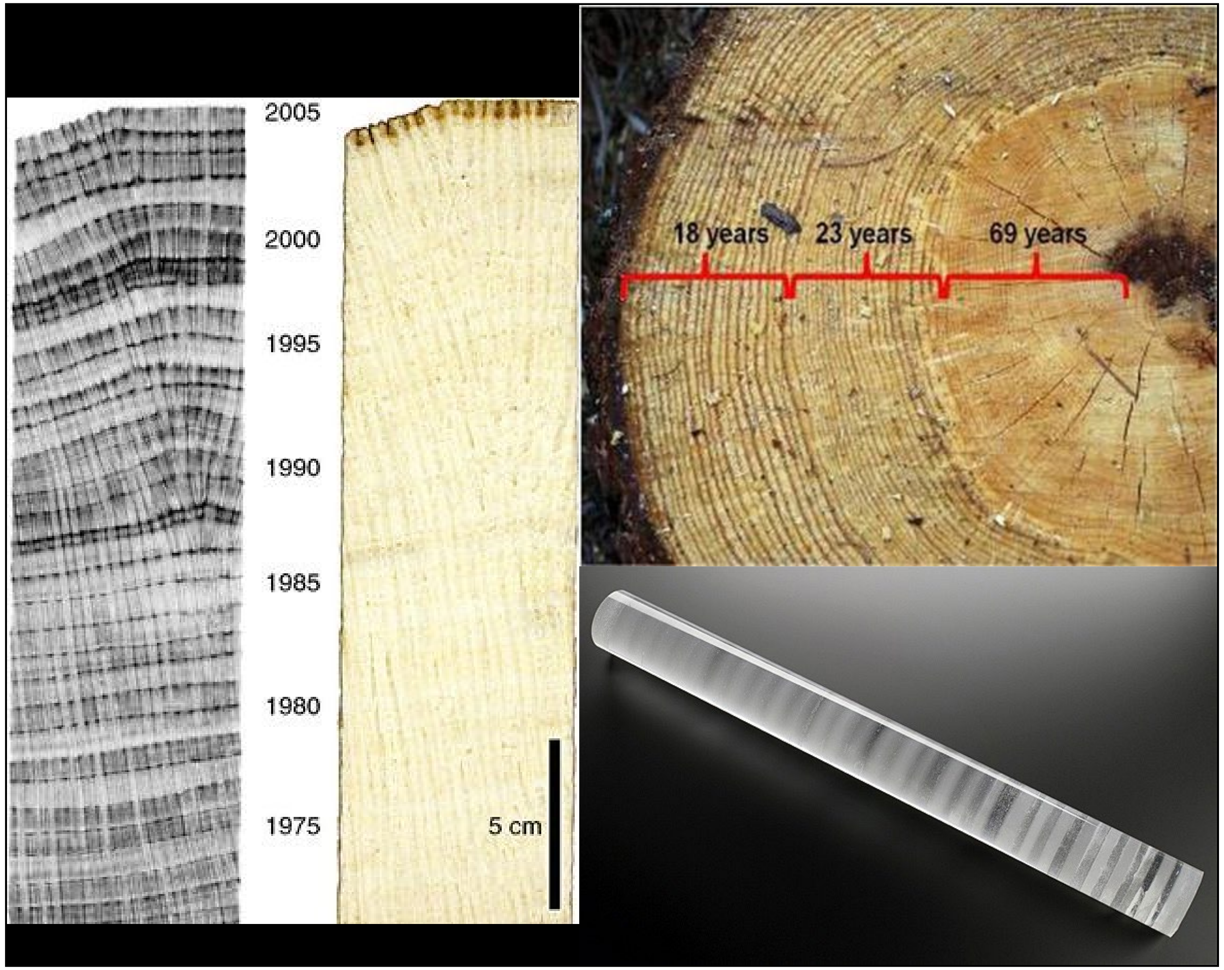
TYPES OF AGE MODELS – absolute dating

2. Absolute Dating

A. **Dendrochronology or coral banding**
B. **Ice Core Dating**
C. **Radiometric Dating**
D. **Astronomical tuning**

A. **Dendrochronology or coral banding**: Uses tree rings/coral bands to date events and environmental changes year by year.

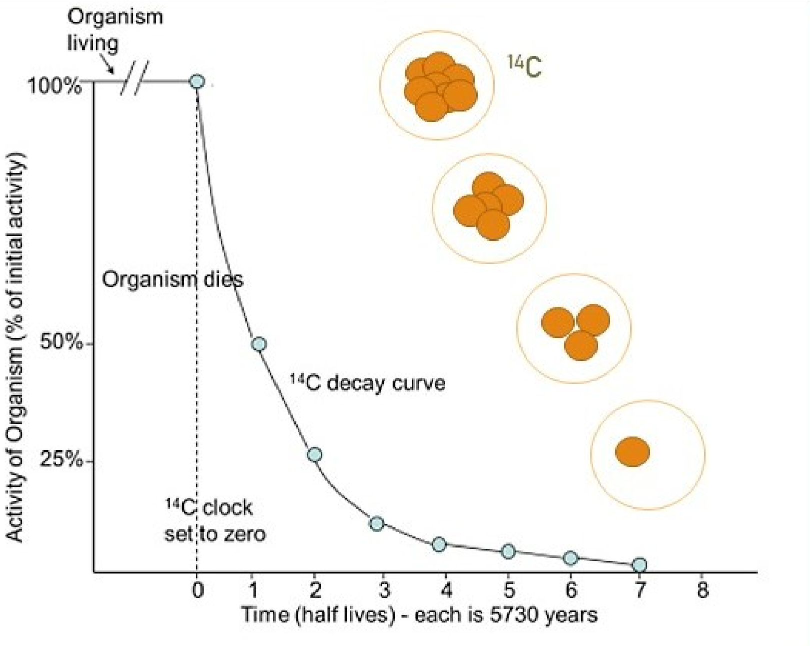
B. **Ice Core Dating**: Layers in ice cores can be counted and linked to specific years, often in conjunction with radiometric techniques for cross-verification.

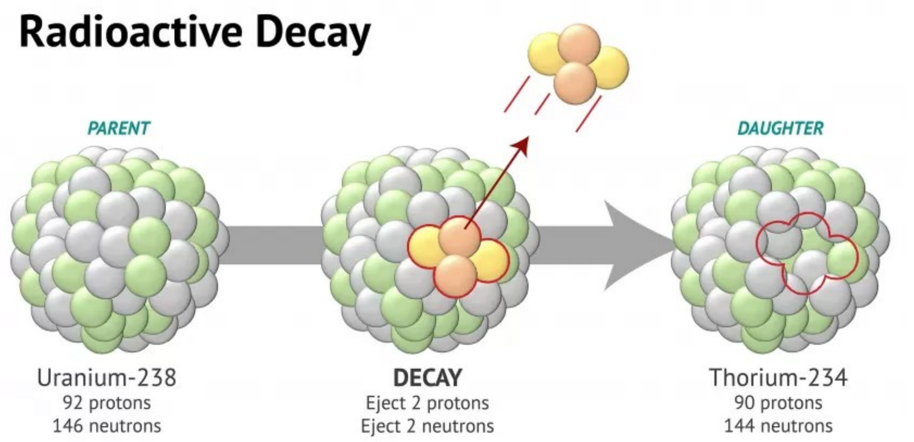


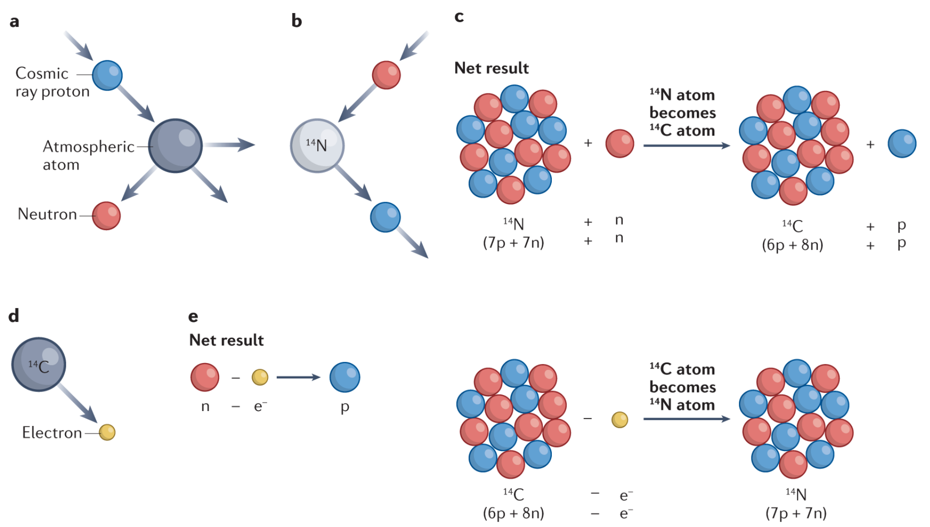
TYPES OF AGE MODELS – absolute dating

2. Absolute Dating

C. **Radiometric Dating**: This technique measures the decay of radioactive isotopes, like **carbon-14** for recent samples (up to ~50,000 years) or **uranium-lead** and **potassium-argon** for much older materials (millions to billions of years). It provides precise numerical ages.



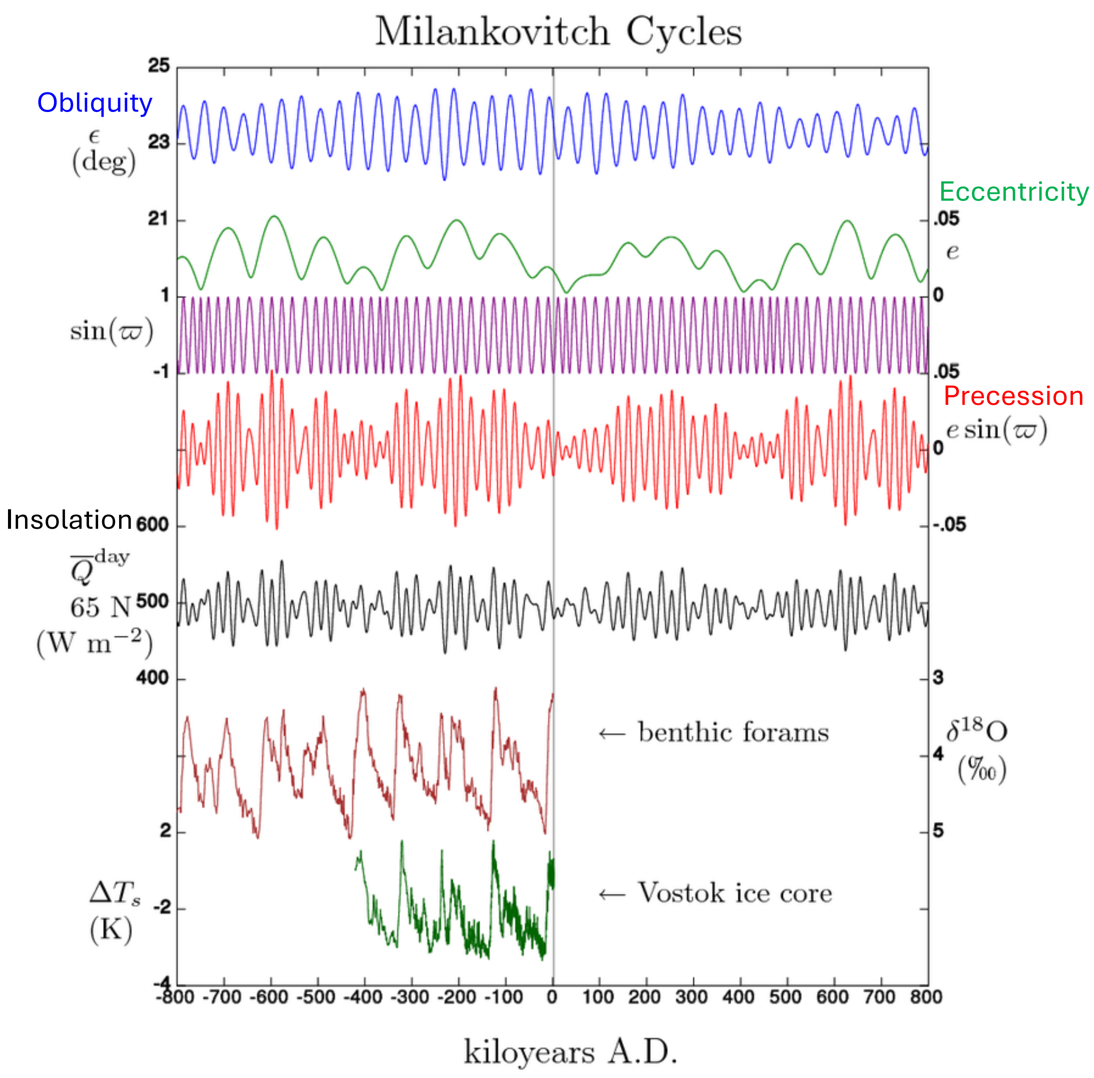




TYPES OF AGE MODELS – absolute dating

2. Absolute Dating

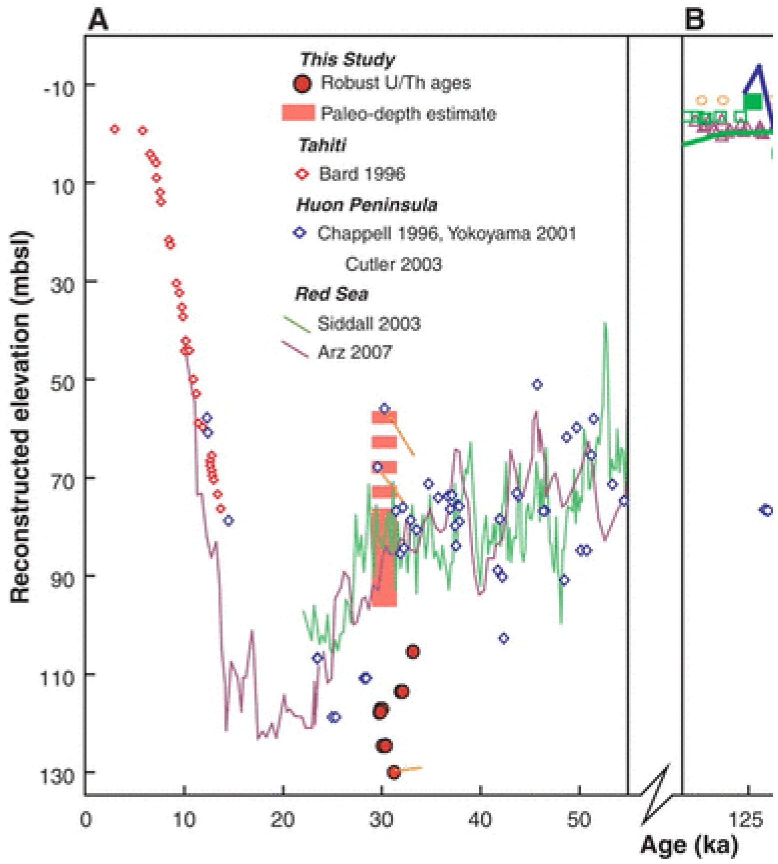
D. **Astronomical tuning** is a technique used for **absolute dating**, although it applies principles of **relative dating**. It involves correlating cycles recorded in sediments with predictable astronomical cycles (**Milankovitch cycles**)



In summary, **relative dating** techniques establish the order of events without exact dates, while **absolute dating** provides specific ages, forming the backbone of constructing age models.

Key Methods for Constructing Age Models: : Examples

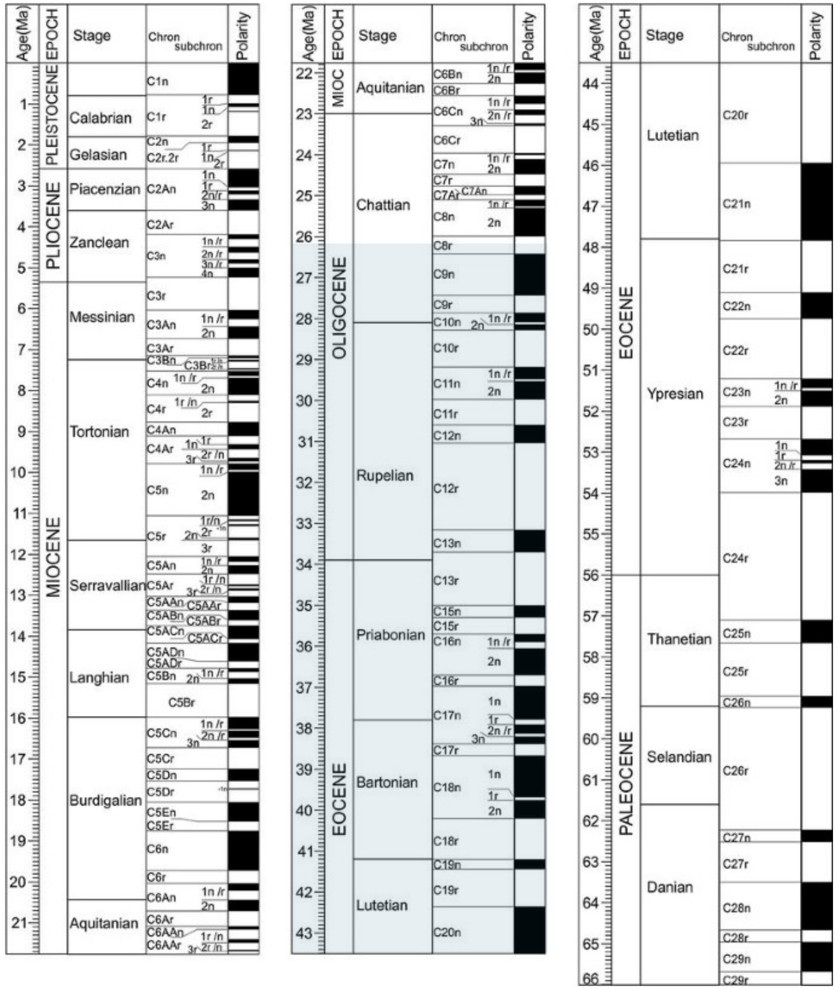
•**1. Radiometric Dating**:
Uranium-Thorium (U-Th) Dating
•**Applicable materials**: Carbonates (like stalagmites, corals, and marine sediments), bones, and teeth.
•**Isotopes used**: **Uranium-238 (U-238)** decays to **Thorium-230 (Th-230)**.
•**Half-life**: U-238 has a half-life of **4.5 billion years**, but Th-230 dating typically covers a range of up to about **500,000 years**.
How it works:
•Uranium is soluble in water, while thorium is not. This means that materials like corals or carbonate sediments accumulate uranium but not thorium. Over time, **U-238 decays into Th-230**, which can be measured to determine the age.
•The ratio of **Th-230 to U-238** increases over time. By measuring this ratio, scientists can calculate how long it has been since the material formed, providing an absolute age.
Example:
•**Coral reef dating**

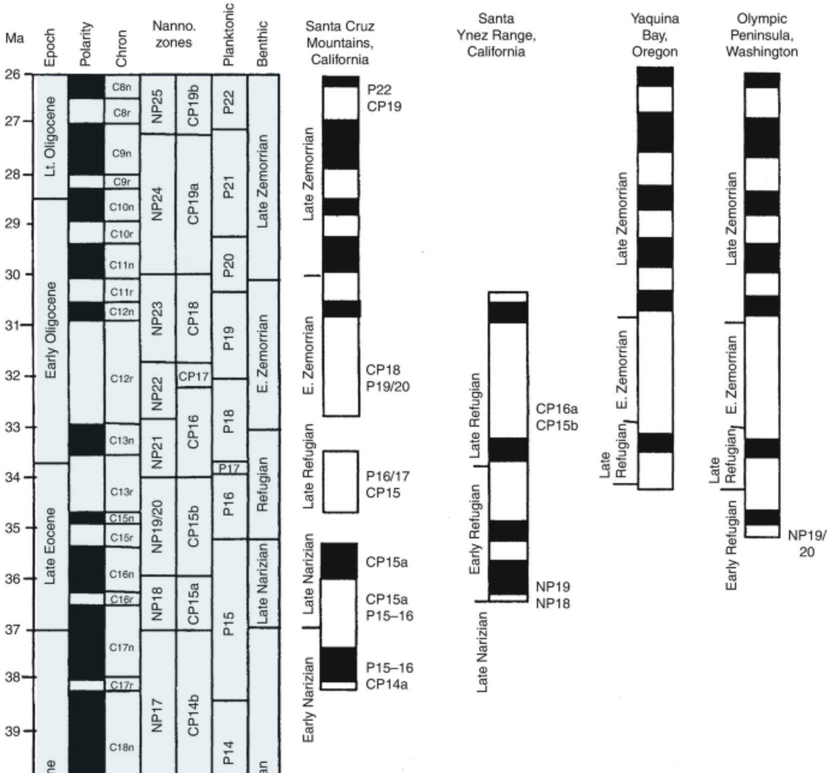


Key Methods for Constructing Age Models : Examples

•**2. Magnetostratigraphy**: geomagnetic reversals provide age constraints by correlating sedimentary layers with the global geomagnetic timescale.

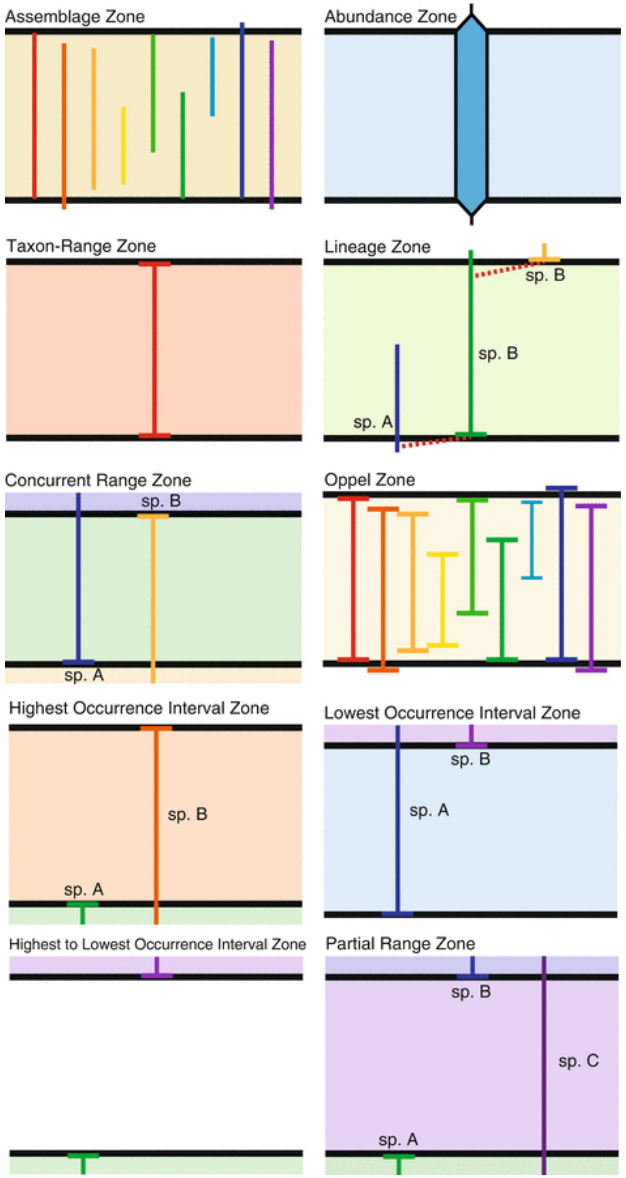
GEOMAGNETIC
POLARITY
TIMESCALE
GPTS

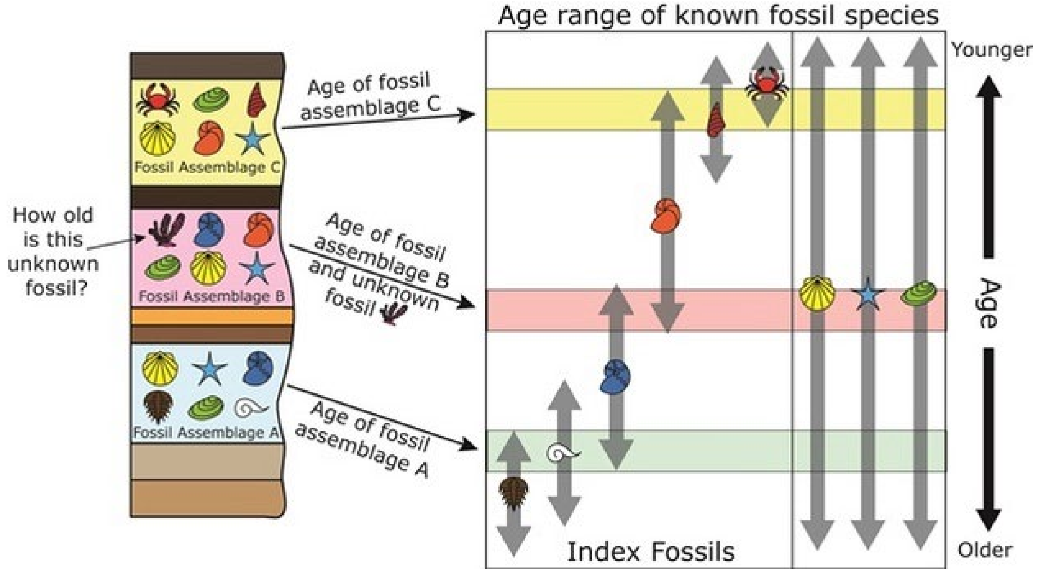




sedimentary successions

Key Methods for Constructing Age Models : Examples





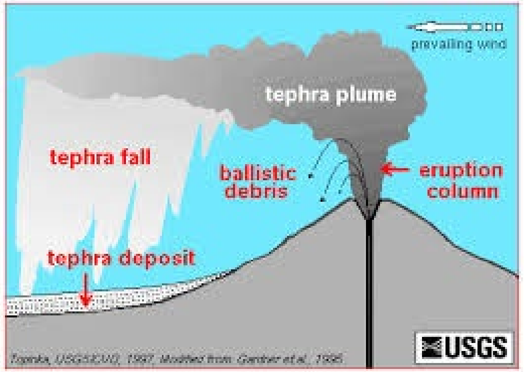
- **3. Biostratigraphy**:
  - fossil assemblages and marker species are used to date layers in sedimentary sequences.

Age (Ma) Ogg *et al.*, 2016	Age		Planktonic Foraminiferal Zones	Datum markers
				Globotruncana ventricosa
	Campanian	E	*Globotruncanita elevate*	*Globotruncanita elevata*
84.2	Santonian	L	*Dicarinella asymetrica*	
		E		*Dicarinella asymetrica*
86.3	Coniacian	L	*Dicarinella concavata*	
		M		*Dicarinella concavata*
		E	*Dicarinella primitiva*	*Dicarinella primitive*
89.8	Turonian	L	*Marginotruncana schneegansi*	

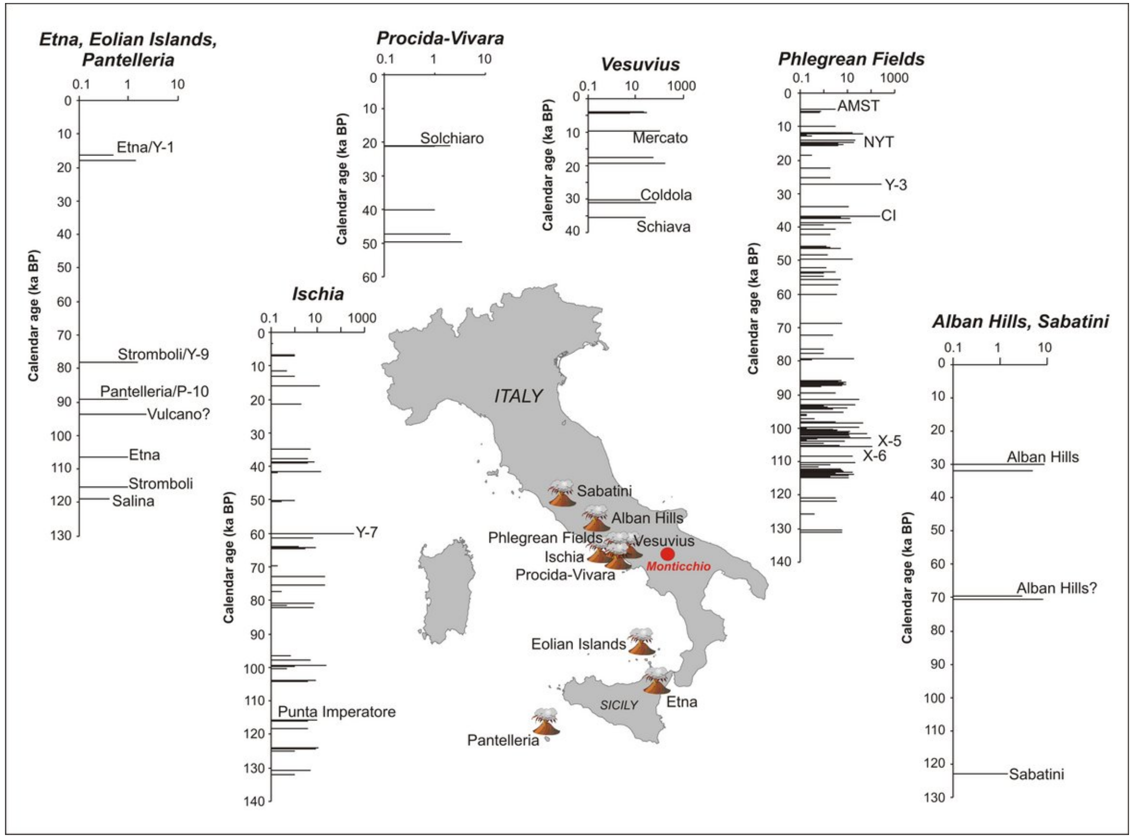
First Occurrence — Last Occurrence

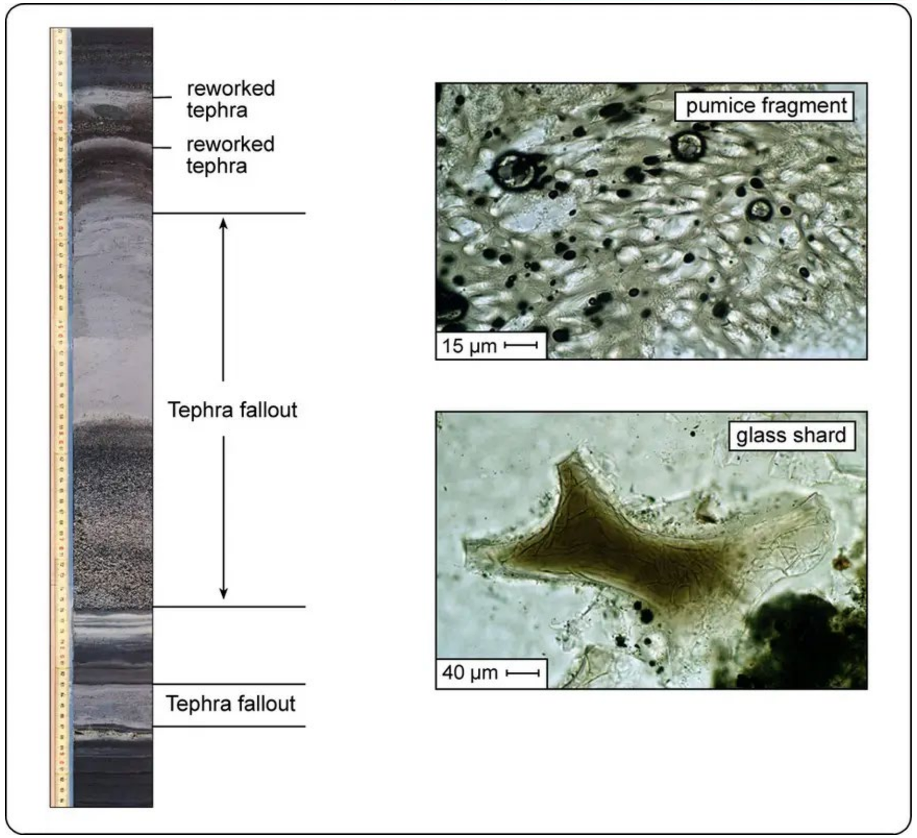
Key Methods for Constructing Age Models : Examples

•**4. Tephrachronology**:
Volcanic ash layers (tephra) serve as time markers because each eruption produces ash with a **unique chemical signature**. This allows the ash to be identified across large areas. Once the eruption is independently dated, the tephra layer acts as a precise time marker in the geological record.



Stratigraphy and thickness of distal tephra layers in the sediments of Lago Grande di Monticchio





Steps to Construct an Age Model

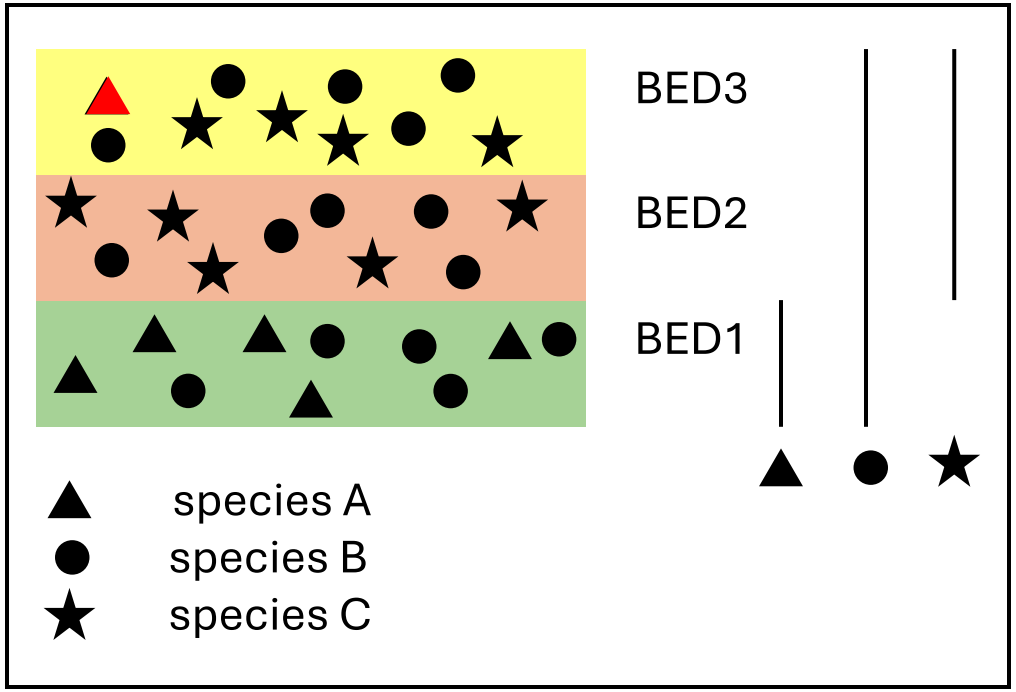
- 1. Collecting and Preparing Data
- 2. Choosing Appropriate Dating Methods
- 3. Assigning Age Points
- 4. Interpolating Between Age Points
- 5. Dealing with Uncertainties
- 6. Exercise

Steps to Construct an Age Model

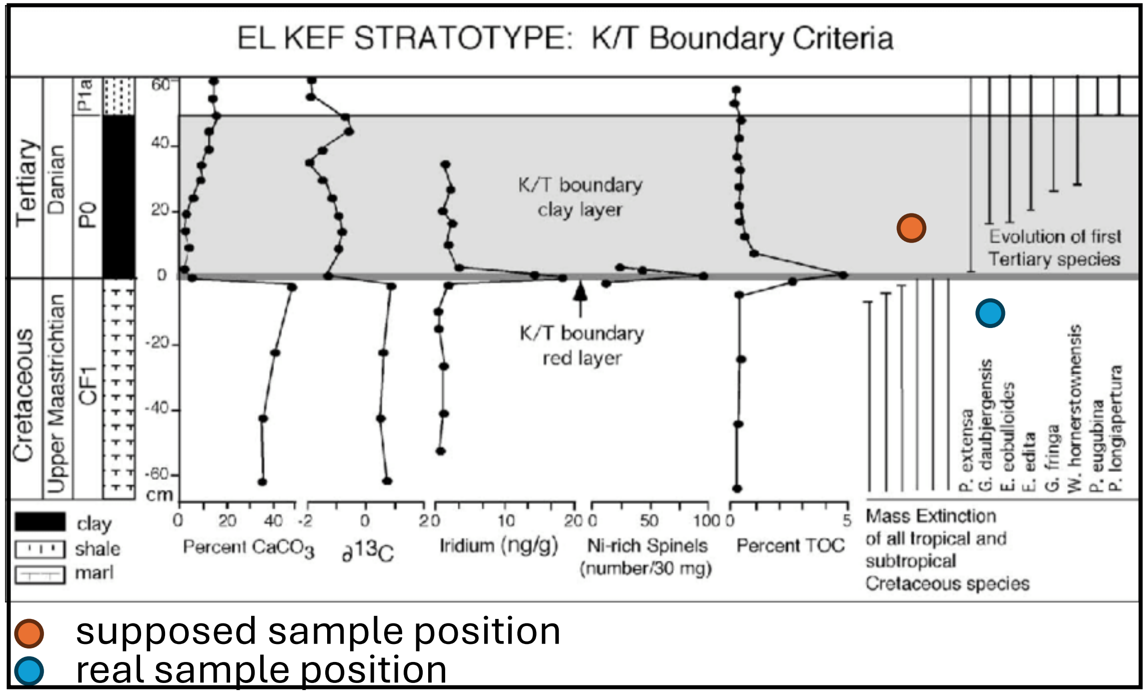
•1. Collecting and Preparing Data:

- the typical sources of data: sediment cores, ice cores, or other **geological archives**.
- the importance of **good sample quality and depth control** (i.e., knowing exactly where in the sequence the samples come from). Poor quality samples or **uncertain depth** can lead to incorrect ages or misinterpretation of the sequence, affecting the overall reconstruction of environmental changes or geological events.

Reworked sediments/downhole contamination



Uncertain or wrong depth

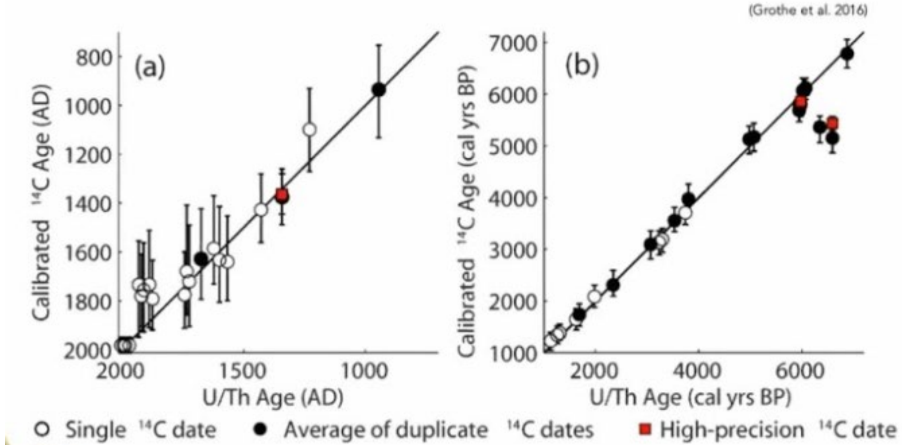


Steps to Construct an Age Model

- **2. Choosing Appropriate Dating Methods**:
  - Depending on the material and available resources, decide whether to use radiocarbon dating, isotopic dating, magnetostratigraphy, or biostratigraphy.

1. Radiocarbon Dating:
Material: A layer of ancient peat containing preserved plant material (peat deposit).
Choice: Radiocarbon dating (C-14) is ideal because the sample contains organic matter and is likely less than 50,000 years old. This method is cost-effective and widely used for dating recent organic remains.

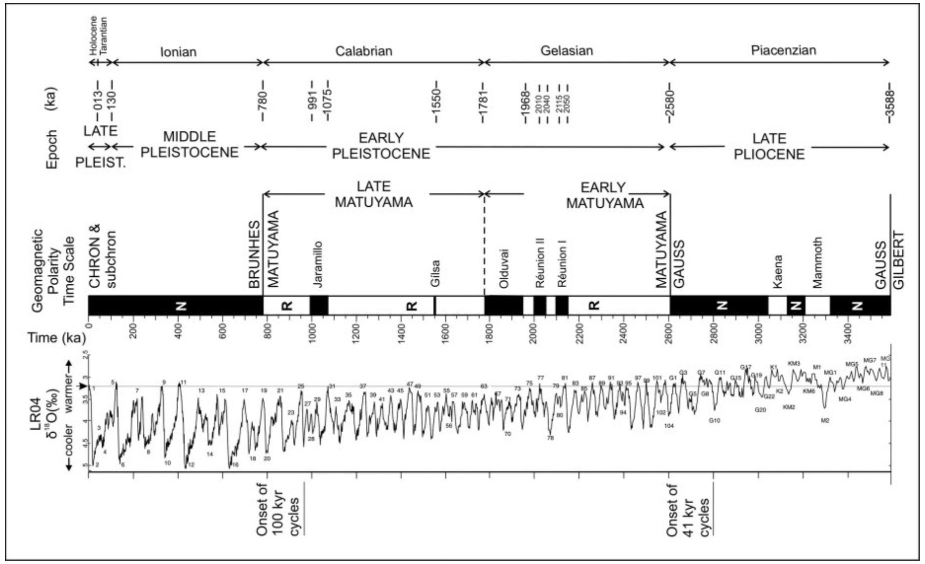
2. Isotopic Dating (U-Th):
Material: A coral reef structure.
Choice: Uranium-thorium (U-Th) dating is appropriate because corals incorporate uranium into their skeletons but not thorium. This method works well for materials up to 500,000 years old, and is particularly useful for dating marine carbonates.



Steps to Construct an Age Model

- **2. Choosing Appropriate Dating Methods**:
  - Depending on the material and available resources, decide whether to use radiocarbon dating, isotopic dating, magnetostratigraphy, or biostratigraphy.

3. **Magnetostratigraphy**:
   Material: A long sequence of sedimentary rocks from a lake core that lacks datable organic material.
   Choice: Magnetostratigraphy is suitable because it doesn't rely on organic content.



4. **Biostratigraphy**:
   Material: A fossil-rich sedimentary sequence with abundant marine microfossils (e.g., foraminifera).
   Choice: Biostratigraphy is ideal here, as it uses the known ages of specific events base of species to date sediments/rocks.

Steps to Construct an Age Model

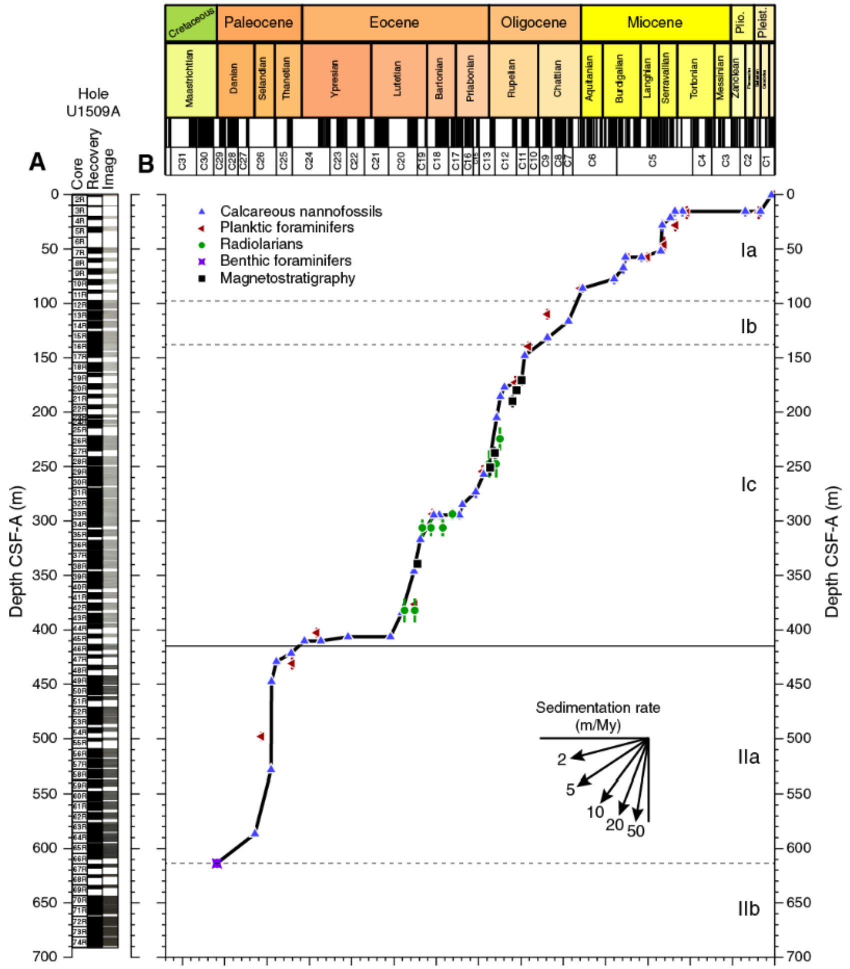
•3. Assigning Age Points:

- Identify key points in the record where absolute dates can be assigned (e.g., radiometrically dated layers or volcanic ash layers

A **tie point** in geology or stratigraphy refers to a specific point in a sedimentary or geological record where an **absolute age** or a well-defined chronological marker can be assigned. These points are used to "tie" or anchor a timeline within a sequence, allowing for more accurate correlations between different records or locations.

Tie points are often based on:
•**Radiometrically dated layers** (e.g., volcanic ash or tephra).
•**Paleomagnetic reversals** (from magnetostratigraphy).
•**Fossil-based dating** (biostratigraphy).
•**Climate proxies** (such as isotope ratios).

Tie points help establish a robust chronological framework within age models, allowing researchers to interpolate the age of other layers relative to these fixed points.



Steps to Construct an Age Model

•4 Interpolating Between Age Points:

- Explain how ages are estimated for sediment layers between dated levels, often using linear interpolation or more complex statistical techniques like Bayesian modeling.

Example: Using Linear Interpolation or Bayesian Modeling for Age Models

Scenario:

You have a sediment core with two **tie points**:

1. A volcanic ash layer dated to **100,000 years ago**.
2. A radiometrically dated layer at **50,000 years ago**.

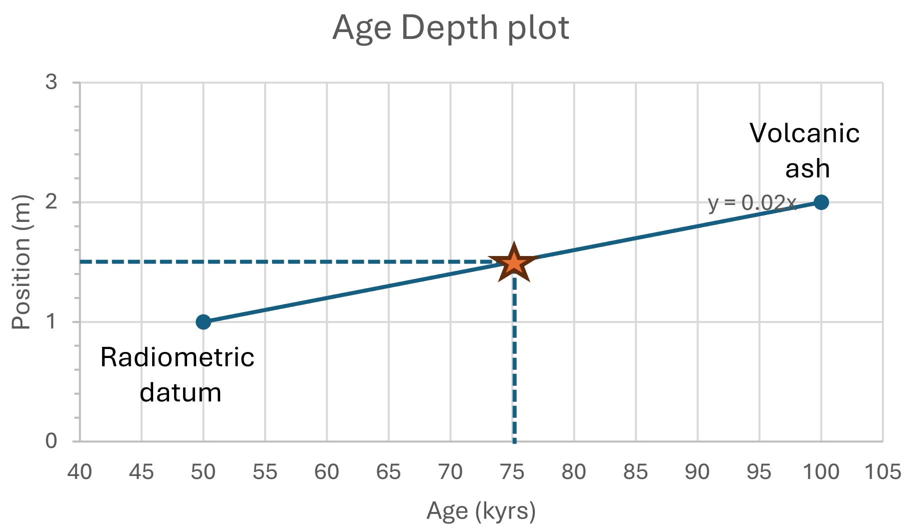
Between these two tie points, you need to estimate the age of other layers in the core.

1. Linear Interpolation:

•You assume that the sedimentation rate between these two tie points is **constant**.

•If a sample is found halfway between the 100,000-year-old and the 50,000-year-old layers, you estimate it to be **75,000 years old**.

•This method is simple but assumes a uniform sedimentation rate, which may not always be accurate.



2. Bayesian Modeling:

•**Bayesian statistics** account for variations in sedimentation rates. This method incorporates **prior knowledge** (such as known sedimentation rate or climate changes) and updates the age model based on the data.

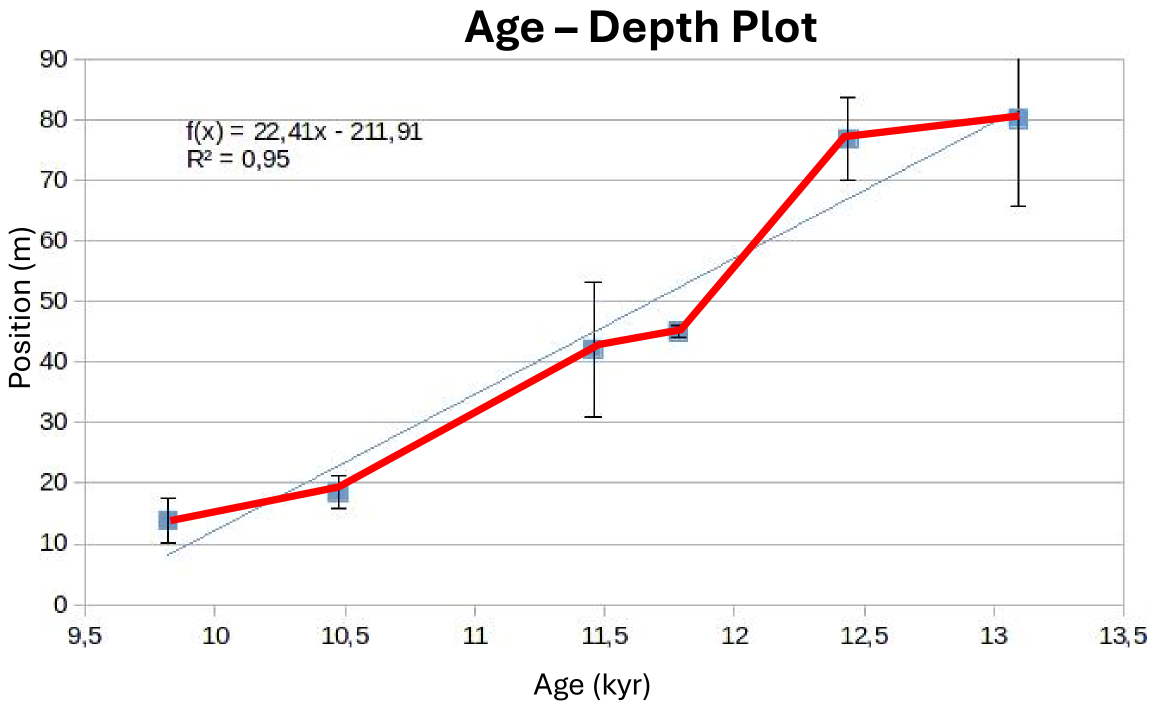
Steps to Construct an Age Model

•5. **Dealing with Uncertainties:**

- how uncertainties in dating (e.g., radiocarbon dating calibration, errors in age-depth interpolation) affect the age model and how these are usually represented (error bars or ranges).

Uncertainties in dating, such as those from radiocarbon calibration or errors in age-depth interpolation, can significantly affect the accuracy of an age model.

These uncertainties are usually represented using **error bars** or **age ranges**, which provide a visual indication of the potential variation or uncertainty in the estimated ages.

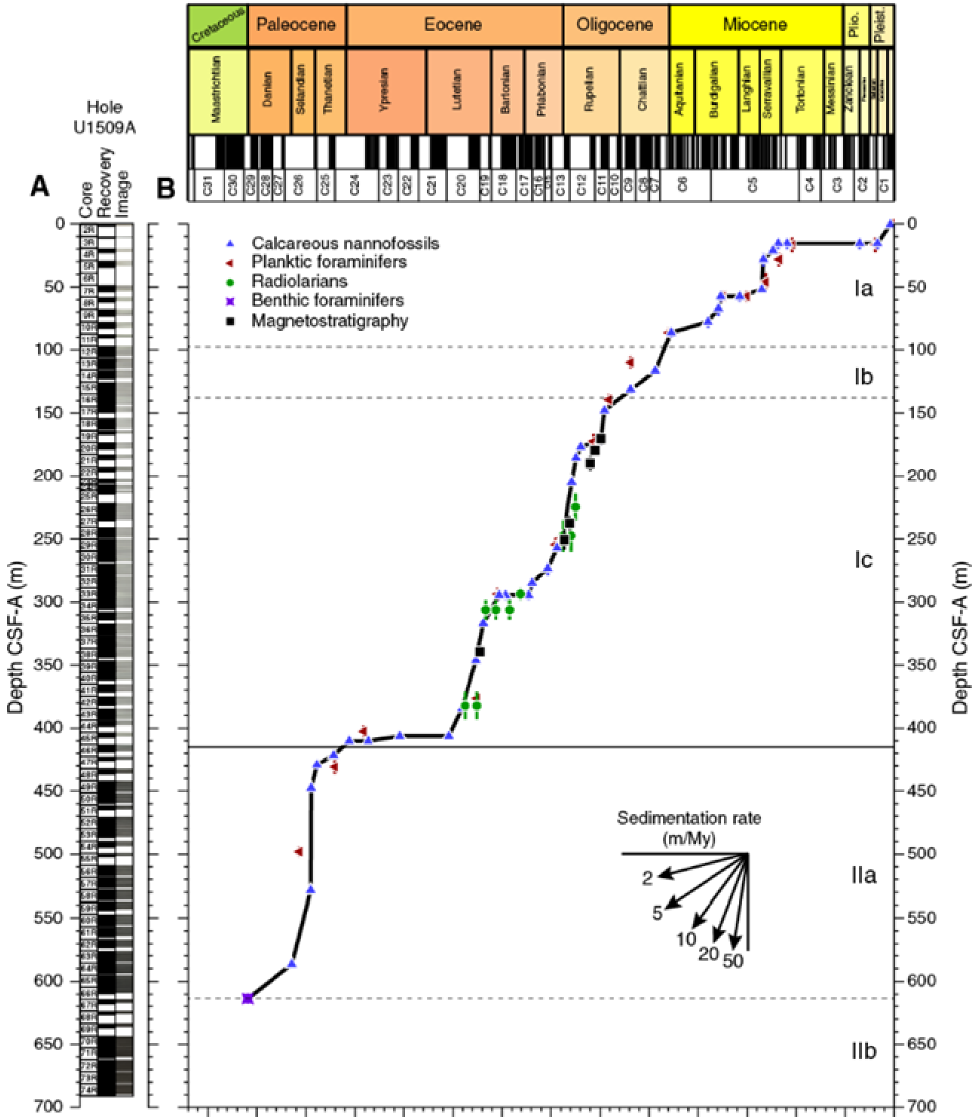


Steps to Construct an Age Model

•5. **Dealing with Uncertainties:**

•**Measurement Error**: This type of error refers to **inaccuracies or uncertainties in the measurement process itself**.
•Related to the instruments and methods used to take the measurements.

•**Resolution Error**: This error refers to the **precision of the dating method** and how fine or detailed the data is.
•Depends on the precision and detail of the data or method, such as how much information is available or the time span of species in biostratigraphy.



Exercise: Building an Age Model and Handling Uncertainties

Scenario:
You have a marine sediment core, and your goal is to construct an **age model** based on various dating techniques. During your study (**sampling resolution 20 cm**), you have identified the following data :

1. **Radiocarbon dating**: A sample from a layer at 1 meter depth was dated to **12,000 ± 300 years**.
2. **Tephra** (volcanic ash): At 3 meters depth, you found a tephra layer from a volcanic eruption independently dated to **20,000 years ± 500 years**.
3. **Biostratigraphy**: At 4 meters depth, you found remains of a foraminifera species known to have existed between **30,000 and 35,000 years ago**.
4. **Linear interpolation**: The layers between 1 meter and 3 meters depth lack direct dating and will need to be interpolated linearly between the two dated points.

Exercise: Building an Age Model and Handling Uncertainties

Questions:

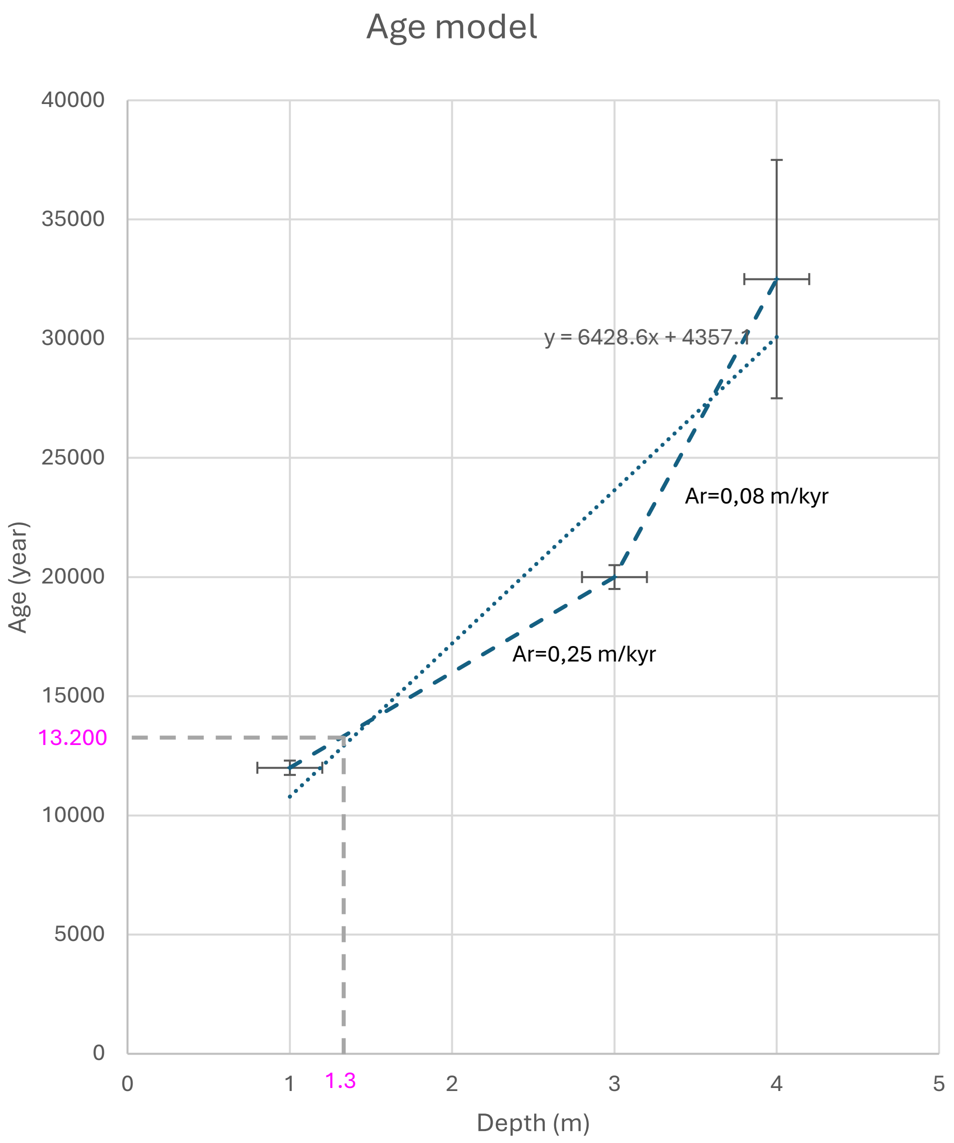
1. **Building the Age Model**: a. Using the provided data, construct an **age-depth model** by linearly interpolating between the point dated at 12,000 years and the one at 20,000 years. What is the estimated age of the layer at 1.3 meters depth?
2. **Uncertainties**: a. What type of **error** is associated with the radiocarbon dating of the sample at 1 meter depth, and how could it affect the age model? b. Why does the biostratigraphic data have **low resolution** in terms of age? What is the range of uncertainty for the dating of the layer at 4 meters depth?
3. **Interpreting the Model**: a. If the sedimentation rate between 1 meter and 3 meters depth is found to be **variable**, would it be better to use **linear interpolation** or a more complex method like **Bayesian modeling**? Explain why.
4. **Practical Application**: a. If the tephra layer at 3 meters is found in other regions, how could it be used to correlate those sediment sequences? b. Explain how representing uncertainties with **error bars** or **shaded ranges** could improve the visualization of the uncertainties in the age model.

Exercise: Building an Age Model and Handling Uncertainties

Expected Answers:

1. **Age Model**: a. Linear interpolation would give an estimated age of **13,200 years** at 1.3 meters depth.
2. **Uncertainties**: a. The error is due to the **measurement itself** in radiocarbon dating and **the (sample) resolution** (0.2 m; ±50 years). The uncertainty of ±300 years means the true age could vary between 11,700 and 12,300 years, affecting the accuracy of the interpolated age. b. The biostratigraphic data has **low resolution** because this datum can be anywhere between **30,000 and 35,000 years**, making it hard to pinpoint an exact age (mid-point).
3. **Interpreting the Model**: a. If the sedimentation rate is variable, **Bayesian modeling** would be better suited, as it can account for changes in deposition rates. This method allows for more flexible modeling by incorporating information on variable sedimentation rates.
4. **Practical Application**: a. The tephra layer could be used as a **tie point** to correlate sedimentary sequences in other regions because it represents a precisely datable event. b. Using **error bars** or **shaded ranges** would help visualize uncertainties in the age model, making it clear where the data is more or less reliable.

Exercise: Building an Age Model and Handling Uncertainties



A_{rate} =Δ depth/ Δ age

$A_{rate_{(1m\ -\ 3m)}}$ =3-1 (m)/ 20-12 (kyr)

$A_{rate_{(1m\ -\ 3m)}}$ =2 (m)/ 8 (kyr)

$A_{rate_{(1m\ -\ 3m)}}$ =0.25 m/ kyr

A_{rate} =Δ depth/ Δ age

Δ age =Δ depth/ A_{rate}

Δ age =0.3m/ 0.25 m/kyr

Δ age =0.3m/ 0.25 m/kyr

Δ age =1.2 kyr

Age =12 + 1.2= 13.2 kyr