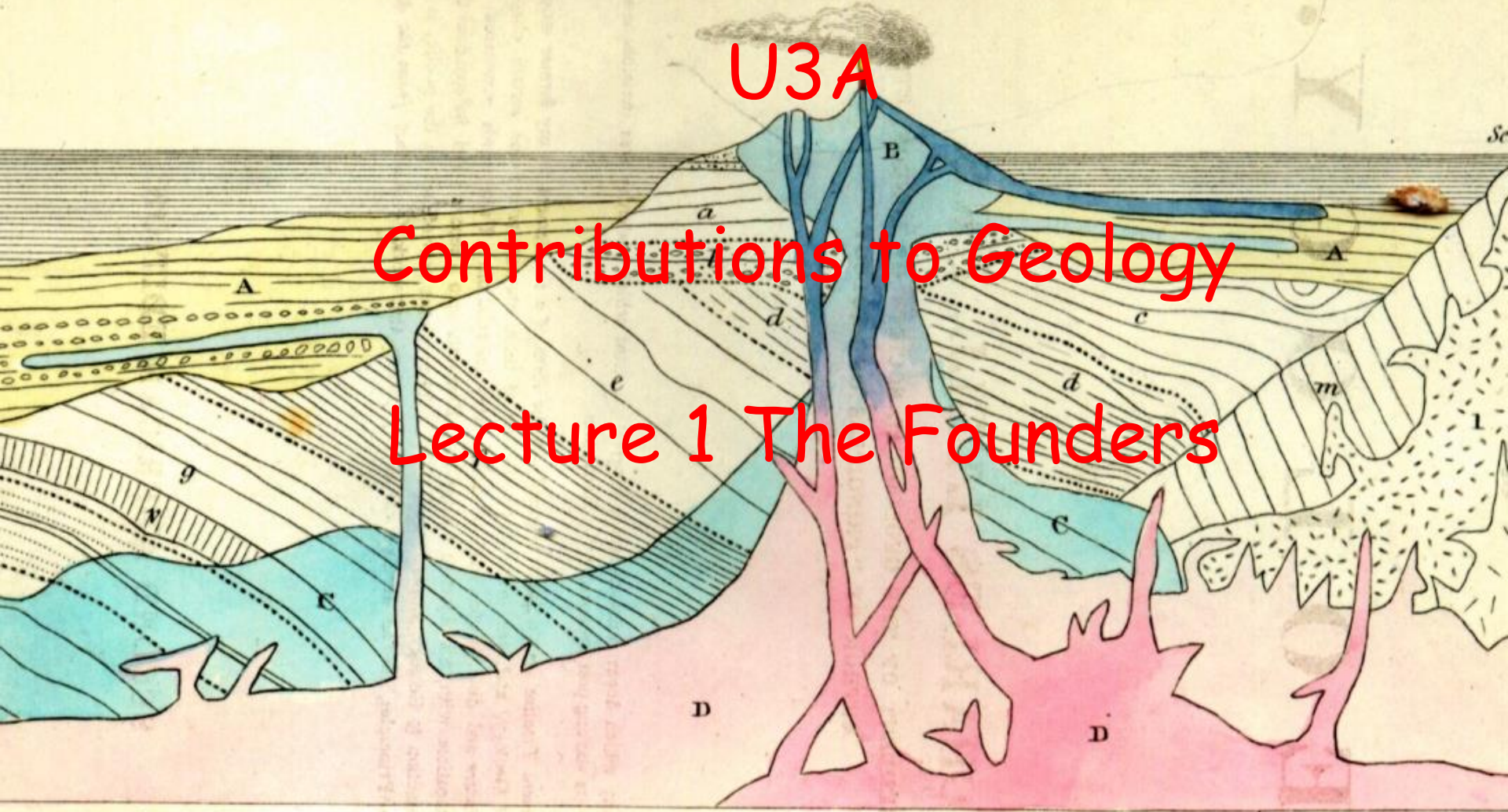
U3A

Contributions to Geology

Lecture 1 The Founders



ECTION of part of the Earth's crust *explaining the theory of the contemporaneous origin of the four great classes of rocks.—see*

A Aqueous

B Volcanic.

C Metamorphic. (*Gneiss, mica schist, &c.*)

D Plutonic (*Granite, &c.*

All the rocks older than A.B.C.D. *are left uncoloured.*

Contributions to Geology Lecture series

- This series will look at individuals that have made major contributions to our understanding of the science of geology
- we will consider groups with similar connections and examine the contributions they made

Lecture 1	The founders of modern Geology
Lecture 2	The palaeontologists
Lecture 3	The mineralogists
Lecture 4	The Australians
Lecture 5	20th century philosophers

Introduction

- Geology – ancient science → basics can be traced back to pre-historic hominids
- early hominids used rocks and minerals for producing fire, tools, weapons *
- through Mediaeval and Renaissance time until early 18th century → important contributions were made to the study of mineralogy
- late 18th century → more holistic approach → scientists began to think about the processes that shaped the Earth → questioned beliefs of the age of the Earth
- some eminent 18th century and early 19th century geologists were clerics → hard to reconcile observations with religious doctrine

Homo habilis – early geologist

Introduction

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James Hutton "Father of Geology" (1726 - 1797)

Scottish geologist, physician, chemist, naturalist and farmer regarded as "The father of modern geology" mainly through his theories of uniformitarianism and plutonism

James Hutton

- Educated at University of Edinburgh where he studied the classics → studied medicine at Universities of Edinburgh, Paris and Leiden
- moved into farming → developed interests in meteorology and geology
- formulated the theory of Uniformitarianism
- recognised that granite was intrusive → molten at time of emplacement
- proposed that the interior of the Earth is hot and that older rocks formed by crystallising magma → Plutonism
- correctly interpreted the origin of unconformities at Jedburgh and Siccar Point (Scotland)

James Hutton (late 1700s)

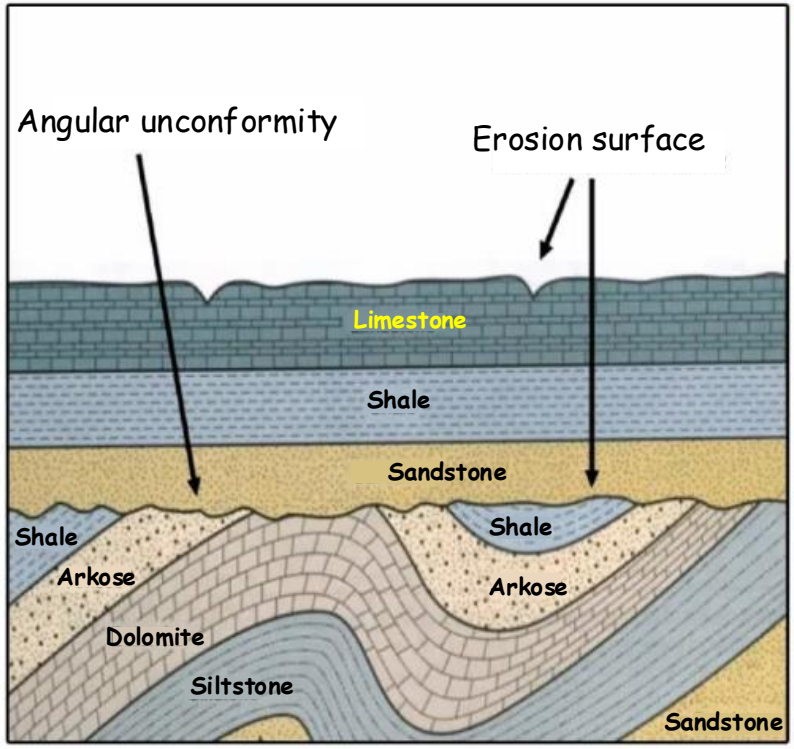
Principle of Uniformitarianism

- geological processes that formed and modified the Earth in the past can be explained in terms of slow, natural processes that we see operating today e.g. sedimentation, erosion
- correctly recognised the immensity of geological time "Deep time"
- Hutton could see " no vestige of a beginning, no prospect of an end" of the Earth
- angular unconformities he observed, provided him with proof for his theory of uniformitarianism

Unconformities

- An unconformity is a surface (or contact) that represents a time gap in the geological record
- the rocks immediately above the unconformity are considerably younger than the rocks beneath
- most unconformities are buried erosion surfaces
- there are three types of unconformity, angular unconformities, disconformities and non-conformities
- an angular unconformity is a contact where the younger strata overlie an erosion surface on tilted or folded layer rock

Angular unconformity



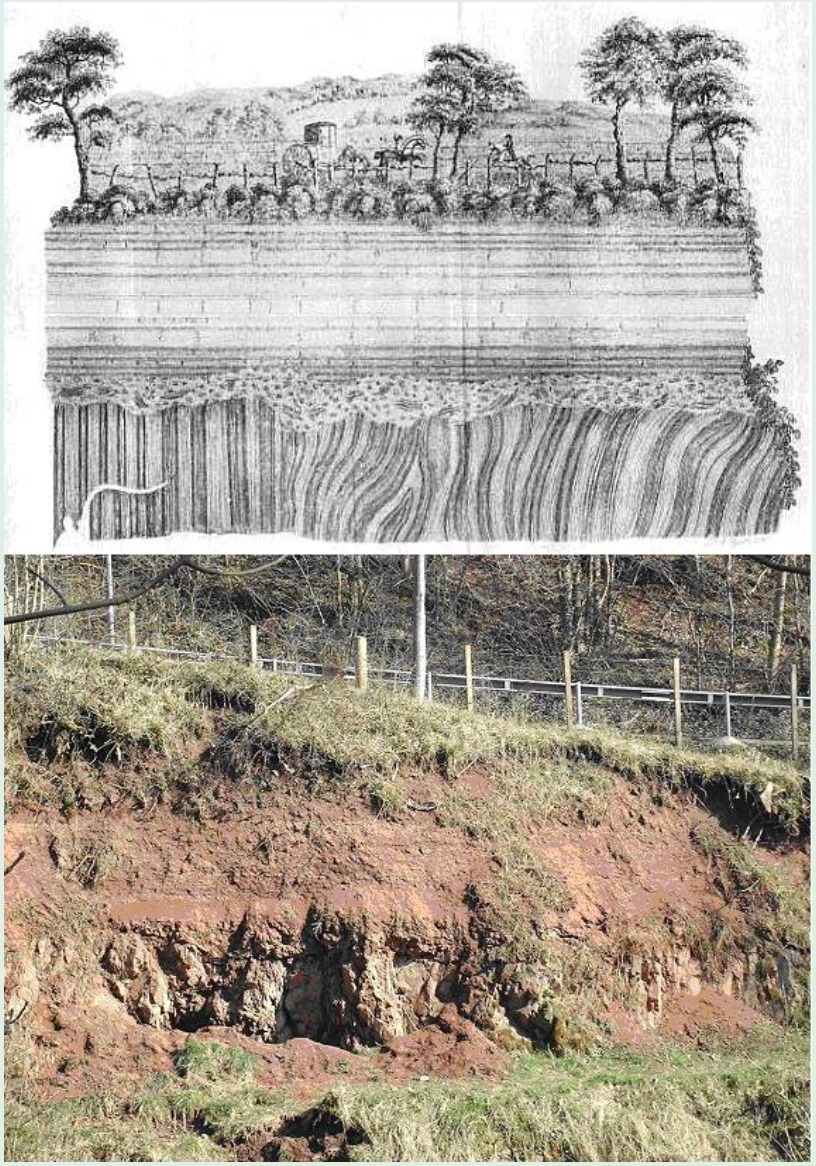
Angular unconformity Telheiro Beach, Portugal

Unconformity Siccar Point

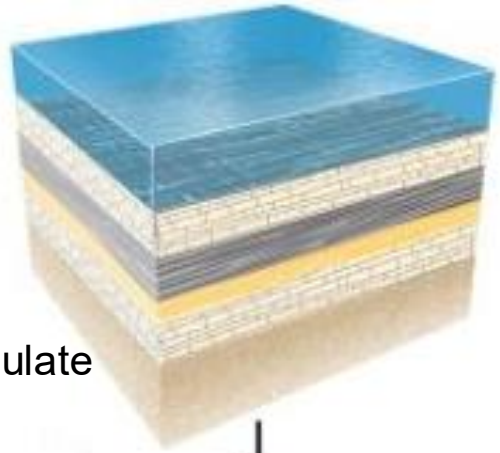
- Siccar Point → small rocky promontory in Berwickshire on SE coast of Scotland
- shallow dipping Late Devonian red sandstone and basal conglomerate layers overlie near vertical layers of Lower Silurian sediments
- age difference between two sequences ~65Mya
- Hutton reasoned there was deposition of sediment on seafloor, then uplift and tilting followed by erosion → deposition of sediments in a trough
- Hutton recognised that the geological processes that formed the outcrop operated over a large period of time based on modern sedimentary rates

Unconformity, Siccar Point, Scotland

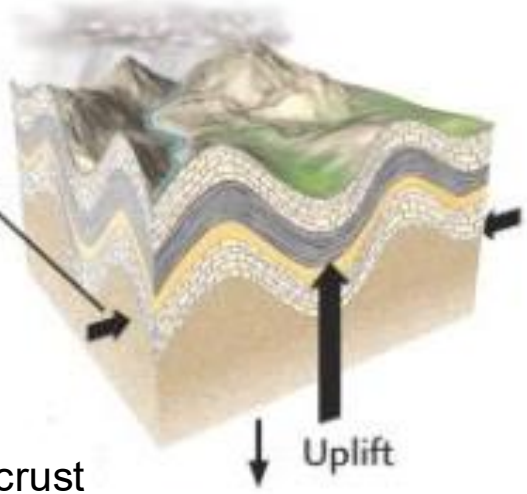
Unconformity at Jedburgh, Scotland



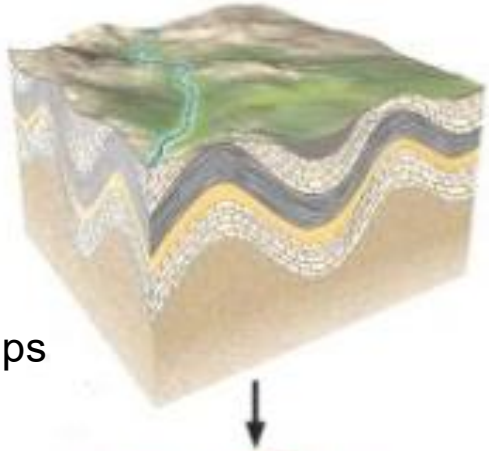
Sequence in formation of unconformity



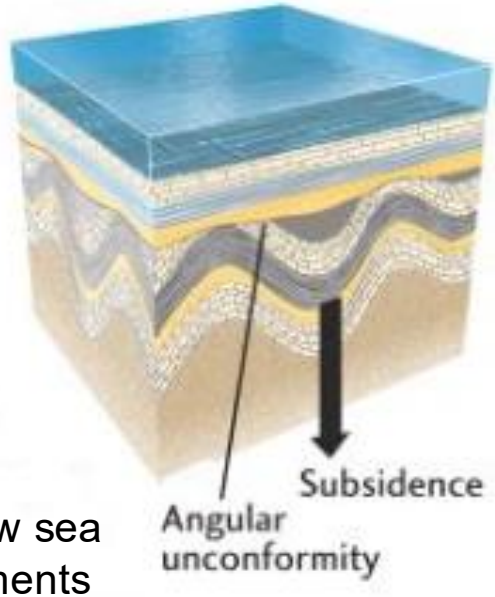
Time 1
Sediments accumulate beneath the sea



Time 2
Compression in crust causes uplift and folding of strata



Time 3
Erosion removes tops of folded layers



Time 4
Subsidence below sea allows new sediments to be deposited

Hutton's legacy

- Hutton's ideas presented in two volumes → "An investigation of the principles of Knowledge and the Progress of Reason, from Sense to Science and Philosophy"

- his convoluted prose impeded the acceptance of his geological theories → elucidated by Charles Lyell 50years later

- his theories on uniformitarianism and plutonism opposed the Neptunist theories of Abraham Werner and continental European geologists

- he proposed the concept of "deep time" suggesting an age of the Earth much greater than 6000years

Hutton's theory of Plutonism

- Hutton proposed that the interior of the Earth was hot and that it was the heat that drove the formation of new rocks

⬇

the land was eroded by air and water with the resultant sediment deposited in the sea

⬇

heat and pressure then consolidated the sediment into rocks then uplifted them to form new land

- this opposed the Neptunist theory of Abraham Werner that proposed that all rocks had precipitated out of a global sea

Developments of concepts of time

Early concepts of time and the Earth

- In ancient times → Earth was thought to be relatively young
- belief persisted in Mediaeval and Renaissance Europe
- various attempts were made over the years to determine the age of the Earth based mainly on biblical calculations
- age most favoured was 6000years based on calculations by Irish cleric James Ussher over two decades up to 1650
- Ussher even provided a starting time and date → noon on 23rd October 4004BC

Developments of concepts of time

Central ideas

- Early concepts → only a short time (thousands of years) required to form the entire record of the history of Earth

- landscape features were attributed to a series of catastrophic events e.g. Noachian flood

- this led to a concept known as catastrophism that reached its peak as an acceptable theory during the eighteenth century

- catastrophism was put forward in an attempt to explain features such as deformation features in mountain belts and volcanoes

Developments of concepts of time

Catastrophism

- Renaissance concept survived until 19th century (and even today?)
- catastrophists believed that the Earth's landscape was modelled by a number of catastrophic events
- prominent scientists Georges Cuvier and Abraham Werner (late 1700s) were strong supporters of the concept
- even though the emphasis in geology since the beginning of 19th century on gradual change (gradualism) certain events in Earth's history (e.g. extinction of dinosaurs, formation of Scablands) occurred rapidly

Catastrophism vs Uniformitarianism (gradualism)

Catastrophism

- Theory that the Earth evolved through a series of of transient universal catastrophic events e.g. Noachian flood
- theory arose to reconcile biblical narratives of creation
- the prevalent view up until the end of the 18th century

Uniformitarianism

- Natural laws and processes that operate in the universe have always operated and occur gradually
- "the present is the key to the past"
- prevalent view after early 19th century

Abraham Gottlob Werner (1749 – 1817)

- German geologist and principal proponent of the theory of stratification of the Earth's crust and a history of the Earth that was called Neptunism

- studied law and mining at Freiberg and Leipzig universities

- appointed mine inspector and teacher of mineralogy at Freiberg Mining Academy in 1775

- famous throughout Europe as a teacher of Geology

Abraham Gottlob Werner (1749 – 1817)

- Wrote first modern textbook on descriptive mineralogy → "On the External Characteristics of Fossils, or of Minerals"
- Werner was the principal proponent of the theory of Neptunism
- Neptunism → a global ocean receded to its present position while precipitating all of the minerals and rocks in the Earth's crust
- considered lavas and volcanoes of obvious recent igneous activity → to have formed by sub-surface burning coal, melting overlying rocks
- Werner could not account for the loss of seawater as younger gravel deposits formed

Werner's Rock series

Werner applied the "Law of Superposition" to divide stratigraphic successions ("rock series") he observed in Saxony

1st Series (Primitive series)	(a) Granites (b) Schists, gneisses	Deep, calm ocean embracing Earth
2nd Series (Transition series)	Slates, limestones dykes, sills, greywackes	Shallower calm ocean that became stormy
3rd Series (Tertiary)	Limestone, salt, gypsum, basalt	Deposited after oceans had subsided below mountain tops - discontinuous
4th Series (Quaternary)	sands, clays, gravels	
5th series	volcanic sequences	Recent

Neptunism vs plutonism

Neptunism

- Theory propounded by Abraham Gottlob Werner in late 18th century
  → Earth was originally completely covered by oceans
- chemicals and sediments dissolved in heated seawater → precipitated on the ocean floor → stratification
- over time water evaporated → exposing the land (where did it go?)
- theory ignored volcanism and metamorphism

Plutonism

- First proposed by Abbe Anton Moro (1687-1764) → embraced by James Hutton
- → rocks were first formed by igneous activity
- weathering and erosion → sediments accumulated
- heat and pressure → sedimentary rocks

William Smith (1769-1839)

- English civil engineer and geologist
- had limited schooling → largely self-educated
- famous for producing first geological map of England and Wales

William "Strata" Smith

- Started his working life as an assistant surveyor building canals
- recorded observations on rock layers and coal seams exposed in cuttings and coal mines
- recognised that the various strata occurred in a predictable pattern → rock strata found in the same relative position in the stratigraphy at different localities
- he also studied fossils in the rocks and noted that the various strata could be identified by their fossil assemblage
- founded the "Principle of faunal succession"

Principle of faunal succession

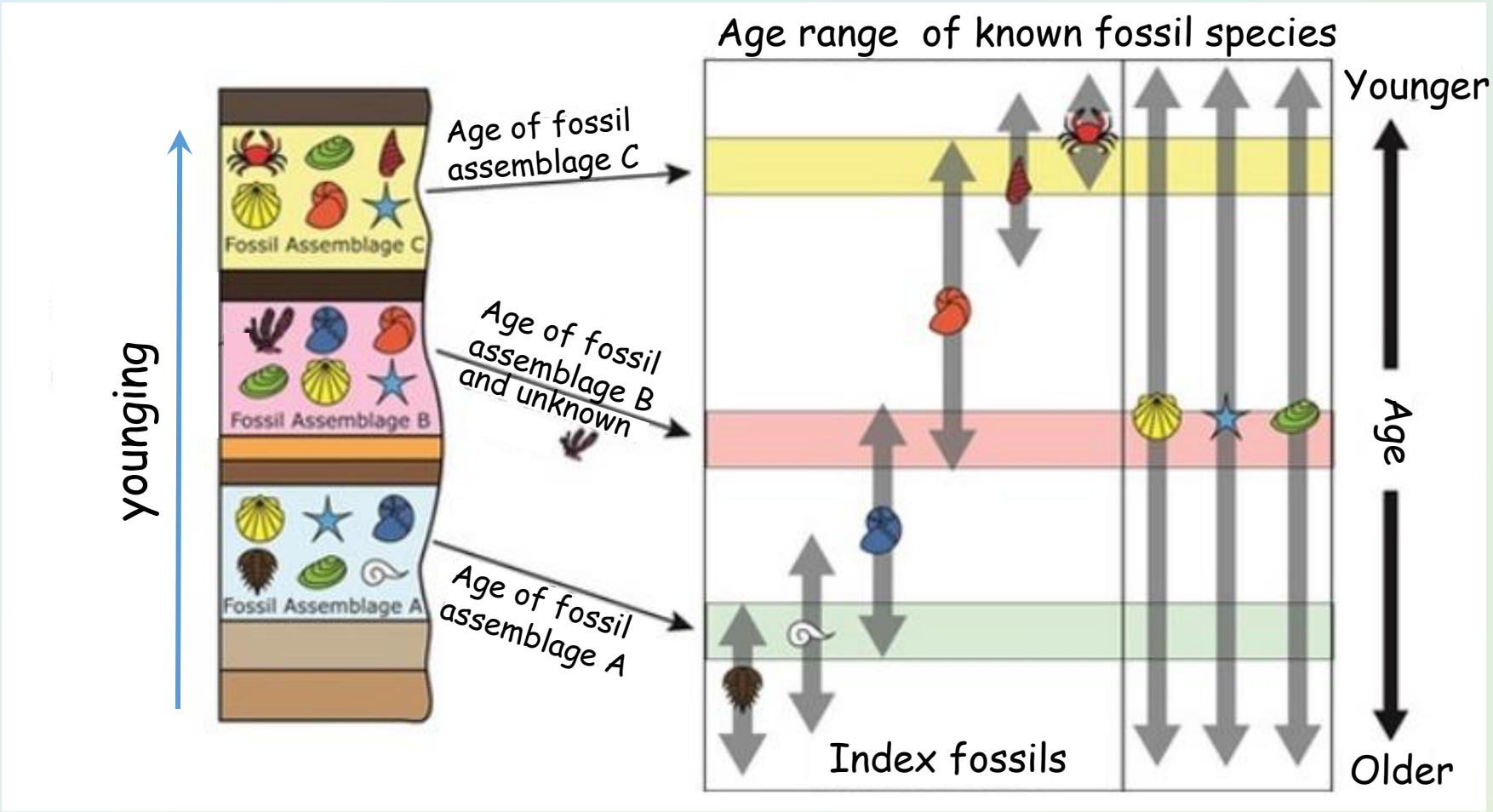
- Faunal succession → fossil species appear, exist and then disappear in a predictable order, once extinct, they do not reappear

- principle → specific groups of fossils succeed one another in the rock record in a definite order

- fossils that lived on Earth for a brief period of time are called index fossils → constrain the age of the rocks e.g. rocks containing ammonites are younger than rocks containing trilobites

- organisms that lived for a long period of time on Earth not so useful

Principle of faunal succession



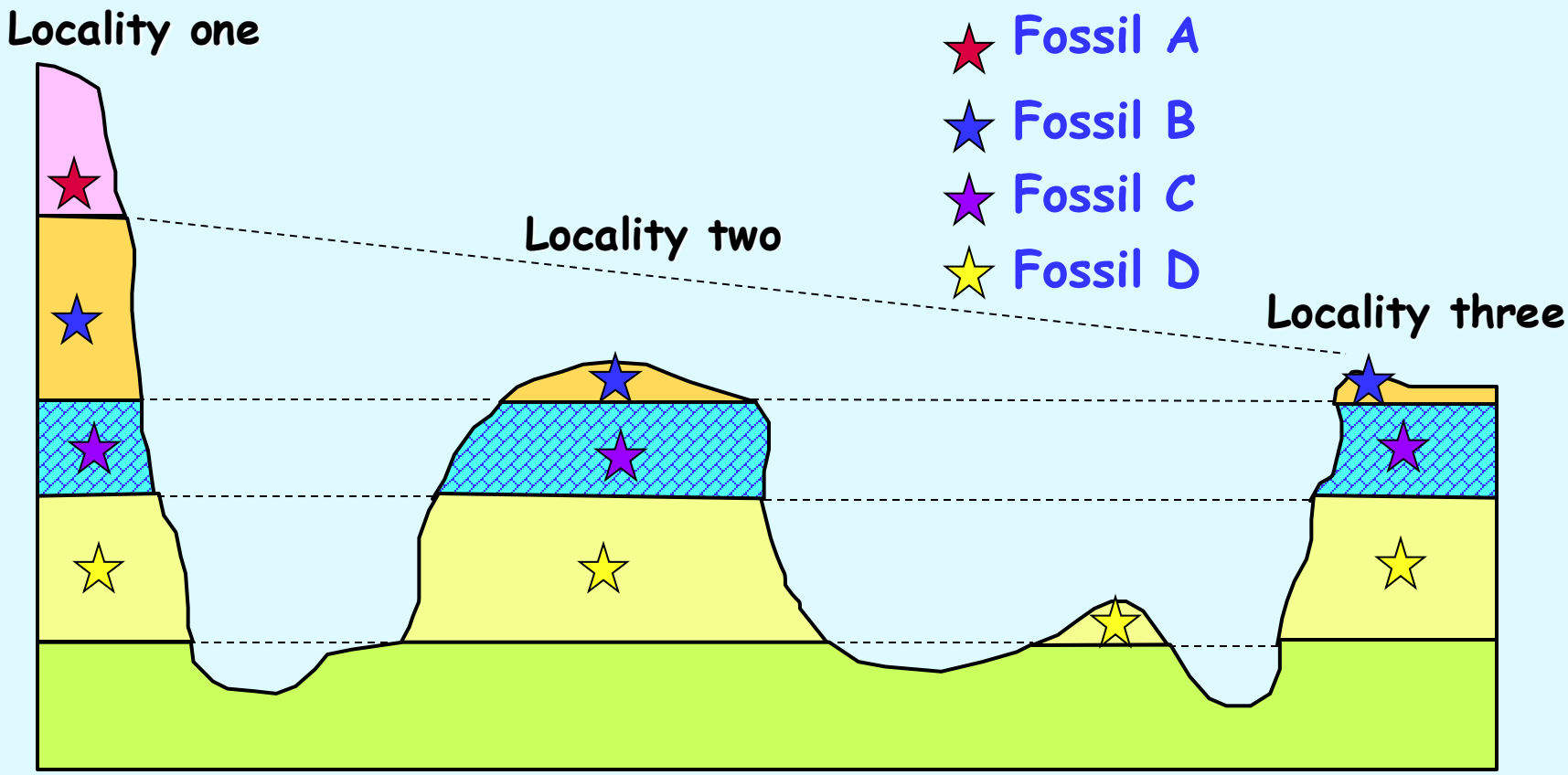
Certain fossils present can constrain the age range of the rocks that contain them

Correlation in relative dating of rocks

- Correlation → establishment of equivalence between rock units at different localities
- the further separated two rock formations are, the less likely they will possess identical fossil sequences
- distal formations may contain individual layers whose similarities suggest they formed contemporaneously e.g. presence of similar fossil groups in different rock units → rocks are of same age
- Smith discovered → certain beds contain fossils unique to that bed and that time of geological history → first person to realise the importance of using fossils for relative dating of rocks
- distant rock sequences can be correlated if they contain the same index fossil bed at several localities

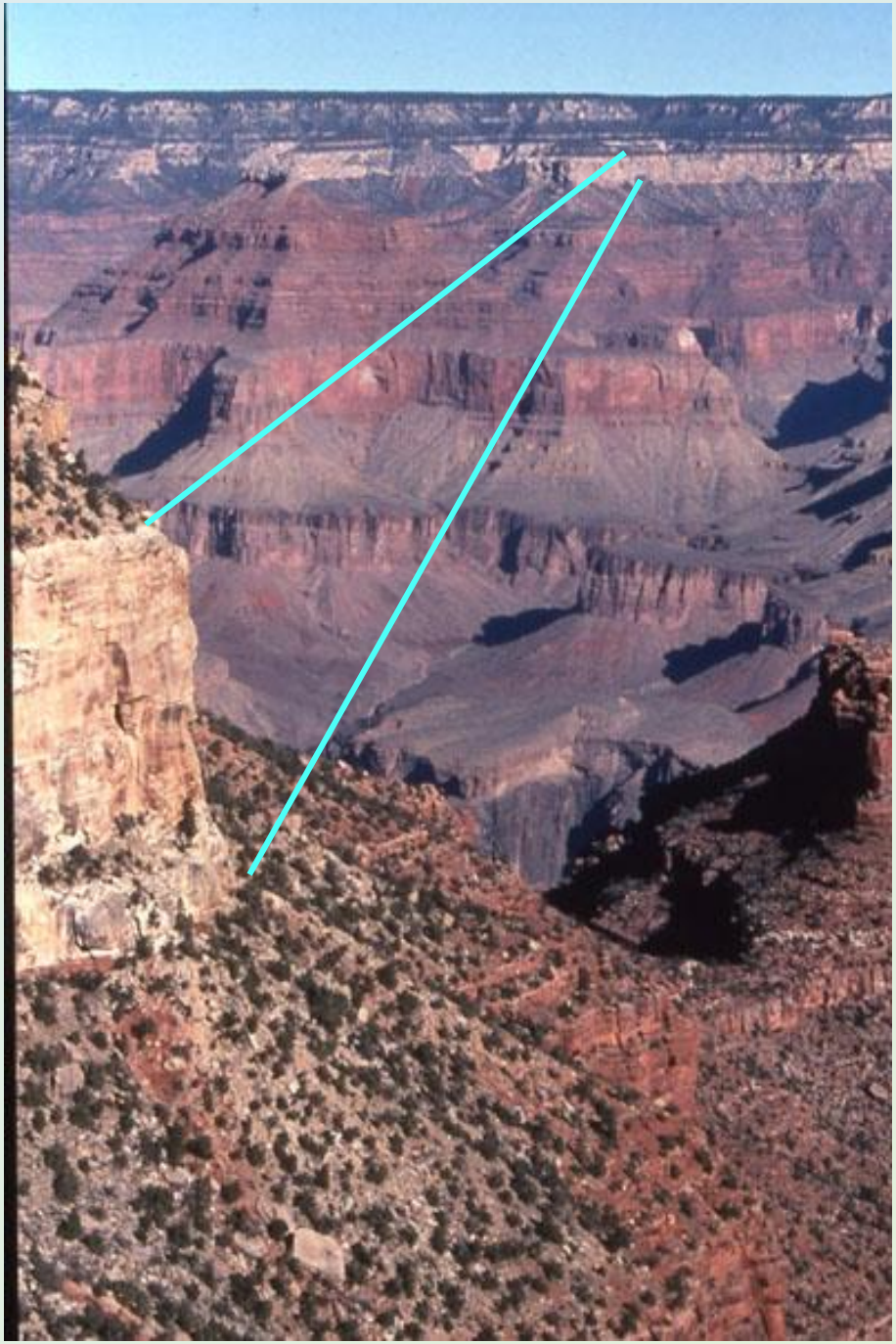
Correlation

Correlation of rock sequences using fossils



Correlation

Correlation of key layers at several locations e.g. Coconino Sandstone on opposite sides of the Grand Canyon



William Smith – later life

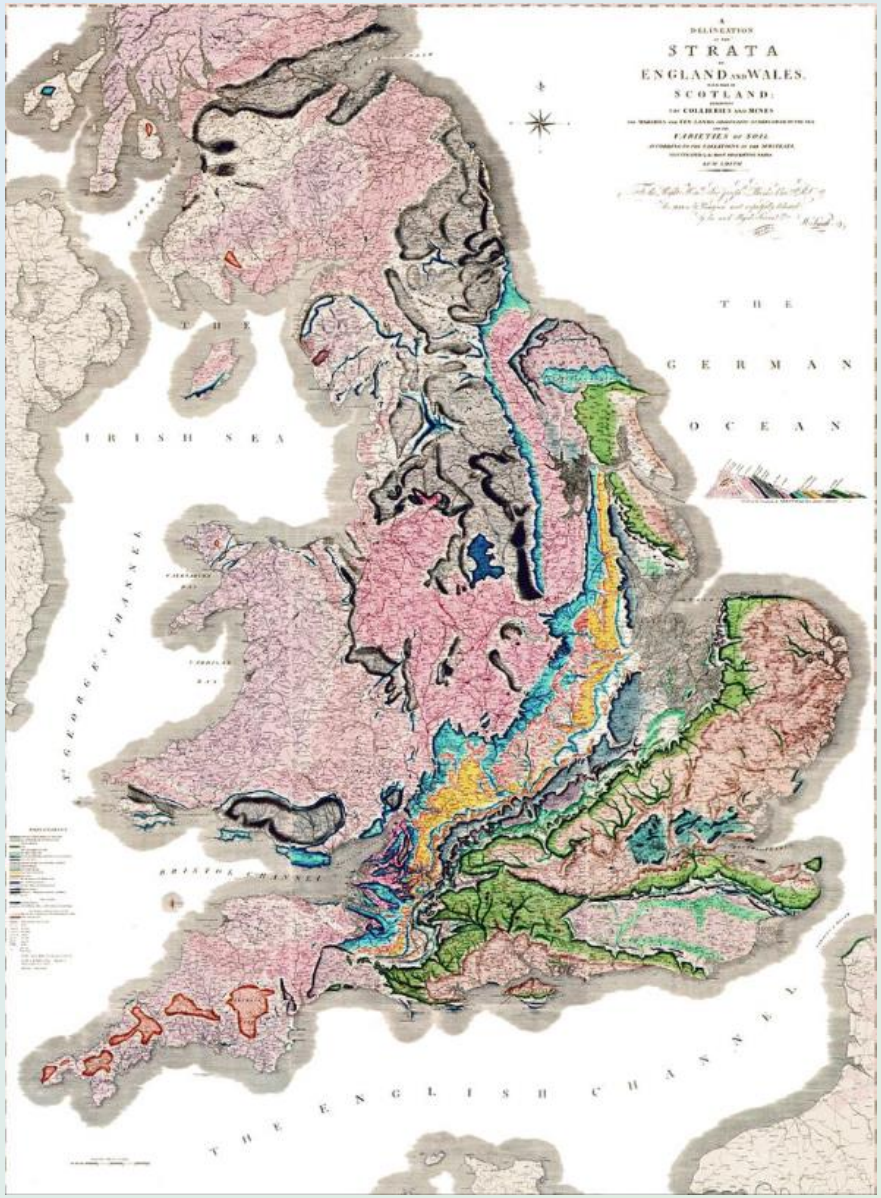
- In 1799 → ceased working on canals → published his first geological map of the Bath district using a colour code to denote different rock types

- 1815 → published first geological map of England he called "*A* delineation of the strata of England" → remarkably similar to modern geological map

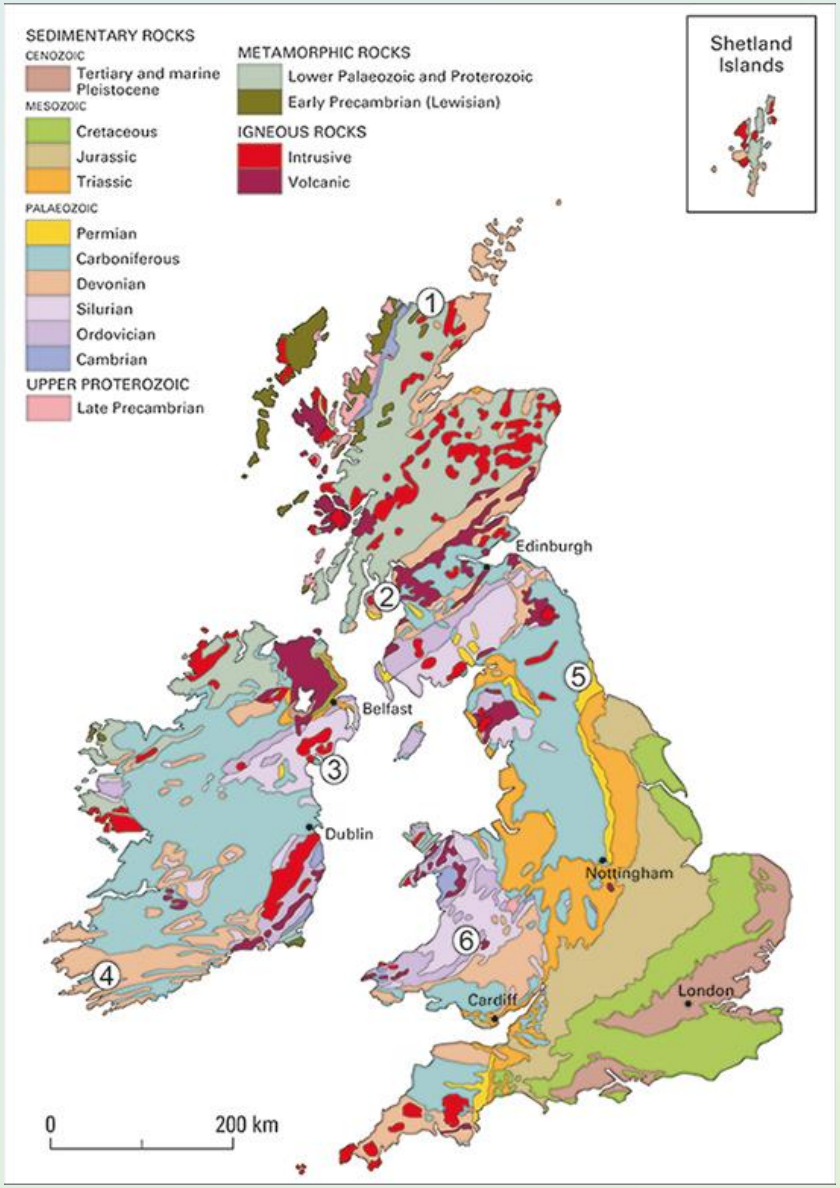
- 1819-1824 → struggled financially → spent some time in debtor's prison

- 1831 → awarded the inaugural, prestigious Wollaston Medal by the Geological Society of London

William Smith's "The map that changed the world"

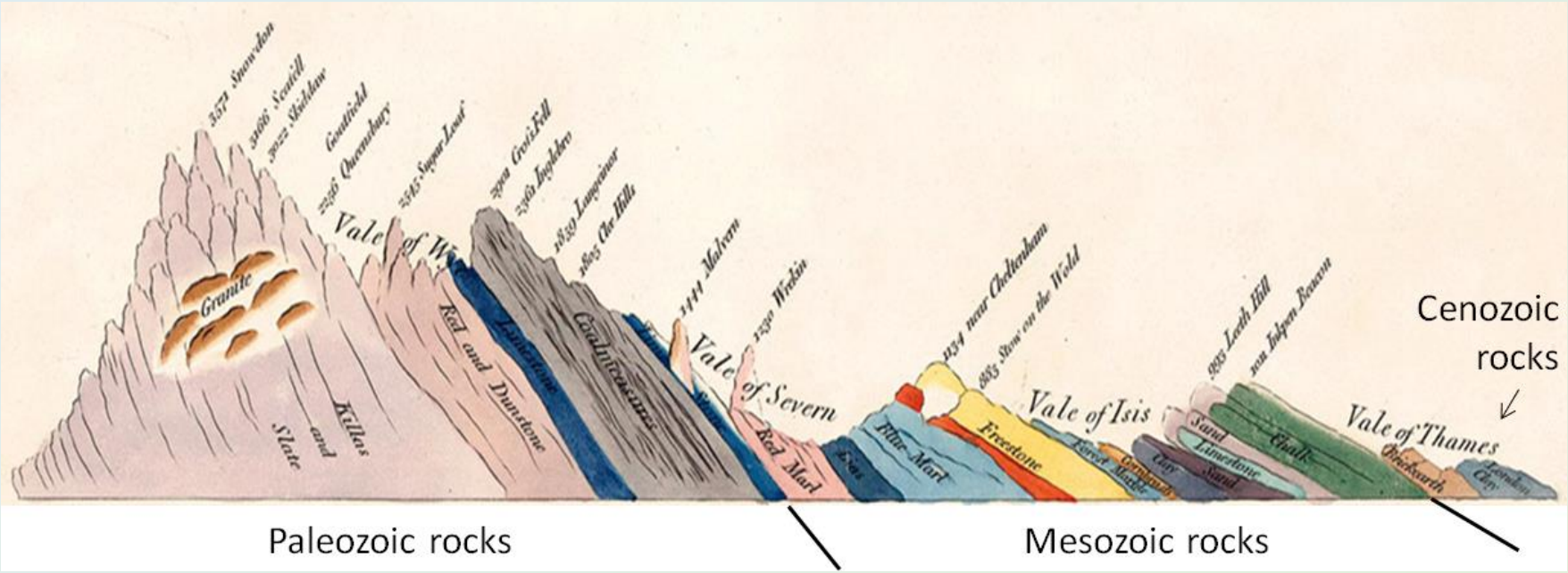


Smith's geological map



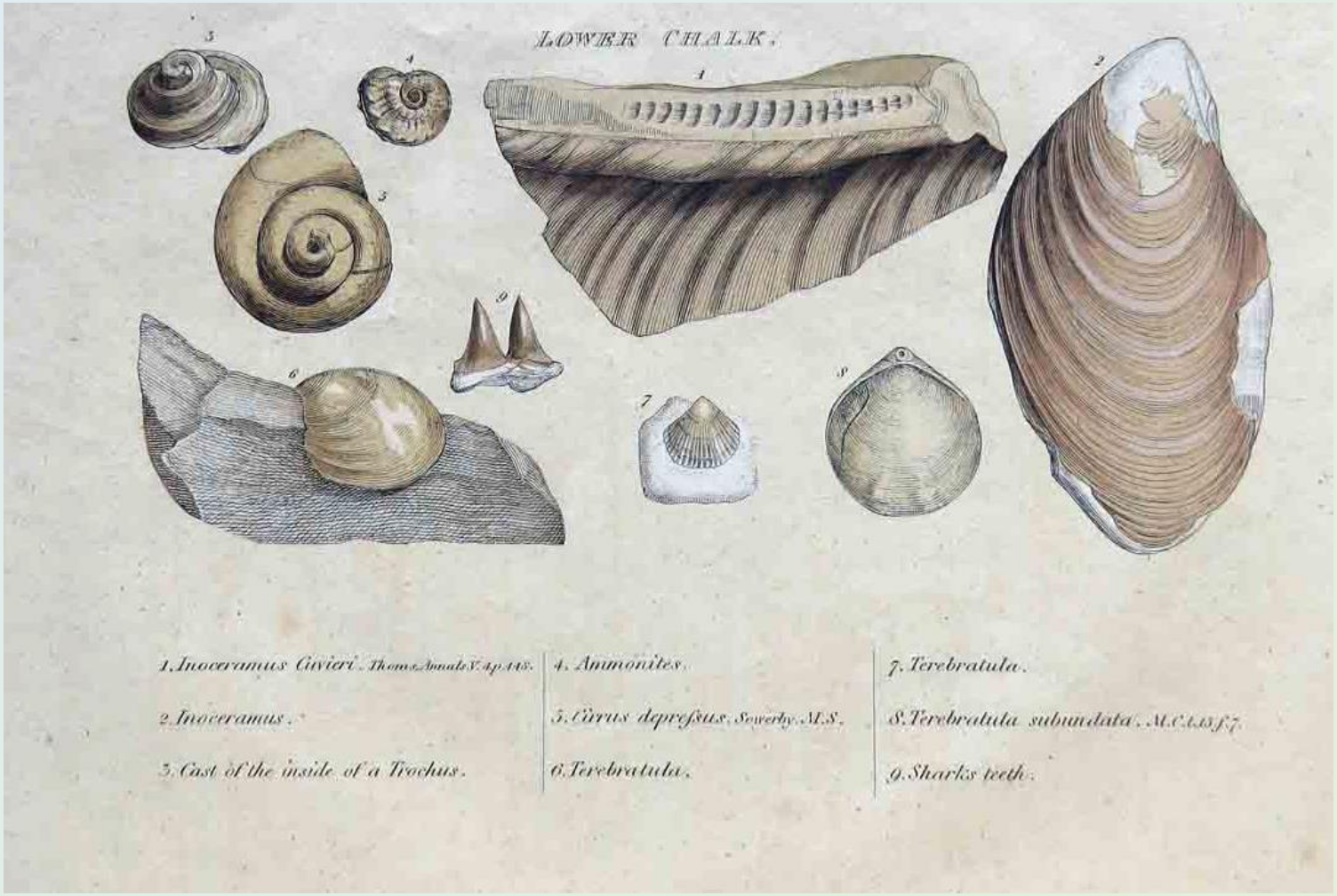
Modern geological map

Cross-section showing stratigraphy between London and Snowdon (dip angle exaggerated) constructed by William Smith



William Smith's Fossils

William Smith's mineral collection (housed in the Museum of Natural History London), consists of 2,657 fossils representing 693 species)



Charles Lyell (1797- 1875)

- Scottish geologist who popularised the work of James Hutton based on uniformitarianism principles → made Hutton's concepts intelligible

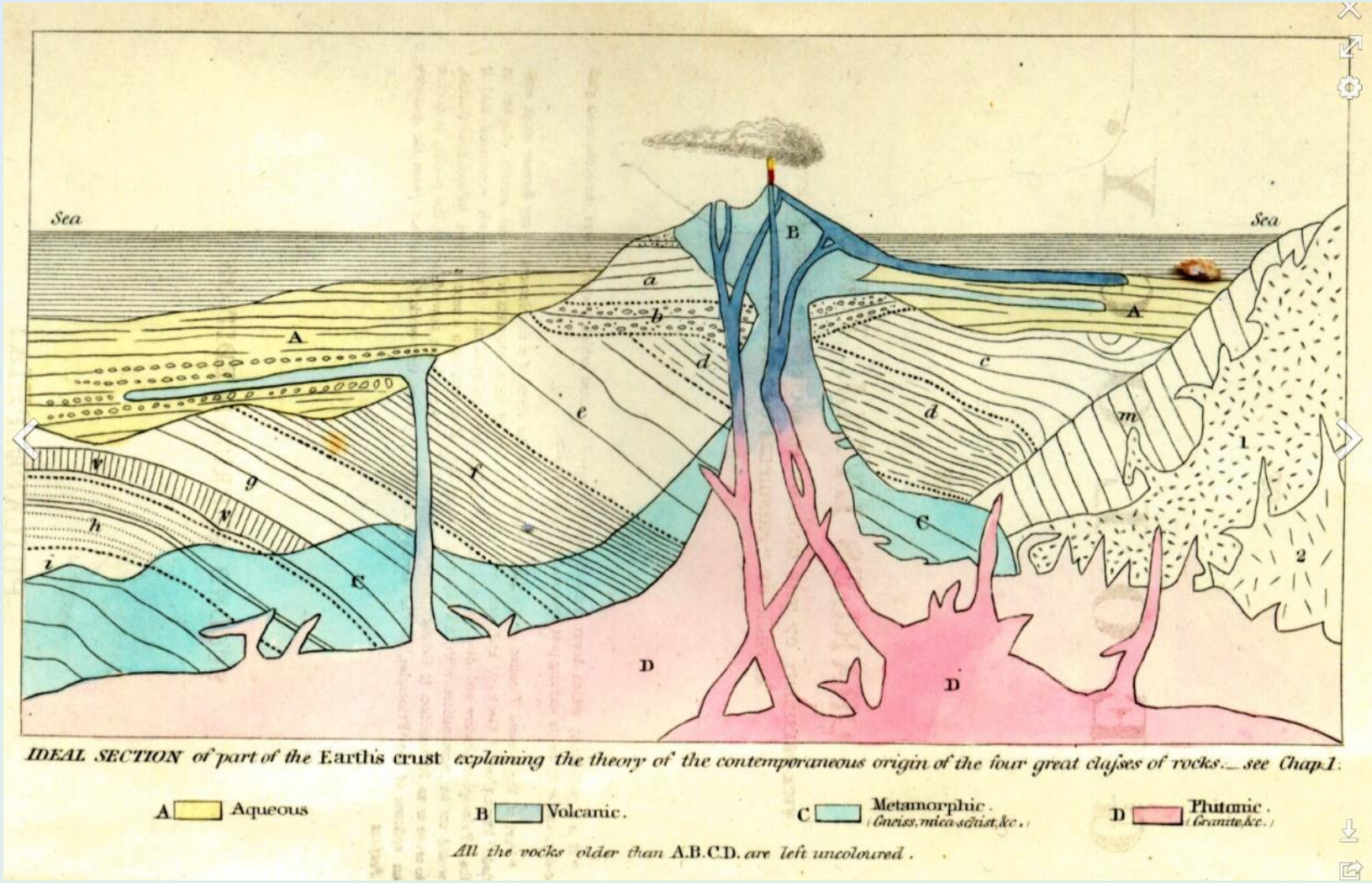
- graduated from Oxford in 1821 as a lawyer → by 1827 had become a full-time geologist

- strongly influenced by the eminent geologist Rev. William Buckland (Oxford professor)

- saw himself as spiritual saviour of geology → freeing the science from religious constraints

Sir Charles Lyell (1797-1875)

- Published "Principles of Geology" (3 volumes) in 1830
- coined the phrase "the present is the key to the past" to describe uniformitarianism
- first person to explain the cause of earthquakes
- concluded that volcanoes develop gradually rather than through rapid upheaval
- his most important specific work was in the field of stratigraphy
  → he concluded rock strata could be characterised by fossil content
- sub-divided the Tertiary into three periods (Eocene, Miocene and Pliocene)



Frontpiece of Lyell's classical text "Principles of Geology"

Sir Charles Lyell (1797-1875)

- Published "Elements of Geology" in 1938 that described European rocks and fossils
- travelled extensively overseas including multiple trips to the USA
- highly influential e.g. Charles Darwin (1809-1882)
- Lyell and Charles Darwin were very close friends even though Lyell never fully shared Darwin's belief in evolution
- when Lyell died in 1875, Darwin was too distraught to attend his funeral but heaped high praise on his geological achievements