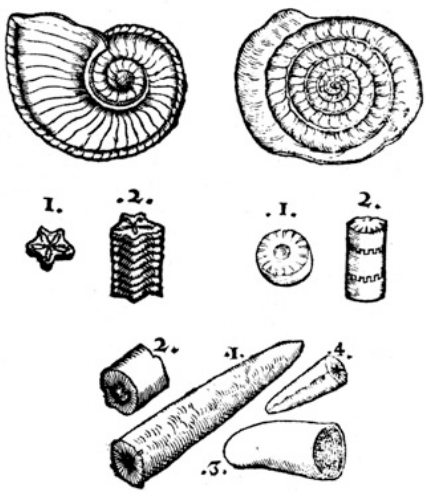
From “Figured Stones” to Geologic Periods

brought to you by the letters C and V
and by the number 9
(and by Dr. Waggoner)



Some “figured stones” looked like living organisms, but others were much less like anything that was known to live. Some scholars argued that “figured stones” had grown in the Earth by some natural power, and had never been alive.

Nicholas Steno
(1638 - 1686)

Steno, a Danish anatomist and later a Roman Catholic priest, found time to look at the “figured stones” that were puzzling people in the 1600s.

Steno proposed that if a “figured stone” or “*fossilium*” looked like a living organism under close inspection, that was because it once had *been* a living organism.

This is his drawing of the head and teeth of a shark, which he used to demonstrate that certain odd stones, called *glossopetrae*, were in fact the teeth of ancient sharks.

This was part of a much more general theory of how solids could form inside other solids (like rock layers, crystals, etc., in addition to what we now call fossils).
Steno derived two general "laws" from his work on solids. . .

(Bryce Canyon, UT)

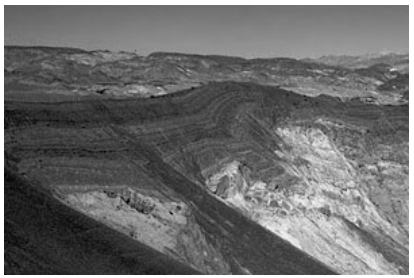
Law of Original Horizontality: In a sequence of sedimentary rocks, the layers of rock were originally formed lying horizontally. (However, they may be disturbed after forming.)

Exceptions to the Law of Original Horizontality sometimes arise, such as these ancient sand dunes now compressed into sandstone.
(Valley of Fire State Park, NV)

(Ventura County, CA)

Law of Superposition: In a sequence of sedimentary rocks, the oldest are the lowest, and the youngest are the highest — *unless* something has disturbed the rocks after they were formed.

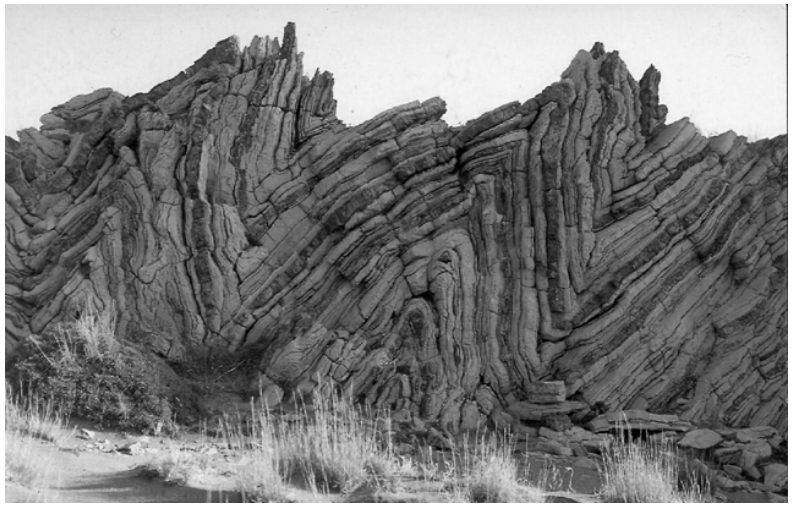
Marjum Pass, UT



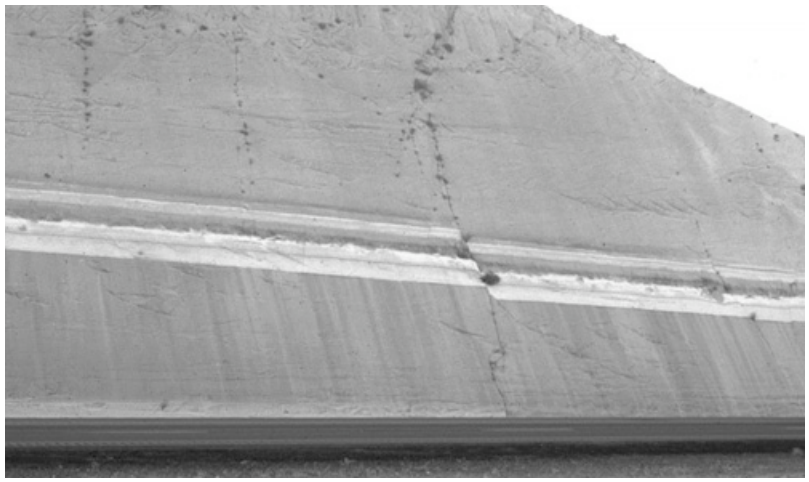
Ubehebe Crater, Death Valley, CA

Steno's Law says *nothing at all* about *how* old a rock sequence is, or how long it took to form. The layers on the left we now reckon formed over several million years; those on the right formed in a few weeks or months. All it is is a statement of *relative age*.

Rock layers may be tipped off the horizontal. . .
(Nopah Range, southern Inyo County, California)

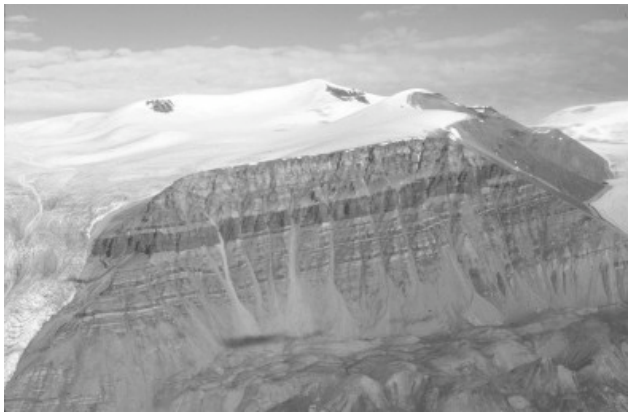


or bent and deformed in various ways. . .
(Haghios Pavlos, Crete, Greece)



or disrupted by faults. . .
(Roadcut on Interstate 40, just west of Kingman, AZ)

. . . or intruded by magma.
(Ellesmere Island, Northwest Territories, Canada)



Layers may be faulted out of their original order. The red cliffs in the foreground are 200+ million years younger than the gray limestones behind them, which were pushed above them along a *thrust fault*.

(Red Rock National Recreation Area, Clark County, NV)

But the point is that when the arrangement of rock layers has been disrupted by this, the disruption leaves traces—we can compensate for changes in the arrangement of rock layers, and reconstruct how they were originally laid down.

Rocks don't have to form a continuous sequence, either. Here the pinkish-red layer (210 million years old) is overlain by a dark brown layer (4 million years old). 206 million years is missing from the rock record. (More later on how we calculate the calendar ages!)

(Painted Desert, Petrified Forest National Park, AZ)

But where had all these layers come from? The German mining geologist Abraham Gottlob Werner (1750-1817) thought that all the rocks in the world had precipitated out from a vast world ocean, a theory called *neptunism*.

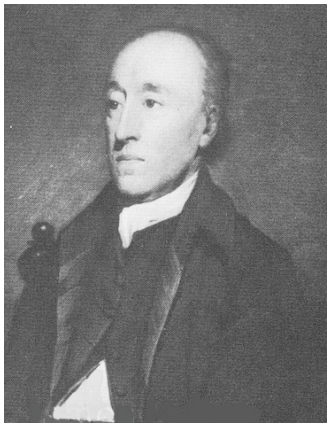
Der feste Erdkörper hat sich aus nasser Auflösung gebildet. . . Deshalb mußte er in der Urzeit hoch und allgemein mit Wasser bedeckt sein. . . dessen Oberflächenstand allmählich und allgemein gefallen ist.

What he meant, of course, was this:

The solid earth was formed out of an aqueous solution. Therefore, in the earliest time, it must have been highly and completely covered with water. . . the state of its surface has come about gradually and generally.

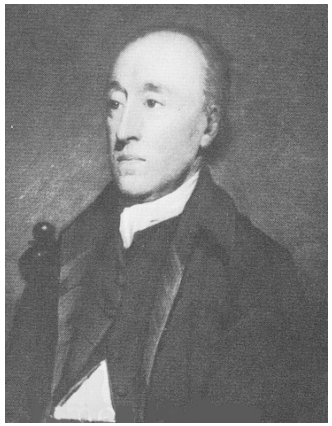
James Hutton (1726-1797)

- Scottish landowner who became interested in geology
- Hutton argued that some rocks had been molten once (*plutonism*).
- He proposed, in his book *Theory of the Earth* (1785) that geologic time had been indefinitely long: "we find no vestige of a beginning,—no prospect of an end."
- For Hutton, the Earth was a self-renewing machine, thanks to its internal heat. As old mountains were eroded away, new ones were uplifted; as the sea covered some lands, it receded from others.

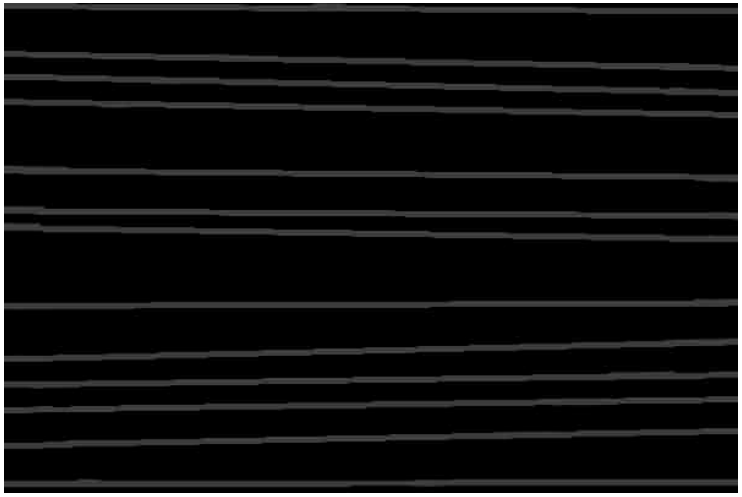


A Web page on Hutton. . .

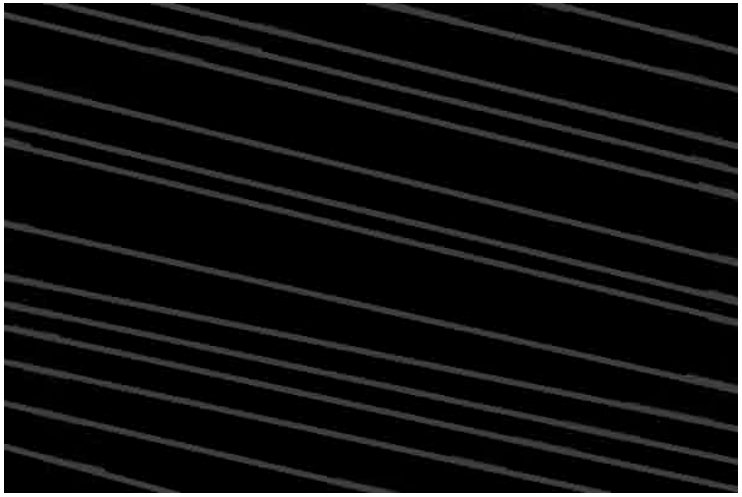
James Hutton, continued. . .



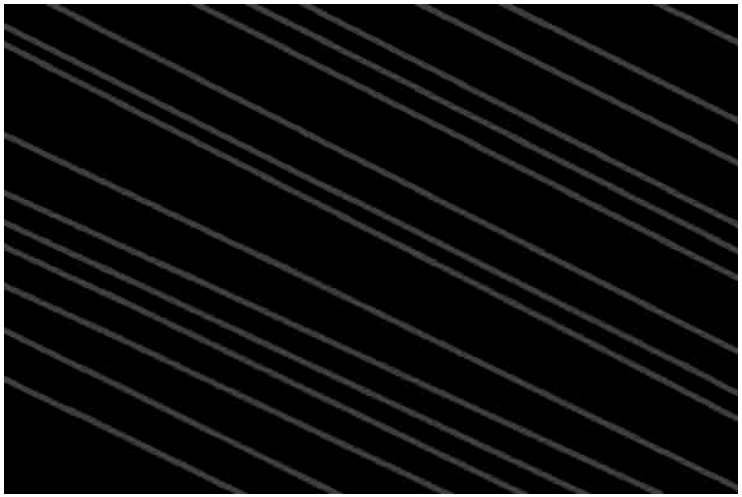
- One of Hutton's strongest arguments for his view of the Earth was his discovery of *angular unconformities*.
- *Angular unconformities* are a type of gap in the order of sedimentary layers. They take a long time to form—they cannot be formed instantaneously.
- The next slides are diagrams that show how an angular unconformity forms. . .



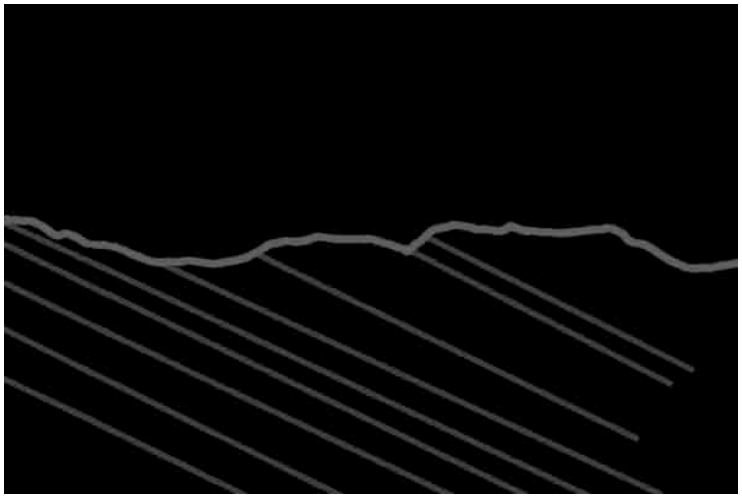
Start with some more or less horizontal layers laid down. . .



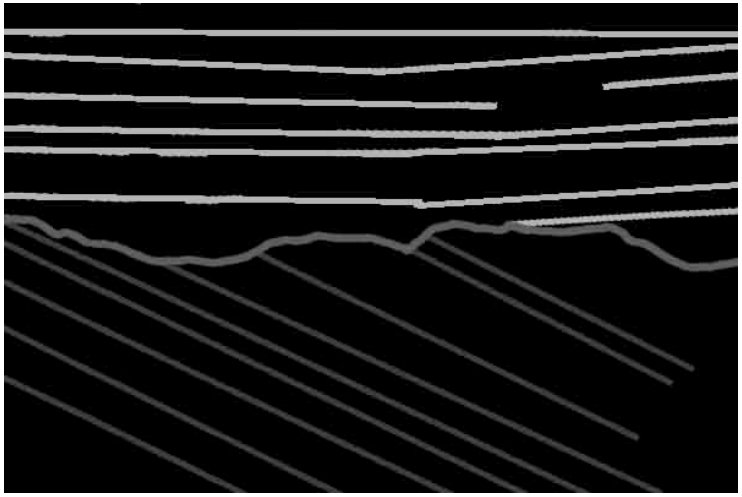
Now geologic forces tip them. . .



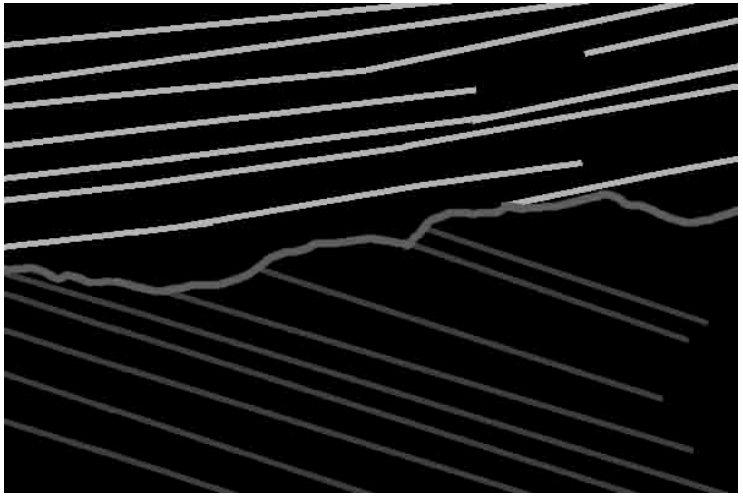
And tip them even further. . .



. . . and then erosion removes a portion.



If newer layers are later deposited on top of the old, we get this.



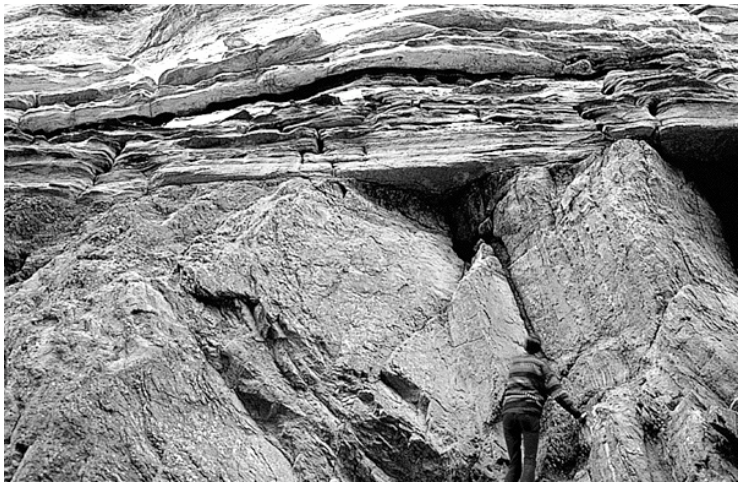
The sequence of sedimentary rocks may tip *again*. . .

And further erosion may erode both newer and older layers. . .

Actual angular unconformity
(China Ranch, Mojave Desert, southern Inyo County, CA)

Another angular unconformity
(California Hwy 190, Death Valley, southern Inyo County, CA)

An angular unconformity marks an interval of many years (just how many years varies) that is *missing* from the rock record.



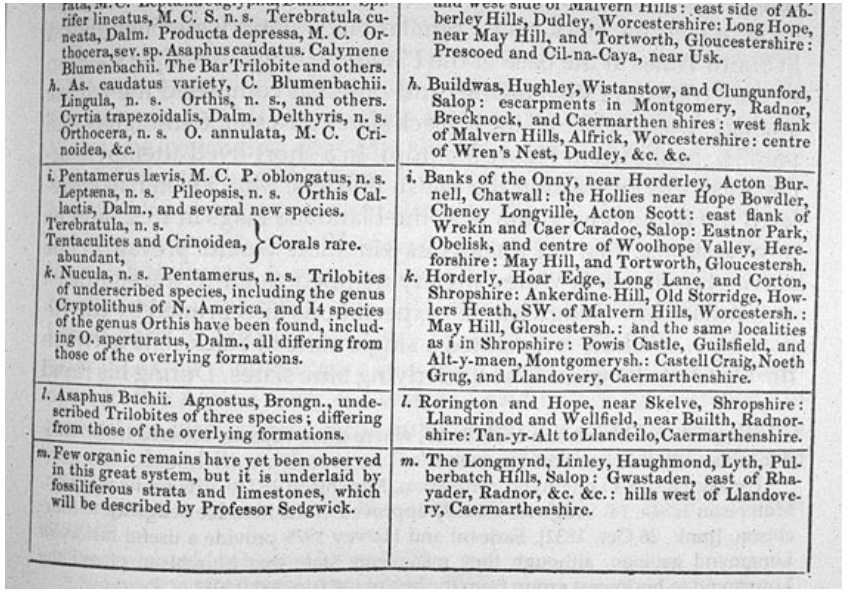
Angular unconformity at the base of the Grand Canyon, Arizona

Get the picture? An angular unconformity can't form quickly — it takes time for that erosion to happen!

Angular unconformity at Siccar Point, Scotland, studied by Hutton

William Smith (1769-1839)

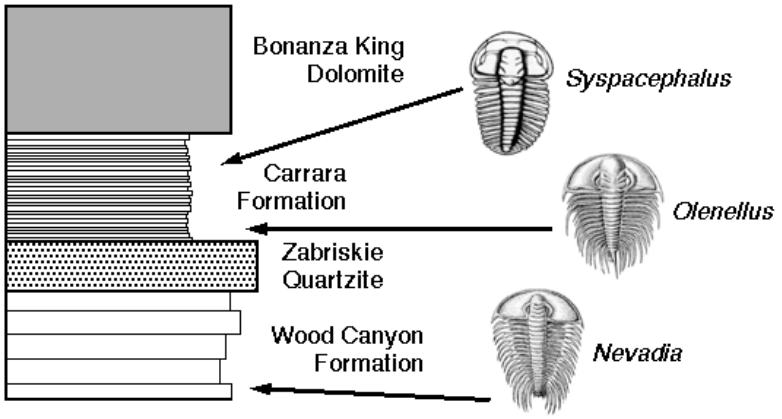
- A civil engineer and surveyor, Smith came across numerous fossils during his work on canal surveying and mine engineering.
- He realized that different layers contained different fossils, but what was more: fossils always occurred in a predictable order of appearance. The order of fossils in sedimentary rocks was the same all over England. This is the "Law of Succession".

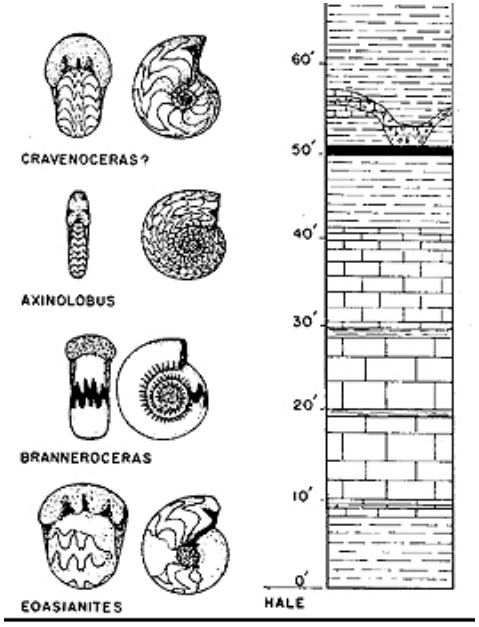


rifer lineatus, M. C. S. n. s. Terebratula cuneata, Dalm. Producta depressa, M. C. Orthocera, sev. sp. Asaphus caudatus. Calymene Blumenbachii. The Bar Trilobite and others.	and west side of Malvern Hills: east side of Abberley Hills, Dudley, Worcestershire: Long Hope, near May Hill, and Tortworth, Gloucestershire: Prescoed and Cil-na-Caya, near Usk.
h. As. caudatus variety, C. Blumenbachii. Lingula, n. s. Orthis, n. s., and others. Cyrtia trapezoidalis, Dalm. Delthyris, n. s. Orthocera, n. s. O. annulata, M. C. Crinoidea, &c.	*h.* Buildwas, Hughley, Wistanstow, and Clungunford, Salop: escarpments in Montgomery, Radnor, Brecknock, and Caermarthen shires: west flank of Malvern Hills, Alfrick, Worcestershire: centre of Wren's Nest, Dudley, &c. &c.
i. Pentamerus lævis, M. C. P. oblongatus, n. s. Leptæna, n. s. Pileopsis, n. s. Orthis Callactis, Dalm., and several new species. Terebratula, n. s. Tentaculites and Crinoidea, abundant, } Corals rare. *k.* Nucula, n. s. Pentamerus, n. s. Trilobites of underscribed species, including the genus Cryptolithus of N. America, and 14 species of the genus Orthis have been found, including O. aperturatus, Dalm., all differing from those of the overlying formations.	*i.* Banks of the Onny, near Horderley, Acton Burnell, Chatwall: the Hollies near Hope Bowdler, Cheney Longville, Acton Scott: east flank of Wrekin and Caer Caradoc, Salop: Eastnor Park, Obelisk, and centre of Woolhope Valley, Herefordshire: May Hill, and Tortworth, Gloucestersh. *k.* Horderly, Hoar Edge, Long Lane, and Corton, Shropshire: Ankerdine Hill, Old Storridge, Howlers Heath, SW. of Malvern Hills, Worcestersh.: May Hill, Gloucestersh.: and the same localities as *i* in Shropshire: Powis Castle, Guilsfield, and Alt-y-maen, Montgomerysh.: Castell Craig, Noeth Grug, and Llandovery, Caermarthenshire.
l. Asaphus Buchii. Agnostus, Brongn., undescribed Trilobites of three species; differing from those of the overlying formations.	*l.* Rorington and Hope, near Skelve, Shropshire: Llandrindod and Wellfield, near Builth, Radnorshire: Tan-yr-Alt to Llandeilo, Caermarthenshire.
m. Few organic remains have yet been observed in this great system, but it is underlaid by fossiliferous strata and limestones, which will be described by Professor Sedgwick.	*m.* The Longmynd, Linley, Haughmond, Lyth, Pulberbatch Hills, Salop: Gwastaden, east of Rhayader, Radnor, &c. &c.: hills west of Llandovery, Caermarthenshire.

An example of Smith's principle. The left-hand side lists fossils in order, from oldest (bottom) to youngest (top). Localities are on the right.

Here's an example. On the left is a diagram of rock layers. On the right are three different fossils called *trilobites*, with the arrows showing where they appear. If you find these fossils anywhere in North America, you'll find them in this order of appearance.

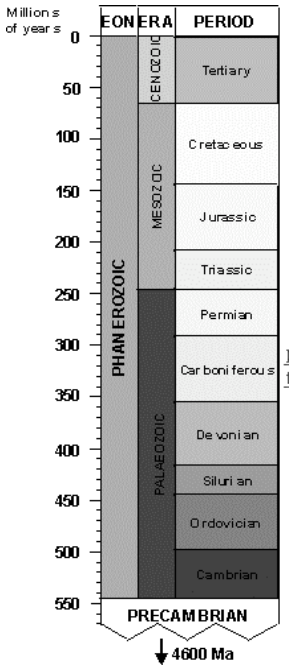




Another example, this time from northwestern Arkansas. The rock layers around Fayetteville (right) contain fossils of coiled shells (technically called *ammonoids*, on the left). Different layers have different shells—and the shells appear in the same order in rocks all over the world.

Smith used fossils as tools to map out where different rock layers were found. His geologic map of England and Wales (published in 1815) was the first of its kind. Each rock layer is represented by a unique color.

Click here for a bit more on Smith's map



Geologic Time Scale

- Because fossils appeared in a predictable order, you can use them as markers of relative time.
- What's more, you can define time periods based on what was living at the time.
- This enabled geologists to construct a *relative* time scale, define time periods, and name them.