The origin of coal

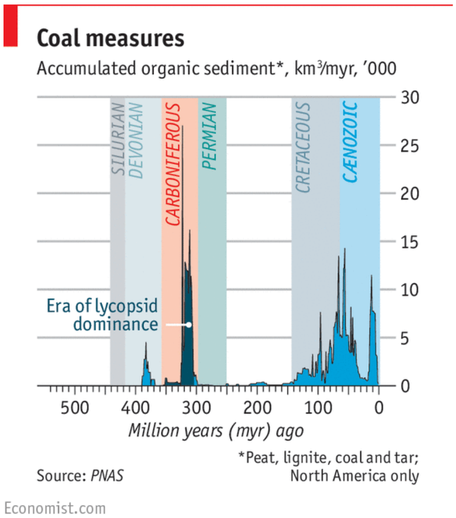
The rock that rocked the world

More than any other substance, coal created modern society. But what created coal?

Print edition | Science and technology Jan 23rd 2016

FOR 60m years of Earth's history, a period known to geologists as the Carboniferous, dead plants seemed unwilling to rot. When trees expired and fell to the ground, much of which was swampy in those days, instead of being consumed by agents of decay they remained more or less intact. In due course, more trees fell on them. And more, and yet more. The buried wood, pressed by layers of overburden and heated from below by the Earth's interior, gradually lost its volatile components and was transformed into a substance closer and closer to pure carbon.

The result was the coal that fuelled the Industrial Revolution, providing power for factories and railways, gas for lighting, a reducing agent for turning ore into iron and steel, the raw ingredients for drugs, dyes and other chemicals, and the energy that has generated most of the world's electricity. Yet the abundance of Carboniferous coal is a puzzle. Forests began in the Devonian, the period before the Carboniferous, and have existed ever since. Not all coal is Carboniferous but, as the chart shows, the spike in coal accumulation then was far higher than anything which happened subsequently. Indeed, the very name Carboniferous alludes to this fact.



So why, the curious ask, was it then in particular that so much coal was created? The swamps certainly helped. Lacking oxygen, they would have slowed the activities of wood-destroying micro-organisms. But swamps are not uniquely Carboniferous. To explain the special boost coal got in this period, it has been suggested that the micro-organisms around at the time were not up to the job of rotting wood. Changes in plant chemistry which let trees grow tall, this hypothesis goes, stymied these micro-organisms, making much plant material indestructible. It is an intriguing idea. But a paper (http://www.pnas.org/content/early/2016/01/13/1517943113) just published in the *Proceedings of the National Academy of Sciences*, by Kevin Boyce of Stanford University and his colleagues, takes issue with it. Instead, Dr Boyce thinks abundant Carboniferous coal, swamps and all, is an accident caused by the movement of the continents.

Reach for the skies

The idea that Carboniferous micro-organisms could not properly digest wood depends on a hypothetical evolutionary time lag. The first vascular plants (those with internal channels to move water around) evolved in the Silurian, the period before the Devonian. Vascularisation meant a plant could suck water up its stem, and thus grow tall. This led to a race, conducted throughout the Devonian, to be tallest and thus able to capture light without being overshadowed. The consequence was trees—and therefore forests.

Trees have to be strong, though, otherwise they will collapse. Part of their strength comes from cellulose, an ancient material composed of long chains of sugar molecules, which forms the walls of plant cells. But what really encouraged trees' evolution was the advent of a second molecule, lignin. This is made of phenols, and phenols are much harder to digest than sugars—so hard, the thinking goes, that it took until after the Carboniferous was over for organisms that could do so to evolve. Meanwhile, the fallen forests simply piled up in the swamps. Though some of their cellulose was consumed, their lignin hung around and became coal.

That thought is supported by analysis of the evolution of fungi. Molecular clocks, which measure rates of genetic change, suggest lignin-digesting enzymes did indeed first appear in this group (which are the main agents of rotting) in the Permian, the period immediately following the Carboniferous. Dr Boyce and his colleagues, however, do not believe it.

Their disbelief is based on a painstaking analysis of Macrostrat, a database of all that is known about the stratigraphy of North America, together with an examination of which types of plant dominated the floras of stratigraphic units containing a lot of coal.

The trees of the Carboniferous were not like those of today. Moreover, which types of tree predominated varied over the vast span of time that it covered. One pertinent observation Dr Boyce and his team make is that the peak of coal formation coincided with the dominance of a group called the lycopsids. Yet lycopsid trunks were composed mostly of tissue called periderm, which corresponds to modern bark and contains little lignin. Forests that existed both before and after these lycopsid woods (but before the supposed evolution of lignin-digesting fungi) had many more lignin-rich species in them, but have yielded far less coal.

Moreover, though Permian rocks in North America do not contain much coal, those in China do. That does not seem consistent with idea that lignin-consumption rates suddenly increased. And, although the fossil record cannot show which enzymes were present in fungi in the past, it does show that fungi were just as diverse and active in the Carboniferous as in the Permian. Altogether, then, the abundant coal of the Carboniferous does not seem to be the result of lackadaisical fungal effort. So, in Dr Boyce's view, the evolutionary-delay hypothesis simply will not do.

Destroying a hypothesis is one thing. But it also helps if you have something to put in its place. And Dr Boyce and his colleagues have one on offer. They think the Carboniferous coal measures were a consequence of continental drift.

During the Carboniferous, the continents were moving around quite a bit. Such movement, particularly when it involves continents colliding (which it did), warps them. That causes mountains and basins to form. It is the basins which interest Dr Boyce. The downwarping that created them meant they would have flooded regularly, bringing sediment that buried the tree-laden bogs, preserving them not so much from micro-organisms as from erosion.

That local subsidence happened during the Carboniferous is not news. Geologists of the 19th century concluded as much—though they knew nothing of continental drift. But previous explanations for abundant coal, such as the evolutionary-lag one, have tended to concentrate on biology. Dr Boyce is suggesting that the actual cause was geological. Buried by subsidence, the coal could not be eroded, and thus survived to the present day.

During the Permian, however, continental movement ceased for a time, as all of the world's landmasses came together in a single supercontinent, known as Pangaea. Not only did this stop the downwarping, it also dried the climate out (for the average point on land is farther from the ocean's moist air in a supercontinent than in a group of smaller ones), meaning there were fewer swamps. Less coal was created, and more eroded than before. It was not until the Cretaceous, some time after Pangaea had broken apart again, that coal formation and preservation resumed. According to Dr Boyce's hypothesis, it is therefore no coincidence that the second-most abundant source of coal today is rocks of the Cretaceous and the subsequent Caenozoic.

If his hypothesis is correct, then, it is the grinding movement of the continents that is ultimately responsible for the Industrial Revolution. No continental drift, no coal. No coal, and humanity, if, indeed, such a species had evolved at all, might still be tilling the fields.