i19 Permo-Carboniferous coals of Southern Laurasia

< Gangamopteris >

> The fossilized Pennsylvanian-age forest ... revealed nearly 30 plant species, and because [its 2,470-acre spread is] so exceedingly well-preserved [that fossilized leaves are still on their branches] ... limited diversity may have been the natural characteristic of some ancient ecosystems. —Josh Chamot.[2]

> There was a whispering in my hearth, / A sigh of coal, / Grown wistful of a former Earth / It might recall. / It listened for a tale of leaves / And smothered ferns, / Frond-forests, and the low sly lives / Before the fauns. —Wilfred Owen.[3]

Coal

Early Permian and underlying Carboniferous coals of Southern Laurasia (found in North America, in western Europe, and in the Donetz Basin of the USSR, ***Figure i19.1***) originated as peat-bog accumulations of leaf litter and fallen trees of the extinct genera: *Lepidodendron, Sigillaria, Calamites*, and *Gangamopteris* (seed ferns). All these trees were spore shedding. Leaves of Pennsylvanian coal swamp flora are well known from museum exhibits of Mazon Creek nodules (split to show the fossil in part and counterpart) from the Francis Creek shale, Illinois. Clothing drier ground, and not contributing much to the coals, were primitive conifers: the cordiatales (extinct by the end of the Permian) with form-genus names for their leaves *Cordaites*, cones *Cordaianthus*, and roots *Amelyon*. Henry Potonié (1913-1857) in 1909 from the pithy (fast growth) cores of the coal-contributing trees, growth rings absent in even the largest trunks (no seasonality of hot-cold or wet-dry), fronds of ferns to several square meters in area (humidity and shade), tree-stem fructification (cauliflory under closed canopy), adduced "tropical rain forest" for the coal-accumulating areas of Laurasia.[4] Modern analogs are histosols (peats and mucks with at least 20-30% organic matter by weight and more than 40 cm thick) of Indonesian equatorial swamp forests [5] and where the "equatorial rainforest climate"extends north of the tropics, as is so for the Okeechobee ("Big Water" in Miccosukee)[6] swamp, Florida.

By contrast, during the Early Permian and Pennsylvanian, the Gondwanaland realm of Pangea accumulate cool climate *Glossopteris*-flora coal over tillites that recorded earlier glacial conditions. Continental ice sheets radiated at different times from different centers on Gondwanaland as the south pole migrated within its southern part and when during the Early Carboniferous its area was the paleocontinent Gondwana. Gondwanide tillites are youngest (Lower Permian) in Australia and the oldest (Lower Carboniferous) in southern South America. At times, gondwanide continental ice flowed to mid-temperate latitudes. The long time of glaciation should be recorded around the world by the evidence of rapid sealevel fluctuations; each fall and rise synchronous with an expansion and diminution of the gondwanide ice sheet.[7] In North American and Eurasian fragments of Southern Laurasia, the record is in the Permo-Carboniferous coal measures in which offlap and onlap formational phases recur many times. But that these record continental glaciation, was long denied. In 1940, fixist Raymond Cecil Moore expressed the consensus opinion that the "periodicity and long persistence of cyclic sedimentation ... in the central United States [*sic*] are evidence [of basinal flexings] opposing assignment of sealevel fluctuation to glaciation and the resulting changes of oceanic volume thorough waxing and waning of ice sheets."[8] In 1989, George deVries Klein and Debra A. Willard expressed the now-consensus opinion that the observed cyclicity is due to concurrent glacioeustatic *and* tectonic processes.[9] Glacioeustatic onlap and offlap is most faithfully recorded in Illinois by Permo-Carboniferous coal bearing sequences separated by disconformities (***Figure i19.2***). Johan August Udden (1859-1936) described their cyclicity in 1912 [10] and **James Marvin Weller** (1899-1976) named them *cyclothems* in 1930.[11] As originally defined, a cyclothem has *marine strata atop coal-bearing continental sediments that rest on a disconformity*.

In Illinois, cyclothems are well defined *cyclic formation*s. Elsewhere, in the Allegheny basin and in the coal measures of Europe, cyclothems exist but are not formations "because," to quote more Moore, "boundaries commonly cannot be defined exactly and, where determinable, they are generally less suited to geologic mapping than combinations of beds that fall within a given cycle."

The epeiric sea that flooded Southern Laurasia (the part that is now in North America) is called the Absaroka. Small changes in sealevel caused the Absaroka shore to regress and transgress over an enormous area where the Permo-Carboniferous coals accumulated. This nearly-flat area was traversed by, and accumulated sediments from, rivers debouching from the Marathon-Alleghenian mountains. An epeiric sea, an extension of the Tethys, also flooded through what is now the area of Europe, from Germany to Ireland, where Carboniferous coals accumulated.

Cyclothems in Illinois
In Illinois, 60 cyclothems, each separated by an offlap unconformity, have been counted. Their thinness (aggregate thickness of 350 meters) records, slow, continuous (20 to 25 My) forebasin subsidence. Transgression of very wide phases (of furthest-offshore fusuline-bearing limestone, offshore marine black shale, and inshore coal swamp) can best account for the enormous (500 kilometer) down-dip width of outcrops traceable for great (650 kilometer) strike distances.

Mid-continent cyclothems
In Kansas, cyclothems are of three types: Council Grove (Lower Permian), Wabaunsee (Upper Pennsylvanian), and Cherokee (Middle Pennsylvanian). The Council Grove type of cyclothem is notable for its coal topped, and very persistent, unfossiliferous (dissolved out?) red (oxidized, so likely emergent before burial) shale. The Wabaunsee type of cycle has extreme persistence of very thin coal beds and fusuline limestone phases. Above and below the fusuline limestone, which would have accumulated furthest from the shore, marine bed phases repeat each other in reverse order, but the terminal and initial marine phases are not characterized by the same assemblage of marine fossils. The heart of the cyclothem is the occurrence of a coal bed (with an underclay) in sandy beds of fine texture and with mica flakes, and nonmarine shale. Even when no disconformity is present at its base, the terminal marine phase of the underlying cyclothem is of unfossiliferous shales possibly laid down in shallow pools or broad tidal flats. These overly algal rich shales. The Cherokee type of cycle is characterized by the relative thinness of its marine phases and relatively thick coals. At the cycle top is a black shaly limestone (with marine fossils but with few fusulinids) that grades downwards to a black shale that is locally calcareous. These are underlain by a thick unfossiliferous black shale that is interpreted as brackish to nonmarine. The Cherokee coals then occur. These are underlain by nonmarine sandy shales above thick, very persistent, nonmarine sandstones (with land plant remains and animal tracks, and locally a channel-fill conglomerate) disconformable on marine deposits.

Cyclothems in the Allegheny basin
In Pennsylvania are low-sulfur bituminous coals. These accumulated in freshwater swamps in the, otherwise, slowly subsiding foreland to the Allegheny fold mountains. The coals accumulated in both levee-overflow swamps, and to the rear of the barrier-beach fronted coast of Absaroka transgressions. The marine part of each Allegheny cyclothem is relatively thin. Beneath the coal, and its associated underclay, in each cyclothem, are irregularly stratified, nonmarine, sandy shales and cross-bedded sandstones. In places, channel-fill conglomerates record a scene of streams meandering across an aggrading floodplain. Coals beds that accumulated in the floodplain area, are thin and disconnected. Coals that accumulated in the freshwater swamp edge to the Absaroka transgressions, are typically thick (2 meters), and very extensive (hundreds of square kilometers).

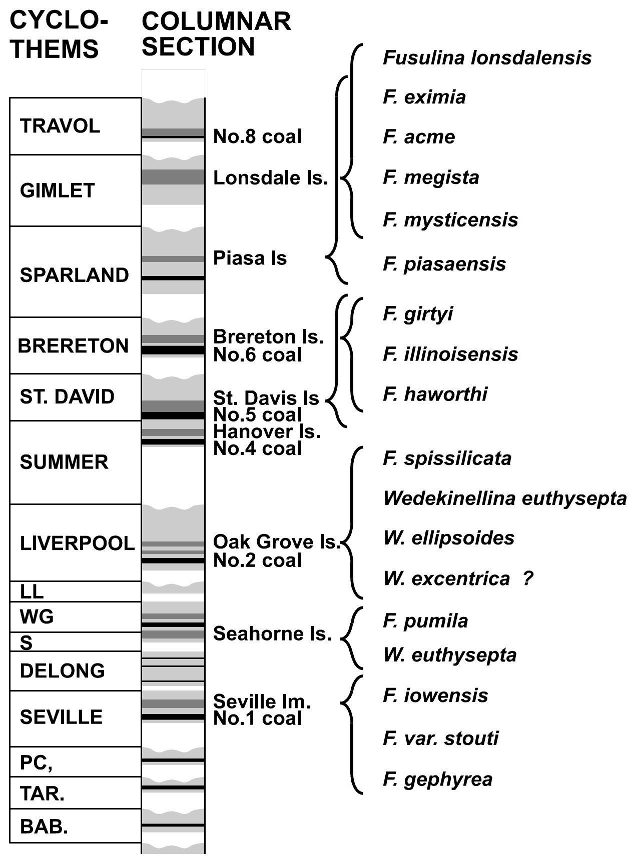
Cyclothems in Europe
Cyclothems in Europe are called "coal measures"– term coined in 1811 by John Farey (1766-1826).[12]

In England, beginning in the 1830s, the repetition of the sedimentary phases of the Carboniferous coal were described as cycles of sedimentation, each (top down): unfossiliferous shale, or shale with nonmarine bivalves, a marine (as indicated by fossils) limestone or claystone (shale or mudstone), coal and its seat-earth (underclay), nonmarine (riverine, deltaic) sandstones and siltstones (***Figure i19.3***). The preferred explanation was that each was initiated by a sudden drop of forebasin elevation to, shallowly, below sealevel, followed by progradation of a delta. A later explanation, which gained vogue, was a slowly deepening foreland basin that accumulated sediments of a flooding epeiric sea except where a crowsfoot delta prograded—the switch of river outlets to a new place started there a new sedimentary cycle with coal. To these local tectonic and sedimentational scenarios must now be added a pervasive global glacioeustatic control.

No one-size-fits-all description of the Permo-Carboniferous coals should be anticipated. For example, in Germany, coal-bearing molasse sequences accumulated in the foredeep to, and in basins between, Hercynian uplifts. The Hercynian fold belt widened during the Carboniferous. As a result, the younger Upper Carboniferous coals are more interiorward and were evidently accumulating when the older Upper Carboniferous coals were being folded. ❑

Figure i19.2[13] (right) Each cyclothem encountered in a drillcore has a top demarked by erosion that truncates freshwater shaly sediments. These, are the top of an offlap sequence: from freshwater downward to marine, the acme (most offshore phase) of which is a fusuline-bearing marine limestone. Below, is an onlap sequence: from the acme down to lagoonal marine overlying freshwater deltaic sediments in which, typically, there is a bed of coal.

Key:
shale (gray)
limestone (dark gray),
coal (black)
sandstone (white)
disconformity



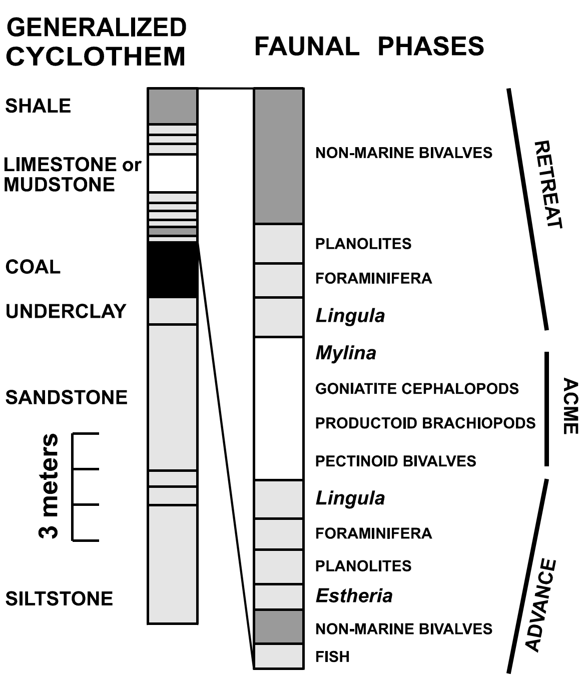


Figure i19.3[14] (left)
An Upper Carboniferous marine band in a cyclothem showing successive transitional stages encountered in a drill core (top down) are: A sea-retreat (offlap) sequence (from freshwater down to fully marine) and a sea-advance (onlap) sequence (from the marine acme down to freshwater). Coal and its underclay. Deltaic sandstone and siltstone.