The Fire Underground

Coal clinkers, baked mudstone, and clues to evolutionary diversity

By Johann Georg Goldammer

Fossil fuel combustion on Earth began long before the Industrial Revolution. The earliest evidence of naturally ignited fires burning in coal deposits is found in the northern Great Plains of the United States, in northeast Wyoming and southeast Montana. Beginning at least 2 million years ago coal-seam fires there began to shape the landscape by heating and baking overlying sediments producing “coal clinker.” Essentially ceramic, this natural material covers some 1,500 square miles, including parts of nearby Theodore Roosevelt National Park in North Dakota. In the past 2 million years such fires may have consumed more coal and released more greenhouse gases than all the coal mined and burned for energy production in the past century.

JAMES ST. JOHN

Wyoming’s coal clinker in: Burning coal seams baked overlying sediments in ancient times, creating this ceramic material.

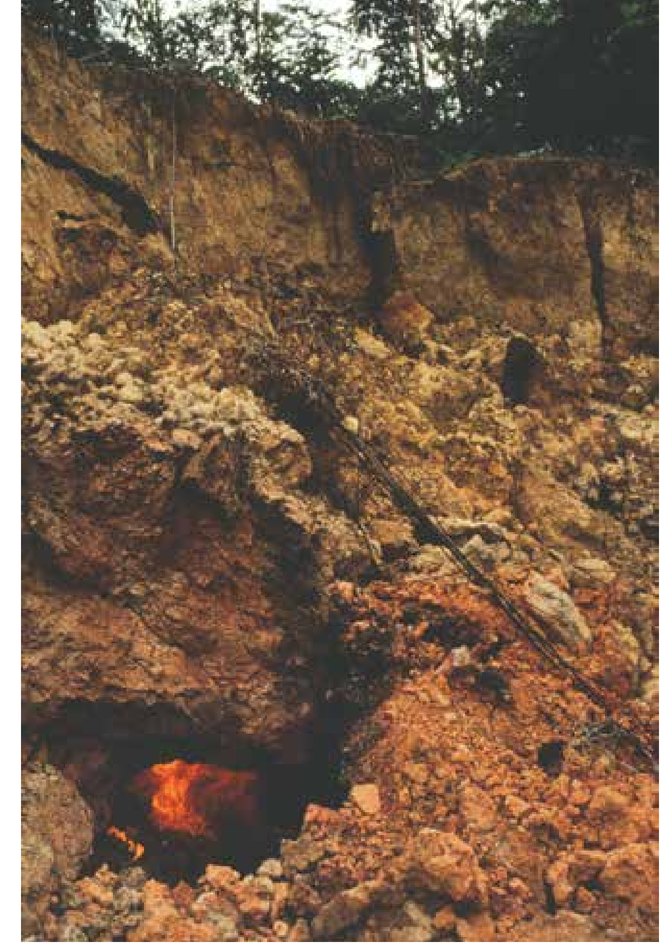
Whether started naturally, accidentally, or deliberately, hundreds of coal-seam fires are burning today around the world, in the United States, Canada, China, New Zealand, Australia, and other countries. One near Saarbrücken, Germany, known locally as Brennender Berg (Burning Mountain) was ignited around 1668 by a shepherd’s campfire and still is burning today. Among the visitors intrigued with it was Goethe, who mentions seeing it in his youth. In his epic autobiography *Aus meinem Leben: Dichtung und Wahrheit* (*From My Life: Poetry and Truth*; 1811–1833; 2nd part, Book 10) he writes: “We entered a gorge and found ourselves in the region of the burning mountain: A strong smell of sulfur enveloped us, one part of the cave was almost glowing red, covered with reddish, white-roasted stones; thick steam came out of the clefts, and one felt the heat of the ground even through thick soles.”

The Burning Mountain in Germany produces a warm microclimate and habitats that favor species that otherwise would not occur in the region. And the residue of potassium alum freed by the heat was a welcome support for the local tanning trade, even leading to additional deliberate ignition of the mountain. The alum was also used as fire retardant for wooden beams for house construction, just as it was in antiquity by the Romans.

What I have found most fascinating are the remnants of prehistoric wildfires and coal seam fires in tropical ecosystems. In the late 1980s, I led an Indonesian-German research team investigating soils of tropical rain forests in Borneo, in the Indonesian province of East Kalimantan. We found charcoal in the soil of undisturbed primary dipterocarp forest as evidence of ancient wildfires. Charcoal samples collected from a 145-mile transect from the east coast inland and subjected to radiocarbon dating proved range in age from about 350 to 17,510 years ago. That revealed that wildfires occurred not only during the relatively dry Pleistocene, when they might be expected, but also after the present wet, rain forest climate stabilized, between about 10,000 to 7,000 years ago.

To explain how forest fires occurred once moister conditions were established, we turned to the likelihood of periodic droughts, such as those caused by the modern El Niño-Southern Oscillation phenomenon. Prolonged drought drastically changes the flammability of the rain forest biome. The stressed plants progressively shed their leaves, while the moisture content of the surface fuels is lowered. Downed woody material and loosely packed leaf litter become ripe for the spread of surface fires, while desiccated climbers and lianas may become fire ladders, potentially resulting in crown fires or “torching” of single trees.

But how could the forest be ignited? Lightning is always a suspect. And the indigenous populations, which had entered Borneo during the last ice age, when lower sea levels had connected the island to mainland Southeast Asia via land bridges, could also be the source. Like people everywhere else in the world, they had developed a culture of fire use. But there was yet another ignition source.



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A coal-seam fire lurks below a tropical rain forest in East Kalimantan, Borneo. Such fires not only create coal clinker but also may serve to ignite forest fires when conditions are sufficiently dry.

During our expeditions in the comparatively moderate El Niño year of 1987, in which we were looking for soil charcoal in a forest reserve, we suddenly witnessed the start of a surface fire. The smell was typical of a forest fire but also tinged with sulfur. The fire had been ignited by a burning coal seam in the middle of the rain forest. This event prompted us to have a closer look at the rain forest soils in East Kalimantan, and we found evidence of the effect mentioned above for North America, the formation of coal clinker. On Borneo the heat from burning coal seams baked an overlying silicate clay mineral called kaolinite. The resulting coal clinker is locally called “baked mudstone” and is used for forest road construction.

We collected baked clay samples from atop an extinguished coal seam not far from an active coal seam fire. Thermoluminescence analysis (a method used to date ancient pottery) later carried out at the laboratory of the Prussian Cultural Heritage Foundation in Berlin proved that the coal seam had been on fire between about 13,200 and 15,300 years ago. From our inspection of the nearby actively burning coal seam, we concluded that the fire progresses slowly through the ground of the rain forest and cannot be extinguished by water. We even saw that a cascade of water over the edge of a burning coal seam could not affect its combustion. These observations, together with the findings on ancient fires, suggest that burning coal seams represent a permanent fire source from which wildfires can spread in the rain forest whenever a drought occurs and fuel conditions are suitable.

In the long term, this interaction between climatic variability, fire sources, and wildfires may have fulfilled an evolutionary function by creating refugia, areas in which populations of plants and animals can survive during unfavorable periods. In the case of rain forests, a seasonal climate with dry times conducive to fires may have created isolated patches of rain forest separated by corridors of savannah vegetation. The gene flow among these “islands” would have been restricted, especially for plants, which depend on seed dispersal and pollination. As a result, the biota of the different refugia would have diverged. Later, under moister conditions, these refugia may have coalesced. That could help explain the present high species diversity now found within the tropical rain forests.

Apart from possibly maintain savannah corridors, periodic fires caused by lightning or burning coal seams can have another evolutionary function. If limited in size, they create gaps in the canopy of the rain forest. These openings enable regeneration and restructuring of the rain forest vegetation. In an undisturbed forest, pioneer and invasive species are excluded, leaving only few dominant “climax” species to prevail. One view is that such instability encourages species diversification. However, that challenges the received wisdom espoused by the American plant ecologist Frederic Clements (1874–1945) and his followers—that it is within the stability of climax forests that, over long time scales, species richness evolves.

Fire’s prehistoric and historic role in Earth’s geology and biology demonstrates its creative power. As we humans unleash fossil fuels, changing the makeup of the atmosphere and bringing on global warming, we may learn that the old proverb “Fire is a good servant but a bad master” applies to geological timescales.

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