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Locus 1
Laura Berman

GEOLOGICAL CYCLES OF THE FLINT HILLS

KEITH B. MILLER

Keith B. Miller's fascinating piece "Geological Cycles of the Flint Hills" really resonated with me. I found myself drawing comparisons between his descriptions of the layers of sedimentary rock and the cycles of the oceans and nature with the natural evolution of music throughout history. Each composer builds upon the rocks already laid down before them, perfectly balancing what we already know and have experienced with new and innovative changes. Music, like nature, is cyclical. It is both the predictable successions and the unexpected that make music so interesting, much like the evolution of the Flint Hills. Art indeed imitates life. — Jason Seber

The history of the Earth is dynamic.

Though it may not be apparent during humans' short span of life, the surface of the Earth and the life it supports are in a constant state of change — both progressive (directional) and cyclic. Earth history is also vast, with time scales that are hard to grasp. Geologic time is often referred to as "deep time" to emphasize its distinction from time as seen from a human perspective.

Rocks provide a window into the deep time of Earth history. In Kansas, the rocks consist almost entirely of sedimentary rocks stacked in nearly horizontal layers. These sedimentary layers are like the pages of a book, and to read the story, one must know where to start. When reading rocks, one must read them from the bottom upward — from those sediments deposited earlier to those deposited later. This key to interpreting the

rock record is referred to as the principle of “superposition” — the rock layers or “strata” at the bottom of a sequence are older than those at the top. In addition, sedimentary rocks preserve evidence that enable reconstructing the environments in which the sediments were originally deposited. A vertical sequence of diverse sedimentary rock layers thus indicates a changing series of environments over geologic time.

SEDIMENTARY ROCKS OF THE FLINT HILLS

The sedimentary rock strata of the Flint Hills of Kansas record a period of time extending from the latest Pennsylvanian Period through the end of the early Permian. This encompasses a time interval of roughly 20 million years from somewhat before 290 million years ago to about 270 million years ago.

The sedimentary rock strata of the Flint Hills can be broadly classified into two types. The resistant layers are carbonate rocks (limestones and dolomites) that are commonly associated with thin, finely layered dark gray shales. These carbonates and gray shales are typically quite fossil-rich. The much less resistant, reddish and greenish-colored intervals are mudstones and siltstones. The repeated alternation between the carbonates and colorful soft mudstones has produced the characteristic terraced

landscape of the Flint Hills area, with the carbonates forming the tops of terraces and the mudstones forming the slopes. The most predominant characteristic of the Flint Hills geology is this cyclic repetition of rock types. These cycles are known as “cyclothems,” and they have been widely traced throughout the Kansas Flint Hills region from Nebraska to Oklahoma.

Many of the carbonate units contain abundant flint (or chert) nodules, which in some cases merge to form thin layers. It is these hard, weather-resistant nodules that give their name to the area. As the enclosing carbonates are slowly removed by weathering, the flint nodules are left behind as a layer of rubble on the surface. These hard nodules prevented the early settlers from tilling the uplands — thus also preserving the native prairie for later generations.

WHAT CAN CYCLOTHEMS TELL US?

The early Permian cyclothems in Kansas typically begin with limestones and gray fossil-rich shales that represent deposition in a shallow sea. These limestones commonly culminate in layers recording intertidal environments and eventual exposure to the air. Various colored mudstones lie above these shallowing marine rocks and show evidence of repeated extensive soil development.



Chase County Map
Bill McBride

This interval of vertically stacked ancient fossil soils, or “paleosols,” is then sharply overlain by another marine limestone, and the cycle begins again. In the early Permian, these cycles are commonly on the order of six to ten meters thick. Dozens of such alternations occur within the late Pennsylvanian through early Permian time period. The midcontinent was thus subjected to repeated flooding by shallow seas followed by exposure as dry land.

The individual cyclothems of the Flint Hills also show consistent internal patterns that record repeated cycles of climate change occurring in step with changes in sea level. Many of the carbonate beds that formed in very shallow marine and coastal environments show evidence of arid climate conditions such as replaced gypsum nodules (often present as quartz or calcite-filled geodes), salt crystal molds and finely-layered dolomites. Overlying these arid coastal sediments are reddish fossil soils that typically contain caliche nodules (some originally formed around plant roots). The calcium carbonate that forms caliche nodules accumulates in modern soils where the climate is relatively dry. Above the reddish paleosols are found the very different looking greenish-colored paleosols that record yet another ancient landscape. The most characteristic features of these paleosols are undulating

or wavy layers. Such soil structures form today in highly seasonal wet-dry, or monsoonal, climates.

To summarize, what is seen within each of the many stacked cyclothems is first a change from a shallow sea to intertidal conditions under rather arid climates. This was followed by the continued lowering of sea level and the exposure of the area as land — first under a relatively dry semi-arid climate, and then under a seasonally wet/dry monsoonal climate. The story of each of these cycles is ended with the dramatic flooding of a vegetated landscape by rising sea level, coming full circle, returning back to the shallow sea where the story began.

CAUSES OF THE CYCLICITY

What caused these dramatic and repeated alternations between marine and terrestrial conditions? Why would the oceans be rising and falling like a yo-yo? To answer the questions, one must look elsewhere than the rocks in the Flint Hills, or even in the midcontinent of the U.S. The answer lies in the continents of South America, Africa, Australia, India and Antarctica, all of which were gathered around the South Pole during this time. Here evidence is found for a great period of continental glaciations, an ice age during the time represented by these rocks. Such glacial periods are characterized by repeated

advances and retreats of the continental ice sheets. Each time the great glaciers advanced, the sea level would fall. Water evaporated from the seas would fall as snow and be trapped in the glacial ice. Conversely, each time the glaciers retreated and melted, water would flow back into the seas, causing the sea level to rise. Thus, the cycles observed in the rocks of Kansas record glacial and interglacial periods on continents half a world away.

Climate change was the cause of the glacial advances and retreats that generated the fluctuations in global sea level. The consistent vertical pattern of climatically sensitive sedimentary features within early Permian cyclothems indicates that climate changed from arid to progressively wetter and provided more seasonal conditions during the formation of each cyclothem. Such a pattern appears to be consistent with computer climate models developed for this period of Earth history.

CAUSES OF CLIMATE CHANGE

A further question can be asked: what caused the climate cycles that resulted in the advance and retreat of continental ice sheets and consequently the rise and fall of global sea level? This is a very difficult and complex question and involves many interrelated factors including atmospheric

carbon dioxide concentration, ocean circulation patterns, continental positions and topography, the reflectivity of the Earth’s surface, and others. However, one important part of the answer can be found by looking at the record of the much more recent Pleistocene “ice age.”

Ice volume changes during the Pleistocene (about 2.5 million to 10,000 years ago) have been attributed to variations in the solar radiation received at the Earth’s surface. These changes result from periodic changes in the Earth’s orbit, axial tilt and “wobble.” Several changes in these orbital variables combine to generate cycles, or “Milankovitch periodicities,” that range from 20,000 to 400,000 years long. Detailed records of climate change and sea level from the Pleistocene show cycles that fall within this range.

Because the sedimentary cycles preserved in the Flint Hills of Kansas are so much older, the dating is much less precise. For rocks of Permian age, it is very difficult to resolve time intervals even as long as tens or hundreds of thousands of years. Based on comparisons with modern soils, some individual fossil soils preserved within these cycles could themselves represent several tens of thousands of years. It is thus hard to estimate the duration of Pennsylvanian and Permian cyclothems, but they were likely between about 250,000

and 400,000 years long. To put this in perspective, 200,000 years is about as long as anatomically modern humans have been on the Earth!

RETURNING TO THE PRESENT

Due to a major erosional period following the Permian, the younger rocks of the Triassic and Jurassic are missing over much of Kansas. Cretaceous rocks in western Kansas consist mostly of marine chalks and some shoreline sands. In a rather ironic coincidence,

in the Flint Hills the rocks of the Permian cyclothem are overlain by loose sediments of the Pleistocene - two global ice age periods separated by a time gap of 270 million years. The Pleistocene sediments are fine, windblown deposits (loess), glacial lake deposits and sediments deposited by glacial meltwaters. Fossil bones and teeth of ice age mammals are preserved within these loose sediments. Lastly, on the surface, one can find the record of North America's native peoples who immigrated during the closing millennia of the Pleistocene.

Keith Miller is a retired geology professor from Kansas State University, where he dedicated 27 years to teaching and research. Keith was a founding board member of Kansas Citizens for Science, a group dedicated to advancing quality public science education in Kansas.

Jason Seber was the Associate Conductor of the Kansas City Symphony from 2016 to 2022. He led the Symphony in over 300 performances during his tenure, including four performances for Symphony in the Flint Hills Signature Events.



Earth Moves 1
Laura Berman