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Geological Cycles of the Flint Hills: Ancient Ice Ages, Sea Levels, and Climate Change

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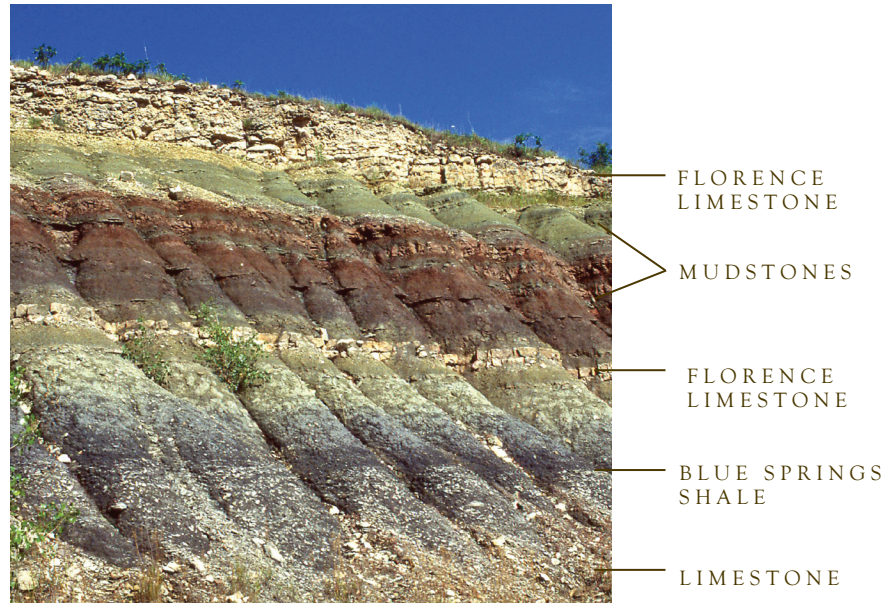
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Geological Cycles of the Flint Hills:

ANCIENT ICE AGES, SEA LEVELS,
AND CLIMATE CHANGE

The history of the Earth is dynamic. Though it may not be apparent to us during our 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.



A TYPICAL KANSAS 'CYCLOTHEM'
Along K-113 in Manhattan, Kansas
Keith Miller

Rocks provide our window into the deep time of Earth history. In Kansas, the rocks we see 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 you must know where to start. If we are reading rocks, we 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 us to reconstruct 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. 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 6 to 10 meters thick. Dozens of such alternations occur within the late Pennsylvanian through early Permian time period. The mid-continent 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

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.

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 we see within each of the many stacked cyclothem is first a change from a shallow sea to intertidal conditions under rather arid climates. This was followed by the continued lowering of sealevel 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 sealevel. We have come full circle, returning back to the shallow sea where the story began.

CAUSES OF THE
CYCLICITY

You may be wondering 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 this question we must look elsewhere than the rocks in the Flint Hills, or even in the midcontinent of the U.S. We must go to the continents of South America, Africa, Australia, India and Antarctica, all of which were gathered around the south pole during this time. Here we find evidence for a great period of continental glaciations, an ice age, during the time represented by our rocks. Such glacial periods are characterized by repeated advances and retreats of the continental ice sheets. Each time the great glaciers advanced, the sealevel 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 sealevel to rise. Thus the cycles observed in the rocks of Kansas record glacial and interglacial periods on continents half a world away.



THE THREE-MILE LIMESTONE
showing the irregular flint nodules and layers that give the region its name
Keith Miller

Climate change was the cause of the glacial advances and retreats that generated the fluctuations in global sealevel. 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 is causing the climate cycles that resulted in the advance and retreat of continental ice sheets and consequently the rise and fall of global sealevel? 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 sealevel 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 chinks and some shoreline sands. In a rather ironic coincidence, in the Flint Hills the rocks of the Permian cyclothems are overlain by loose sediments of the Pleistocene. We thus have sediments recording 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 currently a research assistant professor in geology at Kansas State University. Collecting rocks, shells, and insects, Keith had an early interest in geology. He attended Franklin and Marshall College where he became fascinated with paleontology pursuing that subject as a graduate student at SUNY Binghamton and the University of Rochester. Keith's research interests have included the preservation and paleoecology of marine invertebrate communities, the record of short-term cyclicity within the geologic record, and models for sea level and climate change in the US mid-continent during the Pennsylvanian and Permian Periods.