The Obelisk: Revisited

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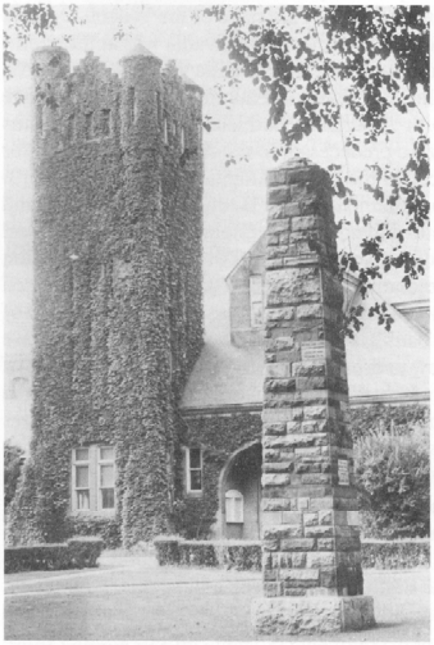
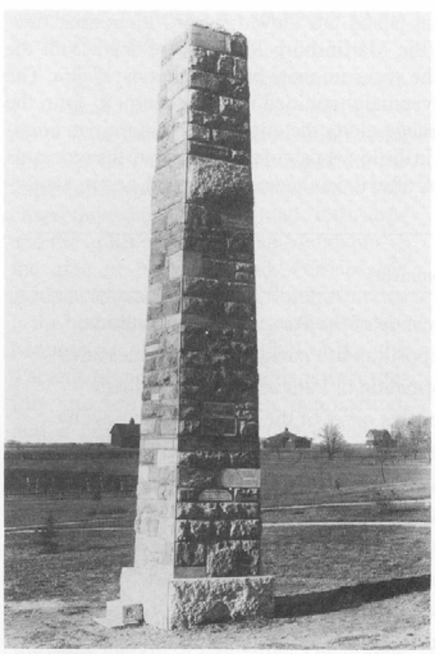


The obelisk was erected near the Armory, one of the campus's major buildings. Regrettably, it was razed in 1964 to make room for the extension to Willard Building.



Looking toward the present location of the College of Earth and Mineral Sciences soon after construction of the monument.

With the exception of the limestone statue of the Nittany Lion near Recreation Hall, very few landmarks on the Penn State campus are as noteworthy as the 33-foot-tall stone obelisk a few dozen yards southwest of Old Main. The obelisk was erected in 1896, under the supervision of the first dean of the School of Mines and professor of mining engineering and geology, Magnus H. Ihlseng, for the purpose of measuring the rate at which building stones crumble when subjected to central Pennsylvania weather. Ihlseng collected 281 stone blocks from stone quarries throughout the Commonwealth of Pennsylvania. Curiously, a few stones from Massachusetts, New York, Ohio, and England were also placed in the monument. At the time, stone was being used extensively in the construction of such buildings as Old Main and there was general interest within the construction industry concerning its long-term resistance to weathering.

Fifty-three years after the construction of the obelisk, John Eliot Allen, professor of geology, evaluated the extent of crumbling and weathering of each stone block and described his findings in an article that appeared in *Mineral Industries* (March, 1949), the predecessor to *Earth and Mineral Sciences*. Using petrographic examination of thin sections from each block, Prof. Allen compared his findings with predictions made in a 1899 B.S. thesis by William L. Affelder for resistance to the elements. Combining Affelder's and Allen's scores, the largest block in the obelisk, a bluish conglomerate found three-quarters of the way to the top, earns highest rating as a building stone.

One feature, which makes the obelisk of great interest to the geologist, is the arrangement of various stones according to their age with oldest at the base. Notable exceptions to this rule are that all crystalline rocks,[a] igneous and metamorphic, are located below sedimentary rocks regardless of their age, and the base of the obelisk is the same bluish-gray conglomerate as the largest block found three-quarters of the way to the top. The age of the rocks varies from approximately 1.1 billion years, a gneiss near the base of the obelisk, to about 180 Ma (Ma = millions of years ago; My = a period of millions of years) for several blocks of diabase, an igneous rock surrounding the gneiss near the base. Between the age of the gneiss and diabase are all of Pennsylvania's sedimentary rocks. These sedimentary rocks constitute a detailed record of the history of a mountain belt, the Appalachian Mountains. This record is remarkable in that many of the famous mountain belts of the world such as the Alps, the Rockies, the Himalayas, and Urals all have a similar history of sequential events, although occurring at different times in the Earth's development.

The history of a mountain belt is best understood in terms of plate tectonics, a theory which grew from the discovery of continental drift. When Ihlseng erected the obelisk, he, like all contemporary scientists, was unaware of continental drift and could not possible have known that the obelisk was a wonderful monument to the theory of plate tectonics.[b] To my knowledge, no man-made structure in the world serves better to illustrate the overall effects of continental drift on mountain building and the sedimentary record than the Penn State obelisk. This is because the large variety of Pennsylvania building stones that make up the monument represent many of the important geological events affecting the Appalachian Mountains during the past billion years, Figure 1.

The various stages of both continental drift and mountain building are part of a cycle of continental rifting, separation, convergence, and collision now called the Wilson Cycle. For the Appalachian Mountains of Pennsylvania, this cycle starts during a period when most of the continental area of the Earth was gathered into one vast supercontinent. Supercontinents form with the collision and suturing of several small continental masses as these continents are swept together into one large land mass. The 1.1-billion-year-old gneiss toward the base of the obelisk contains a deformational fabric developed as a consequence of the assembly of a Late Precambrian supercontinent. Eventually such supercontinents are unstable, and later divide or rift into half a dozen smaller continents, as is found on the Earth today.

The oldest sedimentary rock represented is the Potsdam Sandstone[c] near the base of the monument. In the obelisk, this sandstone marks the start of the Wilson Cycle that ultimately led to the Appalachian Mountains surrounding the University Park campus. Sometime between 650 and 550 Ma, the Late Precambrian supercontinent started to break up, with the formation of rift valleys much like those found in Africa today in the vicinity of Lake Victoria. Such continental rifts fill relatively quickly with sediments derived from nearby mountains. As the rifts widen, the ocean invades the rift valley much as the present Red Sea separates the African continent from the Arabian shield. The Potsdam Sandstone is a beach sand, similar to those found at the edge of the Red Sea.

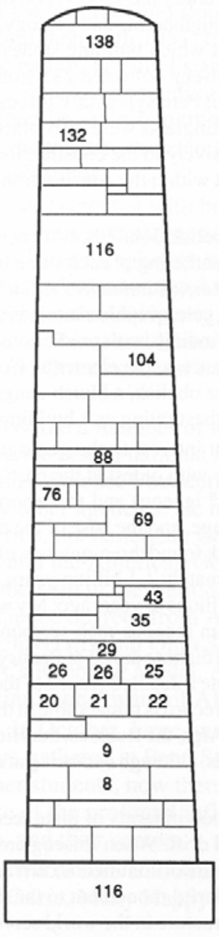


Figure 1. The obelisk's west side charts the formation of Pennsylvania.

As the pieces of the Late Precambrian supercontinent continued to drift further apart, major ocean basins filled the space between the smaller continents. This stage of the Wilson Cycle is called the drift stage. At that time, Pennsylvania was at the southwestern edge of a continent we call Laurentia which was bordered by an ocean named Iapetus, Figure 2. Laurentia eventually became the core of the North American continent, whereas the Iapetus Ocean was a Paleozoic predecessor to the Atlantic Ocean and for this reason is also called the "Proto Atlantic." At this time North Europe was a minor continent within Iapetus. Other smaller land masses within Iapetus included New England, Nova Scotia, and Scotland. For a period between 530 and 480 Ma, the Pennsylvanian edge of Laurentia resembled the Bahama banks, for it was located near the equator where shallow tropical seas favored the growth of massive carbonate banks. Around the State College area, these carbonate banks grew to exceed 2 km in thickness over a period of about 40 My. Blocks from these carbonate banks were placed in the lower third of the obelisk, Figure 1. Some of these stones are mates of those building stones that veneer Old Main and University House (the old President's house) near Deike Building.

As was the case of the Iapetus Ocean, ocean basins do not grow indefinitely because lithospheric plates of continental and oceanic crust move on the the surface of a sphere, the asthenosphere of the Earth, rather than on a flat plane. Eventually, the ocean crust of one lithospheric plate starts to be consumed at a subduction zone, where continents or island arcs of another lithospheric plate move over the ocean crust. At about 480 Ma, the ocean crust attached to Laurentia started riding down a subduction zone which had developed within Iapetus Ocean crust. By analogy, the present Indian Ocean crust is riding under the Indonesian island arc, and the northeast Pacific Ocean crust is moving under the Aleutian island arc.[d]

As this ancient island arc moved toward Laurentia, fine-grained sediments (the Martinsburg Shale) were shed from the island arc to cover the vast carbonate banks of Pennsylvania. The ancient island arc eventually collided with Laurentia to form the Taconic Mountain range along the edge of the Laurentian continent. Some marbles in the lower part of the obelisk are the remnants of the carbonate bank after it was heated, deformed, and metamor-

Block Number	Formation Name	Age (Ma.)	Comments
138	Newark Ss.	230	Breakup of the Pangaean supercontinent
132	Allegheny Ss.	310-290	Deposition of Pennsylvania coal measures
116	Pottsville Cg.	310	Formation of Pangaean supercontinent
104	Mauch Chunck Ss.	320	Denotes onset of the Alleghanian Orogeny
88	Flagstone	360	Deposited during erosion of Acadian Mtns.
76	Devonshire Sl.	370	Signals uplift of Acadian Mts. near England
69	Tully Ls.	380	Carbonate banks after erosion of Taconics
43	Tuscarora Ss.	420	Taconic Mts. in final stages of erosion
35	Bald Eagle Ss.	430	Taconic Mountains start to erode
29	Martinsburg Sl.	440	Island arc forms on southwest of Laurentia
20-26	Ls. & Dol.	530-480	Bahama-like carbonate banks of Laurentia
9	Potsdam Ss.	540	Supercontinent begins to fragment
8	Gneiss	1,100	Piece of Late Precambrian supercontinent

Block numbers as assigned by J.E. Allen (1949); Ss. = Sandstone, Cg. = Conglomerate, Sl. = Slate, Ls. = Limestone, Dol. = Dolomite.

phosed deep within the Taconic Mountains. Likewise, the Martinsburg Shale was metamorphosed to become the slate seen in the obelisk. As is the case along present mountain ranges such as the Andes and Himalayas, the tops and flanks of ancient mountain ranges were subjected to severe weather conditions, which caused rapid erosion with thick piles of sediment deposited adjacent to the mountain range. The Bald Eagle and Tuscarora Sandstones of the obelisk mark the rapid erosion of the Taconic Mountain Range in less than 10 My.

Even as the Taconic Mountains were reduced by erosion, a segment of the Iapetus Ocean still lay to the south of Laurentia. For a period between 430 and 390 Ma the southern edge of Laurentia was again a stable continental shelf where carbonate banks, small coral reefs, and salt flats developed. Because salt is useless as a building stone, the thick salt beds deposited at about 420 Ma in northwestern Pennsylvania are not present within the obelisk. One carbonate representative of this period is the Tully Limestone, deposited at 380 Ma. By this time, North Europe, including the crust that later became England, swept against Laurentia as the lithospheric plates, consisting of both Laurentia and Iapetus, pivoted counterclockwise. Gondwana, the largest remaining piece of the Late Precambrian supercontinent, had moved from an equatorial position to the south pole of the Earth, Figure 3.

By 390 Ma, the southern margin of Laurentia was starting to show signs that it was a subduction zone, with Iapetus Ocean crust sliding under the large continent. This subduction zone was characterized by large magmatic intrusions and the uplift of the Acadian Mountains in the area of New England. Perhaps the Andean Mountain chain of South America is the best modern analogue to the Acadian Mountains of New England. Like the Taconic Mountains, the Acadians were rapidly attacked by weathering and erosion, and a large sedimentary pile called the Catskill Delta was deposited on the southern edge of Laurentia in the vicinity of Pennsylvania. Contemporaneous clastic deposits formed on the English portion of the Laurentian margin. One block of the obelisk from England comes from this period when England and Pennsylvania shared the same margin of Laurentia. The organically rich sediments of the Catskill Delta were the source rocks for much of Pennsylvania's rich crude oil. A thin slab of Pennsylvania "flagstone" of the Catskill

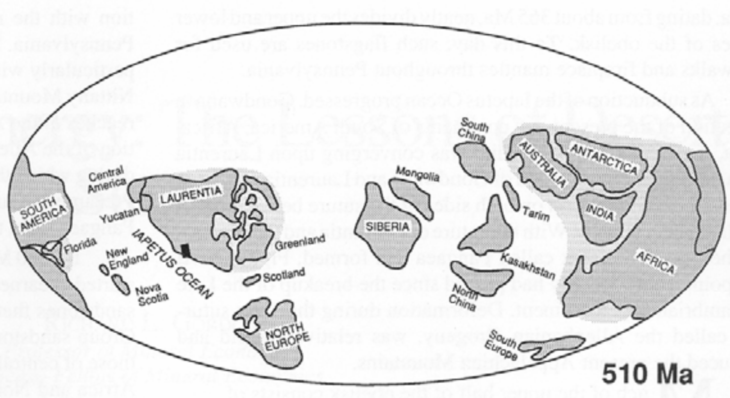


Figure 2. The position of continents on the surface of the Earth shortly after the breakup of the Late Precambrian supercontinent at about 510 Ma. Major continents are identified by capital letters. Minor land masses are identified by lower-case letters. The continental masses of Africa, Antarctica, Australia, India, and South America are assembled in a large continent called Gondwana. At the time, Pennsylvania was located on the southwestern margin of Laurentia (black rectangle). Figures 2, 3, and 4 adapted from Scorese (1984).

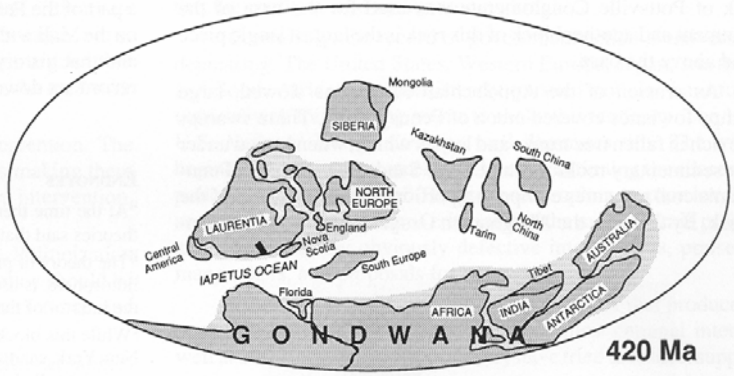


Figure 3. The position of continents on the surface of the Earth shortly after Gondwana had drifted to the south pole of the Earth at about 420 Ma. At the time, Pennsylvania was located near the equator on the southern margin of Laurentia (black rectangle).

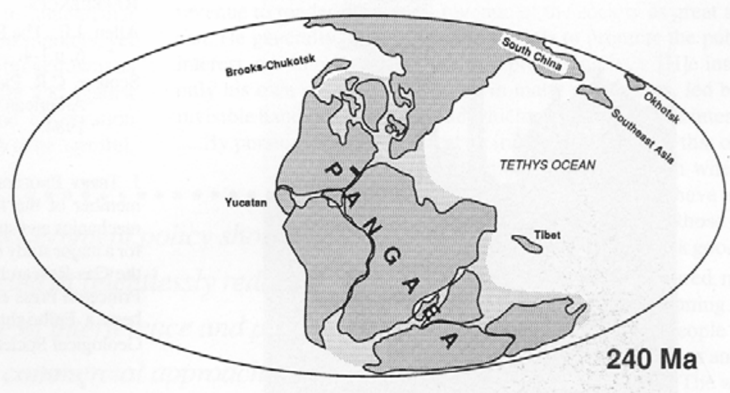


Figure 4. The position of continents on the surface of the Earth at the time of the formation of the Pangaean supercontinent at about 240 Ma. At the time Pennsylvania was located on the equator and well inside the Pangaean supercontinent (black rectangle).

Delta, dating from about 365 Ma, neatly divides the upper and lower halves of the obelisk. To this day, such flagstones are used for sidewalks and fireplace mantles throughout Pennsylvania.

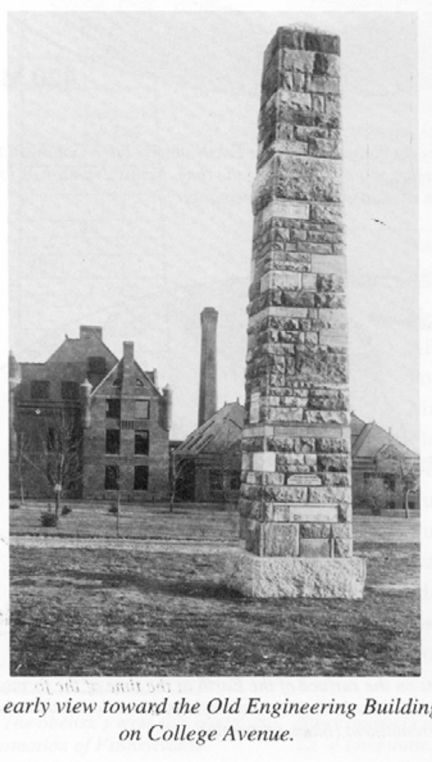
As subduction of the Iapetus Ocean progressed, Gondwana (a collection of the present day continents of South America, Africa, India, Antarctica, and Australia) was converging upon Laurentia from the south. The collision of Gondwana and Laurentia produced tremendous deformation on both sides of the suture between these two large land masses. With the suture of Laurentia and Gondwana, another supercontinent called Pangaea had formed, Figure 4. At this point, some 300 My had passed since the breakup of the Late Precambrian supercontinent. Deformation during this later suturing, called the Alleghanian Orogeny, was relatively rapid and produced the present Appalachian Mountains.

Much of the upper half of the obelisk consists of sandstones deposited on Pennsylvania during the period of about 100 My when it was part of the Pangaean supercontinent and when the Appalachians were being eroded, as in the previous mountainous phases. The Alleghanian Orogeny was complex and had several deformational pulses. Two such pulses are marked by the deposition of the Mauch Chunk Sandstone and the Pottsville Conglomerate found in the upper part of the obelisk. A block of Pottsville Conglomerate was used for the base of the monument and another block of this rock is the largest single piece found above the base.

As erosion of the Appalachian Mountains slowed, large swampy lowlands covered much of Pennsylvania. These swamps were rich in fallen tree trunks and leaves which, when buried under other sedimentary rocks, became coal. Sandstones from the Pennsylvania coal measures comprise a portion of the upper fifth of the obelisk. By 280 Ma, the Alleghanian Orogeny reached a culmination with the massive thrusting and folding of rocks in central Pennsylvania. Some coal measures are wrapped up in the folding, particularly within the anthracite district of eastern Pennsylvania. Nittany Mountain is a syncline formed at this time within the outer reaches of the Appalachian valley and ridge district. The culmination of the Alleghanian Orogeny brings to a close a Wilson Cycle, during which the Iapetus Ocean formed with the rifting of the Late Precambrian supercontinent and ceased to exist with the creation of Pangaea from the collision between Gondwana and Laurentia.

By 230 Ma, the break up of the Pangaean supercontinent had started in earnest. The top of the obelisk consists of Newark Group sandstones that mark the start of another Wilson Cycle. Newark Group sandstones were deposited in rift basins, again much like those of central Africa. During this rifting event, the continents of Africa and North America emerged in their present shapes. The ocean that eventually filled the rift basins of the Newark Group is the beginning of the Atlantic Ocean.

In a sense, the sedimentary rocks of the obelisk span the period between the break up of the last two supercontinents to exist on the face of the Earth. The next supercontinent lies perhaps 100 My ahead, for we are presently in a period between the assembly of supercontinents. Thus, the obelisk, a monument which is so much a part of the Penn State scene that students and faculty pass it daily on the Mall without a second thought, reveals a tremendous history, and that history can be read by geologists much like reading any record set down in the books of Pattee Library.



An early view toward the Old Engineering Building on College Avenue.

Endnotes

[a]At the time there was no way to absolutely date crystalline rocks, and theories said that they must be older than sedimentary rocks.

[b]The theory of plate tectonics states that the upper layer of the Earth, the lithosphere, is divided into a number of plates that continously slide over the interior of the Earth, the asthenosphere.

[c]While this block of sandstone came from the Adirondack Mountains of New York, sandstones of equivalent age and geological setting in Pennsylvania are called the Chickies Quartzite or Antietam Quartzite depending on location within the state.

[d]An island arc develops because the subducted ocean crust melts as it is heated within the Earth. This melt, magma, often flows back to the surface to form a long string of large volcanoes that make an island arc.

References

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Scotese, C.R. Paleozoic paleomagnetism and the assembly of Pangaea. American Geophysical Union, *Geodynamic Series*, V. 12, p.1-9, 1984.

J. Terry Engelder was an undergraduate at Penn State, and became a member of the faculty in 1985. He presently teaches courses in rock mechanics and structural geology. He is currently a principal investigator for a major study of the formation of pressure compartments, sponsored by the Gas Research Institute, and he has just finished writing a book for Princeton Press entitled *Stress Regimes in the Lithosphere*. Engelder has been a Fulbright Scholar (1984) and was elected as a Fellow of the Geological Society of America in 1989.