The Geologic History of Pittsburgh

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Overview

This unit will introduce students taking Earth and Space Science to the geologic history of the region in which they live, Pittsburgh and the surrounding Allegheny County. It begins with an explanation of the principals of stratigraphy and the nature and origin of sedimentary rocks.

This will be followed by an overview of Geologic history, to include plate tectonics. During this section students will be introduced to the major periods of the Paleozoic Era and learn the major geologic and biological events that occurred during each period.

The unit will conclude with an examination of the origin of the stratigraphy of Pittsburgh and the surface landforms that makes up its unique topography.

Rationale

The science course, Earth and Space Science, is characterized by four independent units each nine weeks long. These four units are Geology, Geomorphology, Astronomy, and Meteorology. These units stand by themselves and require no previous knowledge on the part of the students. This paper supplements the material in the first two units on Geology and Geomorphology.

The students who take this subject are typically mainstream students, who have had problems with abstract thinking in other subjects. They typically have problems with higher math. Many of these students take the course as an alternative to Physics or to make up for a failed year in chemistry.

This is a population which benefits from concrete science that is real, immediate, and relevant. If they can see examples of the concepts being presented to them, they can learn the material. What is more significant, they are able to synthesize their new knowledge and apply it to the higher level of understanding indicated by problem solving and critical thinking.

This unit on the Geologic History of Pittsburgh will give the students concrete examples of the processes they will be learning. The learning will be further enhanced by the units relevance to the students, in that they will understand why Pittsburgh is shaped the way it is.

The proposed curriculum will be applicable to the 11th grade course, Earth and Space Science, which uses the text book "Earth and Space Science" by Spaulding and Namowitz, published by Heath in 1994. The chapters to which this material will be applied are:

Chapter 5 How Earth's rocks were formed

Chapter 8 Weathering, soils, and mass movement

Chapter 9 Water moving underground

Chapter 10 Running Water

Chapter 11 Glaciers

Chapter 16 Mountains and Plate Tectonics

Chapter 32 The Rock record

Chapter 33 Precambrian through the Paleozoic

The landforms that make up Pittsburgh provide a concrete example of the processes discussed in these chapters. Students will be taken from the Cambrian Period forward in time and shown how the features around them developed and changed over time. 300 million years ago, where Pittsburgh is now located looked over a great sea which extended out into what is now Ohio.

This was a marine shore environment with 5 distinct environments of deposition. These areas are the origin of the horizontal rock layers seen all around Pittsburgh, to include the Pittsburgh Coal layer. Through a series of uplifts and erosional sequences, the valleys and mountains that make up western Pennsylvania came into being.

These events will be explored in detail and in sequence in this unit. Students will be able to identify the origins of the various rock layers that they see around them, and gain a sense of time from the ages these layers were formed in.

The final formation of the topography of Pittsburgh came about during the end of the last ice age. At this time glaciers were found just north of Pittsburgh. The rivers that had formally flowed north towards the future Erie Lake basin were blocked and forced to flow southwards. The Ohio, once a minor tributary of the Allegheny, became a major river and opened up the interior of the United States from where Pittsburgh would arise.

The great flood of water released by the melting glaciers did the final carving that gave us the Pittsburgh of today. The unit will close with an examination of how this topography shaped the settlement and neighborhood patterns that we see today.

Stratigraphy

Objectives

The study of how sedimentary rocks are laid down is called Stratigraphy. The term comes from the word strata which are flat lying layers of sedimentary rocks. Understanding the origin of sedimentary rocks helps geologists interpret the history of the earth, since their environment of deposition tells us what an area looked like in the past.

For example, if we find a thick layer of sandstone exposed on a cliff face, we can tell that at some time in the past this area had an environment filled with sand. Perhaps it was a desert or a beach.

With an understanding of the origins of sedimentary rocks and three basic laws of stratigraphy, reading the history of rock layers can be as easy as reading a book. These laws of stratigraphy are logical and easily understood and are based on a fundamental principal that underlies all of Geology.

This first principal of geology is the "Theory of Uniformitarianism." This theory was formulated by one of the founders of modern geology, James Hutton. In 1795 he set forth the two proposals that make up the Theory of Uniformitarianism;

1. The geologic processes now at work were also active in the past.
2. The present physical features of the earth were formed by those same processes, at work over long periods of time.

Using this theory, geologists have studied how various sedimentary rocks are being created in the present. With this understanding they are able to determine how ancient sedimentary rocks were laid down.

The three laws of stratigraphy are:

1. The law of superposition
2. The law of crosscutting relationships
3. The law of included fragments

The law of superposition states that in a sequence of undisturbed sedimentary rocks, the oldest layers will be on the bottom and the youngest layers will be on the top. This is like making a layered cake, where the first layer put down is the bottom one, which also makes it the oldest layer. The last layer put down is the top one, which makes it the youngest layer.

Fig. 1

The law of crosscutting relationships states that an event that cuts through rock layers had to happen after the layers were laid down. Therefore, a fault cutting through layers of rock must be younger than the rocks. The same can be said for a magma intrusion that cuts through layers of rocks; it must be younger than the rocks it cuts through.

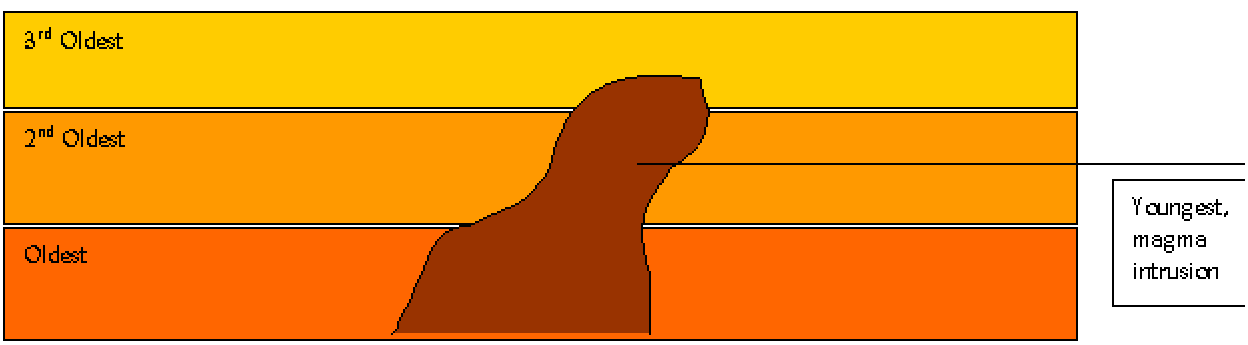

Fig. 2

The law of included fragments states that pieces of one rock found in another rock must be older than the rock in which they are found. For example, if a large stone is found in a layer of sandstone, it had to have been there first for the sandstone to form around it. Hence it must be older than the sandstone.

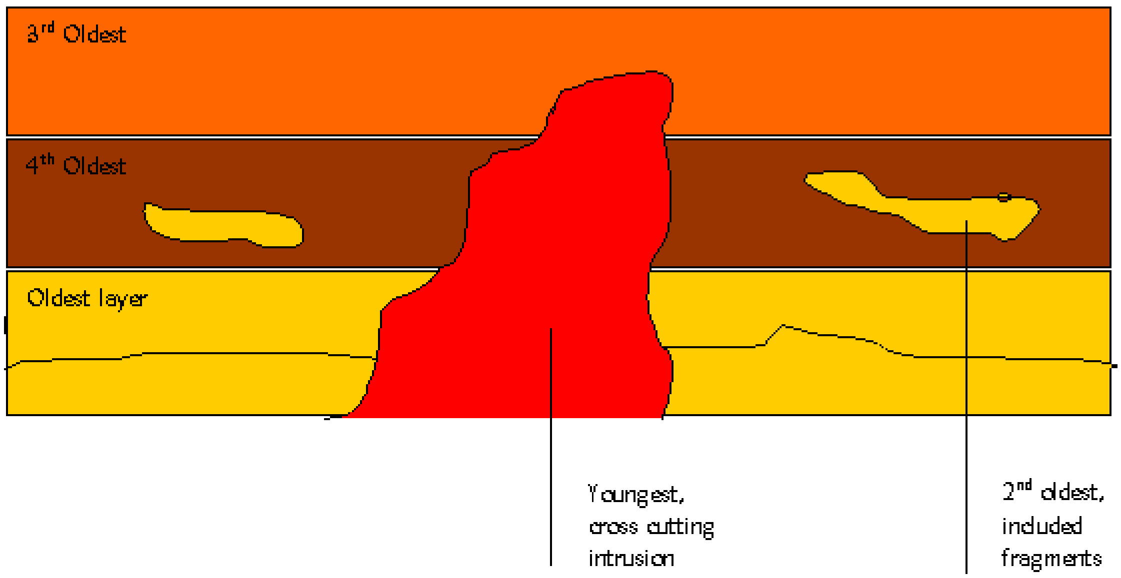

Fig. 3

Sedimentary Rocks

Sedimentary rocks come in three main types; clastic, chemical, and organic. Clastic sedimentary rocks are ones made from the eroded fragments of other rocks. These fragments range in size from silt and clay up to pebbles and cobbles. Chemical sedimentary rocks are ones formed from minerals dissolved in water precipitating out. Organic sedimentary rocks are ones made from the remains of once living organisms. These may be coal from plants or the shells of animals.

Clastic Sedimentary Rocks

The sandstone around Pittsburgh is light to medium gray and turns yellow, tan, or light brown when exposed to air. The large grains make this stone feel like sandpaper. Since it is resistant to weathering, this material tends to form blocky looking cliffs.

Shale and claystone are dark looking rocks that erode very easily. They occur in red, green, brown, gray of black colors. The darker the color the more organic material there is to be found in the rock. The colors are very significant because they can tell us a lot about the environment in which the rock was formed.

The shale tends to split into sheets while the claystone crumbles into fragments. These are the rocks that are seen indented into the sides of cliffs due to their rapid erosion. These layers are often overhung by the more resistant sandstone and limestone rocks.

Siltstone is intermediate between clay rocks and sandstone. The grains are large enough for the rock to feel gritty whereas claystones feel smooth. These rocks may be layered or unlayered.

Conglomerates are cemented gravels and are not commonly found in the area. Where found, they are called basal conglomerate beds, and are located at the bottom of very thick deposits of sandstone.

Chemical Sedimentary Rocks

Limestone and Dolomite are a type of sedimentary rock formed by chemical processes rather than the cementing together of rock particles. Carbonate precipitates out of marine and freshwater bodies. The limestone tends to be gray or blue-gray while the local dolomite will appear a yellow-gray color.

The only way to tell whether these stones formed in a freshwater or marine environment is by the fossil content. If the fossils are freshwater creatures it was a freshwater environment. The best of the limestone beds to find fossils in are the Ames limestone, which is of marine origin.

Organic Sedimentary Rocks

Organic sedimentary rocks are formed from the remains of once living material. The most common form found in Allegheny County is coal. Coal is the accumulated remains of plant debris deposited in a swamp or bog. There are 20 separate coal beds in Allegheny County, of which the most famous is the Pittsburgh Coal seam. This bed extends over an area of 6, 000 square miles.

Environments of Deposition

The sedimentary rocks record the environment in which they are laid down. Those found in Pittsburgh record six major types of environment which occurred where the city sits now.

Open Water

This is the environment found in the open ocean. West of Pittsburgh there once lay a great inland sea into which rivers flowed from the east. This inland sea sometimes covered the area where Pittsburgh lies now, and when it did deposits of marine limestone and shale where laid down. Lesser amounts of siltstone and sandstone may also be laid down in the open water environment.

Swamp

Behind the shoreline of this ancient sea, there were huge swamps filled with primitive plants. These swamps are responsible for the numerous thick beds of coal which helped lead to the settlement and growth of Pittsburgh. Thinner layers of coal indicate the location of smaller wetland areas such as bogs.

Lake Environment

Inland from the great swamps, there were often located lakes of varying size. In these environments the fresh water carbonates were laid down. The lakes were also areas where fine sediments became deposited and turned into shale and claystone.

Stream Channel

Flowing from the east into the inland sea were numerous rivers and streams. Because of the continuous movement of the water, finer particles were carried on to still bodies of water for deposition. In this environment only sand grains and larger particles could settle out.

These deposits of sand are identifiable by the fact that the size of the sand grains decrease as you move up through the sandstone layer. This is because as streams and rivers get older, they slow down more, which allows smaller particles to settle out. These formations may also have a lens shape in cross section.

Flood Plains

When a river overflows its bed, it deposits very fine clay and silt particles in a thin layer. Close to an ocean or sea, the land is so flat that this flooding can cover very wide areas. This results in very finely bedded shale's and siltstones.

Delta Environment

Determining when the Pittsburgh area lay in a delta environment is very difficult because of the complexity of a delta. This environment is a mixture of all of the above environments. This results in layers of intermingled types all on the same level of the stratigraphy. In general, however, when interbedded layers of claystones and siltstones are found of greenish to reddish color, a delta environment was in lace. The coloring indicates oxidation, which took place between periods of flooding and drying.

Cyclothems

When you look at the layers of rocks exposed in Pittsburgh, you can detect a pattern to the sequences. This systematic repetition of rock types through time is called a cyclothem. This change reflects a change in environment, which takes place gradually and in steps. What we see revealed in the rocks is a rise and fall of the sea level lapping at the shore.

Environment	Rock Type	
Open Water Ocean	Marine Limestone	
Beach	Sandstone	
Swamp	Coal	Delta may overlie
Lake	Freshwater Limestone	Delta may overlie

Stream channel	Crossbedded Sandstone	Delta may overlie
Flood Plains	Shale's and Siltstones	Delta may overlie

Table 1.

At times Pittsburgh was under the ocean in the open water environment. When the sea retreated, the environment changed to a sandy beach, then in sequence, to a swamp, lake, and floodplain. Crosscutting these environments were streams and rivers. If a major river flowed through the area, it became a delta with a combination of all of the above. In table 1 you can see the sequence of rock types laid down as the ocean sank. This sequence would reverse itself when the ocean began to rise again.

Fascies

This systematic vertical change in sequences is mirrored by a similar horizontal change that reflects transitions between adjoining environments. For example, a coal bed ends where a swamp ended and is replaced by freshwater limestone where a lake adjoined the swamp. This horizontal change in rock types is called a fascies.

Structural Geology

After these many layers of sedimentary rock were deposited, they were arched, tilted, and broken during the period of the Appalachian mountain building called the Alleghenian orogeny. This took place between 300 and 220 million years ago, and was caused by the collision of North America and Africa. This collision formed the super continent Pangaea in which all the continents of the world joined together. At this time the future Pennsylvania lay almost on the equator.

One of the consequences of this deformation was the jointing of the rock layers. In Allegheny County these joints tend to run NW-SE or NE-SW. These joint directions are directions of weakness in the rocks and influence surface drainage. As a result, many of the streams and rivers are oriented NW-SE or NE-SW in the county.

These rocks form a larger basin structure called the Pittsburgh-Huntingdon Basin. This basin is a syncline formed when the area rocks were folded downward into a U shape. At the time this happened, rocks to the east were folded upwards into anticlines forming Chestnut Ridge, Laurel Hill, and Negro Mountain.

Pittsburgh Rivers

During the early Cenozoic, western Pennsylvania was a broad rolling plain. The rivers that exist now are mainly in the same courses they occupied then. Since the land was so flat, the rivers flowed in broad meandering flat valleys. Being close to their base level they widened rather than deepened their valleys. The remains of this flat plain is found on the top of the flattened hills in Squirrel Hill, the Allegheny airport, Mount Lebanon, and parts of East Wilkinsburg.

In the late Cenozoic the region was uplifted. This increased the gradient of the rivers, which caused them to flow faster. As a consequence, they began to cut down rapidly forming deep valleys 300 to 400 feet below the plains surface.

As the rivers cut down, their flow slowed and they began to cut sideways, enlarging and defining the valleys. These valleys then became stranded 200-330 feet above the present stream levels. These remnant valleys can be seen along side the rivers. This sequence can be seen in the cross section illustrated in figure 4.

Cross section A. Before the first glaciation about 770,000 years go, the rivers flowed in shallow valleys amid low relief plains.

Cross section B. During an early Nebraskan glaciation, increased runoff helped carve the river channels deeper while filling the Allegheny Valley with glacially derived sand and gravel.

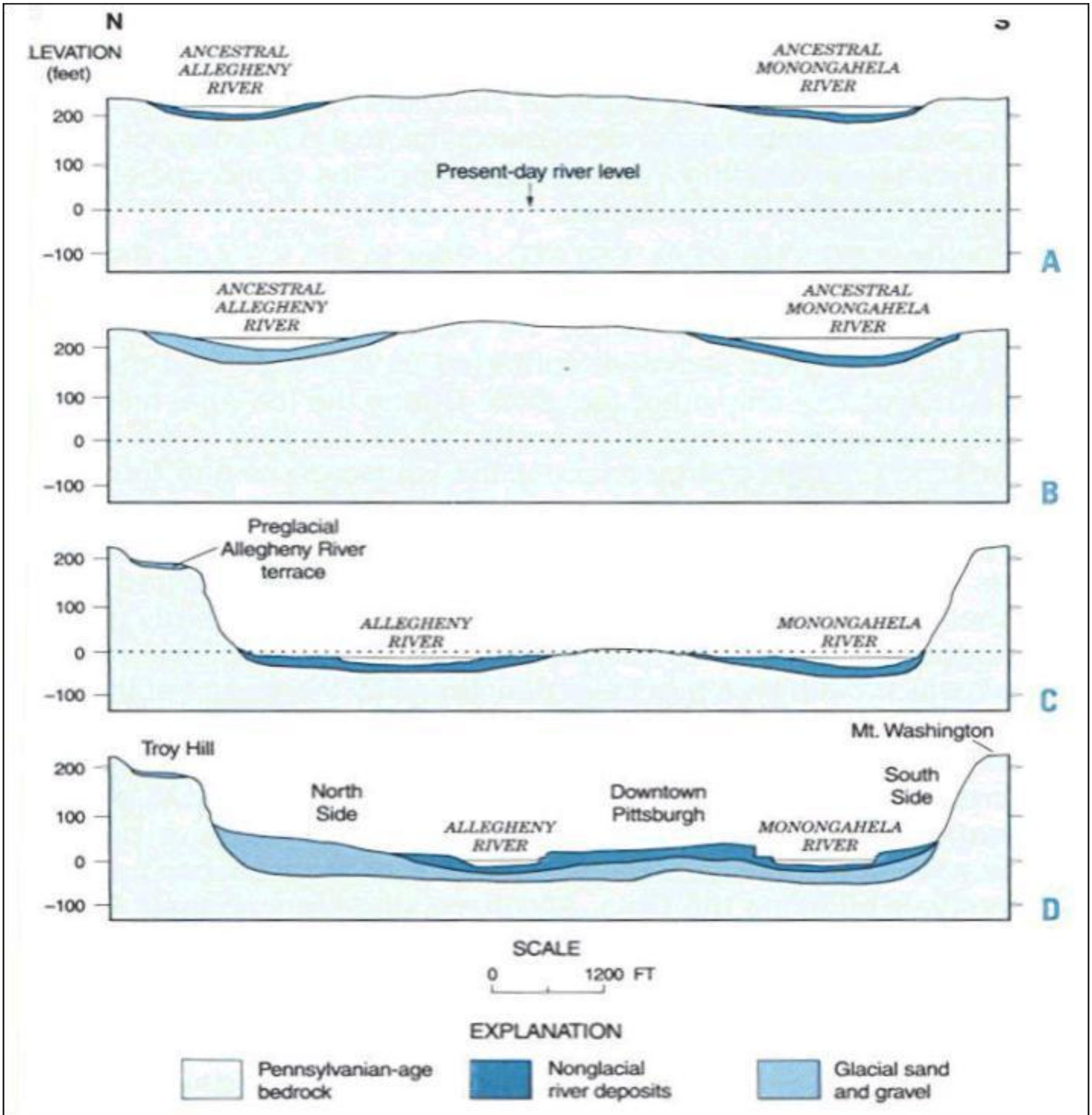

Fig. 4

Development of the Allegheny and Monongahela River valleys over the past 1 million years. From Pennsylvania Geology, Vol. 28, No. 3/4.

Cross section C. Following the initial glaciation, the rivers began to cut downward and laterally into bedrock as the land began to rise. During successive glaciations, this created a single very wide valley at present day Pittsburgh and left remnants of the old river valley floors 200 to 250 feet above the present river level.

Cross section D. During the last glaciation the Allegheny River cut down a little more and filled the entire valley with glacially derived sand and gravel.

The most important of these valleys is the one that leaves the Monongahela River at Rankin and loops up through Swissvale, Homewood, Shadyside, back down through Oakland and back to the Monongahela River (fig. 5). This broad flat valley is the only direct path to Pittsburgh from the east. As such, the principal east-west streets of Pittsburgh, as well as the Pennsylvania railroad mainline follow this remnant valley.

Elevated River valley

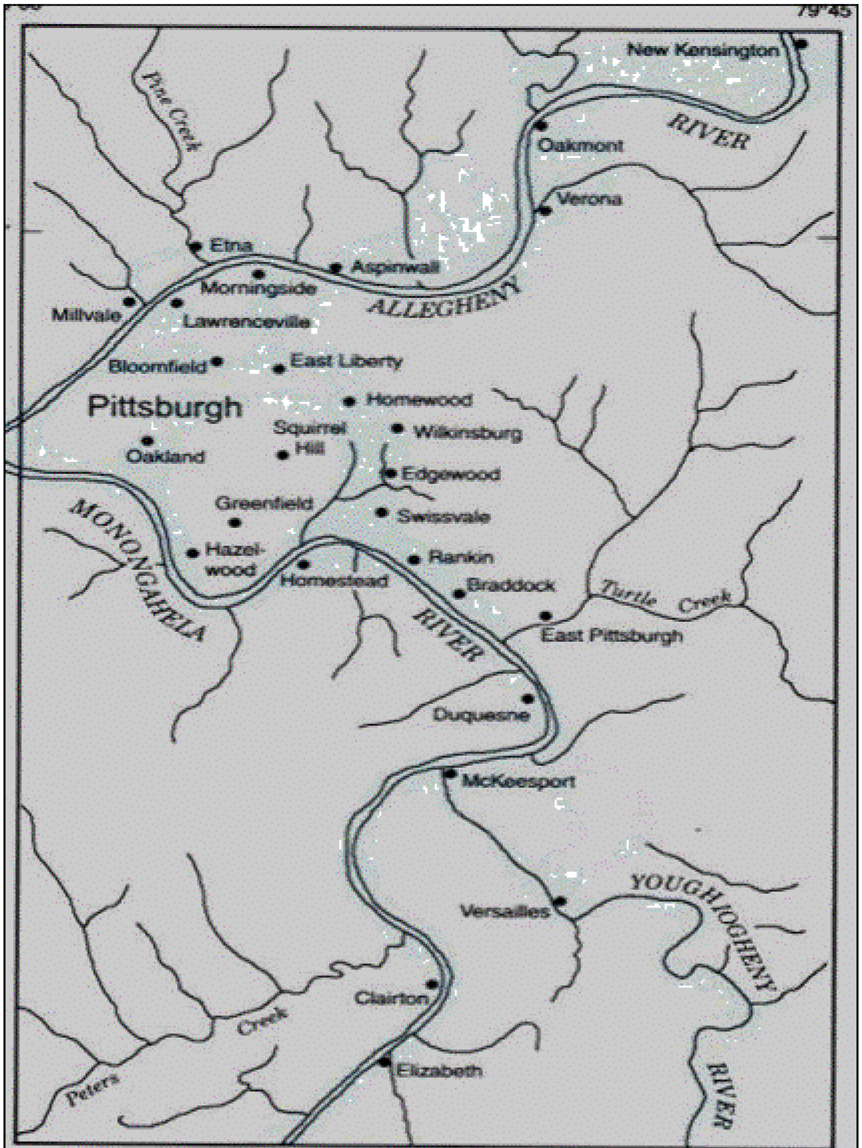

Fig. 5

From Pennsylvania Geology, Vol. 28, No. 3/4.

Urbanization grew up first around this valley because of the desire for proximity to these routes. Only much later did settlements move onto the surrounding hills to the north and south of this valley. Excavations into this remnant valley reveal sediments up to 40 feet deep. These were deposited during the last glaciation.

Pittsburgh and the Glacier Age

As has been mentioned before, Pittsburgh was initially settled because of the strategic confluence of the three rivers. Only later did the mineral resources of the region become significant. The origin of these three rivers go back to the last ice age when a great wall of ice stood to the north of Pittsburgh.

Before the last ice age, the major river in the region was the Monongahela River. It flowed in its present channel north to where Pittsburgh is now. It then turned into the current channel of the Ohio, up to Beaver, and then northwest past New Castle and into the Erie basin. The Ohio was but a tributary of the Monongahela River.

The Allegheny River was unrecognizable at this time since it was three separate rivers draining different parts of the state. All of these rivers eventually drained northward into the Erie basin.

Then, 770,000 years ago the ice advanced into Northwestern Pennsylvania. The great wall of ice blocked the rivers flowing northward, acting like a dam. A huge lake, called Lake Monongahela was formed and grew deeper and deeper. Eventually it became so high it overflowed the divides that separated the streams. This overflow could only go south.

And so the Upper Allegheny joined the Middle Allegheny and the two flowed southward to join the Lower Allegheny making one south flowing river. Meanwhile, the Monongahela backed up and overflowed down the Ohio tributary and cut the divide between the Ohio River and the Kanawha River. All the drainage in the area then headed south and west towards the Mississippi river.

As the glaciers melted, huge quantities of water and sediment were carried south deepening the river valleys. Before the ice age, the rivers in the area meandered back and forth on a flat plain. Afterwards, river valleys cut across the former plains. This cutting down continued at a rapid rate, even after the flow of water from the melting glaciers abated. This is because with the removal of the massive weight of the glaciers, the land literally rebounded upwards. This resulted in the maintenance of a steep gradient for the rivers to flow down, which gave them great erosional energy.

Two subsequent glacial advances, renewed periods of rapid cutting and deposition in the area. This has given Pittsburgh its unique terrain of multiple abandoned river channels up to 200 feet above the current riverbeds. These are the channels that became the prized areas of settlement and routes of transportation into Pittsburgh.

The last of these advances of ice ended 10,000 years ago, and left a large supply of sand and gravel from glacial runoff. Many of rocks found in the gravel of the Allegheny may have been transported clear from northern Canada.

Economic Geology

In 1760, Captain Thomas Hutchins visited Fort Pitt at the site of what would become Pittsburgh, and found a coalmine opened for the use of the garrison. While the location of Pittsburgh was initially determined by the confluence of three rivers, it was coal that drove its subsequent development.

This coal is found in numerous beds underlying much of Allegheny County. The most mined of these beds was the formation called the Pittsburgh Coal, which fueled the future industries of the area. Other important coal beds are the Redstone Coal, Upper Freeport Coal, Middle Kittaning Coal, and the Lower Kittaning Coal. The ready availability of this energy was important for the smelting of iron and the creation of the coke needed to turn the iron into steel. This fuel also powered the brick and glass industries which developed in the area.

Another major source of energy that played a key part in the growth of Pittsburgh industry was natural gas. In the late 19^{th} century, natural gas was discovered in the area . The price of this gas was so low, many industries converted to gas in favor of coal. This caused a major drop in coal mining with subsequent loss of jobs in the area.

However, the low cost of gas permitted massive profits by the industries, which in turn freed capital for further investments in new industries. The widespread use of natural gas for homes meant that there was a major drop in the cost of living in Pittsburgh. As gas remained cheap and distribution systems were put in place, people looked for more uses for this cheap energy.

Inventors in the 1920's created the home gas furnace, water heater, and the gas stove. These remain in wide use today unlike some of the other inventions, such as the gas powered washing machine, vacuum cleaner, and refrigerator.

The natural gas in Allegheny County is found, along with some oil, in sandstone layers. There are some 20 layers of sandstone in the 16,000 feet of sedimentary rock underlying Pittsburgh.   In the present, there is still natural gas being withdrawn from under Allegheny County, but very little oil.

Clay and shale have also been of economic importance to Pittsburgh. Many of the houses in and around Pittsburgh are built of brick because it was widely and cheaply made from the clay and shale in the area. Equally important was the production of special firebricks needed to line the furnaces, which made coke, steel, and glass. In the 1920's there were 13 companies making brick and ceramic pipe in Allegheny County.

The sandstone in the area was also useful for building material. Many houses in the area are built from the Morgantown sandstone. This particular bed of sandstone is uniform in texture and even grained which makes it strong and easy to cut into uniform blocks. This is the buff to gray building stone seen on many of the public buildings downtown.

During the last ice age, large amounts of sand and gravel were deposited by glacial runoff. This material is found in beds in and along the rivers as well as on the bottoms of the valleys left stranded above the rivers. This sand and gravel is important for the building of roads and the mixing of the concrete essential in most construction projects.

Objectives

Students will be able to:

1: Describe the three major types of sedimentary rocks and their origins.

2: Explain the cause of sedimentary sorting by particle size.

3: Name and explain the three laws of stratigraphy

4: Identify the name and the age of the Era in which most of the rocks in Pittsburgh was laid down.

5: Explain how cyclothems and fascies are evident in the rock sequence of Pittsburgh.

6: Describe the origin of the coal and natural gas found in Allegheny County.

7: List the sequence for the development of the three rivers in Allegheny County.

8. Explain how Glaciers affected the landforms of Pittsburgh, to include the origin of the elevated valleys.

Strategies

Students will be given a series of lectures using the material provided in the rationales section to give them the background material needed for the learning objectives. Interspersed between lecture sections, classroom activities and assignments will be given. These will include hands on labs and written assignments.

Classroom Activities

Activity one: Students will construct a timeline using data tape. Students will develop a scale for the timeline, (for example one centimeter equals 1 million years) and plot the major geologic events listed below on the geologic history of Pittsburgh. Students will illustrate the major geologic change points with appropriate pictures on their timeline. Materials needed; One 7 meter length of tape per two students

One-meter stick per two students

One box of colored pencils per two students

1,000 million years ago (mya)- Easter US collides with Europe resulting in the Grenville Orogeny. These mountains rose and then were eroded away. The roots of these mountains remains as deeply heated and twisted basement rock.

650 mya- Eastern US and Europe pull apart, forming the ocean, Iapetus. This ocean widens for the next 200 million years.

450 mya- The ocean, Iapetus, begins to close. As the ocean plate subducts, an island arc of volcanoes forms, fed by the melted subducted ocean plate.

445-435 mya- The US runs into the island arc, causing intense folding, metamorphism, and volcanism. This period of mountain building is called the Taconic Orogeny. Sediment eroded from the Taconic Mountains is carried westward into the basin found where Pittsburgh will be and deposited in the Catskill delta. This delta grows to be up to 4,000 feet thick and extended from New York through Central Pennsylvania

300-220 mya- During the Pennsylvanian and Permian period, Africa collides with North America which begins the Acadian Orogeny. This forms a new range of mountains east of Pennsylvania and the deeply eroded Taconic mountains. Erosion from the Acadians form an even larger delta as material is carried westward.

220-70 mya- No geologic history available for what was happening in Western Pennsylvania.

70 mya- Western Pennsylvania consisted of broad flat plains with slow moving rivers meandering across them.

11 mya- Western Pennsylvania began a period of uplift, that caused the rivers to run faster. The current rivers cut down into the flat plain, dissecting it into valleys.

1 mya- The ice age caused glaciers to advance to just north of Pittsburgh and block the northward flow of the rivers. A great lake formed and filled to overflowing, causing the current rivers to flow in the southward direction they have now.

Activity 2: Students will collect rocks from various areas around their house where the rocks are exposed in situ. These rocks will be brought to class, and the students will use their rock identification table in their books and lab equipment to identify the rock type. After this, the student will use the information given in lecture to form a hypothesis on the age and origin of the rocks they collected.

Activity 3: Students will describe in story form the environment around their house at the time the rocks they collected were formed. They will include the results of research that they did in determining the types of animals and plants that may have populated that environment.

Annotated Bibliography/Resources

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Appendix-Content Standards

Pittsburgh Public Schools Science Standards Addressed

1. All students explain how scientific principles of chemical, physical, and biological phenomena have developed and relate them to real-world situations

2. All students demonstrate knowledge of basic concepts and principles of physical, chemical, biological, and earth sciences

3. All students explain the relationships among science, technology, and society

4. All students evaluate advantages, disadvantages, and ethical implications associated with the impact of science and technology of current and future life

5. All students evaluate the impact on current and future life of the development and use of varied energy forms, natural and synthetic materials, and production and processing of food and other agricultural products