A GEOLOGIC WALKING TOUR

OF TURNERS FALLS MASSACHUSETTS

Geologic Era		Millions of Years Ago
CENOZOIC	Mammal evolution explodes 20 million years ago. Modern humans evolve 500,000 years ago. The last Ice Age begins 80,000 years ago. Glaciers retreat about 20,000 years ago. Residents settle near the Great Falls 10,000 years ago.	65
MESOZOIC	Mesozoic begins with the breakup of Pangea and the opening of the Atlantic Ocean. Lava flows over Turners Falls. Dinosaurs flourish in the Jurassic period and leave their tracks in the Pioneer Valley, before they mysteriously go extinct 60 million years ago.	245
PALEOZOIC	The Paleozoic begins with an explosion of biological diversity 545 million years ago–all of it in the oceans. Life moves on land 400 million years ago. Reptiles evolve 280 million years ago. Pangea forms 250 million years ago.	545
PRECAMBRIAN	The Earth forms and solidifies 4.5 billion years ago. Oceans and the atmosphere form. One-celled organisms evolve.	4500

About the Author

Turners Falls resident and trained hydrogeologist **Steve Winters** is an innovative environmental science educator with a passion for geology and a way of telling the stories hidden in rocks that makes science come alive. Steve combines two careers: Interpreter and Naturalist for the Massachusetts Department of Conservation and Recreation at the Great Falls Discovery Center, and environmental geology instructor at Quinsigamond Community College in Worcester. Most recently, Steve led a series of "climate change" geowalks in Turners Falls to explore the geological evidence of climate change in the early Jurassic period 200 million years ago. Reach him at science_matters@yahoo.com.

This booklet was produced by the Turners Falls RiverCulture Project, a dynamic partnership of leaders from the Turners Falls arts, cultural, and business communities joined together to promote and enhance natural and creative assets in Turners Falls.
For more information on the Turners Falls RiverCulture Project, please visit **www.turnersfallsriverculture.org.**

A GEOLOGIC OVERVIEW OF TURNERS FALLS

Fully assembled Pangea, 250 million years ago.

courtesy USG

The very beginning: A marriage of land masses. The geological story of Turners Falls begins about 250 million years ago, when all the continents on Earth had joined to form one large supercontinent called Pangea. Three hundred million years in the making, Pangea was an assemblage of six to ten ancient continents that collided and fused together. This supercontinent was so huge that its northern and southern edges reached Earth's northern and southern poles.

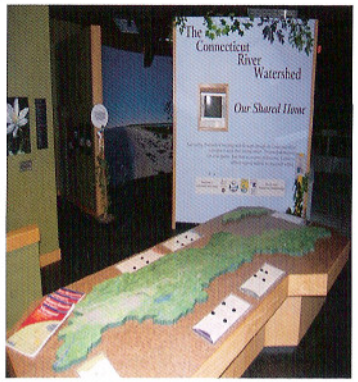
Moving on: The land masses separate. This union of continents did not last long, geologically speaking. Around 245 million years ago, Pangea began to crack or rift apart. Fragments that would become Europe headed east, and those that would become Africa headed south. The basin between North America, Europe, and Africa became the North Atlantic Ocean. Pangea is still breaking up. To this day, the floor of the Atlantic Ocean continues to spread about one inch each year.

Left in the rift. The little village of Turners Falls lies roughly in the middle of an extensive rift valley that spanned Pangea's heart. In this rift valley (called the Newark Superbasin), we can see evidence of both the violent volcanic eruptions that heralded Pangea's breakup and the mild periods of river and lake formation that followed. And we can read the story of the rifting in the composition of rocks found from Nova Scotia to South Carolina.

A lot of geology in a small place. Downtown Turners Falls offers a unique opportunity to see examples of all these features in a very small, easily walkable area. Let's get started!

follow the map on the back cover as we go on our tour!

1 GREAT FALLS DISCOVERY CENTER 2 AVENUE A



The Connecticut River watershed model in the lobby of the Great Falls Discovery Center

Your geologic walking tour of Turners Falls begins at the three-dimensional model in the lobby of the Great Falls Discovery Center, an interpretive museum of the Connecticut River watershed. (A watershed is an area drained by a river.) The Great Falls Discovery Center is a community partnership in natural history and environmental education sponsored by the Silvio O. Conte National Fish and Wildlife Refuge, the Massachusetts Department of Conservation and Recreation, and the Friends of the Great Falls Discovery Center.

THINGS TO SEE

Valleys old and new. A prominent feature of the watershed model is the Connecticut River Valley, a remnant of that great rift valley that once spanned Pangea over 245 million years ago. Looking at the model, you'll see that the modern-day valley extends geographically from the northern tip of New Hampshire to Long Island Sound.

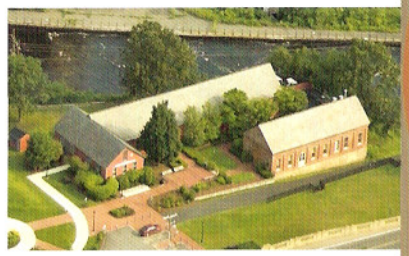
Pangea breaks apart and the land changes. The heating of rock deep within the Earth caused tremendous geologic forces that pulled Pangea apart. Those forces produced the depositional environment that formed the valley now cradling the Connecticut River. (A depositional environment is one in which sediments settle out of water.)

Prodded loose by water and perhaps earthquakes, rock and sediment from ancient highlands to the west and east began to pour into the rift valley. As the valley sank under this heavy load, the surrounding highlands regained their relative elevation. This, in turn, resulted in more erosion and sediment buildup. This process went on for tens of millions of years.

THINGS TO KNOW

Valley sinks down, sediments pile up. As the heavy sediments sank, the southeastern flank of the valley slipped deeper than the northwestern flank. Sediment gradually filled the valley in overlapping deposits called alluvial fans. Eventually, the sediment filling the valley reached a thickness of up to 6,500 feet and, under the pressure of burial, turned to rock. Today, these southeastern-dipping rocks (called the Turners Falls "red beds") form sandstone ridges that extend through Turners Falls and Montague until they disappear underground near the Montague/Sunderland town line.

Rifting helped the river grow. The pulling apart of Pangea caused long north-south cracks to form in the ancient rocks that underlie the valley. Over millions of years, those north-south cracks enabled the development of the Connecticut River, which flows north to south through the valley, from the New Hampshire/Quebec border to the Atlantic Ocean via Long Island Sound.

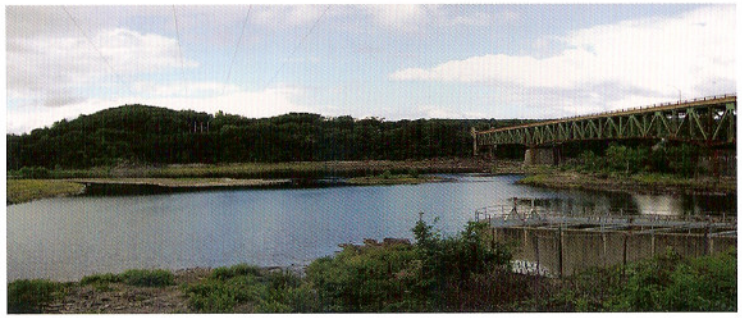


Great Falls Discovery Center

A hard right turn. Notice on the model how the river turns abruptly east at Middleton, Connecticut, before heading south to tumble into the Atlantic at Old Saybrook. The river takes that sudden turn because the basalt (or cooled lava) rock ridges west of the river–a remnant from the violent volcanic break up of Pangea–are too hard for the river to break through.

Step outside the Discovery Center lobby, head down the driveway that runs along side the Great Hall as you face the building, and continue toward the footbridge over the Power Canal. Cross the footbridge and walk to the grassy area under the power lines overlooking the river.

2 A GREAT RIFT RUNS THROUGH IT: RIVER AND ROCK OVERLOOK



View of the Connecticut River below the dam at Turners Falls

Water has been an immensely powerful force in sculpting Turners Falls and the Connecticut River Valley ever since Pangea's breakup began forming our rift valley 245 million years ago. Streams and rivers moved down the ancient mountains, sometimes at tremendous speed, but always, no matter their speed, wearing down the rock and carrying the resulting sediments into the valley. The continuous process of erosion and deposition is still forming our landscape.

THINGS TO SEE

The remains of an early Jurassic landscape. What you see across the river are rocks that were part of a landscape last visible about 200 million years ago, in the early Jurassic period–the days of the dinosaurs! Gradually buried by thousands of feet of sediment, that landscape lay invisible until water and other forces of erosion (wind, frost and thaw, cracking from the roots of plants) began uncovering it some 60 million years ago.

Introducing our village rocks. On this tour, we'll see three rock types resulting from the tremendous forces that broke up Pangaea:
1) the Turners Falls sandstone or formation,
2) the Deerfield basalt, and
3) the Sugarloaf arkose. Across the river at Stop 2, you can see two of these rock types. (You'll see the third, Sugarloaf arkose, at Stop 4.)
First, exposed along the northeast bank, is the Turners Falls formation–a sequence of red sandstones, dark shales, and gray conglomerates–tilting or dipping southeast, towards Boston. You can see the dip of the Turners Falls formation easily in the rocks exposed at the base of the bridge.
Second, look for the dark, massive Deerfield basalt forming the ridge (called Canada Hill) that rises impressively on the northwest side of the river.

Looking west towards Canada Hill

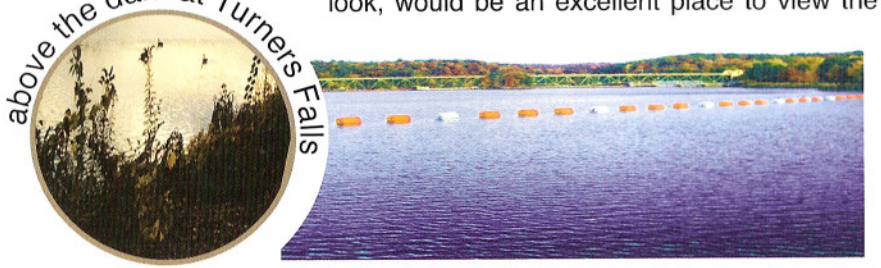
Once there was a lake. The world-famous Turners Falls formation, measuring about 750 feet thick, is the geological remains of a vast Jurassic shoreline, lake, and mudflats. Within about four blocks of the Discovery Center, at least four ancient Turners Falls formation lake beds dip to the southeast. Over many years, these ancient lake beds have been transformed into soft shale; one of the beds contains exquisite fish fossils. (Remember: Unless you have a permit, it's illegal to collect rocks or fossils on public lands.)

THINGS TO KNOW

Reading the valley. The dips in the rocks help us "read" the valley. Originally, sediments were laid down flat (in horizontal beds) as the rift valley was forming. But as the sediments hardened to rock and the rift valley continued to form, the beds were tilted to the southeast as they sank. Because of this dipping, the beds of Turners Falls are stacked like the pages of a book (binding down) tilted on edge: Page 1, the oldest bed, lies to the northwest. Later, younger pages of our geological history book lie to the southeast.

Hot rock. Because the Earth's crust is thinner under a rift valley than in foothills or mountains, hot, melted rock, called magma, comes closer to the surface. Here in our valley, this magma erupted over time through cracks in the Earth's surface and flowed as lava across the valley floor. The lava then cooled and hardened into a rock we call the Deerfield basalt. Today the basalt (tilted up onto its edge) forms the north-south trending ridge called Canada Hill or Rocky Mountain in Greenfield and the Pocumtuck Range in Deerfield. Poet's Seat Tower rests on the Deerfield basalt.

Where are the falls? The Great Falls of the Connecticut River has been a gathering place for area residents for over 10,000 years. Native Americans and, later, colonists, regarded the falls as one of the region's premier fishing grounds. New visitors to Turners Falls wonder where to go to see these amazing falls. Stop 2, the River and Rock Overlook, would be an excellent place to view the



falls, except for one thing: In 1798, the Great Falls was dammed to construct a navigational canal. The canal and nine locks allowed riverboats to travel from Long Island Sound up the Connecticut River to Vermont.
In the 1860s, the industrialists who founded Turners Falls rebuilt the canal and dam to provide power for their factories. Today, the dam and its canal generate electricity for everyone in the valley. Were the Great Falls not dammed, we would see a waterfall drop of about 40 to 50 feet–a reminder that water is still cutting and breaking down rock as it has for hundreds of millions of years.

Walk back to the footbridge and up the driveway, turn right and head into the courtyard near the entrance to the Great Hall of the Discovery Center.

3

RAINDROPS KEEP FALLING ON MY HEAD: A PICTURE POSTCARD FROM THE JURASSIC PERIOD

Tiny crater-like depressions in this rock are 200-million-year-old raindrop impressions.

THINGS TO SEE

As you look at the large rock near the side door in the Discovery Center's inner courtyard, you'll see many small impressions, the size of a dime or smaller. These are the remnants of raindrops from a summer day in the Jurassic period, 200 million years ago.

THINGS TO KNOW

A different climate. Back in the Jurassic, Turners Falls was near the equator, so the noon sun was directly overhead and very bright. Our climate was tropical to semi-tropical, and, because this was a rifting or sinking valley, a shallow lake periodically flooded much of our area.

In fact, the whole Earth was warmer in the early Jurassic than it is now. As with the present-day climate of Costa Rica, summer rains were likely short but intense. The hot sun would quickly dry the fine muddy lakeshore, leaving large mud cracks–like those we can still see today on mud flats in many regions of the world, from Utah to eastern Africa. Once in awhile in those ancient days, afternoon showers would pummel the lakeshore and sometimes these showers left behind tiny raindrop impressions.

How did the raindrop impressions form? Because the warm sun would quickly dry these impressions to a solid or semi-solid state, they were not washed away when the lake water rose. Instead, when more rains would come, the lake waters brought more fine mud that buried the impressions a few fractions of an inch beneath the water surface. Like a photograph from the early Jurassic period 200 million years ago, the raindrop impressions in this rock record a moment in the history of the Earth.

Walk to the Rock Garden in the middle of the Discovery Center grounds.

4

SUGARLOAF ROCK FROM GREENFIELD: JURASSIC ALLUVIAL FANS

An ancient alluvial fan: the Sugarloaf Arkose

THINGS TO SEE

So much of our valley (like much of the ancient east coast of North America) has disappeared as a result of erosion that it's hard even for geologists to visualize the landscape in and around Turners Falls as it was around 200 million years ago.

But these reddish rocks (called Sugarloaf arkose) document what must have been going on. Alpine-scale mountains to the east were being quickly eroded by monsoon-like storms. Mountain stream waters, containing huge amounts of rocky sediment, poured into our ancient valley. We know this by the streambed features and the large, angular pebbles and small boulders you see in these big red rocks.

THINGS TO KNOW

These rocks come from points west of Turners Falls, mainly from the Greenfield area. The streambed deposits from which these red rocks formed were very thick–over a mile in some places. Mt. Sugarloaf (in South Deerfield) consists entirely of Sugarloaf arkose.

We call the rocks that formed from these sediments arkosic sandstones (named for the angular pebbles and coarse sand they contain) and conglomerates (conglomerations, or mixtures, of large but rounded pebbles and cobbles).

These are exactly the materials we expect to see when the sediments from nearby mountains have been aggressively eroded. Mountain stream sediments like these are being deposited today in areas such as Death Valley. We call these deposits alluvial fans.

Walk south across the Discovery Center parking lot to 2nd Street. Walk around the block to the corner of 3rd and Canal Streets.

5 TURNERS FALLS FORMATION UP CLOSE AND PERSONAL: READING CLIMATE CHANGE IN ANCIENT ROCK

Below the rock cliff at 3rd and Canal Streets lies the remains of a Jurassic-age lake.

THINGS TO SEE

The rock face exposed at the corner of 3rd and Canal Streets north of Avenue A offers one of the most interesting and accessible views of the Turners Falls formation you can see anywhere. Notice the alternating thin and thick layers in the formation.

THINGS TO KNOW

What is a formation? A formation is a series of rock types found together that indicate an ancient environment of sediment deposition. The Turners Falls formation exposed on 3rd Street consists of repeating thin-bedded shaley sandstones sandwiched by thick and bulky sandstones.

Thin and thick = wetter and drier. The thin beds indicate the muddy bottoms of deep lakes that formed during wet periods. The thick and blocky beds originated from sediments dropped by streams running through the old lake beds in drier periods, when the lake water was gone. Thus, what we see in this alternating sequence of thin muddy lake bottom sediments and thick streambeds are wet and dry cycles that occurred, on average, every 20,000 years.

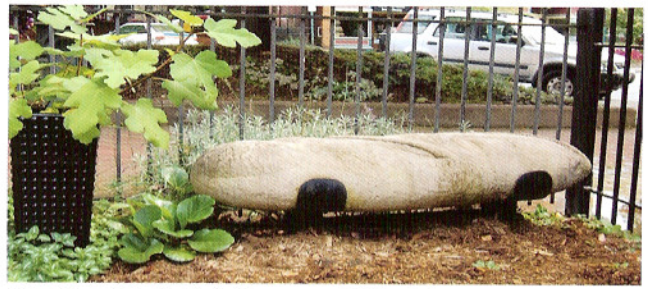
When a rock is a hard place. Where geologists see ridges, they think "hard, weathering-resistant rock." That's exactly what the 3rd Street rock face is. This relatively hard sandstone was once a river channel that now rises up like a small cliff because the less weathering-resistant rock around it has been worn away.

Note, however, the deep cut below the rock face–that rock is anything but hard. What does this sudden difference in rock type mean? Geologists believe the softer rock represents the bed (called lake bed #3) of a deep lake that filled the valley approximately 200 million years ago. These rocks are soft and black because they started out as an organic mud.

As a result of a natural climate cycle in the early Jurassic, the lake dried up and much of its bed was violently eroded away by invading rivers. This cycle happened at least four times in Turners Falls during the early Jurassic.

Walk down 3rd Street to the corner of Avenue A and take a right turn to proceed to Ristorante DiPaolo at 166 Avenue A.

6 DIPAOLO'S BREAD LOAF ROCK: ANCIENT ROCK EVEN WHEN DINOSAURS ROAMED OUR VILLAGE



Bread Loaf Rock sits in its corner at DiPaolo's.

THINGS TO SEE

Ensconced in the corner of the restaurant's outdoor dining area, you'll see a loaf-shaped object that serves as a bench for waiting customers. Carved by Turners Falls artist Tim De Christopher, Bread Loaf Rock is formed from one of the oldest of all the rocks in Turners Falls: a 345-million-year-old limestone from Bloomington, Indiana. Bread Loaf Rock was ancient even when the dinosaurs roamed our village!

If you have an opportunity, look closely at the rock and you'll see innumerable tiny marine fossil shells.

THINGS TO KNOW

The tiny fossil shells in the Bread Loaf Rock tell us the environment in the Midwest approximately 345 million years ago: a warm, shallow sea, such as we may find today off the Florida Keys. Eventually, this ocean (called Panthalassa) became the Pacific Ocean when Pangea broke up 245 million years ago.

Walk on to Peskeomskut Park on Avenue A between 6th and 7th Streets.

7 PESKEOMSKUT PARK: A PLACE TO EXPLORE

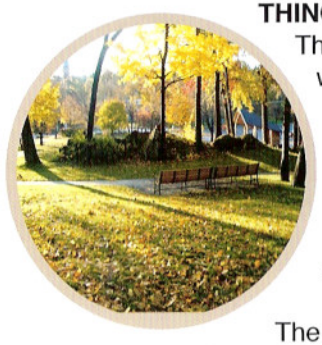
THINGS TO SEE

What's nice about the Peskeomskut Park rocks is that they lie face-up–that is, we can see fossils, bed marks, and other objects as they were deposited on the stream bed surface.

View of the southeast-dipping rock outcrop along J Street.

PESKEOMSKUT PARK: A PLACE TO EXPLORE

Look around at the rock faces. You may find ripple marks, mud cracks, rain drop impressions, and clay chips, called rip-up clasts, embedded in the sandstone.



THINGS TO KNOW

The rocks of Peskeomskut Park reveal a time when the Jurassic lake covering Turners Falls was drying out. Lake waters were retreating (geologists say regressing), and the shoreline underwent significant erosion. The tiny sand dunes or ripple marks, raindrop impressions, and mud cracks on the faces of the rocks are evidence of ancient shallow water.

The rip-up clasts give us further evidence that the lake bed was being eroded. The clasts were pulled loose from dried and cracked mud, carried away, and buried. Rip-up clasts give the rocks at Peskeomskut Park their flagstone appearance.

Walk south along the sidewalk on Avenue A to the pedestrian crossing. Cross the street to a stairway leading up to Our Lady of Czestochowa Roman Catholic Church.

8 OUR LADY OF CZESTOCHOWA: POLISHING THE ROCK RECORD

THINGS TO SEE

The rocks of Turners Falls reveal far more geological history than just the happenings of the early Jurassic period 200 million years ago. Climb the stairs from Avenue A to K Street, which runs by Our Lady of Czestochowa Roman Catholic Church. About 100 feet from K Street, you should see the reddish sandstones of the Turners Falls formation, but they will have a notable polish on their surface.

THINGS TO KNOW

The smoothing-over of the rocks results from the movement of glacial ice over them approximately 25,000 years ago, in the Pleistocene epoch.

OUR LADY OF CZESTOCHOWA

A mountain of ice and snow 1 to 2 miles thick and the size of a continent covered Canada and the northern states of the U.S. from about 1.6 million to 25,000 years ago. This continental glacier did not remain static but grew and shrank as climate cooled and warmed over this period. New England experienced at least four of these glacial advances and retreats over the past 1 million years. Only the last, called the Wisconsinan, left much of a trace.

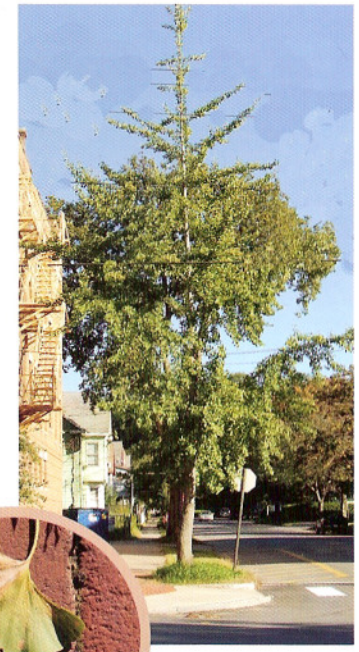
As the glacier moved south into Massachusetts, its southern margin fanned out into lobes bulging southward. Unimaginably heavy, these ice sheets scoured the landscape down to the bedrock. If boulders were lodged at the base of the ice sheet, the glacier would drag them over the bedrock, scouring it with grooves that geologists call striations. Even without boulders, the pressure from the ice alone could smooth and polish the rocks, as if they were gems in a jeweler's shop.

Go back down the stairs to Avenue A and walk to the corner of 5th Street.

LIVING FOSSILS: GINKGOS 9

THINGS TO SEE

Imagine yourself taking a break on a sunny day under the Mesozoic shade of a Turners Falls ginkgo tree–an ancient species almost lost to the world 5 million years ago. Actually, we needn't imagine: Ginkgo trees are alive and well today at the corner of Avenue A and 5th Street in Turners Falls.



THINGS TO KNOW

Once abundant in the Triassic and Jurassic periods around the world, the ginkgo almost went extinct about 5 million years ago, except for a small area of central China where the modern species survived.

Ginkgos are called living fossils. What does it take to earn that moniker? Like the famous coelacanth fish, you need to be a member of a

One of a pair of ginkgo trees at the corner of Avenue A and 5th Street

LIVING FOSSILS: GINKGOS

species otherwise known only from fossils. Plus, you've got to have no close living relatives. You should have an extremely long lifespan (some ginkgos at Chinese temples are believed to be over 1,500 years old), a slow reproduction rate, a wide and apparently contiguous range, and a low population density.

Despite its reputation as a living fossil, the ginkgo is a hardy tree that can tolerate the often polluted and confined soils of cities. It's disease-resistant and rarely attacked by insects. Male trees are particularly valued (some find the female tree's seeds noxious) and are a popular choice to line the streets of many of the world's cities.

Continue along Avenue A to 1st Street, head toward the river, and turn right (east) to walk along the bike path where it follows along the river. At the end, you'll come to a parking lot.

10

THE WORLD-FAMOUS ARMORED MUD BALLS OF TURNERS FALLS

THINGS TO SEE

As you approach the parking lot from the bike path (with the river to your left), look for three large boulders, about the size of riding lawn mowers. These half-ton blocks of stone are the remnants of the Old Red Bridge that joined Gill and Montague from 1878 until the great flood of 1938, when the bridge was irreparably damaged. All that's left today are the stone supports on both the Gill and Montague sides. Some years ago, local history buffs and geologist Richard Little noticed unusual round features called armored mud balls embedded in these stones.

THINGS TO KNOW

How do you make an armored mud ball? Golf- to tennis-ball-sized, these dark brown spheroid inclusions originally were chunks of clay that rolled down the hillsides bordering the Jurassic lake (and sometime mudflat) that was once our Connecticut River Valley. As the inclusions rolled, their corners rounded, and they became ball-shaped.

THE WORLD-FAMOUS ARMORED MUD BALLS

Some of the rolling mud chunks picked up pebbles of hard rock that stuck to their surfaces, as if wrapping the chunks in a protective armor. When the mud balls reached the lakeshore, they were quickly buried by fine mud or sand and preserved for the ages as the Famous Armored Mud Balls of Turners Falls.

A Turners Falls exclusive.
Although not common in the geologic record, armored mud balls from marine environments have been found and are still forming in alluvial fan environments near glaciers or ocean beaches.

But armored mud balls from inland or terrestrial lakes (such as existed in the Connecticut River Valley of the early Jurassic) are found only in Turners Falls.

Here, at the armored mud balls, ends our journey through over 200 million years of geologic history. Be sure to visit the Great Falls Discovery Center and check the resources at the end of this walking tour if you'd like to learn more about the fascinating geology and natural history of our valley.

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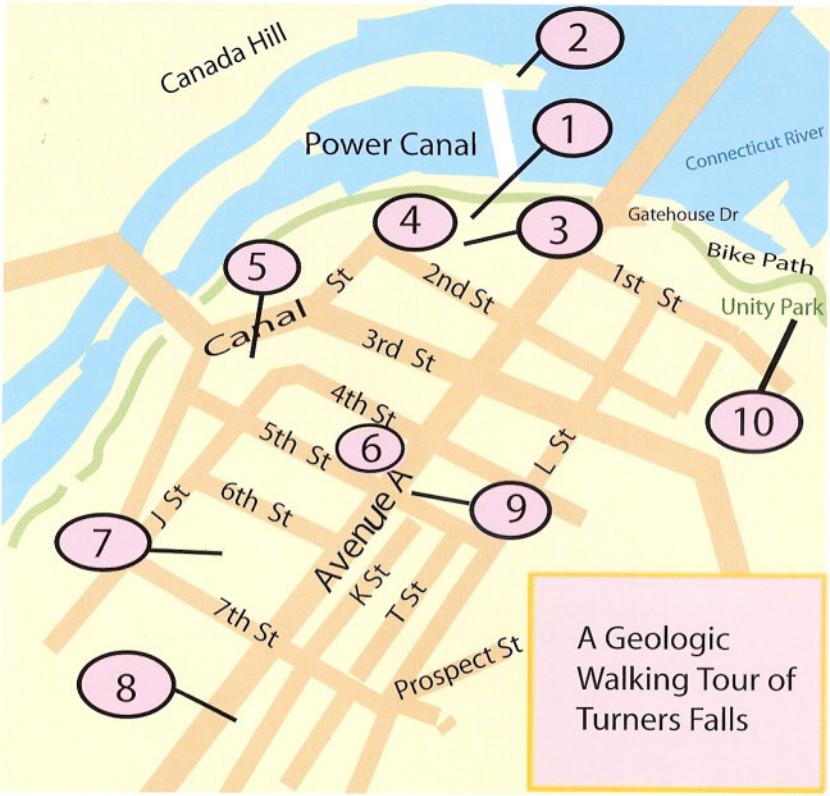

1 Great Falls Discovery Center 2 Avenue A
2 Connecticut River and Rock Overlook
3 Courtyard at Discovery Center
4 Sugarloaf Rock Garden at Discovery Center
5 Turners Falls Formation at Canal and Third St
6 Bread Loaf Rock at DiPaolo's
7 Peskeomskut Park
8 Our Lady of Czestochowa
9 Ginkgos, the Living Fossils
10 World Famous Armored Mudballs

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