What You Might Not Know About Where We Live:
The Geology, Hydrology, and Related History of Long Canyon

by
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> "What's with all those rocks with holes in them? It looks like fossilized Swiss cheese."
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> "How come Bell Mountain Drive has such a short, steep hill and then is basically flat for so long a distance?"
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> "Did someone dump a bunch of old seashells at the back of my lot when they were constructing Long Canyon?"
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> "Can I dig a well in my yard to water my grass and lower my water bill?"

Maybe you have heard someone ask questions like those, or perhaps you have thought of them yourself. The answers to those type questions relate to the geologic and hydrologic setting of Long Canyon Subdivision. And understanding that setting might be helpful in better appreciating what a special place we live in. So let's take a high-level look at it all.

Geology 101 (well, maybe just a couple of days of class)

No, I'm not trying to make any of y'all geologists. (But if you already have an interest in geology or hydrogeology, either as a hobby or a career -- and still do after reading this report!-- I would be happy to talk with you further about what's covered here, or geology in general, types of jobs, etc., if you would like.) For now, I just want to make a couple of points at the outset that might make the rest of this a little more understandable for non-geologists.

First, geology is the study of the earth, and the earth is formed of rocks, which tell us geoscientists about the world as it was when those rocks formed. And it probably seems common sense, but it might be worth a reminder that different rocks were formed at different times in the past and are in a time sequence, generally with younger rocks overlying (resting on top of) older rocks. Basically, the older rocks form the foundation, both literally and figuratively, for the formation of younger rocks. Secondly and somewhat unfortunately, most of what we geologists know with some certainty is only what is readily accessible to us at or near the earth's surface. There is less and less information available as we go deeper and deeper underground, such that uncertainty increases with depth below the earth's surface. This means the older, deeper rocks are less well studied, so less is known about them and what we think we know about them may not be accurate, or complete.

Oh, one other thing. I will try to keep the descriptions below non-technical for you, but if you get lost in places, hang on, and I'll try to help you through it. And no worries…there won't be a quiz at the end, so feel free to skip ahead if something is too boring, or incomprehensible. I will insert a couple of figures here and there that might be of interest and help too. But for now, class is over…let's get started.

Geology and Geologic History of Long Canyon

It's been said that before there is a history of a place, its pre-history is told by the story in its rocks. The story of the Long Canyon we know today is a fairly simple one, geologically speaking, but it is nevertheless rather amazing to consider how it developed. The age of the earth is estimated to be around 4.6 billion years old, give or take a hundred million years. But the rocks at the earth's surface in Long Canyon are quite young, *only* about 100 million years old. Still, think about that – those in-place rocks that we see along the side of our roads and in our yards (and sometimes scrape with our lawnmower blades --- %#&!) have existed right where they now are for tens of thousands of times longer than the earliest humans have been walking around these parts. And that just goes for the "young" rocks we can see at the surface today.

Do you like layer cake? Me too! And it's sad to see a cake plate when most of the cake is gone, isn't it? But when the cake is half-gone, it's really easy to see the various layers of different textures and colors. Now imagine that you could take a humongous cake knife and cut away half of Long Canyon right next to your house deep into the earth, so that you are looking at its subsurface layers from the side, just like a layer cake. What rock layers might you see? As we explore the answers to that question here, it might be helpful to refer to the geologic time scale in Figure 1 on the next page.

The Oldest Rocks Are in the Basement (but you can't go down there…oh, wait)

We are bravely going to start our discussion of Long Canyon's geology and hydrology with what we know least about! As we learned above, that would be about the deepest layer, and therefore oldest rocks. In our layer cake-like view, the bottom-most layer, which geologists aptly if rather unimaginatively call "basement rocks", would be encountered many thousands of feet below your house. These are some of the oldest rocks that are known to exist in Texas, and range from more than one to about two billion years old, formed during what's known as the Precambrian Era of geologic history. These include some igneous rocks, which originated from molten material (think magma in volcanoes), but mostly they are metamorphic rocks, which originate from other types of rocks that are transformed under tremendous heat and pressure over time. The basement rocks in Central Texas have been all mashed together on multiple occasions over the millions of millennia, forming new rocks. Then, a little more than a billion years ago, granite-like material from great depth was forced up into some parts of these rocks in Central Texas.

Probably none of those granites and little of the older metamorphic basement rocks in which they intruded, which formed the growing edges of what we now call the North American continent, extended eastward as far as Long Canyon. But some probably did, although they might be several miles below us -- better get a longer cake knife!

ERA	PERIOD	EPOCH	Rocks in LC	Years Ago
CENOZOIC	Quaternary	Recent	Creek Alluvium	10,000
		Pleistocene	*Probably Never Deposited Here*	1 Million
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene		65 Million
MESOZOIC	Cretaceous		*Later Cretaceous* Edwards and Walnut Formation Glen Rose and Trinity Group	125 Million
	Jurassic	*Missing?*		
	Triassic			200 Million
PALEOZOIC	Permian		Later Paleozoics	
	Pennsylvanian			
	Mississippian			
	Devonian			
	Silurian			400 Million
	Ordovician		Early Paleozoics	
	Cambrian			600 Million
PRECAMBRIAN			Igneous and Metamorphic Basement Rocks	1 Billion 2 Billion
			Older Basement and Crustal Rocks	4+ Billion

Figure 1. General Geologic Time Scale for Rocks of the Long Canyon Area

Not much is known about those rocks' early history. What is known is that about a billion years ago, a couple of hundred million years after the granites intruded, these rocks were uplifted across a broad area of Central Texas into a great mountain range, perhaps similar to today's Sierra Nevada, that existed for hundreds of millions of years.

By the way, while we obviously can't see those deep basement rocks in Long Canyon, if you take a short drive out to the Marble Falls-Burnet-Llano area, some of this region's old basement rocks -- in the form of pink and light-colored granites and even older metamorphic rocks (gneisses and schists, for you rockhounds), which were raised up by those geologic forces a billion years ago -- are exposed at the earth's surface. This area is known as the "Llano Uplift". Both Enchanted Rock State Natural Area between Llano and Fredericksburg and Inks Lake State Park west of Burnet have some of these granite intrusions that are easily viewable and accessible.

What's below these basement rocks? We don't know. Presumably even older basement rocks, until at depths of tens of miles they become plastic-like and then molten under the heat and pressure deep within the earth, and then are reprocessed into new earth's crust. But that's another story.

What Lies Beneath… (…what we can see today)

All rocks overlying these old basement rocks in Central Texas at least originally were sedimentary rocks. As you might guess, *sediment*ary rocks are formed from *sediment*s. Some types of sediments originate from weathering and erosion of rocks that were at the earth's surface elsewhere, and then transported by wind and streams and deposited in this region; some sedimentary rocks form from sediments produced by biological or chemical processes in marine waters. The type of sediment not only determines what sedimentary rocks are formed from it, but it also informs us of the conditions that existed in the area when they were deposited.

But we also don't know much about the earliest sedimentary rocks in the Long Canyon area. This is because not only are they very deep but also after they were formed they underwent some extraordinary transformations (which we'll hear more about on the next page.) But we can infer what might have taken place here back then by looking at rocks of similar ages nearby. Here's what we think we know:

The layers of these rocks that were on top of the basement rocks here originally formed from 600 million to about 450 million years ago. These are rocks from the Cambrian and Ordovician Periods of the Paleozoic Era, as shown on the geologic timescale in Figure 1. Rocks of a similar age are also exposed at the surface to the west of us at various places, on top of the basement rocks in something of a partial concentric ring around the Llano Uplift. They are largely marine limestones and beach sandstones from a near-shore environment. A really good place to see these old limestones is at the falls and canyon of Pedernales Falls State Park. Some of the even older sandstones are exposed in tall roadcuts outside Llano on the way to Brady.

By extrapolation and inference (which geologists do a lot of), we can conclude that the Long Canyon area during this time probably was offshore of an ancient east-west shoreline that moved back and forth somewhat but was mainly to our north and west. So the rocks from this age here in Long Canyon might be a bit different than those that we can see today just to our west, considering the different depositional environment. But we don't really know. What is believed to have been taking place mostly during that time about 500 million years ago was the continual erosion of the mountains of the Llano Uplift, and the transport and deposition of the eroded sediments in, and to the north, east, and south of, our area. In any event, a little math shows that we have a time gap of almost one half billion years, between the youngest basement rocks and these next younger rocks, a gap that we don't have any information about.

On top of those early Paleozoic rock layers are late Paleozoic sedimentary rocks that were deposited in our area after a long period of non-deposition (and therefore no rock record) and after a significant amount of erosion (which removed rocks that had been previously deposited, including some of the early Paleozoic rocks). These rocks were originally formed from sediments deposited from 300 to 225 million years ago, probably in a long, broad trough that bordered the early North American continent. By then the mountains of the Llano Uplift that were created near the start of the Paleozoic Era had been reduced to lowlands and weren't producing as much sediment as before. So this trough also received sediments from farther-away places to the north and east, and from near-shore marine environments. This trough kept subsiding under the weight of these sediments and would eventually contain thousands of feet of limestone, shale, siltstone, mudstone and other fine-grained sediments. This great trough extended from what is now Arkansas through southeastern Oklahoma and North and Central Texas to the Big Bend area.

Then a remarkable thing happened! The sedimentary rocks in this trough, probably along with at least some of what remained of the older Paleozoic rocks, were compressed, deformed, folded, faulted, and uplifted in a great mountain-building period called the Ouachita (pronounced "Watch´-uh-taw") uplift. This mountain-building is related to but distinct from the set of geologic forces that formed the Appalachian Mountains far to the northeast. Geologically speaking, all this occurred rapidly, but it took place over millions of years. But at the end of the Paleozoic Era, about 200 million years ago, the Long Canyon area was in the mountains and might have resembled the setting of, say, today's Taos, New Mexico! Well, without the ski and craft shops.

The rocks that formed these mountains were essentially welded geologically to the margins of the emerging North American Continent. But they started immediately to be worn down by erosion. The eroded remnants of this mountain chain, which are present only in the deep subsurface today, form something of another basement in our area, which is called the Ouachita Belt by geologists. In Long Canyon, the Ouachita Belt is probably first encountered about 1500 feet below the land surface and its rocks are often referred to as "basement", even though we can infer a possible, older sub-basement besides this one, as described earlier. It is likely that the geologic forces that formed the Ouachita Belt melded the basement rocks of those two different ages together so they might not be distinguishable, basically metamorphosing them into one.

But then the geologic record in the rocks of this area has some more time gaps and some more uncertainties. We geologists surmise the Long Canyon area and all of Central

Texas was well above sea level as a result of the Ouachita mountain-building for most of the next one hundred million years or so. The rocks then at the surface in Long Canyon, mainly the Late Paleozoic rocks as described above, were being eroded and transported away from this area, generally to the southeast, to a major new trough that was the precursor to what we now call the Gulf of Mexico. Some sediment of various types was probably trapped in this vicinity from time to time, but as with most of the North American continent, the rock record during this post-Paleozoic, early Mesozoic period is spotty and/or missing. But generally, we had a long period of time during which the mountains once again were eroded away, creating what geologists call an unconformity, before the next, much younger rocks were deposited on top of it in our area.

Finally, Long Canyon Becomes of Age (and she's already worn down!)

By about 125 million years ago, our formerly mountainous area had largely been reduced to undulating lowlands and eventually became an area where deposition dominated, rather than erosion. If you were to visit our area back then, it would probably be something like the present lower Gulf Coast or Yucatan peninsula, generally a coastal plain-marsh-lagoon-barrier island system bordering a warm, shallow sea, although with time it changed back and forth between more inland and more marine conditions. There were likely low islands from time to time in the areas to the west, suggesting that the Llano region was undergoing one or more additional periods of gentle uplifting, and all of this was behind several large reef systems. For about 50 million years, sediments were deposited in this area that became the alternating and sometimes mixed layers of limestones, marls, clays, siltstones, and occasional salt deposits and sandstones of the typical rock formations that we see in our Hill Country today. And because they are accessible to geologists, we know (or think we know) quite a bit about them.

These rocks are of late Mesozoic age, more specifically the early Cretaceous Period. Generally, the warm seas from the Gulf slowly encroached northwestward over this time, and the Long Canyon area changed over time from fluvial (i.e., stream-dominated) to near-shore/marine to offshore/marine environments. Small local differences in topography and marine hydrography affected which of these environments controlled deposition at any given point in time in this period, and therefore determined the rock types that were formed from them.

The older of these Cretaceous rocks, called the Trinity group, are so deep that we don't see them exposed at the land surface in Long Canyon, even in the lowest points of the stream beds. But we know they are there, because they are penetrated by deeper water wells and boreholes, and once again they are exposed to the west of us. But in Long Canyon, it is the younger sedimentary rocks of the Glen Rose formation (which technically is the upper part of the Trinity group) that are exposed at the surface, from the stream beds of West Bull Creek to almost the top of the adjacent hills. The rocks of the Glen Rose run the gamut from fluvial to salt-marsh to supratidal to beach to lagoon to offshore marine in character. All that means they were probably deposited on a shifting, broad shallow marine shelf, similar to our current continental shelf-coastal areas along the Gulf of Mexico. But overall, these rocks provide evidence of a shift during the Early Cretaceous Period from more land-based to more marine-based environments, as the seas transgressed inland. These Cretaceous rocks are probably about 900-1000 feet in maximum thickness in the Long Canyon area, and of course the actual thickness at any one point varies with surface elevation.

But the very top of the hills in Long Canyon and the nearby areas have a thin covering of the clays, marls, and limestones of the Edwards group of formations on top of the Glen Rose formation. Most of the hundreds of feet of the Edwards formation that previously existed in this area and all of the even younger Cretaceous rocks that at one time were on top of them have been eroded away, after this area was exposed to erosion following the deposition, consolidation, and lithification (i.e., the hardening, rock-forming process) at the end of the Cretaceous period. Only the bottom 50-100 feet or so of the Edwards is preserved (i.e., not eroded away) in Long Canyon, and it only exists at the top of the hills and ridges in our area. So in our layer cake, the Edwards can be thought of as the top icing.

The transition between the Glen Rose formation and the Edwards limestones is the Walnut formation (now considered the bottom unit of the Edwards group), which formed in this area as a near-shore, in some places shoal or reef-like depositional environment that supported lots of marine life, and therefore typically has many different types of marine fossils. You can find well-preserved fossil oyster and other shells at places along this horizon in the Long Canyon area; these are fossils of animals that lived some 100 million years ago. Elsewhere in the Austin area, you can see mud cracks and dinosaur tracks preserved in the Walnut clays and can almost visualize these large reptiles tromping through the lagoon marshes that existed back then. But most of the younger Edwards formation is composed of near-shore to offshore marine rocks, meaning the shoreline was probably to the northwest of Long Canyon at the time it was being deposited on that shallow marine shelf.

Consolidated rocks younger than the Edwards formation are not found in Long Canyon; some were there at one time, but are now eroded away. But they are present a few miles to the east and consist of softer, more marine limestone and clays, indicating the continued encroachment of the ancient Gulf of Mexico's shoreline northwestward at the time of their deposition. So, we would have needed to live on houseboats in Long Canyon at that time! And we might not have been able to see any shore – by then, that sea stretched all the way to Canada!

After all the Cretaceous sediments were deposited, the whole region sort of began tilting, with the area to the northwest continuing to gently uplift and the area to the southeast subsiding. The warm shallow sea that was responsible for all the Cretaceous rocks began to retreat southeastward around the start of the Cenozoic Era, about 65 million years ago. It has been retreating more or less ever since, to its present Gulf Coast position. As the shoreline moved to the southeast, the Cretaceous rocks in our area (along with the older rocks to the west) were exposed to the elements and began to erode, with the sediments transported and deposited increasingly toward the southeast, in the process creating more of Texas. Since they were at that time probably rather easily eroded because they were mostly softer sedimentary rocks, and since there was not a great deal of local relief to begin with, erosion for several tens of millions of years was fairly efficient and uniform, producing a rather flat erosional surface in this area. It is also interesting to note that some of the sediments eroded in our area were subsequently transported southeastward, together with sediments from other locations, and now form some of the extensive oil and gas reservoirs in the Texas Gulf Coast region.

As something of an aside because it doesn't have to do directly with what is in the rock record of Long Canyon, it still may be of interest that when the youngest Cretaceous sediments were being deposited in this region, it also was accompanied by some volcanism. At least seven volcanoes formed within a few tens of miles of Long Canyon. (We might have even been able to see some of those volcanoes from our houseboat in the Cretaceous sea!) Geologists postulate that this volcanism was related to areas of weakness in the earth's crust that were stressed by the differential settling of Cretaceous sediments on the basement rocks. Volcanic ash that almost certainly fell on Long Canyon in the Cretaceous period from these volcanoes was eroded away along with the soft limestones and marls in which it was co-deposited. But some remnants of these volcanoes and ash beds can still be seen today elsewhere in the Austin area, most notably at Pilot Knob immediately southwest of Austin-Bergstrom International Airport (it was used as a reference point for pilots when ABIA was an air force base, hence the name) and also at the hill in South Austin where St. Edwards University is located.

That's Not Our Fault, Is It?

While the Cretaceous rock beds in this area are fairly horizontal, sloping very gently to the southeast, regional blocks of these rocks have been vertically displaced along the steeply sloping faults of the Balcones Fault Zone (BFZ), which is aligned in a roughly NNE-SSW direction in this area and extends for hundreds of miles in a gentle arc across Texas. Faults are fractures in the rock along which some movement has occurred. The BFZ has numerous individual faults but taken together, the flat-lying rocks on the western side of the fault zone are higher relative to those flat-lying rocks on the eastern side by about 700-800 feet vertically. Long Canyon is situated within the BFZ, but we're on its far western side and most of the faults are to our east. This faulting occurred in more recent geologic times, from about 50-30 million years ago, during the Miocene Epoch of the Cenozoic Era (see Figure 1 again.) The ground in Long Canyon may have been shaking a lot during that time! After it was all over, the bottom of the Edwards formation that is exposed at the top of the hills in Long Canyon was displaced vertically so that it is only found in deep wells around I-35, on the eastern side of the BFZ.

You don't have to worry about earthquakes in Long Canyon today – the Balcones fault is seismically inactive.

Most geologists believe that the Balcones faulting probably was less the result of the northwestern side's being uplifted, and more the southeastern side's sliding, or being dragged, downward under the weight of all those sediments on the edge of the Gulf basin. The harder underpinnings provided by the basement rocks in the Austin area, relative to those to the southeast, essentially created a flex point for the fault movement of the rocks down to the southeast. There may have been a minor amount of volcanic activity associated with this faulting. But the volcanoes that are near the BFZ that were discussed earlier, while reflecting the geologic stresses along the same basement-rock flex point, preceded the Balcones faulting by some 40 million years.

But What's Really Unbelievable….

While all this intruding, uplifting, eroding, depositing, lithifying, deforming, mountain-building, erupting, metamorphosing, faulting, etc. was taking place in our region over the past two billion years, the entire continental area containing this region (what we now call North America) was very slowly moving around the surface of the earth, as were all the other continental areas across the globe! These continental areas were rotating and moving toward and eventually slamming into each other, forming "super-continents"; and then breaking apart, in somewhat new continental forms, and moving away again. This has occurred repeatedly throughout the earth's history, in what is known as continental drift. So Long Canyon hasn't always been at latitude 30° 22' N and longitude 97° 49' W on a globe! And throughout its history, our area has been a lot different climate-wise than now, as it moved closer to the polar region and to the equator in its various travels and as different land masses affected oceanic currents and jet-streams.

It turns out that this phenomenon is the key to the geologic forces that create mountains and volcanoes and that form new earth crust. (Geologists use a fancy term, "plate tectonics", to describe this global geoprocess. Try working that into your next dinner party conversation.) There's a lot more to this story than we need to go into here, and geologists are actually still trying to understand how all of this is manifested in the geologic record of a particular area. Continental drift is still occurring today, as a measurable phenomenon. But it's not likely to affect your frequent flyer miles -- we are moving away from Europe and closer to Asia only by a few inches per year.

Land Forms and Land Use

The development of land forms (hills, ridges, valleys, streams, etc), the study of which geologists call "geomorphology", is a product of 1) the geology, especially the types of rocks exposed at the earth's surface and their structure, and 2) the climate that operates to change the rock substrate. There are several notable geomorphological elements in the Long Canyon area.

The first is the characteristic "stair-step" topography associated with the alternating softer and harder layers of the Walnut and Glen Rose formations exposed on the hillsides. These strata have different erosional properties, with softer strata forming flatter "benches" along the hillsides and other, harder layers producing steeper slopes. These benches have been commonly used in the past for ranch roads and trails because they are laterally extensive and relatively level; you can still see remnants of these roads on various benches today in Long Canyon.

The second geomorphological element expressed in Long Canyon is the rather flat, laterally continuous surface that comprises the tops of the hills in the area. Bell Mountain Drive, after climbing away from RR 2222 near the valley floor, is situated on hilltops and connecting ridges that all have about the same elevation. In fact, some of you probably have observed that a projection of this surface will also include the tops of Jester Estates, River Place, Westminster Glen, and Tumbleweed Hill, all of which are also flat and have about the same maximum elevation (my crude hand sketch in Figure 2 *may* illustrate this

– but I'm a geologist, not an artist!). At one time this was in fact a more or less continuous, relatively flat land surface. This surface is called the Jollyville Plateau, and it was formed by the regional erosion of the Cretaceous rocks that were exposed to the elements throughout this area during the early part of the Cenozoic Era. The entire area was worn away over a long period of time (in this case, several tens of millions of years) to about the same level, with the level being defined in our area primarily by the harder Edwards limestone layers. Geomorphologists call this type of surface a "peneplain"; maybe you can use that tidbit in your next trivia contest!

The Jollyville Plateau is now being actively eroded at its edges, both by action of various streams at the surface and by dissolving of the limestone layers in the subsurface, through a process descriptively called dissection. The tributaries to the Colorado River such as Bull Creek are responding to the down-cutting action of the master stream as the Colorado makes its way from the uplands west of the Balcones Fault Zone to the retreating Gulf of Mexico at the downstream end. The West Branch of Bull Creek has formed the valley along RR 2222 between Long Canyon and Jester Estates and is working its way northwestward, with Tumbleweed Hill and Bell Mountain Drive's hill near 2222 now at the dissected edge of the plateau. And a sub-tributary, Cow Fork of West Bull Creek, is carving out the smaller valley for which Long Canyon is named and where Long Canyon Drive is located, and these sub-tributaries eventually will dissect the ridge along which Bell Mountain Drive runs, so that it becomes hilly rather than flat. But don't worry – complete dissection and erosion to a peneplain in this area will take considerably more time than any of us have here on earth, by, oh, maybe 20 million years.

A third geomorphological element is related to the Balcones Fault. The faulting has had the effect of placing harder, more resistant-to-erosion rocks on the west side of the fault zone, and softer, less resistant rocks on its east. Over the following 25 million years or so, the rocks to the west of the fault (generally the Edwards limestones) were eroded away much less than the rocks to the east, and they formed what we now call the Hill Country, which of course is the location of Long Canyon. The Balcones Escarpment is the land surface expression of this difference in current rock types along and on either side of the fault.

While it is only a few hundred feet in elevation difference, the escarpment has a dramatic influence on rainfall. Moisture-laden warm air masses rapidly moving inland from mobile low-pressure systems in the Gulf are elevated by the escarpment into slightly cooler air and dump prodigious amounts of water in a short period of time into the small streams along and northwest of the fault zone. This produces some of the most intense rainfalls in the world, and also flash-flooding along the area streams. Long Canyon, like other areas of the Hill Country near the escarpment, has rainfall distributions that vary greatly month to month and year to year, and also locally from area to area.

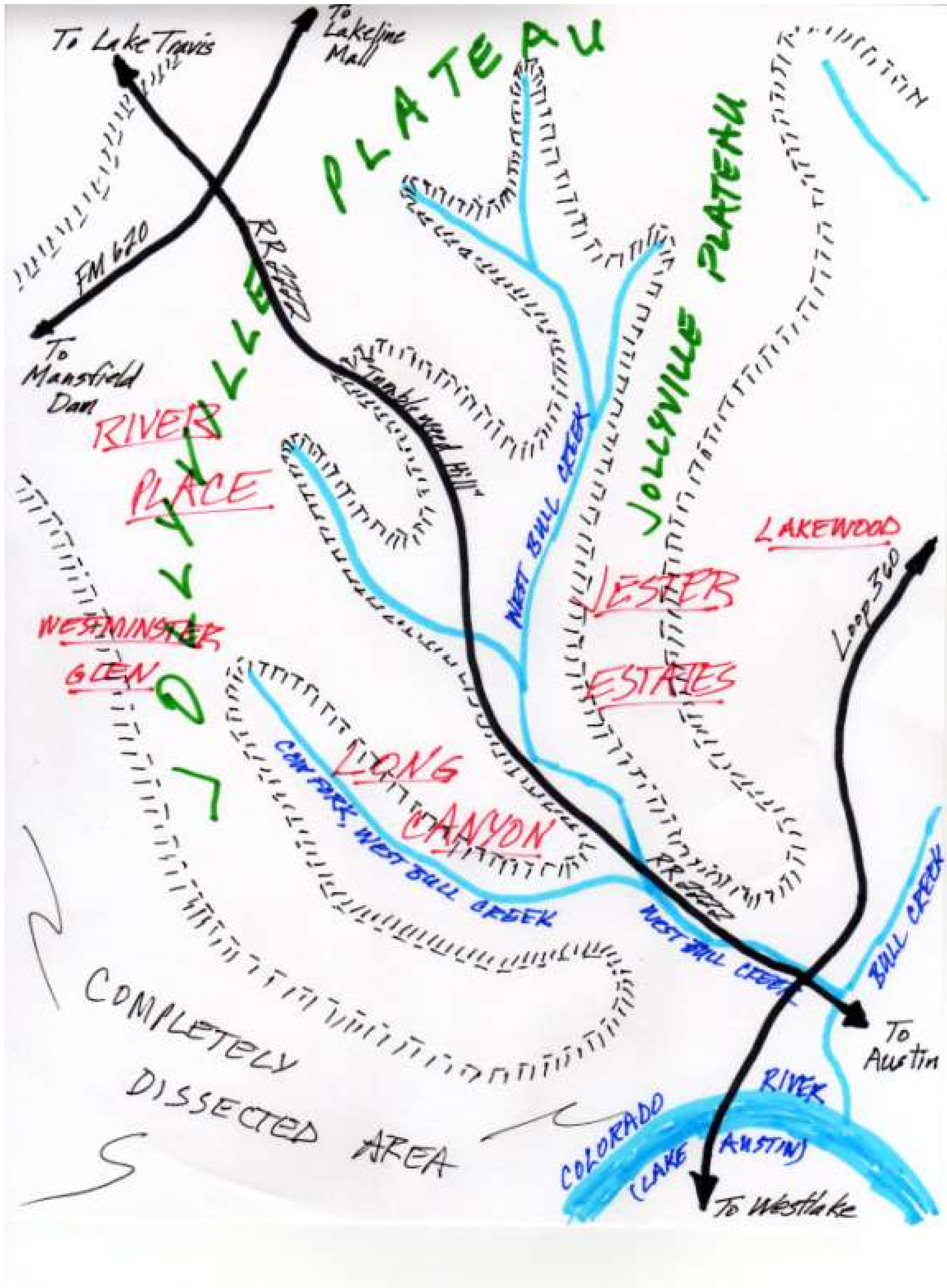

Figure 2. ***The uplands of Long Canyon, Jester Estates, River Place, and other subdivisions are located on the Jollyville Plateau (outlined by the dashed and hachured lines),now being dissected by the streams shown here in blue. (Sketch not to scale)***

Hydrology and Hydrogeology

The steep topography and small drainage areas of the streams on the dissected edge of the Jollyville Plateau generally result in only ephemeral streams in Long Canyon; that is, they only flow during and immediately after rain events. The larger streams in the area may receive enough shallow groundwater discharge along their length that they will flow on an intermittent basis for a while after runoff events; the Cow Fork of West Bull Creek, parallel to Long Canyon Drive and in the Balcones Canyonlands Preserve, exhibits this character. But there is no reliable surface water supply in Long Canyon, as is the situation for most areas of the Hill Country in this area. Lakes formed by impoundments of major streams like the Colorado River are required for a firm-yield surface water supply in this area, especially during drought. But even the Highland Lakes system is a finite water supply, especially important since it serves such a growing population demand.

The Glen Rose formation, the most widespread geologic strata in this area, may yield very small amounts of water to wells in Long Canyon, but it is likely to be variable in quantity and quality. Typically, some of the layers in the Glen Rose have sulfate minerals in them that produce chemical reactions that make the groundwater flowing through them have a rotten-egg smell. A well in the Glen Rose would also probably need to be considerably deeper than the elevation of the stream along RR 2222 to have a chance to produce even small amounts of water on a sustained basis. And the water might be so salty that you wouldn't want to even put it on your lawn.

The uppermost "cap" formed by the Edwards is of limestone that over time has been partially dissolved by weak natural acids in the soils. This dissolution produces enlarged openings for water to flow through, including caves. But the rocks with all the holes that you can see along Bell Mountain Drive really aren't a product of simple limestone dissolution. When those marine limestones were originally deposited, there were also substantial amounts of terrigenous (i.e., earth-derived) material co-deposited along with it. During lithification, the terrigenous materials clumped together, forming generally clayey nodules embedded in the limestone, which we now call the Walnut formation and other members of the Edwards group. This clayey material was subsequently washed out by water moving through the limestone leaving a void, and forming the characteristic "Swiss cheese rocks" we see today – there are some good examples being used for decorative stones along the street corners and driveways of some houses in Long Canyon's highlands. But generally, while these rocks are impressive from a porosity standpoint, most of the Edwards rocks in this area don't have enough thickness or permeability (i.e., connected porosity) such that they could transmit large amounts of water and serve as an aquifer. Elsewhere, especially along, within, and to the east of the Balcones Fault Zone, the rocks of the Edwards are hundreds of feet thick, with well developed permeability from dissolution, and form an important regional aquifer, serving as a water supply for almost two million Central Texans.

Despite its relatively low water-transmitting properties here, the Edwards cap does allow water to infiltrate from the surface, but when that downward-percolating water reaches the less permeable strata, that is, the marls and clays of the Walnut formation, much of that water will be redirected laterally, such that it appears at points along the hillside where the Walnut formation is exposed. (The same process probably is at work lower down on the hillsides, within individual strata of the Glen Rose formation.) But notably, some of this water from the Edwards cap forms seeps along the Glen Rose/Walnut benches, and at several places, probably where there is some joint or fracture system in the overlying rock, wet-weather springs have formed. During the 2006 drought these springs dried up, but they started flowing again with the 2007 rains.

It might be worth noting that because of septic system use throughout Long Canyon, some of the percolating water that seeps out along the hillsides is now likely to be in part infiltration from drain-fields. Generally, the residence time in the soil, subsoil, and geologic strata will have rendered such water innocuous, but Long Canyon residents probably should be aware of any such seeps and springs near their homes, especially if they have children who might want to include them as play areas.

Concluding Remarks

One of the first principles that a budding geologist learns is that "the present is the key to the past." All of the changes that have occurred in our Long Canyon area over the past two billion years are the result of geologic forces that act incrementally, minute by minute, over time periods that are so long it is almost impossible to imagine. And the same geologic forces and processes that have created the geology and hydrology of Long Canyon continue, to a greater or lesser extent, to be active today and/or may reasonably be expected to be active again in the geologic future. I hope that this little treatise has helped provide Long Canyon residents some insight to and appreciation for those remarkable processes and their results, right here in our own backyard.

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