Terrace correlation from soil study along the Maury River, Virginia

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INTRODUCTION

The Appalachian Mountains are interesting not only for their Late Paleozoic folds and thrusts, but also for the geologic processes since then that have drastically altered the topography. Rapid downcutting, inverted topography, knickpoints, and terraces are among the terms being used to describe this continuously changing area. This region of the North America is surprisingly not as "stable" and "passive" as originally thought.

The area for this study is central Virginia's Great Valley. The Blue Ridge to the east is comprised mainly of Precambrian crystalline rocks, but is flanked on the west side with flatirons of Cambrian sandstone. The Great Valley is underlain by Cambrian and Ordovician carbonates and shales. To the west, the Valley and Ridge is composed of folded and thrusted Paleozoic sedimentary rocks; immediately west of the study area, the ridges are capped with Silurian sandstones whereas the valleys are underlain by Cambrian through Devonian shales and carbonates.

The purposes of this study are to map terraces along the Maury River in the Lexington area, and to attempt to correlate them. How fast the rivers are cutting into the bedrock is also of interest; there is a possibility that this is happening more rapidly that previously thought. This specific project entails establishing a soil chronosequence to show how the terraces soils change with elevation (or time) at one location. I also examined terraces at different locations to see if there is variabilityof different terrace levels along the river.

Even though soils cannot be used to get exact ages of landforms, they may be used for relative dating of terraces. Soil development depends on many variables, including mineral composition, particle sizes, compaction, and lithology of the underlying bedrock. The relative age of a terrace can be determined by looking at its elevation above the river and the soils there. Within the soils, thickness of the zone of accumulation (the B horizon) the color, and clay mineralogy can be examined. The longer a surface has been exposed, the thicker the soil's B horizon should be. An older terrace should have more clay accumulation, and more iron oxides, noted by the increase in hue. This is a general statement, however, and is not always the case.

FIELD AREA

The Maury River travels roughly 63 km south from Goshen Pass to the James River at Glasgow, Virginia. It travels through Silurian sandstone at Goshen Pass, but then makes its way over a series of dolomites, limestones and shaly limestones. The lower few kilometers are over shale. One set of terraces was picked to conduct a chronosequence. A chronosequence is a soil study in one area, keeping all variables except time constant: "...because all factors but one are 'ineffective' in the landscape, the influence of the one variable factor is revealed. Sequences of soils can [then] be sought..." (Boul, 1973). The location of the chronosequence is Rockbridge Baths, approximately 25 km upstream of Lexington. To compare the variability along the Maury, five other terraces were picked downstream in Lexington, Buena Vista, and Buffalo Forge (Fig. 1).

METHODS

On aerial photographs terraces can be identified as flat areas along the sides of river valleys. Broad areas outlined by contour lines on topographic maps also indicate terraces. Most of the soil pits were dug by backhoe; at one site (Bee's terrace) soil samples were acquired by auger, and at VMI Pit and Hill terraces, the soils were previously exposed. After the pits were dug, soils were described in the field using Soil Conservation Service nomenclature as in Birkeland (1974). Different horizons were designated by noting color or structural differences. Some horizons were split into two or three subhorizons based on the previously mentioned characteristics. Samples of each section were taken in a horizontal line across the face of the wall to maintain consistency within the horizon. If the section was thin and ungulatory, its pattern was followed, so as to sample within the same type of soil. When there was a unique section within a designated area, ie. manganese accumulation in the floodplain, then this was measured and sampled separately, but included within the designated subhorizon. Complete descriptions of color, texture, and clayskins were made. The pH was determined to help interpret the soils, but the data plots were scattered and did not reveal useful information.

Sample	Location	Elev. AMRL (ft)	Ave. F#	Feldspar %	Clay grains %	Interstitial clay %	Total clay %	Feldspars % + clay grain %
6A	river bed	0	1	1.6	5.2	0.5	5.7	6.8
7A	St. Mary	20	1	6.5	1.6	0	1.6	7.1
1C	clay pit	**	2	2.6	4.4	6.0	10.4	7.0
4A	Rail Road	60	2	0	1.0	6.2	7.2	1.0
5A	Rail Road	60	2	1.4	5.0	1.4	6.4	6.4
10A	St. Mary overpass	20	2	0.4	0.9	2.2	3.1	1.3
2A	trailer lot	70	3	0.9	0.5	8.6	9.1	1.4
3A	Rail Road	60	3	3.8	4.2	13.8	18.0	8.0
1B	clay pit	**	4	0.8	6.7	2.5	9.2	7.5
9A	Cherry Orchard	180	4	0	4.0	13.0	17.0	4.0
8A	landfill	**	5	0	7.8	13.8	21.6	7.8
11A	Carrie's pit	270	5	0.5	0	4.3*	4.3	0.5
1A	clay pit	**	5	0	3.8	16.5	20.3	3.8

Table 2. Data sheet.
*clays localized around fracture
**data not yet available

ACKNOWLEDGMENTS

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REFERENCES CITED

Dodoye-Alali, Bala A., 1998, (title not available at this time), *in* Eleventh Keck Research Symposium in Geology Proceedings: (place, publisher, volume, and page numbers not available at this time).

Elliott, Carrie, 1998, (title not available at this time), *in* Eleventh Keck Research Symposium in Geology Proceedings: (place, publisher, volume, and page numbers not available at this time).

Pettijohn, F. J., Potter, Paul E., and Siever, Raymond, 1972, Sand and Sandstone: New York, Springer-Verlag, 618 p. [text book on sediments]

Schoole, Peter A., 1979, A Color Illustrated Guild to Constituents, Textures, Cement, and Porosities of Sandstones and Associated Rocks: Tulsa, OK, The American Association of Petroleum Geologist, Memoir 28, 201 p. {book of petrographic pictures of grains]

Selley, Richard C., 1988, Applied Sedimentology: London, Academic Press, 446 p. [text book on sedimentation]

Whittecar, Richard G., and Duffy, Debra F., 1992, Geomorphology and stratigraphy of late Cenozoic alluvial fans, Augusta county, Virginia, *in* Whittecar, Richard G., ed., Alluvial Fans and Boulder Streams of the Blue Ridge Mountains, West-Central Virginia: Norfolk, VA, Southeastern Friends of the Pleistocene, p. 79-112. [article in a field trip guidebook]

In the lab, x-ray diffraction (XRD) was used to determine the types of clay minerals in the soils. The sample was initially run in the diffractometer, and then was exposed to ethylene glycol, to make it swell and spread out the spacing between the thin sheets. After another run in the diffractometer, it was heated to 500° C, and run for a final time. After being heated (which forces some clays past their stability thresholds), the mineralogy of the clays can be determined. The different types of clays found in the soils were illite, montmorillonite, and kaolinite. Illite is a clay mineral commonly found in argillaceous rocks. Montmorillonite, a type of smectite associated with illite, is found in these soils. "As for the petrology of kaolinite, it is probably the most ubiquitous aluminosilicate mineral in soils and permeable bedrock in warm, moist regions, forming as a residual weathering product ..." (Moore and Reynolds, 1997). Kaolinite is the most abundant clay mineral found, characterized by its broad, intense peaks in the XRD.

CHRONOSEQUENCE

The chronosequence will be described first, followed by terraces downstream. The chronosequence is located in Rockbridge Baths and will be examined from lowest to highest (Table 1).

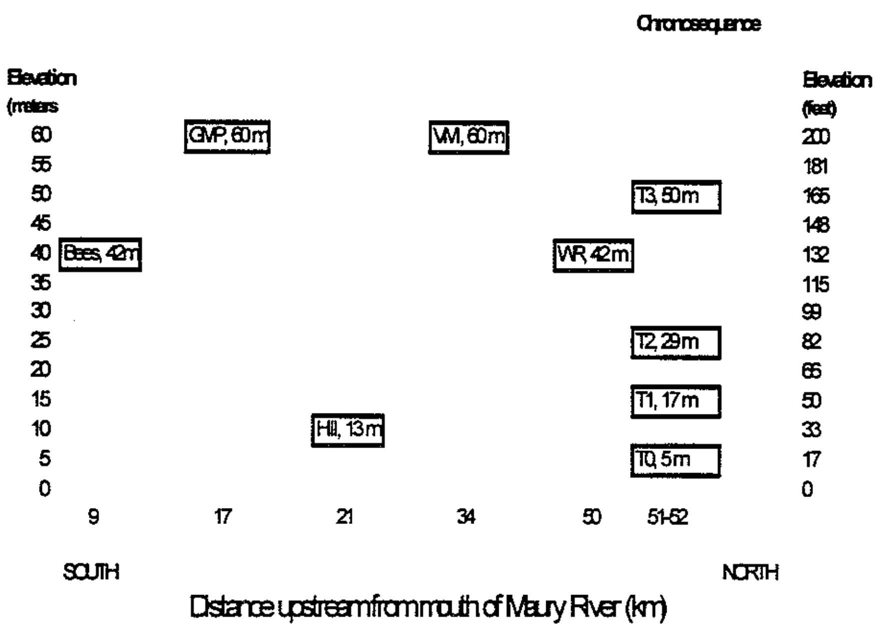
Floodplain. Chrono T0, 5 m above mean river level (AMRL), is the modern floodplain of the Maury River. As depth increases, there is an increase in hue, as well as sediment size. The C horizon is rich in pebbles and cobbles. A thin magnesium rich layer was found in this horizon, and is believed to be at the level of the spring water table.

Terrace level 1. The soil pit for Chrono T1, 17 m AMRL, is a topographic low (possibly a sinkhole), so this is not representative of the entire terrace. The soil is gray and mottled. Compared to T0, the distinctive reddish-brown color, due to iron, is not present in this pit.

Terrace level 2. Chrono 2, 29 m AMRL, has a texture of loam and a hue of 10 YR 5/4 for the uppermost A horizon, and silty clay and 5 YR 4/8 for the lowermost B horizon.Compared to T0 and T1, T2 shows an increase in hue intensity and clay minerals.

Terrace level 3. From the XRD data, Chrono T3, 51 m AMRL shows the most clay minerals. Strong coats and bridges of clays are present. The hue varies from 10 YR 4/4 to 5 YR 4/6. Sandstone cobbles were hit at the bottom of this pit.

Figure 1: Location of terraces along and above the Maury River



DOWNSTREAM TERRACES

There are three levels of downstream terraces (Figure 1). The terraces will be examined from lowest to highest. (No terrace segments were found between the altitudes of Chrono T1 and T2.)

Lowest level. One terrace is intermediate in elevation between Chrono T0 (the flood-plain) and T1. Hill terrace is 13 m AMRL and 52 km upstream from the mouth of the Maury. It has a thick E/BE horizon with a texture of loam to sandy clay loam. Its hue ranges from 7.5 YR 4/4 in the A horizon to 2.5 YR 4/6 in the lowest B horizon.

Intermediate level. Two terrace segments are higher than Chrono T2, but below T3. The Bee's and Wind River (WR) terraces are approximately 42 m AMRL, and 9 km and 50 km, respectively, upstream of Glasgow. The hue of the lowermost B horizon of both terrace segments is 2.5 YR 4/6. A difference between these two is the redder soil found closer to the surface of Bees terrace. This could be due to a plowed horizon that has removed the upper layers of soil. These two terraces are more similar in their deep red color , textures, and relative clay content, than the considerably less red Chrono T2. Chrono T2 is more than 10 meters lower in elevation than the other two. This means that there is another possible terrace level that was not found that correlates with the level of Chrono T2 (Fig. 1). The Wind River and Bee's terrace segments are possibly correlative because of the clays, reddish color, and approximately the same elevation above the river, but they don't correlate with Chrono T2. Compared to Chrono T3, Wind River terrace has considerably redder soil. Wind River is 8 meters lower than Chrono T3, only 1 km upstream, yet has a B horizon hue of 2.5 YR 4/6 whereas the hue of Chrono T3 is 5 YR 4/6. This suggests that an older terrace (based on soil development) is lower in elevation, or closer to the river, than younger terrace. Therefore, the principle that a terrace higher in elevation will have a thicker B horizon and redder soil doesn't always apply.

Highest level. Two terrace segments are higher than Chrono T3. The Glen Maury Park (GMP) and VMI Pit (VMI) terrace segments are approximately 60 m AMRL, and 17 km and 25 km, respectively, upstream from the mouth of the Maury River. GMP has extremely weathered and mottled soil, with an orangish yellow color; its hue ranges from 10 YR 4/3 to 5 YR 4/6. Sandstone clasts, found at the bottom of the pit, can be broken fairly easily by hand. VMI, on the other hand, does not show this high degree of weathering. It is more compatible with Chrono T3, about 20 km upstream, than it is with its downstream neighbor GMP.

DISCUSSION

There are many possible explanations for differences in the soils that are not a result of age alone. One of the features not held constant in this area is the lithology. Downstream of the sandstone at Goshen Pass, the bedrock lithology changes between dolomite, limestone, and shale. If they are strictly alluvial soils, the weathering characteristics depends on differences in particle composition, size, and compaction. This will effect how the alluvial sediment weathers after deposition and exposure. If sediment was deposited on a bar, it will show different characteristics than overbank fines. If there is bedrock near the surface, this will also affect the soil development. The difference could be due to grain size differences at different locations. Both Hill and Glen Maury Park terraces have clays, but are not as red as other terraces, possibly because the underlying bedrock is Waynesboro Shale.

Wind River terrace has a hue that increases from 10 YR 4/4 to 2.5 YR 4/6 as the pit increases in depth. The soil may be influenced by bedrock; it could be above unmapped Edinburg Formation: "The lower contact is at the base of a sequence of reddish weathering limestone..." (Bick, 1960). There are many faults and steeply dipping folds in this area. The Little North Mountain Fault cuts just east of this terrace which is mapped on Beekmantown Dolomite, but it is possible that some Edinburg Formation is in this area. A piece of weathered chert one meter in diameter, was found over 2 meters below the surface, however. Chert is characteristic of Beekmantown dolomite. Another possibility is that a flood or mass wasting event dumped debris here that was derived from the red Clinton Formation at Goshen Pass.

The fact that Wind River terrace is lower than Chrono T3 could possibly be explained by dissolution of the dolomitic bedrock. Many terraces in this are have dolines or "sinkholes" in them. Depending on the purity of the dolomite, only a certain amount of residuum will be left after it dissolves. Therefore, there is a loss of overall volume. This could explain why Wind River is lower in elevation than Chrono T3.

Knickpoint migration is another possibility when discussing variability with in terrace level. "Knickpoints are created by successive drops in base level which simulate intermittent uplift" (Gardner, 1993). Terraces may be the same age, but because of upstream retreat of a knickpoint, terracs downstream will be higher than terraces upstream. Another factor is terrace divergence; downcutting is not uniform along a river. If the river cuts faster downstream, terraces of the same age may be at different altitudes above the river. Both of these causes may explain the soils and other characteristics of older terraces that are lower in elevation, or closer to the river.

It's possible that there is some type of destruction after a terrace reaches a certain height above the river. Higher topography may weather and erode differently than lower areas. Water content is another variable:

"Excessively well drained and saturated soils experience completely different physicochemical conditions and these in turn encourage either the mobilization or precipitation/crystallization of ions within the developing soil profile" (McCraig, 1984).

CONCLUSION

It may not be possible to correlate terraces along the Maury River. There are so many variables during terrace formation and soil development. The bedrock varies considerably from Goshen Pass to Glasgow: sandstone, limestone, dolomite and shale. Mineralogy, grain size, and other characteristics of the soil's parent material are not constant. Also different types of knickpoint migration will affect the terrace levels. More data is needed on terrace formation and soil development. I used only nine terrace segments along the river; with research at more sites, we may gain a better understanding of soil development, terrace formation, and correlation.

Terrace	Location	Distance from mouth (km)	Altitude above Maury River (m)	Depth of pit (cm)	Hue	Texture of uppermost A Horizon	Texture of Lowest B Horizon	Notes
T3	Rockbridge Baths (R.B.)	51	51	150	10 YR 4/4 to 5 YR 4/6	sandy clay loam	silty clay	sandstone cobbles at 1.5 m depth
T2	R.B.	51	29	145	10 YR 5/4 to 5 YR 4/8	loam	silty clay	clay films - coats and bridges in B horizon
T1	R.B.	52	17	142	2.5 Y 4/3 to 2.5 Y 5/4	——	——	topographic low, 7 slope
T0*	R.B.	51	5	173	10 YR 4/3 to 7.5 YR 4/6	loam	sandy loam	manganese deposit at level of spring water table, 1.2 m below surface
WR	R.B.	50	42	210+	10 YR 4/4 to 2.5 YR 4/6	loam	silty clay	very red soil, stong clay films
VMI	Lexington	25	60	240	10 YR 4/4 to 2.5 YR 4/8	loam	silty clay loam	exposed sink hole
Hill	Buena Vista	21	13	200	7.5 YR 4/4 to 2.5 YR 4/6	loam	sandy clay loam	thick E/BE horizon
GVP	Buena Vista	17	60	174	10 YR 4/3 to 5 YR 4/6	loamy sand	sandy loam	extremely weathered sandstone clasts at 1.5 m depth
Bee's	Buffalo Forge	9	42	128	5 YR 4/4 to 2.5 YR 4/6	loam	silty clay	very red soil, stong clay films

Table 1: Terrace parameters. Terraces are listed from the upstream chronosequence (with oldest first) to terraces downstream (* T0 is the floodplain).

REFERENCES

Bick, K.F., 1960, Geology of the Lexington quadrangle, Virginia: Virginia Division of Mineral Resources, 35 p.

Birkeland, P.W., 1974, Pedology, weathering, and geomorphological research: Oxford University Press, New York, 277 p.

Boul, S.W., Hole, F.D., and McCracken, R.J., 1973, Soil genesis and classification: Iowa State University Press, Ames, 374 p.

Gardner, T.W., 1993, Experimental study of knickpoint and longitudinal profile evolution in cohesive, homogeneous material: Geological Society of America Bulletin, v. 94, p. 664-672.

Moore, D.M., and Reynolds, R., Jr., 1997, X-Ray diffraction and the identification and analysis of clay minerals: Oxford University Press, Oxford, 378 p.

McCraig, M., 1984, Soil properties and subsurface hydrology, *in* Richards, K.S., Arnett, R.R., and Ellis, S., eds., Geomorphology and soils: George Allen and Unwin, London, p. 121-140.

Quaternary fluvial terrace and cavern correlation in the Valley and Ridge province, Virginia

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INTRODUCTION

Virginia has some of the earliest described and most extensive networks of caverns in the United States. The Valley and Ridge province of Virginia is home to over 2300 solution caves alone, most of which are found within Lower Cambrian to Upper Mississippian limestone and dolomite bedrock (Holsinger, 1975). During the last few decades, modern mapping tools and techniques have enabled previously unexplored caverns in the region to be described in greater detail, and many previously undiscovered ones to be revealed. As a result, there has been a renewed interest in the utility of caves in solving some of the geomorphic problems relating to landscape evolution which have plagued geologists for almost a century.

Central to this study is the assumption that both caverns and terraces form at, or sufficiently near, the water table to warrant correlation between the two surfaces. If this assumption is correct , then dates of speleothem samples may closely approximate the ages of terraces at similar altitudes above modern river level (AMRL). A similar study relating terraces to former extended base levels was done in the Flint Ridge-Mammoth Cave system of Kentucky with excellent results (Hess and Harmon, 1981, cited in Conners, 1986). Using U-series disequilibrium dating of speleothems in caverns along three rivers in Virginia, this study aims to relate caves with terraces at similar altitudes above modern river level in order to establish fluvial incision rates and landscape evolution models for the Valley and Ridge province.

From Quaternary terrace deposits mapped along the James, Maury, and South Rivers near Lexington, Virginia, statistically determined, preferred terrace altitudes were compared with the altitudes of cavern entrances along these rivers. Paleo-water table was estimated by plotting cave altitude above modern river level against distance from that river, and comparing these points with the modes on the terrace histograms. Initial results indicate that caves and terraces do in fact form at or near the same level, so long as certain assumptions regarding the character of water tables in karst terranes are held to be true. U-series dates indicate that caves are relatively young (< 780 ka), and that the incision rates of the rivers are very fast.

METHODS

Quaternary fluvial terraces and alluvial fans were mapped along the Maury River from Goshen Pass to Glasgow; on the James River, from Iron Gate to Glasgow; and on the South River from the mouth of Saint Mary's River just above Pkin, to its confluence with the Maury River. All deposits were mapped on 1:24,000-scale topographic maps using aerial-photographs combined with field reconnaissance to confirm the presence or absence of river cobbles on suspect surfaces at various elevations.

The frequency of terraces at particular altitudes above modern river level was determined for the James, Maury, and South Rivers by superimposing 100-m grids on the Quaternary deposits maps, and recording the elevation of each point that fell within a terrace; this method is copied from terrace studies along the New River, Tennessee (Mills, 1986). The point count yields the histograms in Figure 1 which show the percentage of total terrace area at any particular 20-ft contour interval (40-ft for the James River) found on each of the three rivers.

Approximately ten caverns were visited in the field in search of datable sediments. Speleothems were collected from five caves in order to determine a minimum age of the cavern based on uranium series ($^{234}U/^{230}Th$) disequilibrium dating, which has become an increasingly accurate method for dating calcite speleothems up to 600,000 years old (Gillieson, 1996). Of the five speleothem samples collected , three yielded dates (Table 1).

In Figure 1, cavern entrance altitude above the modern river is compared with both distance from the river and terrace histograms; these histograms are minus the flood plain in order to accentuate modes at higher altitudes. The paleo-water table levels are drawn where both cave altitudes and terrace altitudes above modern river level appear to coincide. At higher elevations, this admittedly becomes somewhat arbitrary and, at best, only approximates the ancient water-table level. The slope of the paleo-water table graded toward a major river is characteristic of normal water-tables, but is a fact which may or may not be true of water-tables in karst terranes.