The deposition and weathering of heavy minerals relative to South River terrace elevations

Dennis Linney
Department of Geosciences, Elizabeth City State University
1704 Weeksville Road, Elizabeth City, NC 27909
Faculty sponsor: Frederick Lobdell, Elizabeth City State University

ABSTRACT

Heavy minerals with a hardness greater than 5.5 showed little change in overall roundness at the various elevations. Minerals possessing a hardness of 5.5 or less showed considerable weathering. This varied from sub-angular at the highest elevations to well-rounded at the lowest. The downcutting of the South River together with flood episodes over time, appear to be the causative erosive agents. Analysis of these grains may provide information pertinent to the depositional history of the South River.

INTRODUCTION

The primary focus of this investigation was to determine the amount of weathering certain heavy minerals experience and whether or not elevation plays a part in this process. A similar, more in-depth study, has been conducted previously of the New River in southwest Virginia (Mills & Wagner 1984). The scope of this project, however, will be confined mainly to those opaque heavy mineral that can be traced and separated by conventional methods.

The area of interest is located in the west-central section of Virginia amidst the Valley and Ridge province near Lexington (fig.1). Preliminary bank samples of the South River revealed a significant quantity of dark heavy mineral grains. As more samples were collected at various terrace levels, these heavy minerals showed varying degrees of weathering. In addition , the percentage and type of mineral differed as elevation above mean river level (AMRL) increased and decreased. The amount of weathering displayed by specific grains may indicate the length of transport from the source area and quite possibly periods of flood along the South River.

Locale. Thirteen samples were obtained from various terraces along the South River. These were located between Vesuvius at the north end and Cornwall at the south end. This region was chosen primarily because of two major tributaries (Irish Creek and Little Marys Creek) that flow through the major igneous formation. The Pedlar Formation, consisting primarily of hypersthene granodioritic rocks, approaches the South River from the southeast and is separated from the town of Vesuvius by a distance of approximately five miles. In addition, Little Marys Creek skirts the existing terraces before emptying into the South River (fig. 2). The other tributary (Irish Creek) passes through the Pedlar and traverses approximately 25 miles of various terrain and formations before emptying into the South River. Past studies of heavy minerals south of this region revealed that as elevation above mean river level increased, so did the percentage of resistant heavy minerals. Conversely this was accompanied by a smaller percentage of non-resistant minerals (Houser 1981). In addition, research done prior to the aforementioned paper but nearer to the present site, disclosed five heavy minerals that predominated in this locale (Stowe 1939).

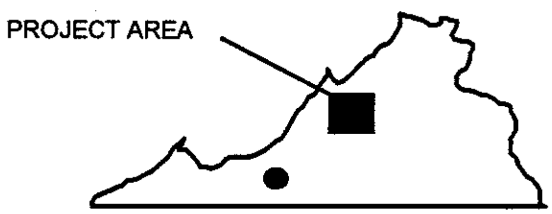

Fig. 1 - Project area reflects current research and that of previous work (Stowe 1939). ● - New River area.

METHODS

The following sampling procedure was applied to the various collection sites to maintain continuity. Bottom and bank samples were first collected at river level to ascertain the type of heavy mineral being transported. This procedure then continued up the mapped terraces with emphasis placed on elevation AMRL. During the collection

The difference between the present profile of the Dan River just before it descends the Blue Ridge escarpment and the better adjusted James River is 550 m (Fig. 3). This difference suggests that the Valley and Ridge incision due to escarpment retreat is 550 m. However, the Dan River should have experienced 50 m of uplift since the mid-Miocene due to Piedmont denudation and off-shore deposition, as in the James System. Thus the Floyd Surface should have been uplifted 50 m relative to the Dan River, which, unlike the small catchments on Floyd, could counter uplift with incision. I propose, then, that of the 550 m difference between the Floyd Surface and the Dan River, 50 m is due to flexural uplift and that the true amount of incision due to escarpment retreat is not 550 m but rather 500 m. This matches the 500 m of James River incision unaccounted for by flexural uplift, suggesting that a combination of only two mechanisms, escarpment retreat and flexural uplift, may account for all of the observed James River incision.

CONCLUSIONS

The average James River incision rate is 160 (± 40) m/m.y. for the last several hundred thousand years. Although extrapolating this rate back to the elevation of the Floyd Surface suggests an age of Floyd Surface abandonment of 4 (± 1) Ma, this age is probably too young since there is good evidence (the Valley Surface itself, as well as other, higher terraces) that the James River has not been incising continuously since abandoning the Floyd Surface. In calculating loads for the flexure modeling, I assumed a Floyd Surface capture age of mid-Miocene (~10-15 Ma), based on a large pulse of sediment delivered by the James to the coast at this time (Poag and Sevon, 1989). This estimate in itself implies an average James River incision rate of 50-70 m/m.y. since the capture of Floyd, a rate still much greater than the 27 m/m.y. in the New River (Granger et al., 1997). The discrepancy between the 50-70 m/m.y. estimate over millions of years and the 160 (± 40) m/m.y. estimate over hundreds of thousands of years may be explained by further uncertanties in the abandonment ages of the Floyd and Valley Surfaces or more simply by noting that erosional activity is not distributed uniformly over time. In any case, it appears as if the James System has been incising, for several millions of years, at a rate much faster than the Appalachian average of 34 m/m.y. (Sevon, 1989).

Many authors throughout this century have suggested that tectonic uplift may explain the observed Valley and Ridge incision and low-relief erosional surfaces (Davis, 1899; Thompson, 1939; Poag and Sevon, 1989). However, little structural or stratigraphic evidence exists to support late-Cenozoic tectonic activity (Pazzaglia and Gardner, in press). I suggest instead that the mid-Miocene sediment pulse to the coast, the high James River incision rates, and the consumption of the Floyd Surface can be explained, without calling for tectonic uplift, by a combination of only two mechanisms: escarpment retreat and geomorphically-driven flexural uplift.

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process care was exercised to take the samples far enough away from road cuts and other man-made structures in order to ensure a representative sample and to guard against contamination from exotic soils and minerals. Each locale was examined macroscopically for the presence of sand grains within a -1 to 4 phi size. This process was sometimes hampered by the coating of silt sized particles with a saprolitic-like film which in turn led to errors in grain size estimation. Laboratory analysis of the specimens involved several stages, the first of which was the separation of the sample into workable quantities.

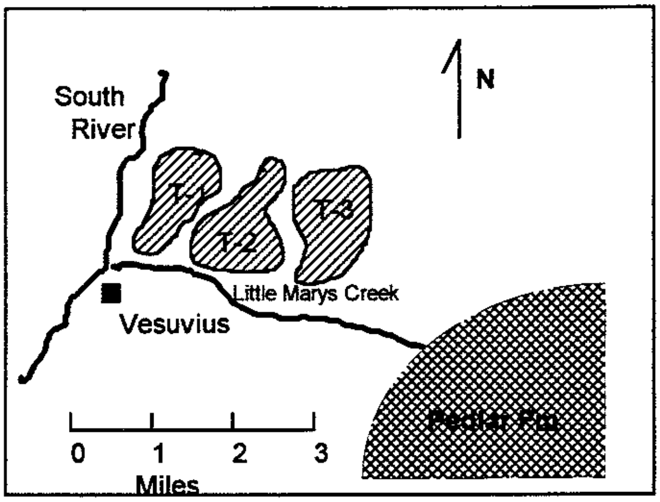

Fig. 2 - Sample Project area, Vesuvius 15' quadrangle approximate locations of terraces 1, 2 and 3 (T-1, 3 and 3)

Wet sieving of the sand fraction aided in the removal of mud, silt and most organic material. The wet sieved fraction was then split again and rewashed using a low sudsing glassware detergent to disperse any remaining contaminants. Due to the toxicity of using tetrabromoethane for separating out heavy minerals, I opted for the less hazardous (although more expensive) procedure using sodium polytungstate. This solution has several advantages over previously used methods. The solution can be easily recycled and reconstituted many times without losing its effectiveness. There are nominal equipment requirements, the only major expenditure being a hydrometer or aerometer for calculating specific gravity (a luxury item which can be duplicated by the use of an accurate scale and calculator). During the process of recycling the polytungstate, caution should be exercised in heating the solution. Application of heat in excess of 65 ^{0} C for a period of time greater than 3 hours, will result in a thick gel rendering it useless. This can be avoided by careful monitoring of the process. If a gel should form, it can be reconstituted by the addition of distilled water and low heat. In order to maintain quality control in the analysis, specimens were weighed out in 1 gram quantities to which 40 ml of sodium polytungstate, adjusted to a S.G. of 2.89, was added. Separation of the heavy mineral suites was basically straightforward (Callahan 1987) with one exception, translucent minerals being difficult to locate. Most had to be plucked from dried filter paper under stereoscopic examination. This however, was a rare occurrence since the most common heavy minerals recovered from the Valley and Ridge province were opaque (Stowe 1939). Grain percentage was determined by counting the number of grains identified and normalizing that percentage (e.g., 15% -magnetite, 20%-ilmenite, 15%-limonite = 30% magnetite, 40% ilmenite and 30% limonite respectively).

OBSERVATIONS

The dominant mineral at the higher elevations was what appeared to be a leucoxene coated ilmenite; at the lower levels, limonite predominates (fig. 3). The presence of magnetite in amounts of 15% or more, appears as the third major mineral. Varying amounts of epidote, tourmaline and zircon round out the suite at different elevations. The weathering of ilmenite (hardness 5.5) varies from very angular - subrounded at river level to 995' AMRL. In contrast limonite (hardness 5 - 5.5), displayed the opposite effect, weathering from well rounded to sub angular (fig. 4). These two minerals were chosen as index minerals because of their appearance at all elevations and similar hardness.

Provenance studies of these two minerals suggest that the possible source for limonite may be the Rome Formation (Bick 1949). This unit, which is composed primarily of red and green shales, dolomites and limestones, parallels the South River as far north as Vesuvius. It is among these elevations (river level to 120' AMRL) that a large percent of the limonite has been uncovered. A possible origin for most of the ilmenite recovered is the gneissic Precambrian rocks of the Pedlar Formation in which samples taken at 120 - 995' AMRL, show comparable percentages of ilmenite.

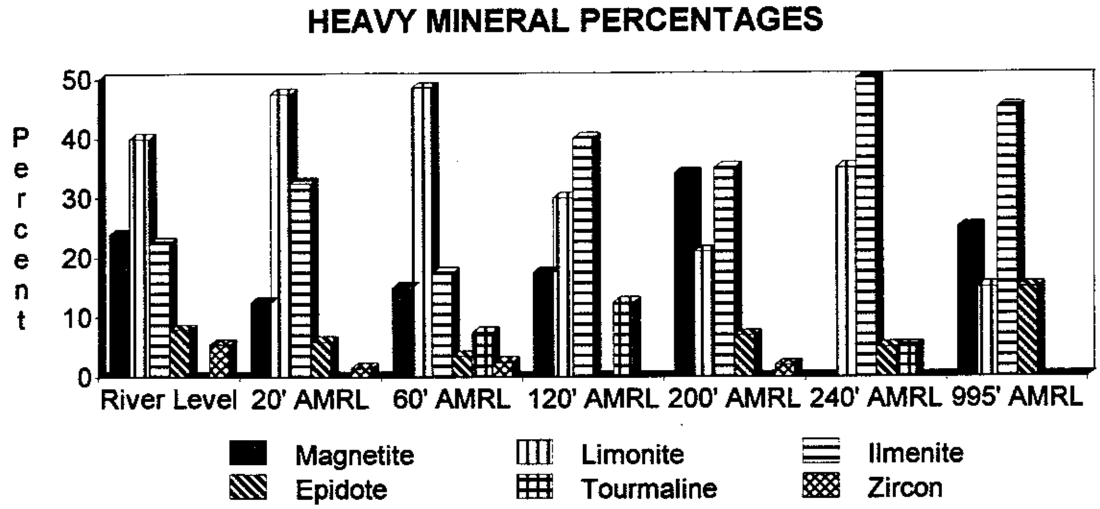

Fig. 3 - Average normalized percentages of heavy minerals recovered per height above mean river level (AMRL).

DISCUSSION AND CONCLUSIONS

There is a disparity that exist between the percentages of the two index minerals at approximately 60' AMRL. It is at this point that ilmenite drops to less than 20% and never again regains prominence. From this point limonite becomes dominant as the terraces approach river level. The roundness of these two minerals also

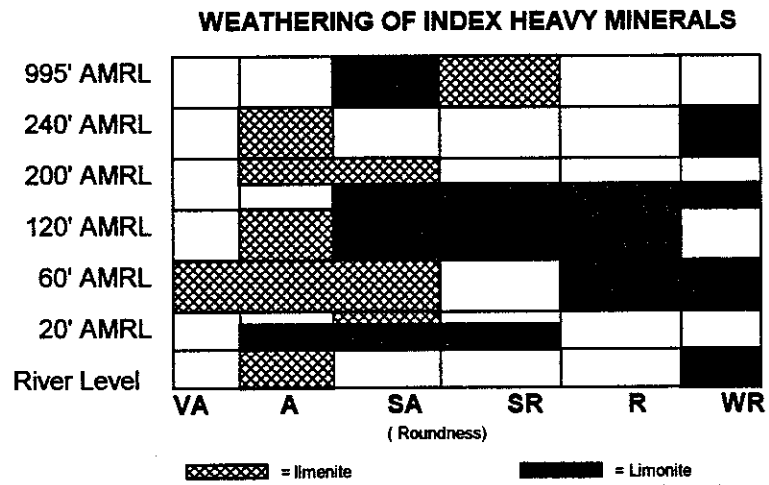

Fig. 4 - Weathering rates of primary and secondary heavy minerals.

seems to overlap at 60 - 120' AMRL. Ilmenite displays a range from very angular to sub angular while limonite progresses from sub angular to well rounded. It is impossible to determine how much of this rounding occurs in transit as compared to weathering in place. River fluctuations throughout the formation of the South River seemed to have occurred most often within the 60 - 120' level. Each flood cycle of the South River reworks the sediment from previous depositions and as the episode of flooding subsides new sediment is deposited. This swash and back wash sequence also aids in the rounding of grains. Previous studies of this area (Stowe 1939) indicate that some heavy minerals will not be transported far from their source. This implies that limonite, whose source area appears to be the Rome Formation, should display little weathering. However, in this instance limonite appears as angular to well rounded grains and ilmenite, derived from the igneous rocks of the upper elevations, displays sub rounded grains at best.

The weathering patterns displayed by these two minerals indicates a trend in the mechanism of weathering. The overlap of subrounded grains suggest a period of equal degradation and aggradation which could be interpreted as periods of flood and slackwater of the South River. The frequency, of this event according to figure 4, could have occurred during the formation of terraces along the 60 - 120' level tapering off gradually to 200' AMRL. This interpretation however, requires more definitive proof since little is known about the depositional history of the South River. Most studies of heavy minerals appear to be limited to those non opaque minerals with little reference to the opaque suite of accessory minerals. The most abundant heavy minerals recovered from this area of the Valley and Ridge province are opaque of which few studies have been conducted. Clearly, more research in this area is necessary before these minerals can be used as depositional and erosional indicators.

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Modes and rates of fluvial bedrock incision in the Valley and Ridge Province, Southwestern Virginia

Justin B. Ries
Department of Geology, Franklin and Marshall College, P.O. Box 3003, Lancaster, PA 17604-3003
Faculty Sponsor: Dorothy J. Merritts, Franklin and Marshall College

INTRODUCTION

The purpose of this study is two address the modes and rates of bedrock incision into Cambro-Ordivician limestone by fluvial systems draining the Valley and Ridge province, Rockbridge County, Virginia. The study consists of field and laboratory components. The field component of the study was conducted as part of a Keck Geology Consortium project during June and July of 1997. It consisted of terrace mapping for the James, Maury and South Rivers. The modes of bedrock incision, primarily knick-point erosion and pothole drilling, and the vertical distribution of terraces were observed during a detailed survey of Whistle Creek, a tributary to the Maury River. The goal of the laboratory component of the project is to determine the relative importance of watershed area and stream slope to bedrock incision. This component consists of empirical analysis of watershed area and channel slope data for two fluvial systems: the Whistle Creek and Kerr's Creek watersheds. The importance of area and slope can be quantified with the variables m and n, respectively, in an equation for bedrock incision (Howard and Kerby, 1983):

$$-dz/dt = KA^mS^n$$

where incision (-dz/dt) is a function of an erosion factor (K), watershed area (A) and stream channel slope (S). The m and n values are constants that can be determined as a ratio, rather than absolute values. However, the relationship between these two variables will be useful in ultimately calculating a bedrock incision rate for these fluvial systems.

GEOMORPHOLOGICAL BACKGROUND

The evolution of the Appalachian landscape is a highly debated topic among geologists who have studied the region. David Harbor, a geomorphologist at Washington and Lee University, has put forth a model for the erosional history of the Appalachians called the "Floyd model," named after the town of Floyd, VA.

Harbor proposes that at one time a gently westward sloping surface, bounded by a giant escarpment to the east, ran the length of the eastern United States. The high escarpment is the continental divide for the eastern United States. Water which falls to the west of the escarpment drains westward to the Mississippi River, whereas water which falls east drains eastward to the Atlantic Ocean. Due to the steep gradient of the eastern slope of the escarpment, streams began to cut back westward through the escarpment soon after its initial formation. These westward-incising, eastward-draining rivers eventually began to intersect the westward-draining rivers, effectively rerouting or "capturing" their entire upstream section (Lobeck, 1939). This process of stream capture dissects the gently sloping plateau west of the escarpment and results in the westward retreat of the escarpment. The dissected terrane left in the path of the retreating escarpment is the Valley and Ridge Province. My study addresses the rate of vertical fluvial incision into bedrock (via stream power) which occurs in response to this retreating escarpment.

As the more steeply sloping eastward draining stream captures the headwaters of the westward draining stream, the westward draining stream must lower its base level to maintain equilibrium (Playfair, 1802). This lowered base level is translated throughout the tributary systems in the form of propagating knick-points, which reflect instantaneous disequilibrium first at the point of stream capture and subsequently at the confluence of the parent and tributary streams (Seidl and Dietrich, 1992).

MATHEMATICAL BACKGROUND

The sediment transport law states that for alluvial channels, the rate of sediment transport can be defined by the equation:

$$q_s = KQ^mS^n;$$

where Q = discharge; S = slope; K, m and n = constants (Gilbert, 1877). For erosion, area of the watershed (A) can be substituted as a proxy for discharge (Q; Howard and Kerby, 1983). Therefore , a rate of incision (-dz/dt) is defined by

$$-dz/dt = KA^mS^n.$$