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AVULSION PROCESSES AND RATES IN A MIXED ALLUVIAL-BEDROCK RIVER, HURON RIVER, NORTH-CENTRAL OHIO (U.S.A.)

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Abstract

Bedrock exerts strong control over fluvial channel migration and channel-switching events (avulsions). This study looked at a river with alternating reaches of bedrock and alluvium to determine the downstream zone of influence that bedrock reaches have on the locations of avulsions in subsequent alluvial reaches. The study area is an 8-km stretch of the Western Branch of the Huron River within the Milan Wildlife Area near Norwalk, Ohio. In the study area, the Huron River has channel bed and banks of the Paleozoic Ohio Shale alternating with Pleistocene glacial till and Holocene colluvium and alluvium. Historical aerial photos from 1950, 1956, 1960, 1969, 1977, 1988, 1995, 2000, 2001, 2004, 2013 and 2015 were collected from the USGS and the Ohio Geographically Referenced Information Program (OGRIP). These were georeferenced using ground control points, input into ArcGIS, and the RMS error was calculated to be between 1-8 meters when comparing each historical image to the 2015 digital orthoquadrangle map (DOQ) acquired from OGRIP and used as a base map. The historical aerial photos were used to find when and where avulsions occurred, as well as changes in channel path length and sinuosity following avulsions. There were 4 significant avulsions recorded during the interval 1950-2015, occurring between 1950-1960, 1960-1969, and 1977-1979. Typically, the exit point from the previous channel was located 190-220 meters downstream of the bedrock reach immediately upstream. One mode of bedrock control is that avulsion direction (azimuth) appears to be controlled by the underlying bedrock joint sets (one set is oriented approximately N-S and another set oriented approximately E-W). Over the interval 1950-2015, sinuosity varied from 1.6 to 1.8, generally increasing to a maximum value prior to an avulsion. To better characterize the avulsion events, eleven trenches up to 2 meters deep were dug at 6 locations along the Huron River and 8 vibracores were collected at one avulsion site. On-going work will link avulsions to known hydrological events from the historical record at a downstream gaging station, and will examine the sedimentological record of cut-and-filling in the avulsion channels.

Introduction

The Huron River (located in northern Ohio) is a mixed bedrock river which exhibits properties of both bedrock rivers and alluvium rivers. Within the Huron River there are alternating reaches of bedrock and alluvium where the bedrock reaches consist of Paleozoic Ohio Shale and the alluvium reaches are composed of Pleistocene glacial till and Holocene colluvium and alluvium. Jointing can be found within the bedrock reaches of the river with 2 primary orientations. One set of the joints runs more N-S while the other set is primarily E-W. These joint azimuths correspond to the orientation of reaches in the current river.

The Huron River has an extensive record of historical aerial imagery which is available from the mid 1900s to present day. The historical aerial imagery provides an excellent look at the channel morphology of the past Huron River and it is a useful tool for mapping the changes within the river over time. These images were used in combination with ground truthing field observations in order to further constrain locations of channel changes (Avulsions). These avulsions are influenced by the jointing, sinuosity, and distance downstream from bedrock reaches.

Huron River Historical Changes

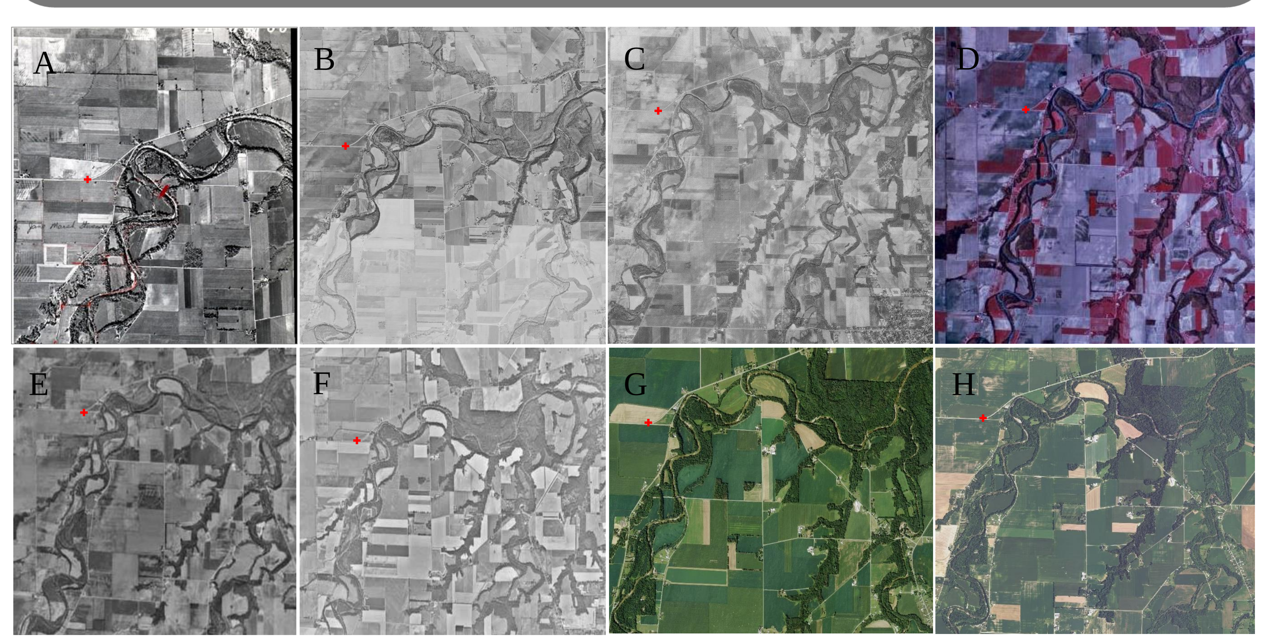

Figure 1: Historical imagery collected from the USGS, USDA, OGRIP and HistoricalAerials.com. Photos show position of the Huron River since the early 1950s. A) 1950 B) 1969 C) 1977 D) 1988 E) 1995 F) 2000 G) 2011 H) 2015. Images also includes red plus sign which shows an example of a ground control point.

Huron River Trenches

Figure 2: Showing images of the Huron River. A) Bedrock high wall consisting of Ohio Shale. B) Jointing within the river. C,D,E,F,G,H,I) Trenches located along the river.

Huron River Vibracores

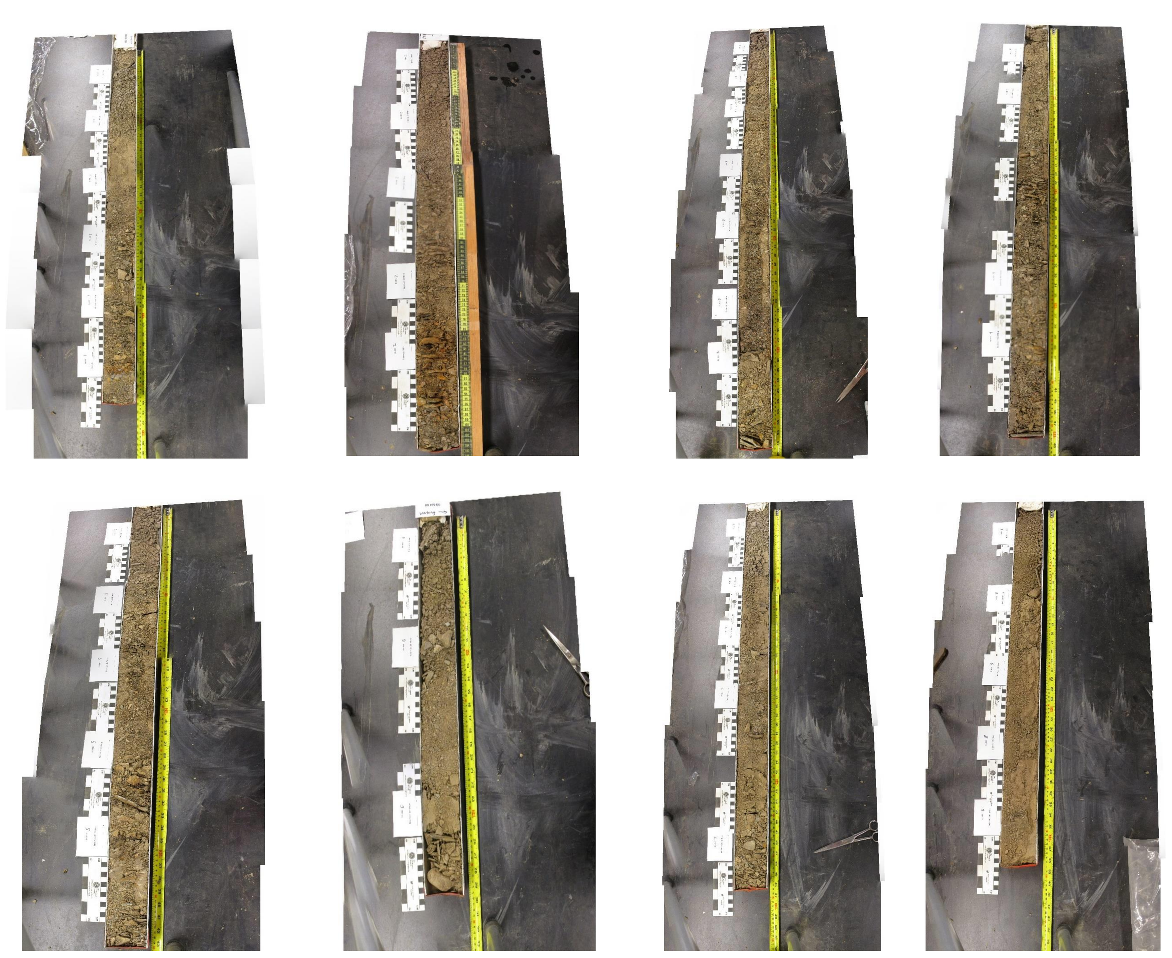

Figure 3: Cores collected from avulsion 1. Cores show sediment sizes ranging from pebble gravels to medium sands. Sizes were measured using sieving which showed an average phi size of 4 for the medium sands. Sieving was done in order to measure differences between active channel material and sediment infill.

Methods

Data Sources and Properties

Fifteen historical images of the Huron River area and 18 historical topographic maps were collected from the Bowling Green Library and the USGS (Figure 1). The historical images were obtained through the USGS, USDA, HistoricalAerials.com, and the Ohio Geographically Referenced Information Program. USGS photographs had scales and elevations as well as the date the photograph was taken. The historical aerial photographs from HistoricalAerials.com had dates flown, elevations of the photograph and the scales. Some of the images were from unknown sources but contained the date of the photograph.

GIS

A 2015 digital orthoquadrangle map (DOQ) of the Huron River was acquired from the Ohio Geographically Referenced Information Program (OGRIP). The image was pre-projected in Universal Transverse Mercator (UTM) coordinates (R17 NAD 1983). The resolution was 1 meter by 1 meter cell sizes. This image was used as a base image for georeferencing the historical aerial photographs. Historical aerial images were entered into ArcGIS and projected into UTM coordinates. These images were then georeferenced to the 2015 DOQ image using ground control points.. The RMS error was calculated by comparing the change in position of the X and Y coordinates in the historical images to their final position when georeferenced. The RMS errors ranged from 0.05 to 8.09 meters with and average RMS error of 4.38 meters.

Shapefiles were created using the polygon tool in ArcGIS for each of the historical images. These shapefiles were overlain on top of each other as seen in figure 4, and if the size of the avulsion was greater than the RMS error calculated it was considered a true avulsion. Four avulsions were found to have occurred from 1950-1979 within the study area (figure 4). Sinuosities were calculated in ArcGIS using the measure tool to measure the path length and feature length of the stream channel for each of the shapefiles. The average sinuosity between 1950 and 2015 for this section of the Huron River was found to range from 1.64 to 1.79 with an average sinuosity of 1.78 (table 1). The sinuosity decreases from years where avulsions were observed. This is likely due to the channel adjusting to a straighter path following the avulsion (table 1). Distance of the avulsions from bedrock reaches was also calculated using the measure tool in ArcGIS. The distances downstream ranged from 190-220 meters away from the bedrock.

Results

Trenches

11 trenches were dug along the Huron River (Figure 2). These 11 trenches were located along potential avulsion sites. Locations were chosen based on sedimentological observations. The presence of finer sediment overlying gravel deposits was used as a key indicator of channel infill and past channel deposits. These observations were used to ground truth GIS imagery.

Core Observations

8 vibracores were provided by the Bowling Green State University geology department (figure 3). These cores were collected along avulsion 1. The cores showed alternating facies of gravels and sands. The sands were described as tan medium to fine grained sands. Gravel intervals were described as imbricated and non-imbricated layers. The gravels ranged from cobble to pebble clast sizes with some gravel layers having sand matrix while others were primarily clast supported. The clast composition is mainly fissile dark shales. The sandy intervals have been interpreted as channel infill sediment from the abandonment of previous avulsions and infilling of finer particles. The imbricated gravels are interpreted to be from the active channel during times when the river had changed position.

Joint Measurments

54 joint measurements were collected at 3 separate locations within the Huron River (figure 5). 25 measurements were made for the E-W oriented joint set (table 2 (1A)) and 29 were made for the N-S oriented joint set (table 2 (1B)). These were plotted in a rose diagram to show the orientations of the joints. The N-S set of joints had orientations between 330-345 degrees while the E-W set had orientations from 45-60 degrees. A p value of the joint orientations was calculated to be below implying the orientation was significant and not random (Table 2).

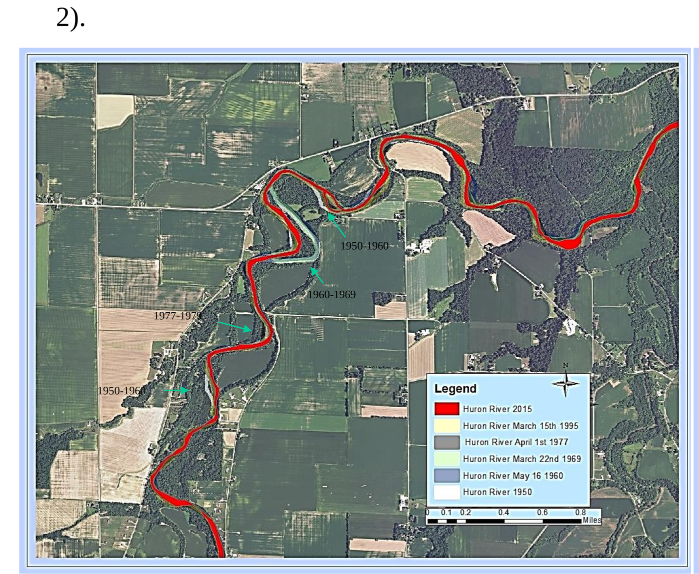

Figure 4: showing shapefiles created from historical aerial images from 1950 to 2015. the image also shows the locations and dates where the 4 avulsions occurred within the study area,

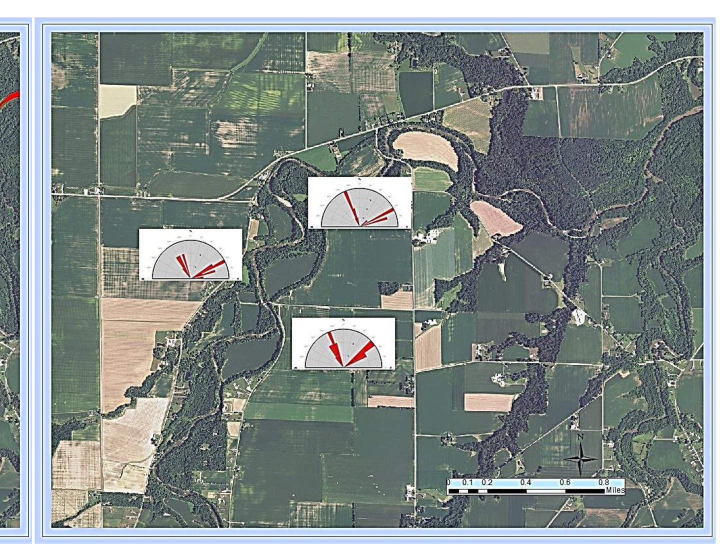

Figure 5: showing the locations of joint measurements taken within the field area. Also showing rose diagrams of the orientations of the joint sets.

Year	Path length (meters)	Straight line distance (Meters)	Sinuosity
1950	5150.1	2900	1.775
May 16th 1960	5678	3200	1.774
1969	4231	2440.8	1.733
March 11th 1977	3283	1826.4	1.797
1979	4854	2868	1.692
April 9th 1988	19531	11321	1.725
March 15th 1995	13780	7730	1.782
2001	4491	2733	1.643
2015	14215	7937	1.791

Table 1: Channel sinuosity values for the Huron River since 1950

Joint measurements		
Area 1	1A	1B
vector mean	45	333
vector magnitude	0.905	0.72
circular std. deviation	35.07	60.52
circular variance	1229.9	3662.56
test of significance	0.00028	0.0056
Area 2		
vector mean	66.12	345
vector magnitude	0.76	0.99
circular std. deviation	56	10.57
circular variance	3136.45	111.81
test of significance	0.0031	0.001
Area 3		
Vector Mean	44.05	345
Vector Magnitude	0.75	1
circular std. deviation	57.17	3.34
cirular variance	3268	11.16
test of significance	0.006	0.0003

Table 2: Bedrock joint set statistical data

Discussion

The Huron River shows dynamic change in channel position from the 1950s to 2015. The georeferenced historical aerial images allowed for the creation of shapefiles which were used to show the change in channel position from one set of images to another. These shapefiles were overlain on a base image and the RMS errors are able to be used to calculate the size of error between photographs. Using my preliminary results the RMS errors for the historical aerial photographs from 1950 to 2015 ranged from .05 meters to 8 meters. Further work can be done to minimize these errors by changing tie points between photographs. The range of error is small enough to see major changes in the channel allowing for mapping of avulsions.

Ground truthing allows for verification of the location of avulsion sites. Medium sands from stratigraphic sections are interpreted as channel infill sands. The channel infill sands represent abandoned channel where finer sand sediment filled the previous channel following abandonment. Gravel deposits are interpreted as representing the past channel and gravel bars. Non-continuous imbricated gravels are interpreted as representing gravel bars within the main channel at the time of the avulsion. Non-imbricated gravels are representative of the main channel gravel deposits.

Sinuosities of the Huron River appear to change over time following avulsions. These sinuosities can be used to show how the channel is adjusting to avulsions in years following the abandonment. They can also be used as a method of determining if the Huron River tends to avulse when the sinuosity passes a certain threshold. Further analysis is needed for the sinuosity measurements however and individual reaches need to be calculated.

Conclusions

- **The Huron River channel has observable changes since the mid-1900s**
- **Photo matching of imagery in ArcGIS can be used in order to determine channel geometry changes within the Huron River system.**
- **Ground truthing of trenches and coring can be used to prove where the active channel was and where the channel has infilled.**
- **Bedrock joint measurements match Huron River channel orientation, documenting bedrock control over channel morphology.**
- **Channel measurements show the sinuosity averages 1.6 to 1.8, but increases prior to channel avulsions.**