EVIDENCE OF STREAM PIRACY AT THE WUTACH GORGE (BLACK FOREST), SOUTHWESTERN GERMANY

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ABSTRACT

Stream piracy describes a scenario of forcible take-over, leaving the weak and plundered river with less or nothing in the stream network for the experience of a take-off just like the stories of the pirates of old**.** This research intends to analyze the recognition of drainage reorganization at Wutach Gorge (Black Forest) with respect to the interactions between the shapes of stream networks, transport processes, and the landforms they create. As a result of this known geomorphological activity, various scientific reasonings established were based on whether there are channels where there is a sudden change in longitudinal stream bed profile caused by previous erosion due to glaciation or variability in lithology, then using the information to establish different relationship(s) between slope steepness and distance from the upper to lower reaches within the Gorge.

I utilize a MATLAB-based software for topographic analysis by visualizing a downloaded DEM of the study area of about 2,979km^2, which covers the Danube and Rhine-Wutach stream network, and quantitatively analyze the river longitudinal profiles by exploring differences in overall profile shape, visualizing the drainage pattern of the stream network, and extracting interpretations from the maps that agree with known river captures and morphological features. The temporal position variation of the stream network indicates the change and development of new tributaries, such as the Rhine-Wutach River capture along the stream network revealing an elbow of capture, whereby forming a gorge by the captor stream through headward erosion across the ridge.

This evidence of stream piracy may have imposed some physical and ecological challenges such as accelerated erosion and deposition of sediments due to the changes in river flow direction whereby causing hanging tributaries in the Feldberg-Donau River channel.

1. INTRODUCTION

The term stream piracy suggests an event of forcible take-over, leaving the weak and plundered river with less or nothing in the stream network for the experience of a take-off just like the stories of the pirates of old. The study of stream piracy in a geological setting can be attributed to the migration patterns for aquatic animals, changes in stream chemistry and changes resulting to the rates of erosion in upland areas [7]. There has been an argument that surface water is the main agent of stream piracy in most geomorphological settings, and as a result different role of surface-water erosion has been on debate (e.g., Lane, 1899). Evidence that stream piracy has occurred in a geological setting are based on observations such as dry valleys, elbows of capture, spiked tributaries, decapitated streams among others [7].

Crosby in his journal published 1937 established methods of describing stream piracy by stating conditions including two surface streams, two subterranean streams or a surface and subterranean stream that are necessary for capture to take place, in this report two streams around the Rhine-Wutach River connections were considered to have create the phenomenon. Furthermore, Yanites et al 2013 also conducted a research by measuring the impact of stream piracy along the Rhine/Aare River system whereby developing a model that indicate rapid response to various capture events because of its landscape evolution.

This research intends to analyze the impact of drainage capture at Wutach Gorge, with respect to the interactions between the shapes of stream networks, transport processes, and the landforms they create. As a result, the scientific questions arise are as to whether there are channels where there is a sharp change in channel slope caused by previous erosion due to glaciation or variability in lithology, then using the information to establish different relationship(s) between slope steepness and distance from the upper to lower reaches within the Gorge. To answer these questions my objectives are based on the recognition of the evidence for stream piracy by visualizing a downloaded digital elevation model of the study area with a Hillshade and the river network, analyzing the river longitudinal profiles whereby exploring differences in overall profile shape (concavity), visualizing the drainage pattern of the stream network, and extracting interpretations from the maps that agree with known river captures and morphological features. My results will be revealing various tectonic activities which are mainly controlled by hydrological conditions and erosion activities along the Wutach.

2. STUDY AREA

The study area (fig 1) is located within the south-east of the Black Forest, Southwestern Germany. It was said to be approximately 30km long and up to 200m deep, created by river diversion after the Ice Age [6]. The upper part of the river was once a tributary of the Danube known as the Feldberg-Danube and was captured by a small Rhine tributary called Rhine-Wutach [4], and because of the capture about 150m deep gorge was incised [6]. In addition, the Wutach basin has experienced a complex geological evolution with various deposits where its old topography was restored by river capture-induced incision [4].

In this study area, my focus is basically on the surface incision the basin exhibits based on its history which provides a steady-state reference point with respect to the Wutach interactions in the region.

Fig 1: Map showing the connection relating the Wutach, Rhine (*Rhein*) and Danube (Feldberg-Donau) River (Wikipedia)

3. METHODS OF STUDY

In other to detect and visualize the evidence of stream piracy in the Wutach river region, a 30m resolution Shuttle Radar Topographic Mission (SRTM) digital elevation modelling data with coordinates relevant to the area of interest was downloaded. The selection area is approximately 2,979 km^2, which covers the Danube and Rhine-Wutach stream network. For qualitative and quantitative analysis of geomorphological activities in the study area, MATLAB-based software for topographic analysis and modelling in Earth surface sciences developed by Schwanghart and Scherler (2014) was adopted for basic and complex simulations.

From the generated DEM, I develop an elevation and slope (gradient) map of the area to have an overview of the terrain surface over Hillshade. Then use the generated map to model the characteristics of stream network whereby extracting the largest connected network, calculate the flow routing based on upstream cells on the flow direction algorithm, and visualize the Longitudinal River profiles by using the information on the connectivity in the stream network. Furthermore, the identification of various knickpoints related to lithological changes were extracted using the knickpoint algorithm. The algorithm iteratively relaxes the concavity constraint along the river profile that exhibit higher elevation properties.

4. RESULTS

The elevation of the Wutach region terrain (fig 2a) varies between 300m and 900m, with a relatively low steepness (fig 2b) which indicates an area of low river channel surrounded by higher ground in most directions. The results of the flow accumulation are used to generate a stream network (fig 3) by applying a minimum drainage area of 1000cells in other to select cells with a high accumulated flow. In the river network, the largest stream network with a trunk stream was extracted (fig 4) whereby showing geomorphological features including the active elbow of capture of the Wutach gorge. The longitudinal profile of the study area (fig 5) generated to evaluate the influence of tectonic activities along the Wutach gorge indicates the connections of river channel along the downstream, and the modelled Wutach river (fig 6) shows the exact area where river reorganization is said to take place. To understand the captured stream features, I analyse the longitudinal profile based on knickpoints (fig 7), the recognized knickpoints were in the main river channel of the known active river incision

around the Rhine-Wutach stream network (fig 8) and along the several tributaries around the study area.

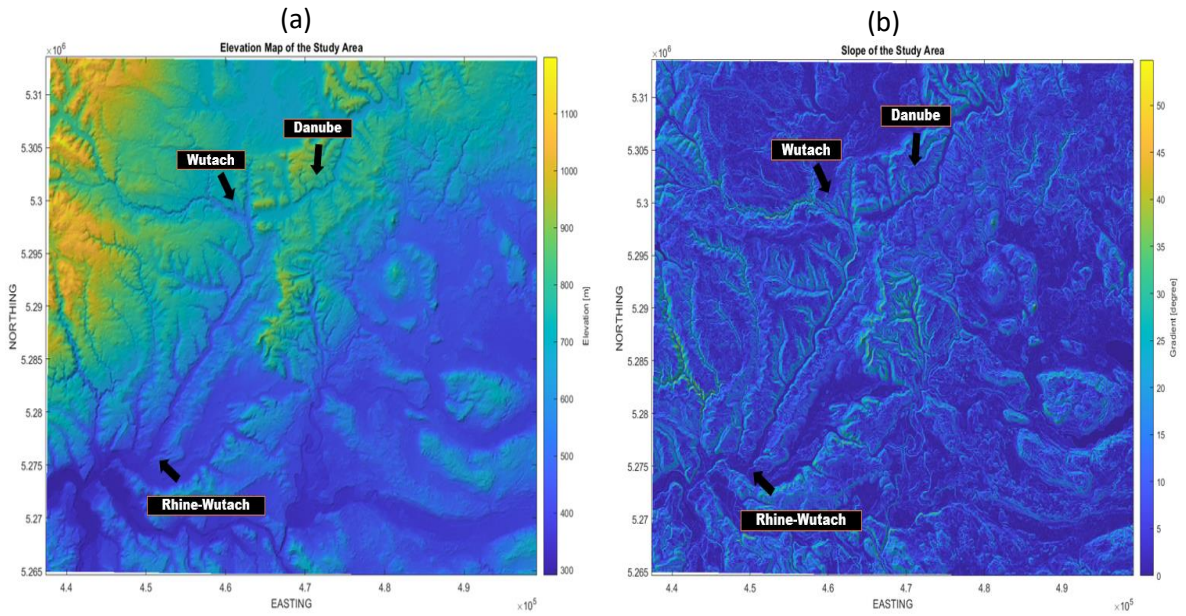

Fig 2: The DEM of the study area showing (a) the elevation map which visualizes the river network and (b) the gradient map showing the numerical steepest downward slope direction.

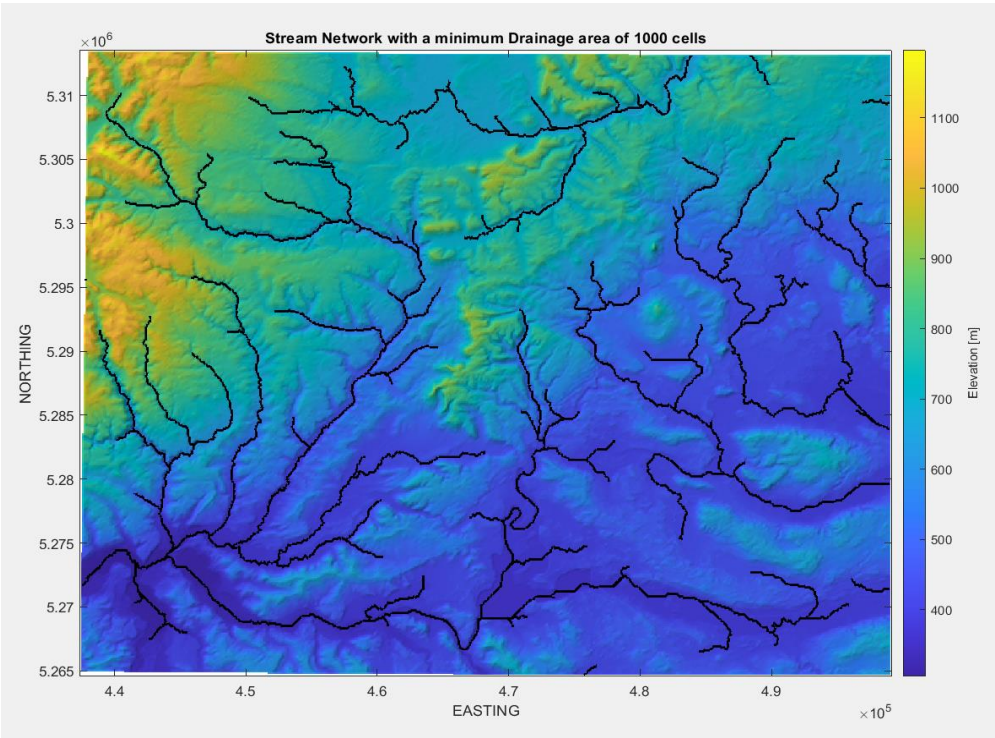

Fig 3: Map of the stream network with a minimum drainage area of 100cells.

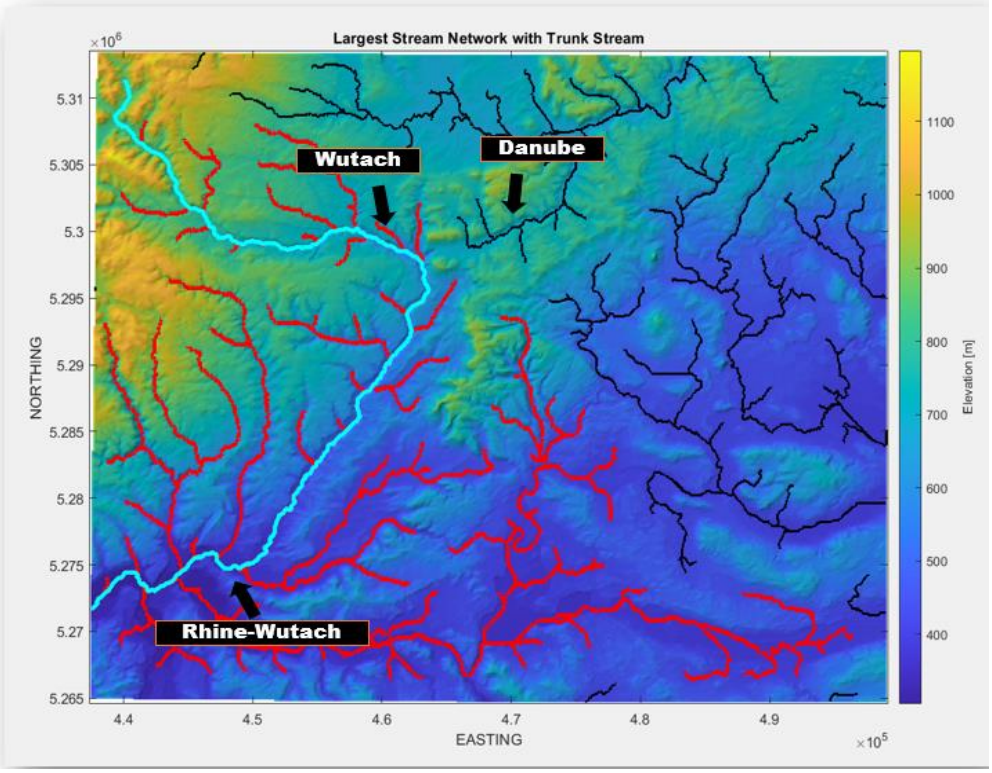

Fig 4: Map of the largest stream network (coloured red) which include the Rhine-Wutach River network and trunk stream (coloured cyan) indicating the capture created by the Wutach.

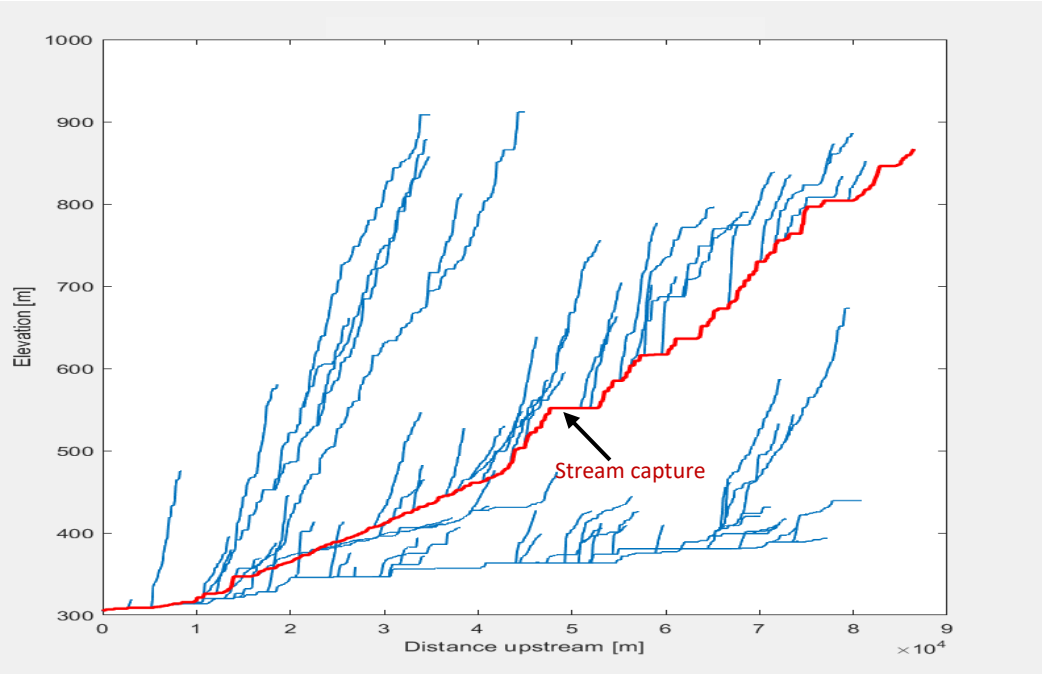

Fig 5: Longitudinal profile of the Wutach (coloured red) and various river channel indicating where the river reorganisation takes place.

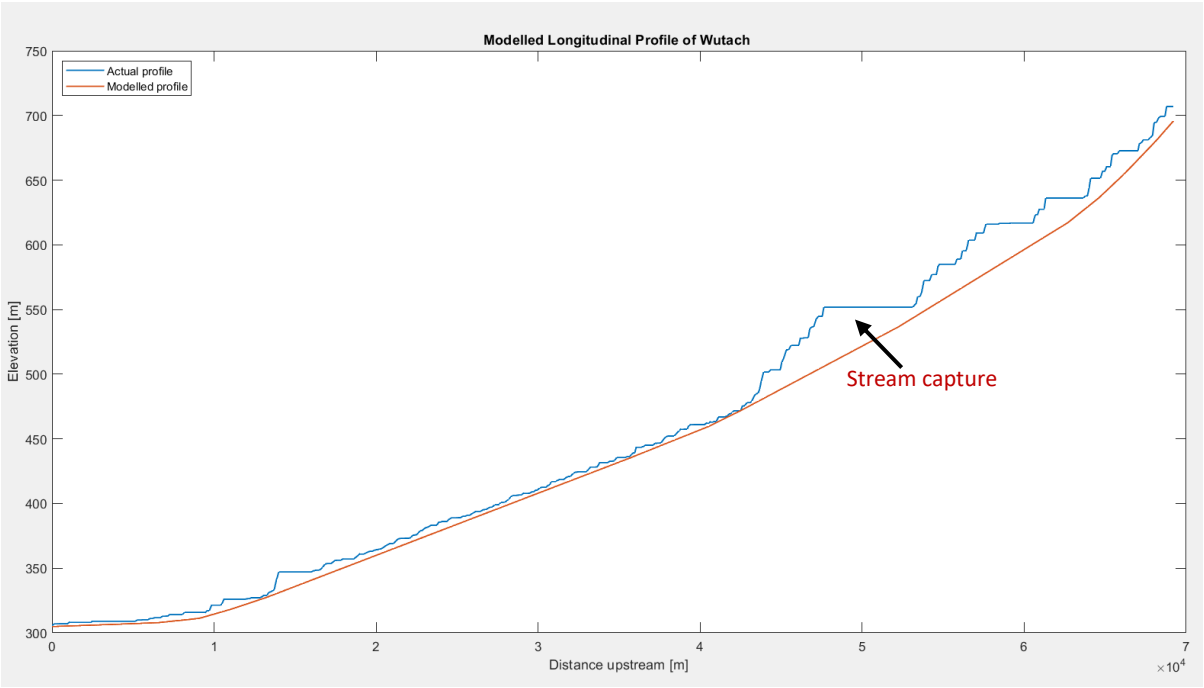

Fig 6: Modelled longitudinal profile of the Wutach river indicating the newly formed river reorganization.

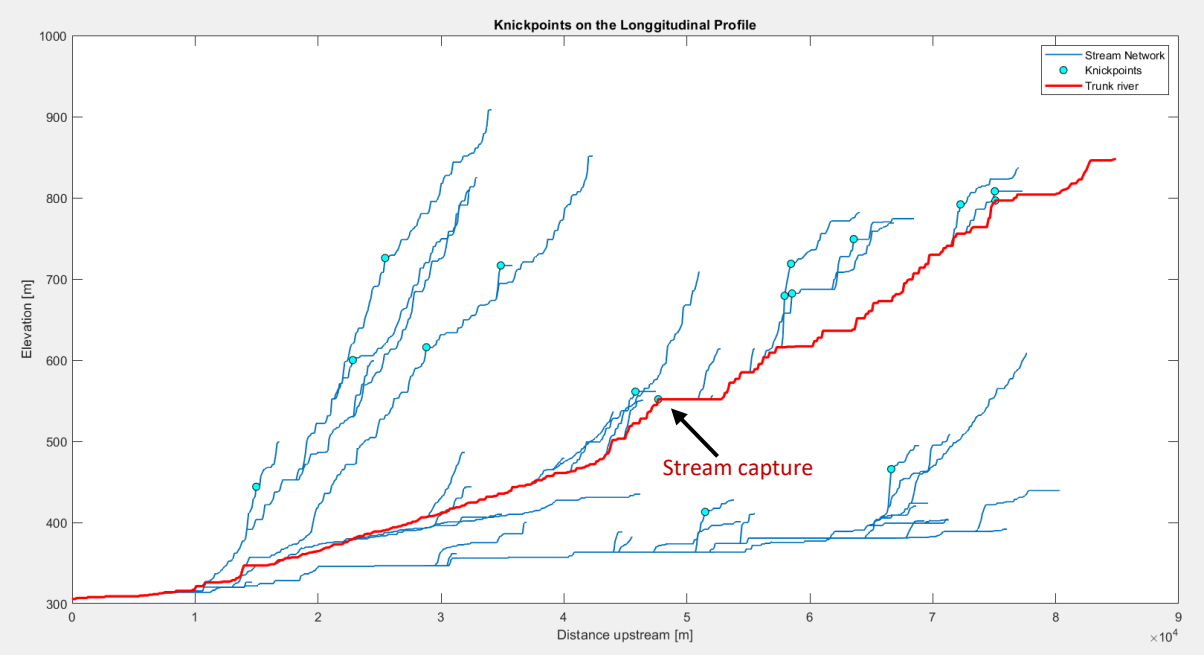

Fig 7: Modelled stream network longitudinal profile based on knickpoints.

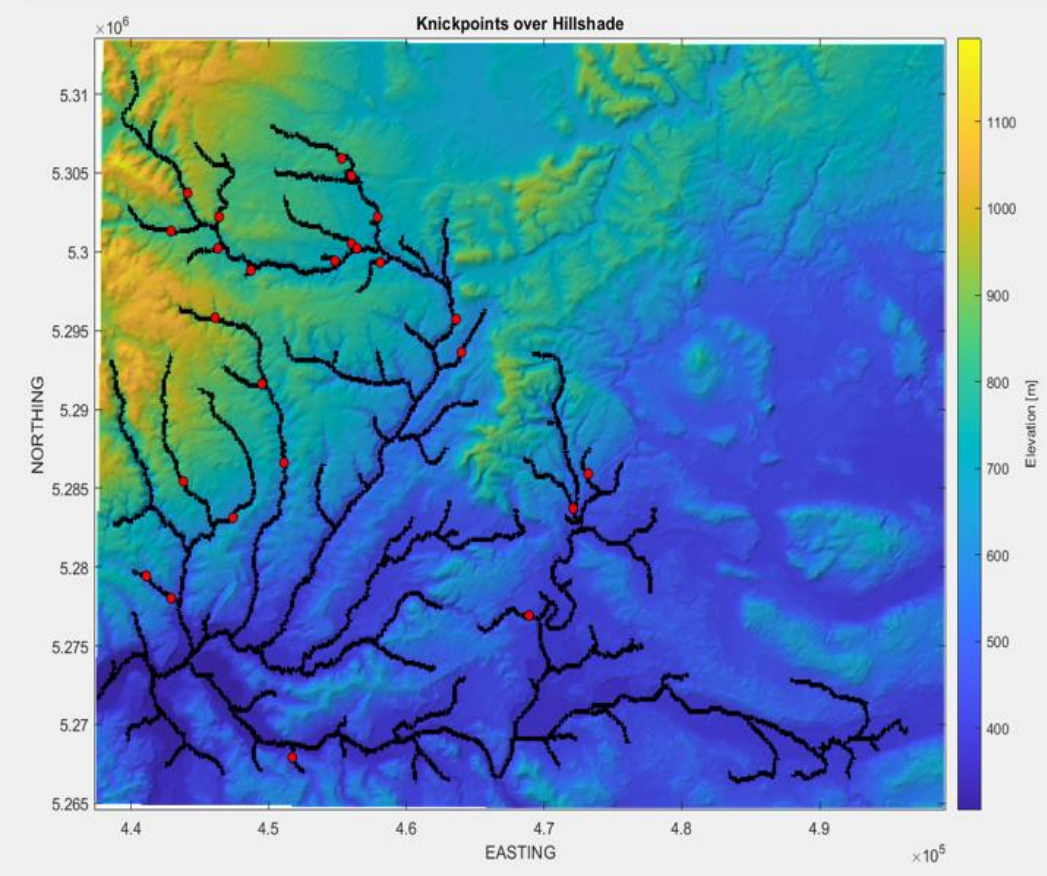

Fig 8: Map of the study area showing the location of the knickpoints.

5. DISCUSSION

The geomorphological activities in the Wutach gorge corresponds to various relief and erosion processes, action of groundwater flow direction and accumulation, and many other tectonic activities. The temporal position variation of the stream network indicates the change and development of new tributaries, such as the Rhine-Wutach River capture. The stream network also reveals an elbow of capture i.e., it denotes sharp turn in almost at right angle along the flow accumulation Map. The water gap between Danube and Wutach as visualized within the figures above denotes a deep and narrow valley in sort of a gorge modelled by the pirated stream towards the head erosion across the ridge.

The upwardly concave longitudinal profiles of all the major rivers draining indicate rates of channel incision that are probably outpaced by tectonic forcing. As the Wutach tributary-trunk channel relief increases, the tributary streams adjust to a new base level. Furthermore, the river profile is not straight and as a result depicts higher gradient as water decreases downstream.

Lithological knickpoints were detected where the river flows indicating a steep reach in the stream network profile. The detected knickpoints indicates area influenced by tectonic and glacial activities, such as the creation of an elbow of capture as the Wutach reorganizes itself from its former source (Feldberg-Donau) whereby creating a sharp change in river channel slope.

6. CONCLUSION

The relative evidence of drainage reorganization from the Danube (Feldberg-Donau) into the Rhine-Wutach River whereby creating a gorge along the Wutach has revealed tectonic events that has occurred in the past denoting the geological principle of uniformitarianism (the present is a key to the past). These tectonic activities are obviously controlled by hydrological conditions and erosion activities along the Wutach. The analysis of longitudinal profiles for the major river draining the stream network demonstrates that the Danube River could not contend with the stream power flowing through the Rhine-Wutach River network and thereby losing its connection with the Wutach.

The evidence of stream piracy at Wutach gorge may have impose some physical and ecological challenges such as accelerated erosion and deposition of sediments due to the changes in river flow direction whereby causing hanging tributaries in the Feldberg-Donau River channel. This report has been able to establish a methodological approach using the MATLAB-based software to interpret stream network evolution and proven evidence of active river piracy at Wutach gorge river channel.

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