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River Capture: A Field and Modelling Study (Ref IAP-17-86)

Newcastle University, School of Computing and School of Geography, Politics and Sociology

In partnership with

Durham University, Department of Geography

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Key Words	Landscape evolution, River Capture, Modelling, High Performance Computing

Overview

Drainage rearrangement by river capture, beheading and diversion (see Bishop 1995 and references therein) is a commonly invoked process within landscape-evolution models and is observed to occur in glacial through to fluvial environments (e.g. Harvey & Wells 1987; Snyder *et al.*, 2008, Shugar *et al.*, 2017). A river capture occurs when an actively incising and headward-eroding river system beheads and re-routes the drainage of a less active system. Such captures may dramatically increase the catchment size of the active 'capturing' stream which has implications for stream power, sediment and water discharge and routing (Mather *et al.*, 2002; Stokes *et al.*, 2002) and thus flood magnitude and frequency. In some cases different bedrock lithologies may be added to the extended

Fig. 1 View across the beheaded and now abandoned Rambla de los Feos valley. Active incision to the left (north) is due to post-capture incision in the adjacent, pirating Rio de Aguas, some 90m below. Note 4 lane motorway for scale in north (left) and south (right) of image

catchment area that can affect the sediment concentrations in flood events, reflected in aggradation or degradation below the capture point, depending on the direction of change (Shepherd 1982).

Fig 2. Example of a post-capture, incision related landslide more than 1km across and more than one million cubic metres in size. Located above the capture point. Satellite image from Google Earth.

Although numerous examples of river captures effecting base-level changes within fluvial systems are documented most of this research is qualitative. A few recent studies have attempted to quantify the spatial and temporal changes in incision at a catchment scale (Harvey et al. 1995; Mather 2000a; Mather *et al.*, 2000; Stokes *et al.*, 2002). Where such stream piracy transpires, rapid base-level changes of 10s to 100s of metres are recorded, to which the fluvial system must adjust (e.g. Harvey *et al.*, 1995; Calvache & Viseras 1997). River capture thus has profound implications for sediment flux and routing between and within sedimentary basins (Mather 2000b; Mather *et al.*, 2000). The wave of fluvial incision associated with capture events is also commonly linked with valley-side slope instabilities such as bedrock landsliding and gullying (Mather et al 2003; Azañón *et al.*, 2005; Griffiths *et al.*, 2005). Thus, quantifying the direction and magnitude of landscape response to river capture events is crucial for enhancing approaches to landscape management, hazard assessment and basin and landscape modelling.

The overall aims of the project are to examine the principal mechanisms of river capture, understand the dynamical landscape response and consider the significance of this process for long-term drainage-network development.

Following from these aims the project has four principal objectives:

1) To use the landscape evolution model PARALLEM to model a specific river capture event;
2) To compare and contrast model outputs directly with field observations for the specific case study;
3) Examine the likely frequency of capture as a mechanism for fluvial network development for the specific case study;
4) Determine the wider significance of river capture as a key mechanism for drainage network evolution.

Methodology

This project will use and further develop PARALLEM, a landscape-evolution model (McGough *et al.*, 2012) designed to leverage the high compute capabilities of GPGPUs (general purpose graphical processing units).

The candidate will be based in the School of Computing, Newcastle University under the supervision of Dr. McGough. The School has extensive expertise in parallel computing and through collaboration with Prof. Maddy (School of Geography, Politics and Sociology) the candidate will have direct access to our state of the art HPC cluster. The successful candidate will be expected to deploy parallel processing techniques using CUDA and MPI to utilise our high performance GPGPU cluster (which currently has 14 GPGPUs). Further algorithm development may also take place via access to the University HPC Rocket cluster.

In order to simulate the mechanisms of capture newly developed algorithms will be needed in order to simulate river channel lateral movement, numerically stable transitioning from single to multi-thread channel geometries, and active slope failure (landsliding). Numerical formulation of these algorithms will be accomplished in close collaboration with Prof. Wainwright (Durham University).

Specifically the project will aim to simulate the well-documented Pleistocene river capture by the Rio Aguas of the headwaters of the Rambla de los Feos in South eastern Spain (see Figs 1, 2 and 3).

Detailed pre-existing data will be made available through direct collaboration with an external supervisor – Prof. Anne Mather (Plymouth University) but additional fieldwork will be undertaken to establish field measurement of key model parameters e.g. surface erodibility.

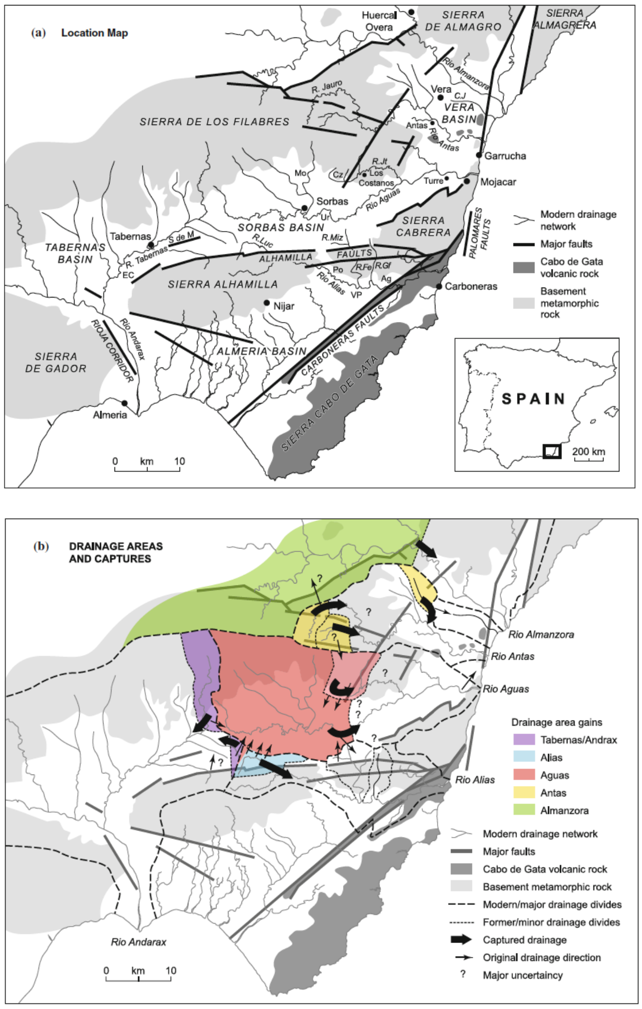

Fig. 3 a) regional setting of field area and b) significant river capture drainage diversions. The best documented, 70ka river capture event diversion is the red 'Aguas' capture in the centre of the figure. From Harvey et al 2014

Timeline

The project schedule is as follows:

Year 1:
Oct-Dec: Background reading. Faculty Training Programme.
Jan-Mar: Introduction to PARALLEM, test runs. Faculty Training Programme.
April/May: 1 week fieldwork around Sorbas (with Supervisors). Introduction to existing stratigraphy. Identification of key areas for investigation.
June-Aug: Lateral erosion algorithm development.
Aug/Sept: 1 week field work. Sampling for model parameter estimation.

Year 2:
Oct-Dec: Initial modelling experiments.
Jan-Mar: Development of multi-channel system algorithm. Modelling Experiments.
April/May: 1 week field work (further model parameter measurements).
June-Aug: Development of landsliding algorithm.

Sept: 1 week final field work.

Year 3:
Oct – Mar: Final modelling experiments. Data analysis and visualisation.
Mar – Aug: Writing Thesis - chapters passed for comment as and when ready.
Sept: Complete thesis draft for comment.

Year 4 (six months only):
Oct – Mar: Complete papers and submit Thesis.

Training & Skills

This project will develop cross-disciplinary scientific training in problem solving, data analysis and report writing. It will provide the student with high-level skills in: (a) high performance computing; (b) earth system modelling (c) field-model data comparison.

The student will also benefit from broad skills training provided in-house at Newcastle (e.g. thesis and paper writing, presentation skills) and from a broad range of environmental science training provided within the IAPETUS Doctoral Training Partnership framework.

References & Further Reading

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Further Information

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