Exploring the past

Ongoing investigations at Arizona State University look set to uncover and quantify the geological and climatic events that have led to the formation of the awe-inspiring landscape of the Safford Basin and Aravaipa Creek Basin.

ONE OF THE aims of geologists is to understand how landscapes change – that is, how they are influenced by climatic and tectonic factors, and in some cases human activity. One method of achieving this end is to look for evidence of change in the past, and use this to understand how landscapes have formed and may continue to develop in the future. It is an ambitious and important geological endeavour, satisfying the basic curiosity of how the Earth once appeared, while also bearing influence in a variety of other fields, from modern geography to evolutionary biology. Building a clearer picture of geological and geographic change could also serve as a useful predictive tool, helping to understand a range of similar landscapes and the changes that have led to their distinct features.

SETTING THE SCENE

Dr Arjun Heimsath of the Arizona State University, USA, is currently working along with his graduate student Matthew Jungers on better understanding landscape changes in Safford Basin and Aravaipa Creek Basin. This particular area of focus is within the Basin and Range Physiographic Province of southeastern Arizona, which is defined by the interspersion of high relief, rugged mountain ranges and low lying basins. This area, once governed by extensional tectonics 8-12 million years ago, is now undergoing post-tectonic landscape evolution, which started approximately 3-5 million years ago. These driving forces brought with them different geological environments, the effects of which have shaped the modern landscape. While extensional tectonics dominated, internally drained structural basins filled with sediment eroded from the adjacent mountains. Waning regional extension has allowed climate and sedimentary system dynamics to become the dominant forces shaping the topography.
area. Collaborations with Greg Balco and David Shuster at the Berkeley Geochronology Center are providing $^{21}$Ne concentrations for cosmogenic nuclide burial dating of deposits beyond the range of more conventional $^{26}$Al and $^{10}$Be burial dating.

Do you consult additional climate proxies to determine or confirm climatic changes during the period? To what extent do you work with scientists from external disciplines?

Paleoclimate proxies from paleosol carbonates in the Upper San Pedro Basin analysed by Dr Gary Smith at the University of New Mexico suggest a wetter climate during the Pliocene that transitioned into a more monsoonal climate during the Pleistocene. One question we are actively investigating is whether a shift to more seasonal precipitation within the millennial scale and oscillating climate of the Quaternary drove regional periods of incision in southeastern Arizona. To further investigate the paleoclimate of southeastern Arizona, we are in the early stages of collaboration with Professor Ron Amundson at the University of California, Berkeley to broaden the coverage of the paleosol carbonate paleoclimate record in southeastern Arizona’s Basin and Range allowing us to more directly link our studies of surface processes with climate forcing.

Is educational outreach an important aspect of your work?

Yes, educational outreach and the communication of our results to the public is something we value in all our research efforts. I give invited presentations several times a year and ensure I convey my active research results to the general public. Similarly, in all of the classes I teach, I actively work to convey the details of research efforts to students who are not familiar with the them. I believe strongly in the importance of conveying science to both the general public and policy makers who are instrumental in how our natural resources are used. As part of this project, in 2012/13, Matthew Jungers was awarded an Arizona State University (ASU)/NASA Space Grant Fellowship to pursue both informal and formal educational projects. In 2012, he produced a series of online teaching modules on the subject of sustainable energy resources in Arizona targeted as a teaching tool for middle school teachers. A year later, he helped develop teaching materials for a senior capstone class within ASU’s School of Earth and Space Exploration. Matthew also wrote a non-technical article outlining our research for the Arizona State Geological Survey and presented our results to local geology groups such as the Arizona Geological Society and the Daisy Mountain Rock and Mineral Club of Anthem, Arizona.

What portion of this research did you present at the American Geophysical Union’s Fall Meeting in December 2013?

Matthew gave a talk entitled ‘Climate and Tectonics Need Not Apply: Transient Erosion Driven by Drainage Integration, Aravaipa Creek, Arizona’, on our work on the Aravaipa Creek Basin and the important effects of drainage integration during transient periods of landscape evolution.

Looking into the Past

In order to tackle these questions, Heimsath is taking full advantage of a technique known as cosmogenic nuclide geochronology. Cosmic rays interacting with oxygen and nitrogen lead to the production of secondary cosmic rays – a cascade of lighter particles also known as an air shower. Some of these bombard the Earth’s surface, and are mostly stopped by soil and rock within the first 1-3 metres of the surface of the Earth. Those particles that collide with quartz can induce spallation reactions in silicon and oxygen atoms, and other such landscapes: to what extent are incision and erosion driven purely by the elevation difference at the time of drainage integration? What are the pace and pattern of Tertiary and Quaternary basin integration events? Has Aravaipa Creek fully adjusted to its new base level? Finally, he hopes to understand how to distinguish between different modes of drainage integration, and establish a timescale for these integration events.

Area of interest in southeastern Arizona. The deposits of interest for this study are: 1) the uppermost, undeformed basin fill surfaces adjacent to mountain range fronts common throughout the region’s main basins, 2) uppermost sedimentary basin fill sediment, best exposed in the Sonoyta, Upper San Pedro, Lower San Pedro and Safford Basins, 3) quaternary terraces best preserved in the Sonoyta, Santa Cruz and Safford Basins.
**OBJECTIVES**

To understand how climate shapes the semi-arid landscape of the Sonoran Desert. Building such an understanding is also applicable to broad swaths of the habitable world due to similarities in climate, and may also help in understanding mysteries surrounding ancient civilisations that existed in the desert southwest and elsewhere. This goal is reached by finding and dating sedimentary deposits from different periods of past climate change, stretching back to nearly 10 million years. This research also seeks to reconstruct the landscape that was likely to be shaped by those past climates.

**KEY COLLABORATORS**

Research Geologists Phil Pearethree and Ann Youberg; Geologist II Joe Cook, Arizona Geological Survey

Dr Greg Balco; Associate Professor David Shuster, Berkeley Geochronology Center and University of California, Berkeley

Professor Ron Amundson, Department of Environmental Science, Policy and Management, University of California, Berkeley

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**RESULTS AND FUTURE QUESTIONS**

Heimsath and Jungers have reached the final stages of sample preparation and data analysis for their study of Safford Basin and Aravaipa Creek Basin, although their study of the Gila River system in the Quaternary period is ongoing. As Heimsath adds: “Our work in Aravaipa Creek Basin suggests that Aravaipa Canyon was carved as a result of drainage integration with the Lower San Pedro Basin, and over 50 cubic kilometres of sedimentary basin fill have been eroded from the basin,” – sediment that had been eroded from the basin due to factors other than climate or active tectonics. The work therefore demonstrates the potential importance of drainage integration during transient periods of landscape evolution.

As for his future work, there are some questions that Heimsath is eager to tackle with the methods his group uses: “The first is how much of an impact are humans having on the Earth’s surface by increasing erosion rates through deforestation, road construction and the like”. He concludes: “The second is how significant the chemical weathering of active mountain belts are in the long-term global climate cycles through the uptake and release of CO₂.”