

Biological footprints in the geological record

Landscapes across the globe are known to show evidence of patterning. Now, **Dr Adam Watts** from the Desert Research Institute, and colleagues at the University of Florida and elsewhere, are showing how natural biological processes, incorporating positive and negative feedback loops, act to create some of these dramatic geological features. Taking the Big Cypress National Preserve (BICY) in southwest Florida as an example of such a landscape, the team have shown how simple factors produce grand results.

The ability to view landscapes through satellite and airborne imaging has made it possible to quickly identify areas which show evidence of patterns. It is these patterns that research groups, such as Dr Adam Watts's, are particularly interested in. In 2008, Dr Matthew Cohen identified a particular patch of karst landscape in Florida as potentially patterned. This inspired a series of researchers, including Dr Watts who set about attempting to prove this hypothesis using statistical, locational analyses of the depressions seen on the surface, showing that they were neither random nor clustered.

A BIRD'S-EYE VIEW

The Big Cypress National Preserve (BICY) landscape is a mix of depressions, containing forested wetland vegetation (known as cypress domes), short hydroperiod (the time in which the area is waterlogged) marshes, and pine forested uplands. By measuring the distances to the nearest neighbours of the different vegetation communities, Dr Watts and his team were able to show that there was significant overdispersion (greater variability than would be dictated by chance alone). Dr Cohen and other members of the team identified a hydrological effect as being the most likely cause of

this phenomenon, with the presence of biological material accentuating and concentrating the dissolution of bedrock in certain areas.

FORMING AN IDEA

It is hypothesised that, as a depression forms, it collects more water, which accelerates dissolution and increases the depression. The presence of water also encourages vegetation and algae, which acidify the local environment as they biodegrade, again accelerating dissolution of the bedrock. The area around the depression now becomes a watershed, preventing the pool from expanding to join with others and create larger pools, as well as providing a distinctly different ecosystem. The result is the appearance of the observed patterning. As the depressions fill with detritus, they form the perfect habitat for larger vegetation, such as the cypress trees, to flourish, creating a relatively isolated ecological niche which is replicated across the landscape.

The BICY landscape is not alone in exhibiting regular patterning as a result of biological processes. Regular patterning has been observed in a variety of landscapes from string and maze fens, to estuarine mussel beds. However, this study is unique in that it ►

Dr Watts's work is vital for furthering understanding of how ecological and geological processes work together in shaping the landscape



This aerial image shows the small depression wetlands (called cypress domes), which create regular surface patterns in the Big Cypress landscape. Watts and his colleagues continue to investigate the ecological drivers causing their formation.

is the first to demonstrate coupled, regular patterning in bedrock and vegetation within a single landscape. That said, Dr Watts and the team believe that the basic processes that shape the BICY landscape are likely to be similar to those that form patterned landscapes elsewhere.

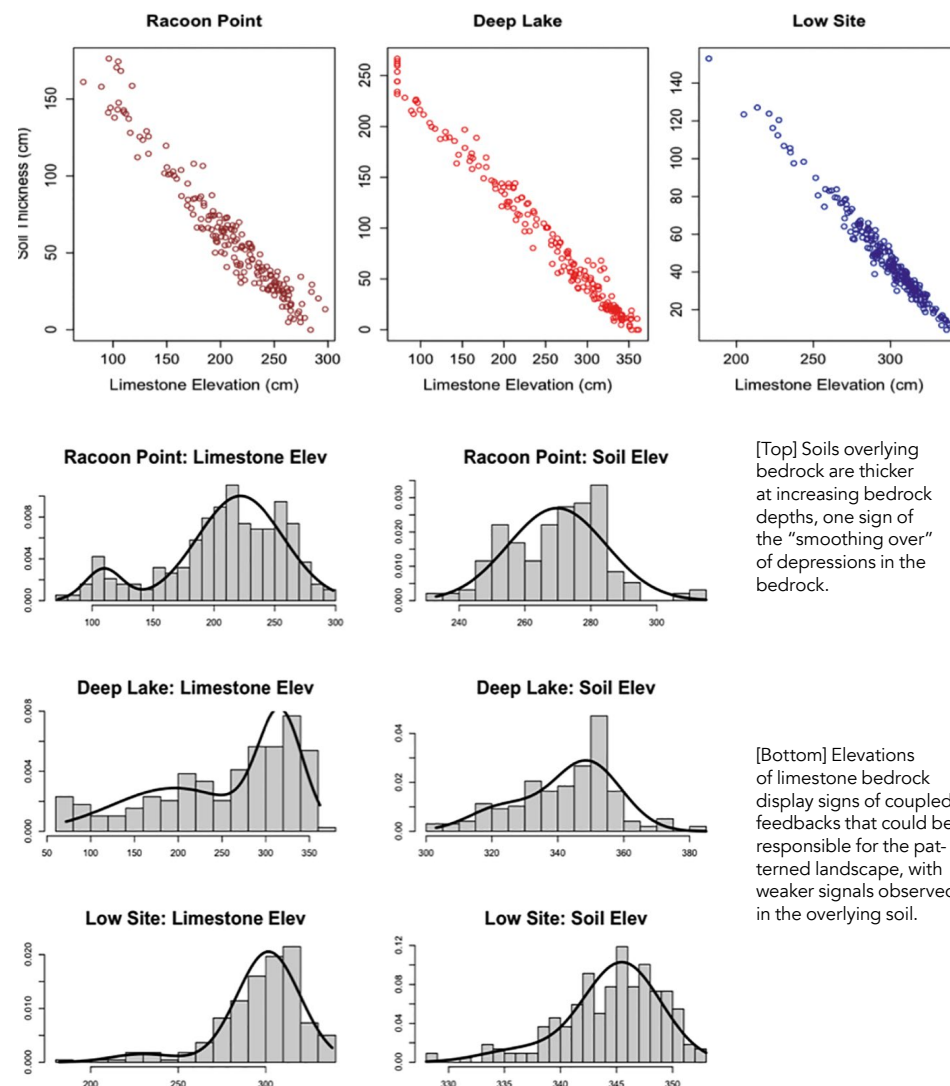
WATER AS DESTROYER AND CREATOR

Karst landscapes (formed by the dissolution of soluble rocks) are, by definition, shaped by hydrological forces – but many other landscapes are also patterned almost solely by the action of water. The team are therefore sure that water is the prime factor in the BICY landscape too, but are investigating the extent to which other factors contribute to the patterning effect. This includes the availability of phosphorous, which is limited in this environment and part of the biogeochemical cycle, as well as the effect of soil and vegetation on the hydroperiod in their location.

The study team are focusing on soil deposition as a key indicator of the relationship between pattern-forming and pattern-smoothing effects. By measuring the relative depths of soil at different sites, they have shown that soil depth increases as bedrock depth increases, supporting the view that pattern forming processes hold sway in concentrating soil (either through water borne transportation or biological generation) into bedrock depressions. This creates another positive feedback loop for the creation of cypress domes by providing the required substrate.

A BIOGEOCHEMICAL MARVEL

Dr Watts believes this work is vital for furthering understanding of how ecological and geological processes work together in shaping the landscape. He sums up the appeal of the research by saying that: “The central idea that patterns on the earth’s surface arise spontaneously from interactions between plants and animals, on one hand, and rocks and water on the other,



is a reminder of the strong and sometimes surprising links that exist in ecosystems.”

At the BICY site, they have found that the wetland ecosystem has been responsible for changing the shape of the land over a prolonged period – perhaps thousands of years. This insight helps in understanding the background to a remarkable landscape capable of supporting a broad collection of organisms and distinct habitats. It also has important implications for the management

of this area through improved knowledge of its hydrological characteristics, which impact on water movements further across the South Florida system. Understanding this information could be potentially vital in mitigating the effects of sea level rise on the local ecosystem and biological processes within it.

WIDER HORIZONS

This, of course, is not just relevant to South Florida: Dr Watts and his team are contributing to a body of knowledge on karst landscapes particularly (which form 20% of the earth’s surface) as well as isolated wetlands more generally. As such, this research has the potential to inform decision making in national bodies aiming to protect and preserve these exceptional and often productive ecosystems.

To this end, the team are partnering with scientists from the US National Park Service to communicate the results of their work.

Q&A

How did you become inspired to investigate the BICY site as a patterned landscape?

The Big Cypress landscape is ecologically fascinating and quite beautiful to explore on foot, but when one is lucky enough to see it from a helicopter or airplane, the landscape displays a patterned appearance that adds a dimension of beauty and stirred our minds to wonder why it looks that way. For me, it was the good fortune of seeing Big Cypress from above the trees that led to this fascination with its pattern and the processes that might create it.

How confident are you that your explanation of the observed phenomena is the correct one?

In the first stages of this project, we saw compelling visual suggestions of patterned arrangement, and our subsequent work was able to confirm it. Now we are measuring the proposed mechanism, such as the rates at which bedrock appears to be dissolving. We’re also checking to see that these mechanisms would produce the same type of patterning that we see, and so far our measurements match the predictions of patterning quite well. I haven’t encountered any other explanation that makes as much sense as the one we’re exploring, and based on the evidence I’m convinced we’re on the right track.

Why does the existence of a biological component make a difference over a purely chemical process?

We often see evidence of natural processes on landscapes that are abiotic in origin – erosion and chemical weathering of rock are examples of physical and chemical processes that generally do not involve

organisms. The role of organisms here is interesting because it seems to be an example of “ecological drilling” at work, and perhaps even the creation and expansion of a habitat niche by an ecological community.

What is the broader impact of this research on ecosystem management?

Here we see an example of a large landscape that continues to see big processes at work, such as wildfires and this amazing process of creating and maintaining patterns in the bedrock. In order to maintain the integrity of special places like this landscape, we should try to maintain the ability of these processes to operate. The implications of such an approach for management includes thinking at big scales and incorporating as much complexity as possible, which is already occurring. Also, my hope is that public and private lands throughout the region can be managed with some cooperation.

What is left to be discovered about the factors influencing the BICY site?

Just in terms of patterning, I can think of several questions: for example, what roles do the dissolved calcium and other materials play once they are exported from the BICY landscape and arrive in other ecosystems? Do other processes, like fires, affect the processes that produce landscape patterning? And certainly, how will changing climate and rising seas affect this “ecological drill”? There are also so many other fascinating questions to ask about the plant and animal species that live in this intriguing landscape, that I feel like we have just begun to explore it.

Detail

RESEARCH OBJECTIVES

Dr Watts’s research interests include fire ecology and fire science, interactive effects of ecosystem processes and disturbance on landscapes, ecological restoration, and unmanned aircraft systems.

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COLLABORATORS

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BIO

Dr Watts received his BS in Biology from Emory University in 1999. He later completed an MS and PhD at the University of Florida in Interdisciplinary Ecology, before continuing his work at the University of Florida as a Postdoctoral Research Ecologist in the Fire Science Lab.

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Dr Watts and his team draw on their knowledge of a wide variety of disciplines to uncover the small-scale hidden processes which result in nature’s grandest designs

Researchers are also offering guided tours of the area to the public, educating them about the uniqueness of the landscape and uncovering some of the captivating elements not immediately visible to the casual observer.

Dr Watts and his team are passionate about the area and their research, a passion which is evident in their commitment to the

project. They are also first class scientists, drawing on their knowledge of a wide variety of disciplines (geological, biochemical and statistical to name a few) to uncover the small-scale hidden processes which result in nature’s grandest designs.

• This article was co-authored by Dr Adam Watts and the Research Features editorial team.