**////Title: The Geological History of Once-Glaciated Regions Affects Current and Future Earth Surface Processes**

**////Standfirst:**

Over the past few millions of years, a succession of ice ages has profoundly influenced the geology of Earth’s northerly latitudes. These past events continue to influence our lives today – particularly in the fertile regions we now rely on for agriculture. By tracing the advances and retreats of ice sheets, Dr Alison Anders at the University of Illinois is gaining important new insights into how the landscapes and ecosystems of these regions are intrinsically linked to the geological past. Her team is also revealing how these areas are responding to a changing climate, and to complex human relationships with the land.

**////Main text:**

All life on Earth is sustained by a deeply complex web of interacting processes in the water, soil, minerals, air, and ecosystems, all of which reside close to the planet’s surface. Today, researchers describe these interactions as taking place within a ‘critical zone’, which extends from the tops of trees, down to the depths where groundwater flow becomes extremely slow.

To study this zone, researchers must have a detailed knowledge of the compositions and structures of geological materials beneath the surface. These materials were shaped by processes in the distant past, long before humanity began to reshape the landscape. As a result, any responses of critical zones to changes in Earth’s climate and human land usage are still profoundly sensitive to this history. However, since the ground beneath our feet has been shaped by a diverse array of processes, accurate assessments of critical zones in certain regions can be incredibly challenging to make.

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So far, most research into critical zone responses has focused on regions where the soil originated from the long-term erosion of local bedrock – brought about by soil creep down hillslopes to rivers which carry it away. In these places, looking deeper into the Earth is equivalent to looking back in time; materials at the surface were once just like materials now found at depth.

However, there are many regions where this picture isn’t applicable. During the succession of ice ages that occurred over the past few million years, vast glaciers extended thousands of kilometres farther south than they do today – covering almost the entire Midwest and Northeast regions of the modern US.

As these glaciers advanced and retreated across the landscape, they transported vast amounts of rock, soil, silt, and sediment across extensive distances – transforming the geology of the regions once covered by them. One such area is the US Central Lowlands, which now extends from North and South Dakota in the west, to New York state in the east. In this vast region, a combination of deep, fertile soil, temperate climate, and high population density has created one of the most productive areas of farmland in the world – making it a particularly important area to study.

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In their research, Dr Alison Anders and her colleagues at the University of Illinois aim to understand how sediment, water, energy, carbon and nutrients move through the critical zone of the Central Lowlands. The team’s approach is based around a conceptual model of how the critical zones of these landscapes were transformed during past periods of glaciation.

As a whole, the Central Lowlands are characterised by thick surface deposits, extending to depths of 150 metres. Within the region, geographical variations in past geological processes have created a broad diversity of materials including silt, sediment, soil, and rock. The changing climate that shaped this geologic record was accompanied by a diverse range of ecosystems, including tundra, boreal and hardwood forest, and open prairie.

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To account for this diversity, the model would need to identify the main characteristics responsible for transforming critical zones throughout glacial cycles. In their study, Dr Anders and her team used the ‘Intensively Managed Landscapes Critical Zone Observatory’, which supports field research at three different sites in Minnesota, Iowa, and Illinois.

In the past, each of these sites experienced successive cycles of glaciation and ice retreat, and they are all now occupied by intensive corn and soy agriculture. These sites are used to study the interactions in the critical zone that control the movement of water, nutrients, sediments, and energy – over timescales ranging from just minutes, to millions of years.

Through their studies at the Observatory sites, the researchers identified two key characteristics of their critical zone structures, which are essential for any accurate model of critical zone development in the Central Lowlands to consider. Firstly, they highlighted the diverse origins and transport trajectories of minerals in the ground. Secondly, they emphasised the variability in climate, ecosystems, and movements of water across the landscape during inter-glacial periods.

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Drawing from these insights, Dr Anders and her colleagues have developed an idealised conceptual model of the interactions between past ice sheets, and the critical zone of the Central Lowlands. In their model, landscapes prior to glaciation experience weathering and soil formation in surface sediments. As glaciers cross the region, they erode surface materials in some places, and deposit sediments transported from distant regions in other places. Sediment transported initially by the ice continues to move in glacial meltwater and preferentially fills pre-glacial stream valleys and lakes.

Pre-glacial stream networks tend to be filled in with sediment, changing the way water moves across the landscape, while pre-glacial soils are preserved in places where old sediments weren’t entirely eroded. At the same time, ecosystems close to the glacier transition into cold-resistant boreal forests, which eventually give way to sparse tundra. At the height of the glacier’s advance, cold, dry conditions cause windblown sand and silt to cover the soil in front of the glacier.

As the glacier begins to retreat, this silt continues to accumulate on the land surface – completely burying the sediment deposited directly by the glacier. Subsequently, the warming climate triggers the growth of new vegetation, which gradually transforms from boreal forests, into hardwood and coniferous woodland – and eventually, into prairies and savannas. While this happens, rivers begin to carve out new valleys and drainage networks into the silt and sediment deposited by the glacier.

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This model provides a detailed picture of how critical zones develop in previously-glaciated regions and shows that the geologic and ecosystem history has strongly influenced materials and landforms present today. The flow of sediment, water, carbon, energy and nutrients through this critical zone is controlled by the legacy of glaciation, and the critical zone continues to evolve in response to past ice ages. Added to this inheritance, human activities have greatly altered the critical zone of the Central Lowlands by altering surface and subsurface drainage, transforming the ecosystems to agricultural croplands, and applying artificial fertilisers. These anthropogenic changes are best understood in the context of the pre-agricultural trajectory of critical zone evolution.

This tie between past and present means that the team’s discoveries are not only interesting to geologists. As the climate warms, and human activities continue to intensively alter the landscape, the complex web of processes that sustain life in these regions remains intrinsically tied to their geological past. As a result, the findings of Dr Anders and her colleagues will help researchers to gain a better understanding of the changes to come.

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This SciPod is a summary of the paper ‘Impacts of Quaternary History on Critical Zone Structure and Processes: Examples and a Conceptual Model From the Intensively Managed Landscapes Critical Zone Observatory’, from Frontiers in Earth Science. [doi.org/10.3389/feart.2018.00024](https://doi.org/10.3389/feart.2018.00024)

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