A

Ansichten der Calzone: Views of the Calhoun Critical Zone Observatory

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The German title of our piece follows Alexander von Humboldt, to honor his 250th birthday in 2019. Humboldt's Ansichten der Natur[1] *was first published in 1804 after his five-year expedition to the Americas.* Ansichten *was a small book that fused geology and biology, nature and culture. We assert here that Humboldt's integrative approach is congruent with the twenty-first-century's Critical Zone science.*

ON A SUNNY MORNING in April 2014, historian of geosciences Dr. Enriqueta Barrera of the US National Science Foundation (NSF) opened a meeting of several dozen Earth scientists from across the United States. The group was gathered at Padgett's Creek Baptist Church in rural South Carolina, in preparation for a field trip to one of the NSF's newest Critical Zone Observatories (CZO). The Earth scientists were surrounded by flowering dogwoods and gentle mild breeze of early spring in the Piedmont, a region known in colonial times as the "Flower of Carolina."[2] The rural community around the church has about 1,200 inhabitants, many of whom are descendants of multigenerational families. Their average age is about forty, 60% are white and 40% black, and about 25% of those working-age are employed by textile-related industries.[3] The landscape and its people have a rich interactive history that is appreciated and explored by contemporary Critical Zone studies that seek to achieve what can be called Humboldtian goals — a merging of scholarly disciplines with rigor and beauty.

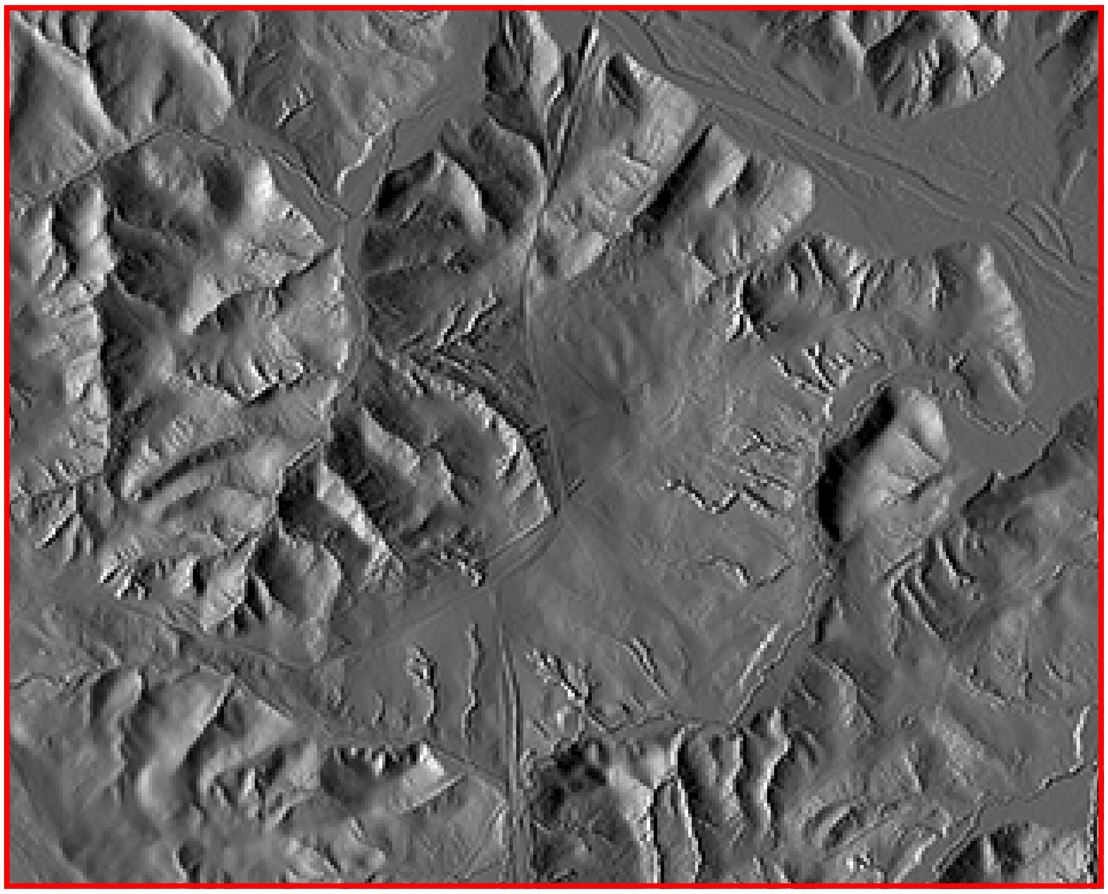
The US South is well known for its writers such as William Faulkner, Charles Chesnutt, Eudora Welty, Zora Hurston, Richard Wright, and James Agee. Much less appreciated is that the South is made famous by scientists. Even during the first decades of cotton farming in the early 1800s, the region's soil erosion and declining soil fertility attracted the attention of geologist Charles Lyell, landscape architect Frederick Olmsted, and agricultural scientist and pro-slavery firebrand Edmund Ruffin.

On this bright April 2014 morning, a new generation of scientists meet at Padgett's Creek Church, excited to learn about the remarkable geology and agricultural legacies of the Southern Piedmont (*see figs.* A *and* B).

The well-respected hydrologist and geomorphologist Gordon Grant opened with a general introduction, pointing with outstretched arm to the hay field in front of the church. Grant suggested that beneath the Piedmont's gently rolling hills were secrets yet to be told, dynamic forces, and past events that were fundamental to the structure and function of the landscape that only a fully integrative Calhoun CZO could discover. In particular, the Piedmont's declension story of how humans have transformed the land is scientifically, historically, and philosophically stunning. The erosion of soils wrought by Europeans and enslaved African Americans since the late 1700s is nearly unbelievable (*see figs.* C 1, 2). Farming for cotton, tobacco, and food crops, most intense from 1810 to 1930, eroded a staggering twenty centimeters of soil across more than ten million hectares.[4] Today, that eroded soil has buried nearly all bottomlands and floodplains under a meter or more of this legacy

1 See Alexander von Humboldt, *Ansichten der Natur mit wissenschaftlichen Erläuterungen* (Tübingen: J. G. Cotta'sche Buchhandlung, 1808). The book is most recently published in English as *Views of Nature*, ed. Stephen T. Jackson, Laura D. Walls, trans. Mark W. Person (Chicago, IL: University of Chicago Press, 2014).
2 See Scott Huler, *A Delicious Country: Rediscovering the Carolinas along the Route of John Lawson's 1700 Expedition* (Chapel Hill, NC: University of North Carolina Press, 2019).
3 See http://www.city-data.com/city/Cross-Keys-South-Carolina.html.
4 See Paul S. Sutter, *Let Us Now Praise Famous Gullies: Providence Canyon and the Soils of the South* (Athens, GA: University of Georgia Press, 2015).

B



FIGS: A — In the midst of the Calhoun CZO sits Rose Hill Plantation, which is today restored to its appearance in antebellum years. The plantation is of interest to natural scientists, environmental anthropologists, historians, and the public. B — In the high resolution LiDAR image (~10km²), the square in the middle of the image is the Rose Hill house with the rose garden the small rectangle to the north of the house. Severe and deep gullies in the old cotton fields encroach on the house from all directions. All the accelerated erosion, gullies, terraces, and legacy sediments occurred from a century of farming, from about 1820 to 1920.

5 See Terry A. Ferguson et al., "Re-investigation of a colluvially filled valley containing deeply buried organic-rich sediments of Pleistocene age, Pauline, *South Carolina," Southeastern Geological Society of America* 51, no. 3 (2019). doi: 10.1130/abs/2019SE-327726.

6 Alexander von Humboldt and Aimé Bonpland, *Personal Narrative of Travels to the Equinoctial Regions of the New Continent*, vol. 3, trans. Helen Maria Williams (London: Longman, Hurst, Rees, Orme, and Brown, 1818), 321. Originally published in French as *Voyage aux regions équinoxiales du nouveau continent*, vol. 3 (Paris: J. Smith et Gide Fils, 1825).

7 Robert H. Montgomery, *The Cooperative Pattern in Cotton* (New York: Macmillan, 1929), 251.

sediment. Of course, in America, "the land of the free," farming with African slaves eroded more than the soil, a view joined by Alexander von Humboldt, who saw slavery as a critical failure in the young American democracy.

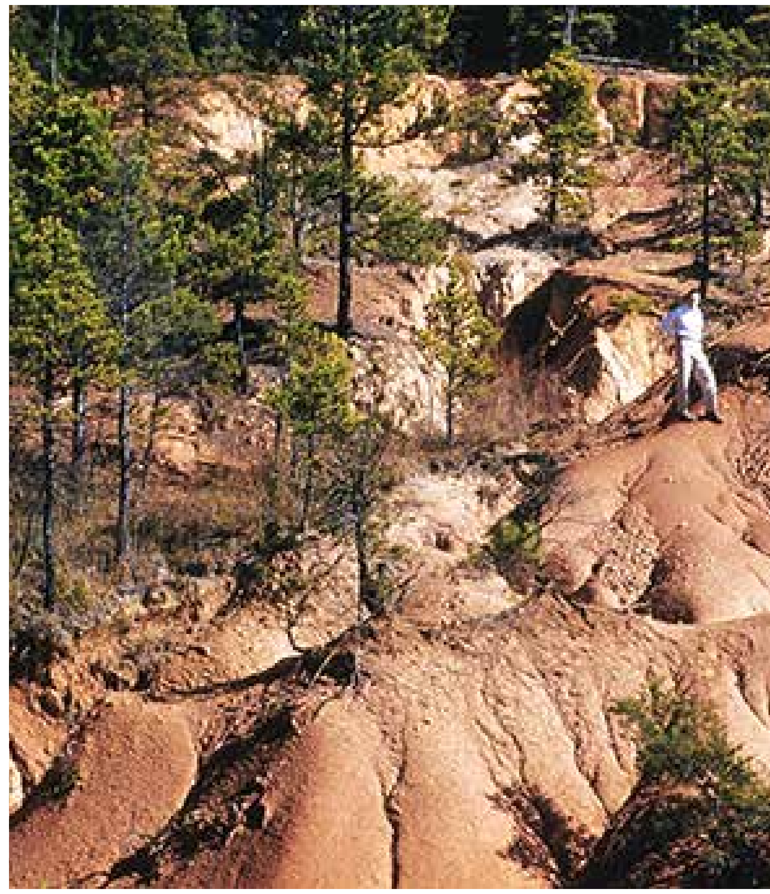
The severity of agricultural erosion across a century of agriculture has long astonished scientists, but equally astonishing are the data being assembled by contemporary scientists. They have quadrupled the estimated age of Piedmont soils to a minimum of two to three million years. Over that time, Piedmont s oils have developed deeply. Soil under the church may extend 40 meters over the granite bedrock. The scientists' work also points to massive instabilities and erosion events throughout geological time.[5] These new data challenge the long-standing paradigm that the Piedmont is one of the most geologically stable regions in America. This new perspective of the Piedmont's inherent instability is reminiscent of Humboldt's comment made after experiencing an earthquake: "We feel that we have been deceived by the apparent calm of nature; ... we mistrust for the first time a soil, on which we had so long placed our feet with confidence."[6]

By the early 1900s, the region became one of the most severely eroded and gullied in America. At that time, it was also home to many of the nation's most impoverished people. In 1929 Robert Montgomery, cotton economist at the University of Texas, wrote that farming had turned the South into "a miserable panorama of unpainted shacks, rain-gullied fields, straggling fences, rattletrap Fords, dirt, poverty, disease, drudgery, and monotony that stretches for a thousand miles across the cotton belt."[7]

The impoverishment of land and people attracted a wave of scientists in the 1930s, many of whom worked in and around Padgett's Creek Church. Within kilometers of the church, river sediments were studied by Hans Albert Einstein, who had a lively correspondence about Piedmont erosion with his father, Albert Einstein, then at Princeton. The accomplished geographer Carl Sauer organized Piedmont erosion research from his home in Berkeley, California. Hugh Bennett, the world's leading champion for soil-erosion control, actively publicized erosion research across the Piedmont. Sociologist Howard Odum wrote prolifically about the human-soil Piedmont problem, and Duke University ecologist Henry Oosting promoted the concept of plant succession that described how Piedmont fields were transforming into secondary forests. Finally, UCLA's Stanley Trimble authored the definitive geographic history of agricultural erosion in the Piedmont, a book still in print today.[8]

By the mid 1930s, the United States Forest Service (USFS) purchased many of the worst-eroded farms in and around Padgett's Creek Church and launched the nearly 1,500 square kilometers Sumter National Forest. The USFS recognized quickly that they were ill-equipped to manage such degraded lands, and in 1947 opened the Calhoun Experimental Forest, which they claimed represented "poorest Piedmont conditions,"[9] given the severity of its land use history, C1

C2



8 See Stanley W. Trimble, *Man-Induced Soil Erosion on the Southern Piedmont*, 1700–1970 (Ankeny, IA: Soil Conservation Society of America, 1974).

9 Louis J. Metz, *The Calhoun Experimental Forest* (Asheville, NC: USDA Forest Service Southeastern Forest Experiment Station, 1958).

10 See Daniel D. Richter et al., "Evolution of Soil, Ecosystem, and Critical Zone Research at the USDA FS Calhoun Experimental Forest," in *USDA Forest Service Experimental Forests and Ranges: Research for the Long Term*, ed. Deborah C. Hayes et al. (New York: Springer, 2014), 405–33.

11 See Daniel D. Richter and Sharon A. Billings, "'One physical system': Tansley's ecosystem as Earth's critical zone," *New Phytologist* 206, no. 3 (2015): 900–12.

12 See Henry J. Oosting, "An Ecological Analysis of the Plant Communities of Piedmont, North Carolina," *American Midland Naturalist* 28, no. 1 (1942): 1–126.

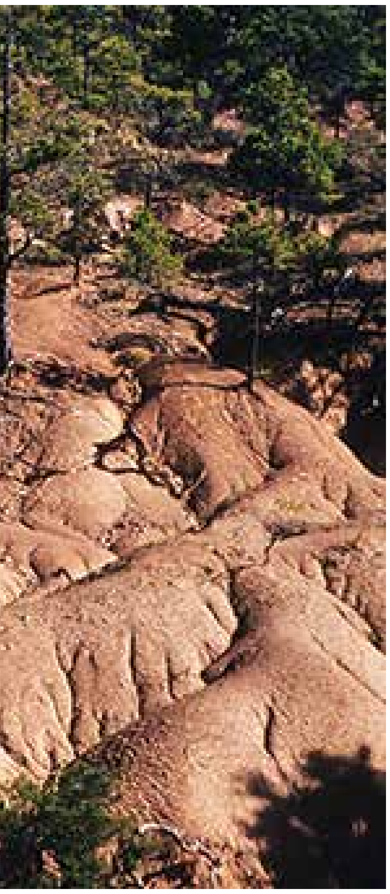
gullying, sedimentation of streams and rivers, and the socio-economic plight of its people. While we can find no documentation explaining why the experimental forest was named after John C. Calhoun, the antebellum senator, vice president, and ardent advocate of slavery, we acknowledge the irony the name brings to this special landscape. After all, the forest was named by the same USFS personnel who selected this landscape for research because it represented "poorest Piedmont conditions."

The Calhoun Experimental Forest had new laboratories and motivated scientists, including Marvin Hoover, Carol Wells, Jim Douglass, and Lou Metz. They brought instrumentation like neutron probes to measure water deep within soils, and delineated experimental watersheds to measure streamflow response to rainfall on deeply gullied and eroded lands. They were particularly interested in how flooding would be attenuated during forest regrowth. Though these Calhoun scientists prolifically published their results, USFS administrators lost interest in the work, and in 1962 curtailed research at the Calhoun Experimental Forest.[10] Fortunately for science, the scientists meticulously archived their treasure trove of samples, data, and photographs.

The 2014 scientists gathered at Padgett's Creek Church are a new wave of investigators to retake the pulse of this severely damaged land (*see fig.* D). They were excited not only to study the Calhoun landscape but to bring their Critical Zone science to pursue and integrate their individual sciences in the same landscape. The Critical Zone after all is defined by a slogan, "From tree top to bedrock," by fluids "from atmosphere to the deepest circulating groundwater," and by its diverse timescales "across human, ecosystem, and geologic time." On the landscape surrounding Padgett's Creek Church, the new Calhoun CZO would engage geophysics, geochemistry, geomorphology, soil science, ecology, hydrology, environmental history, anthropology, and even geopoetry, to gain a Humboldtian understanding of the land. The prospects must have impressed NSF program manager Barrera, for the Calhoun had recently become one of nine CZOs nationwide and one of dozens worldwide, each testing site-specific hypotheses using tools and ideas from a similarly wide diversity of disciplines. Critical Zone science had been championed by Barrera for years, and by 2014 it was vigorously circulating in the Earth and ecological sciences.[11]

Another idea of Critical Zone science is that data are to be shared as common stock, with first-author and student rights of use respected. Scientific papers interweave individual sciences to forge a deeper understanding of the Earth. Critical Zone science provides advanced education to students and veteran scientists alike, as it accelerates interdisciplinary and disciplinary sciences.

One question that scientists regularly ask at the Calhoun CZO concerns the landscape's regeneration following accelerated agricultural erosion and gullying. Because the Piedmont's erosion has diminished greatly during the region's reforestation since the 1930s, today's



D

CI|2 — Nearly 1000 photographs were taken and archived from the 1930s to the 1950s by the United States Forest Service scientists at the Calhoun Experimental Forest. The Forest Service opened the Calhoun Experimental Forest in 1947 to learn more about managing such fragile and eroded landscapes. D — In 2014 nearly 100 scholars and land managers interrogated the Earth's Critical Zone on a trip led by Critical Zone scientists across the Calhoun CZO.

impressive green blanket of trees prompts many to suggest that the seriously degraded fields have undergone significant recovery and even restoration in a matter of decades. Some reference Henry J. Oosting's old-field succession to describe the process.[12] Calhoun Critical Zone scientists, however, bring a more critical perspective to landscape restoration and recovery, and thus to soil, ecosystem, and Critical Zone evolution. Although the Calhoun scientists are impressed that Montgomery's "miserable rain-gullied fields" have regrown into an impressive forest in less than one hundred years, the same scientists have repeatedly demonstrated that this reforestation is more mask than recovery; they argue that the fundamental alteration of the Critical Zone by agriculture — including the hydrology, geomorphology, soils, biology, biogeochemistry, hillslopes, and floodplains — will be attenuated only over many centuries and millennia. A most important lesson from the Calhoun CZO may be that landscape restoration simply does not apply to how landscapes and ecosystems evolve through time.

The great intellectual fascination with Earth's Critical Zone will always derive from the extreme diversity among local Critical Zones, as much as from the interweaving of those diverse Critical Zones into the larger Earth system. There is little doubt that this most Humboldtian approach will carry generations of Earth scientists into the future of environmental science — a future in which both place-based and cross-site Critical Zone research will thrive.