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The origin of relict, thick soils in Central Texas

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Introduction

In contrast to the thin rocky soils that typify the modern Edwards Plateau landscape, thick red soils occur on isolated Edwards Limestone-capped uplands in central Texas. These thick soils are interpreted to be relicts of a formerly more extensive soil cover that was eroded away during the late Pleistocene to middle Holocene. Red clay deposits in central Texas caves and fossils of burrowing mammals contained in these cave-fill sediments provide evidence that thick red soils were once more extensive on the Edwards Plateau (Toomey an others, 1993). Sr isotope variations among fossil plants and animals contained in sediments in Hall's Cave, Kerr County, Texas provide a record of the gradual erosion of the former thick soil cover from 21,000 to 5,000 cal. years before present (Cooke and others, 2003).

Because the relict thick soils are most commonly found on the relatively pure carbonates of the Edwards Limestone, they could not have formed solely from the weathering of the underlying limestone bedrock. Instead, these thick soils may have formed from silicate material derived from eolian dust, alluvium, and/or stratigraphically-higher, clay-rich strata that have been subsequently removed by erosion. Rabenhorst and Wilding (1986) studied the mineralogy and grain morphology of soils overlying resistant limestones on the Edwards Plateau and concluded that neither the underlying limestone nor local dusts were significant sources of silicates to the soils, but suggested an overlying stratum was the potential parent material. We propose that the silicates in the relict thick soils of the Edwards Plateau were derived from the overlying Del Rio Clay. We characterize the geographic distribution of relict soils on the Edwards Plateau and the physical and chemical properties of soils that were collected in Kerr County to help identify the silicate source.

Results and discussion[1]

The geographic distribution of the soils, with respect to topographic position and underlying rock-type, agrees with a Del Rio Clay silicate source. Here I use the distribution of soil types classified by the U.S. Department of Agriculture as Redland range site soils as proxy for the

[1] An extended report of this study will be submitted for publication in 2005 to *Quaternary Research*.

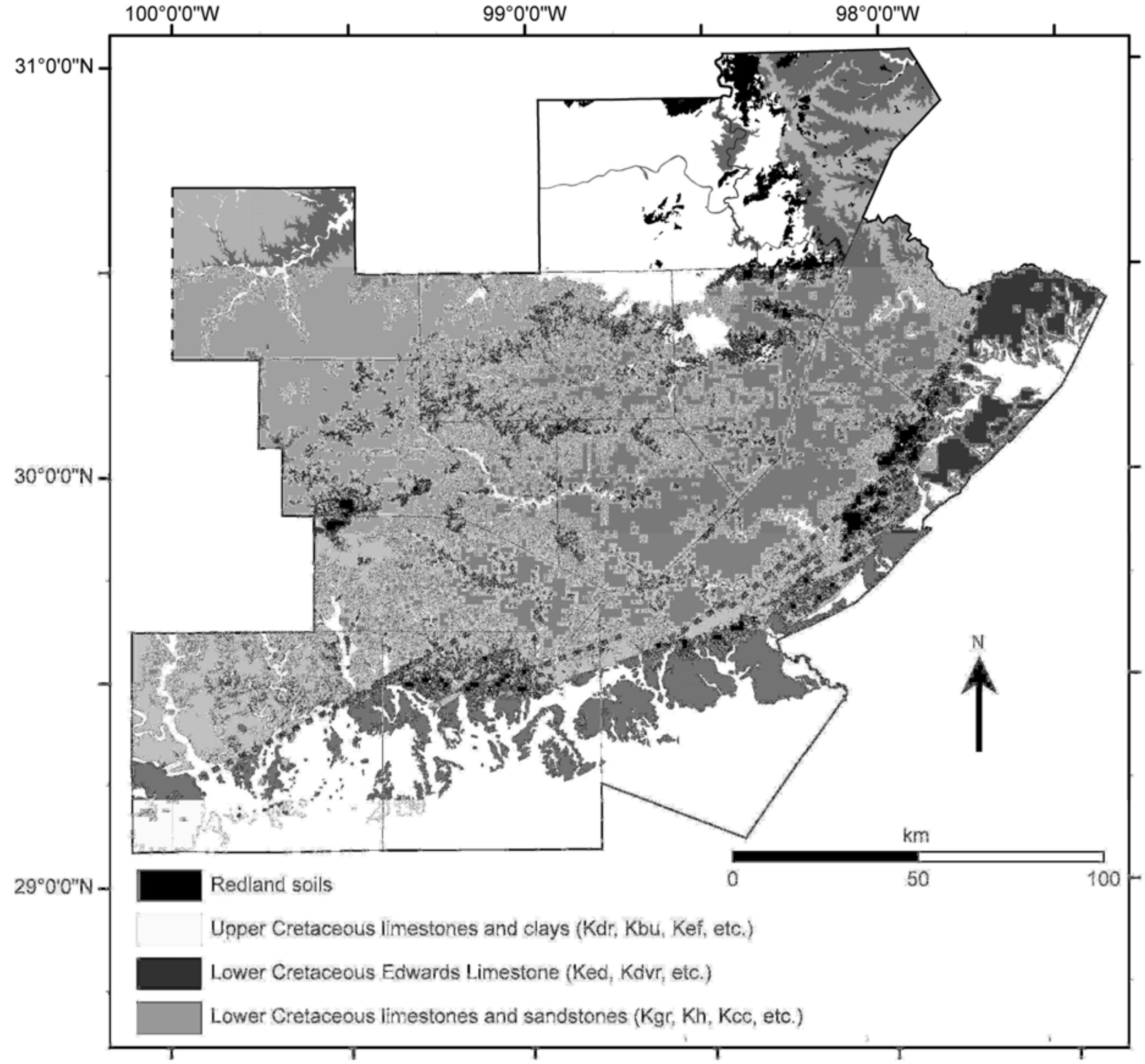

Figure 1. **Map of relict soils (Redland range site soils). Map shows only those soils classified as Redland range-type soils in black. Digital soil maps are from the USDA Natural Resources Conservation Service SSURGO database (available online at www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/). The underlying Cretaceous geology was simplified from the Geologic Atlas of Texas published by The University of Texas Bureau of Economic Geology and digitized by the U.S. Army Corps of Engineers (unpublished data available on CD-ROM). Map area covers Blanco, Bexar, Burnet, Comal, Hays, Gillespie, Kerr, Kendall, Llano, Medina, Travis, and Uvalde counties and the central and eastern portion of Kimble County. Heavy dashed lines indicate the approximate north-easterly trends of faults on the Balcones Fault Zone. Upper Cretaceous limestones and clays include rock types such as the Del Rio Clay (Kdr), Buda Limestone (Kbu), Eagle Ford Group (Kef). Lower Cretaceous Edwards Limestone includes the Edwards Limestone (Ked) and its stratigraphic equivalents such as the Devils River Limestone (Kdvr). Lower Cretaceous limestones and sandstones include rock types such as the Glen Rose Limestone (Kgr), Hensell Sandstone (Kh), and Cow Creek Limestone (Kcc). Precambrian, Paleozoic, and Cenozoic rock types are not mapped (white). Fault contacts that juxtapose the Glen Rose and Edwards limestones also mark an abrupt transition between the absence/presence of Redland soils. This distribution is consistent with an Edwards Limestone or younger silicate source to the relict thick soils.**

distribution of the relict thick soils (Figure 1). Redland soils occur dominantly on uplands north and west of the Balcones Fault Zone and occur at relatively lower elevations within the Balcones Fault Zone. Redland soils sometimes occur in drainages, which may reflect erosion and deposition of the upland soils. In both upland regions and at lower elevations within the Balcones Fault Zone, the Redland soils occur predominantly on the Edwards Limestone and stratigraphically-equivalent limestones and are largely absent on the older Glen Rose

The mineralogy and texture of the relict thick soils are consistent with a Del Rio Clay silicate source. Like the Del Rio Clay, some of the lower horizons of the relict thick soils lack quartz and feldspar. This may indicate that either the Del Rio Clay was providing silicates to the soils or that the soils have experienced diagenetic loss of quartz and feldspar due to intense weathering. The lower horizons of thick soils are clay-rich and have a clay content that is almost identical to the Del Rio Clay (Figure 2). The surface horizon of the relict thick soils is less clay-rich and has a similar texture as the modern thin soils (Figure 2). Thus, the modern thin and relict thick soils likely formed from different parent materials where the lower horizons of the relict thick soils may have been derived from the Del Rio Clay and the surface horizons of the thick and thin soils may have been derived from dust input.

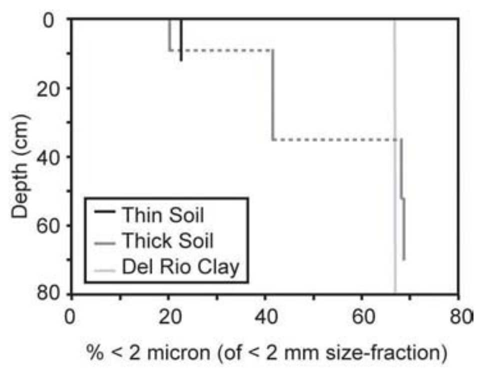

Figure 2. Clay-size fraction comparison. This figure shows variation in the percent clay-sized material with depth in the soil profile of a relict thick soil from the Kerr Wildlife Management Area. Also included are the clay-contents of a thin soil near Hall's Cave and the Del Rio Clay from Shoal Creek in Travis County.

The neodymium (Nd) isotope compositions (expressed as $\varepsilon_{Nd}(0)$ values) and depleted mantle model ages (DM ages) can provide information about the provenance of soil silicates and help identify the parent material. Edwards Limestone bedrock and regolith from Kerr County have $\varepsilon_{Nd}(0)$ values that are higher and DM ages that are lower than the values for the modern thin and relict thick soils (Figure 3). Thus, the Edwards Limestone is likely not the dominant parent material of either the relict thick or modern thin soils in Kerr County. $\varepsilon_{Nd}(0)$ values and DM ages of the lower horizons of relict thick soils from the Kerr Wildlife Management Area (KWMA) are similar to the $\varepsilon_{Nd}(0)$ and DM ages of the Del Rio Clay from Shoal Creek in Travis County (Figure 3). Surface soil horizons of thin and thick soils from the KWMA have Nd isotope compositions and DM ages that are very similar to modern dust collected from attics of historic buildings in Big Spring, Howard County (Figure 3). This supports the interpretation that local dust may be a source of silicates to surface soil horizons of the relict thick and modern thin soils.

The large range of $\varepsilon_{Nd}(0)$ values of the Del Rio Clay samples from several counties in the Edwards Plateau (Figure 3) may reflect the natural heterogeneity in the Nd isotope composition of the Del Rio Clay.

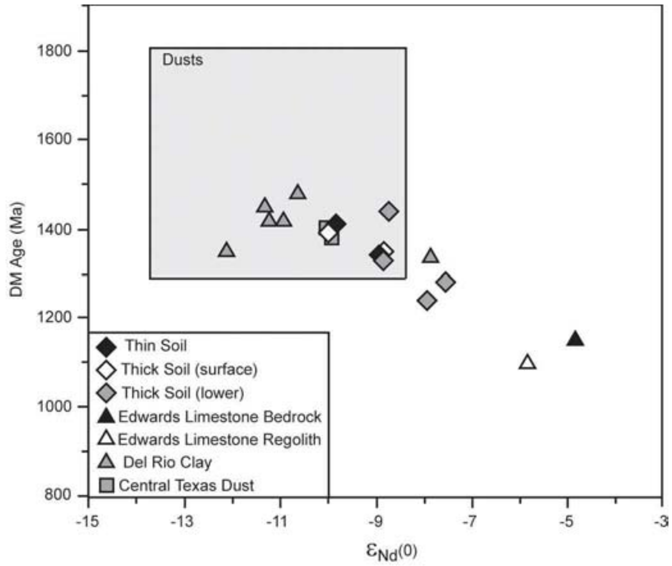

Figure 3. Nd isotope systematics of soils and potential silicate sources. $\varepsilon_{Nd}(0)$ and depleted mantle model ages (Ma) for soils and potential silicate sources ($\varepsilon_{Nd}(0)$ values normalized using a Chondritic Uniform Reservoir $^{143}Nd/^{144}Nd$ ratio of 0.512638). Soils and potential silicate sources were completely digested in HNO_3 and HF; Sm and Nd were separated by ion exchange and analyzed by TIMS at The University of Texas. Thin soils are from the Kerr Wildlife Management Area (KWMA) and the vicinity of Hall's Cave in Kerr County. Thick soils are from the KWMA and road cuts in southwestern Kerr County. Del Rio Clay samples are from Travis, Comal, Val Verde, and Kerr counties. Edwards Limestone (Segovia Member) bedrock and regolith samples are from the vicinity of Hall's Cave and the Kerr Wildlife Management Area. Central Texas dust samples are from attics of historic (early 1900's) buildings in Big Spring, Howard County. Grey box denotes the range of values for modern dust collected over the Pacific and Atlantic oceans reported by Goldstein and others (1984).

Conclusions

The geographic distribution of the Redland soils as well as the texture, mineralogy, and Nd isotope compositions of the relict thick soils are consistent with a Del Rio Clay silicate source. However, it is important to note that ancient alluvial sediment is another potential silicate source to soils on uplands of the Edwards Plateau (Woodruff and Abbot, 2004). The results presented in this study have not specifically addressed an ancient alluvial silicate source but do not preclude an ancient alluvial source, warranting further investigation.

In agreement with a Del Rio Clay source, Redland soils on the Edwards Plateau do not occur where the Del Rio Clay was never deposited. While most soils forming from the Del Rio Clay today are olive to tan, the pyrite-rich Del Rio Clay may oxidize to produce red soils, especially under more humid conditions in the past. In fact, red soils have been observed forming from the Del Rio Clay (i.e., the Felipe soils over the Del Rio Clay in Val Verde County). The presence of chert in the relict thick soils supports the interpretation that the underlying limestone provides some silicate material to the soil. Thus, we propose that *in situ* weathering of the Del Rio Clay, along with partial weathering of the upper portion of the chert-rich Edwards Limestone, produced the thick red, clay- and chert-rich soils that rest on the more resistant Edwards Limestone. Other studies have found overlying strata, rather than the underlying limestone, to be the parent material for soils occurring over resistant limestones (Driese and others, 2003; Laignel and others, 2002; Durn and others, 1999). These and our results support the conclusion that in other areas in central Texas and around the world an overlying clay-rich stratum may be the parent material for soils over resistant limestones more often than is recognized. If an eroded overlying stratum is the parent material for the relict thick soils on the Edwards Plateau, the soils can be considered a non-renewable resource.

Acknowledgments

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Brian Hunt discussing geology at the Elgin-Butler Brink Company (photo by Robert Mace)