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Evidence for the silicate source of relict soils on the Edwards Plateau, central Texas☆

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Abstract

Relict soils provide insights into Quaternary soil formation and erosion on the Edwards Plateau of central Texas and into soil-forming processes in karst terranes. Late Quaternary climate-driven soil erosion produced a mosaic of thick and thin soils on the Edwards Plateau landscape. Thick soils on uplands of the Edwards Plateau are interpreted to be relicts of a formerly more extensive soil cover that was eroded during the late Pleistocene to middle Holocene. The relict, thick soils are silicate-rich and most commonly overlie the relatively silicate-poor Cretaceous Edwards Limestone, which supports the idea that the thick soils did not form from weathering of the underlying limestone. Other potential sources of silicates for the relict soils include dust, alluvial sediments, and the Del Rio Clay, a stratigraphically higher but locally eroded clay-rich unit. Here we investigate the geographic distribution, texture, clay-sized mineralogy, rare earth element geochemistry, and neodymium isotope composition of the relict soils. We have found that the relict, thick soils are deeply weathered soils that occur dominantly over the Edwards Limestone and have a high clay content and a neodymium isotope composition that is similar to that of the Del Rio Clay. Thus, we propose that *in situ* weathering of the Del Rio Clay, along with partial weathering of the upper portion of the underlying Edwards Limestone produced thick chert- and clay-rich soils over resistant limestone. In areas like the Edwards Plateau, where pure limestones are interbedded with clay-rich strata, the overlying clay-rich strata must be considered as a possible silicate source to soils on pure limestone bedrock.

Keywords: Soil; Relict; Edwards Plateau; Texas; Limestone; Del Rio Clay; Neodymium

Introduction

Objective

The occurrence of thick, clay-rich soils on the Cretaceous limestone bedrock of the Edwards Plateau region of central Texas (Fig. 1A) is enigmatic because the underlying limestone has a low abundance of silicate minerals, which may weather to form clays. The goal of this research is to identify the silicate parent material of the relict, central Texas soils by integrating the following approaches: (1) determining the spatial distribution of the relict, thick soils in relation to geomorphic position and underlying rock type; (2) comparing the texture and mineralogy of the modern, thin, and relict, thick soils to potential silicate sources; and (3) applying variations in the neodymium isotope composition, depleted-mantle model age, and rare earth element concentrations of the soil as a constraint on the provenance of the silicates. Possible silicate sources include: (1) the underlying Edwards Limestone bedrock, (2) a stratigraphically higher formation as proposed by Rabenhorst and Wilding (1986) and specified here as the Del Rio Clay, (3) eolian sediments, or (4) ancient alluvial sediments.

Edwards Plateau soils

The Edwards Plateau is an exposed Cretaceous limestone upland that has been locally dissected by streams (Fig. 1). The southern and eastern margins of the plateau are bounded by the

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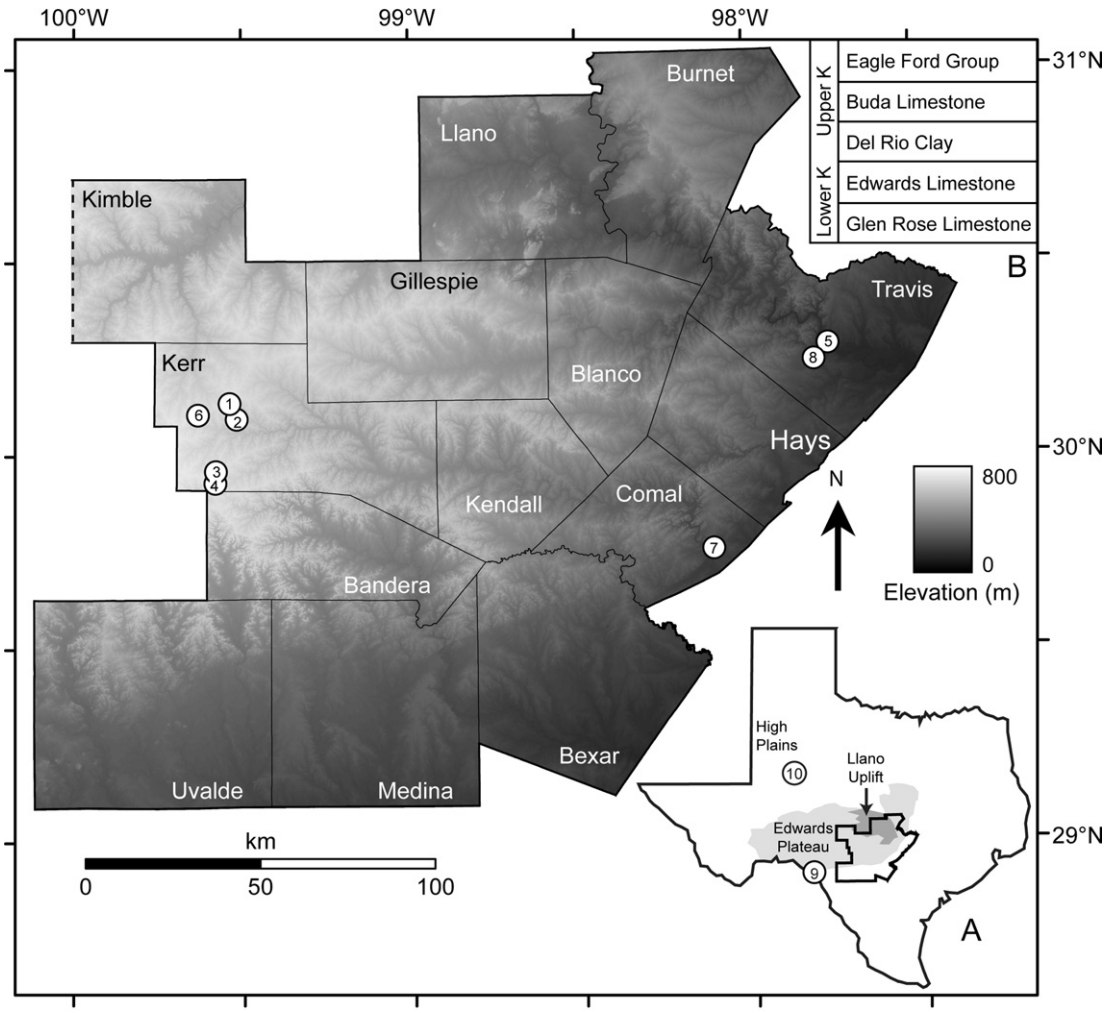

Figure 1. Study area location, elevation, and stratigraphy. Shaded relief map (National Elevation Dataset) (Data available from the U.S. Geological Survey Eros Data Center, Sioux Falls, SD) of the geology and soil map area in Figure 2. The dashed line indicates that Kimble County continues to the west. Inset A shows the location of the map area in Texas as well as the locations of the Edwards Plateau, Llano Uplift, and High Plains physiographic regions. Inset B is a simplified stratigraphy of Cretaceous rocks in the study area.

Miocene-age normal fault system of the Balcones Fault Zone (Weeks, 1945; Young, 1972). To the north, the Edwards Plateau merges with the High Plains, an abandoned alluvial surface capped by Tertiary fluvial deposits (Reeves and Reeves, 1996).

As one would expect of soils forming from pure limestone parent material in a semiarid environment, most of the soils on the Edwards Plateau are thin and rocky. These thin soils (typically <30 cm) of the Edwards Plateau are dark brown, clay-rich mollisols that support live oak and juniper savanna and woodlands and are often relegated to ranchland. However, in isolated areas of the Edwards Plateau, there are thick, red to brown, chert- and clay-rich soils that are classified as alfisols and vertisols. Descriptions of a typical thin soil profile and several thick soil profiles are provided in Appendix A. The thick soils are described as Redland range sites due to their unusual texture, thickness (~0.5 to 2 m), and atypical vegetation such as black jack oaks and post oaks (Dittemore and Coburn, 1986). Some Redland soils have an abrupt enrichment of clays below the A/B-horizon boundary, providing evidence for truncation of the upper soil horizon (Dittemore and Coburn, 1986). These thick, Redland range soil types occur in upland areas over hard, indurated limestone and compose only <1 to 15% of the total soils in several counties spanning the Edwards Plateau region (Figs. 1 and 2; Table 1).

The thick soils are interpreted to be relicts of a former thick soil cover that was once more extensive on the Edwards Plateau. This interpretation is supported by the presence of red clay sediments and fossils of burrowing mammals in central Texas cave-fill deposits in areas that currently lack thick soils (Toomey, 1993; Toomey et al., 1993). Other evidence for a more widespread, thick soil cover in the past includes "terra rossa" karst-fill features and silicified fossils in Cretaceous limestone (Young, 1986). Reddened and silicified portions of the Edwards Limestone that lack soil today may have been produced by silicate leaching from a former soil cover (Young, 1986). While the age of the relict soils is not well constrained, they were at least formed by the late Pleistocene because several central Texas caves contain sediments from the eroded soils (Toomey et al., 1993; Cooke et al., 2003). Sedimentological variations and changes in faunal assemblages in central Texas