Mt. Blanco revisited: Soil-geomorphic implications for the ages of the upper Cenozoic Blanco and Blackwater Draw Formations

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ABSTRACT

Mt. Blanco, on the eastern edge of the Southern High Plains of Texas, contains stratigraphic features significant in interpreting the late Cenozoic history of the region and the vertebrate paleontology of the Great Plains; however, the stratigraphic relations are confused in the literature or are unreported. Mt. Blanco is the type locality for the Blanco Formation and the Blanco Local Fauna, which occurs throughout North America and is the type fauna for the Blancan Land Mammal Age in North America. Here also occur exposures of the Blackwater Draw Formation, an extensive (~120000 km^2) eolian sheet that is the surficial cover of the region and contains the 1.4 Ma Guaje Ash and several buried soils. A reexamination of the section shows that (1) the Blackwater Draw Formation, an eolian deposit, contains three well-expressed buried soils (5 *YR* hues, argillic horizons ≥1 m thick, Stages III and IV calcic horizons) and the similar regional surface soil (Paleustalf); (2) the Guaje Ash is within the lower Blackwater Draw Formation but is separated from the Blanco Formation, a lacustrine unit, by about 1 m of sediment, including the lowest buried soil; and (3) the lowest buried soil shows a Stage IV calcrete formed at the top of the Blanco Formation and the base of the Blackwater Draw Formation and probably took about 200 ka to form. These new data suggest that deposition of the type Blanco sediments may have ended by about 1.6 Ma or earlier. Since that time, the Blackwater Draw Formation has accumulated episodically; periods of nondeposition are characterized by landscape stability and pedogenesis.

INTRODUCTION

Mt. Blanco, in Crosby County, Texas (Fig. 1), is the type locality of the upper Cenozoic Blanco Formation and the well-known Blanco Local Fauna (Schultz, 1977). This fauna occurs throughout the Great Plains and across much of the continent and is the type fauna for the Blancan Land Mammal Age in North America (Schultz, 1977; Kurtén and Anderson, 1980). The origin and age of the Blanco sediments and the age of the Blanco Local Fauna have long been the subject of debate (Schultz, 1977; Kurtén and Anderson, 1980). Recent investigations at Mt. Blanco have yielded new information on the age of the end of Blanco sedimentation. These data are also critical for dating and interpreting the Blackwater Draw Formation, an extensive eolian mantle (~120000 km^2) that overlies the Blanco Formation and forms the principal surficial deposit of the Southern High Plains (Reeves, 1976; Holliday and Gustavson, 1988). Little data have been published concerning the geochronology and stratigraphy of this huge and agriculturally important eolian sheet.

Mt. Blanco is located on the eastern escarpment of the Southern High Plains (Fig. 1). The Blanco and Blackwater Draw Formations are exposed along the escarpment in the walls of Blanco Canyon, a reentrant drainage cut into the High Plains by the White River, a tributary of the Brazos River. Mt. Blanco is a small outlier of the escarpment and is composed of the Blanco Formation.

PREVIOUS INVESTIGATIONS

The sediments and faunal remains of the Blanco Formation have been studied for almost a century, beginning with Cummins (1890, 1892). Subsequent investigators include Cope (1892, 1893), Meade (1945), Evans and Meade (1945), Frye and Leonard (1957, 1965), and Dalquest (1975). Schultz (1977) summarized the history of investigations in the area, devoting special attention to the paleontology and the controversy surrounding the origin and age of the Blanco Formation.

Deposits of the Blanco Formation in the Mt. Blanco area occupy a broad basin inset into the Miocene-Pliocene Ogallala Formation. The

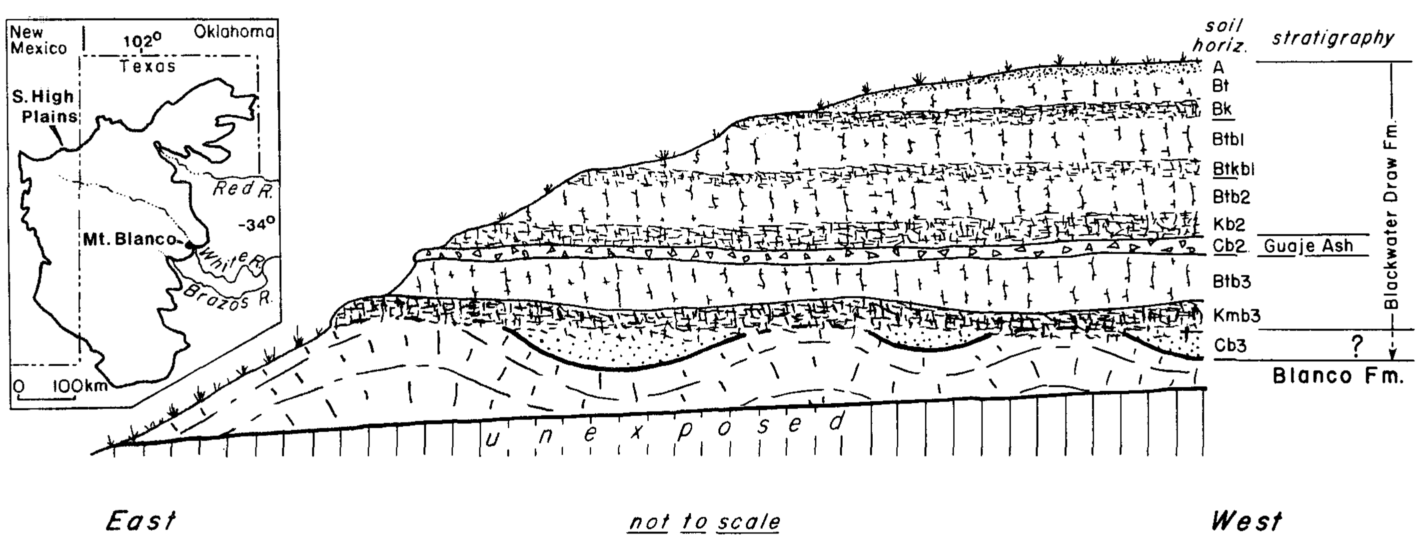

Figure 1. Schematic drawing of soil stratigraphy exposed at Mt. Blanco road cut. Soil horizons are simplified from those presented in Table 1. Inset is location map of Mt. Blanco on Southern High Plains.

Blanco deposits have been interpreted as both alluvial and lacustrine and as having formed under a variety of climatic conditions (Schultz, 1977). The most recent and comprehensive geologic study of the unit shows that Blanco deposition occurred in a seasonal to semipermanent lake that existed between frequent periods of desiccation under an arid to semiarid climate (Dalquest, 1975; Pierce, 1973, 1974).

The age of the Blanco Formation and Blancan faunas has been considered to be Pliocene, early Pleistocene (Nebraskan or Aftonian), or late Pliocene–early Pleistocene (Dalquest, 1975; Schultz, 1977; Kurtén and Anderson, 1980). Study of several layers of volcanic ash in the type area, as well as paleomagnetic stratigraphy, has clarified some of the dating problems. The Blanco Ash, the source of which is unknown, is found within the Blanco sediments immediately above the Blanco bone beds; it yielded a fission-track date on glass shards of 2.8 ±0.3 Ma (Boellstorff, 1976). The Guaje Ash, derived from the Jemez volcanic field in New Mexico, is higher in the section and yielded fission-track dates on glass shards of 1.4 ±0.2 Ma (Izett et al., 1972) and 1.77 to ±0.44 Ma (Boellstorff, 1976). Nilsson (1983, p. 410–411) erroneously concluded that the Blanco and Guaje ash deposits are the same deposit.

Lindsay et al. (1975) studied the magnetic polarity of the Mt. Blanco section by collecting 13 samples from the Guaje Ash down to the base of the Blanco Formation and including the Blanco Ash and the bone-bearing level. The entire sampled section is reversed magnetically and is interpreted as occurring in the lower Matuyama magnetic interval, between 1.4 and 2.4 Ma. This suggests that the glass-shard age of ~2.8 Ma for the Blanco Ash (Boellstorff, 1976) is falsely old.

Published descriptions of the stratigraphic relation of the Guaje Ash to the Blanco Formation are very confusing. Izett et al. (1972, p. 558) described the ash as "interbedded in reddish-brown sandstone . . . that overlies the typical . . . Blanco Formation. It is not certain if the sandstone that contains the ash bed was included in the Blanco Formation as the Blanco was originally defined." Pierce (1974, p. 10) mentioned that the Guaje Ash "occurs in the cover sands above the Blanco beds." Boellstorff (1976, p. 57) described the Guaje Ash as "the upper of two ashes exposed in the sediments of the Blanco Formation at its type locality." Hawley et al. (1976, p. 258) noted that the ash rests on a pedogenic caliche (calcrete) formed at the top of the Blanco Formation. Dalquest (1975, p. 47) said that the ash is lying "nearly at the surface of the ground and is separated by 30 or more feet of weathered caliche rubble from the uppermost . . . Blanco Formation." Schultz (1977, p. 122) described the ash as occurring "nearly at the surface of the ground in the cover sands which disconformably overlie the Blanco Formation." Clearly, the relation of the Guaje Ash to the Blanco Formation must be more firmly established.

The Blackwater Draw Formation has received considerably less scientific attention than the Blanco Formation and was never investigated at Mt. Blanco. Frye and Leonard (1957, 1965) first described "cover sands" mantling the Southern High Plains. These widespread sediments which support the lucrative agricultural industry of the region were considered to be of Illinoian age and to contain a Sangamon soil. Reeves (1976) proposed the term "Blackwater Draw Formation" to replace "cover sands," but still considered the sediments to be Illinoian, although no absolute age control was available. These sediments are obviously eolian: they cover the Southern High Plains as a sheetlike body, grading from sandy in the southwest to clay loam in the north and northeast; the texture of the sediments is uniform at any one section (Seitlheko, 1975; Hawley et al., 1976; Reeves, 1976). Several authors (e.g., Allen and Goss, 1974; Hawley et al., 1976) have also recognized that locally the Blackwater Draw Formation contains several buried soils. This is significant because it indicates that the formation is composed of several layers of material and that long periods of landscape stability separated depositional events.

This study was conducted in an effort to clarify the age of the Blanco and Blackwater Draw Formations and the pedologic history of the latter. The investigations focused on (1) the stratigraphic relation of the Guaje Ash to both formations and (2) the soil-geomorphic record of the Blackwater Draw Formation as an indicator of its age and origin. Field work was carried out at a large road cut along State Highway 193 on the west side of Blanco Canyon (Fig. 1). The section exposes the Blackwater Draw Formation and upper Blanco Formation, including the Guaje Ash and Blanco calcrete. This exposure is at the northern end of the area where most of the Blancan fossils were recovered (Schultz, 1977) and is the same section examined by Izett et al. (1972). Three sections along the road cut were described, resulting in a composite description of the entire exposure (Table 1). Standard pedologic nomenclature is used in the descriptions (Soil Survey Staff, 1975; Guthrie and Witty, 1982). The stages of calcic-horizon development are based on Machette (1985).

STRATIGRAPHY

The Blanco Formation comprises the lower 4 m of the section exposed in the road cut (Fig. 1). Locally, the Blanco is up to 14 m thick, and near the center of the ancient basin, the unit is as much as 27 m thick (Pierce, 1973). In the road cut, the upper Blanco is a highly contorted, olive clay with considerable vertical and horizontal jointing. The sediments are folded into a series of broad anticlines and synclines. Within the trough of each downwarp is a pocket of reddish sand up to 1 m thick.

A subhorizontal, strongly developed pedogenic calcrete (Km horizon) has formed across the tops of the upfolds in the Blanco clay and across the top of the pockets of reddish sand. The calcrete is apparent at the top of the Blanco Formation throughout the area. The Km horizon is up to 1 m thick and locally pisolitic, and it has occasional thin carbonate laminae at the top (Stage IV calcic horizon). This horizon is probably related to a soil formed in the overlying sediments (discussed below).

The Blackwater Draw Formation, over 5 m thick, overlies the Blanco Formation. The Blackwater Draw Formation is a reddish-brown, sandy deposit disconformably overlying the Blanco Formation, as described by Frye and Leonard (1957, 1965) and Reeves (1976), and is identical stratigraphically, lithologically, and pedologically to the type section of the Blackwater Draw Formation in Lubbock County (Reeves, 1976; Gustavson and Holliday, 1985). Most of the field characteristics of the Blackwater Draw Formation are the result of soil-forming processes; no primary sedimentary structures are preserved. The sandy sediments within the downfolds of the Blanco Formation and below the calcrete are probably deposits of the Blackwater Draw Formation unmodified by pedogenesis.

The Blackwater Draw Formation at Mt. Blanco contains three buried soils (from top to bottom, b1, b2, and b3) plus the surface soil, and it can be subdivided by using the soils and the Guaje Ash. The ash occurs about 1 m above the base of the Blackwater Draw Formation. Below the ash is the lowermost buried soil (b3). This buried soil is present below the ash in many other exposures in the area. The soil includes a Bt horizon with 5 *YR* hues, well-expressed prismatic to subangular-blocky structure, and the previously described Km horizon formed in the uppermost Blanco Formation and lowermost Blackwater Draw Formation (Table 1). In the Bt horizon, films of illuvial clay are common on ped faces (Table 1) and are very common in thin section, coating quartz sand grains and the walls of voids. Opaque material, probably illuvial opal, is also common in thin section. Silica derived from the weathering of the overlying ash was probably translocated into the Bt horizon.

The ash zone includes a layer of virtually pure ash up to 30 cm thick overlying a zone of mixed ash and sand up to 50 cm thick. The ash rests disconformably on the b3 soil. The thickness of the ash layer varies considerably throughout the area, and the ash is absent at the west end of the road cut.

Above the ash are two buried soils (b1, b2) and the present surface soil. The number and continuity of buried soils in the general Mt. Blanco area are unknown. The surface soil, at the west end of the road cut, away from the edge of Blanco Canyon, is typical of the strongly developed

TABLE 1. SOIL PROFILES OF UPPER BLANCO AND BLACKWATER DRAW FORMATIONS, MT. BLANCO

Depth (cm)	Horizon	Dry color	Texture*	Structure†	Eff§	Boundary**	Comments
0-25	A & Bt	7.5 YR 4/4	SCL	1cpr, 2msb	non	aw	Remnant of Paleustalf?
25-35	K(lam)	5 YR 8/2	---	m	ev	aw	Laminar zone
35-85	K	5 YR 8/4	---	m	ev	cs	Stage III; common very hard carbonate bodies up to 3 cm diameter
85-102	Btk	5 YR 6/4	SCL	m	ev(k)	cw	Stage II-III; common threads, bodies, and hard carbonate concretions
102-159	Btk1b1	5 YR 5/6	SCL	1fsb	ev(k)	aw	Common areas up to 15 cm wide with soft and hard carbonate bodies; few Mn stains on carbonate and Bt; colors for Bt; common thick clay films; structure broken up by areas of carbonate
159-195	Btk2b1	5 YR 5/6	SCL	1fsb	ev(k)	cs	Forms "bench" in outcrop; common very hard carbonate bodies up to 15 cm wide; few Mn stains
195-245	Bkb1	5 YR 8/2 5 YR 8/3	---	m	ev(k)	cw	8/2 = ped interiors; 8/3 = ped exteriors; on weathering fractures into platy structure; common Mn patches; few areas of Bt material few mm wide and few cm high
245-305	Btk1b2	5 YR 8/2 5 YR 8/3	---	m	ev(k)	cw	Very similar to Bkb1; ladder matrix carbonate; thick clay films
305-365	Btk2b2	5 YR 8/2 5 YR 8/3	---	m	ev(k)	cw	As above; fewer clay films
365-415	Kb2	5 YR 8/2	---	m	ev	cs	Stage III-IV with no laminar zone
415-435	2C1b2	N8	---	pl-m	non	aw	Clean Guaje ash; up to 30 cm thick
435-455	3C2b2	5 YR 8/4	---	m	e	aw	Reworked ash; up to 50 cm thick; few Mn patches
455-475	3Btk1b3	5 YR 7/4	fSCL	1fpr, 3msb	ev(k)	cs	Ladder matrix carbonate; some secondary Si on ped faces
475-555	3Btk2b3	5 YR 6/6	fSCL	2fpr, 3msb	ev(k)	aw	Up to 1 m thick; ladder matrix carbonate
555-655	3Kmb3	7.5 YR 8/1	---	m	ev	cw	Stage IV; locally see effects of dissolution; formed in Blanco clay and pink sand
655-730	3Ckb3	5 YR 8/2	S	m	ev	aw	Locally up to 1 m; in folds in Blanco clay
730+	4Rb3	N9	C	m	ev	--	Blanco Fm; secondary carbonate locally common; highly contorted; very common vertical and horizontal jointing.

*S = sand, C = clay, fSCL = fine sandy clay loam.
†Grade: 1 = weak, 2 = moderate, 3 = strong. Size: f = fine, m = medium, c = coarse. Type: sb = subangular blocky, pr = prismatic, pl = platy, m = massive.
§Effervescence from reaction with dilute HCl: non = noncalcareous, e = weakly effervescent, ev = violently effervescent, ev(k) = violently effervescent carbonate bodies; matrix is otherwise noncalcareous.
**Distinctness: a = abrupt, c = clear. Topography: s = smooth, w = wavy.

surface soil of the region; it has a Bt-K or Btk profile and is classified as a Paleustalf (Table 1). The Bt horizon is about 1 m thick, with 5 *YR* hues, and prismatic to subangular-blocky structure; clay films are common on ped faces. Illuvial clay is also common in thin section; clay films coat quartz sand grains. The upper part of the zone of carbonate accumulation is a laminar K horizon about 10 cm thick (Table 1). Below the K horizon is a Stage II-III Btk horizon probably developed, in part, in the upper part of the b1 soil. The Btk horizon consists of vertical rootlike nodules up to 3 cm in diameter that follow ped faces. There are also common subhorizontal coats of carbonate on the tops of peds. This carbonate morphology is informally referred to as ladder matrix (McGrath, 1984, p. 131) and is typical of recalcified Bt horizons of the Blackwater Draw Formation (McGrath, 1984; Gustavson and Holliday, 1985). The K-Btk horizon crops out as a ledge at the east end of the road cut (Fig. 1), where erosion along the walls of Blanco Canyon has removed the upper part of the profile.

The two buried soils above the ash are both about 1.2 m thick and contain Bt horizons with morphologies identical to the surface soil (Table 1). The b1 soil also has a ladder-matrix Btk horizon which appears to have formed in the upper part of the b2 soil. The b2 soil has a Stage III-IV K horizon formed just above the zone of pure Gauje Ash. The parent material for the K horizon may have contained some reworked ash, on the basis of its low bulk density, fine-sand texture, and the gradual boundary between the K horizon and the ash layer. Both carbonate horizons crop out as ledges at the east end of the road cut (Fig. 1).

INTERPRETATIONS AND CONCLUSIONS

The soil-geomorphic investigations at Mt. Blanco shed considerable light on the upper age limit of the Blanco Formation and the age and depositional history of the Blackwater Draw Formation. The buried soil below the Guaje Ash, in particular the Km horizon formed in the top of the Blanco Formation and the bottom of the Blackwater Draw Formation, is indicative of a considerable period of landscape stability following the end of Blanco sedimentation and prior to deposition of the ash. The rate of calcrete formation is dependent on a variety of factors, including climate and carbonate content of the parent material. These parameters are not well known for the soil in question, but the climate of the region during pedogenesis in the lower Blackwater Draw Formation was probably semiarid and similar to that of today (Holliday, 1987); there is no indication that the primary sediments of the Blackwater Draw Formation were high in carbonate. The Stage III Btk horizon common in the Paleustalfs of the High Plains surface probably took about 50 ka to form (Holliday and Gustavson, 1988). Stage IV calcretes are usually substantially older. Machette (1985), in a study of calcretes throughout the arid southwestern United States, showed that it takes at least 100 ka for Stage IV calcretes to develop and in most cases it takes more than 200 ka. Given what is known about the climate and parent material of the b3 soil and the data on rates of carbonate accumulation, it seems reasonable to assume that buried soil b3 took at least 200 ka to form. Adding this plus the time it took to deposit the soil parent-material to the minimum age of 1.4 Ma for the Guaje Ash would provide a minimum age of 1.6 Ma for the end of deposition of the

Blanco Formation. This would place the age of Blanco sedimentation entirely within the Pliocene if the age of 1.6 Ma is accepted as the age of the Pliocene/Pleistocene boundary (e.g., Aguirre and Pasini, 1985; Berggren et al., 1985).

The presence of buried soils and the Guaje Ash suggests that the Blackwater Draw Formation accumulated episodically throughout much of the Quaternary. Deposition was cyclic; there were periods of relatively rapid eolian sedimentation and minimal pedogenesis, followed by landscape stability characterized by very slow deposition and soil formation. The time it took to deposit these sediments is not clear, but pedogenesis of each soil probably took at least 50 ka, on the basis of limited information for the surface soil (Gustavson and Holliday, 1985). Erosion, probably by wind deflation, may have preceded depositional episodes. At Mt. Blanco, if the sediments above the Guaje Ash are not eroded, the soils should show stronger morphologies, such as more advanced stages of carbonate accumulation. In addition, different exposures of the Blackwater Draw Formation throughout the region have different numbers of buried soils and the tops of some Bt horizons have abrupt upper boundaries with overlying soils (Gustavson and Holliday, 1985; Holliday and Gustavson, 1988). The result of these processes is a formation containing several thick, strongly developed Bt-Btk soil profiles that are "welded" (terminology of Ruhe and Olson, 1980).

The late Cenozoic section exposed at Mt. Blanco is significant for reconstructing the landscape evolution of the Southern High Plains and refining the age control for the Blancan fauna and for the Blancan Land Mammal Age. Soil-geomorphic investigations, combined with data on the tephrochronology and stratigraphy of the section, are particularly useful in showing that (1) the Blanco Formation is probably Pliocene in age, deposition having ended by about 1.6 Ma, and (2) the Blackwater Draw Formation has accreted episodically throughout the Quaternary.

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Reviewer's comment

The data presented here go a long way toward resolving questions of age, and therefore significance, of the Blanco Formation and Blancan Land Mammal Age applicable to much of interior North America.

Wakefield Dort, Jr.