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Quantifying Pedogenic Carbon Content Within the Boise River Terraces Using Pressurized Calcimetry

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Abstract: Soil carbon is the third largest carbon pool within the global carbon cycle; however, soil carbon amounts are not well quantified, and exchange rates of soil carbon are not well understood. Soil carbon can be divided into organic carbon and inorganic carbon, where inorganic carbon (pedogenic carbonate) is precipitated during soil formation and accumulates over time in semi-arid and arid environments. Calcic soils within the semiarid regions of the Boise Valley result from active pedogenic accumulation of secondary $CaCO_3$ resulting in prominent 'caliche' layers in soils formed on the Boise River terraces. The larger goals of this project are to quantify inorganic carbon sequestered within the Boise River terraces, and investigate rates of carbonate dissolution due to irrigation. This portion of the project focuses on developing methods for measuring inorganic carbon content in soils using pressurized calcimetry. Samples are acidified within a closed system to form CO_2 under constant temperature, allowing time-pressure readings to delineate the levels of inorganic carbon present. Future work will reveal trends in carbon content with depth in individual soil profiles, and variations in carbon content for terraces of different ages.

INTRODUCTION

This study quantifies amounts of inorganic carbon in terrace soils of the Boise River; future studies will investigate variability in soil carbon with terrace age and land use.

Why is inorganic calcium carbonate important?

- Inorganic calcium carbonate ($CaCO_3$) or 'caliche' forms naturally in semi-arid and arid soils
- Ongoing and future climate change driven by increases in atmospheric CO_2 have highlighted the importance of understanding where carbon is stored and quantifying rates of carbon exchange
- This 'caliche' may represent a large carbon sink, but amounts of inorganic soil carbon are unknown
- Furthermore, anthropogenic activities such as irrigation may be dissolving this carbon

Terraces and soils of the Boise River Valley

- 8 river terraces within the Eastern portion of the valley and 6 within the Western portion (Fig.2 & Fig. 3).
- Accumulations of carbonate occur in various stages from filaments, wisps, and nodules to carbonate coatings on clasts,(pendants) and indurated nodules or laminae (Fig.1). These stages are indicative of age, moderate precipitation, and a good supply of wind-blown loess which supply the soluble ions needed for the development of calcium carbonate.
- The Amity Terrace is the fifth terrace above the Boise River, and is believed to be analogous to the Deerflat Terrace which is situated to the West.
- The Amity terrace is constrained in age by K/Ar and Ar-40/Ar-39 dating of lava flows above and below the Amity Terrace to between 1.001 ± 0.098 Ma and 1.376 ± 0.205Ma (Othberg and Burnham 1990).
- Currently we have collected and analyzed carbon samples from 4 locations within the Amity terrace (Fig.3) as a first step towards gaining a better understanding of fluxes within our local carbon cycle.
- We expect to find measurable variations in carbon levels among and within terraces due to inherent variability in soil forming processes.

Figure 1. Various stages of $CaCO_3$ accumulation. Wisps and filament (A). Clastic coatings (B). Indurated calcic plugs and laminae (C).

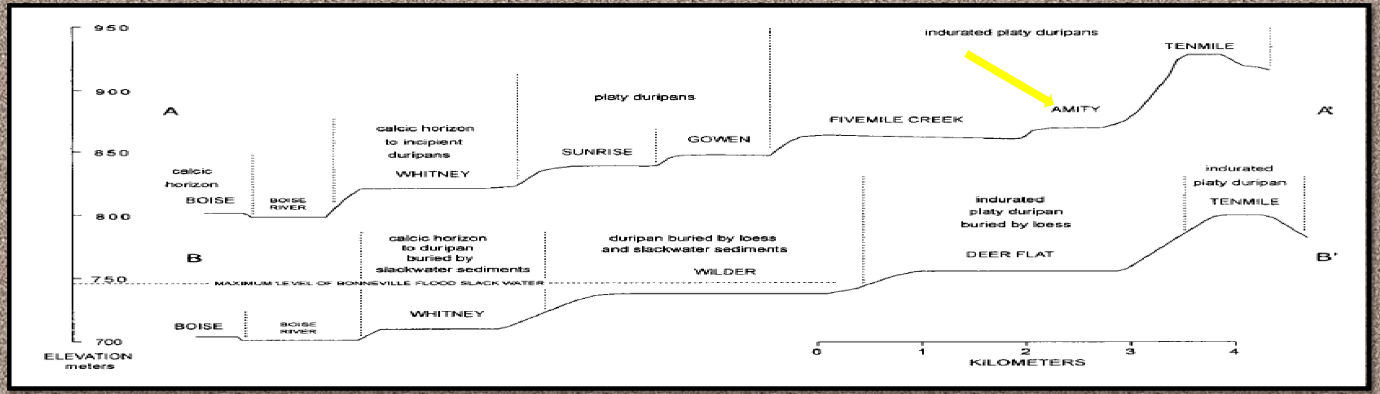


Figure 2. Profiles of the Eastern and Western Boise Valley terraces, accompanied by corresponding soil characteristics (Othberg 1997).

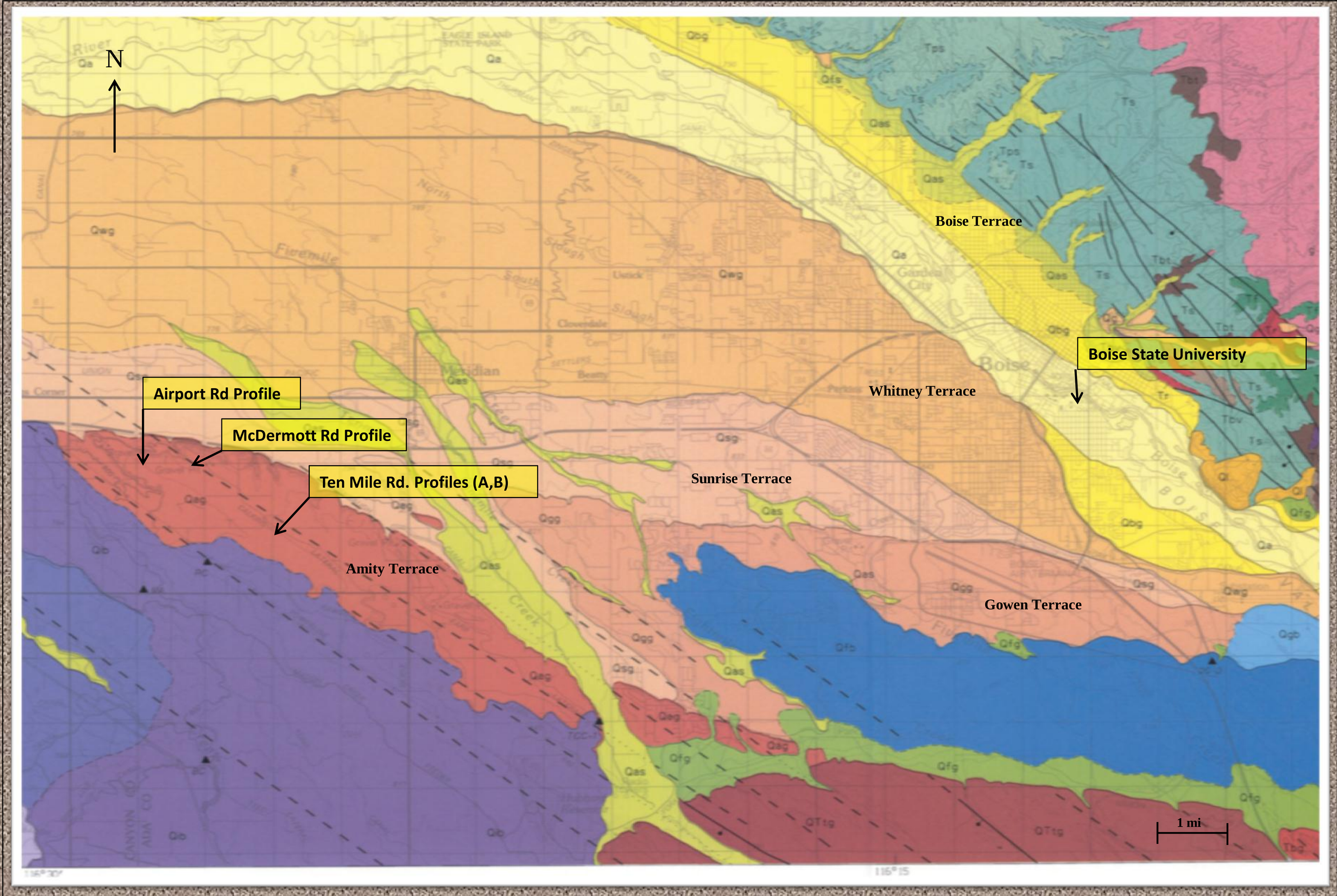
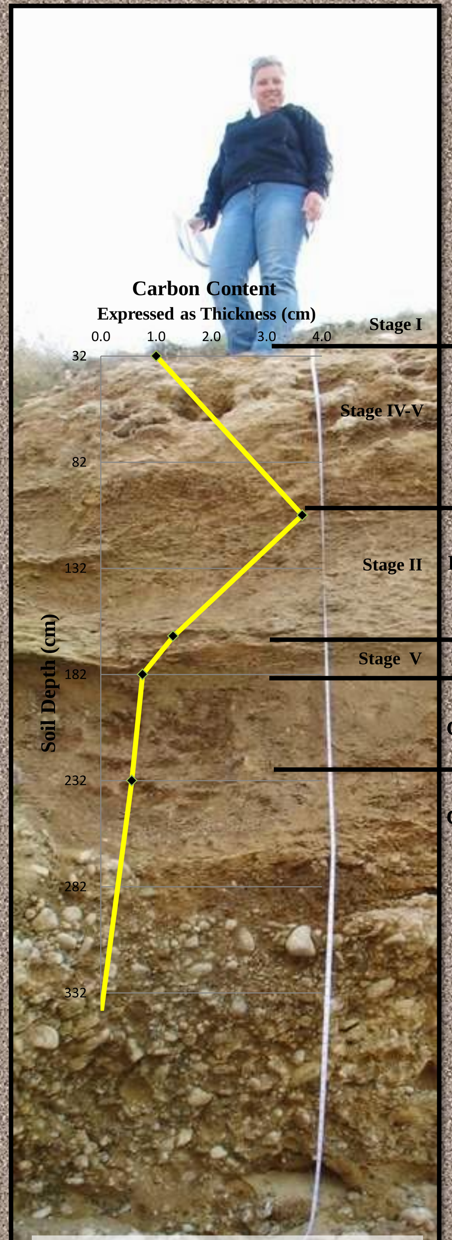


Figure 3. Geologic map of the Boise Valley terraces. (Othberg and Stanford, 1992).

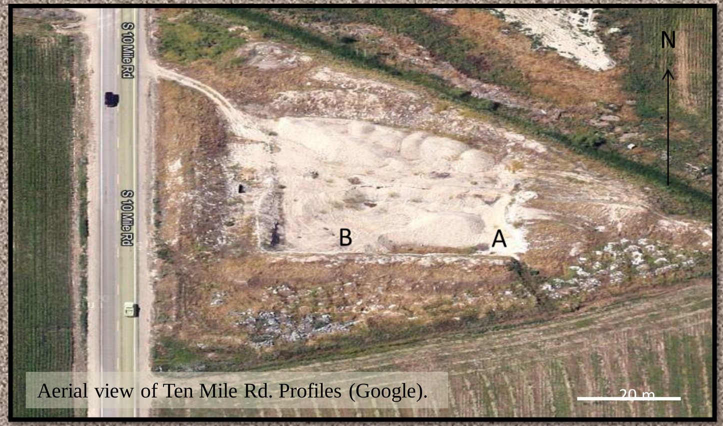
METHODS



Ten Mile Rd-A Profile
Carbon contained within the horizon as an expression of thickness (cm).

As minerals are leached from the surface, they are translocated with the aid of precipitation through pore spaces and accumulate within the B horizon. (left).

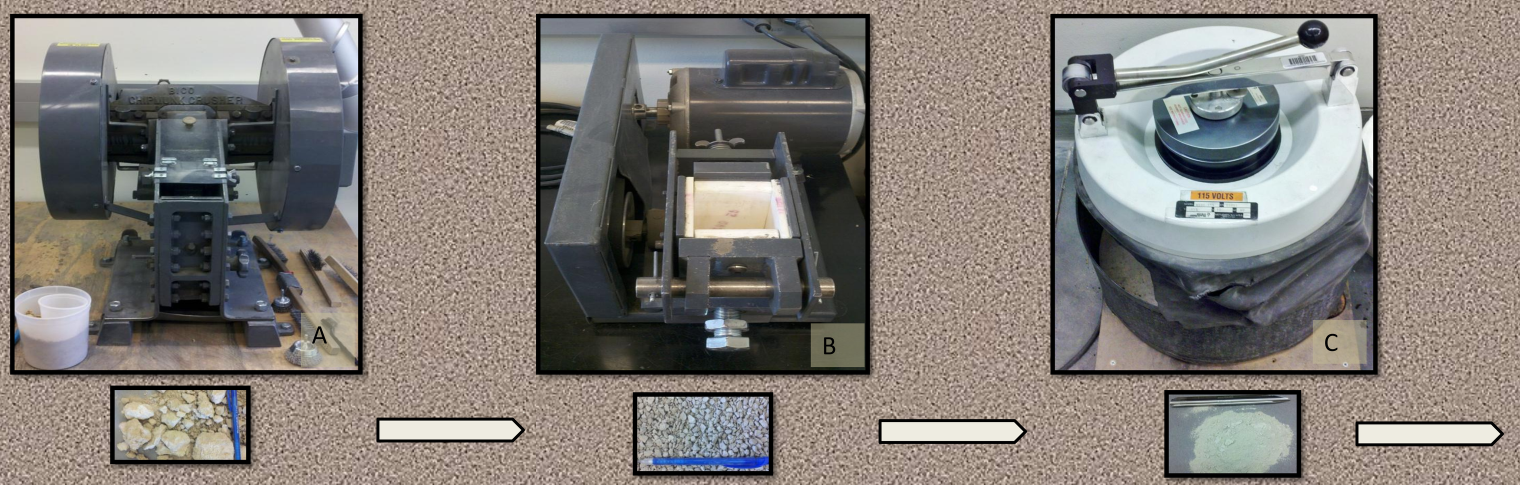
Carbonate plugs can develop at the base of B horizons where accumulation and cementation of minerals occur. This can form an indurated shelf , known as a K horizon, which subsequently inhibits the further translocation of soluble minerals downward in the profile. (left)



Aerial view of Ten Mile Rd. Profiles (Google).

STAGE	GRAVELLY PARENT MATERIAL	$CaCO_3$*	NONGRAVELLY PARENT MATERIAL	$CaCO_3$*
I	Thin discontinuous clast coatings; some filaments; matriz can be calcareous next to stones; about 4% CaCO3	4%	Few filaments or coatings on sand grains; <10% CaCO3	4%
I+	Many or all clast coatings are thin and continuous	8%	Filaments are common	8%
II	Continuous clast coatings; local cementation of few to several clasts; m,atrix is loose and calcareous enough to give somewhat whitened appearance.	10%	Few to common nodules; matrix between nodules is slightly whitened by carbonate (15-50% by area), and the latter occurs in veinlets and as filaments; some matrix can be noncalcareous; about 10-15% CaCO3	10%
II+	Same as stage II, except carbonate in matrix is more pervasive.	15%	Common nodules; 50-90% of matrix is whitened; about 15% CaCO3	15%
Continuity of fabric high in carbonate				
III	Horizon has 50-90% of grains coated with carbonate, forming an essentially continuous mediuml color mostly white; carbonate-rich layers more common in upper part; about 20-25% CaCO3.	20%	Many nodules, and carbonate coats so many grains that over 90% of horizon is white; carbonate-rich layers more common in upper part; about 20% CaCO3.	20%
III+	Most clasts have thick carbonate coats; matrix particles continuously coated with carbonate or pores plugged by carboante; cementation more or less continuous; >40% CaCO3.	50%	Most grains coated with carbonate; most pores plugged; >40% CaCO3.	50%
Partly or entirely cemented (irrespective of parent material)				
IV	Upper part to K horizon is nearly pure cemented carbonate (75-90% CaCO3) and has a weak platy structure due to the weakly expressed laminar depositional layers of carbonate; the rest of the horizon is plugged with carbonate (50-75% CaCO3).			80%
V	Laminar layer and platy structure are strongly expressed; incipient brecciation and pisolith (thin, multiple layers of carbonate surrounding particles) formation.			95%
VI	Brecciation and recementation (multiple generations), as well as pisoliths, are common.			95%

Table 1. Stages of carbonate morphology in gravelly and nongravelly parent material [Modified from Birkeland et al. (1991)]



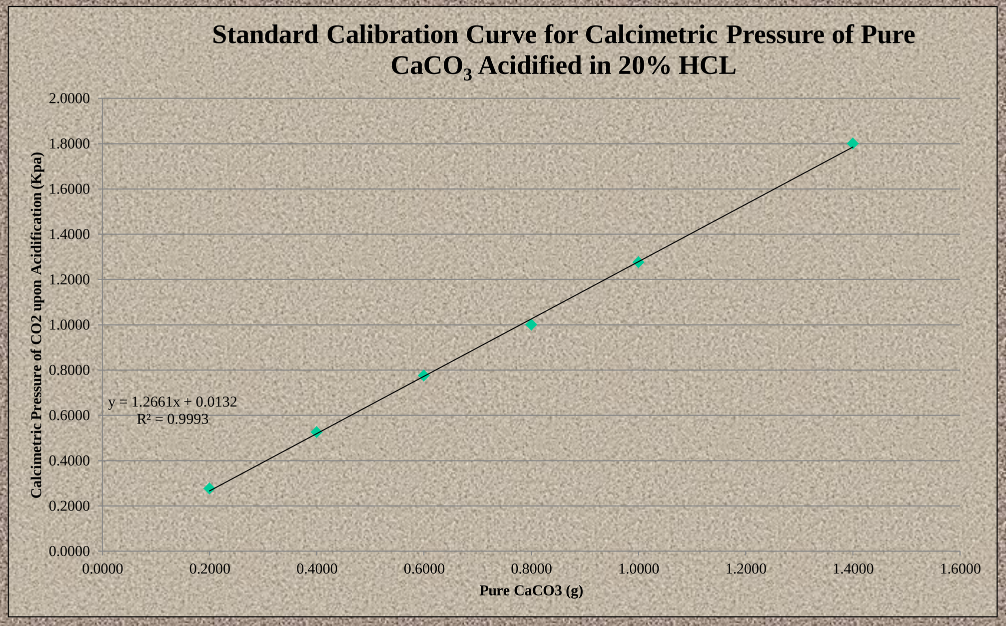


Figure 4. To ensure that a true representative sample is attained, all sediment is systematically pulverized , divided, and powdered to reach a final consistency of 250µm. Chipmunk crusher reduces cobbles to coarse gravel (A). Small crusher reduces gravels to ~2mm or less (B). Sediment is then portioned into ~60 gram subsample using a soil divider (not shown). The shatterbox reduces the subsample into its' final consistency (C). Samples are then weighed into ~2.0g and acidified using 10.0mL of 20%HCl and reacted within a pressurized calcimeter. (D).

RESULTS

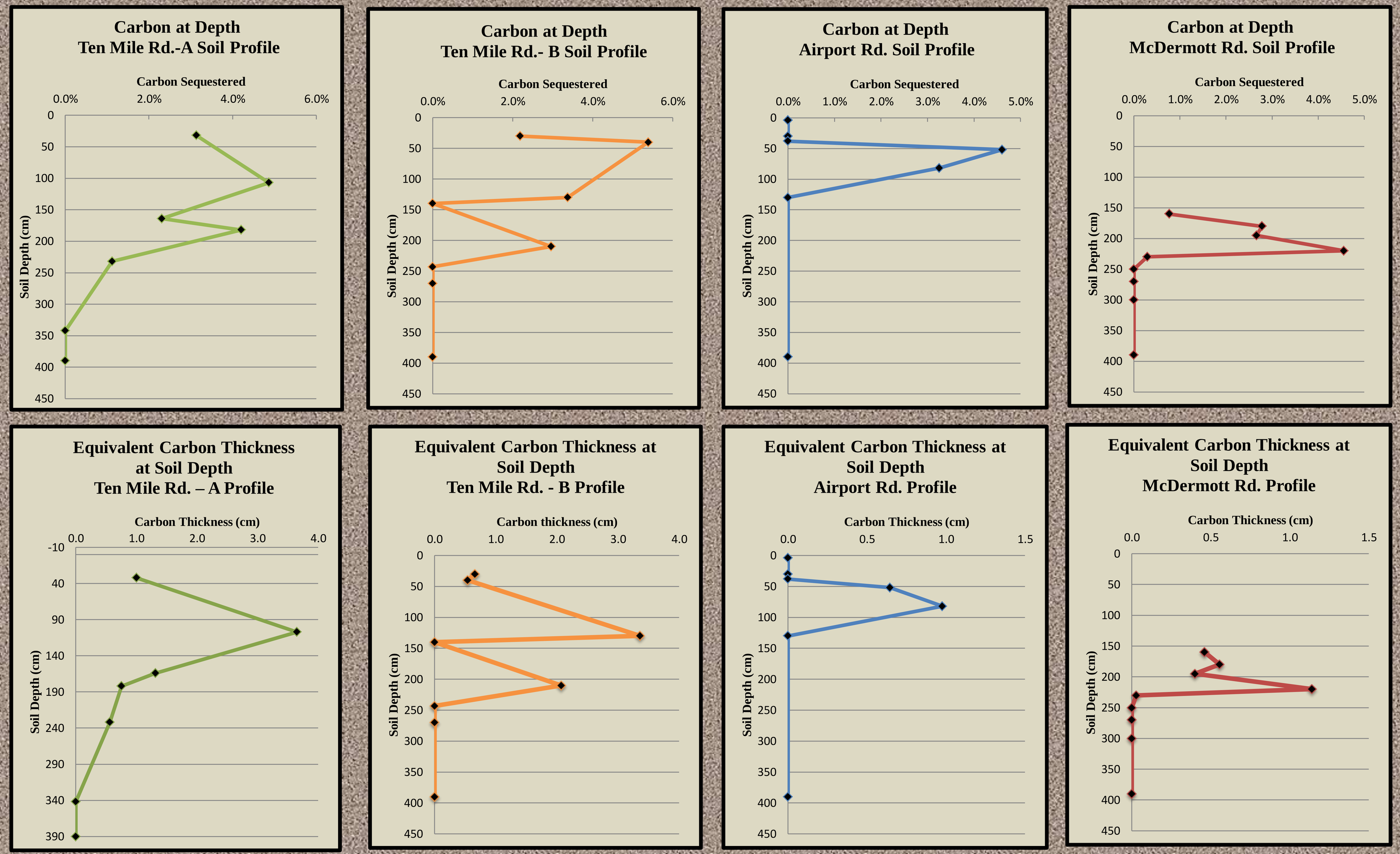


Figure 5. Carbon at depth indicates the estimated carbon percentage within each soil horizon sampled. Higher levels of $CaCO_3$ yield higher percentages of carbon since carbon constitutes 12% of its' mass. Equivalent carbon thickness at soil depth is a compilation of carbon found within each soil horizon as if it were condensed into tabular form with a visible thickness. Each thickness is plotted at a depth analogous to the depth of the horizon from which it is derived.

CONCLUSIONS

Ten Mile Rd. Profiles:
The inorganic carbon content within the Ten Mile Rd profiles are located south of an irrigated field and appear to be undisturbed where the profiles were taken. The eastern corner of the outcrop , nearer to profile A, contains an ephemeral stream. Profile A contains 2.1% carbon, a slight decrease from profile B, which is located approximately 30 yards to the west along the same outcrop. (Table 2). Profile B contained slightly higher levels of sequestered carbon (2.3%). The increase in precipitation nearer to profile A suggests that perhaps calcium carbonate is under active dissolution. Both of these profiles also contain a bimodal carbon peak (Fig. 5), which indicates a variances between rates of accumulation. These types of bimodal peaks may indicate a climatic shift which would have affected temperature and precipitation levels causing period of high leaching and caliche accumulation followed by periods of slow leaching and high loess deposition.

Airport Rd. and McDermott Rd. Profiles:
The location of these sites is situated within a largely disturbed gravel pit, whereby some of the soil has been buried or remixed. There are no irrigation sources located near the sites currently. Carbon levels for Airport Rd. are 1.3%,, nearly 45% less than that of the Ten Mile Rd. sites. The McDermott site was the most disturbed of the profiles, and contained .66% carbon, which is a 70% drop from that of the Ten Mile Rd. sites. While the pre-disturbance values of pedogenic carbonate are unknown, measured $CaCO_3$ values are lower for disturbed areas.

Factors involved in lateral variations of Carbon at depth between each site:

- Variation in loess deposits between sites would control the amount of soluble minerals available for leaching
- Surface flow of water ultimately controls the translocation of soluble minerals through the profile
- Faunal variations between sites which aid in the precipitation of calcium carbonate through absorption of water from the soil

Profile	Equivalent Thickness of Carbon (cm)	Profile Depth (cm)	Overall Carbon Sequestered (%)
Ten Mile Rd - A	7.3	342	2.1%
Ten Mile Rd. -B	6.3	270	2.3%
McDermott Rd.	2.6	390	0.66%
Airport Rd	1.6	130	1.3%

Table 2. Estimated percentage of each profile that actively contains carbon

FUTURE WORK

1. Quantify the carbon within terraces, determine variations in carbon content with terrace age, and extrapolate soil carbon values to larger areas
2. Investigate if and to what extent variations in carbon storage can be measured due to irrigation

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