Soil Development and Stream Terrace Genesis in the Potamia Stream Valley, Grevena, Greece

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Introduction

The Potamia stream valley runs NE to SW and is located near the Vourinos Mountains in eastern Grevena. Many of the streams in the nomos are incised into the underlying bedrock, which is Plio-Pleistocene conglomerates in this section of the nomos. Periods of aggradation and deposition have also occurred in the nomos during the Holocene. The result of these processes has been the formation of fill terraces throughout valleys such as the Potamia. In my project area, there are three unpaired fill terraces on the western side of the valley. The terraces contain ancient soils (paleosols) as well as modern ones. An archaeological site of Hellenistic and Roman age lies on the hill above the three terraces, and pottery sherds are present in the highest of the three terraces.

Bull (1990) and Knuepfer (1988) have successfully used stream terrace soils to aid in dating times of stream incision. The amount of pedogenic clay and $CaCO_3$ accumulated in the B horizons tend to increase through time. The aim of this project is to use properties like these, and soil development in general , as tools to date stream incision and terrace formation within the Potamia valley. In addition, this project should aid archaeologists trying to determine if colluvial and alluvial events during the Holocene occurred simultaneously with settlement in the region.

Field and Laboratory Methods

Field work entailed completing soil descriptions for both modern soils and paleosols, as well as noting the stratigraphic relationship of soils to alluvial and colluvial fills. Soil properties were recorded using soil description cars designed by the New Zealand Division of Land Resources. The properties recorded are similar to the ones suggested by the United States Soil Conservation Service and Birkeland (1984). Soil horizons were identified, field textures noted, and samples collected for further study in the United States. One charcoal sample was removed from a paleosol on the eastern side of the valley, but a radiocarbon date was unavailable at the time of this writing.

Laboratory work was conducted to supplement data obtained in the field. The percentage $CaCO_3$ was determined for each soil horizon using a Chittick device. The parent material for all modern soil is carbonate rich, so $CaCO_3$ amounts reflect both pedogenic accumulations and the $CaCO_3$ that was already present at the time of deposition. Particle size distribution was also determined for each soil horizon. Most A horizons were treated with hydrogen peroxide to remove organic matter and a deflocculent (sodium hexametaphosphate) was added to all samples. Every sample was then sieved to remove sands and the silt/clay fraction was allowed to settle in a column of distilled water. Pipetting was done at specified intervals to obtain draws of the silt and clay. Numerous problems were encountered using this method of analysis and are discussed in the Results section of this paper.

The stream terraces were noticeably lacking in organic materials suitable for radiocarbon dating, so the Harden profile index and maximum profile index was used to evaluate the relative ages of the terraces (Harden, 1982; Harden and Taylor, 1983). The indices provided a means of quantifying soil properties and proved to be very useful in my attempt to understand the formation of the terraces. An accurate measure of the true thickness of most of the paleosols was impossible to obtain, either due to erosion of the A horizon, inadequate outcrop exposure, or both. Therefore, paleosols were compared to modern soils using the maximum horizon index instead of the Harden profile index. Using this method enabled me to compare soils on the basis of horizon, not profile, properties.

Results

The three terraces in the study area display a complex arrangement of colluvial deposits, alluvial deposits, modern soils, and paleosols. The paleosols are particularly significant because they represent a time of stability in the landscape (soils tend not to form if their parent material is being intensely eroded or covered with new sediment). The middle terrace in the sequence contains two well-developed paleosols beneath a thick colluvial deposit. One of the buried soils, referred to as the dark-gray paleosol (profile 1) has peds 3-4cm in diameter and slickenslides on the ped faces, a sign of movement within the soil profile due to shrinking or swelling of clays. $CaCO_3$ covers most ped faces and carbonate nodules are present in the lower 30cm of the profile. This paleosol is cut by lenticular deposits of alluvium, indicating stream channel incision in this buried soil. A later soil with firm, subangular blocky peds has formed on this deposit of alluvium and $CaCO_3$ coats the surface of the peds, but carbonate nodules are absent.

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Figure 1. Cross Section of Valley
(Surface Levels Actual, Below Surface Hypothetical)

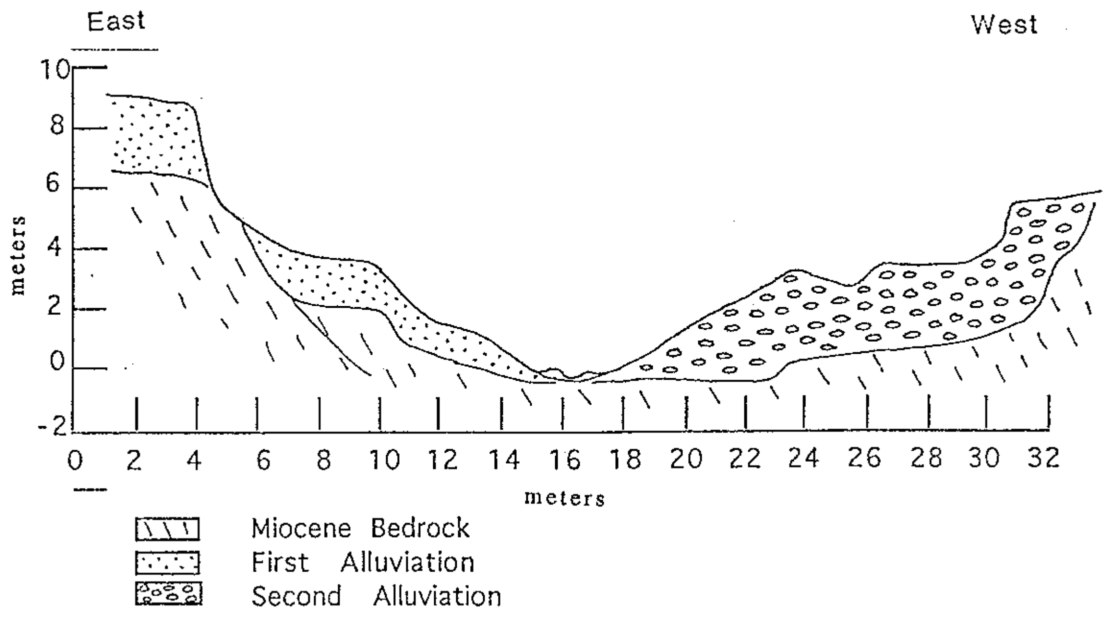
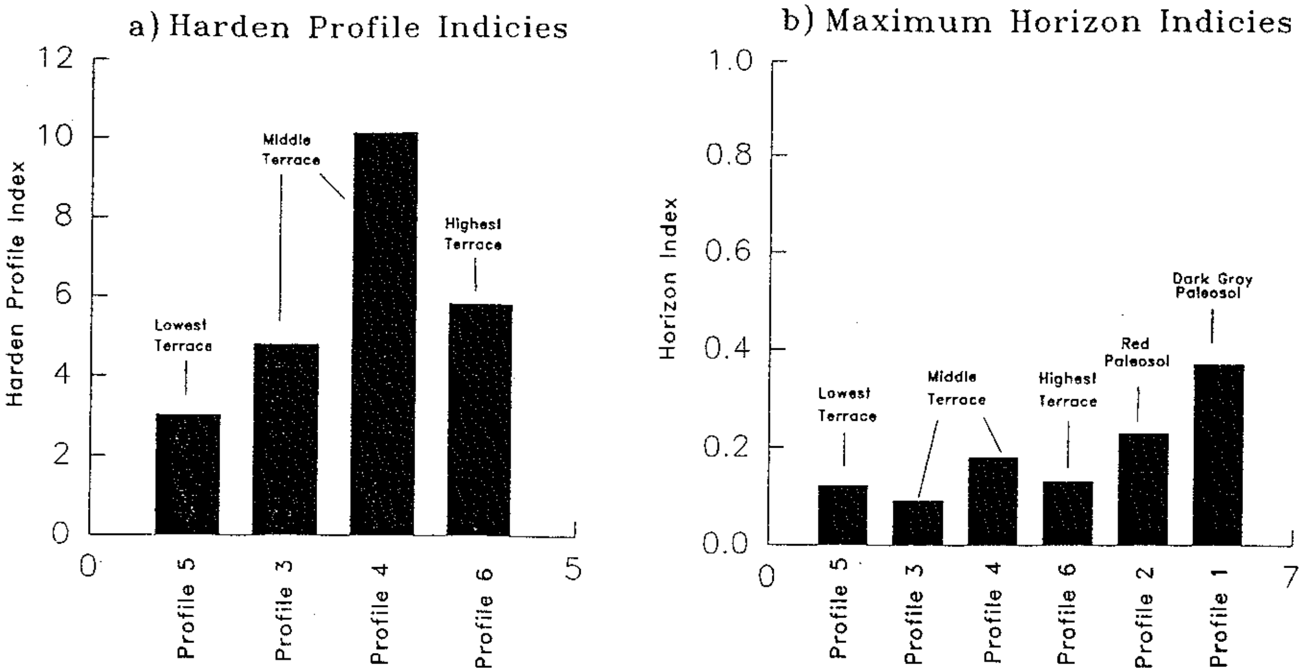


Figure 1.



In sharp contrast to the well-developed features in these paleosols are the soils forming on the modern terrace surfaces. Thin horizons, poor structure, and little, if any, pedogenic $CaCO_3$ accumulation characterize these soils. Since the sequence of terrace must become younger the lower they are in the sequence, one would expect soil development to be greatest on the highest terrace. Field observations did not show as strong a trend as one might expect, so the Harden index and laboratory work was completed to aid in deciphering finer trends.

Harden profile indices for the three modern soils (Fig. 1a) show profile 3 on the middle terrace as having the greatest degree of soil development Profile 3 is located on the colluvial deposit directly above where the two paleosols (profiles 1 and 2) are exposed and profile 4 is on the eastern edge of the terrace. The higher profile indices for the middle terrace when compared to the lowest and highest terraces might be due to modern colluvial deposition. Colluvial deposition could cause horizons to become thicker than they would otherwise (the Harden profile index takes horizon thickness into account).

Doyle (1990) made similar observations in the nearby Leipsikouki drainage, and suggests comparing the maximum horizon indices for each terrace to lessen the affect of colluvial over thickening. The maximum horizon index for each modern terrace soil is shown in Fig. 1b. Maximum horizon indices for the two paleosols are also included. Fig. 1b illustrates the strong degree of soil development in the paleosols in comparison to the modern terrace soils. Maximum horizon indices also factor in the thickness of the given soil horizon, so the values for the paleosols are probably minimum values since the lower horizon boundaries for each paleosol were obscured.

$CaCO_3$ percentage data (Fig. 2) for each of the modern soils show minimal carbonate accumulation in the B horizons. Machette (1985) has shown $CaCO_3$ content of soil profiles to increase the greatest in the B horizons. On the basis of laboratory data, it was impossible to assign the carbonate morphologies (stage I, I+, II etc.) that Machette discusses in his paper. The carbonate content of the parent materials is too high. However, distinguishing morphological features such as carbonate filaments and nodules were noted in the field. Type I+ to II morphologies are present in the dark-gray paleosol and type I+ in the red colored paleosol . No carbonate features were present in the modern terrace soils.

The particle size analysis was conducted to determine if illuvial clay buildup occurred in the B horizons. Data from this analysis (not shown) contained clay amounts 20-40% lower than anticipated. For example, the field texture for horizon A_2 in profile 5 was determined to be a light clay (30-35% clay). The laboratory determined clay content, however, was only 5.9%. It appears that the deflocculent was insufficient to disperse the clays so they could pass through the sieve. Birkeland (1984) states soils high in $CaCO_3$ commonly cause flocculation of clays. Removing the $CaCO_3$ with HCl, doubling of tripling the dispersant added, ultrasonic treatment, and shaking the samples in deflocculent overnight might have prevented this problem from occuring.

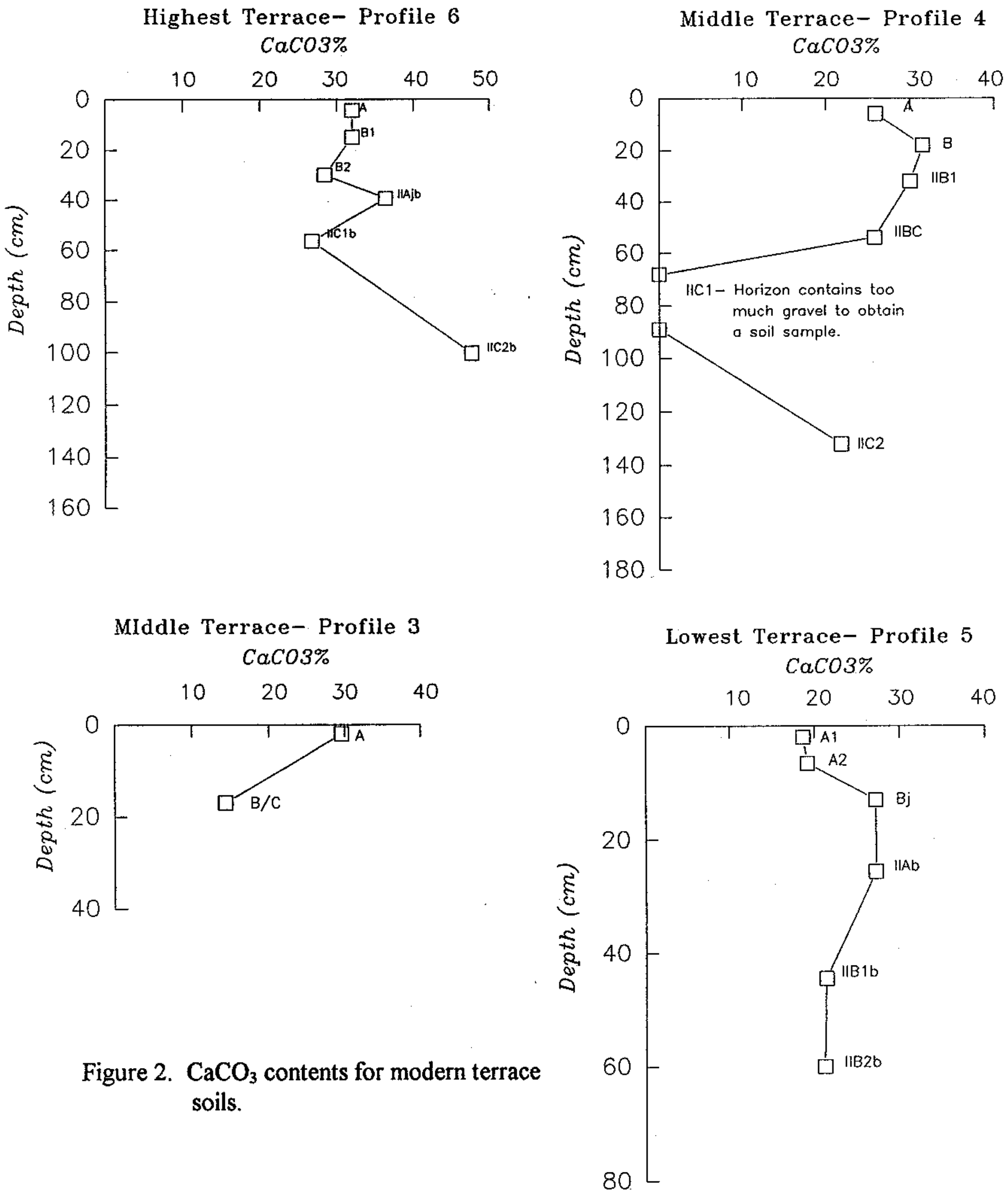


Figure 2. $CaCO_3$ contents for modern terrace soils.

Conclusions

The presence of the stream terraces indicate three separate periods of incision occurred. The alluvium present in each of the terraces indicates aggradation followed by incisional events. Since there are few paleosols in the lowest and highest terraces, stream incision probably occurred soon after the deposition of the alluvium. Soils on the modern terrace surfaces are still poorly developed. None of these soils have Harden profile indices of greater than 10. Furthermore, all of the soils exhibit weak pedogenic $CaCO_3$ accumulation. Together, these features suggest that these soils are all very young. According to Doyle (1990), soils with this degree of development are <1,500 years old. If this is true, stream incision occurred after the Hellenistic and Roman time periods when the nearby archaeological site was inhabited. Colluvial deposition on these terrace surfaces, however, might prevent soils from developing to their full potential given the time elapsed, so the terrace surfaces might be older.

The presence of the well-developed paleosols in the middle terrace indicates a long period of local landscape stability. After the dark-gray paleosol formed, stream channels cut the soil and deposition of alluvium occurred. This even was followed by a hiatus of alluvial deposition sufficient in length to allow a soil exhibiting stage I+ $CaCO_3$ morphology to develop. The time of parent material deposition is difficult to determine without radiocarbon datable materials, and it is unclear whether the paleosols are early Holocene aged or relicts from the Tertiary period. Soils on the highest terrace are insufficiently developed to indicate they are as older than the paleosols in the middle terrace. There are a number of ways the higher development of these paleosol relative to the highest terrace's soil might be accounted:

1)both paleosols formed before the Holocene. Subsequent back filling of the valley occurred, burying the two soils. Stream incision during the Holocene exposed both of the soils and created the terraces.

2)the paleosols formed during the Holocene. Stream incision creating the highest terrace occurred during the early Holocene. This was followed by the soil formation which created profile 1 and later channel incision into the soil. Colluviation late in the Holocene removed soil from the highest terrace, and some of this sediment was deposited on top of the two paleosols.

Regardless of the age of the paleosols, soil development on the three terraces point towards probable stream incision and intense colluviation during the late Holocene. Settlement of the area occurred during this time, and it is possible the cause of these events is anthropogenic.

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