Depth to pedogenic carbonate horizon as a paleoprecipitation indicator?: Comment and Reply

COMMENT

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Royer (1999) has recently used a large data set from the U.S. Natural Resources Conservation Service (NRCS) to reexamine the relationship between mean annual precipitation and depth to the calcic horizon in soils. The extremely poor correlation between these variables in his NRCS data ($r^2 = 0.03$) stand in contrast to good correlations (which he has confirmed) in previously published data sets of Jenny (1941), Arkley (1963), and Retallack (1994: r^2 = 0.56–0.64). As Royer indicates, his own correlation is virtually useless, but this does not mean that the others need be abandoned. Jenny (1941), Arkley (1963), and Retallack (1994) took pains to constrain competing variables in soil formation. The global compilation of Retallack (1994), for example, is limited to soils of friable sedimentary parent materials (not limestone, basalt, granite) and moderate development (some 10^3–10^4 years indicated by nodular calcic horizons; not pseudomycelia, veins, plugged or laterally continuous carbonate) that were undisturbed by human activity (unploughed, not overlain by construction materials or eolian dunes) and in sedimentary settings such as alluvial fans and riverine plains (not hill slopes, plateaus, or paleokarst). Contrary to Royer's assertion, I have not found these features difficult to determine from paleosols in sedimentary sequences when using these relationships to estimate paleoprecipitation. The soil pits of Arkley (1963) and Jenny (1941) were carefully chosen and measured by them in the field, and their empirical relationships also remain useful for interpreting paleosols. Such climofunction research aims to be exclusive, whereas soil survey data like that of NRCS aims to include all mappable soils, so it is not surprising that NRCS data, including bedrock, nonnodular, and hill slope soils (Royer [1999] did exclude disturbed soils and surficial calcic horizons), shows such a poor correlation between depth of calcic horizon and precipitation. Royer's graph and correlations are an impressive display of brute computing power, but also an outstanding example of the old computer adage, "garbage in, garbage out."

Royer (1999) suggested that the most useful paleoclimatic indicator to emerge from his data comes from the observation that 95% of his calcic soils are in climates with mean annual precipitation of less than 760 mm, but such paleoclimatic implications for paleosols may only be true for the Rocky Mountains, Great Basin, and California, United States (source of 81.5% of his data). The boundary between calcareous and noncalcareous (pedocals versus pedalfers) soils in the midwestern United States is near the 500 mm isohyet in cool Minnesota but closer to 600 mm in warm Texas (Birkeland, 1984). The boundary between calcareous and noncalcareous soils (ustic versus udic moisture regime) is near the 750 mm isohyet in Natal, South Africa, where 75% of rainfall is in summer, compared with 350 mm in Israel, where almost 100% of rainfall is in winter (Yaalon, 1983). This criterion is thus unreliable for interpreting paleosols.

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REPLY

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The data of Jenny and Leonard (1934) strongly influence the worldwide compilation of Retallack (1994b). These data, in particular those with a depth to carbonate horizon (D) > 100 cm (n = 35), anchor the regression of Retallack (1994b). Removal of these 35 data points, which decreases his sample size by only 11%, reduces the r^2 of the regression from 0.62 to 0.44 (Royer, 1999). Removal of all D > 100 cm data from the data set of Retallack (1994b) (n = 67) further reduces the r^2 to 0.38. Most studies applying this modern relationship to the geologic past use paleosols with D < 100 cm

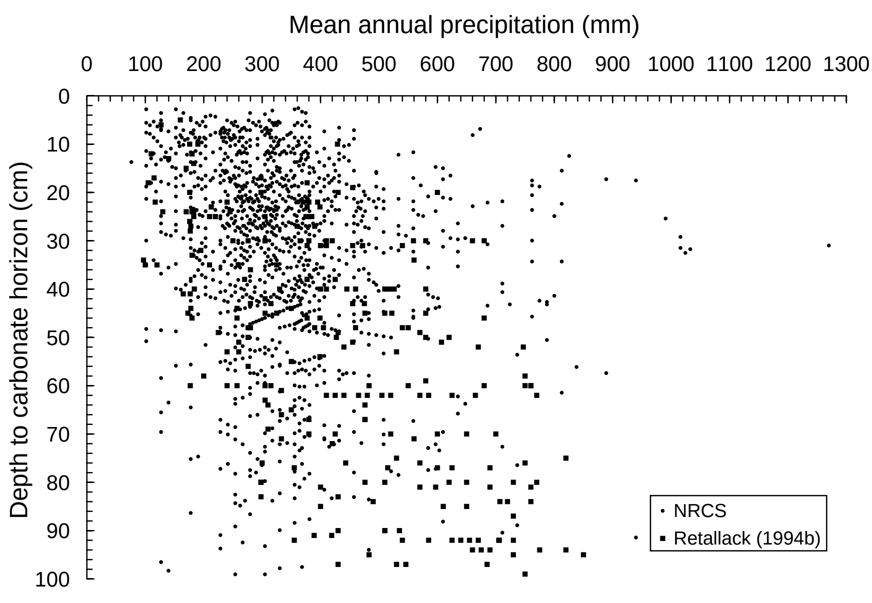

Figure 1. Relationship between depth to carbonate horizon (D) and mean annual precipitation (P) for D < 100 cm. r^2 for combined data sets (NRCS + Retallack) is 0.11 (n = 1407). r^2 for Retallack data set only is 0.38 (n = 246).

(Retallack, 1992, 1994a, 1994b, 1997; Caudill et al., 1996). Given these relationships, "garbage" paleoprecipitation estimates will surely result.

Furthermore, the Natural Resources Conservation Service–based data set of Royer (1999) suggests that the correlation between *D* and mean annual precipitation (*P*) is even poorer than previously considered at all depths. Unlike the data set of Retallack (1994b), which is based largely on transect studies, the NRCS-based data set approximates a random sample. Therefore, unlike transects studies which are designed to highlight differences in *D*, the NRCS-based data set better quantifies the frequency distribution of *D*. For the United States, soils with $D < 100$ cm dominate (Royer, 1999). Soils with $D > 100$ cm exist, and can be included in transect studies (e.g., Jenny and Leonard, 1934), but unfairly bias regressions for *P* estimates when the paleosols under study have $D < 100$ cm. When only data with $D < 100$ cm are plotted, a discouraging "bull's-eye" pattern emerges (Fig. 1).

In contrast to Retallack's assertions, care was taken in selecting pertinent soils for the NRCS data set. As mentioned, disturbed soils and soils with surficial carbonate horizons ($D = 0$) were eliminated. Ninety-four percent of the soils were described as containing carbonate masses, nodules, accretions, flakes, or weakly cemented grains (Royer, 1999). While parent material and texture were not controlled for, removing soils with carbonate-rich parent material and/or a given textural class (sand, silt, clay) did not affect the regression (Royer, 1999). The only parameter not considered was sedimentary setting.

I agree that the presence versus absence of pedogenic carbonates as an indicator of *P* below or above 760 mm, respectively, should only be applied to paleostudies overlapping in geography with this study's, namely the Rocky Mountains, Great Basin, and California, United States. I regret the oversight in the original publication.

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The Channeled Scabland: Back to Bretz?: Comment and Reply

COMMENT

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The major controversy regarding the origin of the Channeled Scabland is whether the landforms were formed mainly by multiple periodic floods or by a grand-scale cataclysmic flood from late Pleistocene Glacial Lake Missoula. Evidence for the multiple flood—as many as 40 as estimated by Waitt (1980; 1984; 1985)—hypothesis is derived mainly from lake deposits in Ninemile Creek and flood deposits in Burlingame Canyon. Shaw et al. (1999) reevaluated these sedimentary sequences and concluded that the sequences do not imply multiple floods separated by decades or centuries. They suggest that the sediment records indicate that there were sources of water immediately north of the Channeled Scabland, and the scabland flooding might have partially originated from an enormous subglacial reservoir that extended over much of central British Columbia.

We have developed a 3-dimensional numerical code in order to simulate the flood processes in a more realistic manner than the conventional 2-dimensional models. The code can compute movement of a water element under the influence of gravity by the Manning Equation. We assumed that the discharge rate calculation (O'Connor and Baker, 1992) at the Spokane Valley–Rathdrum Prairie conducted by the 2-dimensional HEC-2 program using high-water marks obtained in the field is reliable. The Spokane Valley–Rathdrum Prairie reach is immediately downstream of the breakout point of Lake Missoula, hence the estimated maximum discharge rate by O'Connor and Baker (1992) fairly accurately constrains the maximum possible outflow condition from Lake Missoula. We adopted the hydrograph proposed by O'Connor and Baker (1992) with the maximum discharge of 17×10^6 m^3/s and total amount of water (2184 km^3) equal to the volume of Lake Missoula. We also assumed that the depth of flood erosion is small compared with the maximum water depth and the present-day topography is close to the late Pleistocene one. The simulated water flow was thus fit to the modern-day topography. Our simulation has been able to reproduce accurately the reconstructed flood behaviors, such as hydraulic ponding in the Pasco Basin (Fig. 1). The major finding was that the calculated depth of water in each flood reach except for the Spokane Valley–Rathdrum Prairie is much shallower than the observed depth derived from field evidence. For example, the calculated water depth at the Pasco Basin–Wallula Gap transition zone is about 190 m, significantly less than the 280–300 m indicated by high-water marks. In addition, some flood reaches such as the Cheney-Palouse Scabland are not fully covered (Fig. 1). This is the case despite the fact that we adopted a relatively large Manning coefficient n = 0.1 for this kind of calculation. This implies that there was not enough water from Lake Missoula to explain the observed water depths in the downstream reaches. Furthermore, we also found that if we run the simulation with a smaller discharge rate, for example 2×10^6 m^3/s (Clarke et al., 1984), some major reaches including the Cheney-Palouse Scabland are not even covered by floods since the water then finds a more efficient path through the Columbia River valley. This means that a flood of magnitude about $\sim 10^6$ m^3/s could have not made the high-water marks.

The conservative estimate of the total volume of water in the subglacial reservoir by Shaw et al. (1999) is on the order of 10^5 km^3 that is far exceeding 2×10^3 km^3, the volume of Lake Missoula. Our simulation indicates that the volume of water necessary to cover the observed flooded area and to reach the high-water marks is about three times greater than that of Lake Missoula assuming the maximum discharge rate of 17×10^6 m^3/s, Manning coefficient n = 0.1, and water supply from Lake Missoula. Apparently, even the whole lake-draining scenario of Lake Missoula cannot explain the field evidence of high-water marks if our simulation results are valid. This is consistent with the view that, although floods from Lake Missoula certainly played a role for the formation of the Channeled Scabland, there were other sources of water. The subglacial flooding from the north