Mima mounds as upper soil biomantles: What happens when the dominant bioturbators leave and invertebrates take over?

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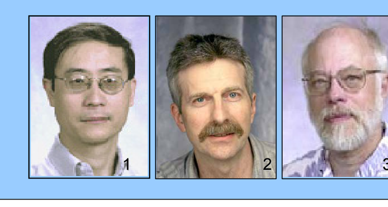

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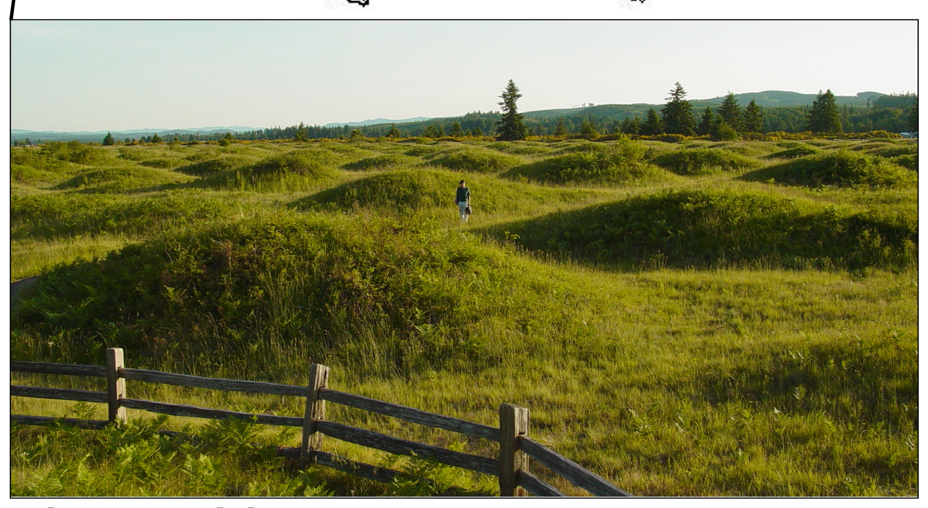
Can we explain soils beyond the 5 factors model? Yes, by drawing on biodynamic principles with embedded biomantle and process vector concepts.

We compared the biomantles of Mima mounds at Diamond Grove Prairie, Missouri, with those at Mima Prairie, Washington State (a work in progress).



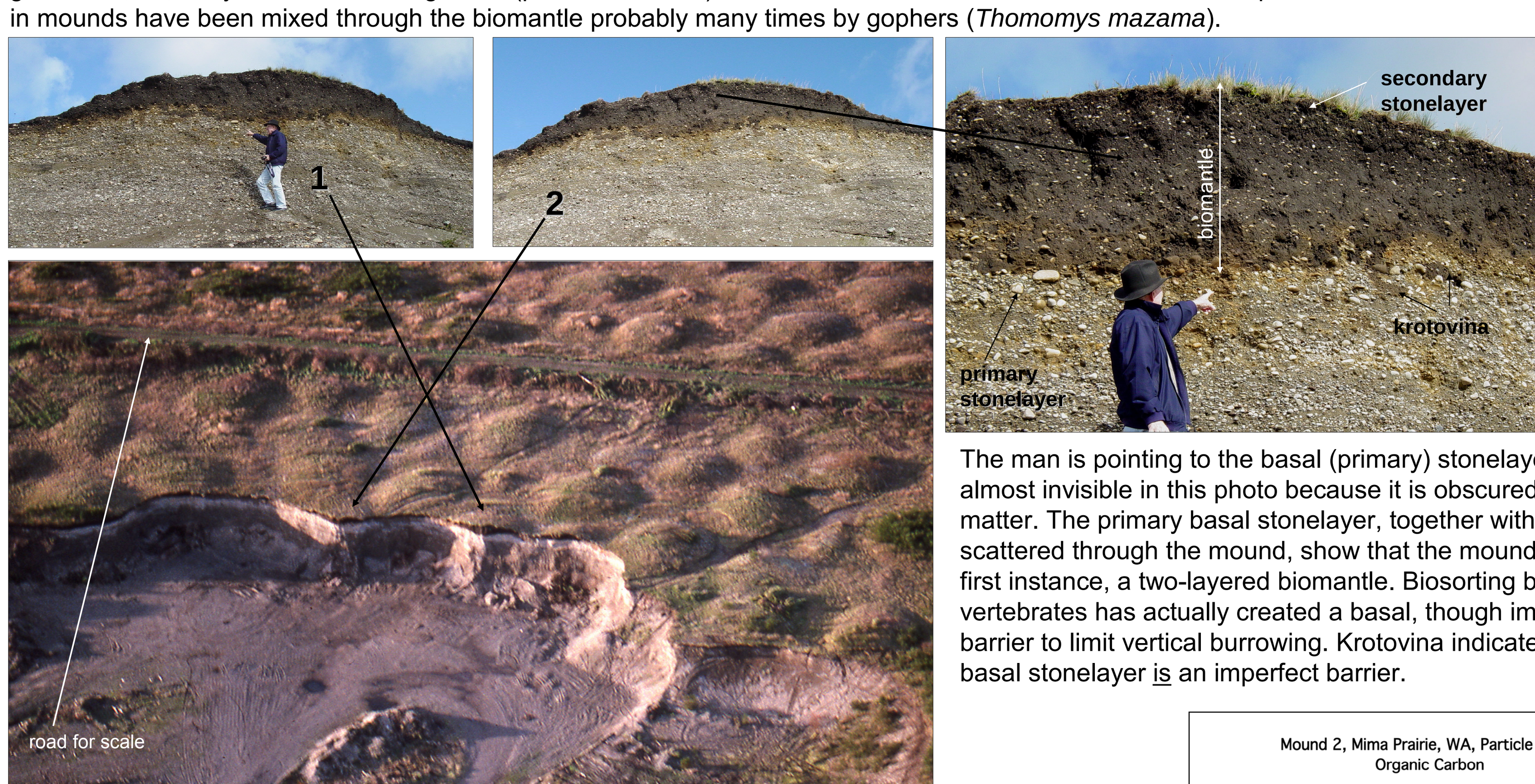
Mima Prairie. The mounds in Washington formed in young gravelly outwash associated with the nearby Vashon lobe of ice that terminated some 14,000 years ago. **Mima mounds** are produced by small vertebrates that bioturbate in shallow soil over hardpan, bedrock, or high water tables. They are **point-centered, locally thickened biomantles**. The mounds at both Diamond Grove and Mima Prairie are gravelly, and thus two-layered biomantles (i.e., they are texturally *biosorted* by animals).

Diamond Grove Prairie. The mounds lie 200 km south of the glacial boundary on the Springfield Plateau, a very old surface, which during the Pleistocene received several loess dustings (Horwath 2002). Before the plow arrived, Mima mounds were once common throughout much of the western Mississippi basin, and intermittently across western North America. Pocket gophers (*Geomys bursarius*) are active in many parts of Missouri, including this region, but are now locally absent at Diamond Grove.

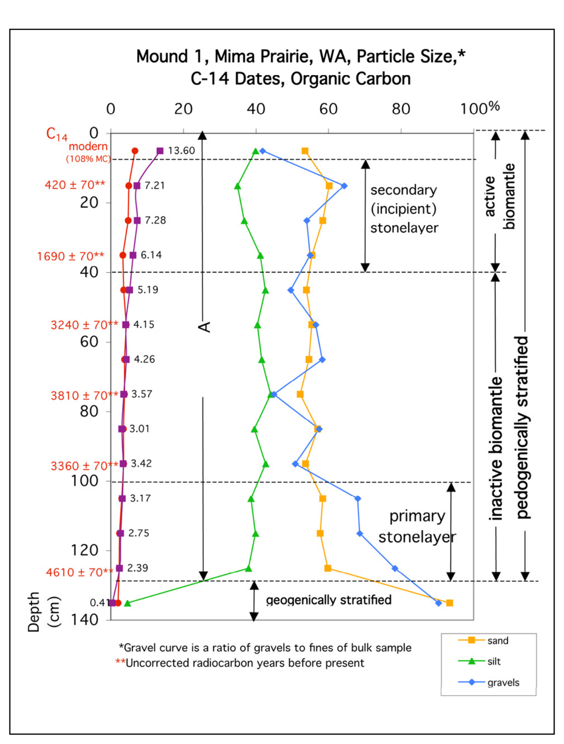
Gravel size is <u>key</u>:

Gravels in the mounds are the size that will pass through a gopher/mole burrow (≤ 6.5 mm). Note that within mounds the gravels are this size or smaller. Pedologists traditionally have not dealt with such animal-gravel-mixing concepts and issues, but they <u>must</u> in order to maximize interpretive skills!

Borrow Pit at Mima Prairie. Black arrows point to the two mounds studied. Note light-colored geosorted, 14,000 year-old outwash gravels (parent materials) and dark-colored biosorted biomantle. All small pebbles in mounds have been mixed through the biomantle probably many times by gophers (*Thomomys mazama*).

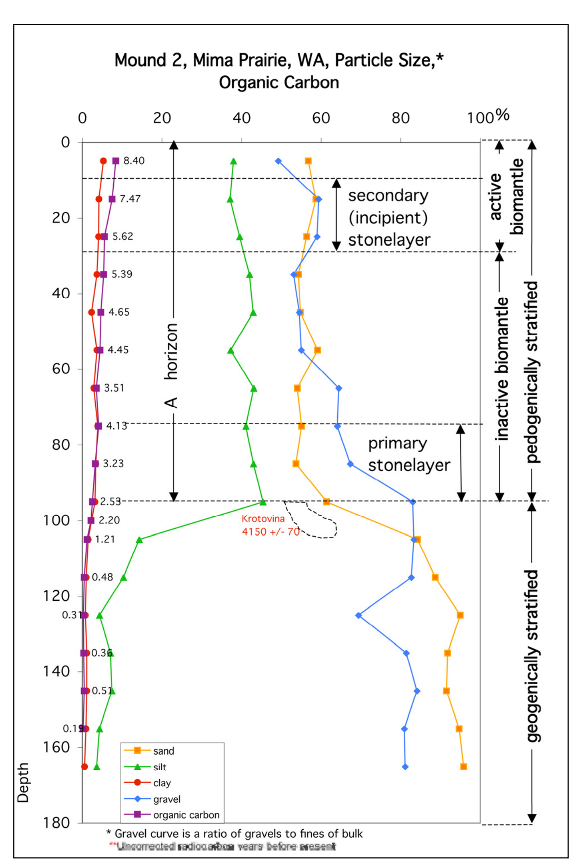


The man is pointing to the basal (primary) stonelayer that is almost invisible in this photo because it is obscured by organic matter. The primary basal stonelayer, together with the pebbles scattered through the mound, show that the mound is, in the first instance, a two-layered biomantle. Biosorting by small vertebrates has actually created a basal, though imperfect, barrier to limit vertical burrowing. Krotovina indicate that the basal stonelayer <u>is</u> an imperfect barrier.



Laboratory Data: The data for Mima Prairie mounds 1 (left) and 2 (right) show that a well developed basal (primary) stonelayer is clearly present in both mounds, and thus presumably all mounds. But a qualification is in order because an incipient (secondary) stonelayer -- and biomantle -- are now forming in the upper 30 cm of both mounds. (The same is true for Diamond Grove Prairie in Missouri.) We interpret these incipient biomantles as now being actively formed by *invertebrate* soil animals being expressed in the absence of pocket gophers. Continuing this logic, the bulk of each mound constitutes an inactive biomantle (a legacy of gopher bioturbation).

Time-averaged radiocarbon dates on soil OC: Note that ^{14}C dates are generally older with depth, suggesting that pocket gophers began forming the mounds long ago, probably in early Holocene time. Gophers, now absent, departed so recently that neither a textural B or other horizons are yet expressed, except stonelayers. Our data indicate that soil formation is extremely complex, and that bioturbation is a fundamental part of the soil story.



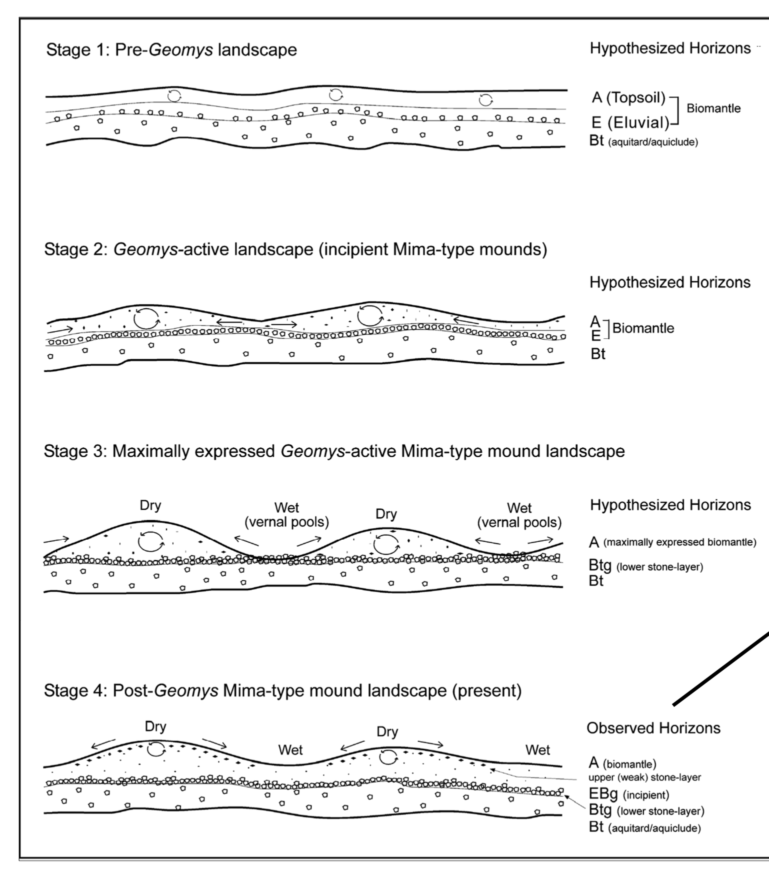
In our study we ask:

1. What happens to Mima mounds when the small vertebrate bioturbators (e.g., gophers) that dominantly produced them disappear?
2. Does the previously active biomantle now become inactive?
3. Do other bioturbators, like invertebrates (ants, worms, etc.) whose effects were masked by the dominant bioturbator, begin imparting morphological signatures to the biomantle?
4. And do subsidiary processes beyond biodynamics (e.g., leaching, eluviations-illuviations, shrink-swell, chemical transformations, etc.) that were countermanded by the dominant bioturbators -- but still coevally operating, become morphologically expressed?

<u>Our data indicate:</u> that for both Diamond Grove and Mima Prairie the answers are "Yes"!

Soils of Diamond Grove mounds:

The mound soils in Diamond Grove are mapped as Keeno very cherty silt loam (loamy-skeletal, siliceous, active mesic *Oxyaquic Fragiudalfs*), and in Mima Prairie as Spanaway gravelly sandy loam (sandy-skeletal, mixed, mesic *Typic Melanoxerands*). Official descriptions vary somewhat from our mound descriptions. The mound soils in both areas are very gravelly and comprise whole-soil, two-layered biomantles (Horwath and Johnson, 2006; Johnson, 1990; Schaetzl and Anderson, 2005). But, these soils -- and the soilscapes of which they are a part -- have experienced far more complex pedologic and biodynamic histories than is conveyed by these otherwise useful soil taxonomic descriptors.



The role of burrowing animals:

Evidence indicates that Mima mounds are dominantly produced by pocket gophers. These are sausage-shaped members of the Geomyidae family of rodents that regularly burrow outward from their nesting-food storage activity centers. Pocket gophers are aggressively territorial and supremely adept underground burrowers. They can move enormous volumes of soil per year in some tracts, and their point-centered mounds often reflect a nearest-neighbor pattern formed over many generations. However, at both Diamond Grove and Mima Prairies pocket gophers are now locally absent, and have been absent historically, though they occupy nearby tracts. Evidence of their former presence at both prairies is, however, persuasive. Moles presently inhabit both prairies, and at Mima Prairie their bioturbational role is uncertain. Myriad invertebrate bioturbators (ants, worms, etc.) also occupy these prairies and bring mainly fine fractions to the surface and upper profile. Invertebrates are, we believe, responsible for the secondary (upper) stonelayer.

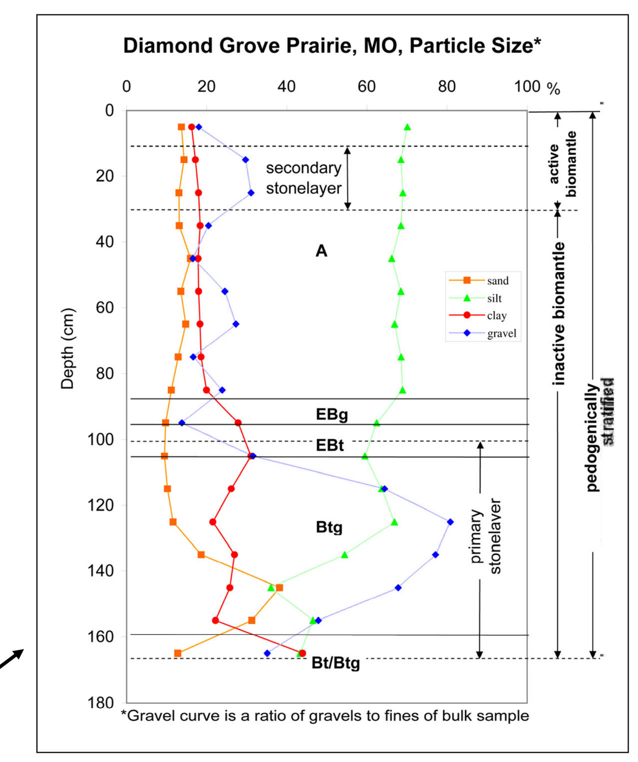
Pocket Gopher

Our operating philosophies:

Biodynamics: Biodynamic pathways of pedogenesis consist of various complex processes, products and conditions, that include: bioturbations (at all scales); biologically mediated physico-chemical transformations; bioaccumulations of living and non-living soil organisms and debris; biovoids that compose biofabric produced by biomechanical-metabolic processes; and soil volume expansions (from Johnson et al., 2005b).

Biomantles: constitute the epidermis of soil produced dominantly by bioturbation (by animals, plants, fungi, etc.) aided by subordinate processes (leaching, rainwash, eluviation-illuviation, biochemical weathering, etc.). They are either one-layered -- those <u>without</u> basal stonelayers and thus formed in non-gravelly soil, or they are two-layered -- those <u>with</u> basal stonelayers and thus formed in gravelly soils (Johnson, 1990).

Process vector analysis: Process vector analysis (pva) is a useful graphic, conceptual, semiquantitative-quantitative device that weights the relative effects and/or rates of two or more coacting processes. It is applicable to any science, but is particularly useful in providing explanatory insights to complex processes in soils, especially horizonation vs bioturbation processes. (Johnson et al., 2005b).



The evolution of Mima-type mounds at Diamond Grove Prairie, Missouri.

Process Vector Analysis: The charts/graphs, upper left & above, demonstrate the usefulness of the graphic-conceptual aspects of process vector analysis (pva). In the upper left graphic, 4 stages show our hypothesized evolution of the Springfield Plateau landscape in southwestern Missouri.

Stage 1: The pre-Geomys landscape. Biomantle consists of A and E horizons and basal (primary) stonelayer; Bt horizon is a claypan that is an aquitard when dry and aquiclude when wet. (Landscape is periodically wet.) In terms of pva: for biomantle, bioturbation ≤ horizonation, and vertebrate bioturbation < invertebrate bioturbation; for Bt horizon, horizonation > bioturbation.

Stage 2: At beginning of stage, pocket gophers (*Geomys)* arrive and choose driest ground for nesting-food storage (activity centers). Because of their territoriality and centripetal burrowing style, they begin forming mounds at activity centers. In terms of pva: for biomantle, bioturbation > horizonation, and vertebrate bioturbation > invertebrate bioturbation; for Bt horizon, same as Stage 1.

Stage 3: End member version of Stage 2. Vernal pools now seasonally present; all fines and small gravels now on mounds and mixed throughout; large clast stone pavement between mounds; mounds now maximally developed as point-centered, two-layered biomantles. In terms of pva: same as Stage 2.

Stage 4: post-*Geomys* (present) landscape. New horizons are forming in mounds (cf. above graph). Mounds slowly downwasting into intermound areas. New, incipient (active) biomantle now forming via invertebrate bioturbation, with upper (secondary) stonelayer in old (inactive) Mima-type mound. In terms of pva: similar to Stage 1.

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