

MASS WASTING AND THE DEFORMATION OF TREES

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ABSTRACT. The concept of slow mass wasting, or soil creep, is allegedly supported by the displacement of surface objects. Curvature of tree trunks is a widely used manifestation of the process, although in the search for evidence of soil creep the more logical deforming agents are disregarded and the physiology of tree growth has been ignored.

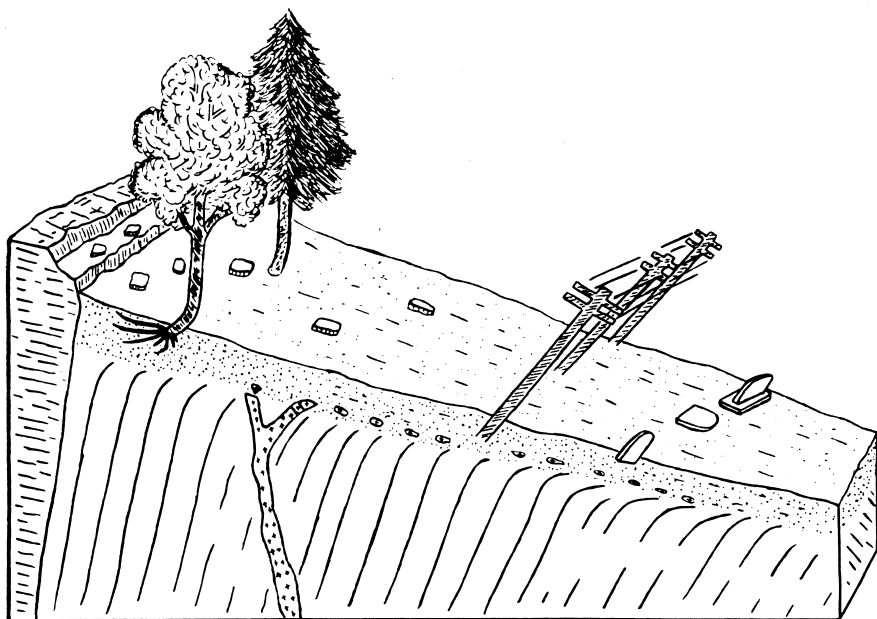
This paper presents the mechanical and physiological causes for tree deformation and discusses the type of curvature which would develop under concomitant tree growth and soil creep. It is concluded that the proper tree curvature is rarely, if ever, observed, and that alternative explanations for the development of the curvature which does exist are probably more valid. With doubt cast upon one of the principal evidences of soil creep, it seems pertinent to subject the other criteria to a more thorough examination and perhaps re-evaluate or redefine soil creep as a geomorphic process.

INTRODUCTION

Most geomorphic processes operate so slowly that the mechanics must be inductively postulated, and the evidence proposed to support these processes is, therefore, frequently drawn from non-geologic fields. Such being the case, the evidence must be critically tested by principles of applicable scientific disciplines, and thus "the practicing geomorphologist will be more effective if well versed in soil science and acquainted with principles of hydraulics, meteorology, oceanography, and botany" (Sharp, 1950). One widely accepted concept that has not passed the necessary test and which becomes less reasonable and possibly invalid by critical examination is the presumed correlation between tree curvature and soil creep.

Soil creep,¹ having received almost universal acceptance as an important degrading agent, is included in all geomorphology texts. Phenomena cited to support soil creep include the bending of trees, dislocation of surficial objects, and such subsurface features as warped beds and lines of stones (fig. 1). The bending of trees is in most cases emphasized as indicative of downslope movement or slow flow of soils. One author states: "The movement is very slow, but can be measured as it influences the growth of trees. The root system of these is anchored in the deeper horizons which move more slowly, or in the living rock itself, whilst the quicker moving superficial layer presses the upper parts of the root system downslope. This rotation couple makes the trees oblique at the base, while the trunks as a whole tend to grow vertically upwards. Thus they show curvature, convex on the downslope side" (Penck, 1953, p. 109). Another states, "Downhill tilting of trees and a compensating upslope curvature of their trunks is unusually well developed on hillsides of relatively loose material . . ." (Sharpe, 1938, p. 24). A third says, "The trunks of trees are sometimes tilted by the downslope displacement of the soil about their roots, and they may even develop a curved shape, bending convexly down the slope

¹ Although the term creep was used by Davison in 1889, the most definitive and widely quoted study of mass wasting was made by Sharpe (1938). In this study soil creep was defined by Sharpe (p. 21) as the "slow downslope movement of superficial soil or rock debris, usually imperceptible except to observations of long duration"; he concluded that the slow downhill creeping process is continuous although partially due to an infinite succession of very minute movements. Unfortunately, the term soil creep has come to encompass a wider variety of gravitative processes than was seemingly intended, until now it is frequently used as a catch-all term or a convenient pedagogical tool.



CONVENTIONAL EVIDENCE OF SOIL CREEP

(MODIFIED FROM C. F. S. SHARPE, 1938)

Fig. 1. The conventional evidence of soil creep, showing displacement of surface and subsurface objects.

in their efforts to grow into the normal vertical position" (Monnett and Brown, 1950, p. 60). Similar statements can be found in other geological texts, although in botanical writings soil creep is disregarded as a contributing factor to tree curvature during growth. It would appear that the willing acceptance by many geologists of distorted trees as an evidence of soil creep, without examination of the physiology of the growth, has been, in effect, search *for* rather than examination *of* the evidence. It is pertinent and timely, therefore, to examine and evaluate this correlation which apparently is so firmly imbedded in the minds of many.

HYPOTHETICAL TREE CURVATURE

Without exception, illustrations of trees allegedly bent by creeping soil portray one sharp curve above which the bole is vertical. The curve supposedly results from pressures set up by faster-moving surficial soils against the roots of the tree which are anchored in deeper slower-moving soils or in the bedrock. The downslope tilt of the tree resulting from these stresses is corrected by geotropic response, the renewed vertical growth producing one relatively angular curve. But if soil creep is a slow but continuous movement as defined, and downslope bending of trees the result, there should be no straight segment of the tree stem; rather, the trunk of the tree should assume under these

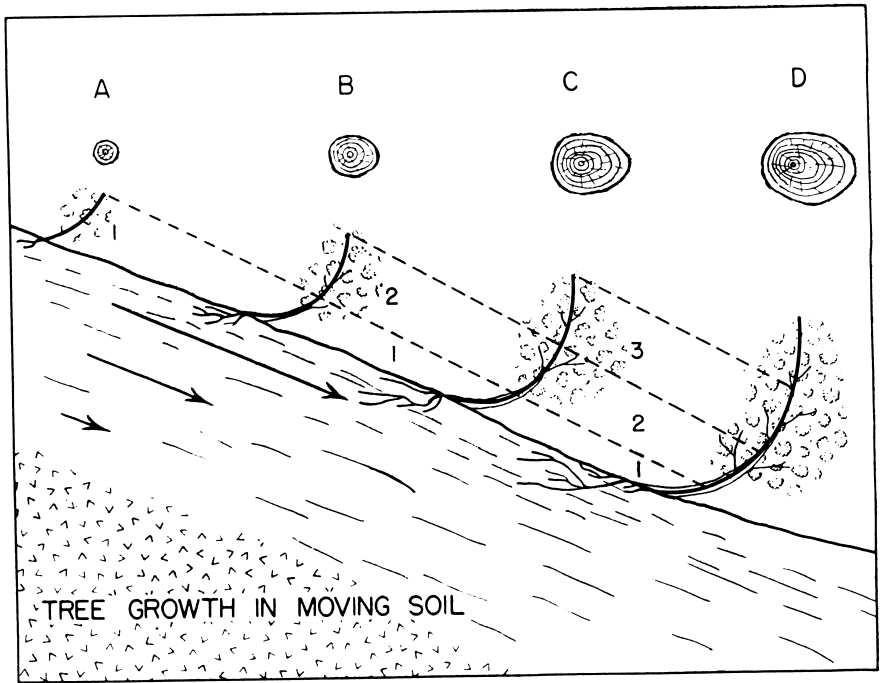


Fig. 2. The hypothetical sequence of tree growth in slow, continuously moving soil. Of significance is the single sweeping curve from terminal bud to base and the asymmetrical growth rings.

conditions a long continuous curve with only the terminal buds attempting to maintain a vertical attitude. Figure 2 illustrates the hypothetical sequence of tree growth in a continuously slow-moving soil. The curvature produced by initial movement (A-1, fig. 2) must persist throughout the life of the tree, since growth is restricted to the peripheral layer, and only the terminal buds respond geotropically. Significantly, the deformed tree remains curved, for it is only a board, and the initial curvature produced in stage A-1 must be constant in degree and relative position throughout the life of the tree. This is demonstrated (fig. 2) in the succeeding downslope positions (B, C, D) of the tree. The segments of the stem below the broken line extending from the crown in A-1 to the base of the trunk in stage D are identically curved, differing only in that they are increasingly canted downslope. Later bending, represented by B-2, C-3, and in D, are upward extensions of the already deformed bole, the degree of curvature reflecting the rapidity of downslope movement of the soils and tree. Carried to the extreme, the first and lowest curve (D, fig. 2) would be recumbent.

Cross sections of these curved trees (fig. 2) should have asymmetrical growth rings which are increasingly wider on the downslope side of the tree. Botanists generally credit this asymmetry of growth to (1) gravitational concentration of growth hormones, the added wood or compression tissue on the downslope side of the trunk strengthening the tree, the bulk of whose weight

is not directly above the base; and, (2) to translocation of food resulting from more favorable light or edaphic conditions on one side of the tree. Although this feature in itself would, therefore, not be definite proof of soil creep, trees deformed by continuously moving soil should show a sweeping curve and asymmetrical cross sections from tip to base. Vertical stem segments and symmetrical growth rings would indicate a static condition of the soil during the periods in which this growth was occurring. Such lengthy intervals of soil stability would preclude, by definition, a condition of creeping soils.

ROOT PATTERNS

Because tree curvature is allegedly the result of roots anchored in bedrock or more slowly moving soils, they are depicted as strung out upslope behind the moving tree (fig. 2). Accepting the corollary of tree curvature, upslope extension of roots, and soil creep, a tree with an initially radial root system would, in a creeping soil, encroach upon a portion of its own roots, contorting and concentrating them beneath the trunk until as movement continued they became unraveled and drawn out upslope. Logically, old and mature trees growing on active slopes should have few, if any, roots extending downslope. However, examination of trees on even steep slopes shows radial distribution of roots with an occasional concentration downslope.²

The common belief that tree roots penetrate to considerable depths is unrealistic, for the roots of most species are concentrated at surprisingly shallow depths, with some variation imposed by site conditions. In well stocked mature stands the intertwined roots form a shallow tangled mat developed so compactly that movement of individual trees is impeded, if not precluded. Where minor slumping or other rapid movement disturbs the forest, the mat of roots and trees above moves as a unit, similar to a toboggan. If the movement is moderate both in distance and velocity the trees may remain vertical or be unevenly tilted; but should the mass movement be violent and extensive, the trees are felled and the forest destroyed.

SUBSTANTIATED CAUSES FOR TREE CURVATURE

Although deformed stems are characteristic of all woodlands, there is usually no common denominator of degree, direction, or position of curvature (pl. 1-A), and the hypothetically curved trees (pl. 1-B) are significantly absent. At each site more careful observation suggests that factors other than

² Illustrations in a paper by Helmers et al., (1955), display root systems growing on considerable slopes in Southern California. In all cases a radial pattern is developed, and exposure of the roots of chaparral yucca showed that "an equal number of roots grew in all directions from the plant, but those growing downhill extended 11 feet while those growing uphill extended less than 6 feet" (p. 675). It should be noted that the authors refer to roots growing uphill and no reference is made to roots being strung out upslope by soil creep. No uphill dragging of the roots is exhibited in an illustration of Eastwood manzanita, although they penetrate more than 9 feet into the bedrock. In fact, this species is recommended by the authors as a plant useful in preventing mass movements on over-steepened slopes. This seemingly contradicts the statement that trees anchored in bedrock move downslope, leaving their roots trailing behind. It appears probable that if roots anchored in the bedrock help stabilize the slope, then soil creep would be minimized or non-existent at such localities; but if the roots are not anchored, soil creep would produce no tilt of the trees and, therefore, no opportunity for the supposed curvature to develop.

PLATE 1



A. Short leaf pine (*Pinus echinata*) growing on a 20° slope in the mid-Piedmont of Georgia. The curvature of the two trees is diametrically opposite, whereas the small yellow poplar (*Liriodendron tulipifera*) between has almost perfect vertical growth. A number of deformed stems are visible in the background.



B. Large loblolly pine (*Pinus taeda*) in background and persimmon (*Diospyros virginiana*) in left foreground are growing vertically on a 30° slope composed of loose fill. The trees are 60-80 years old. Location is 2.5 miles northeast of Athens, Clarke County, Georgia.

soil creep are undoubtedly more critical in the deformation. More realistic causes can be broadly classified as mechanical and physiological. The mechanical causes include the effects of unusual weather conditions, i.e., high winds, ice, snow, damage during logging, and obstructions to growth from rock outcrops. The physiological factors result from gravity working upon trees whose supporting roots have been weakened in any way, i.e., pathogens, fires, etc., to destruction of the terminal buds in any manner, to growth responses to light or food conditions, and to vegetative regeneration. It is evident that rarely, if ever, is the aerial portion of a tree perfectly balanced, enhancing the probability that it will topple under certain circumstances. In fact, the ultimate fate of the majority of trees is to be felled by this imbalance in conjunction with one of the weakening agents.

Omnipresent pits and mounds on forest floors, produced by displaced roots as the trees were tilted or felled, testify to the past and continuing destiny of all trees. The disturbance of soils by the upheaval of roots was noted by Shaler (1891), Holmes (1893), Van Hise (1904); Lutz and Griswold (1939) demonstrated clearly the profound changes in the soil profile accompanying this process. A detailed study of mounds and pits in the Harvard forest by Stephens (1956) reveals that "the area has been subjected to four periods of major uprootings The fourth and oldest was estimated to have occurred between 1400 and 1500 from evidence existing solely on the ground" (p. 115). It is notable that in an area of active frost heaving, a condition said to be conducive to soil creep, the gross anatomy of mounds and pits has been retained for such lengthy periods. Significantly, soil creep is disregarded by Stephens in the discussion of contributing causes for the throwing of trees, and he concludes that "uprooting assumes the proportions of a general process of the forest; and . . . can be considered in the same way as other generally recognized processes, such as growth, reproduction, and podzolization" (p. 116). With complete felling of trees playing this widespread role in forests, the same factors would doubtless produce even greater numbers of partially felled or tilted trees.

ANALYSIS OF SPECIFIC SITES

Examination of a specific illustration of tree curvature used to support soil creep (Sharpe, 1938, p. 27) substantiates the belief that the correlation is tenuous and that alternate causes for tree deformation are more significant. The sketch (fig. 3) is of a photograph taken in Lassen Volcanic Park, California. Here the conifers are growing in relatively loose volcanic soils, with each tree possessing a single curve occurring at a uniform height, above which the trunks are vertical. Considering the evidence, a number of causes other than soil creep are seemingly more valid: (1) While they were still saplings a sudden slump of surficial soils and root mat tipped the trees downslope, after which they righted themselves geotropically, producing a straight bole above a single bend. Similar age and height within the stand at the time of slump is suggested by the uniform position and direction of curvature. Although the circumstances are unknown, perhaps oversteepening of the slope during road construction explains the sudden slump of the inherently unstable vol-



Fig. 3. Sketch of conifers in Lassen Volcanic Park, California. Taken from photograph used by Sharpe (1938) to illustrate the effects of soil creep upon trees.

canic soils. (2) Clearing the right of way for the road, if not directly responsible for the slump, may have changed the light conditions and provided the impetus for phototropic responses and non-vertical growth of saplings growing in the shade of an overstory. (3) Also possible and highly probable at this site are unusual weather conditions, including severe ice and snow loads, or gale winds. One of these mechanical agents may have deformed the trees while still saplings.

Not only has reconnaissance of the forested slopes of the Georgia Piedmont failed to reveal tree curvature that can be definitely attributed to soil creep but the feature is also absent in specific sites where ideal conditions are apparently fulfilled (Parizek and Woodruff, 1956). For example, the 30° slope (pl. 1-B) developed by the artificial fill for a reservoir dam is composed of loose material that has been in situ for more than 80 years. The long straight boles of the mature forest attest to the stability of the soil at this locality, or to the ineffectiveness of soil creep in tree deformation.

SUMMARY

Trees curved concave downslope have long been held to indicate soil creep; but examination in the light of botanical knowledge contradicts such a correlation. Concomitant tree growth and continuously slow-creeping soil should hypothetically develop trunks with a long sweeping curve from ground to terminal bud rather than the elbow-type curve and vertical stem segments believed to manifest soil creep. The widespread occurrence of trees with the latter type of deformation can be more validly related to mechanical and physiological causes.

However, granting that a correlation may exist between deformed trees and soil creep, detailed study suggests: (1) soil creep is much less important than believed because uniformity of curvature in stands is the exception and not the rule; or, (2) if soil creep is widespread, then there must be a counteracting process or unknown soil conditions which effectively prevent the development of the properly related tree curvature.

Because tree curvature as supporting evidence of soil creep is, therefore, tenuous or at least over-emphasized, the relevancy of other displaced objects of soil creep should be tested by principles of applicable fields. The results of further investigation may require re-evaluation or redefinition of the concept of soil creep.

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