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FINE ALLUVIAL FILLS IN THE ORANGE AND VAAL BASINS OF SOUTH AFRICA

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ABSTRACT. The drainage of the upper Orange and the Vaal Rivers has been affected by active gully-cutting and soil stripping. This is attributed to overgrazing and burning which has degraded the grassveld and partly replaced it by an open shrub vegetation that provides little soil protection. Prior to this disturbance (since the 1880's) there was little geomorphic change on the interfluves, with accumulation of fine sands or silts in the larger stream valleys. This "Younger Fill" has been dissected in very recent times to form terraces at 3–8m above mean flood-level. During the late Pleistocene three units of fine alluvium (now forming terraces at +6 to +15m) were deposited in the river valleys and low country, with colluvial sheets extending over the footslopes. Although derived in part from older eolian deposits, this "Older Fill" accumulated slowly with an effective grass cover, impeded runoff and increased percolation. Reflecting climatic constrasts, the facies vary from formations rich in carbonates and eolian derivatives in the drier west, to gleyed sediments in the moister east. The intervals of downcutting preceding, interrupting and following alluviation of the Older Fill were drier, with accelerated runoff. Close analogies can be drawn with cut-and-fill cycles in the American Southwest.

The majority of the continental surfaces are mantled with a variety of non-functional surficial deposits that range from glacial till and loess mantles to lake beds and alluvial formations. From one region to another the age of such non-functional surfaces of deposition may range anywhere through the last million years or so, although the bulk of the surficial deposits preserved in most continental areas dates to the late Plesitocene, usually to the last 30 to 60 thousand years. The very fact that such formations are non-functional, and that they are of some antiquity, suggests that the majority are not related to the same environmental parameters that govern modern geomorphologic balances.

Surficial deposits are of considerable significance and interest, well beyond that of the historically-oriented geomorphologist: they form the parent material for most contemporary soils; they determine the erodibility of these soils in terms of both material and morphology; and they commonly represent the contextual medium of prehistoric man in the New and Old World. More esoteric and but no less relevant geographically is the little-realized fact that the dominant classes of surface sediments are as much an aspect of the physical environment as are climate or vegetation: they are subject to areal variation and patterning, and liable to multivariate analysis and interpretation. The distribution of tills and loess plains in North America and Eurasia is an obvious case in point. Less apparent are the patterns of surficial deposits in subtropical or tropical latitudes, or in arid to semiarid settings. In the American Southwest one of the best known prehistoric legacies is the complex of fine-grained valley fills that has been dissected by gully-cutting since the late 19th century, with disastrous results for the agricultural resource base (see Tuan, 1966; Denevan, 1967, with further references). The history of these silty floodplain deposits has been recently unravelled with the help of radiocarbon dating, with the recognition of many generations extending back over 15,000 years or more (see Haynes, 1968, with references). Little known is the fact that similar alluvial silts form extensive surfaces in other semiarid environments of the world such as South Africa, India, and parts of Australia.

The purpose of this paper is to describe and discuss the fine-grained alluvial fills of South Africa which are remarkably analogous, from several points of view, to those of Arizona and New Mexico. Surprisingly enough, these South African features have previously escaped the notice and attention of geographers, geologists, agronomists or prehistorians. Gully-cutting has been the scourge of most of the Interior Plateau of South Africa since about the turn of the century. Yet despite the concern of soil-conservationists, the close coincidence of gullying with tracts of silty alluvium has not been recognized (see, for example, Wellington, 1955; King, 1963; Molter, 1965). Furthermore, despite the study of individual occurrences from one point of view or another, conservationists, geomorphologists and prehistorians have ignored the almost universal distribution of fine alluvial fills in particular topographic situations.

DISTRIBUTION OF FINE ALLUVIAL FILLS IN SOUTH AFRICA

Fine-grained alluvial fills in South Africa are best developed in the continental interior and here primarily in drainage systems developed in rocks of the Karroo System. Temporally, the Karroo units range from late Paleozoic to early Mesozoic; lithologically, they consist of sandstones and shales, with interbedded tillites and coal measures, capping flood basalts, and intrusive dolerites; structurally, the Karroo System is relatively undisturbed, at least in the interior, where strata are usually subhorizontal and seldom faulted. The Karroo rocks erode fairly readily, providing broad plainlands with butte or mesa-form residuals commonly formed, capped or otherwise preserved by dolerites or basalts. The dominantly sandy or shaley sedimentaries provide an abundant supply of sediment for overland flow, stream transport and local eolian reworking. Other geological provinces, such as the quartzites and dolomites of the Precambrian and earlier Paleozoic, provide more limited sediment or, in the case of the late Tertiary Kalahari Sands, a surfeit.

Additional factors affecting the development of alluvial fills are relief and climate. The relief and increased gradients of the coastal ranges and uplands favor coarse-grained, gravelly to sandy alluvia, usually restricted to comparatively narrow valley systems. By contrast, the interior is dominated by Mesozoic to Tertiary planation surfaces (King, 1968; Wellington, 1955) that provide only limited relief and extensive tracts of gently-sloping land. Climate is also effective in several ways, with optimal development of fine alluvia and maximum gullying in semiarid to subhumid environments with high rainfall variability from year to year.

In practical application, fine alluvial fills are characteristic of the interior of the Cape Province, and of most of the Orange Free State. Study was essentially restricted to the upper Orange River, the lower Vaal River, and the tributary streams between the Orange and Vaal. This area displayed sufficient horizontal variability to allow the establishment of a stratigraphic framework and to recognize patterns of regional variation that must ultimately be related to climatic [1] and lithologic factors. (Fig. 1)

THE YOUNGER FILL

Within the upper Orange and the Vaal drainage, modern floodplains lie between suits of well-preserved terraces recording two major generations of fine-grained alluvial fill. The contemporary floodplain is essentially limited to broad, shallow channels of low hydraulic radius. Bed-load deposits are dominant and abundant, in the main part sands, occasionally with concentrations of pebbles or cobbles. The channels are fringed by low, sandy ramparts at 1 to 4 meters above mean low water (or stream floor); incompletely covered with vegetation, these are periodically activated during exceptional flood surges and represent bed-load deposits rather than flood-silts. Dunes, primarily barkhans, are developed downwind of some broad, sandy stretches of the Orange River, modelled by the effective northerly to north-westerly winds.

The active floodplain is generally paralleled by narrow terraces of fine sands or silts, the surface of which typically lies 3 to 8 meters above mean flood-level (Fig. 2). This relatively recent fill is well-stratified, uncemented and has not been compacted except where clays are abundant. Soil profiles are rudimentary, being limited to shallow humification and rooting; however, this dissected alluvium lies well above the level of 1-in-10-year catastrophic floods, and a mature, fringing woodland may be found on the surface. Texturally, the sediments are homogeneous at any one location, and are either comparable to or finer than modern bed-load deposits. There are longitudinal contrasts in texture and along some stretches of the Vaal, where suspended materials outweigh bed-load, clayey components become important.

Provisionally designated as the "Younger Fill," these alluvia are best represented in the major valleys; they are commonly absent in smaller tributary systems, or may be recorded by nothing more than narrow erosional benches or sloping shoulders cut into older deposits. Development is optimal along the Orange and the lower Riet Rivers, where two major substages—separated by an interval of downcutting—can be recognized over considerable distances. Elsewhere there is only one

[1] The present climate of this study area ranges from dry-subhumid to semiarid by the Thornthwaite classification, with moisture indices of 0 to -40, and little or no water surplus at any season (see Schulze, 1958).

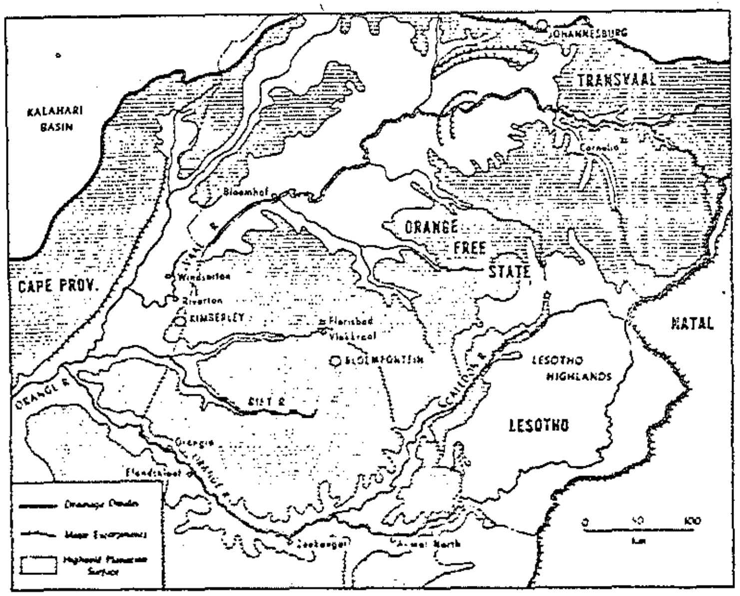

Fig. 1. The upper Orange and Vaal Basins. Highveld planation surface modified after King (1968).

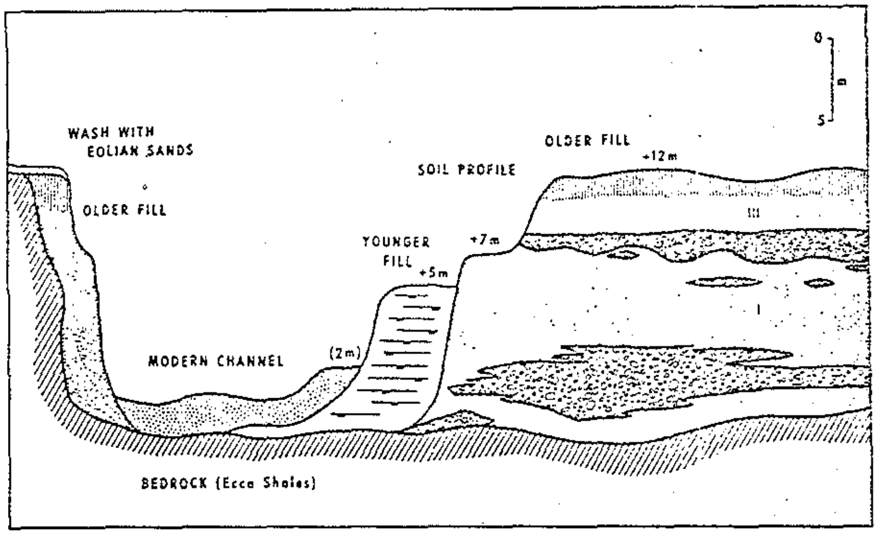

Fig. 2. Composite profile of the Younger and Older Fill terraces. No horizontal scale.

body of Younger Fill. The gradient of these terraces is not identical to that of the modern channels: it is reduced upstream of major valley constrictions, but increased downstream; in the major tributaries gradients were also reduced in the lower stream courses approaching confluences with the Orange or Vaal. So, for example, the relative elevation of the highest Younger Fill terraces fluctuates between +5.0 and +12.5m through the succession of rocky gorges and basins between Aliwal North and the Orange-Vaal confluence. In lower-order tributaries the Younger Fill terrace ultimately terminates in steep-walled, flat-floored valley heads cut into older alluvium, with micro-pediments covered by silty or clayey materials; however, headward erosion was incomplete in most tributary systems, and some fine alluviation ultimately prevailed upstream as a new steady rate was achieved. The period of dissection that preceded accumulation of the Younger Fill appear to have been brief and, as an impulse, it travelled upstream from the Orange and Vaal. Downstream alluviation may have begun before the hemicycle of downcutting was completed.

The age of the Younger Fill remains conjectural. There appear to be no materials susceptible to isotopic dating, and no primary archeological associations were found. Even waterworn stone artifacts are very rare, although equivalent beds of surface wash may contain Late Stone Age materials of post-Pleistocene age. The lack of a real soil profile suggests that accumulation was underway as recently as the 19th century; however, rock engravings in several styles—and attributed to the last several millenia (Fock, 1968 and unpublished)—are found on bedrock under the modern bed of the lower Riet River.

THE OLDER FILL

Beyond the Younger Fill terrace(s), valleys are floored by a great expanse of older alluvium, typically at 6 to 15 meters above modern flood level. This "Older Fill," as it is provisionally labelled, is compact and at times calcreted. Mature soil profiles are normal and range from humic floodplain soils to dark, clayey vertisols or oxidized soils with carbonate horizons, depending on the parent material and drainage conditions. Texture varies considerably. Massive exposures of poorly-stratified, homogeneous course silts or fine sands are typical along the former axis of major through-streams, while complicated profiles of alternating gravels, clays, marls and buried soils may be found in tributary systems.

From the air the surface of the Older Fill shows impressive traces of former floodplain features: cut-off meanders, channel bifurcations, basins or backswamps, and even some low dune forms with blow-out scars. These once poorly-drained surfaces extend laterally into every tributary valley and peripheral basin and, depending on the restriction of local gully-cutting ("*donga* erosion"), there may still be flats of poorly-drained ground. The gradient of the Older Fill terraces is also irregular, steepening rapidly below valley constrictions and flattening out above major confluences. Thus, the higher Older Fill terrace variably rises and falls between +8.5 and +16.5m along the Orange River. An additional element of importance is the channel trace, which can sometimes be reconstructed from air photos: rivers had much greater sinuosity, with intricate meander loopings where the geometry of the abbreviated modern channels is characterized by markedly reduced wave amplitude, together with increased meander wavelength and radius of curvature. Consequently the streams responsible for alluviation of the Older Fill had a rather different dynamism, with longer channels, broader floodplains, reduced longitudinal gradients, and a higher proportion of suspended sediments.

Upstream the Older Fill differs fundamentally from the Younger Fill. The alluvium not only fills out rock-cut channels but characteristically extends smoothly up the adjacent footslopes, changing facies to a relatively fine wash. In semiarid country these colluvial sheets may terminate in broad piedmont zones or pediments below residual hills; in subhumid settings they extend up gentle slopes of 2-4°, thinning from the valley bottom. Frequently such colluvial facies show a vertical gradation from a basal detritus to clayey sediments. There can be no question that aggradation was widespread on the lower parts of the interfluves, essentially coeval with alluviation downvalley.

The Older Fill comprises 2 or 3 discrete bodies of alluvium, separated by intervals of downcutting or erosion (Fig. 2). In most cases, the second generation rests directly upon the first. In other instances there may be distinct terrace bodies offset vertically by some 2 to 5 meters. The *first* generation of fill frequently has basal gravels, mainly a subangular detritus transported over limited distances, that give way to massive clayey silts, sometimes with intervening lenses of current-bedded sands. In the semiarid part of the study area, this basal unit is commonly enriched in carbonates, with zones of calcretion and root-drip or, where lime is abundant, grading into marls; in the subhumid areas, gley phenomena indicate seasonal or permanent waterlogging. The *second* generation of Older Fill is silty, clayey or marly, mainly massive with evidence of cracking dynamism and a tendency to vertisol development; carbonate or gley horizons may again be present. There is also sporadic evidence for a *third* substage, sometimes evident as a brief phase of regrading, with limited alluviation on a restricted floodplain cut out during an interval of dissection; elsewhere this third generation was marked by renewed alluviation of silts over the vertisols of the second phase of aggradation.

The Older Fill spans a long period of time judging by the vast volume of relatively fine sediment, the presence of 3 major depositional breaks, the mammalian faunas, and the prehistoric industries. The basal strata of the first generation include the mammalian faunal site of Cornelia, which has a high proportion (71%) of extinct horses, suids and bovids (Cooke, 1963, 1967). Another assemblage, that of Florisbad (Cooke, 1963), is rather more modern (31%) extinct forms) and appears to relate in part to a higher level in the first generation of the Older Fill, in part to later units. A third assemblage, from Vlakkraal, comes from either the second or third generation; it has 44% extinct forms (Cooke, 1963). Whereas the Cornelia fauna is considered as late Middle Pleistocene, the Florisbad and Vlakkraal faunas are accepted as Upper Pleistocene (Cooke, 1967). The Florisbad assemblage has C^{14} dates of "greater than 48,000" and "greater than 35,000 B.P." (L-271B), while that of Vlakkraal probably correlates with a level bracketed by dates of 28,450 and 19,350 B.P. (L-271C, 271D) at Florisbad. A last faunal assemblage, from the basal Older Fill in the Vaal River near Bloemhof, remains to be published (Mason, 1969).

Bifaces and choppers of the "Early Stone Age" (Acheulian and "Fauresmith") have been found in the basal strata of first-generation Older Fill at a good number of sites, including one or more occupation sites near Bloemhof (Mason, 1969). "Middle Stone Age" assemblages or occupation floors have been recovered from the middle and upper parts of first-generation Older Fill in the Vaal (at Riverton, Fock, unpublished) and the Orange valleys (Orangia "1," Elandskloof "13" and Zeekoegat "27" of Sampson, 1969). At and near Florisbad, where the second-generation Older Fill is best related to a peat dated 28,450 B.P. (L-271C), a significant "Middle Stone Age" assemblage comes from what appears to be the base of the third generation, as is also the case at Vlakkraal.[2] To permit a more general dating of the Older Fill, inorganic carbonates, snail shells, and carbonaceous deposits were collected from the various stratigraphic units, and have been submitted for radiocarbon dating. At present it appears that the Older Fill spans most or all of the later Pleistocene.

Accumulation of the Older Fill was preceded by a long period of erosion with some bedrock incision, so that the Older Fill normally rests on bedrock and has not been observed superimposed directly on older alluvia. Deposits of greater antiquity do occur, but they are found at higher elevations (from 15 to 55 meters above floodplain). They include high gravel terraces or conglomerates resting on broad erosional platforms, as well as widespread caliche crusts, freshwater limestones and other calcrete formations, found on the interfluves of the drier parts of the study area. Samples of the youngest of these carbonates, related to "Early Stone Age" sites, have been submitted for uranium dating and may provide a more precise lower temporal limit for the Older Fill.

INTERPRETATION OF CUT-AND-FILL CYCLES IN THE ORANGE-VAAL DRAINAGE

It would be premature to attempt interpretation of these geomorphic cycles until sediment analyses have been completed, further tests made for pollen, and a more satisfactory dating framework obtained. The train of events does, however, merit a provisional discussion. Basic to any interpretation is the close dependency of geomorphic equilibrium upon vegetation cover. The "natural" vegetation of the study area is grassveld or grass savanna (Acocks, 1953) which, in an undisturbed situation, provides excellent soil protection and slows down surface runoff and indirectly smoothes out discharge maxima. In the stream channels of even the largest tributaries, such conditions favor finer-grained sedimentation across channel beds choked in grass, reeds and sedges, and dotted by disconnected pools of water even at the end of the dry season. Situations like this, which contrast strongly with bare sand and gravel floors else-

[2] Although Florisbad and Vlakkraal are spring sites, the former can be linked to a local alluvial sequence with comparable lithostratigraphic units, while the latter can be directly tied in with the Older Fill of the Modder River.

where, have been reconstituted below a series of water-control dams. Consequently, geomorphic equilibrium, with slow accumulation of suspended sediments, is best associated with shallow, vegetated channels and a high water table even during the dry season; on the other hand, deep channels with exposed bed loads and low water tables relate closely to stream incision and headward donga erosion.[3]

The present geomorphic trend in the Orange-Vaal drainage was established during the period 1880–1930 as the grassveld was overstocked with cattle and sheep, and repeated burning accelerated the process of range deterioration (Acocks, 1953; Talbot, 1961). Over much of the area former grassland has been invaded or replaced by communities of low, succulent ("Karroo") shrubs where the soil is generally bare at the end of the dry season. Runoff is rapid and unimpeded, stripping topsoil by sheet erosion and cutting gullies wherever flow concentrates on steepening gradients. Stream discharge is marked by aperiodic flood surges that carry large quantities of sediment and mainly deposit bed-load along the major rivers; the intervening base-flow is minimal. As a result there is erosion and dissection, with rapid headward incision, everywhere except along the largest through-rivers, e.g. the Orange, Caledon and lower Vaal. The intensity of donga erosion during the present century was not paralleled during earlier periods of downcutting. Gullies are initiated in the Older Fill but rapidly cut through these alluvia and colluvia into Karroo shales below; nowhere can the Older Fill be seen to cover a comparably dissected surface.

Flowing across a low-gradient surface and separated from the ocean by repeated stretches of cataracts and waterfalls (Wellington, 1958), the upper Orange and the Vaal drainage have not been affected by changes of base level nor, for that matter, is there evidence for tectonic interference during the later Pleistocene. For these reasons the cut-and-fill cycles that predate human disturbance must be attributed to changes of effective ground cover and, indirectly, climate. At first glance the Younger Fill appears to correspond to the model of a semiarid landscape affected by headward erosion and downvalley alluviation during a period of declining rainfall (Bryan, 1941; Antevs, 1952). In detail, however, there is no evidence of contemporary gully cutting, and sediment must have been supplied by sheet wash. Since the Older Fill remained undissected until the 20th century in many tributary drainage systems, the Younger Fill represents a period of vegetation and geomorphic balance most probably representative of undisturbed conditions prior to 1880. From all appearances, accumulation of the Younger Fill was abruptly interrupted by sudden and intensive disturbance of the grassveld by the white settlers of the late 19th and early 20th centuries. In the mediterranean rainfall belt of the Cape, and possibly in the Orange-Vaal drainage,[4] there also was a notable decline of precipitation from 1892 to 1930, with a brief improvement 1901–05, and a renewed increase since the 1930's (Vorster, 1957; Hofmeyr and Schulze, 1963). Possibly it was a combination of interference and a series of dry years that upset the existing steady state, resulting in rapid downcutting, apparently between 1880 and 1930. This first adjustment completed, a new steady state with abnormally rapid and intensive denudation was established within a few decades. Soil-conservation measures remain half-hearted, and even the growing succession of concrete weirs on major rivers and earth dams in low-order drainages has barely served to check the rate of soil erosion.

In general, the Older Fill suggests long periods with slow geomorphologic change, and a highly effective vegetation. Improved moisture conditions are implied, with a more complete mat of vegetation and increased percolation, so reducing the rate of runoff and discharge, with gradual aggradation of both the footslopes and valley floors. At such times a lush grassveld, neither disturbed by man nor overgrazed by native game, must have prevailed. Periods of dissection or accretion of crude slope detritus probably marked periods of drier climate, with a correspondingly more open vegetation. Such an interpretation is strengthened by the pollen profiles from Florisbad (van Zinderen Bakker, 1957) and Aliwal North (Coetzee, 1967) which indicate repeated and significant shifts of vegetation communities between grassveld and Karroo shrub during the late Pleistocene. Interestingly, the radiocarbon dates from these

[3] See Mehringer and Haynes (1965) for an excellent description of analogous conditions in southeastern Arizona before and after gully-cutting.

[4] Unfortunately there are no climatic records from the northern Cape, the Orange Free State, or the Transvaal that predate the turn of the century. Consequently, no certain inferences can be made, nor can it be determined whether rainfall variability has increased or seasonal distribution changed, features that may simulate a decline in mean total precipitation in a grassland setting.

sites suggest that a closed vegetation was present during the cooler glacial stades, open shrub vegetation during the warmer interstadials. Although beyond the scope of this paper, widespread eolian deposition and local deflation or dune modelling were repeatedly active in drier sectors of the Orange-Vaal drainage, apparentely during periods of stream cutting. Silts and sands of eolian origin were subsequently reworked by running water, and much of the fine sediment accumulated in the Older Fill was derived from older eolian veneers on the interfluves.

The late Pleistocene to Holocene alluvial history of the upper Orange and the Vaal drainage is summarized in Table I, together with the inferred human and climatic factors. The close analogies of these cut-and-fill cycles with those of the American Southwest extends from such phenomena as recent gullying to sediment properties and morphology (see, e.g., Haynes, 1968; Tuan, 1966; Denevan, 1967; Martin and Mehringer, 1965; Wendorf *et al.*, 1961). Above all, the primary controlling factor in both areas is the alternation of closed grass cover and open shrub vegetation in a semiarid climate. Other environmental parallels include a subtropical latitudinal position in the belt of overlap between winter and summer rains. For all intents and purposes these two regions provide a good example of how environmental parameters affect geomorphology.

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TABLE I. RECENT ALLUVIAL HISTORY OF THE UPPER ORANGE AND THE VAAL DRAINAGE

GEOMORPHIC EVENTS	INFERRED FACTORS
10. Active gullying, with alluviation of major channels; local eolian activity	Continuing human disturbance with degradation of vegetation, accelerated runoff
9. Rapid dissection of Younger Fill; initiation of gully cutting	Initial, intensive human disturbance (ca. 1880–1930), coeval with dry years 1892–1930.
8. Alluviation of YOUNGER FILL (2 substages locally), downstream and midstream	Representative of pre-1880 vegetation and geomorphic balance
7. Dissection of Older Fill in major stream valleys, sheet erosion and some gullying upstream; local eolian activity; preceded or followed by long period of soil development	Relatively dry or rainfall declining; vegetation mat incomplete. Soil development coeval with moist conditions and geomorphic balance
6. Alluviation of OLDER FILL, substage 3. Includes abundant, derived eolian sands or silts; brief and localized	Relatively moist, with improved ground cover
5. Limited dissection of larger valleys; local eolian activity	Relatively dry, with reduced ground cover
4. Alluviation of OLDER FILL, substage 2. Slow accumulation of floodplain mucks, vertisols	Moist, with optimal ground cover
3. Limited dissection of larger valleys	Relatively dry, reduced ground cover
2. Alluviation of OLDER FILL, substage 1. Basal detritus grading up into massive, fine-grained sediments with derived eolian silt; extend from valleys onto footslopes	Relatively moist, with increasing or fluctuating ground cover
1. Prolonged dissection and general denudation; local eolian activity	In part, relatively dry with reduced ground cover
Various older gravels, calcretes, and freshwater limestones, in part with Lower to Middle Pleistocene faunas	

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