THE CORRELATION OF WEATHERED TRANSPORTED SOILS

Chas. F. Shaw
Professor of Soil Technology
University of California.

At the meeting of this Association a year ago, a question was asked regarding the correlation of bottom land soils which had been reclaimed and protected from overflow by the construction of levees; the question indicating the possible feeling that such soils being no longer subject to periodic inundation, should conceivably be classed in a different soil province as "terrace" soils. In our western surveys we have to do a great deal of work on transported soils. In fact by far the major part of the soils possible of agricultural development lying west of the Great Plains are made up of soils that have been transported by wind or water. In California over 75 per cent of the arable land of the state has been covered by detailed or reconnaissance surveys. Of the 25,700,000 acres on which the measurements of the soil areas have been completed and tabulated, we find that about 5 million acres are classed as non-agricultural (rough mountainous land, riverwash, etc.), about 4 million acres are residual soils, over 300,000 acres are peat and muck, and over 15 million acres are transported soils. Of the latter, about 6,600,000 acres are "Recent Alluvial", over 500,000 acres are "Aeolian" or wind-transported soils, about 800,000 acres are "Lacustrine" or lake-laid soils and over 7 million acres are "Old Transported" or "Old Valley-filling" soils, these latter being comparable to the "Terrace" soils of the east. In other western states the relative importance of the transported soils would be about the same as in California.

In the strictly arid portions of the country much of the transported soils consist of alluvial fan deposits. The alluvial fans are great aerial deltas built by streams having an intermittent or greatly fluctuating annual flow. They consist of a mass of water-borne materials of a typical fan or cone shape with the apex at the mouth of the canyon through which the stream emerges from the mountains, spreading out from this point with a decreasing gradient out towards the center of the valley. The individual alluvial fans built out from the many canyons, coalesce to form great slopes of deep alluvial material. Each year the streams that form these fans overflow their channels and carry out their annual load of sediment which is spread over the fan through the many distributaries and added to the increment of the previous years. On the upper parts of the fan, the soils are coarse and stony. The intermediate slopes are sandy, while the lower, flatter slopes are heavy in texture. Usually the fans from the different sides of the valley lead out to a central basin where the heaviest clays are deposited under semi-lacustrine conditions.

When for any reason there is a change in the regional drainage systems brought about usually by changes in the elevation which would increase the gradient of the land, the streams that have previously built up the alluvial fans begin to cut through these deposits eroding them and carrying the new load of material out to be spread on a new lower fan farther out towards the center of the valley. In some cases we can find two or more generations of alluvial fans showing the occurrence of successive uplifts or tilting of the mountain blocks that border the valleys. This change in drainage conditions is responsible for certain marked changes in the character of the soil. The alluvial material that previously had been under a condition comparable to that of an

eastern river bottom with periodic overflow and addition of sediment now becomes a region subject to erosion and to the attacks of the weathering agents. In my discussion of the changes in the soil section brought about by these agencies, I will ignore for the present the modifications brought about by erosion and will consider only the changes that occur in the soil which remains in place.

Under conditions of heavy rainfall or under normal humid conditions, these soils would go through a continuous process of leaching with the result that the readily soluble bases, particularly lime, would soon be removed from the surface soil and carried deep down into the soil mass or possibly through to the ground water and out through the underground drainage systems. Under conditions of lower rainfall, the lime would be carried from the surface soil down to the subsoil or substratum where it would be more or less concentrated as a lime bearing or calcareous layer. The lime might accumulate as nodules or small concretions, or as seams, lenses, plates or layers of calcareous material. At the same time that the lime and other soluble materials was being removed from the soil by leaching, there would be a progressive development of clay particles due to the weathering of feldspars and other hydrous aluminum silicates with a migration of this clay into the subsoil. This clay migration is quite evident in any of the older soils, either transported or residual. The heavy subsoils that are characteristic of nearly all of our residual soil series are due to a considerable extent to migration of the clay. The heavy and sometimes nearly impervious subsoils of the soil series derived from glacial till are due in a very large measure to the downward movement of the fine clay particles and their accumulation in the subsoil. The same thing is true of soils that were originally transported and deposited by water or by wind. The heavy subsoils that are characteristic of most of the series in the Atlantic and Gulf Coastal Plains are due in a large measure to the downward migration of the clay resulting from the weathering and leaching of these water deposited materials.

It is easy to recognize these evidences of progressive weathering when the changes that have taken place are so striking and so complete. In our western work we frequently encounter soils which have been weathered for a relatively short time or which have been weathered under conditions of such restricted rainfall that the result is not at all pronounced and the age, as evidenced by degree of weathering, can only be determined by careful study. Under strictly desert conditions where the occasional rainfall is usually accompanied by deposition due to the flow of water over the alluvial fan, there is little or no leaching taking place and the Recent soils contain lime in the surface layers. If, however, the rainfall is somewhat higher or the volume of water spread over the fan appreciably great, the lime is leached from the surface soil and hence the presence or absence of lime in the surface is not a safe indicator of the relative age of the soil. The presence of lime in the subsoils or at any zone or horizon a short distance below the surface, is an indication of at least the beginning of soil weathering, the beginning of early maturity of the soil mass.

The migration of the clay begins very early in the weathering of the soil mass. The colloids that are formed during the times when the soil is wet, are carried down through the interstices of the soil, and accumulate in a definite subsoil zone. This accumulation is evidenced first by a slight compacting of the subsoil layer which when dry may become hard and difficult to cut with the auger, but which will soften up and be readily penetrated when wet. The soils also show a tendency toward stickiness, and usually there is a sufficient accumu-

lation of lime to give a slight effervescence when tested with weak hydrochloric acid.

As the accumulation in the subsoil continues there is developed a rather characteristic jointed structure, with cracks and lines of weakness quite similar to the columnar structure developed in basaltic rocks. This structure may exist at any degree of intensity from that of a very slight development with some indications of parallel cracking to cases where the subsoil is decidedly dense, cracked into more or less regular columns and jointed in a very regular manner. The zone of jointing is usually quite distinct from the soil above and from the deeper subsoils below. This is due to its progressive development, for as the downward migrating clay accumulates in the pores in the subsoil zone, it decreases the possibility of colloids passing through and consequently tends to concentrate the deposition in the upper parts of the zone, making it markedly heavier and more compact.

In those soils which contain considerable quantities of readily soluble silica and iron, the progressive weathering which accompanies the formation and migration of the clay, will also develop considerable quantities of iron and silica compounds which may be either in a completely dissolved condition or may exist as colloids. These materials will be carried into the subsoil zone and there precipitated, making the subsoils more and more compact and impervious until in time they become so thoroughly cemented that water or roots can no longer penetrate them. This accumulation of iron and silica cementing materials in a subsoil zone gives us our "red iron-hardpans" that are characteristic of a considerable area of the soils of the state, over two million acres having already been mapped. The hardpans vary in depth below the surface, this apparently being determined by the depth of penetration of water during formation and by the amount of subsequent erosion. They also vary in thickness and in hardness, these features being apparently related to the relative age of the soil mass. The hardpan layers are hardest on the upper or top portions, and the iron and silica may continue to accumulate on the top of the cemented zone to the extent of forming a thin, very hard layer of hardpan closely resembling an iron bearing sandstone rock or even as thin plates of impure hematite.

In our work in California we have encountered soils in all these stages of weathering. For instance, our recent alluvial soils from granitic rocks may fall into the following general succession of series. The newest and rawest washes where the soil has had little opportunity of weathering generally have a light gray color and have been classified as the Tujunga Series. Where this material is spread over a broad fan on which vegetation grows each year, and some alteration of the soil grains may take place, but where there is no evidence of any changes in the subsoils or any real evidence of weathering, it develops a brown color and other changes in character and is classed as the Hanford Series. There are other series in this succession, the Foster and Chino, whose differences, being due to differences in drainage conditions, I will not discuss.

On the valley margins above the present fans of Tujunga and Hanford soils, we find the terraces and benches that have been formed of the same kind of granitic material, and with definite evidence that it was laid down in the same manner as the lower and younger fans. An elevation or tilting of the mountain block or the over-building of the fan with subsequent off-slipping of the water courses, caused the parent stream to abandon the deposit it was building up, and to start active erosion and destruction of these fans. The benches and terraces are the small remnants of the former extensive alluvial slope.

Where material, that was originally comparable in every way to that which forms the Hanford Series is weathered for a period certain changes in character and structure occur. The soils develop a richer brown color, often with a slightly reddish tint when wet. The subsoils become more compact, develop a heavier texture, a somewhat jointed structure and show a tendency to become sticky when wet. These changes are sufficient to materially affect the water-relations of the soil, and to modify crop adaptations, and irrigation and tillage practices. We recognize these changes as sufficient to warrant a series distinction, and have recognized these slightly weathered soils as the Ramona Series.

Where a longer period of weathering, or a greater intensity of weathering activity has taken place, we find that the soil has suffered further changes in character. The color becomes reddish brown with a marked redness when wet, and a tendency to bake together in harder lumps when dry. The subsoil becomes much heavier and shows a definite jointed and columnar structure. When dry it is very compact and hard, while when wet it is quite sticky, becomes softer and can be readily penetrated with the soil auger. This condition we have recognized as the Placentia Series.

When weathering of the same class of material has progressed to the stage of cementation instead of compaction of the subsoil, a real hardpan is present. This hardpan is practically impenetrable to the auger or to water or roots, and these hardpan soils are recognized as San Joaquin, Madera, Redding or Alamo Series, depending on color, character of substratum and other related features.

Where the weathering has progressed to a considerable extent, it is not difficult to distinguish these different soil series. Where erosion has been active since the parent stream abandoned the deposit, it is not at all difficult to recognize the older soils, their age being readily evidenced by the irregular rolling, hummocky or terrace-like topography. Our great difficulty occurs when we find a region in which erosion has not been active, a region which has a topography indicative of youth with smooth, regular slopes, uniform in surface configuration. In such places we must depend for our evidence entirely on the soil section, and must, through many borings and careful examination of the subsoil, determine whether or not there has been an appreciable migration downward of clay with or without a concentration of lime and the compacting and possible cementing that accompanies continued weathering.

In answering the question which was raised a year ago, I would then say that leveeing a river bottom would not immediately change or alter the soil and consequently would not warrant its being put into a new group, as, for instance, moving it from the bottom lands to the terrace group. The action of the weathering agents is very slow and it is hardly possible that material changes could be produced during a normal lifetime. Undoubtedly, such protection from overflow will ultimately induce changes in the soil character that would warrant a future change in correlation. Such changes should be made only when the character of the soil section and particularly the subsoil is such as to definitely indicate a change in the soil condition and the separation should be based not on the purely artificial and accidental point of protection from overflow by human interference, but on a progressive development of new conditions within the mass of the soil itself.