ANTHROPOLOGICAL RECORDS

17:3

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UNIVERSITY OF CALIFORNIA PRESS
BERKELEY AND LOS ANGELES
1963

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ANTHROPOLOGICAL RECORDS
Vol. 17, No. 3

UNIVERSITY OF CALIFORNIA PUBLICATIONS

ANTHROPOLOGICAL RECORDS

Editors (Berkeley): J. H. Rowe, J. D. Clark, D. H. Hymes

Volume 17, No. 3, pp. 281-334, 16 figures in text

Submitted by editors April 24, 1962
Issued March 15, 1963
Price, $1.50

University of California Press
Berkeley and Los Angeles
California

Cambridge University Press
London, England

Manufactured in the United States of America

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EROSION MORPHOLOGY AND OCCUPATION HISTORY IN WESTERN MEXICO

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I. INTRODUCTION

Some years ago I discussed erosion patterns in Central Mexico as indicators of the past history of populations inhabiting an area and the intensity with which they used the land (1949 a, b). This purely qualitative field approach proved suitable for the indirect evaluation of prehistoric and protohistoric ecology and demography. Thus, in a study of the Teotlalpan region of southern Hidalgo, it was possible to establish a three-cycle erosion pattern with superposed soil profiles. This pattern in turn could be associated with three principal occupations, or cultures: that centering around Tula several centuries before the conquest, the Otomi-Aztec dominion of the fifteenth and early sixteenth centuries, and the Spanish-Mexican occupation extending to the present. It was also possible in other areas to segregate clearly the land alteration caused by the introduction of European cattle and agriculture from the soil destruction, and partial recovery, associated with the huge populations and advanced cultures which preceded the Spanish conquest.

It now appears that other modes of attack upon the same basic problem are feasible, modes of attack diverging widely from the more conventional archaeological approach which rests essentially upon rigorous analysis of mortuary and cultural remains, as well as upon an intricate stratigraphy in the field. The methods here explored embrace a combination of observation of soils in the field with physical and chemical analysis of adequate sample series in the laboratory.

Field observation will include the inspection of the depth and appearance of the topsoil as it is exposed by stream cutting, excavating, and road construction. The depth of the topsoil, set against the background of the profiles which have developed normally in the same region, is an indicator of the presence or absence of man and to a great extent of the intensity of his activities. Analysis of the soil constituents, either in a surface series or a profile in depth, brings to light anomalies of distribution, which in turn may furnish clues to past events and conditions. The results of both field and laboratory tests may be evaluated in the light of facts derived from formal archaeological study, if there are any such facts, or in their absence may serve as guideposts for more intensive archaeological investigation.

Field descriptions and sample analyses are developed and carried out by conventional techniques borrowed from soil science and agriculture and may be reduced to a few very simple procedures available to any biological laboratory. Since the purpose is primarily comparative and descriptive there need be no attempt to study mechanisms of soil formation and weathering, or to consider the structure and chemistry of the soil as a medium for the growth of plants or the support of animals. In other words the examination of soil features is a means to an end, not an end in itself.

In a certain locality some particular field or laboratory method may be deemed appropriate, at other places a combination may be possible. Each area of historical or archaeological interest thus constitutes an individual problem, although certain basic principles of soil formation and destruction apply to all of them. This monograph, therefore, consists of a series of more or less distinct studies, or essays, each dealing with a different subject, and each approached from a somewhat different point of view.

Subsequent to the introduction, the first section recapitulates briefly the general theory of land use and soil erosion dynamics as it applies to the study of past cultures and populations at large, but with particular reference to conditions as they appear to have existed in central and western Mexico. Nothing new is brought out here but the guide lines are established for application to specific situations. The next section states briefly some of the field and analytical methods which have been found suitable.

The section numbered IV then explores the problem of whether it is possible to employ topsoil depths along a linear transect (or any other spatial pattern) as a means of distinguishing those local areas which may have been subjected to more than average intensity of occupation. If such localities can be thus detected in the first instance, then other historical and archaeological methods can be brought to bear in order to confirm and extend the initial findings.

Section V tests the hypothesis that laboratory analysis of adequate profile sample series taken from a well-recognized habitation site can provide information consistent with that already obtained or easily obtainable by conventional excavation and descriptive

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The author wishes to acknowledge with thanks the financial assistance provided for field work by grants from the Associates in Tropical Biogeography, University of California, Berkeley, and for laboratory analysis by Grant No. G-16112 from the National Science Foundation. He is also deeply grateful to Professor Clement Meighan, Department of Anthropology, University of California at Los Angeles for the series of column samples taken during his excavations at Amapa, Nayarit.

analysis of cultural remains. If this hypothesis is valid then it might become possible to utilize soil data at known or suspected sites where the application of other methods was not desirable or feasible. In the present instance most of the samples were taken by Dr. Clement Meighan in the course of an extensive investigation.

Sections VI, VII, and VIII select three areas without reference to local, detailed archaeology. The first, quite restricted, is south of Actopan in southern Hidalgo, the second and third, both of considerable territorial extent, center respectively around the cities of Tepic, in Nayarit, and Guadalajara, in Jalisco. The purpose was to examine the terrain intensively with respect to the erosion morphology, including not only topsoil depths, but also gullying, sheet erosion, alluviation, buried profiles, and visible evidence of recovery from previous denudation. In spots which appeared to have critical value, both surface and profile samples were taken, brought back to Berkeley, and analyzed for a few significant components. The two groups of data were then considered in their mutual relationship. Over most of these regions there is little if any valid archaeological evidence available, or at least known to me, although there is a good deal of historical information extending back to the Spanish conquest. Where such evidence is extant it has been used to supplement the soil data, as at Ixtetepe near Guadalajara, and of course the presence of potsherds or other artifacts is always a valuable guide to former human occupation. Nevertheless the primary aim of the survey of large areas has been to test the value of soil data, as such, in detecting and assessing the extent of human occupation.

This work is, as it always will be, unfinished. Certain omissions will occur to any archaeologist, such as chemical examination of soil for phosphate and the trace elements. With regard to these, work is still going on and the omission is deliberate. The soil scientists will want a far more sophisticated treatment of the soils in the laboratory. This is needed but is for the future.

II. EROSION MORPHOLOGY AND ITS INTERPRETATION IN CENTRAL AND WESTERN MEXICO

The Central Mexican plateau and adjacent escarpments constitute a unique area for the study of changes in land surface induced by human occupation. Nowhere else in North America, and rarely in other parts of the world, do such a variety of conditions exist within such a small territorial compass. The substratum includes many types of volcanic and sedimentary rock, from recent lava flows to ancient granites. The altitude ranges from sea level to well over 15,000 feet. The climate shows all gradations from humid tropical coast to practically rainless desert. The soils embrace nearly every type known to pedology. Human occupation on an advanced cultural level has existed at some points for fully three millenia, at other points only for approximately four centuries, and at other points scarcely at all. It is not surprising that the interaction between man and his environment has here produced a series of soil responses and allied phenomena which are bewildering in their complexity.

FACTORS IN EROSION PATTERNS

The pattern imposed upon a land surface by erosion is determined initially by the nature of the underlying rock, or, in terms of soil formation, the parent material. By this is meant the raw stuff, which through the influence of external factors becomes converted by weathering into soil. The great diversity of these materials in Mexico precludes any attempt to describe soil types in detail but there are two general categories which are outstandingly conspicuous, extensive, and representative.

The first of these is a soil rich in organic matter which at maturity forms a deep black surface horizon. One to several feet under the surface there is commonly generated a heavy hardpan, which, when denuded of the overlying material and dried out, assumes the consistency of soft rock and is called "caliche" or "tepetate." Such a hardpan may be formed over a limestone in a rendzina type soil, or may appear under a prairie soil, a desert soil, or a chernozem. Caliches are found predominantly in regions characterized by moderate or low rainfall. The second type consists of a pink, light red, or brick-red profile of great thickness, with little or no hardpan development, the properties of which resemble those of the classical terra rossa, or latosol. At maturity there is formation of recognizable dark and light brown "A" and "B" horizons over a bright red "C" horizon which may extend many feet and grade into partially weathered and then into unweathered bedrock. The latter is frequently basalt of volcanic origin but may be sedimentary rock of various sorts. Since we are not dealing necessarily with terra rossa or latosols as technically defined, the noncommittal expression "red earth" may be used to indicate this class of soil. The first category mentioned is encountered widely, for example, in the Teotlalpan of Hidalgo, the Valley of Mexico, central Puebla, the Mixteca Alta in Oaxaca, and throughout Queretaro, Guanajuato, Zacatecas, and San Luis Potosi. The second is more restricted in occurrence, but is seen well developed west of Morelia, Michoacan, near Yanhuitlan, Oaxaca, and in central Nayarit.

When these two soil types are exposed to the action of running water the former tends to exhibit sheet erosion, or slope wash, whereas the latter produces highly dissected gullying. From the standpoint of erosion morphology, therefore, the constitution of the parent material here is of less significance than the physical consistency of the soil developed, that is whether there is a hardpan produced or a deeply weathered, soft, clayey, red earth.

Secondary only to parent material is climate. The mean annual temperature is an index to both the rate of weathering and the density of vegetation. The rate of weathering is important particularly in the reconstruction of devastated soils, and recovery may be many times more rapid in the hot country, such as the piedmont of the escarpment, or the coastal plains, than in the *tierra fria* of the high plateau itself. The density of vegetation, to be sure, is determined by moisture as well as temperature, but given comparable rainfall, the hotter countries tend to show a more rapidly growing vegetation, with plants closer together, than do the colder areas. The effect of greater density is twofold: recovery of denuded soil, with humus formation,is much accelerated, and the visible surface destruction caused by previous erosion is rapidly blanketed and rendered difficult of observation.

Moisture exerts much the same influence as temperature. The higher the rainfall the more rapid is weathering and the denser is the plant cover. Consequently all soil processes are accentuated and the traces of former land destruction are quickly concealed. It is probably for these reasons that the marks of ancient erosion are so clear in the highlands and so nearly absent on the coasts.

THE PROCESS OF EROSION AND RECOVERY

In turning to the erosion process itself, it should be reiterated at the outset that we are not dealing with *geological* erosion, which continues under all conditions at a relatively slow rate, but with *human* erosion, which appears only at the site of human intervention with soils and which may become extremely rapid. It is true that in some parts of the world one must be on the lookout for short-term effects of nonhuman origin. Thus sudden and drastic climatic changes, especially in marginal areas, have been known to induce changes in the rapidity of degradation and aggradation which simulate the influence of human culture. However, in Mexico and the Pacific Coast generally, it is doubtful whether there have occurred within the past millenium any climatic shifts of sufficient magnitude to interfere with the evaluation of soil conditions produced by man.

The first step must always be the removal of the natural plant cover and the exposure of the naked soil to the action of water falling as rain. Such exposure usually occurs in conjunction with one or more of four well-recognized cultural activities: (1) clearing for habitation and dwelling construction; (2) clearing, or burning, and ploughing for the planting of crops; (3) cutting or burning of forests; (4) ranging of livestock. When such an event takes place in virgin territory we have the inception of a primary erosion cycle.

An uncomplicated primary cycle is characterized by four aspects or stages. The first is removal of natural cover, as pointed out above. The second is degradation, the third aggradation, the fourth recovery. The second and third are simultaneous in time, preceded by the first and followed by the fourth.

It is frequently, but by no means always, possible to identify the process whereby ancient erosion was initiated. A good deal depends upon the length of time which has subsequently elapsed. In Central Mexico certain areas may demonstrate erosion which on historical, documentary, or other grounds surely antedates the Spanish conquest—thus precluding livestock as an agent. The general nature of the vegetation and the terrain, plus archaeological evidence, then, will furnish clues to the originating process. In the valleys, grass or brush is likely to have been cleared for the building of villages and the planting of crops. In the high mountains, forests may have been destroyed for timber, charcoal, or other products, with no subsequent attempt to cultivate the land. Still other areas have been subjected to damage only within recent centuries, and here the active agent has frequently been livestock, although agriculture (corn, bananas, sugar cane, citrus fruit), lumbering, burning, and urban construction have been universal contemporary causes of erosion.

Degradation takes two forms. In the first, running water cuts a channel through the soft upper layers of the soil and forms a valley, or trough. Such a channel is known variously to students in different fields of knowledge, and in different parts of the world. In the United States it is customarily referred to as a gully. In Latin America it is known widely as an arroyo. Either term will be used here, and restricted technical definitions will be ignored.

The form of the cross section of a gully depends upon the physical structure of the terrain, the force and volume of the water, and the age of the channel. In soft ground, water cuts rapidly down and more slowly laterally, giving the cross section a V-shape, with sloping sides and a very narrow floor, or bottom. Underneath a hardpan, or other stratum of tough consistency, the sides tend to be perpendicular and the bottom wide and flat. Thus the cross section is almost rectangular. A similar rectangular form is produced in desert regions when powerful currents following very heavy rain cut their way with great force through silts, sands, or gravels which are easily washed away. Kirk Bryan (1925) would limit the term arroyo to this type of wash, a type frequently seen in northern Mexico and the southwestern United States. When a gully becomes mature and is no longer being actively incised, the floor may fill with debris and the banks may tend to slump or to be washed downward. There results a U-shaped cross section, or often a condition in which the tops of the U are bent outward so as to produce a reversed curve like the cross section of bowl. Such a figure is almost invariably evidence of senescence and recovery in a gully.

The soil profile exposed to view by the cutting of an arroyo depends in detail upon the condition of the area. If it is untouched territory and has suffered no damage, a section through the new arroyo will show the normal profile, with the A, B, and C horizons in position. If the area has been subjected to serious wear prior to the cutting of the gully, as frequently happens toward the active heads of old or mature arroyos, then the A or B or both horizons may be lacking. In extreme instances the arroyo may reach and even cut deeply into the bedrock, depending upon the consistency and organization of the latter (see figs. 1-3).

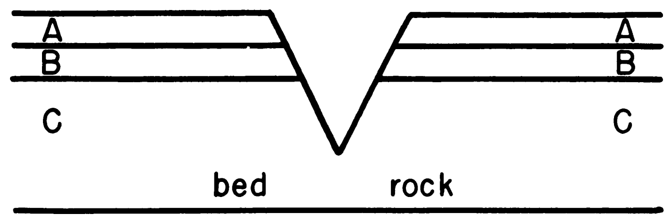


Figure 1.

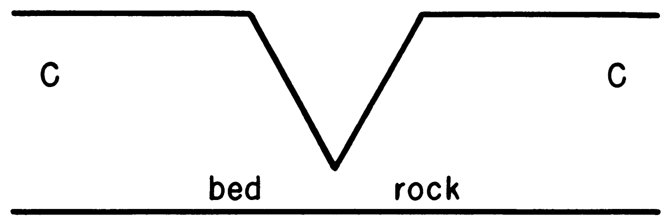


Figure 2.

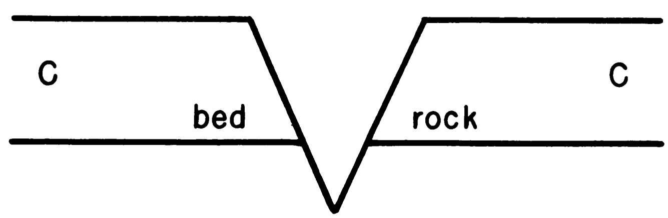


Figure 3.

Since the gradient tends to steepen toward the upper end of a gully we find that it normally grows by extending its length backward, or headward. Thus the oldest portion is toward the foot, the youngest toward the head. Occasionally cutting may have ceased entirely at the foot while the head is still actively extending. A very fine example of this phenomenon may be found on the open, grassy plains in the northern part of the Toluca Valley.

Arroyos are disposed to branch. Lateral streams cut channels into the main gully. The active heads fork and split. Eventually a highly ramified system results, and when the original, or parent arroyos are numerous and close together the final result may be an extraordinarily dissected badland, such as dismays the traveler at Yanhuitlan or Tzintzuntzan.

It has been suggested that arroyo formation is most highly developed on soft soils where local unevenness conduces to effective concentration of water volume and rapid deepening of its channels. In central and western Mexico this process is best observed in the red earth areas. Where the soil is underlain either by horizontal strata of solid rock such as limestone, sandstone, or shale, or more often by a thick hardpan or caliche, gullying is certainly present. It occurs locally on a small scale while the soft, mature, virgin soil is being destroyed, and generally on a large scale when prolonged exposure to erosion has permitted channels to be excavated in weak spots in the native rock or the caliche. Here deep barrancas are found which may be of great age but which rarely present a high degree of ramification or digitation.

Where the subsoil structure is resistant the second type of erosion is the more conspicuous and destructive. This is sheet erosion, or slope wash, as it may be more familiarly termed. The water, instead of being confined to separate channels, moves in a layer, or sheet down the hill. The surface remains relatively smooth, but the soil is carried away in successive increments. The effect is first the removal of the A horizon, followed by the B and the C horizons, and if the process continues long enough all the loose material is displaced, and the hard, underlying structure is laid bare. Spectacular examples of ruin by sheet erosion are the dazzling white stretches of tepetate to be seen from the air over northern Oaxaca and southern Puebla.

There are many modifications of sheet erosion. If the effect is relatively mild only the topsoil may be removed, leaving perhaps a truncated B or C horizon which is still capable of supporting agriculture. If the parent material consists of hard rock the finer particles may be washed out leaving behind the larger, unweathered rock fragments to form a layer, often many inches deep on the surface. Such a layer may be called a "rock mantle" and is found widely along the west coast from Colima to Sonora.

The clay, sand, and gravel which is carried from its position by moving water during degradation of the hill slopes must eventually come to rest in the lowlands, the plains, and valleys. The latter thus undergo aggradation. The morphology of aggradation depends upon the volume and distribution of the water in which the material is suspended. In a small arroyo the soil brought down from the head may be deposited at the foot. A creek or a river spreads its load over its bed or its flood plain. With light precipitation and moderate stream volume, watercourses all aggrade the area close to their normal bed. With heavy rainfall, however, these streams may flood and deposit relatively large sheets of soil far into the surrounding country. Indeed in the arid regions of central and northern Mexico it is the heavy floods which cause the important changes, the great alluvial deposits which now cover so many of the river basins and former lake beds.

A special case is presented by sheet erosion. The displaced soil is not channelized and carried long distances, but is moved only to the foot of the slope from which it originated. Here it accumulates as a deposit, the long axis of which runs parallel to the contours of the slope above. With a simple hillside merging into a plain a section across the slope would be as represented in figure 4. When two slopes meet to form a valley the latter receives soil from both and may become filled so as to present a level surface (figure 5).

Following exposure and active erosion, processes of recovery become established which characterize the fourth aspect of the cycle and which tend ultimately to restore the land to its original state. As a matter of fact we are dealing with relative rates. During phases two and three destruction is outrunning recovery, although the tendency to recover is always present and may even assert itself locally while destruction is continuing over the area at large. If, however, the initiating factors—habitation, ploughing, forest removal, or grazing—are at any time suspended, then recovery proceeds more rapidly than further denudation and if permitted to do so continues to completion.

Recovery assumes many forms, some of which are susceptible to direct observation in the field. First and most important is weathering. Weathering occurs on slopes which have been stripped of topsoil and there subsoil, or even bedrock, are exposed to the air. It also proceeds on alluvial deposits of all kinds, for the latter consist of detritus in which there is predominantly random chemical and physical organization. In cool, dry climates weathering is a very slow process indeed; in the hot and humid tropics it is accomplished with great rapidity. The zone of alteration is at first extremely thin, then thicker, and finally becomes differentiated into true soil horizons. In the meantime translocation and accumulation of solutes may result in the new formation of hardpans. The presence of any degree of weathering on denuded or alluvial surfaces may therefore always be taken to indicate a substantial period of quiescence, or absence of the factors which conduce to erosion.

A second manifestation of recovery is the filling in, or healing, of arroyos formed during the degradation phase. It has been pointed out that a young, active gully may be V-shaped, or sharply rectangular in cross section, whereas in maturity or senescence the section assumes a curved, or shallow bowl shape, owing to the washing in of the banks and filling of the floor. The latter condition consequently may be regarded as prima facie evidence that the constructive processes are surpassing the destructive.

A third factor, which is associated with recovery, although not necessarily a part of it, is the recrudescence of vegetation. A new cover of grass, or shrubs, or perhaps forest on wasted land facilitates repair in two ways: it binds the loose earth and prevents further

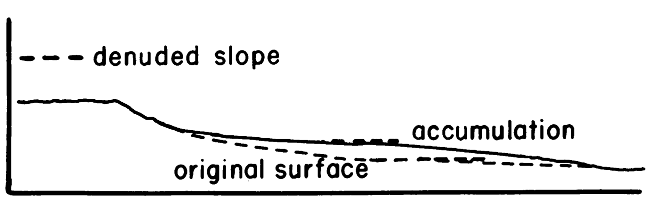


Figure 4.

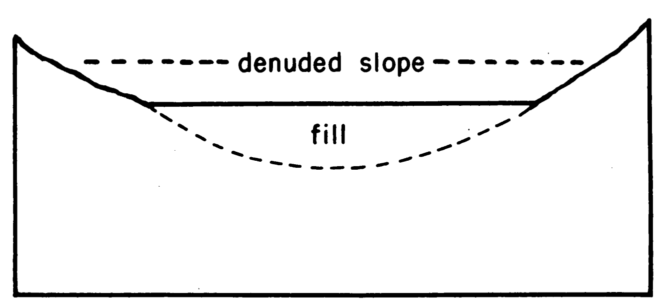


Figure 5.

loss from water flow, and it provides a source of organic matter, a necessity in the formation of new soil.

The time element in the erosion cycle is of great importance, but unfortunately is extremely difficult to evaluate quantitatively. The initial impetus is likely to be sudden, the clearing and exposure of the land. Nevertheless, if the causal agent is livestock, exposure may be relatively slow and uneven, taking decades indeed to become of significance. Degradation and aggradation may proceed slowly, with steady wearing away of cultivated lands and increasing size and complexity of arroyos. Simultaneously the soil which has been washed out will accumulate elsewhere layer by layer. On the other hand, areas are well known, especially in arid climates, where catastrophic storms and floods have induced more destruction in a few hours than was caused by normal weather conditions throughout many years. There are no fixed rules governing rates of erosion and no empirical formulas. An assessment must always be made in the individual instance, based upon all known contributing facts.

Recovery is normally much slower than destruction; centuries or perhaps millenia are consumed in the complete reconstitution of mature soil profiles. Depending upon mean rainfall and temperature, weathering of raw rock or mixed alluvium may proceed at rates varying from imperceptible to a few inches per century. In central Mexico, at least, the existence of a new, substantial, weathered zone is evidence of the lapse of considerable time. Differentiation into horizons, or the presence of incipient hardpans, requires a minimum of several centuries.

Vegetation is often helpful as an indicator. Its entire absence in an area where prolific growth is possible denotes little or no recovery. Rather it demonstrates that active erosion is still in progress. A fair-to-dense cover on washed slopes, on young alluvial deposits, in healing arroyos, and the like is evidence of a time interval sufficient to establish that cover. The minimum interval naturally depends for its value upon the type of vegetation. A growth of thin grass requires only a few years, a thick sod may mean from several to many decades. In temperate regions a young-to-mature forest needs from fifty to two hundred years for its establishment. The rain forest of the lower plateau escarpments, however, renews itself within the memory of a single man. A case of special interest is that in which a large tree of great age is found growing in the bed of a stream. Since the bed had to be in existence prior to the sprouting of the seed, the stream must have been in its present location at least as many years as the tree is old. The soils through which the stream has cut must, therefore, be still older.

DOCUMENTARY REFERENCES TO LAND CONDITIONS, AND THE PRESENCE OF ARTIFACTS

As a further point with regard to time it may be mentioned that occasionally direct references to land conditions are to be found in documentary sources. Where such occur they are of the utmost value, provided the source is reliable. Not only is the history of a local area established, but also such an area, once known in detail, can be cross-checked with other areas and knowledge of the latter thus indirectly obtained.

For the purpose of associating land changes with the presence and disappearance of extinct populations the occurrence and location of human residues are of the greatest significance. Such residues almost invariably take the form of relatively imperishable detritus or artifacts, of which in central Mexico the most frequent are obsidian chips and potsherds. Occasionally fragments of animal bone or of charcoal may also appear. However these substances must be unequivocally attributed to the activity of man in order to be of use. We must also except from consideration most ceremonial structures and burials, since these rarely bear a significant relation to the phenomena of erosion. What we are really preoccupied with, consequently, is the rubbish, the day-to-day accumulation of debris which is the inevitable sequel to human living. This debris is cast at random over the scene of habitation and there becomes part of the soil itself.

The refuse first accumulates on the surface. Much of it may remain <u>in situ</u> indefinitely, as the surrounding finer soil is washed away. Hence the presence of appreciable quantities of such material on an eroded surface is immediate proof of occupation and destruction of the area by man. The cultural affiliations of the artifacts are direct clues to the period of active occupation, for deposits of this type may remain for a very long time without removal.

Artifacts on an eroded surface also may be an indication of population density. In a general way, the higher the density of potsherds or obsidian, the greater the number of people who contributed the refuse. The sites of religious centers, villages, or even cities are thus detectable. Furthermore it is an empirical postulate of real validity that where heavy artifact accumulations occur one is likely to find at least the scars of ultrasevere erosion. The converse is frequently but by no means always true. Extreme sheet erosion or a highly dissected arroyo system, is always to be regarded as a possible site of ancient human activity, but they do not necessarily yield high densities of artifacts, and the intensity of habitation cannot be expressed numerically as a function of refuse distribution. On the other hand, the presence of any artifacts at all bespeaks some degree of occupation.

Many pieces of refuse, once thrown upon the surface of the ground, do not, as assumed above, remain in place while the dirt and gravel is washed away around them. Numerous fragments are carried off by the flow of water, like any other small pieces of rock, and are dropped in the stream beds and valleys. They may then be exposed and observed when for any reason the alluvium is opened up. The discovery of such artifacts in water-borne deposits is of primary value in dating human habitation, for two conclusions are immediately warranted: (1) Man must have occupied the area from which the new soil was derived. (2) The occupation must have predated the degradation phase which ultimately resulted in the stream deposit containing the artifacts. If, now, the alluvium can be shown to have a certain age, a minimum antiquity is established for the culture which produced the artifacts.

SECONDARY AND SUBSEQUENT EROSION CYCLES

The preceding discussion has concerned itself with the characteristics of a <u>primary</u> erosion cycle. Complications are introduced when <u>secondary</u> and subsequent cycles have been present.

The duration of a primary cycle is indeterminate as expressed in years. It is contingent only upon the existence and completion of the four phases mentioned at the outset. Even this statement is subject to modification because the final aspect, recovery, very rarely brings about full restoration of the original conditions. Almost always a partial restoration is achieved, which may or may not closely approximate the original state. Therefore we are in practice forced to regard the primary cycle as fulfilled if the recovery is reasonably advanced and is clearly recognizable through morphological criteria as recovery.

The admission of this qualification is mandatory, because, with the special case of sheet erosion, degradation on open slopes may cease for long periods without the appearance of any noticeable change in the terrain. If, thereafter, another period of degradation begins, the effect will be directly additive. We can consider the second period of active wear only as a delayed continuation of the first, with no clear segregation of cycles. Consequently no satisfactory sequence of events can be established in time, and from the denuded area itself no deductions can be made.

Where recovery takes the form not of a mere suspension of all soil activity, but of a positive process, no matter how slight, the situation is different, for now we have criteria for observation and measurement. As noted previously recovery is manifested most distinctly in (1) the filling or healing of arroyos, and (2) the weathering of water-borne deposits either locally in stream fills or generally on outwash plains. A third manifestation is frequently observed, the weathering of denuded surfaces, usually on slopes. A prerequisite here, however, is that the weathered horizon not be removed by sheet erosion during the interval between two cycles.

Let us suppose that, the initiating cause of the primary cycle having been liquidated and recovery having been accomplished, a new attack is made upon the land by its human occupants. Active degradation, associated with aggradation, will follow. In their mechanics the processes of this secondary cycle will resemble those of the primary cycle. But the substratum upon which they act will be different, that is, not a virgin soil but one already altered by the primary cycle. Certain characteristic features are developed, some of which merit brief description.

1. A primary arroyo, upon cessation of erosion, begins to fill, as described previously, and assumes a broad U-shaped, or shallow bowl-shaped cross section. If subsequently a new cycle begins, the cutting resumes, but now the incision is made into the new fill rather than the native soil. A section resembles the diagram in figure 6. The extent of cutting varies. Usually the two cycles can be distinguished, as in figure 6, but occasionally the action of the water is strong enough to wipe out the fill entirely and begin enlarging the primary cut. If so there is no means of segregating the two cycles at the particular point observed.

Recovery from degradation may occur in the secondary cycle. If so the secondary cut will be filled and in turn will become U-shaped or bowl-shaped in cross section. Vegetation which grew on the primary fill will be dislocated or washed out where the secondary cut impinges upon it. Otherwise it will remain in place and during recovery will spread to the secondary fill.

2. Secondary erosion cycles very often result in carving new stream channels or arroyos across flood plains and alluvial deposits so as to expose fresh profiles. A characteristic feature of such exposures is the appearance of a compound, or "reversed" profile, in which the original soil is seen to be overlain by mixed material from the primary cycle. The buried soil may still show its normal horizons, or it may be truncated (see figures 7 and 8). Moreover, if weathering following the primary cycle was of long duration before the onset of the secondary cycle, incipient stratification may be observed in the upper layers. Thus figure 7 may be modified to give figure 9.

3. The phenomena just outlined represent degradation in the secondary cycle acting upon aggradation structures of the primary cycle. However, the secondary cycle may also aggrade upon material laid down in the primary cycle. It is true, of course, that the resulting structure will later have to be exposed to view either by artificial cuts, such as road excavations, or by stream action during a tertiary cycle. Assuming such exposure, three superposed aggregates will be detectable: the original soil, the deposit of the primary cycle, and the deposit of the secondary cycle. Each of these may show layering due to weathering and advanced profile formation, in differing degree, the

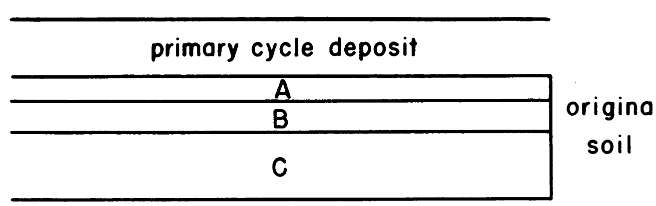


Figure 7.

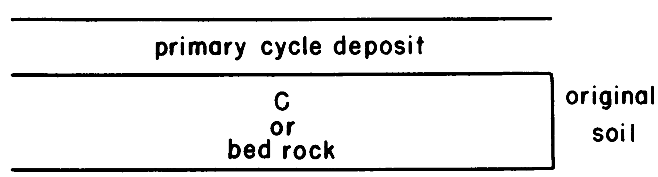


Figure 8.

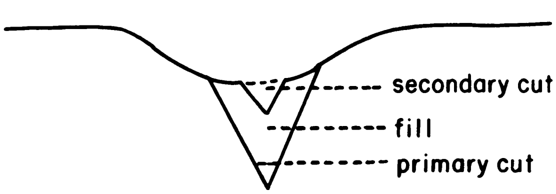


Figure 6.

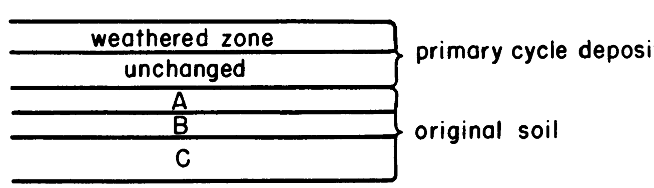


Figure 9.

variants being indefinitely great in number and not requiring detailed description here.

The occurrence of artifacts follows the same pattern in secondary and tertiary cycles as in the primary cycle. Any human residues left on the surface of the ground prior to the formation of a fill or stream deposit and capable of being washed in the proper direction, may occur in the deposit. Furthermore potsherds and obsidian may be washed out of an old deposit and incorporated in a new one. Hence it follows that each increment in a series of deposits may contain relict material from all periods prior to its formation. The distribution of artifacts according to age, however, will tend to show those of a certain period predominating in the corresponding stratum. Actually, thorough statistical analysis of potsherd occurrence has never been made in such a case. Hence only the general principle can be enunciated.

Tertiary cycles have been found in central Mexico. Possibly quaternary cycles exist, but if so their interpretation would be very difficult and would be of little significance to archaeologists and prehistorians.

III. PROFILE ANALYSIS AS AN INDEX TO OCCUPATION: GENERAL THEORY AND METHODS

Every parent material which goes to make up a soil, whether igneous or sedimentary rock, water-borne or wind-blown deposit, if allowed to be acted upon by the agencies of the physical and chemical environment, undergoes the process of weathering. Ultimately there arises a distinctive distribution of weathering products to form the horizons characteristic of a mature soil. Such a distribution is usually referred to as a profile. Of these there exists a vast array of recognized and described types, differing one from another according to the nature of the parent material and its response to the varying factors of the environment. Under human occupation these profiles are altered, particularly as the upper horizons are destroyed or modified by habitation, agriculture, and livestock. Both the total quantity of material and the pattern of distribution of component substances may undergo wide changes. It is reasonable to hypothesize, therefore, that if these changes are recognizable and consistent, an association might be established between soil composition and human occupancy which would permit conclusions concerning the past history of the land and the people on it.

There are numerous criteria which may be employed, both physical and chemical. They fall rather naturally into two groups, those based upon visual observation in the field and those requiring the analysis of samples in the laboratory. The field methods will be considered first.

FIELD CRITERIA FOR PROFILE ANALYSIS

In the preceding section attention was paid to the severe slope denudation and gully formation, as well as to the extensive stream deposition so characteristic of erosion in the old inhabited regions of the Mexican plateau. Such conspicuous results of land use are, however, not always present, despite the fact that settlements have been in existence for many years and the land has suffered perceptibly. In their absence, there are other phenomena which might serve as criteria and which deserve to be explored. One of these is the comparative depth of the soil itself.

When a mature soil is subjected to disturbance by man, one effect widely observed is the removal of the upper layers of the soil. The magnitude of the effect is highly variable, ranging from barely perceptible scarification to the complete denudation which often accompanies extreme sheet erosion. Normally the first result is the loss of the so-called "A" horizon, followed by a progressive lowering of the surface level. The lower limit may be a matter of judgment and definition. Thus the zone of removal may reach beyond the conventional "A" and "B" horizons into the "C" horizon. This may consist of a stratum of more or less weathered and altered bed rock, or it may be composed of the unaltered rock or other parent material itself. Since conditions vary widely from region to region it is necessary to define in each instance just what is to be regarded as "soil," in order that valid comparisons may be made.

Since the distinctions between "A," "B," and "C" horizons are likely to be highly technical, and since we are dealing actually with a single parameter, total depth, it is useful to employ the empirical category of <u>topsoil</u>. By this term we mean those upper horizons of a profile which can be distinguished by visible criteria from the underlying unaltered, or imperceptibly altered subsoil, or parent material. The criteria have to be texture, or consistency, and color. For each area under study a decision has to be made just where the line is to be drawn. The method becomes somewhat arbitrary but if systematically applied yields valid data.

Since the method requires the direct observation of numerous profile exposures it is conveniently employed by means of a linear transect. Such transects at the present time are best selected along predetermined strips of recently constructed highways in uneven or hilly country where frequent road cuts, borrow pits, and casual excavations are to be found. The pertinent information is then recorded in as quantitative a manner as possible for subsequent graphic or numerical treatment. Finally the human occupation, past and present, is associated with the observations, and the degree of correspondence evaluated.

In order to detect a correlation between topsoil depth and the activity of man a reasonably large number of observations must be made. Local variation in the physical and biotic conditions, together with the difficulty in achieving a high precision of measurement, necessitates considerable tolerance in estimate. Thus within a horizontal distance of a few feet the topsoil depth may vary from none at all to several inches or to a foot or more. Consequently a large array of measurements or estimates is required. The limit will usually be imposed by the frequency of available exposures. Many other factors must be controlled. Some of these are discussed in section IV below, where an illustrative study from central Sinaloa is presented, and to which reference may be made for further detail.

Apart from the total quantity, or depth of the topsoil, it is often feasible, in the field, to evaluate its differentiation into layers, or horizons. In a mature soil, distinctions can usually be perceived by eye; if not, and if the profile is important, samples can be taken for laboratory analysis. As surface erosion progresses horizons are successively obliterated until only the subsoil remains. Such complete truncation of the normal profile is usually discernible.

If recovery replaces destruction, weathering first produces disintegration of the coarser particles with formation of finer material and very likely some clay. Simultaneously in all but the most arid climates plants seed in, grow, die and decompose to produce humus. The organic matter thus formed accumulates and becomes visibly manifest in a darkening or even blackening of the surface layer. Further development exhibits a deepening of the dark horizon, and finally in most soils a segregation of zones according to color or consistency, which actually are the outward reflection of ionic and molecular reactions and translocation. If this chain of events is completed a new, mature soil has been produced. However, in areas settled by man, degradation may not come to a complete halt with the end of the intense erosion cycle, but may continue at a reduced rate and thus conflict with or counteract the forces of recovery so as to produce some kind of intermediate condition. Thus there may be established an equilibrium state wherein weathering and accumulation of organic matter may proceed at a reduced rate. Within the weathering zone differentiation between "A" and "B" horizons may or may not take place.

This all means in practice that a sure diagnosis of soil history can be made only under restricted circumstances, and even then preferably when confirmed by other evidence. In any area selected for study by this method, a deep, mature, well-differentiated profile should first be sought in order to secure a basis of comparison with eroded profiles of the same type. Mature, undisturbed profiles are rare in Mexico, but when found they may be accepted as having remained unchanged since very ancient times, and thus may serve as a model of the type.

A truncated profile, with any of the expected upper horizons reduced in depth or missing, must be regarded as either (1) very recently eroded, or (2) eroded at a past time but prevented from recovering by subsequent continued land use, for example, for grazing. A profile showing one to many inches of weathering and humus accumulation directly in contact with unaltered or partially decomposed parent material indicates a period of former erosion followed by some degree of recovery. However, the time element is indeterminate unless the recent and present rate of soil depletion can be estimated.

As a result of the shortcomings mentioned, direct field description of horizon differentiation, by itself alone, will be inadequate for the full definition of past land use, and must be supplemented and reinforced by other types of evidence. With this reservation, however, the existence, the loss, and the gain of individual soil horizons, by whatever names they may be called, are of great assistance in reconstructing the history of land use and human occupation.

LABORATORY CRITERIA FOR PROFILE ANALYSIS

The second group of criteria available to profile analysis includes a series of physical and chemical tests made in the laboratory on samples taken in the field. The data provide information concerning the quantity and the vertical or horizontal distribution of various substances which are thought to be associated in different ways with the activities of man.

Progress has been reported by several investigators in following the level of phosphate in the soil, and also of trace metals such as copper and zinc. However the simplest and most direct diagnostic approach to soil changes would be to evaluate the formation and distribution of clay, the universal product of weathering, and of the omnipresent organic matter derived from plants and microorganisms. To these might be added the hydrogen ion concentration, and, where applicable, the lime content. It is worthy of comment that little attempt has been made as yet to explore the use of these outstandingly important materials, either individually or as a group, for detecting soil alterations referable to human intervention.

The principles underlying the formation and fate of clay and organic matter are well understood by pedologists, and are exhaustively set forth in many texts and monographs on soil technology. Clay is formed at the weathering surface of any rock or soil. As the soil ages the clay tends to move downward until it accumulates in a lower, often the "B" horizon. The depth of this zone of accumulation may be very great. Organic matter will likewise take its inception at the surface, through the growth, death and decomposition of vegetation. Hence the upper levels of any soil, save those most arid and those most sterile, contain organic matter. This material, consisting of plant residues, largely cellulose, is reworked by microorganisms almost as fast as it is formed, with the consequent appearance of humus and other products. Thus even a few years of plant growth establishes a zone ranging from light gray to black at the surface. As time goes on the lower boundary of this horizon moves deeper, until, in ancient, mature soils, it reaches a condition in which the humification processes are balanced by the oxidative removal of the organic matter.

Any interference by humans with these processes, through habitation, land burning, agriculture, destructive logging, or stock grazing, will distort the normal distribution of clay and organic matter through the soil in depth. Such distortion, in turn, when found by analysis should be a clue to the time and intensity of occupation.

The absolute values of soil components will of course depend upon the type of soil. Thus a pure silicious sand, or a porous volcanic ash deposit might be expected at maturity to show a lower clay content than a compact, deeply weathered basalt. The climate within past centuries is also highly significant. The degree of weathering and the profuseness of vegetative growth is dependent upon moisture and temperature. Hence dislocation due to activity of man must be considered within the framework of the normal soil resulting from specified parent material and edaphic factors. Within these limits some formulation of past history may be attempted.

If a surface soil upon analysis shows a relatively low clay content then it must be considered the upper horizon of an old soil from which the clay has been displaced downward, or an early stage in the formation of a new soil from material which has hitherto been only slightly weathered. In the first instance the lower levels should have a high clay content, owing to the downward movement of clay formed in the superficial horizons. In the second instance the lower levels should contain little clay, since there has been only feeble weathering at the surface and no significant downward movement. A special case of this sort is frequently observed on stream deposits and slope washes caused by rapid erosion of the soils above. The clay content may be small, but where the eroded soils were themselves mature and rich, it may be surprisingly great. Nevertheless only little weathering on the deposit need be assumed provided that the clay content is approximately constant throughout its depth.

On an old or original land surface, if the superficial horizon shows a high clay content then we have either the former lower level of an old soil which has been eroded away, or an intermediate stage in new soil formation. In the latter case the underlying strata should also show a high clay content. In the former there should be a rapid reduction of clay with increasing depth.

If the clay distribution indicates a mature soil then the organic matter should be high at the surface and should extend downward, diminishing slowly, for a considerable distance. If we have the initial stages of new soil formation the organic matter might be high at the surface but should diminish rapidly with depth. If we are dealing with the badly eroded surface of an old soil the organic matter might appear in small quantity throughout, but if we have an intermediate stage in new soil formation it might be present in large quantity both at the surface and in the lower levels.

The fact should not be neglected that, whereas the formation, distribution, and destruction of organic matter, that is, of humus, is relatively rapid, that of clay is very slow. Hence there is no necessary correlation between the profile of humus and that of clay, particularly when detritus or severely truncated older soils are being weathered or reconstituted. Each process must be studied individually. It must also be borne in mind that the general precepts offered above are to be taken as a broad guide. Individual situations are likely to show sharp deviations from any categorical formula.

A subsidiary criterion with respect to organic matter is provided by the carbon-to-nitrogen ratio. If the C/N ratio is high at the surface and diminishes rapidly below, the exposure is unstable, since most of the plant residue is in the form of cellulose or derived carbohydrates which have not yet had time to be converted to the protein of microorganisms. On the other hand, if the C/N ratio persists at a more or less constant and relatively low value it indicates that reworking by soil organisms has been proceeding for a long period without disturbance. By inference, therefore, the soil is old.

This principle applies only to such horizons as provide a comparatively high level of organic matter. When the anlyses for carbon and nitrogen show very small quantities of these elements, the margin of analytical error is great, and the ratios become extremely erratic. If the nitrogen falls below 0. 03 per cent and the carbon below 0. 3 per cent, the C/N ratio has little or no significance and may best be disregarded.

The presence of specific elementary and ionic soil components may or may not be contingent upon human occupation or activity. The hydrogen ion concentration is determined primarily by the chemical nature of the soil itself, although it may be modified by agriculture or habitation. The outstanding exception is the matrix or accumulation deposited as a result of long continued occupation of a restricted area by significant numbers of persons. This is the so-called habitation <u>midden</u> frequently found associated with archaeological sites. It very often tends to be moderately or highly alkaline even in areas where the pH of the country soil is low. Midden constitutes a special type of material, since it does not arise through the normal processes of soil formation. For its study methods have been developed which are not applicable to a general soil investigation, and which are not pertinent here.

Phosphate and the trace elements appear to accumulate as the result of occupation of land by man or the domestic animals. This accumulation is probably referable to the excretion of these substances, after their concentration in the body of the organism. Hence habitation sites should demonstrate on analysis larger amounts than the adjacent open land, and conversely the discovery of an abnormally high level of phosphate or copper would be taken as evidence of human or animal occupation. However, although the analysis for trace substances has real promise for the study of prehistory, the deposition of these elements is not an integral component of the process of erosion and soil reconstitution, the subject of the present discussion. Hence the soil dynamics of phosphate and copper are best left for future, separate consideration.

The actual laboratory methods employed in this study are adaptations of well known, conventional procedures. Most have been taken directly from the recent monograph of Jackson (1958) on soil analysis. They have been selected for simplicity rather than refinement, for the error introduced by the variables inherent in the material itself is of a much greater order of magnitude than that referable to experimental method.

Determinations of pH are made with the standard Beckman pH-meter on suspensions of 10 grams of soil in 30 milliliters of water. The nitrogen is estimated by the micro-Kjeldahl procedure. Organic carbon is determined by a modified Walkley-Black technique, with dichromate and titration against ferrous sulphate. The heat is mild and the yield is approximately 80 per cent. On the other hand the results are closely reproducible and consistent. These qualities render the method highly suitable for a study the objective of which is to secure reliable and accurate comparative results rather than a precise estimate of total carbon as such. Furthermore, the fact that charcoal is not included in the determination, as it would be with more drastic methods such as dry combustion, is a distinct advantage in dealing with soils which have been exposed to numerous fires of human origin.

Calcium carbonate is determined as CO_2 released by acid. The gas is collected in an absorbent and weighed. This analysis is performed only with samples previously found to have a pH value of more than 7. 0.

The clay has been estimated by a decantation method, wherein a column 270 millimeters deep is allowed to settle 24 hours and then the supernatant liquid poured off. The soil suspension is rendered slightly alkaline after each decantation with weak ammonia. The supernatant liquid is poured into 0. 1 N HCl for flocculation. The clay fraction is finally washed, dried, and weighed. This method is somewhat crude and arbitrary and would not be suitable for separation of a series of soil fractions according to predetermined particle size. For present purposes, however, it is quite adequate, for it furnishes a simple, rapid method for isolating the finest component with an arbitrary, but constant upper limit of particle size. This component may be regarded as being completely synonymous with, and indicative of, the clay fraction of the soil.

By these methods soils have been examined from several areas in Mexico. For some of these areas it is not only possible to draw conclusions from the chemical approach but also possible to combine the analytical results with those derived from field observation of soil profiles and erosion patterns. The degree to which these quite diverse methods reinforce each other or conflict with each other may be judged from the detailed descriptions and discussions which follow.

IV. TOPSOIL DEPTH AND OCCUPATION INTENSITY: CENTRAL SINALOA

The linear transect which formed the subject of this study was a fifty-mile stretch along National Highway No. 15, as it existed in 1958. The road runs south from Culiacan through level country for several miles, then traverses nearly one hundred miles of rough, low hills, finally to emerge on the coastal plain near Mazatlan. Near the half-way point the rivers Elota and Piaxtla are crossed. The segment extending from 20 miles north of the Rio Elota to 20 miles south of the Rio Piaxtla has the merit of relative uniformity of terrain, underlying rock, climate, and vegetation. Its recent human use has been confined almost wholly to stock ranging, with the exception of the area near the Rio Elota which has contained small villages for centuries.

Certain factors must always be recognized and if possible controlled. Some of these are now discussed with particular reference to the area of interest.

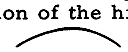
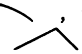
NONHUMAN FACTORS

The soil layer measured. In this region of uneven, somewhat hilly landscape a characteristic profile displays a true soil of variable depth. It is reddish to dark brown in color, and with few exceptions shows no visible segregation of horizons. Under favorable conditions, such as in creek beds or damp depressions, there may appear in addition a surface layer of dark brown to black color which represents an accumulation of organic matter or humus. This horizon where present might be regarded as an "A" horizon, in which case the usual brown soil would have to be designated a "B" horizon. There is doubt, however, whether these terms are appropriate, since the distinction is based only upon color and the presence of humus. Let us then for simplicity and convenience of reference denote either or both of these horizons collectively as the *topsoil* without commitment as to the physical or chemical nature of the color zones.

With the exception of a few sand and gravel deposits in the river bottoms all the soils here observed are derived from sedimentary or metamorphic rock. Irrespective of its intrinsic composition, this rock throughout the entire area has undergone very profound decomposition, in some instances reaching depths of twenty feet or more. Consequently nowhere do we find the topsoil resting directly upon, or even close to unaltered bed rock, but always upon an intermediate zone of weathered, decaying, disintegrated rock. According to one point of view this zone might be regarded as a "C" horizon and part of the soil itself. If so the unaltered rock at the base would be considered the parent material from which the complete profile was derived. For present purposes, however, this controversy is irrelevant, since only the uppermost layers, not the intermediate, partially weathered zone, can have been affected by human culture. By *topsoil*, therefore, we mean only the strata above the zone of decomposing rock. It is true, to be sure, that the line of separation between the topsoil and the region of disintegrating rock is rarely like a knife edge in sharpness, and that there is usually an intermediate band of transition between "soil" and "weathered rock." Nevertheless a reasonable estimate may be made by eye of the lower limit of the soil. Soil depth, therefore, includes all material above this limit, regardless of possible subdivision into narrower horizons.

Parent material. In this area under the prevailing environmental conditions of great heat and moderate moisture all types of native rock tend to disintegrate with considerable rapidity. Hence soils approach a common level with respect to mass and extent, although differences in the parent material are reflected no doubt in chemical differences between soils. It follows that as far as depth is concerned, the importance of parent material becomes secondary to that of the other soil forming factors, and with a few exceptions may be neglected.

Topography. Local land formation is of critical significance in the evaluation of comparative soil depth. The extent of soil development within a small, restricted area varies widely depending upon slope and exposure. Consistently, in the Sinaloa coastal area as elsewhere, the thickness is at a minimum at the top of knolls, hills, and ridges, increases greatly as the slopes are descended, and reaches a maximum at the foot of the slopes and in low spots such as meadows, stream beds, river bottoms, etc. It is essential, therefore, if we wish to use depth of soil as an index to some other factor, such as human interference, that the physiographic position be described, and if possible that it be kept uniform.

Now in following a highway it is common observation that the cuts cross high points and that in depressions and on flats no profiles are exposed. Consequently it is not only convenient, but almost obligatory, if a large number of examples is to be recorded, that the cuts through high points be utilized. In this study, as a consequence, a consistent selection has been made of soil depths at the *summit* of each exposure. Rarely does a road cut cross the top of an isolated hill. Usually it traverses a *ridge*, or, in an irregularly hilly region, a *spur* of the slope of a hill, mountain, or range. The soil is observed, as a result, at the hill, ridge, or spur *crest*. In most instances the cross section of the hill or ridge is bounded by a curved line, thus,  , rather than by straight lines and an angle, thus,  . The summit consequently is relatively flat, and the surface of the ground relatively level for a distance of at least several feet and frequently several meters. As a result there will be microvariations in the depth of the soil horizon and the value of the latter will have to be expressed as a range rather than as a single figure.

In addition to the *lateral* slopes to each side of a ridge there may be a *longitudinal* slope parallel to the axis of the formation. If the latter slope is steep, as on many side hills, it must be taken into consideration, or the area discarded altogether, for it is clear that soil may wash downward along a gradient parallel to the axis of the ridge or spur as well as at right angles to it. This factor is not of significance for the stations upon which this survey is based.

Climate. Precise data for rainfall and temperature are not available for this portion of Sinaloa. However, certain derived facts are reasonably certain. Since the area lies essentially on the coastal plain to the seaward of the Sierra Madre Occidental, the mean annual temperature is high and, furthermore, probably does not vary significantly over the fifty-mile stretch concerned. The rainfall, which occurs wholly in the summer, is moderate. At the same time the total moisture probably increases from north to south. This possibility is supported by the figures cited by Sauer (1932, page 7) of 700 millimeters annual precipitation for Mazatlan, and 550 for Culiacan. Such a trend would be reflected in deeper soils at the southern end of the transect.

Vegetation. At the northern end of the transect the vegetation is that characteristic of the semiarid extension of the Sonora desert. It consists of many species of Leguminosae, together with some Cacti and grass in open areas. On the whole it presents a dense thicketlike appearance. In the larger depressions and stream bottoms tall deciduous trees may be found. Toward the south the spiny Leguminosae and Cacti are gradually replaced by an arboreal vegetation with dense undergrowth of the type, although not of the extensive development, of the so-called rain forest. From direct observation, without any detailed taxonomic study, it is evident that many species disappear and others appear during the traverse of fifty miles.

The transition seems to follow a shift from the zone designated by Leopold (1950) as Thorn Forest to that he called Tropical Deciduous Forest. Sauer and Brand (1932, page 7 and footnote 6) are in essential agreement although they use a different terminology. They say: "Climatically, the area is tropical savanna (Aw of Koeppen) at the south, steppe at the north (BSh), the central portion being transitional." Also: "For the present, by inference from changes in vegetation, the Piaxtla may serve as dividing line between drier north and more humid south until more data are at hand." (For a good description of the plant environment reference may be made to Sauer and Brand, 1932, page 8.)

The vegetational change, both in species and in density, is undoubtedly associated with the climatic shift, since the southern portion would receive a higher rainfall than the northern. The progressive increase in plant density, apart from speciation, might be expected to be correlated with heavier soil development in the south.

HUMAN FACTORS

When we turn to the human factor we find that Spanish and Mexican occupation has been continuous since the invasion of the west coast by Nuño de Guzman shortly after the conquest. Even prior to this time there was occupation by aboriginal tribes.

The archaeology of the region has been studied by Sauer and Brand (1932) and to a lesser extent by Kelly (1945). Sauer and Brand found very little evidence of extensive occupation. They say (page 27): "The Piaxtla country in general gave only small, obscure sites, because we think this meager land held only settlements." This sentence is found under the heading, "Plain about the Lower Piaxtla River," but presumably refers also to the lower Elota River. Kelly says the Tacuichamona culture embraced the lower courses of these rivers but did not herself investigate them.

The earliest historical mention is in the documents relating to the 1530 expedition of Nuño de Guzman. These are described with much commentary by Sauer and Brand (1932, pages 46-47). After leaving the region near Mazatlan "The expedition thereupon encountered the lean country of the Piaxtla. . . . Lopez, scouting for the army, complained of the lack of food and even of water. The army marched for about a week through little pueblos, perhaps reaching the Piaxtla about Ixpalino. [Ixpalino is several miles above the modern highway crossing.] The river was settled to the sea on both sides." But there appear to have been here no towns of real consequence.

Shortly beyond the Piaxtla, Guzman's party reached the Rio Elota, "least of the streams crossing the coastal plain, but far superior to the Piaxtla in alluvial land". Here were found several large towns. Sauer and Brand identify two of these: Bayla, or Baila, and Abuya, which still persist. They mention (page 47, footnote 47) as existing at the end of the sixteenth century: "Elota, Apacha (Baila?), Vinapa, Avuya, and Tabala."

The next document of importance is the Suma de Visitas, compiled in about 1548 (see Borah and Cook, 1960). Here are mentioned several villages in the area concerned:

Abucho, with 53 tributaries (No. 78); Vayla, with 131 tributaries (No. 789); Elota, with 39 tributaries; Cololo, Casalne, Patino, and Apomia (with 58 Indians), and Cabaa with 24 Indians--all No. 279. Several of these are shown on the Ortelius map of 1579 (reprinted by Kelly, 1945, plate 12): Abuya, northeast of Culiacan; Bayla, northeast of Tebuchamana; Tavala, on the San Lorenzo River near Tebuchamana: Elota, Cosaluc (Cosalne), Parmo (Patino) and Aponia, all on the right bank of the Elota River half way from the coast to the hills; Cololo and Cabaa, both on the left bank of this river.

Turning to modern maps we find some of the ancient villages. Tebuchamana (now Tacuichamona) is given on the state map of Sinaloa (1: 1,000,000) as about 8 miles south southeast of San Lorenzo. Tavala is nearby, according to Ortelius. These towns are considerably outside the present area of interest. Abuya is shown on the Culiacan sheet of the 1: 500,000 map as in Lat. 24° 14' N, Long. 107° 2' W, and about 27 miles northwest of Elota. Baila (formerly Vayla) is in Lat. 24° 10' N, Long. 106° 58' W, and 22 miles northwest of Elota. These towns are near but not on Mexican Highway No. 15, although the old wagon road passed through them. Elota is in Lat. 23° 57' N, Long. 106° 43' W, on the Rio Elota and very close to the highway. The other villages on the same river, mentioned in the Suma, and on the map of Ortelius, do not appear on any modern map and have probably passed out of existence.

With respect to the Piaxtla basin numerous settlements are shown on the Ortelius map along the upper course of the river, and four along the lower river. Between these groups, where the present highway runs, there are none. The descriptions in the Suma are in general conformity with the Ortelius map and with the statements found in the Nuño de Guzman documents.

Summarizing the data for the sixteenth century we may say that at the time of the Guzman conquest there existed a relatively numerous native population from a point some 20 miles northwest of Elota on the Rio San Lorenzo. The valley of the Rio Elota itself contained at or near the highway crossing four or five villages with a fairly dense population. The latter diminished rapidly southward, and at the point where the highway crosses the Rio Piaxtla there was no habitation of consequence. For the next thirty miles through the low hill country toward Mazatlan no occupation is recorded.

As a result of the devastation of the early sixteenth century the aboriginal population was drastically reduced. Some villages were wiped out completely. A few such as Abuya, Baila, and Elota survived and are still inhabited, although whether upon the ancient sites is difficult to say.

The land was taken over by the Spaniards who used it, through the big ranches, primarily for stock raising. As Sauer and Brand (1932, page 8) put it: "For at least three and a half centuries the monte was heavily stocked with cattle, which, browsing on certain plants and avoiding others, must gradually have altered the composition of the vegetation." The matter of plant species is beyond the scope of this study, but it is pertinent to note that soil changes would be expected to accompany any profound shift in the vegetation. Furthermore the continuous beating by the hoofs of steers and goats and the close cropping of grass by sheep would tend to disturb and cause the removal of the upper soil horizons throughout the entire area, and particularly on exposed spots such as the crests of ridges and spurs. We may therefore be looking at the soil picture not at all as it was aboriginally. On the other hand alteration due to this factor would be uniformly distributed throughout the entire region. In brief, as one travels the West Coast Highway today from 20 miles north to 30 miles south of the Rio Elota, he traverses a region modified as a whole by live stock, at the northern end of which there may be some peripheral agricultural effect due to the settlements at Abuya and Baila, in the middle of which there is the modern village of Elota on the river bank, and in the southern half of which there are no traces of substantial, permanent human settlement.

OBSERVATIONS OF TOPSOIL DEPTHS

Let us now consider the depth of the soil layer in a transect through this country. The data consist of a series of observations. These may be presented in two ways, first by a series of verbal descriptions, second as a graph (fig. 10). Both methods are used here. The descriptions are given below, even though they are long and detailed. The graph is to be examined in the light of the descriptions.

Distances are given in miles north (N) or south (S) of the Rio Elota. The vegetation is "monte" unless otherwise specified (see the previous discussion of vegetation). The topsoil depths, in inches, represent the approximate range at the summit, or maximum development, of a road cut. Descriptions in brackets apply to localities where the conditions do not conform to the standards established for comparison, but which are of general interest; these are not included in the graph. The expression soil is to be understood as topsoil as previously defined.

The graph shows depths of soil at points from 18 miles north (left) to 30 miles south (right) of the Rio Elota. Each line represents the range of the depth observed at a specific locality where the distance traversed along the highway is not more than approximately 100 feet. The blocks, or tied lines, show the average conditions, for several such localities, extending along stretches of highway of from several hundred feet to as much as two miles.

16.3 miles N. Crest of a long ridge crossing the highway. Bedrock shale. Soil 3-12 inches over the zone of weathered rock.

16.1 miles N. Another exposure of the same ridge crest. Bedrock shale. Soil 3-12 inches over the zone of weathered rock. The latter is soft, friable, and decomposed to a depth of 5-8 feet, grading imperceptibly into unaltered rock.

15.8 miles N. A 5-degree slope to the south. Bedrock shale. Soil 3-12 inches as previously.

15.1 miles N. Crest of a ridge which crosses highway. Bedrock shale. Soil 3-12 inches as previously.

14.5 miles N. Ridge crest. Bedrock a fine conglomerate. Soil 0-12 inches over 3-4 feet of weathered and disintegrated rock. In places soil as such completely absent and the underlying, unaltered material exposed.

14.1 miles N. Crest of a low ridge which crosses highway. Bedrock shale. Soil 0-12 inches.

13.7 miles N. Crest of a low ridge, similar to the preceding. Bedrock sandstone. There are 0-12 inches of mixed soil and rock fragments over 2-5 feet of weathered rock.

10.5 miles N. At this point the highway is cut through a local elevation near the summit of a long, gentle (5-degree) slope to the east. Bedrock shale. The soil layer is deeper than farther north: 12-24 inches. The underlying weathered zone, or "C" horizon is 2-6 feet. Toward the foot of this slope the soil layer is considerably deeper: 24-48 inches. This increase in depth at the foot of slopes is characteristic of the area. However, there is no horizon differentiation, or recognizable layer of dark humus, or organic matter at the surface.

9.9 miles N. At a minor elevation near the summit of a 5-degree slope to the east. Soil free from fragments of rock, 6-24 inches over the weathered rock. Bedrock shale.

8.7 miles N. The crest of a low ridge, itself lying in an extensive low, level area, or bottom land. Bedrock sandstone and conglomerate. Soil 6-24 inches with a concentrated layer of stones on the surface, a rock mantle. This profile is found commonly throughout this sector. The rock concentration, or mantle, represents weathered fragments remaining after the finer material has been blown or washed away, and is clear indication of recent surface erosion.

The soil layer overlies the usual several feet of disintegrated bedrock. Cultivated fields are near this area and the vegetation at the point of observation is unusually immature, indicating use of the land in the recent past.

7.4 miles N. The crest of a low ridge which crosses the highway. There are 6-18 inches of dark soil over 2-6 feet of weathered rock. Bedrock sandstone.

6.6 miles N. The crest of a low ridge, the long axis of which dips at 5-10 degrees across the highway. Bedrock sandstone. Soil 6-18 inches. A rock mantle on the surface.

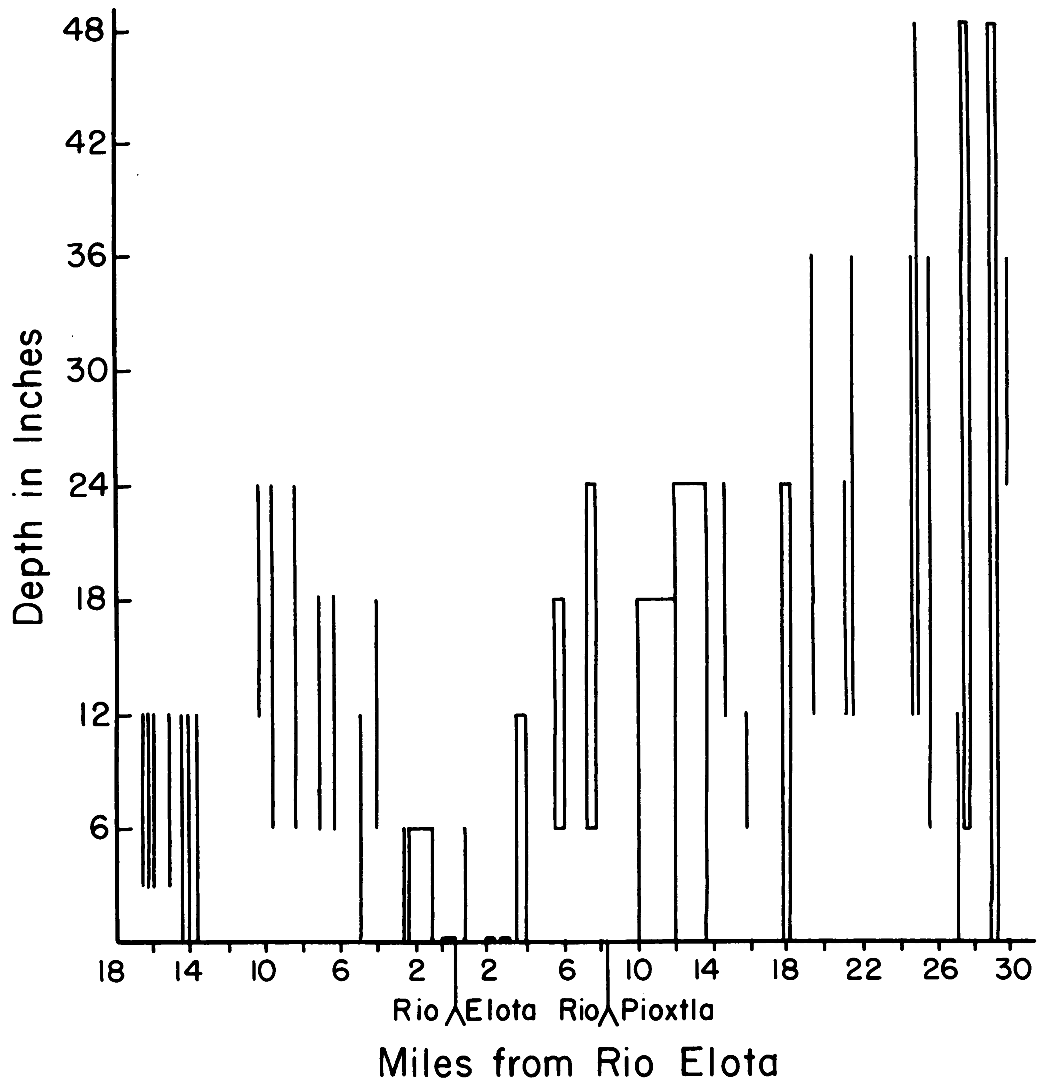


Figure 10. Depths of soil in the Rio Elota area.

[6. 1 miles N. A road cut at the foot of a steep hill. The soil is very thin; 0-12 inches. The underlying weathered horizon is 6-8 feet. Bedrock hard sandstone. The vegetation is denser, with numerous deciduous high shrubs or trees.]

[5. 7 miles N. Identical with the preceding. These points are not included in the graph because they are located at the foot of slopes, not at the summits.]

5. 0 miles N. The crest of a ridge, the main axis of which slopes across the highway. The soil is 0-12 inches, much mixed with rock fragments. Bedrock shale and sandstone. Vegetation relatively dense, as in preceeding localities.

4. 1 miles N. The crest of a ridge. Bedrock a hard igneous or metamorphic rock, possibly gneiss or granite, which is deeply weathered and disintegrated. A differentiation of horizons is evident:

"A": a dark organic or humus layer, 0-6 inches.
"B": a fine, red brown horizon, 6-12 inches.
"C": decomposing parent rock.

2. 5 miles N. Crest of ridge. Parent rock the same as in the preceding locality. The soil however is very thin: 0-6 inches, with no horizon differentiation, over weathered bedrock.

2. 3 miles N. Crest of ridge. Soil features the same as in the preceding locality.

2. 3 to 1. 3 miles N. There are several similar exposures at the crests of low ridges through which the highway is cut. These cuts are shallow and permit observation to only a few feet in depth. In this locality there has been extensive clearing of the "monte" with subsequent corn cultivation.

The summits of the banks show the parent material of the soil to be a coarse, sandy deposit, of brownish color, which may be either an ancient alluvial deposit (although no stratification is visible) or a very deeply and thoroughly weathered body of decomposed bedrock. The nature of the latter can not be determined because of the shallowness of the exposures.

The soil, as distinguished from the highly altered parent material, is a light red brown horizon 0-6 inches thick, in many spots having vanished entirely, or remaining in small, discrete pockets, with the crumbly, weathered underlying material exposed at the surface. This upper horizon has the appearance of a former B_2 horizon, with a residual impregnation of iron derived from former overlying horizons.

0.7 mile N. Here is a highly decomposed, apparently granitic rock, of structure similar to that of the previous locality, but with the superficial red brown soil horizon completely absent, leaving the upper surface of the weathered zone ("C" horizon) exposed. This formation is seen as far as the north bank of the Rio Elota.

0.7 mile S. Crest of a ridge which is cut through by the highway. Bedrock conglomerate. Soil 0-6 inches, in most places none with the underlying weathered bedrock exposed.

[1.3 miles S. Cut through the top of a knoll, or small hill. The underlying material is a sandy silt. There is a dark, humus-containing layer at the surface but no clear soil horizons can be defined.]

1.9 miles S. A cut through the top of a knoll. Parent material gravel. There is no soil at all. The unaltered, or slightly weathered gravel is exposed on the crest of the knoll.

2.6 miles S. Crest of a ridge. Bedrock conglomerate. There is no distinguishable soil whatever. The weathering zone of the decomposing bedrock is exposed at the surface, and the area appears as if the soil as such had been completely removed.

3.6 - 4.0 miles S. Several ridge crests are cut through. Bedrock conglomerate or sandstone. Some of the crests show no soil layer. Others have occasional spots of soil, mixed with rock fragments 0-12 inches deep.

5.5 - 6.0 miles S. Numerous highway cuts through low ridges. Bedrock harder, metamorphic or igneous. Soil layer is uniformly present, without horizon differentiation, 6-18 inches deep, over decomposing rock zone.

[6.8 - 7.2 miles S. At this point there is a swale, or bottom land between two ridges, in which there are silt, sand, and gravel deposits. The latter are stream laid or may be wash from the adjacent slopes. There is an accumulation of 12-24 inches of dark, humus bearing soil over a weathered zone of undetermined depth.]

7.4 - 7.8 miles S. There are several road cuts through the crests of ridges. The latter are composed of sands and gravels similar to the deposits mentioned at the previous locality. There is a layer of mixed soil and rock fragments at the surface, 6-24 inches deep. This overlies a weathered zone which in turn grades into unaltered gravel.

8.4 miles S. The highway crosses the Rio Piaxtla. There are no ranches or villages. The river runs here through a narrow, wooded canyon. The vegetation contains some mezquite and other spiny plants, but deciduous trees predominate, together with herbaceous undergrowth.

10.1 - 12.1 miles S. There are several exposures where the highway cuts through the crests of spurs or ridges. The parent material consists of gravels. The soils are variable, ranging from zero (weathered gravel exposed) to 18 inches in depth. Where visible the soil may consist of a thin layer of light brown material 0-12 inches in thickness, or may be overlain by a black, humus-containing layer 0-6 inches deep. The latter condition appears to represent the mature soil type (i.e., an "A" horizon of dark soil, a "B" horizon light brown in color, and a "C" horizon consisting of gravel somewhat altered by weathering).

12.2 - 13.8 miles S. Several ridge crests are cut through by the highway. The vegetation here shows a definite trend away from the thorny mezquite and cactus and becomes denser with an initially developed deciduous arboreal cover.

The formation underlying this area consists of compacted gravels, consolidated several feet below the surface of the ground almost to conglomerate. The black organic "A" horizon, mentioned at the previous locality, is absent or very thin, reaching a maximum of 6 inches. The light brown "B" horizon is present (or occasionally absent), reaching a maximum thickness of 18 inches. It includes numerous unweathered rock fragments. The average depth of the combined "A" and "B" horizon, therefore ranges between zero and 24 inches, as indicated in figure 10 for this region of the highway. There is of course in addition a zone of weathering in the underlying gravel, which, although the alteration is not profound, may extend to a depth of 2-6 feet. On the lower slopes of these small ridges and spurs the brown "B" layer may increase in thickness to 4 feet. But even here little if any of the black, humus-containing surface, or "A" horizon persists.

14.7 miles S. The crest of a ridge. Parent material sandy silt. There is a zone of brown color at the surface 12-24 inches deep, which may be regarded as corresponding to the second layer, or "B" horizon of the preceding localities.

15.9 miles S. A low ridge, in a small, cultivated creek bottom, cut by the highway. The parent material is silt. There is a dark layer of soil on the surface, 6-12 inches deep.

17.8 - 18.2 miles S. Several highway cuts through crests of ridges and spurs of low hills. The bedrock consists of sandstone, shale, and conglomerate. The soil layer is variable, from absent to a depth of 24 inches. The vegetation is thorn brush and shrub, with relatively little forest.

19.3 miles S. The hills are here higher (200-400 feet elevation above the coastal plain). The upper soil layer is 12-36 inches deep, often with a black "A" horizon 0-12 inches in depth over a brown "B" horizon 12-24 inches deep. The "A" horizon is particularly well developed on the lower slopes of the ridges.

21.3 miles S. The crest of a ridge cut through by the highway. Soil horizon 12-24 inches, over weathering shale. Vegetation deciduous forest.

21.6 miles S. Ridge crest, or crest of a long spur. Bedrock shale. Brown soil 12-36 inches deep. No black "A" horizon. No horizon differentiation.

24.5 miles S. Crest of a low ridge. Bedrock shale. Soil brown, mixed with unweathered stones, 12-36 inches thick, over deeply weathered parent material. Other exposures in the vicinity show the soil very thin to almost absent on the summits of the knolls and ridges. At the same time the lower slopes have a much deeper brown soil, 1-5 feet thick, with occasionally traces of a black "A" horizon above the brown stratum. Vegetation here, in a definitely hilly region is quite dense and consists of deciduous forest.

24.7 miles S. Crest of a low ridge, or spur. Bedrock shale, deeply weathered. Soil 12-48 inches.

25.6 - 25.8 miles S. Three small ridge crests, close together. Bedrock shale. Two exposures show thin soil, 6-12 inches, the other a thicker layer, 12-36 inches.

27.3 miles S. The highway cuts across the crest of a ridge. At the summit the soil is thin, and in a few spots absent. In nearby valley bottoms the soil is from 2 to 4 feet deep and is marked by a dark brown to black "A" horizon overlying a light brown "B" horizon. The vegetation consists of deciduous forest.

27.5 miles S. Several ridge or spur crests are cut by the highway. The soil varies widely from very thin (6-12 inches) to quite deep (12-48 inches). The depth and development depend upon very local conditions of topography and in part are probably functions of moisture at the top and on the slopes of the ridges.

29.1 - 29.3 miles S. Several exposures where small ridges are traversed by the highway. In one place the soil is relatively deep (12-48 inches); in others it is shallow (0-6 inches).

29.7 miles S. Highway crosses a ridge crest. Bedrock shale. Soil red brown, no horizon development, 24-36 inches deep, overlying weathered bedrock. Vegetation deciduous forest.

[Southwest of 30 miles S. the same conditions prevail for several miles. As the coastal plain toward Mazatlan is approached the soils exposed at the summits of the road cuts continue to vary from one to several feet in depth.]

From the descriptions given above and from the graph (fig. 10) two conclusions may be drawn.

1. Proceeding from 20 miles north to 30 miles south of the Rio Elota there is a progressive deepening of the topsoil at the summits of small elevations and the crests of ridges and lateral spurs of the hills. Simultaneously the soils in the bottoms, valleys, and minor depressions are uniformly quite thick. This trend on the exposed summits seems to reflect the climatic shift toward generally heavier rainfall to the southward, together with the transition from a semiarid monte to a relatively dense deciduous forest. In any event the edaphic factors have operated independently of human interference.

2. Between 12 and 18 miles north of the Rio Elota the observed soils are decidedly shallow (0-12 inches). Between 4 and 12 miles, in terrain very similar to that immediately northward, they are undoubtedly deeper (6-24 inches). From 4 miles north to 4 miles south of the river the soil at the summits of knolls becomes extremely thin, and over wide areas has been totally depleted (0-6 inches). From 4 to 18 miles south of the Rio Elota a much greater average depth is seen (0-24 inches), and through the subsequent 12 miles to the southward, the soil, although varying widely with local circumstances frequently reaches a depth of 4 feet (range 0-48 inches).

Disregarding any systematic change due to climatic shift, it is clear that the upper soil horizons have been reduced or destroyed at two distinct points: at the northern extremity of this transect, and in the basin of the Rio Elota. There is no perceptible change in the valley of the Rio Piaxtla. These findings conform broadly to the pattern of human occupation.

For the moment the effect of livestock may be disregarded, because domestic animals have ranged freely and uniformly throughout the region, and such surface erosion as they may have engendered will be evenly distributed and will not be localized. The soil picture then reflects actual settlement by sedentary populations in restricted localities, where agriculture and day-to-day living wear and dissipate the superficial horizons. There are two such localities along Highway No. 15. The first is at the northern end of the transect and beyond and is represented at the periphery of the complex by the villages of Abuya and Baila. The second is the village of Elota, quite near the highway, on the north bank of the river. All these settlements have been foci of human activity for at least 500 years. It therefore seems reasonable to conclude that the correspondence is established between intensity of occupation and the degree of attrition of the topsoil.

It is significant that all the topsoils examined appear to have been at least partially depleted, those near the inhabited localities more than elsewhere. If the villages concerned had flourished up to the late sixteenth century and had then gone out of existence we would expect to find evidence of soil recovery. On the contrary some degree of active erosion is still in progress. Hence we must conclude that the areas near the villages have been subject to continuous degradation for a long period, with no opportunity for reconstitution of a mature profile.

The region as a whole, apart from the vicinity of inhabited sites, demonstrates no fully mature, undisturbed topsoil profiles, but rather a moderately severe, generalized reduction of the upper horizon. This condition must be ascribed, as previously suggested, to the ranging of livestock. Since here, also, there is no indication of reversal, or recovery, it must be concluded that the mild damage to the soil caused by livestock has been inflicted over four centuries and persists even at the present time. The erosion caused by local habitation and agriculture is superposed upon that induced by unrestricted grazing.

V. PROFILE ANALYSIS OF HABITATION SITES ON THE COAST OF SINALOA AND NAYARIT

This section concerns a series of habitation sites on the coastal plain of Sinaloa and northern Nayarit.

SERIES 1

The first of these, which I examined, is a sand mound, described, and designated by Kelly (1945) as site No. 60, lying just north of Eldorado, 500 meters north of kilometer 59 on the paved road to Culiacan. Only one profile was sampled, from an excavation close to the road. The matrix is filled with potsherds, shell, charcoal, and scraps of bone. At this point the deposit is at least 8 feet deep. The surface is covered with mezquite and other thorny shrubs. The analytical results are given below.

The clay content is relatively constant to a depth of 80 inches. There is no evidence of recent clay formation at the surface, nor is there any accumulation at lower levels. One must therefore conclude that the clay is derived directly from the soil which went to construct the mound, had been previously formed, and was incorporated in the mound matrix. The organic content is low, both in nitrogen and carbon. Nevertheless there is a slight increase (seen in the carbon) at the surface, over the more or less uniform values found at lower levels. The C/N ratio diminishes with depth. These phenomena, as was pointed out in connection with some of the Tepic soils, lead to the supposition of recent, incipient profile development. The soil contains considerable acid-extractable carbon dioxide, distributed in an erratic fashion from top to bottom. Much of this calcium carbonate is undoubtedly derived from fragments of molluscan shell which are scattered at random through the site. The pH is slightly alkaline.

The indications are, therefore, that this is a mound constructed out of soil taken from the surrounding country, to which has been added certain residues of human occupancy, that is, shell, charcoal, etc. The construction was in the era of the Spanish conquest, in the sixteenth century, or perhaps earlier—a view which is supported by the archaeological evidence (see Kelly, 1945). In four or five centuries the heaped-up soil has developed no visible horizons and has only begun to segregate organic matter and clay. This gives us some notion of the time span necessary for the establishment of a mature profile in the warm, damp, coastal climate, when the parent material is predominantly alluvial river sand.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	Carbon dioxide (per cent)	pH	C/N ratio
1	6	14.6	0.04	0.64	1.16	7.84	16.0
2	18	11.1	0.02	0.23	1.72	8.02	11.5
3	36	11.9	0.04	0.37	1.25	8.07	9.2
4	60	15.1	0.05	0.37	0.00	7.11	7.9
5	80	15.6	0.04	0.25	0.54	8.39	6.2
6	100	-	0.05	0.40	0.79	8.11	8.0

SERIES 2

The second series of analyses are of samples from a group of former habitation sites near Amapa, a village four miles west of Santiago Ixcuintla, on the coastal plain of northern Nayarit. The excavation was made and the samples obtained by Professor Clement Meighan of the University of California at Los Angeles.

At this location there is a closely aggregated group of mounds. Soil sample series were secured from three test pits in three separate mounds, the different series being designated respectively as "Herman's Mound," "Pit B," and "Pit D." Since we have a comprehensive statement from Professor Meighan (personal communication) concerning the stratigraphy, archaeology, and history of these sites, excerpts from which statement may be quoted verbatim, it will be appropriate to present the data from the soil analyses and then see to what degree they coincide with and confirm the conclusions of the field investigators. The analytical results therefore follow herewith and are amplified by conclusions derived exclusively from these data.

The data from analyses follow. It will be noted that the organic content rests entirely upon analyses for carbon, for we have not yet been able to carry out the nitrogen analyses. However the carbon content is a very good criterion of total organic matter.

In Herman's Mound, except for a very slight beginning of clay formation in the upper 12 inches and a very slight accumulation of organic matter, there is almost no variation from top to bottom. The implication is that the mound was artificially constructed with the use of surface soils found in the general vicinity. Such building materials would naturally contain appreciable quantities of both clay and organic carbon which would appear with apparently random distribution throughout the site. The slight excess of these components found in the upper foot of the site may be taken as the degree of new soil formation since the completion of the mound.

Herman's Mound

Sample No.	Depth (in.)	Clay (per cent)	Carbon (per cent)	Carbon dioxide (per cent)	pH
1	4	11.84	0.84	0.00	7.0
2	12	12.65	0.42	0.00	7.3
3	20	8.66	0.24	0.00	7.6
4	28	8.35	0.25	0.00	7.6
5	35	8.70	0.27	0.00	7.7
6	43	9.11	0.30	0.00	7.9
7	51	9.11	0.26	0.00	7.9
8	59	8.18	0.26	0.00	8.0
9	67	8.42	0.30	0.00	8.0
10	75	8.98	0.33	0.00	8.0
11	83	7.32	0.32	0.00	7.6
12	91	10.26	0.27	0.00	7.4
13	99	8.38	0.31	0.00	7.0
14	106	10.52	0.32	0.00	7.2
15	114	13.48	0.30	0.00	7.3
16	122	9.80	0.31	0.00	7.6
17	130	8.31	0.34	0.00	7.9
18	138	7.77	0.32	0.00	7.9
19	146	7.07	0.34	0.00	7.9
20	153	10.13	0.32	0.00	8.0
21	161	8.90	0.36	0.00	8.0
22	169	8.49	0.35	0.00	8.0
23	177	11.45	0.34	0.23	9.2

Pit B

Sample No.	Depth (in.)	Clay (per cent)	Carbon (per cent)	Carbon dioxide (per cent)	pH
1	4	15.37	0.63	0.00	7.5
2	12	17.49	0.49	0.00	7.0
3	20	17.62	0.21	0.00	7.3
4	28	13.01	0.25	0.00	7.3
5	35	15.36	0.29	0.00	7.3
6	43	13.15	0.26	0.00	7.1
7	51	11.83	0.27	0.00	7.4
8	59	5.19	0.12	0.00	7.8
9	67	6.93	0.60	0.37	7.9
10	75	12.25	0.26	-	8.3
11	83	10.40	0.37	0.38	9.0
12	91	9.79	0.35	0.23	9.1
13	99	9.69	0.24	0.24	9.1
14	106	11.57	0.30	0.63	9.0
15	114	14.42	0.37	0.31	8.9
16	122	17.24	0.57	0.00	8.7
17	130	16.43	0.48	0.00	8.7
18	138	13.78	0.31	0.00	8.7
19	146	13.24	0.33	0.00	8.7
20	153	8.51	0.18	0.00	8.7
21	161	14.55	0.17	0.00	8.6

Samples 22 and 23 may indicate the original soil surface. The clay content rises slightly, acid-extractable carbon dioxide makes its first appearance and the pH shifts markedly toward the alkaline side. The reaction of the entire site is somewhat alkaline. At the same time, above the mound base there is no carbonate. It may be concluded therefore that the alkaline reaction is associated with the presence of salinity, derived perhaps from sea salts.

In Pit B there is also indication of recent weathering on the surface, although the profile as a whole shows no formation of visible horizons. On the other hand there is clear evidence of discontinuity in composition. At samples 9, 10, and 11 (depth range approximately from 65 to 85 inches) there is a sudden increase in pH, an increase in organic carbon, and the appearance of acid-extractable carbon dioxide. With sample 16 (depth 122 inches) the carbonate disappears and the organic carbon rises. It is as if there had been three different and successive periods in the construction of the mound, with an interval following each during which incipient soil formation had proceeded at the surface.

Pit D

Sample No.	Depth (in.)	Clay (per cent)	Carbon (per cent)	Carbon dioxide (per cent)	pH
1	4	7.58	0.89	0.00	7.2
2	12	3.49	0.60	0.00	7.5
3	20	4.28	0.65	0.00	7.7
4	28	6.38	0.25	0.00	7.9
5	35	4.98	0.26	0.00	8.1
6	43	3.21	0.27	0.00	8.1
7	51	2.67	0.27	0.00	8.0
8	59	2.51	0.27	0.00	8.0
9	67	2.31	0.79	0.00	8.2
10	75	4.52	0.33	0.00	8.4
11	83	6.00	0.28	0.00	8.2
12	91	7.11	0.29	0.00	8.4
13	99	9.81	0.33	0.00	8.4
14	106	7.66	0.43	0.00	8.8
15	114	2.09	0.11	0.00	9.1
16	122	2.00	0.04	0.00	9.2
17	130	6.82	0.17	0.00	9.3
18	138	10.44	0.28	0.00	9.2
19	146	12.21	0.22	0.00	9.1
20	153	11.57	0.24	0.00	9.1
21	161	10.79	0.26	0.00	9.1
22	169	19.28	0.34	0.00	8.9
23	177	28.68	0.25	0.00	8.7

In Pit D the moderate rise in organic carbon suggests some surface modification, although very little new clay has been formed. There is some indication of discontinuous construction of the mound for there is a change in pH and a considerable increase in clay content from the 110- to the 140-inch level. These shifts, however, may have been due to variation in the material used for construction. It is possible that the surface of the original soil is reached with sample 23 at 177 inches depth, for the clay content suddenly rises greatly. However, in view of the wide fluctuation in percentages of clay throughout the mound this suggestion remains only a possibility.

There are certain features common to all three of these sample series which have definite bearing on the past history of the area. First, the complete absence of horizon formation associated with weathering of the parent material and consequent redistribution of the weathering products within the body of the mounds is almost conclusive evidence that the eminences, or mounds, are of geologically extremely recent origin and that they were built up rapidly by human agency. Second, the erratic distribution of clay, organic carbon, and acid-extractable carbonate leads to the conclusion that these mounds were deliberately constructed, rather than being the slow, casual accumulation of habitation midden or refuse. They cannot have existed in their present form more than a few centuries.

Now let us turn to the field observations. With regard to Pit B, Professor Meighan says:

"This pit was dug at the end of a constructed mound. Over 3 meters of it are below the surrounding soil surface, although the whole area...has at least 2 meters of refuse in it. Hence the present land surface is an artificial one....

"In this pit there is a fairly sharp cultural break at 280-300 cm (about 120 inches). This may or may not be accompanied by an abandonment of the site. The 280-300 cm. level dates from about 600 A.D., according to our present typological cross-ties; hence everything lower is older and everything higher is later in time. The topmost level should go to about 1200 A.D."

The cultural break at 280-300 centimeters coincides with the analytical break found at about 120 inches, and the two results reinforce each other. The relatively slight or moderate surface clay and organic matter accumulation can now be stated as being not more than 750 years old. If we bring Professor Meighan's date of 1200 A.D. for completion of the site to its most recent possible limit we get a figure of 450 years. Hence in this climate, and with this type of sandy or silty soil we get a range of from 450 to 750 years for the formation of little clay and a little organic matter at the surface.

The upper discontinuity, at approximately 70 inches, is not noted by Professor Meighan as having cultural significance. However it was no doubt of the same character as the lower break, and occurred some time between 600 and 1200 A.D.

Pit D, according to Meighan, is located in an area which was built up rapidly during the later phases of the construction of the mound in which Pit B is located. This would put its completion as roughly contemporary with the other site, a hypothesis which is borne out by the similar distribution of clay and organic carbon.

The history of Herman's Mound is interesting in the light of our analytical results. Professor Meighan says concerning it:

> "It is located about 200 meters north of Pit B-14 [Pit B], in the end of one of the largest constructed mounds on the site. ...There is no visual profile of changes in soil in the whole column, except that the top foot or so is more friable and contains plant roots, iguana holes, etc. The physical and cultural evidence indicates that this whole mound...was built deliberately all at once, and in a very short period. The material used was river silt, apparently scraped up from the adjacent area out of borrow pits which are ponds at the present time. There are few sherds in this material, but what there are are late in the history of the site and this construction phase can be tentatively dated at about 1000-1200 A.D."

With respect to Meighan's conclusion that the site was built rapidly approximately 750 to 950 years ago, we observe the uniformly low-organic matter and clay throughout the depth of the profile, and the random fluctuations in these components. These findings confirm his deductions from the archaeological evidence. The slight increase in clay and organic carbon in the upper 12 inches, supports his implication of weathering in this horizon and, furthermore, again gives us a notion of the rate of horizon formation in this kind of material and in this climate. Professor Meighan says that the mound does not go below the surrounding ground level, but the sudden jump in pH and the appearance of acid-extractable carbon dioxide in sample No. 23 at 177 inches is strong indication that the original soil surface had been reached.

SUMMARY

If we consider the site tested near Culiacan as well as those near Santiago Ixcuintla, it is clear that we have some idea of the rate of aging of these coastal profiles. A new soil consisting of river-deposited sand and silt begins to form clay and incorporate organic matter within a few hundred years such that a demonstrable accumulation of either or both at the surface (upper 12 inches) is evidence of plant growth and weathering for 500 to 1,000 years. A deep, progressive accumulation of organic matter, or a definite translocation of clay to a depth of several feet would thus require several thousand years. Such a period would so far antedate the Spanish conquest and any known cultural occupation that the soil would have to be regarded as a natural, as opposed to a human formation, always allowing that the parent material is raw sand or silt and that the climate has not altered significantly during the past few thousand years.

There is very little difference between Culiacan and Amapa with respect either to new soil formation or to stratification of soil used as construction material. Culiacan No. 60 may have been finished near the period of the Spanish conquest, and the Amapa sites 200 or 300 years previously. For distinctions of this character the archaeological evidence must be relied upon. The soil features do not permit of such refined differentiation. It is equally possible that Culiacan No. 60 was completed decades before the conquest, or in the same era as saw the construction of the Amapa mounds. In any case it is clear that this portion of the Mexican coast was being actively inhabited from one to five centuries before the Spaniards arrived, and was still occupied at the time of the conquest.

VI. PROFILE ANALYSIS IN SOUTHERN HIDALGO

A portion of the plateau north of Mexico City covers the north central portion of the state of Mexico and the south central part of the state of Hidalgo. The soils in general give evidence of very severe use for many centuries, and the region prior to modern times was heavily populated. In this respect Hidalgo differs from its neighboring states to the north and west, such as San Luis Potosi, Durango, and Chihuahua, which are equally arid but which until recently had never supported more than a very sparse population.

For this investigation two localities were selected, and selected because they had been carefully surveyed with respect to erosion patterns more than ten years ago. A report was made at that time and the localities were among those described in the monograph by Cook (1949a). They are on the Laredo highway, between Pachuca and Actopan. On this visit particular attention was paid to the securing of samples in order to test weathering rates in this area. The two profiles concerned will be designated Nos. I and II.

PROFILE I

(Mexico City-Laredo highway, northwest of Pachuca, at kilometer stone 88)

The location is about half way up an approximately five-degree slope, from 2 to 3 miles long. The soil consists of a gray, sandy wash derived by sheet erosion from the slope above. There are 30 inches of this wash resting upon what appears to be the smoothly eroded surface of an ancient caliche. The exposure is by means of a roadside ditch. The analytical data are given below.

This profile shows a moderately high clay content and also a moderately high level of organic matter. The latter diminishes rapidly with depth whereas the clay does not. Since the soil here consists of former top soil washed down from the slope higher up it may be concluded that the clay was derived from this source and not produced in situ. The organic matter in the upper 12 inches probably was formed in place. The surface is slightly alkaline, becoming neutral below. The calcium carbonate is below the measureable limit.

According to the history of the region, as previously reconstructed (Cook, 1949a), the deposition of this slope wash occurred no later than the sixteenth century. Within a minimum of 400 years, therefore, this soil has undergone only a very slight degree of weathering, if any.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	Carbon dioxide (per cent)	pH
185	3	15.0	0.10	0.93	0.00	7.7
186	6	14.1	0.05	0.68	0.00	7.8
187	12	16.0	0.09	0.60	0.00	7.0
188	24	15.6	0.06	0.32	0.00	6.9

PROFILE II

(Mexico City-Laredo highway, due west of the village of Arenal, at kilometer 111.5)

A lateral dirt road runs at right angles to the highway, and at 100 yards reaches an arroyo, an affluent of a large dry-wash which here for several miles holds a course parallel to the highway on the west. The terrain is nearly level but with a slight downward gradient to the west. The surroundings are cultivated in part but are predominantly covered with cacti, prickly pear, mezquite, and very thin grass.

The principal arroyo has cut a channel from 40 to 50 feet wide, with vertical banks from 10 to 20 feet high through a deep, sandy alluvial deposit which has been washed down through a very long period from the rugged mountain range to the east. It has been shown elsewhere (Cook, 1949a) that the deposition of this material was associated with a land use probably related to the civilization which centered at Tula. At the point where this profile was examined the main arroyo is joined by a lateral stream which has cut through the alluvial deposit down to and into a heavily compacted caliche. This underlies the entire area, and perhaps represents the original, prealluvial land surface. The age of the primary gully (and of its subsidiary) may be gauged from the fact that a pepper tree four feet in diameter grows in the flat bed of the gully at this locality. Samples were taken from the bank of the lateral affluent close to its point of junction with the main stream and extended from the present surface of the ground to the top of the caliche, about ten feet below. At the spot where the samples were taken there is little if any vegetation, although the adjacent area has long been cultivated to maguey and corn. There was no visible formation of horizons in this entire profile. The analytical data are as given below.

This soil, derived from the eastern mountain slopes, is calcareous, as indicated by the acid-extractable carbon dioxide. Yet the values at different depths show only random variation, indicating no tendency toward a downward displacement of lime. The organic matter is not present in great quantity at the surface, and tends to become even less at the lower levels. The clay content is low throughout the profile. The two high values at 24 and 36 inches may be ascribed to fortuitous variability in the material as it was deposited. Otherwise there does seem to be a slight increase in clay at 0-12 inches.

As measured in terms of visible horizon development and production of clay and organic matter at the surface, this soil shows only the bare initiation of weathering and organization of a new profile on the alluvial deposit. The channelling of the washes, as deduced from tree growth, artifact occurrence, and documentary evidence, must have taken place no later than the great population maximum in the Teotlalpan in the early sixteenth century. The deposition of the detritus from the east undoubtedly antedated the arroyos by several centuries, perhaps by as much as 1,000 years. Weathering and horizon formation, therefore, are extremely slow in this area of moderate temperature and great aridity.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	Carbon dioxide (per cent)
196	3	7.8	0.08	0.80	0.91
197	6	8.8	0.07	0.71	0.91
198	12	7.9	0.08	0.64	0.96
199	24	14.7	0.09	0.36	0.74
200	36	15.2	0.06	0.38	0.75
201	48	5.2	0.06	0.23	0.74
202	60	6.3	0.06	0.43	0.94
203	72	4.1	0.03	0.19	0.76
204	120	4.7	0.11	0.73	0.83

VII. PROFILE ANALYSIS AND EROSION PATTERNS ON THE TEPIC PLATEAU

On the more-or-less level area surrounding the city of Tepic, Nayarit, there are three types of soil, distinguishable on the basis of their history and their parent material. The first is that formed upon a white, coarse, friable pumice, or volcanic ash, which originated from the volcanoes to the south and probably was distributed within the past three millenia. The second is a red earth, or latosol, of very ancient origin, derived by deep weathering of the basaltic country rock or, in places, ancient sediments. The third consists of coluvial deposits, or slope wash from the surrounding hillsides, such accumulation presumably being caused by human agency.

Here we present the data by means of a series of samples. These were taken from fourteen profiles, selected as characteristic of the area. After setting forth the analytical results we submit the descriptions taken in the field of the condition of the soil and of the erosion pattern. The two types of evidence are then synthesized so as to show the relation between them and to reach general conclusions concerning the history of the area.

RESULTS OF PROFILE ANALYSIS

Profile I B (3.6 miles north of the northern corner of the park, on Highway No. 15)

There are former pastures or cultivation. At present there is grass, small shrubs, and a few small trees. This is a mature red earth, or latosol, buried under a thick layer of pumice.

The analytical results are given below.

Here is the nearest to a mature red earth, or latosol, which we may hope to obtain in the area. It has been buried by the deposition of volcanic ash for centuries. The clay content is high and increases in the lower horizons (as far as one can secure samples). The organic matter is low throughout. However in this buried soil the organic matter has been undergoing slow oxidation since the deposition of the ash, and it is noteworthy that any is left at all.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
15	147	28.4	0.01	0.14	14.0	6.09
16	156	46.7	0.02	0.27	13.5	6.28
17	180	56.0	0.02	0.18	9.0	6.27
18	240	58.9	0.03	0.12	4.0	6.89

Profile VI (11.7 miles west of church at western edge of Tepic, on highway to Compostela, at kilometer stone 19, on the crest of a low ridge)

This is a mature soil on white volcanic ash, or pumice, which is soft and highly permeable.

The analytical results are given below.

The clay has been moved downward relatively rapidly to the level of 8-10 feet. The organic matter is quite high at the surface and diminishes only gradually with depth. The C/N ratio is constant throughout, showing long-term bacterial action. This soil is old and has been undistrubed for a long time, very likely since the volcanic ash was deposited. This soil, or something similar, may be taken as the prototype of a mature soil formed upon this kind of substratum.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
46	6	0.74	0.52	5.89	11.3	-
47	12	0.62	0.37	3.97	10.6	-
48	24	0.55	0.24	2.88	12.0	-
49	48	0.80	0.14	1.85	13.2	-
50	72	0.68	0.05	0.67	13.4	-
51	96	1.15	0.01	0.14	14.0	-
52	110	15.60	0.00	0.10	-	6.30
53	124	10.70	0.00	0.08	-	-

Profile XII (5.3 miles west of the plaza of Jalisco, on the road to Compostela)

On the slopes of the high range to the northwest, in open grass land, there is a new gravel side road. The road cuts, together with two large new arroyos in the slope at right angles to the road, show 20-30 inches of black "A" horizon over 2-6 feet of lighter colored "B" horizon, the latter over white ash. This is a relatively mature soil formed on ash, similar to Profile VI.

The analytical results are given below.

The analyses show quite high organic matter persisting in quantity to a depth of approximately 6 feet. The clay is substantially absent above a depth of 3 feet but becomes fairly heavy in amount between 4 and 6 feet. The pH is probably on the acid side of neutrality. The C/N ratio is moderately high and stable to a depth of three feet. This soil resembles Profile VI in that it is an old, relatively undisturbed soil, although perhaps not so mature.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
375	3	0.8	0.231	3.87	16.7	-
376	6	0.9	0.176	3.14	17.8	-
377	12	0.8	0.112	1.72	15.3	-
378	24	1.7	0.067	0.96	14.3	-
379	36	5.3	0.033	0.61	18.5	-
380	48	17.1	0.005	0.33	-	-
381	72	21.6	0.062	0.35	-	-
382	96	7.3	0.004	0.05	-	-

Profile XIII (10.1 miles west of the plaza of Jalisco; or 2.0 miles west, or below the summit, of the Tepic-Compostela highway)

The ash in large measure ceases to be found at the summit and is replaced by soils developed upon older substrates such as red earths and forest soils. However, at this point there is a deeply matured soil over a local area of volcanic ash, at the base of steep slopes. The upper horizon (black) is 24-30 inches deep, and the lighter colored intermediate, or "B," horizon is 20-40 inches. The underlying, unaltered ash is very deep, and extends below the road cut. The analytical results are given below.

The analyses show relatively high organic matter persisting to a depth of about 4 feet. The C/N ratio is stable and high to a depth of 4 feet. The clay is small in amount to a depth of 3 feet and increases markedly at 4-6 feet. In its general characteristics this soil resembles Profiles VI and XII.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
383	6	0.0	0.106	2.94	27.7	5.6
384	12	1.0	0.120	2.55	21.2	5.8
385	24	1.5	0.081	1.90	23.5	5.5
386	36	3.3	0.062	1.51	24.3	5.4
387	48	10.6	0.030	0.68	22.7	4.5
388	60	20.6	0.005	0.12	-	4.0
389	72	25.1	0.009	0.14	-	3.8

Profile I A (The same location as Profile I B)

This is the overlying pumice layer, approximately 12 feet deep.

The analytical results are given below.

The pumice has been weathered to about 15 inches with considerable formation of both clay and organic matter. However, there has been no downward displacement of clay and the organic matter disappears within one foot of the surface. It may be deduced that the pumice here once had developed a mature profile, but was worn off or eroded very deeply. Subsequently a new weathering cycle has begun and has developed a rejuvenated "A" horizon. This process must have begun a fairly long time ago. The antecedent erosion may have occurred in the era of the Spanish conquest, that is, in the sixteenth century.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
10	3	21.8	0.34	4.72	13.9	6.80
11	8	20.7	0.20	2.30	11.5	6.98
12	15	7.3	0.01	0.27	-	6.56
13	120	3.1	0.00	0.00	-	7.00
14	144	2.1	0.01	0.00	-	7.09

Profile II (5.4 miles north of the park on Highway No. 15)

This is a small road cut next to a level ploughed field. The soil is formed on pumice.

The analytical results are given below.

The clay formation is moderate in the upper horizons, the organic matter slight and shallow. Assuming a prehistoric mature profile this area has been denuded and thoroughly eroded. There is some recent recovery but it had proceeded only briefly when the road cut was made. It will be noted also that the C/N ratio diminishes rapidly below the surface, indicating a relatively brief period during which the organic matter could be reconstituted.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
19	6	22.0	0.10	1.52	15.2	6.10
20	18	17.3	0.05	0.35	7.0	5.90
21	30	4.2	0.00	0.02	-	6.20

Profile III (2.3 miles north of the park on Highway No. 15)

Here is a small borrow pit west of the road. The parent material is pumice. The "A" horizon is thin, generally about 6 to 8 inches. The "B" horizon is variable, from 6 to 30 inches, forming pockets in depressions in the pumice. The surface shows recent use for pasture or cultivation. The vegetation is grass and low shrubs.

The analytical results are given below.

This profile is similar to Profile H. There is considerable clay formation and a moderate degree of organic matter formation at the surface. Both diminish rapidly with depth, as does also the C/N ratio. The soil has been profoundly eroded, up to recent times, and has but lately begun to recover with weathering at the surface. It must be regarded as a new soil.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
22	6	24.9	0.20	2.47	12.3	5.70
23	12	6.6	0.10	1.03	10.3	5.40
24	24	10.3	0.06	0.74	1.2	5.50
25	36	3.5	0.00	0.25	-	5.10
26	48	1.7	-	0.08	-	-
27	84	0.0	-	-	-	-
28	180	-	-	-	-	-

Profile IV (7.4 miles north of the park on Highway No. 15 on the crest of a long, low ridge in open pasture or formerly ploughed land)

A deep ditch along the roadside to the west shows a light-colored upper horizon ("A") 1-2 feet deep, a second, darker brown horizon ("B") 2-3 feet thick, then the "C" horizon, red or brown earth, indefinitely deep.

The analytical results are given below.

This profile shows an increasing clay content with depth, and a moderate organic content at the surface which diminishes markedly but persists to a depth of seven feet. The C/N ratio is relatively constant. The profile may be regarded as a mature latosol, truncated at the surface, but with the main body undisturbed. The surface erosion is probably due to relatively recent overgrazing and cultivation. It is doubtful if this area was ever extensively occupied or used in early colonial or preconquest times.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
30	3	45.9	0.24	1.99	8.3	-
31	6	44.7	0.07	1.37	19.6	4.8
32	12	45.3	0.08	0.81	10.1	5.1
33	24	57.6	0.06	0.45	7.5	5.4
34	36	53.2	0.04	0.23	5.6	-
35	48	67.2	0.02	0.21	10.5	6.1
36	84	72.5	0.03	0.09	3.0	5.3

Profile IX (4.8 miles east of the city limit of Tepic, on the gravel road to the sugar refinery at Puga)

This is just over the crest of the ridge separating Bellavista from Puga. It is on a north-facing slope. The parent material is the country rock, a heavily compacted sediment, probably derived from a basalt. The weathering is very deep. The upper 2-3 feet are dark reddish brown merging into a light brown horizon. The upper portion may be residual "B" horizon, for even this stratum has disappeared in many places, leaving the underlying light-colored soil ("C" horizon) exposed. The latter extends without visible alteration as deeply as it may be followed--10 or 12 feet. This condition is more or less typical of the generally denuded and eroded low hill slopes. Samples are from the north side of the road cut.

The analytical results are given below.

The clay content here is high at the surface and increases to very high values at depths of from 10 to 13 feet. This argues an old latosol, the upper layers of which have been lost. The organic matter is only moderate in extent, even at the surface, but is present in small amounts even to the lowest sample. The C/N ratio falls through the upper 2 feet but then remains constant to the 5-foot level--as low as analysis can pick up nitrogen. The pH slowly rises throughout. These findings all show a badly truncated latosol of ancient origin. The mature surface horizons have been destroyed, probably by human occupation throughout a considerable period extending up to the very recent past. This area may have been occupied at the time of the conquest; it certainly has been occupied steadily since then.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
65	3	38.1	0.06	1.16	19.3	4.80
66	8	31.5	0.06	0.97	16.2	4.90
67	15	38.7	0.05	0.76	15.4	4.90
68	24	46.7	0.05	0.58	11.6	5.30
69	36	49.1	0.03	0.34	11.3	5.00
70	48	46.8	0.02	0.32	16.0	5.30
71	60	67.8	0.02	0.21	10.5	5.20
72	84	60.6	0.00	0.18	-	5.60
73	108	54.8	-	0.15	-	5.90
74	120	77.1	-	0.18	-	5.60
75	150	65.1	-	0.15	-	5.30

Profile VII (2.9 miles east of the Tepic city limit on the gravel road to Bellavista and Puga)

This is a north-facing slope fairly high on the hillside overlooking Bellavista. The vegetation is grass and scrub oak. The rock is a deeply weathered shale. The upper horizon shows approximately one foot of brown soil with from 2 to 3 inches of organic matter at the surface, over a latosol.

The analytical results are given below.

The clay content is high but diminishes with depth. The organic matter is low but persistent to 72 inches. The C/N ratio declines. This seems to be the badly eroded residue of an old latosol cut down such that the present surface is toward the lower levels of the original profile.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
54	6	49.6	0.08	1.09	13.6	-
55	12	42.3	0.05	0.63	12.6	5.30
56	24	46.1	0.02	0.37	18.5	5.30
57	48	39.3	0.02	0.24	12.0	5.20
58	72	31.0	0.02	0.15	7.5	5.30

Profile VIII (4.4 miles from the Tepic city limit on the road to Puga)

This is at the crest of a ridge separating Bellavista from the low tableland of Puga. The vegetation is grass and scrub oak and mesquite. The country rock, a shale, is deeply weathered. There are no visibly developed soil horizons toward the surface of this road cut. The soil generally is a red earth, or latosol.

The analytical results are given below.

Here again appears to be the residue of what was once a mature red earth. The clay content is that characteristic of the lower "C" horizon. The amount of organic matter is low despite existing vegetation. The C/N ratio is quite constant, indicating the stable lower horizons of an old soil, rather than a soil which is rejuvenating.

Profiles IV, IX, VII, and VIII may be regarded as old latosols which have been surface eroded and destroyed intensively and continuously within recent centuries. Particularly the area east of Tepic, extending to Bellavista basin and Puga, seems to have been subjected to incessant active occupation by agriculture and cattle since the Spanish conquest. Prior to that time it is also probable that native utilization of the land was heavy.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
59	6	17.5	0.06	0.73	12.2	5.50
60	12	19.2	0.06	0.64	10.7	5.40
61	24	15.3	0.03	0.42	14.0	5.40
62	48	14.9	0.03	0.35	10.7	5.50
63	72	19.9	0.04	0.47	11.7	6.00
64	96	9.5	0.00	0.05	-	5.60

Profile V (6.1 miles west of the church at the western edge of Tepic, at the start of the road to Jalisco and Compostela)

The exposure is a recent deep gully caused by road construction. It is compound, consisting of about 9 feet of slope wash deposited over volcanic ash, or white pumice. The uppermost 2-4 feet are discolored as by accumulation of organic matter and also contain numerous potsherds and obsidian chips. The locality itself is not an archaeological site, hence these artifacts must have been washed down from the slope above.

The analytical results are given below.

Considering the slope wash profile above 108 inches, the clay content is variable and erratic. There is no obvious new formation at the surface and likewise no significant accumulation in the deeper layers. To all appearances the clay was washed down with the rest of the loose surface material and was deposited in a random fashion above the old soil surface. Since this deposition there has been little if any sorting or redistribution. The organic matter was carried down from the slopes above in a similar manner. However there has been a tendency toward new soil formation in the upper strata such that a layer 2-4 feet deep of dark brown or black material has become manifest. The C/N ratio is equivocal since it is not constant throughout but, on the other hand, does not diminish sharply with depth as one might expect at the surface of a new exposure. We may conclude that two sources may contribute to the organic matter, the material washed in from former surface horizons on the upper slopes, and new formation *in situ.*

This deposit reaches back a long distance historically, although it has no great age in terms of soil formation. The gully here is well developed, and has been in existence for some time. The slope wash took a good many years to accumulate. It would be safe to estimate the original erosion and deposition of this soil as dating from the sixteenth century, or perhaps earlier.

When we examine the soil upon which the slope wash was laid we find a pumice soil in which the clay content is moderate to considerable but dimishing greatly at 6 feet below the surface. There is very little organic matter, nitrogen, or carbon. The original organic matter characteristic of a mature "A" horizon may have been eroded off prior to deposit of the alluvial soil above the pumice, or it may have decomposed slowly in subsequent centuries. I think it probable that the original condition was one of severe erosion with loss of the top soil. Upon this erosion surface was deposited the 9 feet of slope wash. If this interpretation is correct then we have here an area of ancient occupation, certainly dating back to 1530, which denuded the original soil and then caused the washing in of great quantities of surface soil from the slopes above. That the sweeping down of this surface soil postdated the occupation of the land and the erosion of the original pumice soil is proved by the presence of artifacts in the slope wash deposit.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
37	6	29.1	0.15	1.96	13.1	5.40
38	24	34.4	0.09	1.48	16.4	5.40
39	48	25.5	0.08	1.25	15.5	5.60
40	72	45.2	0.04	0.37	9.2	-
41	108	20.1	0.00	0.18	-	6.20
42	108	23.8	0.00	0.17	-	6.30
43	120	29.5	0.01	0.14	14.0	6.40
44	144	30.3	0.02	0.20	10.0	6.40
45	180	8.2	0.02	0.25	12.0	6.30

Profile X (9.35 miles south of the intersection of Highway No. 15 and Avenida Mexico, in Tepic, and on Highway No. 15)

This is a road cut through a low ridge, the latter itself being on a long, gentle, north-facing slope down from the mountain to the southeast. The vegetation is grass, mezquite brush, and scattered corn fields. The bedrock is a solidly aggregated or consolidated deposit of stones, rocks, and boulders -- almost a conglomerate. The soil is variable. In general the "A" horizon, 0-15 inches deep, is dark brown to black. The "B" horizon, 0-15 inches thick is light brown. The "C" is profoundly weathered aggregate, or conglomerate. That this mixed formation is not of great antiquity in the geological sense is attested by the presence of potsherds and obsidian flakes throughout the upper two feet of soil, as well as frequently on the surface for some distance around. It appears as if the mixed detritus had been moved down from the higher slopes of the mountain within relatively recent times and had since been compacted into an incipient conglomerate at the same time that weathering was active from the surface downward.

The analytical results are given below.

The clay content is quite high at the surface, but nevertheless increases perceptibly to a depth of 18 inches, below which it may fall off somewhat. The organic carbon and nitrogen are moderately high at the surface and diminish to a depth of 48 inches, although organic matter is still present. The C/N ratio is nearly constant. All these features imply a relatively new soil formation but yet one which has progressed to a somewhat advanced stage, at least sufficiently for the downward translocation of clay to be evident and for the C/N ratio to stabilize to a considerable depth. This is clearly a much more advanced condition than is seen in the pumice Profiles II and III, although by no means as thoroughly matured as Profiles IB and VI. The composition of the parent material suggests a downward movement of soils and rock from the overlying mountainside, perhaps caused by some natural cataclysm. However the presence of potsherds in the upper 20-30 inches of this material is sure indication of prior human occupancy of the region. If this is true then we may postulate some type of agricultural activity as the agent inducing the deposition of the existing pseudoconglomerate on this spot. If there was such human occupation then it must have been present in very early times in order for the newly formed deposit to form a fairly well-developed profile. In terms of historical events it must have long antedated the Spanish conquest.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
76	3	23.8	0.15	2.04	13.6	5.20
77	6	30.2	0.13	1.81	14.0	5.00
78	12	35.8	0.09	1.14	12.7	5.20
79	18	38.0	0.08	0.74	9.3	5.20
80	24	37.0	0.07	0.77	11.0	5.20
81	36	29.9	0.06	0.58	9.7	5.40
82	48	34.0	0.02	0.28	14.0	5.40

<u>Profile XI</u> (11.0 miles south of Tepic on Highway No. 15, and 1.65 miles south of Profile X)

The vegetation is grass, mezquite, and other shrubs. The upper 0-18 inches of this soil is brown, with a layer of loose stones on the surface, indicating recent washing out of the finer surface material. Underneath is a very deeply weathered layer of old rock, probably a sandstone or shale. Samples were taken from the bank west of the highway.

The analytical results are given below.

This soil does not seem to be an accumulation of material washed down from higher elevations, but rather a native rock weathered in place. At the same time the clay increases to a maximum at 18 inches of depth, then diminishes; the nitrogen and carbon occur in considerable quantity at the surface and diminish below. The nitrogen becomes too slight for analytical detection below 70 inches but the carbon persists. The C/N ratio is quite stable to the same depth.

This formation appears to be the remains of a very old soil which was disturbed, with possible loss of the upper horizons, by erosion. Thereafter recovery occurred and has reached approximately the same point as is demonstrated in Profile X. This condition likewise implies a very ancient, but intensive occupation by man.

Sample No.	Depth (in.)	Clay (per cent)	Nitrogen (per cent)	Carbon (per cent)	C/N ratio	pH
83	3	21.1	0.13	2.03	15.6	5.80
84	9	30.0	0.10	1.24	12.4	5.40
85	18	32.0	0.06	0.93	15.5	5.30
86	30	30.0	0.03	0.48	16.0	5.60
87	50	23.1	0.02	0.26	13.0	5.60
88	70	22.1	0.01	0.21	21.0	6.00
89	90	24.2	0.00	0.25	-	6.00
90	110	17.8	0.00	0.29	-	6.00

<u>Summary of Profile Analyses</u>. –From the preceding descriptions it is evident that on the Tepic plateau a series of soil conditions may be recognized. Thus one may distinguish mature, relatively unaltered profiles, either on the surface or buried under volcanic ash. Then there are soils which have been disturbed but which show advanced recovery, soils which represent erosion within historic times but which have begun to recover, and finally soils which even recently have been denuded. The past history at the points where the profiles were examined can be to some extent reconstructed. Thus we can place preconquest populations just west of the town of Jalisco, and some ten miles southeast of Tepic. Continuous and intense occupation probably dating back to the conquest can be ascribed to the Bellavista basin.

It is of course tedious, expensive, and difficult to take series of samples from a large number of points along roadsides and riverbanks, or to put down deep borings every few hundred feet, thereafter to carry out several analyses on each sample. Such a procedure, however, is probably unnecessary. Once the chemical and physical properties of a certain soil type are established these features can be associated with the visible appearance of an exposure, and deductions made concerning the past experience of the soil. Therefore, in conjunction with the distribution of substances in the profiles, as just described, the erosion patterns as directly observed should be considered. The erosion patterns should take into account the degree and style of gully formation, sheet erosion as demonstrated by the depth of the topsoil and its constituent horizons, the depth and extent of weathering of slope washes and other alluvial deposits. The two approaches of laboratory analysis and field observation should thus complement and reinforce each other, such that the use of either or both of them should lead to the same ultimate conclusions. An experiment in this type of synthesis has been attemped in the Tepic area. The analytical results have been set forth above. We now present the field observations covering the same local areas.

RESULTS OF FIELD OBSERVATIONS

In order to set forth the field data we follow the highways as radii emanating from Tepic as a center and interpolate the data from profile analysis at the locations where they occur. This procedure differs somewhat in method from the previous mode of description but consolidates all information into a single account.

Field data A. We start with the Compostela road, with the church (near the barracks) at the western edge of Tepic as the zero point. In condensed form the field observations are as follows.

0.15 mile. There is a recent cut in a knoll or ridge which exposes a dark to light brown layer of soil 6-18 inches deep over unaltered white pumice, or ash. The vegetation is mixed grass, mezquite, and weeds.

0.2 mile. This is a road excavation. The parent material is pumice. There is a black, top horizon, 0-3 inches deep which may be designated "A," and an underlying brown horizon, 2-6 inches deep which may be considered "B." Both this and the previous locality indicate intensive land use continuously for a long period, long enough to dissipate the mature profile and reduce the organic matter to those few inches which can be formed from contemporary vegetation, subject to incessant grazing and agriculture.

The horizon geometry is variable and produces what may appear confusion in the descriptions. The superficial, humus-bearing layer may in some places be clearly differentiated into a definitely black upper horizon below which the black gives way to dark and then light brown strata, or there may be a continuous downward bleaching of the black, or dark brown topsoil into the unaltered white ash deposit. In the latter case it is impossible to distinguish sharply between an "A" and a "B" horizon. These terms are used therefore only in a purely descriptive sense, and only where an apparent differentiation could be perceived by eye.

0.4 mile. Here is a healed gully. It is an arroyo which was once cut to a now undiscoverable depth, but which has since been filled in and become overgrown by grass and brush. The cutting took place some time ago for there has been opportunity to refill and become covered by vegetation. Relatively recently the area has been actively cultivated.

1.5 miles. Another arroyo of the same character.

1.6 miles. A new bank cut in a small ridge shows a dark horizon, 6-12 inches deep, over white ash.

1.7 miles. New road excavations. Several exposures showing 3-12 inches of dark brown soil over ash.

1.8 miles. Relatively undisturbed pumice shows an "A" horizon 2-12 inches deep and a "B" horizon 6-12 inches deep. Denudation of the surface, however, is attested by the accumulation of stones and cobbles on the surface and in the upper few inches of the soil. At a point nearby a recently cut arroyo discloses 2-8 feet of alluvial slope wash from the hill to the west. This wash contains pumice almost entirely, characterized by the presence of numerous large stones (any stones larger than very small rock fragments are rarely encountered in untouched pumice deposits). The deposit indicates long-continued heavy erosion of the hill slopes directly to the west.

2.0-2.2 miles. Several exposures show the dark surface horizon reaching depths of 3-12 inches, but in many spots being absent altogether. At such localities the surface of the ground is formed by the white, unmodified volcanic ash. This is the "C" horizon, or the parent material, as one wishes to regard it. Devastating land use is clearly evident.

2.3 miles. Here is another low ridge crest with approximately 3 inches of dark surface layer.

2.4 miles. This is the foot of a steep slope facing east. There are about 5 feet of slope wash derived from the soil formed over pumice. The layer of black, organic matter, approximately 6 inches deep, includes stones from the wash, which are apparently derived from the ancient soil underlying the volcanic ash deposit. There is no alteration due to weathering below a depth of 6 inches. Two pieces of obsidian and one potsherd were found in this slope wash. It was once an inhabited area; it was washed out; it has weathered since to a depth of from 3 to 6 inches. All this indicates a relatively ancient occupation, followed by use of the land more or less continuously since then, presumably by the now resident population.

2.6 miles. The crest of a low spur. The dark surface layer shows some differentiation such that the "A" horizon is 0-6 inches and the "B" horizon 0-6 inches deep.

2.9 miles. Here is an arroyo which could be clearly observed in the summer of 1958. In the summer of 1960 it had been covered by new shrubs and brush such that the banks could not be seen. This is an indication of the rapidity with which new bank exposures become overgrown with vegetation in this climate.

3.2 miles. An old arroyo, 5-10 feet deep and 100 feet across overgrown with grass and brush, except for an active channel at the bottom perhaps 5 feet wide.

3.5 miles. Here is a gully, 10 feet deep, primary, and of recent origin. It exposes an alluvial deposit of silt and a little gravel. There were no artifacts observed. The deposit is probably quite ancient. The zone of formation of organic matter is from 1 to 2 feet deep, but indicates a continuing loss of top soil.

4.2 miles. Here is the plaza of the town of Jalisco. The stretch from Tepic to Jalisco shows consistent severe denudation of the upper soil horizons together with numerous arroyos, or gullies developed by the cutting of minor streams. Some of these arroyos expose deep deposits of slope wash from the hills to the northwest, at least one of which contains artifacts. These conditions imply relatively dense settlement for a long period. We know from documentary sources that this has been so since the time of the first entry of the Spaniards in the early sixteenth century.

4.9 miles. Here is a fresh cut at the foot of a slope. The dark superficial layer is 6-12 inches deep.

5.1 miles. This is a relatively flat area at the foot of hills to the west. Borrow pits to the west of the road and stream cuts to the east expose 10 feet of consolidated slope wash, composed of silt and gravel. There is an arroyo which, above the road, is 10 feet deep and 100 feet across. Its profile discloses two or more small terraces, indicating successive stages of formation. No artifacts were found. The weathering zone at the surface is several inches in depth. Here again is ancient occupation, surface erosion, deposition, and incipient profile formation prior to the cutting of the recent arroyo.

6.1 miles. This is the exposure described in detail under the heading Profile V. The indications were of an accumulated wash, similar to that seen at 5.1 miles (see above), but containing artifacts and with a formation of clay and organic matter reaching to a depth of more than 1-2 feet. The formation of the black organic layer was estimated as representing perhaps four centuries. Previously there had occurred severe erosion of the original land surface, with loss of clay and organic matter. The analytical data thus support the hypothesis that there was occupation and intensive land use long prior to the advent of the Spaniards.

6.6 miles. Here the exposures become quite variable. Some show deep, dark horizons at the surface, some show the dark surface horizons to be very shallow.

6.9-7.0 miles. Here is the crest of a knoll, or ridge, the parent material being still pumice. At the crest the dark superficial layer runs 6-12 inches deep. At the foot of the lateral slopes "A" and "B" horizons are distinguishable, each ranging from 12 to 18 inches in depth.

7.5 miles. Here the road is cut along the contour line of a gentle slope. In general the "A" horizon is 12-18 inches deep and the "B" horizon may reach 4-5 feet in depth. The former horizon in spots may become as deep as 24 inches, and is black soil. The latter is weathered, brown ash. The underlying parent material, or "C" horizon, is white ash.

7.8-8.0 miles. There are several profile exposures over pumice. At this point the darker layers on the surface are again very shallow. Of particular interest is a new (in 1960) exposure cut in a preëxisting cut. There is a steep bank, some 30 feet high. This bank was excavated in approximately 1950 or 1951, through raw, unweathered white ash. The new exposure shows about one half inch of black organic matter formed directly over clear white ash. This gives an idea of weathering rate. There is no intermediate brown or yellow zone. Hence the black layer is not residual but has been produced de novo on the unaltered parent material, within a time span of certainly no more than ten years. The deepening of such an organic zone is not a linear function of time, but its rate of formation diminishes progressively. Thus one half inch in ten years might indicate a full inch in from twenty to thirty years and 2 inches in a century. Several inches would reasonably imply several centuries of formation. This suggestion is in fair agreement with the depth of weathering horizons found at the surface of ancient slope washes and other coluvial deposits which also contain relics of human occupation.

8.6 miles. The soils here are weathered pumice, or an older brown earth, or a forest soil derived not from pumice but from the underlying bedrock. The upper horizons are variable but tend to be deeper than those described hitherto, ranging from 6 inches to 3 feet for the combined "A" and "B" horizons.

9.5 miles. At this point there is a new gravel side road. The soils exposed show consistently a dark "A" horizon 1-2 feet deep, and a brown "B" horizon 1-6 feet deep. This is the location of sample Profile XII, previously described.

10.2 miles. Here are numerous exposures of the volcanic ash, or pumice, deposited over older red and brown soils, some of them reaching great depth.

10.8 miles. Here is a fresh exposure of a pumice soil on a ridge crest, with grass and brush vegetation. The dark brown to black "A" horizon is 1 foot, the light brown "B" horizon 3 feet in depth.

11.1 miles. There is a wide arroyo to the south. It is 15-20 feet deep, with vertical sides, and is recent, showing a deep, alluvial soil, probably derived from the mountainside to the northwest. The black, upper horizon is from 3 to 5 feet thick. This accumulation must be relatively ancient, and must have been practically undisturbed to have permitted the formation and retention of such a deep weathered layer. Land use within the past few centuries must have been light.

11.5 miles. Here are several deep arroyos, recently cut, and clearly associated with farming operations, the base for which is a group of nearby ranch houses. The soil destruction which is now proceeding is serious.

11.7 miles. Here was taken the sample series designated Profile VI, previously described. It was found upon analysis to be a mature profile formed on pumice, with little sign of agricultural disturbance. In this area there are numerous similar exposures all indicating maturity and only superficial erosion, if any at all. Evidently we have reached the limit of former, or ancient, habitation on the east side of the low range separating the Tepic basin from the sloping plain which extends from Compostela to the sea.

To approximately nine miles southwest of Tepic, through Jalisco, the soils demonstrate intensive, uninterrupted erosion, and hence land use. The evidence of this condition is seen in the almost complete removal of the original top soils and the deposition of silts and gravels at the foot of the slopes. The latter have weathered only superficially. It is likely therefore that this nine-mile strip has supported a heavy population which occupied and used the land intensively since a period before the Spanish conquest. Beyond the southwestern limit of this strip there probably was little and perhaps no sedentary occupation. Along the strip it may be concluded that there was an unbroken line of villages and agricultural operations.

Field data B 1.--Here we start north on Highway No. 15 from Tepic, beginning with the northeast corner of the park, just west of Highway No. 15, in Tepic.

0.0-0.5 miles. Approximately the first half mile consists of built-up city.

0.8 mile. Here is a bank exposure on flat ground, with 2-3 inches of dark surface layer over ash.

1.0 mile. An arroyo has cut through flat ground. There are 3-6 inches of dark surface horizon over white ash.

2.0 miles. This is the junction of the road to Jalcocotan and Mecatan. At this point there are two visible exposures.

One is a borrow pit to the east of the road, at the edge of a cultivated field. The parent material is ash, or pumice, over a weathered latosol. The weathered, humus-containing surface layer is from 12 to 16 inches deep. The other is a bank exposure with 6-8 inches of dark surface horizon. Both are in flat land.

2.3 miles. There is a small pit, or excavation, in level ground, to the west of the highway. The "A" horizon is 6-8 inches, the "B" horizon 6-12 inches, or deeper in depressions or pockets. Here is Profile III, described above. The analyses indicate a newly forming soil on an old erosion surface. The depth of the organic zone implies a substantial recovery from earlier land use.

2.4-2.6 miles. To the east of the highway there is a large new excavation used as a pit for getting road material. One series of exposures shows the dark upper, "A" horizon to be 0-6 inches and the lower, brown, "B" horizon 3-6 inches. Another exposure shows the dark surface layer to be 8-12 inches deep.

3.2 miles. A fresh excavation on the side of a steep slope shows the dark surface layer to be 3-10 inches, mostly 3-6 inches deep.

3.3 miles. A bank exposure on a gentle south-facing slope. The "A" horizon is about 6 inches, the "B" horizon 6-12 inches, over 2-3 feet of consolidated sand, which in turn is over an ancient red earth.

3.6 miles. Here is pumice over red earth. This is where Profiles I A and I B were taken. The combined "A" and "B" horizons are about 15 inches deep. The analyses indicate an early period of denudation followed by a period of recovery.

4.3-4.4 miles. Here are exposures several years old. The dark surface zone is 6-12 inches deep.

4.7 miles. Here may be obtained a view of the considerably eroded hill slope to the west. There is generally ash over red earth and the ash exposures appear to have about one foot of dark surface horizon. The valley to the west descends from the road to run just north of the village of Puchon. The erosion in this valley is severe. There are many branched arroyos running toward the creek in the valley bottom. The plowing on the steep lateral slopes exposes white ash through the darker surface layer.

5.4 miles. Here is a road cut adjacent to a ploughed field. The soil is derived from pumice and the horizons are quite deep: "A" is approximately 18 inches and "B" is nearly the same. Profile II was sampled here, a profile which shows a considerable accumulation of clay and organic matter in the upper levels but no downward translocation. Hence this appears to be a newly reconstituting soil over an old erosion surface.

6.9 miles. Here is a deep red earth with no overlying deposit of volcanic ash. The top soil is brown, roughly 3 feet in depth.

6.6-7.4 miles. The red earths in ditch exposures uniformly show 1-2 feet of dark brown "A" horizon and 1-2 feet of pale brown or yellowish "B" horizon over a dark red "C" horizon. There is little if any admixture of stones or rocks either at the surface, or above the zone of weathered bedrock.

7.4 miles. This is a very deeply weathered, ancient soil, a red earth, on the crest of a long, low ridge, with open pasture. There are unweathered rocks on the surface. The "A" horizon is light brown, 1-2 feet deep, the "B" horizon dark brown, 2-3 feet deep, the "C" horizon red, weathered rock. This is Profile IV, which was characterized as a truncated latosol, with only the surface disturbed. This disturbance seems to have been recent, and is consistent with the persistence of well-developed horizons. There is little evidence of ancient disturbance and more recent recovery.

7.8 miles. Here is a deeply decomposed conglomerate with the bedrock softened to a depth of 30 feet. The "A" and "B" horizons together vary locally from 2 to 5 feet in depth. There is some recent surface erosion but the soil underneath is not disturbed.

Summary of field data A and B1.--To summarize the descriptions given above, it may be stated that along Highway No. 15, north of Tepic, surface erosion is severe to a point approximately 4 miles north of the city. Beyond this line the evidence indicates an early occupation which produced serious loss of the mature upper horizons but from which significant recovery has taken place. These signs of early occupation are lost at about 7 miles to the north of the city, beyond which appear deep latosols which may be superficially denuded, but the lower levels of which seem to be relatively well preserved. The superficial erosion may be referred to agriculture and grazing within the past several decades.

In other words, at one time habitation, or at least agricultural use, of the land extended to the vicinity of seven miles north of the present city. It then contracted to an approximate four-mile limit, and within this limit has persisted probably in varying degree until very recently.

Field data B2.--At 2.0 miles from Tepic a newly paved road branches west from Highway No. 15, to run to the low-lying banana-producing towns of Jalcocotan and Mecatan, near the coast. The distances are estimated from the junction.

0.4 mile. A road cut; 0-12 inches of dark surface layer over white ash.

0.5 mile. A road cut; 6-12 inches of dark surface layer over ash.

1.0 mile. A borrow pit; 3-6 inches dark layer.

1.7 miles. A bank at the foot of a slope. The dark surface horizon is 12-15 inches deep.

1.9 miles. A similar exposure at the foot of a slope; the dark layer is 12-18 inches deep.

2.5 miles. At the foot of a slope there are 12-18 inches of black organic horizon over 24-36 inches of yellow brown weathering zone, or "B" horizon. This is over white ash.

2.7 miles. Here is a borrow pit dug in level ground. There is a dark horizon, 6-24 inches deep over ash.

3.0 miles. On a slope there is a dark upper horizon, 12-18 inches deep over 12-24 inches of brown weathered and accumulation horizon, the latter over white ash.

3.9 miles. At the crest of a small ridge, near some farm houses, there is a 6-12 inch dark layer over ash.

4.2 miles. Generally on the hill slopes there is 1 foot of dark "A" horizon, and 1-2 feet of brown "B" horizon.

4.2 miles to 5.7 miles. On all sorts of terrain and soil types there is characteristically a dark upper horizon 6-18 inches in depth and a variable underlying "B" horizon.

6.0 miles. Here is a black surface layer 1 foot in depth over the weathering or accumulation layer 3 feet deep, both over white ash.

6.3 miles. This is the summit of the divide between the Tepic basin or plateau and the slopes which descend to the coast. For the first two miles to the west there is oak and pine forest. The soils are still formed principally over the typical white ash or pumice, but are frequently much deeper than on the eastern side of the divide. The dark brown or black top soil, or surface horizon is 1-2 feet deep and the light brown "B" horizon may reach 4-10 feet in depth. At this point the ash ceases and is replaced principally by sedimentary rock. The moisture and temperature rise and the weathering goes very deep.

With regard to habitation history the first two miles of this road display the same characteristics as are seen in all areas close to Tepic, a very thin top soil over unweathered parent material. Habitation here has been long and intense. The next three miles show much less soil wear although the horizon development is by no means mature. It is suggested that there has been long-continued but perhaps intermittent and relatively light land use. There is no evidence of intensive ancient occupation followed by an interval of abandonment. At and beyond the summit of the divide there is no indication of more than sporadic and casual deforestation and stock running. Furthermore, beyond the summit we enter an entirely different ecological province where the criteria of soil erosion used near Tepic can no longer be applied without modification.

Field data C.--The area east of Tepic is traversed by a gravel road to Bellavista and Puga, along which are numerous profile exposures. Except near the town there is no pumice. The soils are all deeply weathered red earths. The zero point for distances is the city limit, at the eastern end of the bridge, at the eastern edge of the city. The road runs over a flat land and at about 2.5 miles crosses a low divide, or ridge. Close to the town are several exposures of pumice, all having very shallow surface horizons.

2.7 miles. Over the crest of the ridge; the vegetation is brush. The surface is bare red earth. A bank cut shows a much weathered shale at least ten feet deep, but with no visibly differentiated horizons at the surface.

2.9 miles. This is also a north-facing slope, with grass and scrub oak. The road cuts show approximately one foot of brown soil with 2-3 inches of dark organic matter at the surface, over the deep "C" horizon. Here is Profile VII. The analyses show a high clay content slowly diminishing with depth. The organic matter is appreciable at the top but drops off within 24 inches to a low value which persists to 72 inches. These findings are interpreted to signify an old latosol which has been swept clear of the original "A" and "B" horizons. Little if any rejuvenation of the clay is to be found, and the moderate increase in organic matter at the surface implies a brief, recent period of plant growth. The over-all picture is of a very heavy erosion cycle several centuries ago with sufficient land occupation in the period since then to prevent much recovery. This view is supported by the entire appearance of the terrain for several miles northward, where much surface exposure and gullying is to be seen.

3.2 miles. A bank is cut on the same north-facing slope. There is one foot of loose soil over weathered shale. This soil contains many unweathered stones, a good indication of the washing away of the finer soil from the surface, leaving the heavier components behind.

4.0 miles. Several profiles show nearly complete loss of the upper horizons.

4.1 miles. The land is here quite flat, with a slight slope to the east. A red earth is weathered to a depth of many feet but with no visibly differentiated horizon at the surface.

4.4 miles. The crest of a low ridge; grass, brush, and scrub oak vegetation. Deeply weathered rock. No visible horizon developed at the surface. Here is Profile VIII. The clay content and the organic content are both low throughout and confer the appearance of the mere residue of a former latosol. There is little if any evidence of rejuvenation, despite the fairly prolific plant growth. There has been continuous occupation and denudation for a long period.

4.6 - 4.7 miles. Similar bank exposures.

4.8 miles. A deep bank cut at the foot of a gentle slope. Here is Profile IX. A residual "B" horizon may be present, and there is a moderate accumulation of organic matter at the surface. Otherwise the conditions approximate those seen in the profiles described above.

5.3 miles. A shallow road cut. There is a thin layer of brown soil on the surface at certain points, none at others. This is perhaps recent soil formation, already removed where exposed to tillage and grazing.

5.5 miles. This is another exposure similar to the preceding one.

The area represented by mileage points 2.5 to 5.5 miles has been intensively populated for a long period. The entire surface soil has been lost and recovery has scarcely started. It is probable that this process of soil destruction has been going on since before the sixteenth century. The analytical data previously given indicate likewise that we have here a series of soils which have been consistently exposed to erosion for a very long time, and from which "A" and "B" horizons have been removed, with little opportunity for recovery.

Field data D.--Starting from the junction of Highway No. 15 and Avenida Mexico in Tepic, the former road may be followed southeast.

1.3 miles. In the flat land south of the city an excavation discloses several feet of black, alluvial deposit, containing numerous fragments of unaltered pumice. Hence it is clear that this alluvium was formed after the pumice was deposited. Its source was the hill slopes to the west and northwest.

2.5 miles. At the railroad overpass there is a pure pumice formation with a surface horizon of 6-30 inches of dark soil. This soil is probably ancient, since it is overlain extensively by an alluvial deposit derived apparently from the hills both to the east and the west.

3.1 miles. The hills directly east, at 2-3 miles, appear to show an ancient arroyo pattern, now wholly healed, but still marked by the lines of vegetation. On the other hand, the more distant hills to the east and southeast at 3-8 miles have perfectly smooth contours, especially on the lower slopes. The arroyo pattern indicates former land use and erosion in the area indicated.

3.0-7.0 miles. The plain reaches to the beginning of a long rise at San Cayetano (6.7 miles). There is a black, deep alluvium covering the original land surface.

7.1 miles. Here is a cut made at the original construction of the highway. It shows what appears to be the former weathered "C" horizon of the bedrock, consolidated with slope wash and mixed with red soil at the surface. There are numerous unweathered stones mixed with the soil in the upper portion. Also there are a number of potsherds in the top one foot of the bank, as well as many sherds on the surface of the ground in the vicinity. The surface sherds of course demonstrate a former human domestic occupation, and their presence in the upper horizon indicates that the occupation preceded the formation of the soil from the downward washing of the slopes above and to the east.

7.3 miles. To the west of the road, at the foot of a short, steep slope, and 100 feet from the highway, is an extensive new excavation. There are exposed about 5 feet of black slope wash, or alluvium, mixed with small stones and rocks. Among them are a few potsherds in the upper 1 foot of the profile.

8.1 miles. The bank of a road cut shows 1-2 feet of weathered topsoil, brown and mixed with stones, over weathered volcanic rock. Potsherds are numerous to a depth of at least 1 and perhaps 2 feet.

8.4 miles. The road has now climbed the first, lower slopes of the southeastern mountain. At this point there is a low ridge crest, or spur, covered with grass or low brush. The country rock is a hard basalt. There are 0-3 feet of brown, undifferentiated soil over relatively unweathered rock. This soil carries numerous inclusions of undecomposed rock fragments. Apparently there has been considerable recent weathering of an old erosion surface on the basalt, accelerated perhaps by some accumulation of wash from the slopes above. In any case considerable time must have elapsed since the erosional loss of the original profile.

9.0 miles. Here is a small arroyo, shallow, filled with trees up to ten feet high. There is no recent gullying. The soil is red-brown and rocky, formed directly over slightly weathered basalt.

9.1 miles. Here is a new road cut. There are 2-3 feet of mixed rock and red soil over the weathered bedrock. Sherds are seen to the depth of 1 foot.

9.35 miles. Here is a road cut through a low spur on the long, gentle, north-facing slope from the mountain to the southeast. The parent material is a conglomerate, or consolidated aggregate, derived probably in very ancient times from the southeastern volcano. The "A" horizon is 0-15 inches, dark brown, the "B" horizon is 0-20 inches. There are potsherds and obsidian flakes throughout the upper portion of the soil. Here is Profile X. The analysis of that profile indicated a relatively new horizon formation but one in which the weathering and associated movements of soil components had progressed appreciably. More than a few decades, or even centuries, would have been required, even in the warm, damp Tepic climate, to reach the present stage of development. The erosion cycle, the recovery from which is displayed in this profile, must have occurred at least a thousand years ago, and perhaps longer.

10.0 miles. This is the crest of another spur from the southeastern mountain. The vegetation is grass and low brush. There is a red-brown surface soil over deeply weathered rock, resembling the exposure previously described. Potsherds were found in the banks of the road cut.

10.6 miles. Here is a broad hollow between spurs from the eastern mountain. It is overgrown with brush, but the banks are very gently sloped and the bottom is relatively flat. There is a small existing arroyo in the bottom which appears to have been cut during recent decades but which shows at least partial recovery. On the bottom of the hollow is red-brown soil, mixed with stones. Both soil and stones probably have been washed in from the banks.

11.0 miles. Here is a low ridge, or spur, with the same vegetation. There is brown soil 0-18 inches deep, with a rock mantle, grading into a deeply weathered old rock, probably sandstone or shale. Here was taken the series from Profile XI. The analytical data suggest an ancient occupation, with resulting denudation of the then mature surface horizon. This would have been followed by reconstitution of the exposed lower horizons with the formation of the present brown upper layer. The latter appears to have been washed and partially truncated in relatively recent times, producing the existing rock mantle.

There are no potsherds in this profile, since this soil has weathered in situ and there has been no deposition of material from the slopes above, as there was at the area of Profile X.

11.1 miles. Here are 1-2 feet of mixed rock and red soil over the weathered bedrock. There are potsherds in the upper few inches of the bank exposure, making it clear that the soil-rock mixture has been moved in from above.

11.1 - 12.7 miles. This stretch, which ends at the summit of the divide between the Tepic basin and the valley to the south, continues to show the same types of soil exposure, mixed rocks and soil over the weathered and disintegrated bedrock.

Summary of Field Observations.--As will be noted from the foregoing descriptions, the long, lower slope of the high mountain to the southeast of Tepic seems to have once been the site of intensive human settlement. Erosion removed the mature upper horizons. This period was followed by one of vacancy, during which there was time for the redevelopment of a weathering surface horizon, containing clay and organic matter, to a depth of roughly 1-2 feet. This newly weathered zone, as indicated by Profiles X and XI, was formed upon the old truncated soil surface, or upon a mass of detritus moved down by water action from the higher ground to the east. If the new parent material was such detritus, potsherds from the preceding occupation are still to be found buried in it. If the old erosion surface has been reweathered there will be no sherds.

Conditions vary from one locality to another with respect to the degree of preservation of the secondary surface horizon, for the land has been used for agriculture and stock raising at least to a moderate degree in modern times. At a few spots, such as where Profiles X and XI were taken, the new soil is clearly evident as a light or dark brown superficial layer overlying the invariably red soil which grades into fragmented or disintegrated bedrock. At most places, however, the existing surface is composed of the red soil, mixed with sharp, unweathered rock fragments, ranging from the size of a pea to several inches in diameter. Such a condition bespeaks an accumulation from an old erosion surface, higher up the slope, which has been denuded a second time by modern human operations, or which has never been permitted to develop a new soil on its surface. Of the two possibilities the former is the more likely on historical grounds, since there is no mention of villages to the southeast of Tepic in the sixteenth-century documents, and there is no reason to suppose that this area was reoccupied intensively until at least the end of the eighteenth century.

CONCLUDING DISCUSSION

The analysis of soil constituents combined with examination of erosion patterns gives us an initial insight into the habitation history of the Tepic area which may eventually be supported by evidence derived from cultural remains. Three principal occupation cycles may be suggested. The first is ancient, probably long antedating the Spanish conquest, and can be allocated to at least two areas; the lower slopes northeast and southwest of Jalisco and an ecologically similar region to the southeast of Tepic, beyond the village of San Cayetano. Both spots were inhabited by pottery-producing peoples. They no doubt had agriculture, since they were responsible for profound erosion of the native, mature soil profiles and for extensive alluvial deposits at the foot of the lower slopes.

The second occupation, which to be sure may have been simply a phase of the first and continuous with it, was in existence at the beginning of the sixteenth century when the country was overrun by the Spaniards. It covered, beyond much doubt, the lower slopes as far as a few miles southwest of Jalisco, the escarpment country to perhaps five miles north of Tepic, and the irregular hill and plateau area several miles to the east and northeast. The bottom lands to the immediate south of Tepic should also be included, for such a fertile stretch of land would not be neglected by even a primitive culture. The presence of local recovery of the surface soil horizon on the lower mountain slope to the southeast indicates a rather long period of quiescence at this point and therefore relative absence of use during the second phase of occupation. Where it was intense this phase was accompanied by the general removal of all topsoils and the formation of numerous and deep arroyos.

The third stage extends from the mid-sixteenth century to the present time, and includes most of the area mentioned in connection with the second stage. The effect of milpa agriculture and the livestock introduced by the Spaniards has been to reduce the topsoil about as fast as it is formed and to maintain very shallow horizons of organic matter on both white ash, or pumice, and red earth. Locally the strain on the soil has been variable. In a few relatively rare instances the former erosion surface, or accumulation of the wash detritus from the slope above, has had an opportunity to initiate the formation of a new soil. More commonly there has been serious truncation or complete elimination of the upper horizons, leaving unmodified parent material, or "C" horizon, at the surface of the ground. Simultaneously many active primary arroyos are noted, some of the older of which may display the beginning of recovery.

The conclusions based upon examination of soil conditions conform in a general way to what is known of the history of the region from documentary and archaeological sources. Sites established by pottery-producing cultures prior to the conquest have been described on the lower slopes of the mountains facing both sides of the valley. The earliest Spanish invaders (as seen in the accounts of the expeditions by Francisco Cortez and Nuño de Guzman) found large villages or towns at Tepic and Jalisco. Secondarily Jalcocotan and Mecatan are mentioned, although Compostela was a Spanish settlement. No villages appear to have existed in the sixteenth century to the southeast of Tepic, a fact which is in conformity with the absence of extreme, recent erosion in that vicinity. After the conquest the population declined almost to the vanishing point but rose again in the seventeenth and eighteenth centuries. At this period, or later, the Bellavista-Puga area was developed with sugar cultivation and a cotton mill. The contemporary severe surface erosion near these pueblos, with profound loss of top soil, therefore dates probably from the past one or two hundred years. It continues to the present day. The region north of Tepic to and beyond the junction of the road to Jalcocotan seems to have been less intensively occupied in historical times, although it is now suffering considerably.

I include a sketch map indicating the suggested possible areas of land use near Tepic (see fig. 11).

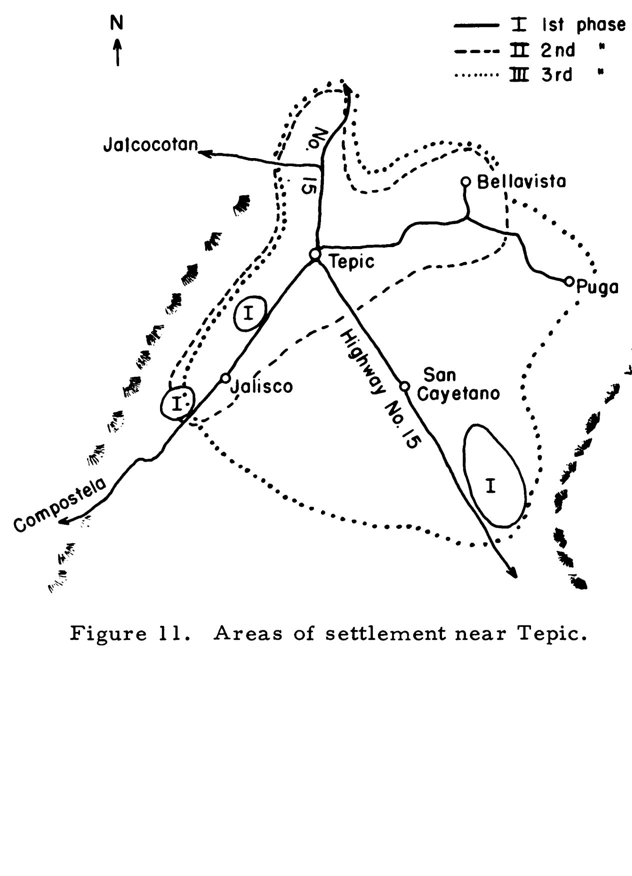


Figure 11. Areas of settlement near Tepic.

VIII. PROFILE ANALYSIS AND EROSION MORPHOLOGY IN THE VICINITY OF GUADALAJARA

The modern city of Guadalajara contains approximately 800,000 inhabitants and is solidly built up over an expanse of roughly 40 square miles. The suburbs extend from three to five miles beyond the formal city limits. The entire metropolitan complex lies in an uneven plain, traversed originally by the small stream known as the Rio Atoyac. The plain is bounded by the Rio Santa Rita (an affluent of the Rio Grande de Santiago) on the east, northeast, and north, by the high ranges north of Lake Chapala on the south, and on the west by the broken, hilly country which merges into the valleys of Tala and of Cocula. The elevation is close to 5,000 feet, the climate relatively cool and dry.

Such a large area can not be subjected to a complete and intensive soil-habitation study, particularly in view of the vast urban development in the center. Yet it is worth some attention as constituting a type of environment intermediate between the warm, rather damp Pacific escarpment to the west and northwest, on the one hand, and, on the other hand, the cool but arid interior plateau which in the east reaches from the western Bajio to the Atlantic escarpment. It has been necessary, therefore, to select certain accessible and illustrative localities for detailed examination.

THE TONALÁ REGION

The first test area may be designated the Tonalá region (see fig. 12). One arrives there by way of National Highway No. 80, which emerges from the center of the city east-southeasterly so as to pass just north of the suburban town of Tlaquepaque. Here is found the junction of Highway No. 80 with a side road which proceeds south to enter Tlaquepaque. Along the highway the country becomes open and subject to heavy cultivation. The land rises very gently for the next two miles as far as the junction with a paved road which passes north-northeast approximately 2-1/2 miles to end at the town of Tonalá.

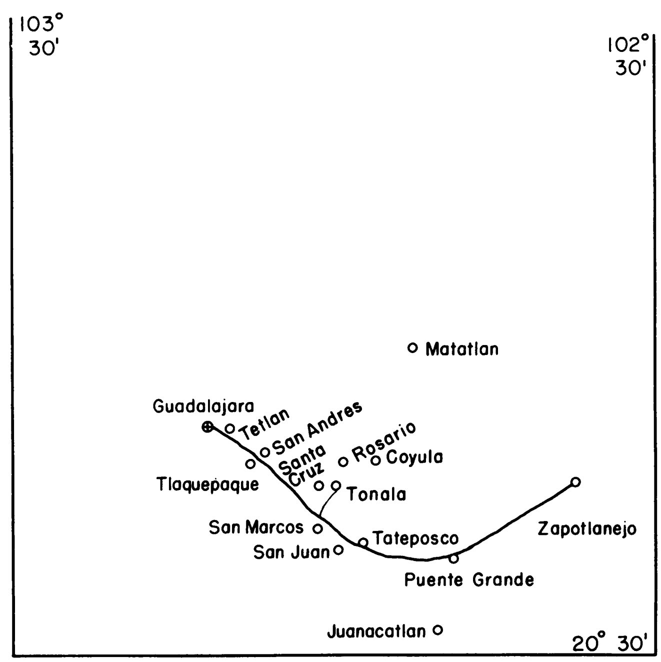


Figure 12. The Tonalá region.

To the east of this road and parallel to it is a low ridge culminating in a hill 200-300 feet above the level of the road and of the town of Tonalá. On the other side this ridge falls away southeastward to a level plain, or bottomland, perhaps three miles in its longest dimension. Meanwhile if one continues to pursue Highway No. 80 beyond the junction of the Tonalá road he descends another easy grade, dropping diagonally down the southeastern slope of the ridge 1.9 miles to the very small village of Tateposco at the foot of the slope. East of Tateposco the highway crosses the bottomland, keeping a range of low hills one half mile to the north, for about three miles and then enters hilly country. Interest here is confined to the Tonalá ridge and immediately adjacent lowland.

The underlying country rock is predominantly a dense, gray basalt. This rock once underwent profound weathering to form red-colored soils such as are now frequently seen throughout western Mexico. At a more recent date extensive portions of the territory were covered with a deposit of volcanic origin. This material is at certain points a clear, pumicelike ash, but more frequently is a relatively compact, usually stratified, mixture of ash with silt, sand, or even gravel, almost invariably containing finely fragmented obsidian. The ashy deposit may reach depths of five or ten meters and weathers to form gray, brown, or even black soils with highly developed, thick caliches, or hardpans. On slopes under extreme erosion the entire ash-sand deposit may be swept away, to expose the underlying red earth or basaltic derivative, or the latter may be brought to view by deep gullying or channel cutting.

Wherever thus exposed, the surface of the red basaltic material shows an apparently extreme degree of erosion. There is never the semblance of a mature soil profile in place. The topmost layer of the red earth under the unconformity consists of partly or profoundly weathered fragments of rock, mixed with varying quantities of finely divided soil, perhaps clay, but never with the indication of an "A" or a "B" horizon or any significant accumulation of organic matter.

We must assume that the deposition of the sandy ash occurred prior to human occupation of the area. This is for several reasons:

1) The universal and extreme destruction of the former red earth surface, if accomplished by man, would have required enormous agricultural activity. On the other hand, it can have been an accompaniment to generalized devastation following volcanic disturbance.

2) The topsoils on the sandy ash deposit, where they are well developed, will have required at least several centuries for their formation.

3) The depth of the caliche formed in the sandy ash may reach several feet. This also will have required a very long period of time.

4) Despite the occurrence of numerous potsherds and worked obsidian on the surface of the ground, nowhere within the deposit itself can any trace of such artifacts be found. Such an absence is inexplicable if heavy human occupation preceded the laying down of the ashy deposit. This conclusion is reinforced by the discovery at several places of potsherds within alluvial washes derived at a later date from the original ash-sand complex.

We now discuss a series of localities in the Tonalá region which illustrate the effect of human occupation on the terrain as described in the preceding paragraphs.

Test locality 1. The first locality is 0.9 mile east of Tateposco, just north of Highway No. 80, and one half mile from the foot of the ridge to the southeast of Tonalá. The bottomland has been excavated at numerous spots for the manufacture of adobe bricks and shows one or more feet of dark gray topsoil over a caliche of considerable depth. Here a gully has cut its way from north to south. It has vertical sides from 15 to 20 feet deep and is from 20 to 40 feet across. The bottom is flat and covered with grass and bushes, attesting an age of at least several decades. There are 2-3 feet of topsoil over a caliche that extends 5 or 10 feet downward, eventually to grade into unaltered stratified silts and sands.

A series of samples showed the following composition; (Profile No. IX):

No.	Depth (in.)	pH	Clay (per cent)	Carbon (per cent)
311	4	6.4	11.21	1.46
312	8	6.4	12.44	1.36
313	12	6.3	11.63	0.73
314	24	6.4	13.36	0.66
315*	30	6.4	3.11	0.02
316	36	6.4	7.06	0.20
317	48	6.6	6.69	0.12

*Top of caliche

Several matters deserve comment. The pH is uniform through 48 inches, and is on the acid side of neutrality. The caliche therefore is not calcareous, and the soil is low in carbonates if indeed they are not absent entirely. This condition is found consistently throughout the Guadalajara region with soils derived from the volcanic ash-sand deposit and distinguishes this region sharply from other areas on the Central Mexican plateau, such as the Valley of Mexico, where the hardpans yield pH values of 8.0 to 9.0 and are unquestionably calcareous. The problem of caliche formation on the western plateau deserves much more careful study than I have been able to give it.

The clay is uniform at about 11-14 per cent in the topsoil, but the percentage is much lower in the caliche. This difference indicates that the caliche was formed prior to the development of the present clay content in the topsoil. On the other hand the uniform distribution through 30 inches of topsoil implies either that the clay has been formed too recently for vertical translocation to have been effective, or alternatively that the upper horizons have suffered artificial disturbance. The organic matter, according to the carbon content, is likewise much reduced in the caliche, although it does show a maximum at the surface, diminishing significantly to a depth of 30 inches. Such a distribution of organic carbon would require a relatively long period for development without any material disturbance.

It is probable that we have here an old soil, representing an advanced degree of maturity, originally formed on the volcanic ash-sand deposit. It had time to develop a very thick caliche, or hardpan, and a well-differentiated surface profile. It subsequently suffered disturbance or loss to this profile above the caliche such that the distinction between horizons was obliterated. Still more recently there has been reconsitution of the organic matter with gradation of concentration, and perhaps some new formation of clay.

Just when the disturbance of the mature soil occurred is impossible to determine from the visible evidence. However the land surface today is strewn with potsherds, whereas none appears in the vertical exposures. Since this locality is half a mile from the nearest slope the sherds cannot have been washed in, but must have been dropped in situ. They are sherds typical of the late preconquest or early colonial era. This means that the present surface came into existence no later than the sixteenth century. Consequently the soil disturbance must have been contemporary with, or have antedated, the distribution of potsherds.

Test locality 2. On the entire southeast face of the ridge, and extending down the slope to and past the highway, are numerous gullies. Furthermore the steeper portions of the slope show sizable areas laid bare by surface denudation, slumping, and other manifestations of general and intense erosion. Examination of the gullies crossing the highway--too numerous to warrant description in detail--shows some of them to be active and of very recent origin, some to be ancient and now inactive, with grass and brush growing on the sides and bottom, and some to be ancient but now undergoing rejuvenation. The severity of the land wear much exceeds that visible elsewhere in the vicinity, for instance in the hills a few miles toward Puente Grande or in those immediately to the southeast. Moreover all the gullies have been and are being cut through the original soil, that is, the volcanic ashy sand, or even into the underlying basaltic red earths. On these slopes, at least, there is no evidence of aggradation, with buried artifacts and secondary arroyo formation. We are dealing with a primary erosion cycle only, a cycle which probably began several hundred years ago, but which has never ceased and is still in progress.

Test locality 3. A particularly large gully of the type just discussed crosses Highway No. 80 about halfway down the grade between the Tonalá road junction and Tateposco: at 1.1 miles southeast of the junction. It has developed vertical banks, in places 20 feet deep, and is perhaps from 40 to 50 feet across. It shows the upper 12-18 inches to be dark gray in color, and consists of dense, compacted, ashy silt down to the very tough caliche at 48 inches. There are many surface potsherds but none in the banks. A sample series was taken as far down as it was possible to reach (Profile No. X) which showed a composition as follows.

No.	Depth (in.)	pH	Clay (per cent)	Carbon (per cent)
318	4	7.1	8.62	1.16
319	8	6.6	14.00	0.98
320	12	6.5	14.80	0.75
321	24	6.5	11.78	0.36
322	36	6.7	9.77	0.49

The pH is slightly acid. The clay distribution is somewhat erratic, and no significant trend can be established. The organic matter as deduced from carbon is high at the surface and falls rapidly below. Thus the appearance is much the same as that of Profile IX and gives evidence of an ancient soil which has lost its surface horizons. Although at present there is indication of only slight translocation of clay there has been definite reconstitution and redistribution of organic matter. The loss of the original topsoil consequently occurred within the past few centuries but not within recent decades. As in the preceding profile the potsherds were laid on the surface after the loss of the former "A" or "B" horizons.

Test locality 4. A point 0.25 mile southeast of the Tonalá road junction is almost at the top of the grade surmounted by Highway No. 80, although the long axis of the ridge itself continues to rise to the northeast. Here an excavation for road construction has produced a vertical bank approximately 4 feet high, in which the exposed profile differs from those previously described.

The upper 24 inches consists of a loosely aggregated brown soil, without visible horizon differentiation, containing potsherds throughout the matrix as well as on the surface, and clearly having been derived as an accumulation washed down from the slope of the ridge immediately to the northeast. This soil rests unconformably upon an ancient eroded red earth which consists of weathered and disintegrated basalt, mixed with finer material, in part clay. A series of samples was taken here (Profile No. XI).

No.	Depth (in.)	pH	Clay (per cent)	Carbon (per cent)
323	4	6.7	9.30	0.43
324	8	6.4	12.52	0.53
325	12	6.4	11.97	0.45
326	24	6.5	8.59	0.30
- - - - - - - -		unconformity - - - - - - - -		
327	1	6.3	18.75	0.17
328	12	7.1	-	0.07
329	24	6.8	13.11	0.07

The pH is slightly acid throughout the profile, the small differences observed being of little significance. The clay content of the slope wash is somewhat variable but of the same order of magnitude as previously found. The organic matter as given by the carbon does not diminish downward from the surface, and moreover has a generally low value. These conditions imply a relatively recent accumulation of mixed soil which has not yet begun to show an organized distribution of its components. This view is supported by the presence of numerous sherds within the soil itself. Thus the accumulation is clearly postoccupational and can have a maximum age of no more than 200-300 years.

The underlying soil has a somewhat but not greatly higher clay content, and is almost devoid of organic matter. It appears to have been severely truncated prior to the deposition of the slope wash. Although the destruction of the red earth soil may have occurred long prior to any human activity it is to be noted particularly that the volcanic ash-sand deposit which is found generally in the area is completely absent in this locality. Hence it must have been quantitatively removed during the occupational period, and the underlying basaltic formation laid bare. As a result the slope wash was afterward deposited directly upon the truncated remnant of the basaltic soil. Such a condition must denote an intensity of occupation far in excess of that which was present on the lower slopes of the ridge toward and beyond Tateposco to the southeast, and can signify only concentrated inhabitation, rather than land use for agriculture. The period of maximum pottery production and village organization is likely to have occurred somewhere near the year 1500.

Test locality 5. We proceed north northeast on the road toward Tonalá. At 0.5 mile the ridge crest to the southeast is clearly eroded heavily and is worn down to bare rocks and boulders. A gentle down-slope continues a mile or more to the west. A roadside ditch has exposed a very shallow top soil (2-10 inches) passing into a caliche. There is no evident formation of organic matter at the surface. Sherds are on the surface but not in the banks. This is the original ashy sand deposit almost completely denuded of top soil, the sherds having been placed after the denudation.

Test locality 6. At 1.1 miles from the junction there are several instructive exposures. One of these is on the western side of the road. A gully with steep sides and flat, grassy bottom brings to light a profile cut through stratified silty sand, fine at the top, grading into coarse at the bottom. The upper 3-6 inches show as a darker horizon which evidently contains some humus. There are surface sherds but none in the banks. We are dealing, therefore, with another truncated profile with sherd deposition on the surface subsequent to the loss of the original topsoil.

Test locality 7. At 1.1 miles on the east side of the road is seen a contact between the ash-sand deposit and the underlying ancient red earth. Road work has removed all but the lower 2-3 feet of the stratified silt and sand and has exposed a foot or more of the decomposing basalt. The latter appears again as a deeply cut erosion surface.

Three samples were taken (Profile No. VI), one six inches above the unconformity, one two inches below it and the third eight inches below it.

No.	Depth (in.)	pH	Clay (per cent)	Carbon (per cent)
129	6 above	6.6	5.8	0.10
130	2 below	6.0	56.2	0.30
131	8 below	5.9	38.2	0.17

The difference in clay is striking: above the zone of contact about 6 per cent, directly below it 56 per cent. The high value for the red earth is testimony to the long period of development of the ancient soil prior to its destruction and burial by the volcanic ash-sand deposit, long before the advent of man. The carbon values attest the almost complete absence of organic matter in both types of material.

Test locality 8. Not more than 50 yards from locality 7, on the east side of the road, is an excavated exposure at the foot of a long, and relatively steep, southwestward-facing slope. The result of the excavation has been to cut an 8-foot vertical section at the base of what must have been, prior to the building of the modern road, a rather sharp decline. The relations are depicted in fig. 13 where the vertical component is highly magnified.

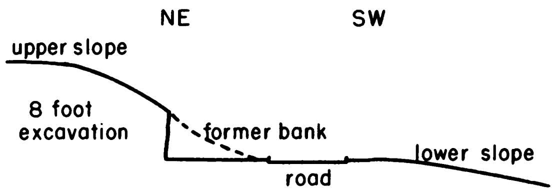


Figure 13.

The parent material consists of finely layered, or stratified, ash, gravel, sand and silt, the coarser material being toward the bottom and the finer in the upper levels. A great deal of finely divided natural obsidian is seen throughout the profile. Ploughing and planting have been carried on until recently at the surface. A sample series was taken at a point where the bottom of the excavation did not reach the underlying red earth, but where the lowest horizons appeared to consist of substantially unaltered coarse sand and gravel (Profile No. XII).

No.	Depth (in.)	pH	Clay (per cent)	Carbon (per cent)
330	3	6. 9	5. 63	0. 54
331	6	6. 7	6. 70	0. 52
332	12	6. 6	5. 79	0. 26
333	24	6. 2	9. 00	0. 41
334	36	6. 4	7. 63	0. 21
335	48	6. 2	9. 94	0. 34
336	72	6. 6	5. 19	0. 04
337	96	6. 9	3. 50	0. 03

In this profile the clay content is low and irregular from top to bottom. The organic matter, as shown by the carbon, has a moderate to low value at the surface, a low value from 1 to 4 feet, and, from 6 to 8 feet, disappears almost completely. There has been no perceptible caliche formation. Probably the inclination of the bank at this point was so great in the past that accelerated drainage prevented a hardpan from being formed. A careful search disclosed no potsherds in the bank, although they are numerous on the surface.

The low and erratic clay content and the failure to demonstrate a significant amount of organic matter in the upper horizons indicate that we have here a profile from which the weathered zone has been entirely removed, leaving what once may have been the "C" horizon together with the underlying mass of unaltered parent material. The relative steepness of the slope and the operation of agriculture has favored continued surface erosion and prevented the establishment of a new weathering zone in the upper few inches of the soil. The period of acute sheet erosion probably coincided with that of maximum occupation, a few centuries ago. Consistent land use in the intervening centuries has effectively obstructed recovery.

Test locality 9. For the next 0. 8 mile (1. 1-1. 9 miles from the junction with Highway No. 80) the Tonalá road traverses the western slope of the main Tonalá ridge. The land shows uniformly very severe surface erosion whereby the topsoils on the ash-sand deposit have been removed down to the caliche. In many areas the entire ash-sand deposit itself has disappeared with widespread exposure of the red earth, or even the unaltered bedrock. These conditions are particularly manifest on the upper and steeper slopes toward the summit of the ridge.

As an illustration a borrow pit at 1. 4 miles may be cited. There is a deposit of white, sandy ash in direct contact below with a red earth. The deposit is from 3 to 5 feet deep but its surface consists of bare caliche, all softer material having been washed away. There are potsherds lying on the exposed caliche but none in its matrix. This denudation probably first occurred at the time of intensive local habitation.

A similar state is observed at 1. 5 miles where an old arroyo which had remained inactive for a long time was reopened below the paved road by the concentration of run-off during storms. The arroyo is now approximately 20 feet deep and 50 feet across. The exposed profile shows patches of residual topsoil alternating with raw caliche, a caliche 2-4 feet thick grading into ash and sand. The latter lies, as usual, unconformably on red earth, or even directly on unaltered boulders, or masses of basalt. There are an unusually large number of surface sherds, but none buried in the soil.

Test locality 10. The road reaches the summit of the ridge crest at about 1. 9 miles from the junction, and 0. 5 mile from the modern town of Tonalá. The ground is here level and gullying is absent. There is an excavation which has produced a pit with walls some 4 feet high. The exposure is of an incipient topsoil developing over gravelly, partially weathered sandy ash. The excavation just reaches the top of the original caliche, which is unusually far below the surface. Samples were taken (Profile No. XIII).

No.	Depth (in.)	pH	Clay (per cent)	Carbon (per cent)
338	3	6. 7	6. 82	0. 57
339	6	6. 6	6. 00	0. 36
340	12	6. 6	5. 24	0. 29
341	24	6. 7	3. 25	0. 21
342	36	6. 7	4. 57	0. 16
343	48	6. 6	2. 57	0. 19

The percentage of clay is low but shows a slightly greater value toward the surface. The carbon value is only moderate but is at a maximum at the surface, diminishing consistently below. We have here the original parent material, denuded of its topsoil, but just beginning to develop new clay and organic matter. The reconstitution is possible, despite agriculture and grazing, because the land is level, and there is no contemporary tendency to wash off newly produced fine material, as on the slopes of the ridge.

Summary of findings in the Tonalá region. --The foregoing observations indicate the following sequence of events in the area south and southeast of the present town of Tonalá. At some geologically recent time the native basaltic rock had produced a soil high in an iron-bearing clay, of the type to which we refer as a red earth. In some manner this soil was devastated and on it was laid a deep deposit of ash, silt, and sand, frequently showing by its fine stratification that it was water borne. These events took place prior to occupation by man, or at least prior to any pottery-making culture.

Subsequently a new soil matured on the ash, probably of a gray or brown type, with from two to four feet of dark, humus-containing topsoil. Where climatic and drainage conditions favored it, in particular on level areas and gentle slopes, thick caliches were formed under the topsoils. Then the area was settled and an erosion cycle ensued. Topsoils were washed away, and numerous gullies, or arroyos were formed. During this period large numbers of potsherds and worked obsidian chips and artifacts were distributed over the surface of the ground. In some localities (I found only one) sherd-containing detritus was accumulated at the foot of slopes.

The center of occupation, and the focus of really intense erosion lay along the crest and slopes of the ridge south and east of the modern village. The occupation area may, to be sure, have extended past the town to the low hills northwestward, but I was not able to examine that locality. There is little doubt, however, that the thickly settled, or built-up area was far more extensive than at present.

The era of maximum human activity could not have fallen in remote antiquity. New weathering and reconstitution of "A" and "B" horizons on truncated profiles has not proceeded far. In some profiles (Nos. IX, X, XIII) the renewal of organic matter at the surface has reached appreciable or considerable quantities, whereas in others (Nos. XI, XII) the values are low, and very uniform throughout the profile. With respect to clay content, nowhere is there such a substantial and unequivocal gradient, diminishing downward, as would indicate significant new formation in the upper horizons. The higher percentage values for clay found in Profiles IX and X above the caliche probably represent a residue from the original mature soils rather than recent new formation.

We must recognize of course that the land in the general vicinity of Tonalá has been subject to continuous agricultural use and to grazing during the past few centuries and that the establishment of new surface weathering would thereby be retarded. Nevertheless if the primary erosion cycle had reached its peak in extreme antiquity one would expect a more substantial recovery than is now to be observed. Furthermore the ceramics which are universally scattered over the land surface are well executed and appear to represent a technically advanced culture.

These considerations tend to the conclusion that the single severe erosion cycle demonstrable in the Tonalá region may be ascribed to the period of the Spanish conquest, in the late fifteenth and early sixteenth centuries. At that time the town was much larger than it is now and probably extended southward along the ridge one or two miles beyond its present limits. Shrinkage occurred during the population decline of the sixteenth century and much formerly inhabited land was deserted. The peripheral areas, in particular southeastward to the bottom land beyond Tateposco, which had not been densely inhabited, but which presumably had been intensively cultivated, were allowed to undergo a perceptible degree of recovery. Nevertheless, the continued use of this land, even on a much reduced scale, for corn planting and grazing, has seriously retarded this recovery.

THE AREA WEST AND SOUTHWEST OF GUADALAJARA

We now turn to the area west and southwest of the city of Guadalajara (see fig. 14). It covers perhaps 300 square miles, plain and ranges of low hills. Much of it was occupied by native villages at the time of the arrival of the Spaniards, although some of it may have been very sparsely held.

Today our access is by two portions of a single highway, National Highway No. 15. The turning point is at the circle in Guadalajara, near the arch at the western end of Avenida Juarez. From this point Highway No. 15 runs westward 14 or 15 miles to the junction with the paved highway to Ameca, then northwest and north to Tequila, Ixtlan, and the west coast. The other segment of the highway proceeds south from the circle, past Santa Anita, and Santa Cruz de las Flores to the junction of the road to Acatlan, and then on to the western end of Lake Chapala, Morelia, and Mexico City.

From the junction of the Ameca road to that of the Acatlan road, with the exception of the purely urban portion, the area traversed by the highway has been observed. What has been done in effect is to take a transect representative of the western sector of the Jalisco plateau, fifteen miles east and west, then fifteen miles north and south. The purpose of the examination has been to determine as far as possible to what extent the degree of former occupation can be deduced from contemporary soil conditions. To this end several methods are employed: gross observation of erosion and gully formation, frequency and numbers of artifacts deposited, depth of top soils, physical and chemical analysis for a few components of profile samples.

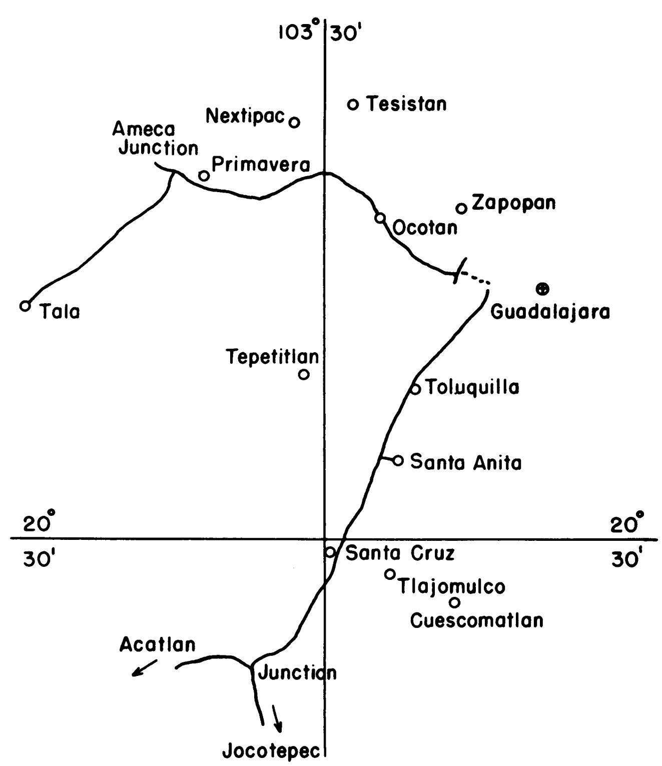


Figure 14. Area west and southwest of Guadalajara.

Throughout the transect mentioned the soils are formed upon a deposit of volcanic ash, sands, and silts, the same generic parent material as was found in the Tonalá area. There is considerable variation in detail. At certain points the deposit is a fine white ash, or pumice. At others there is stratified silt, sand, or even coarse gravel. Frequently there are intimate mixtures of all categories. Occasional exposures in deep barrancas, or on hilltops make it clear that the ash-sand complex was laid down on a preëxisting red earth which in turn had developed on a dark gray basalt, or in some localities a dense, black, vesicular pumice.

The ash-sand tends to weather so as to form a light to dark gray topsoil, depending upon the humus content. At a variable depth below the surface a caliche is usually produced which becomes deeper with age. The top of the caliche is characteristically exposed when the looser top soil is washed off following land use for agriculture or grazing.

For purposes of exposition we may discuss the land along the highway as one observes it in passing from the junction of Highway No. 15 and the Ameca road to Guadalajara, and thence to the junction of the road to Acatlan. On the first portion of the highway the direction is approximately 30 degrees south of east, and on the second approximately 30 degrees west of south. In order to segregate areas of different characteristics I have arbitrarily divided the entire stretch of Highway No. 15 into six segments, or sectors. The first sector extends from the junction of the Ameca road to a point approximately ten miles west, or northwest of the Guadalajara city limit; the second, from this point to one four miles west of the limit; the third, from this point to the city limit. Proceeding now southward, the fourth sector extends from the southern city limit to a point 9.7 miles beyond the limit; the fifth, from this point to the railroad crossing at Santa Cruz Flores; the sixth, from Santa Cruz to the junction of the road to Acatlan.

SECTOR 1.

At a point approximately ten miles west of the Guadalajara city limit a stream emerges from the range of hills to the south, approaches Highway No. 15 within 100-200 yards and runs parallel to it in a narrow valley for the next three miles. It then bends westward and continues in the direction of Tala. This stream is one of the headwaters of the Rio del Arenal, which eventually discharges into the Rio Grande de Santiago.

Throughout that portion of its course which can be seen from the highway, the river shows itself to be actively cutting its channel and exposing numerous deep profiles along its vertical banks. The channel averages 100-300 feet in width, with banks 30-50 feet high. The substratum is uniformly ashy sand, with a visible humus layer and a caliche of considerable depth. Near the junction of the Ameca road, where the river turns southwest across a broad meadow, the unconformity between the white, ashy sand deposit, and the underlying brick-red soil is very sharp and conspicuous.

Along this four-mile strip the north- or northeast-facing slope, across the river, displays clear evidence of former erosion. There is a close succession of steep arroyos with dimensions apparently reaching 30 feet in depth and 60-100 feet in width. Their cross section is characteristically V-shaped. The sides are smooth and covered with vegetation. Indeed the upper portion of many of these arroyos is covered with pine trees. Some of the trees reach a height of nearly 50 feet, and must be 50 or more years old. Toward the junction of the Ameca road the pine is mixed with oak, and the forest effectively conceals the ancient erosion pattern.

The arroyos along the hillside run of course at right angles to the axis of the small river, or creek, and when active emptied into it. At some places, however, the mouths of the arroyos have now been pushed back by the stream, which has progressively undercut its southern bank. This has left the arroyos hanging in a manner similar to that seen in those streams which discharge their water over the upper edge of certain glacial valleys. A considerable period must have been required for the deactivation of these arroyos, for the smoothing of their contours, for their reforestation, and for the cutting away of their mouths by lateral extension of the main watercourse.

Numerous profiles are exposed along the highway. One of the most interesting appears at 1.1 miles east of the road junction. Here a recent, big arroyo has been incised nearly back to the highway pavement from the river, and indeed its recent extension has probably been produced as a direct result of highway construction, although in its lower reaches, close to the river, small trees and shrubs have had time to grow in the bottom of the gully. It is 20-30 feet across, and nearly 100 feet deep, with perpendicular sides and flat bottom. The exposed profiles show a caliche many feet thick passing gradually below into the customary stratified silts, sands, and gravels. Above the caliche there is a dark brown topsoil, separated by a sharp change in consistency from the caliche. The topsoil varies in extent from almost complete absence to a depth of 3 feet. Where the depth is at a maximum the upper few inches are visibly darker in color and contain more organic matter than the rest of the topsoil.

This remnant, for it seems to be such, is the most highly developed soil which I was able to observe in the area, and may be taken as probably approximating the original mature profile. The latter would thus be conceived to embody four principal horizons: (1) the uppermost several inches to perhaps 1 foot (the "A" horizon in the technical sense?), passing into (2) 1-3 feet of lighter brown, looser soil (the "B" horizon in the technical sense?), separated by a knife-edge discontinuity from (3) a tough caliche, 1 to several feet thick, which in turn merges into (4) the unaltered parent material, ashy silts and sands. The degree of erosion caused by human occupation can, of course, be judged by first, the depth and frequency of gullies cut through the topsoil and caliche, and second, the extent to which the topsoil over the surface has been washed away, leaving the caliche bare and exposed.

The following specific localities are also to be noted:

<u>0.3 mile east of Ameca road junction.</u> At the foot of a long slope, there are 3-6 inches of dark brown soil, overlying 1-2 feet of light brown material, grading below into unaltered white ash. This profile also appears to have been only moderately reduced in depth if at all.

<u>0.8 mile east of junction.</u> At a flat area, near the river bank, the topsoil is absent and bare caliche is exposed over a range of perhaps 100 yards.

1.6 miles east of junction. A road excavation exposes 1-3 inches of topsoil over a caliche 1-2 feet thick, over stratified white ash.

1.7 miles east of junction. A small, shallow arroyo exposes 2-3 inches of gray topsoil over caliche.

2.7 miles east of junction. On the crest of a low ridge there is no topsoil and the surface of the caliche is bare.

3.3 miles east of junction. The perpendicular north bank of the creek is close enough here to be seen clearly. There is uniformly a dark upper layer about 6 inches deep, directly on the caliche.

4.0 miles east of junction. Here is a similar view of the south bank of the stream. There are 4-8 inches of topsoil.

From these illustrations it is clear that the region as a whole has suffered variable, but in spots extreme, loss of topsoil. From this loss there has not yet been appreciable recovery. Two factors would conduce to this failure to show significant rehabilitation. First, the land has no doubt been subject to at least moderate occupation since the peak of the erosion cycle, with some agriculture but particularly grazing. Second, the formation of new soil must in most instances have involved the weathering and disintegration of the exposed caliche, and the latter is quite resistant to the weathering process. It is of interest to contrast the condition here with that seen near Tepic, where, although the volcanic ash deposit is very similar to that found near Guadalajara, no caliches have formed. At Tepic, surfaces denuded of topsoil by ancient intense erosion have since formed distinct new weathering horizons several inches deep, containing much humus, in spite of continuous human occupation and agriculture. The most obvious difference between the two environments, apart from climate is the presence or absence of a caliche.

Evidence of ancient human occupation is found in the widespread prevalence of potsherds and less frequently of obsidian artifacts. Along the four-mile stretch of highway here discussed, a canvass was made for potsherds at eight locations, all level tracts near the road. At two of these no sherds were seen; at four a few to a moderate number were seen; at two the sherds were very numerous. There is little doubt that if a systematic hunt were carried out potsherds would be found nearly everywhere. Moreover, they are typically premodern, dating at least to the sixteenth century.

Although a reasonably exhaustive search was made no potsherds were ever found buried in the soil: they all lie on the surface. This condition implies that they were deposited at the time, or after the time when the topsoil was being washed out.

The existence on the steeper slopes of numerous large arroyos which have undergone extensive or complete recovery, and the severe, but not total, loss of topsoil from over the caliche speak for a single intense, although not utterly devastating erosion cycle. The presence of surface potsherds places the end of the active phase of the cycle no later than about 400 years ago. Its peak may have occurred considerably earlier.

The number and distribution of the potsherds is significant. They appear only on the surface, thus precluding a double erosion cycle and a culture antecedent to that indicated by the erosion phenomena just described. They never are observed in the great masses and profusion characteristic of dense, urban population. On the other hand they are scattered in appreciable numbers over a wide territory.

The primary conclusion which may be drawn from these findings is that several centuries ago there existed in the region here considered a rather numerous but scattered population. Its activity, probably by agriculture, was sufficient to cause massive soil damage. These people may have formed widely dispersed, small settlements of the ranch type, or they may have been permanently attached to more substantial towns or villages and have physically moved over the land only for purposes of crop cultivation. We do know that documentary sources and archaeological research give no indication of any sizable habitation center in the territory crossed by the four-mile stretch of Highway No. 15, east of the Ameca road junction. Nevertheless towns existed in the sixteenth century, and hence previously, in the Tala valley, and also several miles to the northeast. These towns could have supplied the agricultural population either in ranches or estancias, or even by temporary seasonal occupancy.

SECTOR 2

From the point where the Rio del Arenal emerges from the hills, if one drives along the highway eastward, or southeastward, as far as the junction of the paved road to the military airfield, he covers a distance of a little more than six miles. The highway and the railroad, side by side, follow the foot of the slopes of the low hills to the south and southwest. Northeastward a rolling plain, with here and there a few low west-facing bluffs, extends to the canyon of the Rio Santiago. We have measured distances along the highway in this sector west and northwest from the junction of the road to the airfield.

The over-all erosion pattern resembles that seen in sector 1. From the slopes to the southwest emerge numerous arroyos, many of them reaching and crossing the highway. As a rule they show considerable age.

At approximately five miles northwest of the airfield road junction, the hillsides to the south are conspicuously dissected by gullies which issue from the heavy stand of pine and oak covering the upper slopes. The heads of the arroyos are filled with the trees, some of which are from 10 to 30 feet high. The banks of the arroyos are smooth and the cross section is in the shape of a wide V.

Meanwhile if one looks across the railroad to the north he sees at a distance of a mile or two a line of bluffs perhaps 100 feet high. These have been incised by steep arroyos, spaced at intervals of from 200 to 300 feet along the face of the bluff. The banks are now sloping, with the bottoms smooth and grassy. In many of them are trees growing to a height of fully 50 feet.

This general picture of relatively severe gully erosion from which there has been substantial recovery continues throughout the sector. It represents an extension of the conditions observed in sector 1, further west.

Certain arroyos present features of special interest with respect to exposed soil profiles and occurrence of artifacts.

5.5 miles northwest of airfield road junction. Here a ditch has been excavated parallel to the highway, on the southwest side. There are 5 feet of alluvial, stratified sand and gravel lying unconformably over the surface of a fine-textured, laminated clay. There are 2 feet of weathered topsoil, dark gray to black, over the unweathered gray-brown sand. There was one potsherd found at the bottom of the ditch, but its source could not be determined and diagnostically it was useless.

At this site the soil appears to be a product of washing from the slopes above, rather than the standard volcanic ash-sand deposit. The 2 feet of gray-black topsoil, passing directly below into unaltered sand is a measure of the weathering and new horizon formation, and implies that the sandy wash is more than four centuries old.

4. 9 miles northwest of junction. An ancient arroyo is seen here, nearly 100 feet across, but very shallow and nearly filled in. The bank exposures, only 2-3 feet high, show the topsoil to have been removed down to the caliche. There are numerous sherds and obsidian flakes on the surface of the ground behind the banks. This, clearly, is an arroyo of large dimensions, cut through the original soil, but now almost completely reconstituted. The bordering topsoil, however, once worn away to the caliche, has not been reformed.

4. 0 miles northwest of junction. There are three old, deep, digitate arroyos emerging from the foot of the steep hill a quarter of a mile to the south, and passing down the gentle slope to the highway and railroad. At the highway they are about 100 yards apart each being 10-25 feet deep and 75-150 feet wide. They have well-developed sod and several small pine trees growing in the bottoms. The banks are smooth and slope gently except in places where recent rains or excavations have cut new exposures.

The parent material is alluvial sand of undetermined depth, derived from outwash from the hill immediately south. The upper 2-3 feet have been weathered. Of this, 0-12 inches are dark topsoil and 1-3 feet are caliche, this caliche clearly having been formed in situ during the weathering of the sandy alluvium.

Surface sherds are fairly abundant, some of them being technologically of a primitive type, unglazed, thin, and brown. At one bank exposure of the center arroyo I found a single obsidian flake and 2 sherds at a level 12 inches below the upper surface of the caliche.

It is evident that we have here an example of a double, or at least compound erosion cycle. The nearly complete recovery of extensive arroyos, the thin topsoils over a caliche, and the presence of numerous surface potsherds all simulate the conditions previously described which were taken to represent occupational activity by local groups from four to six centuries ago. In this area, however, the arroyos were channelled into alluvial, sherd-bearing slope washes, instead of into geologically original soils. Therefore the more recent occupation must have been preceded by one which caused the erosion giving rise to the alluvium which was later transected by the arroyos. Cultural and secular interpretation is not possible in detail without study of the ceramics involved, but we are justified, for this particular locality, in referring to two occupation stages. We might call them, solely for convenience, early and late.

3. 7 miles northwest of junction. Here is a small arroyo at the foot of the hills which has recently cut a new trench 5 feet deep. The soil is a sandy wash from the slopes above. There is a thin weathered layer on the surface; the deposit is relatively modern. No potsherds were seen.

2. 4 miles northwest of junction. An old arroyo, 6 feet deep and 150 feet wide shows approximately 6 inches of dark, humus-containing topsoil over a caliche. The parent material appears to be alluvial sandy wash from the slope to the south. No sherds were seen.

2. 0 miles northwest of junction. This is an arroyo similar to the preceding one. The topsoil is worn off to the bare caliche. No sherds were seen.

1. 3 miles northwest of junction. Here is a rounded knoll, about 200 feet in diameter, which, on the side facing the highway, has been deeply excavated. It is formed of stratified, or laminated ash mixed with sand. At the summit, an elevation of approximately 30 feet, the visible soil consists of only a dark gray layer, containing humus, 3-6 inches in depth. At the foot of the knoll the weathered horizon is deeper, 18-24 inches, of which the upper 3-4 inches are gray-black humus and the remainder a caliche, grading into unaltered ash.

From the observations cited it is evident that sector 2 resembles sector 1 as an area of general loss of topsoil and of arroyo formation. The frequency of potsherds is somewhat less and this may suggest a lighter land use. On the other hand, the discovery of several exposures by gullying of local washes from adjacent slopes, at least one of which contains artifacts, is evidence of an occupation antecedent to that responsible for the widespread gully erosion.

SECTOR 3.

This sector covers the 3. 5 miles from the junction of the road to the military airfield to the western city limit as it was posted in 1960. The character of the terrain does not differ appreciably from that noted previously. Certain specific localities present features of particular interest, and are herewith described.

1. 8 miles east of the junction of the airfield road. At this point lies the modern suburb of Colonia Granja, with a great deal of recent real estate developement. It is built on, or very close to, the site of the sixteenth-century village of Ocotlan, which has disappeared, at least under that name. At or near Colonia Granja it is possible to obtain several good views of the southwestern hill massif, the northeastern escarpment of which has receded from the line of the highway and railroad and now is three miles away, more or less. The intervening space is nearly level plain. The hills are clearly eroded, for many areas of surface denudation and numerous arroyos can be distinguished at a distance of several miles.

If one leaves the highway at Colonia Granja, and drives 1. 2 miles directly through the town he reaches the church. Back of the church is a low hill, which in 1960 was still open land. The slope is completely covered with old, grassy, but only partially recovered arroyos. Considerable intensity of former occupation is implied by the closeness with which the arroyos are spaced. Several potsherds were picked up in the immediate vicinity of the church.

0. 2 mile east of junction. Along the front of an escarpment, 20-30 feet high, paralleling the highway and facing the flat lowland which extends southwestward toward the hills, there have recently been several hundred yards of excavation of dirt for road and other construction A wide reach of profile has thus been

exposed. The parent material is stratified volcanic sandy ash, or pumice of the type found generally in the area The friable topsoil is 0-3 inches deep over a caliche which is darker in color then the unaltered ash beneath and has a depth of 6-24 inches. There are numerous surface potsherds, but none in the matrix of the soil. A series of samples was taken at this point (Profile No. III).

No.	Depth (in.)	pH	Clay (per cent)	Carbon (per cent)	Character of material
106	1	5.5	4.90	2.42	topsoil
107	3	5.9	6.30	1.02	topsoil
108	6	6.4	3.50	0.18	caliche
109	12	7.0	2.10	0.09	caliche
110	24	7.0	3.80	0.05	unaltered ash

The pH varies from neutral to rather acid at the surface. The clay content is low, but slightly higher in the topsoil than in the caliche. The organic matter is high at the surface but diminishes rapidly to an insignificant quantity at a depth of 12 or more inches. These results suggest destruction and loss of mature topsoil down to the caliche. Detectable recovery has taken place in the upper few inches with a slight increase in clay (effect of weathering) and more than a moderate amount of organic matter. However, this recovery has been confined to only the first few inches. The caliche itself retains its original character: a hardpan containing little clay and only traces of organic matter. This means that the surface recuperation has been recent, postdating the sweeping away of the assumed original surface horizons.

A special problem is posed by the color, for the caliche is impregnated with gray as far as the zone of transition to unaltered ash. The color is no doubt referable to substances derived from humus, and capable of penetrating the dense caliche. They have diffused downward, and perhaps have accompanied those materials, as yet undetermined for these soils, which have served to cement or solidify the caliche. This diffusion process, it must be considered, occurred during the formation of the original soil, not recently, while the surface topsoil has been generating new organic matter.

The presence of potsherds on the surface leads to the conclusion that the intense erosion, which caused the loss of the former mature surface horizons, can be ascribed to the circumconquest, or "late" prehistoric occupation. Hence 300-400 years would be allowed for the development of new clay and organic matter in the residual superficial strata.

<u>1.1 miles east of junction.</u> One sees several borrow pits and scattered diggings for commercial purposes. The upper 2-3 feet of the sand-ash deposit uniformly are light gray in color and consist of a hard caliche, covered by 0-3 inches of loose topsoil.

Several other profiles may be found just west of the city limit. All are essentially similar to those just described, and demonstrate moderate to severe surface and gully erosion associated with generally intense land use.

SECTOR 4.

This sector includes a stretch of 9.7 miles on Highway No. 15 as it takes a southerly direction from the circle and monument at the western end of Avenida Juarez in Guadalajara. The measurements are from the southern city limit, as posted in 1960. Other key points are the junction of Highway No. 15 with the side road to the archaeological site at Ixtépete, and with the side road (now cobblestone) to Santa Anita, respectively close to 2 and to 7 miles south of the city limit.

The terrain in this sector is generally level. The highway skirts the western edge of the plain which extends south of the city of Guadalajara as far as the east-west range of high hills just north of Tlajomulco and Cajititlan. The plain is broken here and there by isolated eminences, and is bounded on the west, at a distance of 0.5 to 2 miles by the eastern escarpment of the hill massif which covers most of the southwestern quadrant of a circle having the city for its center.

These western hills consistently show the scars of ancient gullying, which at one time was severe, but which now seems to have undergone significant recovery. The general appearance resembles that of the northern and northeastern escarpment as viewed from Highway No. 15 west of Guadalajara and described under sectors 1, 2, and 3. Indeed it is evident that the erosion of these hills is more or less continuous throughout their entire extent.

To the east of the highway the low hill directly south of the town of Santa Anita shows marked local gullying and sheet erosion which is still active. This is, however, confined to the lower slopes of the hill and is probably associated with contemporary habitation, gardening, and grazing activities of the villagers. Indeed this little locality furnishes a neat example of how urban or village occupation can intensively devastate the soils immediately adjacent to the center of the population.

At <u>2.4 miles south of the city limit</u> the highway crosses an arroyo approximately 100 feet in width and with banks 2-6 feet high which traverses the plain from the direction of the western hills. The exposures display an alluvial sand, with admixture of silt, apparently derived by outwash from the higher ground. There is little topsoil but a caliche of variable thickness reaches close to the surface. In the vicinity are a few potsherds.

If one follows this arroyo toward its source for about a mile, he reaches an archaeological site, Ixtépete, which has been partly excavated during the years 1958-1960. It rests on the sandy plain and consists of a compound pyramid roughly 100-125 feet across and 25-30 feet high. A ditch has been excavated in front of the base on the east side, and the top is reached by a series of steps. A preliminary study has been conducted and is summarized in the recent work by Corona Nuñez (1960). He assigns the earliest construction to "the beginning of the Christian era" and the cultural affiliations to the classical period at

Teotihuacan. The area evidently was a ceremonial center, for there are a number of smaller, unexcavated mounds in the close vicinity. There are relatively few potsherds to be found, far too few for a heavily inhabited spot.

The excavations have made it clear that the pyramid was built upon the surface of the plain. If one walks from the site about a half mile southeastward, he reaches the arroyo previously mentioned at a point where an extensive cut has been made to secure sand for construction. Here the arroyo has gouged into a slight rise or knoll in the plain and has produced a bank 15 feet in height. The soil is composed of water-deposited silt, sand, and fine gravel to a depth exceeding the height of the visible bank. There is a recent secondary channel, developed as a result of digging operations, which is 30 feet wide and 4 feet deep, thus carrying the total vertical exposure to nearly 20 feet. At the undisturbed surface of the ground there is a weathered zone 24-30 inches thick. It is gray-black in color, grading into light gray and then into unaltered yellow sand. The relationships of the arroyo and the site are shown in schematic profile in figure 15.

Certain conclusions may be drawn from these observations.

1. The outwash deposit was formed long enough ago to permit the development of a minimum of 30 inches of humus-bearing weathering zone.
2. The pyramid was built after the deposition of the main body of the outwash.
3. If the pyramid is of the Teotihuacan period the transport of wash from the western hills must have occurred still earlier.
4. The potsherds and obsidian found on the modern surface must have been deposited after the outwash was laid down on the plain, and may well have been deposited during or after the building of the platform.

At 5.6 miles south of the city limit there is an arroyo which has been cut very deeply by excess road drainage. A compound profile is visible. The upper 4-8 feet consist of alluvial sands of varying consistency, together with coarse gravel which contains numerous stones and cobbles. These sands and gravels lie unconformably on an ash or pumice of the volcanic ash-silt-sand type found widely in the Guadalajara region. The latter soil, itself, displays several inches of a weathered horizon, probably truncated, but demonstrating that there had been a mature soil prior to the deposition of the sandy alluvium. The overlying sands have in turn weathered at the surface sufficiently to form a gray-brown horizon 2-4 feet in depth. Of this, when dry, the upper 2-3 inches is loose topsoil and the remainder caliche.

There are numerous surface sherds in the neighborhood, but, more important, also sherds in the caliche formed on the alluvial sand. This fact makes it clear that the sandy outwash was deposited at this locality after the beginning of human occupation in the area from which the outwash was derived.

A series of samples was taken here (Profile No. IV), which yielded the following data.

No.	Depth (in.)	pH	Clay (per cent)	Carbon (per cent)
111	3	5.5	15.6	1.57
112	6	5.9	14.9	1.06
113	12	5.5	12.9	0.75
114	24	5.7	12.6	0.58
115	36	6.2	5.5	0.27
116	48	7.1	2.8	0.11
117	60	7.1	4.4	0.39
118	84	6.5	7.5	0.39
119	108	6.1	6.2	0.25

The parent material was composed exclusively of the sandy and gravelly outwash. It did not include any of the primitive ash profile, buried beneath the outwash. The caliche extends to a depth of 2-3 feet, grading into unaltered sands. The profile shows a substantial content of clay in the upper 24 inches, which embraces most of the caliche. A long period of weathering is thus indicated. The carbon, that is, the organic matter, is high at the surface but diminishes steadily to a constant low value at about three feet. Here is evidently a new soil at a moderately advanced stage of development.

At the junction of the lateral road to Santa Anita, 7.0-7.1 miles south of the city limit, is another arroyo meriting consideration. It is an old channel, part of an intricate system which runs from the hills approximately a mile to the west, and continues eastward to and beyond Santa Anita. Until recently it was relatively inactive and had a grassy bottom 30-40 feet across and slumping banks 8-10 feet high. During the past few years it has been excavated much more deeply by heavy rains pouring off the pavement of the highway and is now cut to a depth of 12-15 feet close to the road. Several stages of the history of the arroyo can be observed at this locality: former cuttings and later fills have been reopened and exposed in profile. Repeated minor cycles of disturbance and quiescence are thus brought to light. To work these out in their temporal sequence would require a lengthy study, but their character can be illustrated by a single example, as shown diagrammatically in figure 16. To produce even the degree of complexity shown above would require a very appreciable period of time.

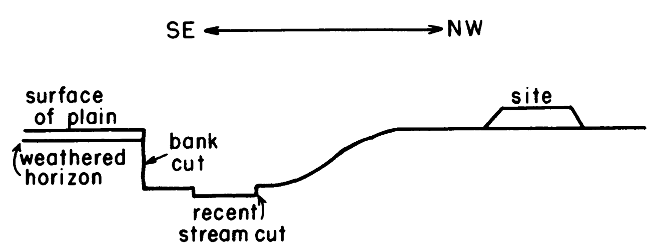


Figure 15.

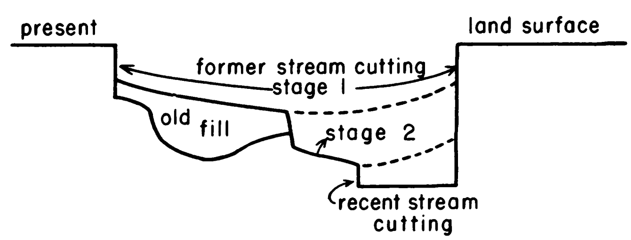


Figure 16.

The soil and subsoil consist of sandy or gravelly wash of the type found elsewhere in this area, although it appears to be deeper than at the locality previously described. At the surface the dark gray weathering zone extends downward no more than 6-12 inches. The topsoil is thin (2-4 inches), and covers a caliche of the usual depth, and extremely indurated at its surface. In a newly exposed portion of the bank three potsherds of primitive type were found at depths below the ground surface of 1, 2 and 3 feet respectively. A sample series taken here gave the following results (Profile No. XV).

No.	Depth (in.)	pH	Clay (per cent)	Carbon (per cent)
359	3	6. 8	5. 89	0. 90
360	6	6. 7	9. 76	1. 51
361	12	6. 6	7. 28	1. 30
362	24	6. 7	6. 69	0. 71
363	36	6. 7	6. 17	0. 42
364	48	7. 3	4. 65	0. 23
365	60	7. 3	4. 61	0. 22
366	72	7. 3	4. 63	0. 22

The reaction is nearly neutral with a slight increase in alkalinity with depth. The clay content is rather low but with perceptibly higher values toward the surface. The carbon is high at the surface, diminishing below to a minimum at 48 inches. The picture is one of a soil that is forming a new weathering zone at the surface but which has progressed only a short distance toward maturity. Alternatively the formation of new topsoil may have been impeded by the presence of men and animals for many decades at the junction of the main highway and the road to Santa Anita. Whatever the circumstances, it is probable that the age of the deposit is less than that seen at 5. 6 miles south of the city limit.

Several other arroyos are visible in this sector, together with numerous ditches and excavations which expose at least the surface horizons. These consistently bring to view alluvial sandy or gravelly washes. The topsoils and the zone of discoloration by organic matter are variable, but frequently are verv shallow, indicating either relative immaturity of development, or, perhaps more likely, continuous loss of substance due to agriculture and grazing.

SUMMARY OF FINDINGS AT SECTORS 1-4

In summary it may be proposed that the plain south of Guadalajara, and east of the southwestern highland, was originally covered with the sandy, ashy volcanic deposit widely found in central Jalisco. A mature soil profile was develped. Subsequently human activity in the hill region caused extensive erosion of slopes and the discharge of the loosened material onto the easterly lowland as outwash or alluvium. The peak of this cycle occurred a sufficiently long time ago to permit the growth of young soils, with a weathering depth of three or more feet on the relocated sands and gravels, even despite significant denudation of these new soils by the agriculture and grazing of the past several centuries. In the meantime artifacts in the form of potsherds were carried down with the wash, at least during the late stages of its deposition.

In more recent times other processes and events have taken place. Scattered but relatively numerous sherds have been dropped on the existing ground surface, many of which date to the era of the Spanish conquest, or previous thereto. Caliches have formed to a depth of 2-4 feet. Perhaps contemporaneously with the Teotihuacan period in the Valley of Mexico, buildings were constructed on the surface of the alluvial outwash in the plain. Finally a second erosion cycle has attacked the sandy washes laid down during the first cycle. The arroyos thus formed can be shown to have undergone secondary subcycles with alternate excavation and filling and to have now, in certain areas, recovered and been obscured by mature vegetation. In brief, the evidence from this sector reinforces that from sector 2 to the effect that long antedating the settlements found by the Spaniards in 1530, an "early" culture existed with one of its habitation centers in the hill region southwest of Guadalajara.

SECTOR 5

From approximately 10 miles south of the city limit to the railway crossing at Santa Cruz de las Flores, the highway leaves the plain and ascends a pass through a range of hills 200-600 feet above the level of the lowland. These hills are outliers of the main highland to the west. The area is interesting in the present connection chiefly because of an extensive system of gullies which is found here. This system, as far as can be observed from the highway, extends to the slopes 1-2 miles west, and southward to the edge of Santa Cruz. On the east it is confined to the lower, west-facing slopes. The most intense development is along a narrow valley, 300-400 yards wide, which parallels the highway and which is restricted by the steep slopes on both sides of the road, until, in its lower course, it widens and merges with the Santa Cruz lowland to the south.

The arroyos are very numerous, in many places forming branching, or digitate patterns, such that there is almost none of the original land surface left. Some of the gullies appear to be old, highly dissected, from 10 to 40 feet deep, with a V- or a U-shaped cross section, but, regardless of shape, covered with grass and brush at the bottom. Others, at scattered points, but particularly near the highway, are younger, indeed very recent, and from 10 to 30 feet deep. A few hundred yards beyond the summit of the pass on the highway and down the southern grade, a small tributary valley is seen to the east of the road which is similarly dissected by arroyos. At the foot of the south slope, near Santa Cruz, the arroyo system ceases, except for the lower courses of a few big terminal channels.

The principal soil in this area is the ash-sand generally observed farther north. However, the hill directly to the east of the highway at the summit of the pass exhibits a soil derived from the native bedrock. It consists of a mixture of fine, red-brown silt or clay and unweathered rock fragments. Frequently the rock fragments heavily predominate, and always the surface is densely strewn with rocks and boulders. This area has not been gullied but has definitely been denuded of its topsoil and reduced to partially weathered and disintegrated parent material.

Many of the arroyos expose slope wash, or alluvium in their banks. For instance, the narrow valley to the west of the highway, and just south of the summit of the rise, is channelled throughout its length by a wide, deep gully. The cut has been made through a slope wash more than 20 feet deep, derived from the badly eroded sides of the valley above the bed of the arroyo. For nearly a mile north of the railroad crossing at Santa Cruz de las Flores the highway descends from the foot of the northern hill over a gentle slope which represents an alluvial fan produced by the discharge of the arroyo system. New creek channels are being cut through freshly deposited stratified sands and gravels.

The topsoils have been badly devastated. At a point 2.1 miles south of the junction of Highway No. 15 and the side road to Santa Anita is an excavation which exposes 8-10 feet of ash-sand, with 0-16 inches of dark surface layer. At 2.6 miles south of the same junction, and at the foot of the low range of hills to the south, a roadside ditch shows 12-24 inches of dark surface soil, or weathering zone, over unaltered ash. These two profiles are typical of the region south of Guadalajara. But in sector 5, at the top of the rise and on the south slope through the arroyo system, the topsoil has been removed in toto, revealing extensive areas of naked caliche. Furthermore the hilltop soil over the native bedrock, previously described, indicated extreme truncation of the surface horizons. Finally, on the outwash south of the hills and just north of Santa Cruz, little if any weathering or new soil formation is to be found.

Evidence of human occupation is widespread. Throughout the area surface potsherds and worked obsidian are common. Furthermore, in two localities sherds were found in the soil. The first of these is at the foot of the southern slope, about 0.8 mile north of the railway crossing. Numerous sherds are seen in the banks of the terminal arroyos to a depth of 1-2 feet in the caliche. These sherds were washed down from the north, at a time contemporary with the general erosion of the land. The second is 2.5 miles north of the railroad crossing, at the point of maximum development of arroyos on the upper portion of the south-facing slope of the hills. Here sherds are found 1-2 feet under the surface of the caliche. They have been exposed by the cutting of the arroyos, which themselves have long been inactive.

From these facts it is clear that the soil itself is slope wash from the hill to the north, that sherds from prior occupation were buried in it, that a heavy caliche subsequently developed in the wash, that an arroyo system was then carved into the area, and that this system has since aged for a considerable period of time. These circumstances again argue for an "early" culture, which induced the first erosion cycle, long prior to the Spanish immigration of the sixteenth century.

SECTOR 6.

This sector includes that portion of the highway which runs south from Santa Cruz de las Flores across the lowland about 2.5 miles to the foot of the next ridge. The road climbs this ridge to its summit at approximately 5.5 miles from Santa Cruz and perhaps 500 feet above it, then drops slightly for another 0.7 mile to the junction of the road to Acatlan. The appearance of the hillsides is in marked contrast to that of the slopes north of Santa Cruz.

To the southeast, the north face of the high range (approximately 2,000 - 3,000 feet above the level of the plain) which lies between Tlajomulco and Lake Chapala is clearly visible. There are no perceptible gullies or denuded areas. The declivities are smooth and covered with shrubs and forest, and if serious erosion, due to man, was ever present the recovery has been virtually complete. Nearer at hand, on the north slope of the ridge facing Santa Cruz, there are a few arroyos, relatively widely scattered. Most of these are old, inactive, and filled with grass and mezquite; a few are recent and still undergoing enlargement. The system as a whole shows by no means the territorial extent nor the intensity of destruction of the complex arroyo pattern described for sector 5, north of Santa Cruz.

The soils are thin. On the steeper gradients of the ridge the topsoils are none or very scanty over the usual caliche, the parent material being ash or ashy sand. At the more-or-less level top of the ridge, before reaching the junction of the Acatlan road, the ash soils give way to those derived from the more ancient underlying rock, predominantly dark gray basalt. Here we find the upper horizons to consist of fine red-brown silt or clay, with extensive mixture of unweathered rocks and boulders, but with no caliche formation. Both the soils formed on ash and those on basalt appear to have undergone considerable loss of surface material, but on the other hand there is little or no excavation of arroyos. With respect to cultural residues, I found no surface potsherds between Santa Cruz and the Acatlan junction, whereas north of Santa Cruz they are abundant.

SUMMARY OF SECTORS 5 AND 6

The conclusion is warranted that the hills north of Santa Cruz were the site of intensive human occupation, either for habitation or agriculture, while those south of the village were lightly occupied, prehistorically, or not at all.

Certain specific points merit further attention. The conclusion just enunciated is based essentially upon the presence or absence of the following observed features of the terrain: (1) systems of closely spaced, deep, ramifying arroyos, some of which give the appearance of long inactivity, or recovery, (2) waterborne deposits in conjunction with these systems, that is, washes at the foot of slopes, alluvial fans, extensive sand plains, and the like, (3) potsherds or worked obsidian in profusion, some of the artifacts even being buried in secondary deposits associated with the arroyo systems.

In addition to these factors we have to consider the topsoils. In both sectors 5 and 6 the upper horizon of those soils formed on ash or sand constitutes a very thin layer, over a caliche, or none whatever. In soils formed directly on the bedrock, where no ash or sand deposit exists, the upper level is derived from what is evidently a residue of brick-red, or brown mature "A" or "B" horizons, mixed with unweathered rock fragments. In other words this is a badly truncated soil of a forest or a red-earth type. Since the depletion of upper horizons, regardless of soil type, is found to the same degree in both sectors 5 and 6, it follows that the condition of the topsoil must be at least in some measure independent of the ancient occupation to which extreme gullying, wash accumulation, and artifact deposition have been referred, and must be associated with some factor operating equally in the two regions. The factor which most clearly satisfies the conditions is the occupation for farming and grazing purposes which has lasted from the sixteenth century to the present day. The use of the gentler slopes and the flat country for corn cultivation and of the steeper slopes plus all other untilled land for the maintenance of cattle, horses, sheep, and goats, carried on consistently for 400 years, has undoubtedly reduced the plant cover, worn off the soft, mature topsoil, and exposed the caliche or unweathered rock layers. Recovery has also been restricted by the uninterrupted attrition of newly forming humus and clay.

CONCLUSIONS

These considerations may now be applied to the entire Guadalajara basin. In certain localities which it has been possible to examine closely, dense, intricate arroyo systems have been developed, for example, on the ridge south of Tonalá, in scattered locations along the northern escarpment of the southwestern highland, in the low hills north and northwest of Santa Cruz de las Flores. Associated with these systems are outwash deposits, some of them very extensive, such as the plain between Guadalajara and Santa Anita. Occasionally are found traces of double, or compound erosion cycles, in which artifacts have first been deposited by water transport and later exposed in the banks of modern arroyos. Such buried artifacts are seen on the Tonalá ridge, at a point 4.0 miles northwest of the junction of the military airfield road with Highway No. 15; in sector 2, along Highway No. 15 near Santa Anita; and on the slopes north of Santa Cruz de las Flores.

These localities may be designated as the probable centers of former human habitation. Some of them are ancient (I have called them "early"), although they can not be dated precisely. Among them might be included the settlements which produced the sandy outwash plain just southwest of Guadalajara, and those which were responsible for the elaborate arroyo system north of Santa Cruz. Others are more modern ("late"), such as the ridge just south of Tonalá which can be accounted for by the town and its estancias as described by the Spaniards in the first half of the sixteenth century, or such as the town site and hill slopes near Colonia Granja, which may be the former site of Ocotlan.

Finally, many arroyos which are still active, together with the universal denudation of topsoils, must be ascribed to cultivation and grazing throughout the past four centuries, and particularly in the more recent decades.

What we appear to have in the vicinity of Guadalajara is a chronological spectrum of soil disturbance. The process seems to have begun with settlements in the hills and on the ridges which caused loss of the mature horizons and the other phenomena of erosion. In one form or another the occupation has continued to the present day, undergoing in the meantime profound shifts of location and intensity. Enough is known now to establish the broad picture. Further careful and localized study should clarify the details.

IX. DISCUSSION AND SUMMARY

ARROYO PATTERNS

In both the Tepic and Guadalajara areas a generalized pattern in the distribution of arroyos is apparent. Near Tepic numerous primary arroyos are found on the slopes of the southwestern hills for some distance beyond Jalisco, to the north beyond the small village of Puchon, to the northeast in the vicinity of Bellavista, and to a lesser extent along the slopes of the mountain to the southwest. In those portions of the Guadalajara basin which were examined a comparable arroyo density was found on the heights east and south of Tlaquepaque and Tonalá, and throughout the hills south and west of Highway No. 15 from the junction of the branch road to Ameca, through the edge of the city, and south as far as Santa Cruz de las Flores. Peripheral to the areas mentioned, the frequency of the gullies diminished sharply. For instance in the hills east of Tateposco (near Tonalá), and those south of Santa Cruz de las Flores, there was very little evidence found of serious arroyo formation.

Since arroyo density over a substantial territory is an index to degree of land use, it is legitimate to conclude that within a radius of ten miles of Tepic, along the Tonalá-Tlaquepaque axis, and in the hill massif southwest of Guadalajara, there has been in the recent or remote past a substantial human occupation. Beyond the limits mentioned occupation has been at a much lower level.

Within the occupation areas variation in space can be clearly discerned. At Tepic arroyo density and extent is at a maximum near the city, as might be expected in view of the continuous history of the city for at least five centuries. Another zone of high density is near Jalisco, also of great age. However, a vast system of arroyos, amounting almost to a bad land, is seen south, west, and north of the village of Bellavista. The existing village can by no means account for the devastation of the land and it must therefore be ascribed to the pre-modern period.

Near Guadalajara there are four local concentrations of arroyos which have been observed. One is just south of Tonalá, in which the gullies are close together and cut deeply into the underlying bedrock. The second is at Colonia Granja where older arroyos have been kept alive by continuous and modern land use. The third is just south of Santa Anita. This town was probably developed as a habitation center after the Spaniards occupied the country, and the dissection of the southern hillside can be ascribed only to its inhabitants. The fourth is the great ramifying arroyo system north of Santa Cruz, which within the memory of man has never been a habitation area.

It is a postulate supported by much evidence that where arroyo systems in Mexico are developed to a density and severity of depth and ramification far beyond that seen in the area at large, the human land use has reached the proportions of permanent habitation in the form of towns or villages. At Tepic we would therefore look for villages, or close farming cummunities along the slope from Tepic to Jalisco, and beyond, and in the low, hilly country between Tepic and Bellavista and Puga. At Guadalajara we would predicate dense habitation on the ridge south of Tonalá, and a series of villages, or other human aggregates along the front slopes of the hills from 15 miles west to 10 miles south of the present city limits. In addition, we have to assume a village or town from 2 to 4 miles north of the present village of Santa Cruz de las Flores.

Within the occupation areas the time element can be evaluated, at least to some extent, by the degree of recovery displayed by the arroyo systems. An active, presently eroding system of gullies denotes very recent or contemporary land use, or, alternatively, an older system which has been in continuous operation up to the present. A system which has been partly or completely filled, slumped, and covered with vegetation is evidence for a period of active denudation in the past, with ample opportunity for recovery. The duration of the recovery period may be roughly estimated. For instance in the vicinity of Bellavista, near Tepic, the badly dissected hill slopes have been covered with a new growth of chapparal and young oak trees which must have taken fully a century to establish. On the sides of the southeastern hills, near Tepic, however, the arroyos have been refilled, and smoothed over, such that in the distance the only visible traces left are the rows of trees which follow the ancient courses. The active phase of these gullies must have occurred centuries ago.

Similarly at Guadalajara arroyo systems of great antiquity are to be seen in relatively uninhabited localities, such, for example, as near the junction between Highway No. 15 and the paved road to Ameca. Here the arroyos on the faces of the hills to both sides of the highway have been healed and covered with mature vegetation. The intensive occupation of this region must be dated to several centuries ago.

The arroyos just discussed are predominantly, if not exclusively, primary, and moreover, cut into the native soil. This means that they were formed during the first severe erosion to which the land was subjected. At certain points, however, such as to the southwest of Tepic, beyond Jalisco, and to the southeast of the city, on the lower slopes of the high mountain, primary arroyos of relatively recent origin have been cut through slope washes derived from an erosion cycle which occurred long before the gullying took place. These slope washes were caused by human intervention, as is made manifest by the inclusion of potsherds in the soils thus exposed. Likewise west and south of Guadalajara deep and mature arroyos have been incised in sherd-bearing slope washes and alluvial fans. Some of these themselves show compound profiles caused by alternate cutting and filling. The original deposition therefore must have been quite ancient.

On the basis of the preceding discussion and the detailed data presented in prior sections, it may be concluded in summary that arroyo patterns can (1) delineate the outlines of former land use, (2) indicate the localities of intense soil destruction, such as would be caused by actual habitation, and (3) give some idea of the time element by (a) the degree of recovery and (b) the existence of recent arroyo cutting in deposits bearing human artifacts.

VISIBLE TOPSOILS

A study in central Sinaloa has made it clear that under favorable conditions the measurement of top soils (or the total soil above the "C" horizon) can be used as diagnostic of former land use. In this area it could be established that, over a fifty-mile transect, gross climatic shifts can be detected, such as a pronounced increase in total rainfall. In the Tepic and Guadalajara areas similar large environmental variations do not exist, and hence would not be reflected in distinctions between soils.

In all three regions--central Sinaloa, central Nayarit, and central Jalisco--a widespread, almost universal, removal of the upper horizons of what once was the mature soil profile was observed. The degree and manner of such removal depends upon the nature of the soil and can be evaluated best when mature, untouched profiles can be found to establish a basis for comparison. None was found in the Sinaloa transect, but adequate examples were seen in the other two areas. At Tepic the two dominating parent materials are (1) a white volcanic ash or pumice and (2) a deep red earth, or latosol, formed on basalt and various types of sedimentary rock. Both produce mature soils with differentiated "A" and "B" horizons several feet in thickness. At Guadalajara the parent material is an ashy silt or sand somewhat similar in composition to the Tepic pumice. It also weathers deeply and shows horizon differentiation. However, unlike the other soils, the Jalisco type under proper conditions of drainage developes a thick, indurated hardpan, or caliche. When the surface layers are eroded off in central Sinaloa and at Tepic the lower horizons are progressively exposed, the depth depending upon the intensity and duration of the erosion. In Jalisco, however, a limit is imposed by the caliche, which itself strongly resists attrition. Hence near Guadalajara are found wide areas where the caliche is laid bare or covered with a very thin integument of residual topsoil.

The universal denudation of the surface soil in this part of Mexico, and indeed in many other parts as well, is of fundamental significance. It can not be ascribed to ancient civilizations predominantly or even significantly, because it is seen in wide territories where no ancient civilization existed. It covers thousands of square miles regardless of the presence or absence of arroyos or any other erosion phenomena. It must be referable to a single omnipresent, comprehensive factor. That factor which above all others satisfies the conditions is the ranging of livestock, which began with the Spanish conquest and which has been operative ever since in every corner of Mexico. Cattle and sheep were introduced in the sixteenth century on an enormous scale. Horses, burros, and goats have been pastured on every uncultivated acre for 400 years, and the topsoil has been damaged by the grazing, the browsing, and the beating of hoofs. Hillside farming and milpa agriculture have also contributed, but the topsoil has been eroded in areas which the farmer has never reached.

The degree of generalized soil loss can be associated with centers of cultural activity, particularly habitation. Beyond the widespread denudation attributable to livestock and, secondarily, to corn agriculture, there appear numerous areas in which the extent of surface erosion goes far beyond anything which could be caused by cattle or ploughing. Commonly these areas are also characterized by unusually dense arroyo systems and may be suspected of being the sites of former towns and villages, if indeed they are not at the present time centers of population.

Along the central Sinaloa transect the soils were found to become abnormally thin in the immediate vicinity of the Elota River, but not in that of the Piaxtla River. On the banks of the former is an ancient village, Elota; those of the latter are uninhabited. Near Tepic the topsoils formed on the extensive white ash deposits are very conspicuous by virtue of their black or dark brown color. It is very obvious that the average depth of the black surface layer is at a minimum close to the city and increases progressively at a greater and greater distance from it. Moreover secondary minima and progressions can be seen at or near the village of Jalisco, and westward along the road which branches from Highway No. 15 a few miles north of the city and runs toward the coast near Jalcocotan. On red earths in the Tepic basin several feet of top soils have been removed south and west of Bellavista, a locality in which there has been an extraordinary development of gully erosion. Near Tepic and Jalisco the topsoil depletion may be in large measure ascribed to the intervention of population aggregates which have been continuously in existence for centuries, and which are now becoming more and more active. In the vicinity of Bellavista, however, there has been no center of population for centuries other than the very small village itself. The soil destruction must have occurred at a relatively remote period.

At Guadalajara a clear evaluation of topsoil depths as such is difficult if not impossible because of the almost universal presence of a caliche. When the overlying soft horizon has been swept away the caliche can be worn off only with extreme slowness. Hence a graded series of depths can not be recorded, as they can for the horizons overlying the soft subsoils of Tepic and central Sinaloa. A partial substitute, and one that works very well in many areas, is the observation of the relative extent to which the caliche is laid bare. In the plateau portion of Jalisco, east and northeast of Guadalajara, these denuded areas are very conspicuous around and near towns, villages, and even isolated ranches. On a far vaster scale, the exposure of wide stretches of caliche, or tepetate, may be observed (best from the air) in the states of Mexico, Puebla, Tlaxcala, and Oaxaca.

In the south and east of Mexico badly denuded areas of caliche are observed in localities which are not today heavily inhabited, but which are known on the basis of historical or archaeological evidence to have been the sites of large pre-Spanish populations. The occurance of such denuded areas may indeed be taken as prima facie evidence of ancient intensive land use. A few such localities are to be found in those portions of the Guadalajara plain which I observed. All are characterized by extensive gully systems, as well as by sheet erosion of the caliche. A representative instance is the hill slope north of Santa Cruz de las Flores, which once must have been a focus of human settlement.

Recovery from topsoil depletion is contingent upon two primary factors: (1) the weathering rate imposed by local soil and climatic conditions, and (2) the recovery rate as determined by continued land wear inflicted by grazing or agriculture. Weathering is considered in the subsequent discussion. Retardation of recovery by man is generally present and is referable to the same processes which caused the loss of topsoil in the first place.

WEATHERING RATES

Weathering is the common and convenient term employed to designate the sum total of all the processes involved in the development of new soils. Its progress and rate may be measured by a host of criteria, many of which are highly technical and of interest chiefly to the agricultural soil scientist. We have employed here three relatively simple tests which can be applied with comparative ease and which constitute adequate indices for the stage of maturity displayed by a soil. These are the visible depth of discoloration due to the presence of organic residues, the formation of clay, and the level of organic matter as shown by the analysis for either nitrogen or carbon, or both. The time necessary to produce weathered zones may sometimes be estimated with reasonable accuracy, and thus the age of a profile can be ascertained within broad limits.

Clearly the time required for the formative processes to bring into being a mature soil will depend upon the nature of the parent material, the climate, and a large number of other edaphic factors. Hence at least the parent material and climate must be described in each case at issue. If possible, for comparative purposes, a fully mature soil corresponding to the pertinent parent material and climate should be available. In the territory covered by this report such mature soils could not always be found, particularly since in some of the localities only human constructions are concerned, and there has been no chance on these to develop mature soils.

South of Culiacan, one habitation site, built with sand in a hot, fairly dry climate showed little carbon and no clay development in 400-500 years. At Amapa, under very similar conditions, there was slight carbon and slight clay formation in 400-800 years. South of Actopan, in Hidalgo, the parent material being alluvial detritus, of a calcareous sandy nature and the climate being very dry but moderately cool, a very slight amount of organic carbon and no clay has been formed in a period represented by 600 to 2,000 years before the present. It is quite evident that in the more arid areas of central Mexico a really deep weathered zone on a slope wash or alluvial deposit, or alternatively on an artificial dirt construction, demands fully 1,000 to 3,000 or perhaps more years for its production.

At Tepic and Guadalajara mature, native soils are to be found on ash or silt. Near the former city, with a moist, warm climate, the surface value of clay reaches from 10 to 20 per cent with much higher values in the lower horizons due to the rapid translocation in this soft, porous material. The carbon content is from 3 to 5 per cent. On the latosols, or red earths, the clay may reach from 40 to 70 per cent, with relatively slow downward displacement. The organic carbon in the surface horizons will attain from 2 to 3 per cent. The visible depth of the modified surface horizons may attain from 3 to 5 feet. In Guadalajara the soils formed on the sandy, silty ash which covers the plateau may show from 2 to 4 feet of topsoil over the invariable caliche. No mature soil profile was sampled and subjected to analysis.

At Tepic the rate of reconstitution of eroded native soils depends upon the nature of the parent material. On white ash, or pumice, recovery is relatively rapid. On a fully eroded substrate of this type the new black horizon may reach a depth of from 6 to 10 inches. The organic carbon may amount to from 1 to 5 per cent and the clay to 20 per cent. There will have been little if any downward movement of the clay, however. An interesting example is the area previously mentioned where white ash completely exposed by a road excavation formed in ten years a black surface layer one centimeter in depth. Assuming the downward extension of the organic matter to be an exponential function of time, we may postulate that the weathered surface layer would reach a depth of 4-5 centimeters in 100 years and 20-25 centimeters in 400 years. Such a rate would be quite consistent with the appearance of numerous recovery horizons of 6-12 inches on surfaces which were probably eroded during the population maximum of the fifteenth and sixteenth centuries. Such recovery rates obviously are far more rapid than those described for the more arid areas to the north and in Hidalgo. Additionally the loose, friable ash will weather far more rapidly than the compact, sandy deposits found along the coasts and as outwash plains in the interior.

The red earths at Tepic, once denuded, recover much more slowly than the soils derived from ash. For the same and even longer time periods the carbon content reaches only from 1 to 2 per cent. The clay may attain a value of from 20 to 30 per cent at the surface but its downward translocation so as to reach concentrations of from 50 to 70 per cent in the lower levels must require millenia for completion. Two cases of weathering on slope washes were examined. One of these was on material derived from ash, and the other on detritus from basaltic or sedimentary rock. The former was relatively young and the latter probably much older. Both showed 6-24 inches of dark surface horizon, 1-2 per cent of carbon, and 20-30 per cent of clay, concentrated at the surface. The condition of the two soils is more or less the same. The disparity in time of exposure may be accounted for by the more rapid weathering on the loose detritus from ash than on the denser wash from original soils formed on basalt and other heavy rock.

Near Guadalajara, where the climate is moderately moist but cool, weathering of the eroded surfaces of the indigenous ash-silt complex produces from 0.5 to 2.5 per cent of organic carbon, and from 3 to 15 per cent of clay in about 400 years. The rate is therefore slower than on the Tepic pumice but more rapid than on the red earths and similar soils. A slope wash at Tonalá has produced 0.4 per cent carbon at the surface and 8-12 per cent clay, in roughly 200 years. The alluvial plain, near Santa Anita, in the surface weathering zone, colored gray from 2 to 4 feet deep, has carbon at a maximum of 1.5 per cent and clay at 10-15 per cent. The gray zone, with carbon and clay as indicated, extends well into the underlying caliche. The deposit may have been in position from 1,000 to 3,000 years. Along Highway No. 15, 6-8 miles west of Guadalajara, and on the outwash plain near Ixtépete profiles were observed but no samples were taken. At the former locality a sherd-bearing slope wash more than 400 years old showed a weathered topsoil 2 feet deep.

At the latter, there is a zone of weathered, gray, humus-containing surface soil 2-3 feet in depth. This deposit has probably been in position from 2,000 to 3,000 years.

The data briefly summarized above make it clear that, when allowance is made for local conditions, weathering of eroded land surfaces and of new human constructions proceeds sufficiently rapidly to permit an estimate of the time involved. Such an estimate will be in very approximate terms but will permit comparison of different areas and segregation of large secular intervals. It sould not be forgotten, however, that extent of weathering should always be considered in conjunction with the existing arroyo patterns and topsoil depletion, for the latter processes may readily modify or nullify the soil formation produced by weathering reactions.

The field observations and soil sample analyses upon which this discussion is based make possible the following final conclusions with regard to the areas studied.

1. The distribution of clay, organic carbon, nitrogen, and pH in habitation mounds near Culiacan, Sinaloa, and Amapa, Nayarit, and the degree of surface weathing, conform closely to the archaeological findings with respect to the artificial construction and to the probable age of these sites.

2. Numerous measurements of topsoil depths along a transect which follows Highway No. 15 between Culiacan and Mazatlan, Sinaloa, indicate that the areas of depletion beyond that which may be accounted for by stock ranging are associated with the presence of villages several hundred years old.

3. In the Tepic basin, in central Nayarit it has been feasible to combine observation of topsoil depths, arroyo patterns, and potsherd distributions with analysis of clay and organic matter in several selected profiles so as to work out some of the history of land use in the region. There probably have been three cycles, or phases of human activity. The first, noticed near Jalisco and on the lower slopes of the high mountain to the southeast of Tepic, much antedates the Spanish conquest, since the upper horizons of water-borne detritus at the foot of slopes not only contain pottery and obsidian artifacts, but have undergone substantial weathering as well. The second is observed throughout the entire area, with particularly intense development north of Tepic, southwest of Tepic through the village of Jalisco, and in the low hills surrounding the village of Bellavista. In these localities there are extensive arroyo systems and severe depletion of topsoils. At numerous points, surface weathering zones and advanced recovery of arroyos makes it evident that the initial damage was suffered during a period of heavy occupancy which was subsequently dissipated. This period can only have been in or near the fifteenth century. The third phase is represented by generalized loss of topsoils, and intense, active arroyo systems located near existing centers of population, such as Tepic itself, and Jalisco. This phase has developed within the past century or two, and is still in progress.

4. In the vicinity of Gùadalajara a three-cycle or three-phase history may also be established. The earliest phase is seen in the formation of potsherd-bearing slope washes along the foot of the low hills from 5 to 10 miles west of the city, and the extensive outwash plain to the southwest. This sandy plain also includes buried potsherds which can have been derived only by water transport from the western hills. These slope washes and alluvial deposits, where cut by modern arroyos or artificial excavations, expose weathering horizons of a depth and maturity surpassing any seen elsewhere in the area, except on mature, undisturbed soils. Archaeological evidence can also be brought directly to bear. The platform, or truncated pyramid recently excavated at Ixtépete, just southwest of Guadalajara, rests upon the surface of the outwash plain just mentioned, and has been stated to date from the Teotihuacan period, from 1,000 to 2,000 years B.P. Hence the civilization which eroded the hills and produced the outwash must have existed long previously, perhaps from 2,000 to 3,000 years B.P. This ancient, or early, culture may have been of wide territorial extent, for it may have been responsible, at least in part, for the profound, but almost completely recovered arroyo systems visible near the junction of Highway No. 15 and the lateral paved road to Ameca, together with similar systems which extend along the northern and eastern front of the hills, following Highway No. 15 past Guadalajara nearly to Santa Cruz de las Flores.

The second phase, or period, produced local areas of intense arroyo dissection, and extreme denudation of surface soil so as to expose great expanses of caliche. Fine examples of such local centers of gully and sheet erosion are found just south and east of Tonalá, at Colonia Granja, and in the high ground north of Santa Cruz de las Flores. So devastated is the land within these points of small compass that the conclusion is unavoidable that they represent centers of actual habitation, which probably were densely populated at or about the era of the entrance of the Spaniards in the early fifteenth century. Some of these centers have persisted in one form or another, for example, the hacienda at Colonia Granja, the reduced village of Tonalá. Others have disappeared completely, such as the settlement which must have existed north of Santa Cruz. Indeed it is quite likely that we are today looking at the sites of a succession of villages rather than of a group which flourished simultaneously.

The third phase, like that at Tepic, is modern: universal attrition of topsoils and active gullying caused by stock ranging and agricultural operations which followed directly upon the second phase and which is not only still in progress but is also daily gaining momentum. The effect, even at a low level of intensity, through four centuries has been to retard recovery from the second phase, prevent weathering of eroded topsoils, and develop new and active arroyos.

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