Causes of Soil Boundaries in an Arid Region: II. Dissection, Moisture, and Faunal Activity[1]

LELAND H. GILE[2]

ABSTRACT

Studies of soils in arid regions show similar boundaries between many soils. This paper illustrates some of the boundaries caused by differences in landscape dissection, soil moisture, and faunal activity. Some of the boundaries are apparent at the land surface and others are not.

In dissected terrains a change from Argids to Orthids has been caused by slow, long-continued soil truncation associated with the dissection. The boundary occurs as a gradual, lateral change from a noncalcareous, reddish-brown, and red argillic horizon to a calcareous, brown cambic horizon.

Differences in moisture movement in the past have caused soil differences resulting in boundaries between Typic Haplargids and Petrocalcic Paleargids. During Pleistocene pluvials, soil moisture moved deeply into reddish-brown pipes (preventing carbonate accumulation) but not in adjacent petrocalcic horizons. Typic Haplargids occur in the pipes whereas Petrocalcic Paleargids occur adjacent to the pipes.

Soil boundaries have also been caused by differences in moisture movement at present. Runoff from fan-piedmonts increases vegetation and organic carbon in and along margins of basin floors. This and associated increases in clay commonly result in a boundary between Typic Haplargids on the fan-piedmont and Ustollic Haplargids on the basin floors and adjacent toeslopes.

In places, soil fauna have obliterated argillic horizons by mixing A and B horizons. This causes a boundary between Argids and Orthids.

Additional Index Words: soil classification, soil morphology, cambic horizon, argillic horizon, calcic horizon, petrocalcic horizon.

SOIL DIFFERENCES caused by landscape dissection, soil moisture, and faunal activity in a study area of southern New Mexico (Fig. 1) are described in this paper. The landscapes, soils, boundaries, stratigraphic relations, diagnostic horizons, and other morphological features are shown diagrammatically. The geologic and geomorphic setting (Dunham, 1935; Ruhe, 1964, 1967; Hawley and Kottlowski, 1969) and soil boundaries caused by differences in soil age and materials have been presented in the previous paper (Gile, 1975).

SOIL BOUNDARIES AND OBLITERATION OF THE ARGILLIC HORIZON

Soil boundaries caused by development of the argillic horizon have been discussed (Gile, 1975). Boundaries caused by obliteration of the argillic horizon are considered in this paper. Examples and evidence of obliteration are presented in later sections (Sites I and III). The obliteration is usually the result of two main factors—landscape dissection, with its associated soil truncation and carbonate engulfment, and faunal activity.

The Argids and the adjacent soils (in which the argillic horizon has been obliterated) are mostly of Pleistocene age. The morphological change is usually from an argillic horizon that is readily identified (because of its distinct silicate clay maximum and reddish-brown and red colors) to a B horizon lacking these features. Carbonate accumulation is involved in the obliteration process since argillic horizons tend to become less red and lighter colored with increasing carbonate accumulation. Carbonate also affects the estimation of silicate clay, which is needed to assess the requirement for clay increase. Some horizons feel fine-textured enough but analyses show that the increase in fineness is due to fine-grained carbonate instead of silicate clay.

In the study area, several factors are useful in the field distinction between Argids and their associates in which the argillic horizon has been obliterated. These are effervescence with acid, color, and macroscopic carbonate. If part of the horizon of clay accumulation is still noncalcareous, then enough oriented clay remains for the horizon to qualify as an argillic horizon. If the argillic horizon is calcareous it can still have enough oriented clay. The point at which the horizon in B position contains too little oriented clay is marked by a shift in color. If part of the horizon of silicate clay accumulation is reddish-brown (approximately 5YR 5/4, dry) or redder, then enough oriented clay usually remains for the horizon to qualify as an argillic horizon. As carbonate continues to accumulate and hues become yellower than 5YR, in most soils there is so much carbonate that essentially all of the oriented clay has been obliterated and this marks the shift to the Orthids. At this point macroscopic carbonate is visible as grain coatings; and in very gravelly materials, pebble coatings are prominent. Also, the carbonate content in these horizons is high enough that estimates of silicate clay are less reliable.

There are all degrees of obliteration of the reddish-brown and red argillic horizon material. If the horizon in B position has at least 10% by volume of argillic horizon material the soil has been classified as an Argid in the study area. If the horizon has < 10% it is classified as a Calciorthid or a Paleorthid as the case may be. The 10% figure has been used because long exposures of soils illustrating the Argid-Orthid transition indicate that much smaller percentages may occur in the transition zone. Such minor amounts might easily be missed with an auger or small pit.

Observations elsewhere in the Southwest and in desert regions of northern Mexico indicate that similar relations for obliteration of the argillic horizon are extensive in arid regions similar to the study area. However, the argillic horizon is generally not as red in the colder deserts, and the

---

[1] Contribution of Soil Survey Investigations, Soil Conservation Service, USDA. Presented before Div. S-5, Soil Science Society of America, 12 Nov. 1973. Acknowledgment is made to Sam Horn for drawing landscapes in the block diagrams. Received 15 Apr. 1974. Approved 24 Oct. 1974.

[2] Soil Scientist, Soil Survey Investigations, SCS, and Adjunct Professor of Agron., Texas Tech Univ., Lubbock 79409.

color changes caused by landscape dissection and soil truncation would probably differ accordingly.

SITE I. BOUNDARIES CAUSED BY LANDSCAPE DISSECTION

Soil change caused by landscape dissection (Fig. 2) ranges from minor truncation with no change in classification to the truncation of all diagnostic horizons and a resultant change from Aridisols to Entisols.

Difference in Landscape Dissection (Fig. 2, 3); Boundary between Argids and Orthids—The transition from Argids to Orthids occurs where the soil parent materials were derived largely or wholly from noncalcareous rocks, so that an argillic horizon had formed and is still preserved on stablest sites. In these soils (which range in age from late- to mid-Pleistocene) the argillic horizon is usually underlain by a calcic or petrocalcic horizon. If a calcic horizon is present, loss of the Bt horizon causes a change from a Haplargid to a Calciorthid. If a petrocalcic horizon is present, the change is from a Paleargid to a Paleorthid.

The illustrative soils (Fig. 3) occur along the valley border, where dissection has been caused by downcutting of the Rio Grande (Fig. 1, 2). The parent materials are rhyolitic sediments derived from the Organ Mountains upslope. Petrocalcic Ustollic Paleargids occur where the argillic horizon is still preserved. These are on remnantal ridge crests that are level or nearly level transversely (Fig. 2, 3) and have been little affected by the dissection. The petrocalcic horizons commonly have engulfed the lower part of once-thicker argillic horizons (Gile, Hawley, and Grossman, 1970) so that even on these stable sites, partial obliteration of the argillic horizon has already been accomplished. Ustollic Paleorthids occur on rounded ridge crests in and near drainageways, where the argillic horizon has been truncated or engulfed by strong carbonate accumulation. The boundary between Argids and Orthids occurs between these areas (Fig. 3) and can be predicted, therefore, from landscape position and form.

The morphological change from Argids to Orthids on a given ridge usually occurs over a distance of only a few meters. Downslope from the Argids of ridge crests that are level transversely, the argillic horizon first becomes calcareous, with little or no visible carbonate. With increasing distance downslope, macroscopic carbonate appears and gradually rises in the soil as truncation of thin upper horizons brings partially carbonate-impregnated horizons closer to the surface. (Truncation, by increasing slopes and runoff, also causes carbonate to accumulate at depths shallower than in adjacent areas that are level transversely.) Finally, < 10% of the reddish-brown, argillic horizon material remains and the soils are classified as Orthids.

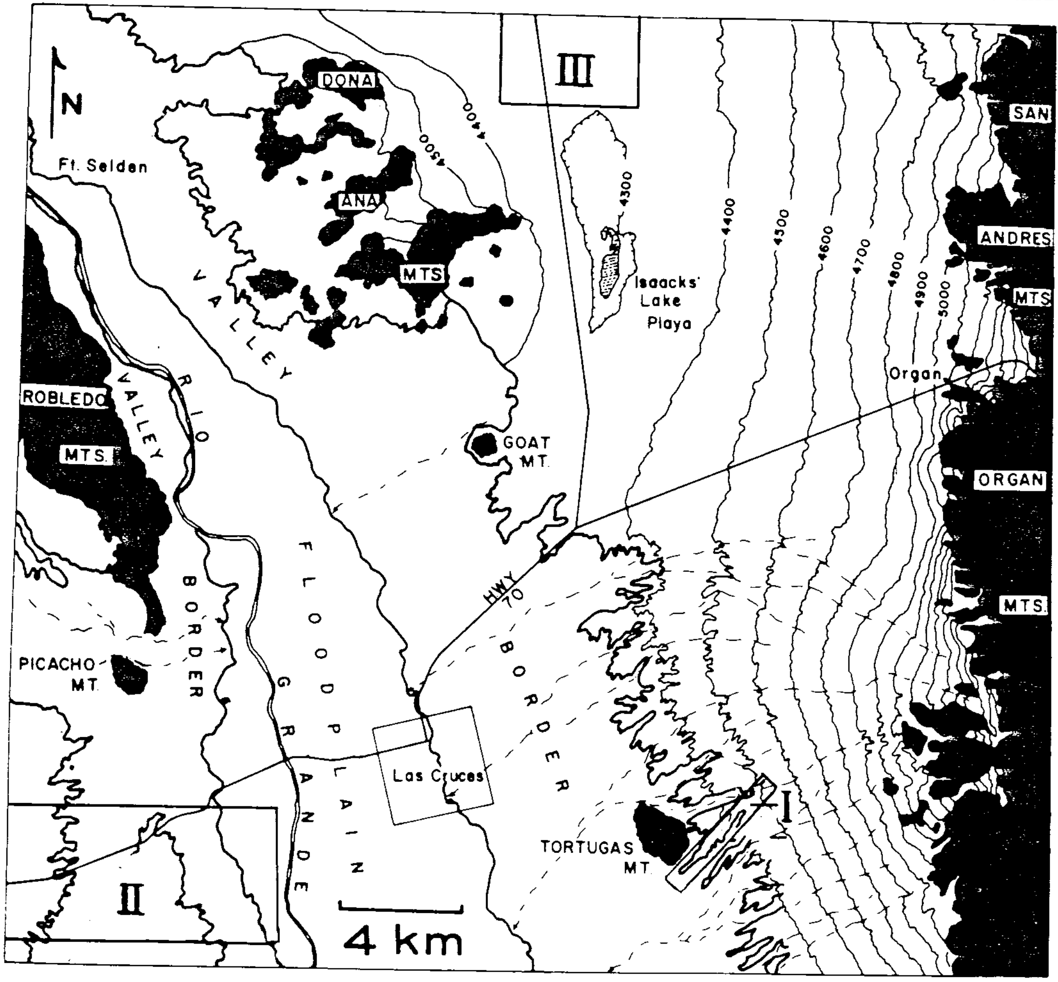

Fig. 1—Major physiographic features of the study area in southern New Mexico. Location of sites I-III shown.

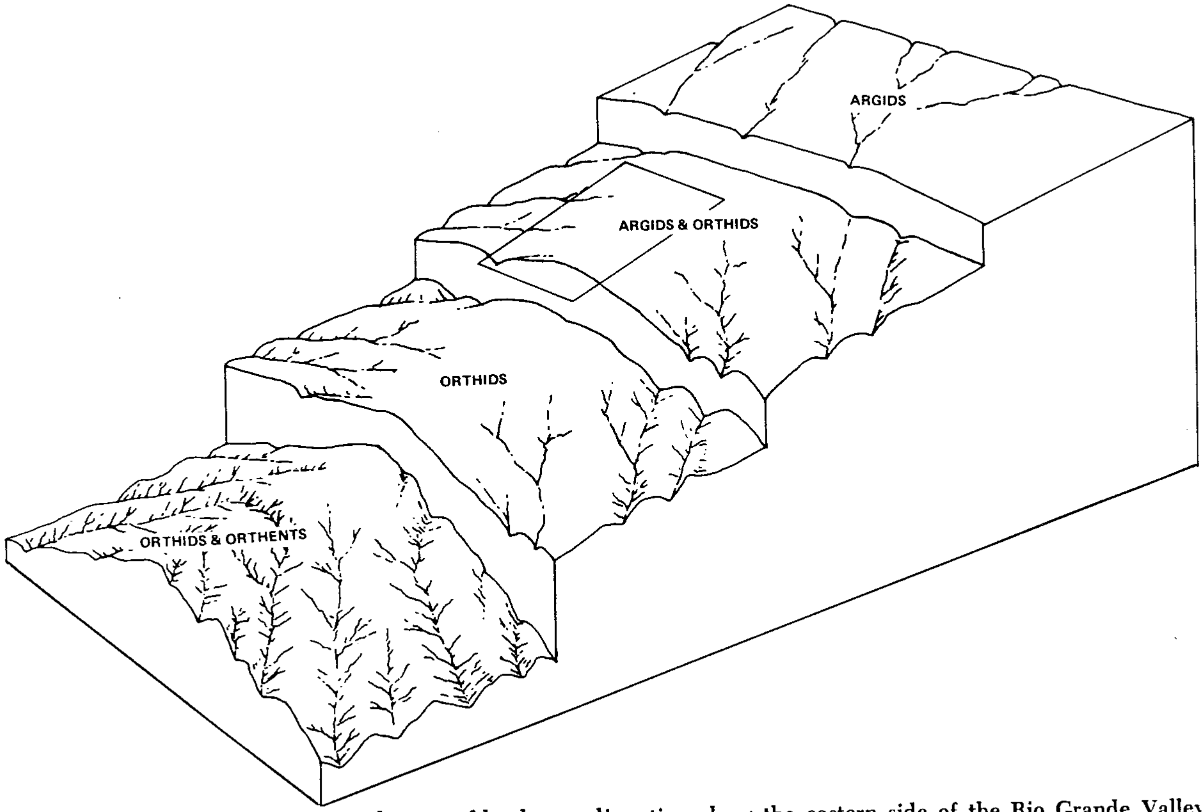

Fig. 2—Site I. Diagram illustrating various degrees of landscape dissection along the eastern side of the Rio Grande Valley. Dominant suborders are in the landscape positions indicated. Aridisols (Argids) occupy nearly all of the land surface in the block at the right. Aridisols are also dominant in the second block with Entisols present on the lower sides of ridges. Entisols increase in the next block, occupying all of the ridge sides, and no Argids are present on ridge crests. Entisols occupy nearly all of the land surface in the block at the left. On ridge crests, the diagnostic calcic (or petrocalcic) horizons have been truncated in many places, forming saddles and a change from Orthids to Orthents. Location of large-scale diagram (Fig. 3) shown.

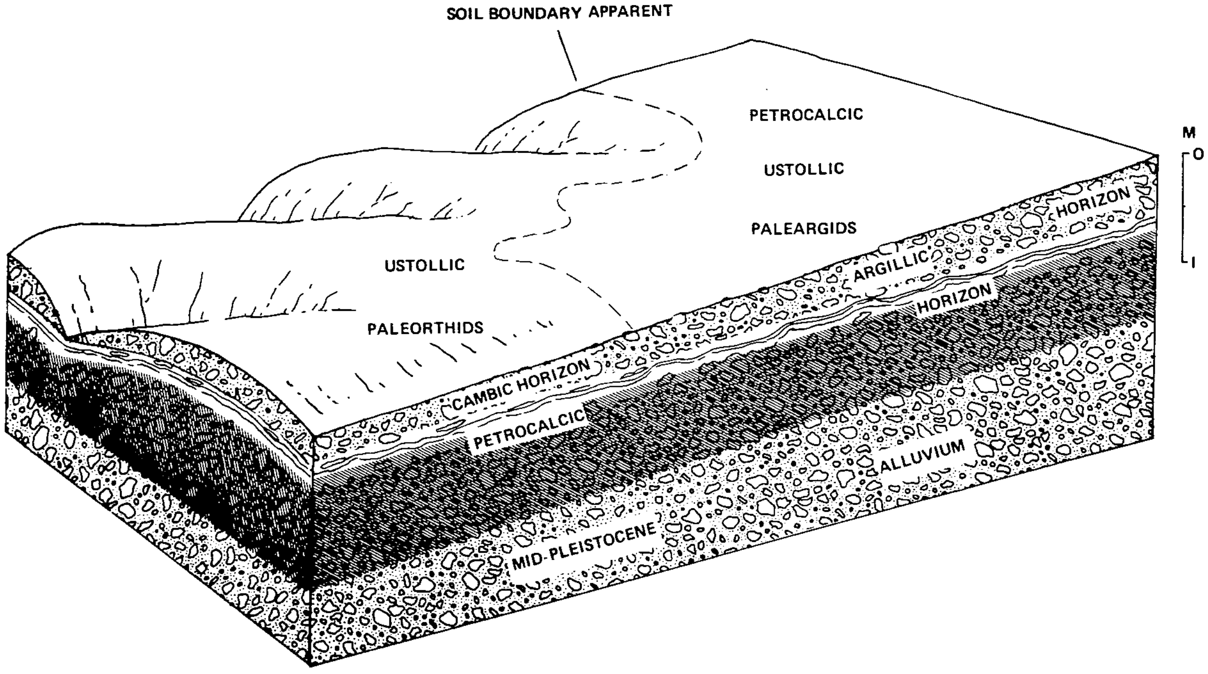

Fig. 3—Boundary between Argids and Orthids, and its relation to the dissection pattern. Paleargids occur in areas little affected by the dissection (ridge crests that are level transversely). Paleorthids occur on rounded ridge crests, and in and adjacent to drainageways.

The transition from Argids to Orthids in terraced terrain differs in different parts of the terrain. Where the argillic horizon has been obliterated on highest ridges it may be well preserved on younger, less dissected terraces below. With increasing dissection valleyward, the argillic horizon is finally obliterated on these younger surfaces also.

The calcic or petrocalcic horizon occurs continuously beneath the transition zone from the argillic horizon to the cambic horizon (Fig. 3). The soil-landscape relations (Fig. 2, 3) illustrate the close genetic connection between these Argids and Orthids, and demonstrate that Orthids can form as a result of soil truncation.

The boundary between Argids and Orthids occurs extensively in dissected terrains similar to the study area. Clearly, large areas of Calciorthids and Paleorthids in arid regions owe their genesis to landscape dissection.

Difference in Landscape Dissection (Fig. 2); Boundary between Orthids and Orthents—The change from Orthids to Orthents is not illustrated in large scale but it occurs in two general landscape positions (ridge sides and ridge crests) depending upon the character of the dissection. With increasing dissection the Orthents are first encountered on ridge sides, just below the point at which the calcic or petrocalcic horizons have been truncated, exposing the underlying parent materials. The soils downslope from this point are usually calcareous throughout and have the weak horizon of carbonate accumulation characteristic of Holocene soils. In more strongly dissected areas there is gradation from Orthids to Orthents on ridge crests, with the Orthents occurring in drainageways that form saddles in the ridge crests, truncating the calcic or petrocalcic horizon. Psamments may be encountered instead of Orthents if the materials are sandy and have little gravel (Soil Survey Staff, 1975, in press). In some areas buried soils have been exhumed by dissection. In these cases the classification is determined by the morphology of the buried soils; in this area most are Haplargids.

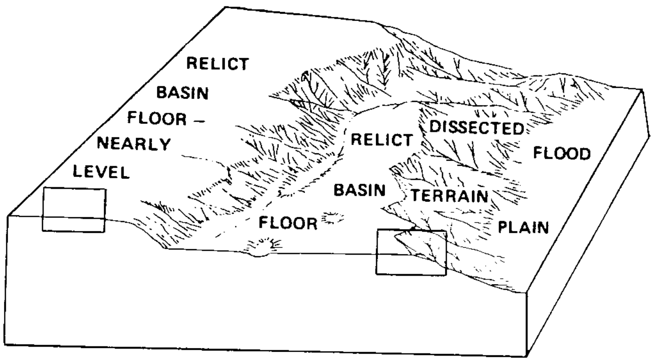

Fig. 4—Site II. Relict basin floor of mid-Pleistocene age, and dissected terrain adjacent to the Rio Grande flood plain. Location of large-scale diagrams (Fig. 5 and 6) indicated.

SITE II. BOUNDARIES CAUSED BY DIFFERENCES IN LANDSCAPE DISSECTION AND SOIL MOISTURE

Site II (Fig. 4) illustrates soil boundaries caused by differences in dissection and soil moisture in the past. Large remnants of the relict basin floor occur along the margins of the valley. Soil parent materials are sandy, low-carbonate sediments deposited by the ancestral Rio Grande. Coppice dunes occur in places (Fig. 5) illustrating boundaries caused by differences in age (Gile, 1966).

Landscape dissection has caused the development of structural benches bordering the scarp cut in the relict basin floor (Fig. 5; Thornbury, 1969). Structural benches occur extensively along river valleys where surficial low-gravel materials have been eroded and underlying gravelly beds

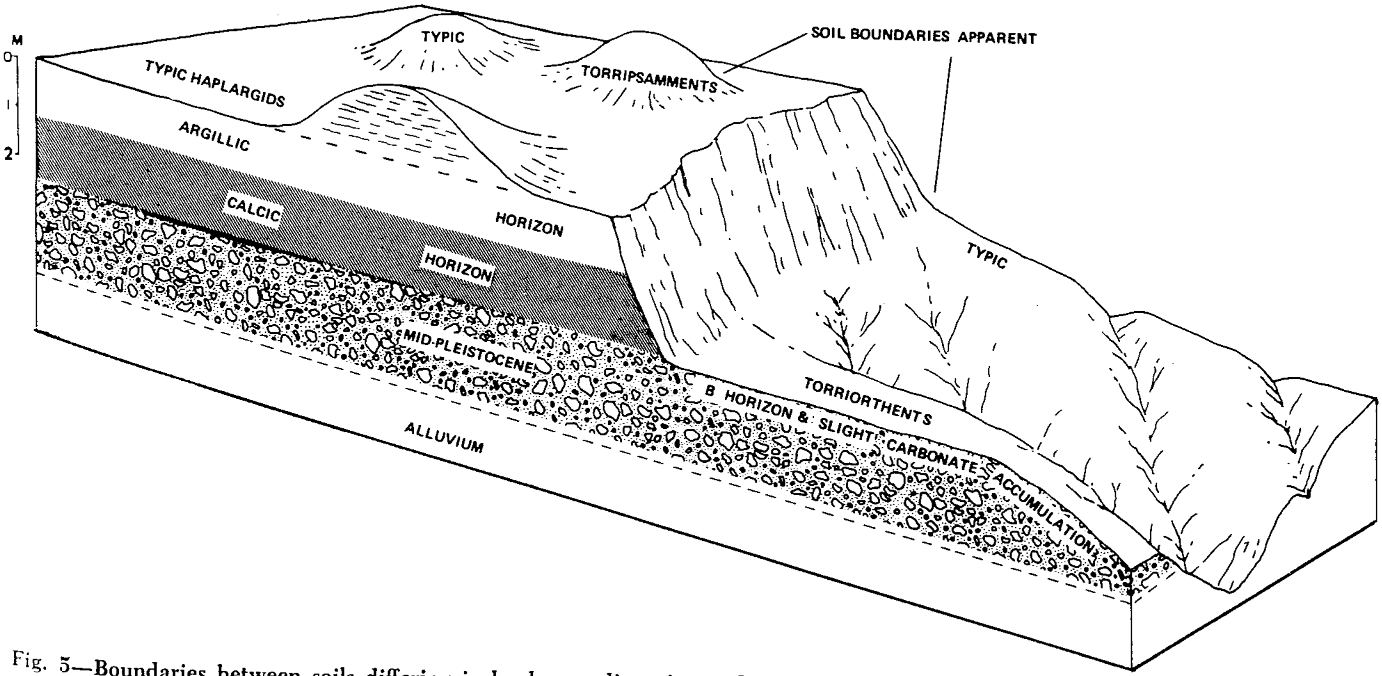

Fig. 5—Boundaries between soils differing in landscape dissection and soil age. Typic Haplargids dominate the basin floor and are overlain in places by much younger Torripsamments of coppice dunes. Landscape dissection along the scarp has exhumed horizons above the gravel, forming a structural bench in which Torriorthents are dominant. The soil boundaries are apparent.

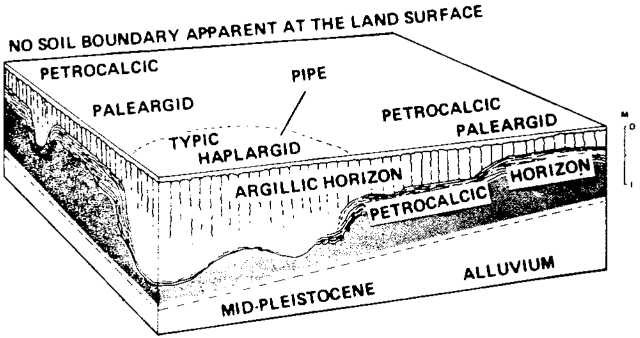

Fig. 6—Boundary between soils formed by differences in soil moisture in the past. The pipe (with Typic Haplargids) was largely formed by deep penetration of moisture in Pleistocene pluvials. Adjacent petrocalcic horizons of the Petrocalcic Paleargids are carbonate-plugged and nearly impervious. The soil boundary is not apparent at the land surface.

have been exposed. The gravelly beds are resistant to erosion and tend to form gravelly ridges with their crests at about the same elevation. Slopes are much steeper here than on the east side of the valley because the deeply entrenched flood plain is close (Fig. 1). For this reason the soil change caused by dissection is from the Argids to the Entisols. The Orthids, so common on gentler slopes on the east side of the valley, seldom occur on the west side.

Difference in Dissection (Fig. 5); Boundary between Haplargids and Torriorthents—Typic Haplargids, with thick argillic horizons and calcic horizons, are dominant on the relict basin floor along the scarp shown in Fig. 5. Downslope from the scarp Typic Torriorthents, sandy-skeletal, are dominant on the ridge crests (the structural bench, Fig. 5). This illustrates the extreme effect of dissection; all diagnostic horizons have been truncated and young soils are now forming in the underlying materials. This involves the soil-forming factor of age since the materials exposed by the dissection process have weak horizons typical of Holocene soils in these materials. The Torriorthents have thin, brown B horizons and slight horizons of carbonate accumulation. The soil boundary is apparent and is well marked by the scarp.

Difference in Soil Moisture (Fig. 6); Boundaries between Haplargids and Paleargids, and between Typic and Ustollic Haplargids—In many soils there are roughly funnel-shaped zones of reddish-brown, argillic horizon material that descend into carbonate horizons. These zones, which are termed pipes (Fig. 6), have been observed only in soils of Pleistocene age and must therefore have formed in the Pleistocene. Many pipes of mid-Pleistocene basin floors are particularly large. These pipes must have been deeply flushed with moisture in pluvials, moving carbonate to substantial depths. In contrast, adjacent petrocalcic horizons were plugged with carbonate and funneled water into the pipes. The morphology indicates that the lower parts of the pipes would seldom if ever be wetted at the present time (Gile, Hawley, and Grossman, 1970). Typic Haplargids occur in the pipes, where the petrocalcic horizon is below 1-m depth or is absent. Petrocalcic Paleargids have a petrocalcic horizon within 1-m depth and are adjacent to the pipes. The boundary between the Haplargids and the Paleargids is prominent in exposures but cannot be seen at the land surface because the slope and land form are the same across both.

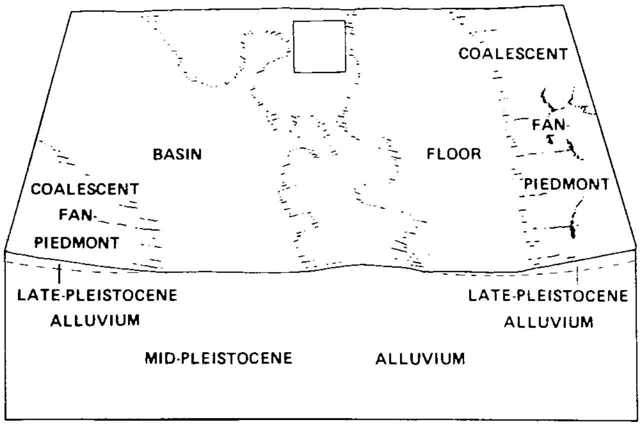

Fig. 7—Site III. Basin-floor of mid-Pleistocene age and adjacent fan-piedmont. The illustrative soils (Fig. 8) occur on a slight ridge in the basin floor. Location of large-scale diagram (Fig. 8) indicated.

Soil differences caused by changes in present soil moisture are also significant. One of these changes is caused by fan-piedmonts that contribute runoff to the basin floors. These boundaries are not illustrated in large scale, but their general physiographic location is shown in Fig. 7. The soils in basin-floor positions receive substantially greater moisture than from precipitation alone (Herbel and Gile, 1973). More effective moisture tends to increase plant cover and organic carbon, and this can affect classification. In low-carbonate parent materials, for example, the soils commonly change from Typic Haplargids on the fan-piedmont to Ustollic Haplargids on the basin floor and adjacent fan-piedmont toeslopes, as indicated by organic carbon and sand/clay ratios (Soil Survey Staff, 1975, in press).

SITE III. BOUNDARIES CAUSED BY DIFFERENCES IN FAUNAL ACTIVITY

Site III (Fig. 7) illustrates soil boundaries caused by faunal activity. The basin floor is level or nearly level, with occasional slight ridges. The soil parent materials are sandy, low-carbonate sediments deposited by the ancestral Rio Grande. The soils are of mid-Pleistocene age and in these parent materials distinct argillic horizons would normally be expected.

Figure 8 shows part of a slight ridge in the basin floor. Typic Calciorthids are dominant on the ridge; they have cambic horizons and thick calcic horizons. Textures of the cambic horizons are sandy loam and light sandy clay loam. All soils are calcareous throughout; sand grains and the few pebbles are thinly coated with carbonate. Very little oriented clay is visible because of the carbonate. The horizons are yellower than 5YR (commonly they are 7.5YR) and color is quite uniform throughout.

Several factors indicate that argillic horizons were once present over the whole ridge, but now have been largely obliterated by soil fauna. (i) Argillic horizons are still preserved in a few areas. (ii) In places, pipes of reddish brown Bt material are preserved in the thick calcic horizons, and descend below B horizons with numerous termite burrows.

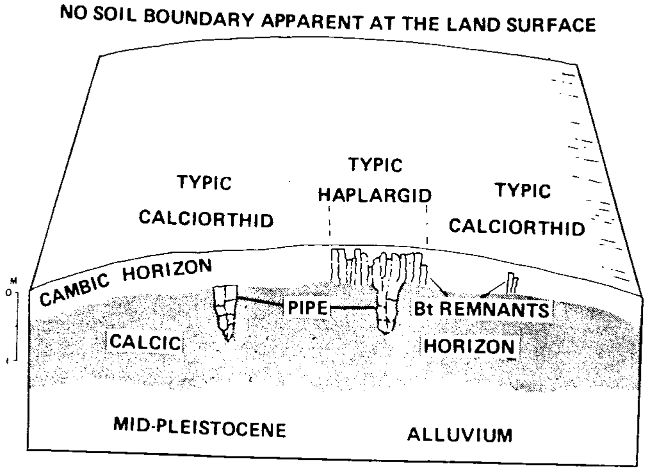

Fig. 8—Boundary between Argids and Orthids. Calciorthids are dominant over the ridge crest because B horizons have been mixed by soil fauna, but remnants of Bt horizons have been preserved in places. The soil boundary is not apparent at the land surface.

Soils with such pipes in other parts of the study area are commonly connected to argillic horizons. (iii) Analyses of particle size (carbonate-free basis) of A and B horizons show a silicate clay distribution unlike that of typical Argids in the area. In some instances there is more clay at the surface than in the B horizon (Gile et al., 1970). (iv) Presence of termite burrows, and mounds and tunnels constructed by rodents.

Although termite tunnels are less obvious than those constructed by rodents, they may have obliterated larger areas of the argillic horizon. Lee and Wood (1971) state that "termites have developed the capacity to burrow and mould structures from soil and organic matter to a level unknown in any other group of soil animals." They also note their importance in the physical disturbance and overturning of profiles, especially in movement of fine materials from deep horizons to the surface. Termites in the study area are not in mounds but instead are subterranean. Their workings include numerous tunnels (many of which are partly or completely filled with fine earth) in the cambic horizon and sheaths of fine earth on shrubs and on twigs on the soil surface. Such movement of fine earth could account for the erratic distribution of silicate clay and would contribute carbonate to upper horizons. The boundary is not apparent at the land surface since the slope and landform continue smoothly across the change from Calciorthids to Haplargids.

The area described above represents the most extensive area of argillic horizon obliteration by faunal activity observed in the study area. The precise reasons for this are not known, but the following appear to be contributing factors. Textures of the B horizon are sandy loam and light sandy clay loam. Such textures are not as hard and are easier to burrow than heavier textures. A nonindurated, high-carbonate horizon is near the surface. This should expedite faunal transport of carbonate from the top of this horizon to upper horizons. The high-carbonate horizon might also tend to restrict the general zone of termite activity, resulting in maximum churning within the B horizon. The argillic horizon must have formed largely in Pleistocene pluvials, and the present Holocene conditions, described above, apparently do not favor its preservation.

DISCUSSION AND CONCLUSIONS

Soil boundaries in the study area have been caused by differences in landscape dissection, soil moisture, and faunal activity. Boundaries between soils with argillic horizon and soils without them occur in many areas. Obliteration of the argillic horizon after it has formed is one of the major causes of the boundary. Landscape dissection is the most common cause of obliteration but faunal activity is important in some areas.

A change from Argids to Orthids has been caused by fan-piedmont dissection and associated slow, long-continued soil truncation. This change in classification occurs in soils that have formed in low-carbonate parent materials and that range from late- to mid-Pleistocene in age. Soil truncation has been accompanied by carbonate engulfment of remaining parts of the argillic horizon. The transition commonly occurs over a distance of a few meters and is marked by a gradual shift from a noncalcareous, reddish-brown and red argillic horizon to a calcareous, brown cambic horizon. Where the argillic horizon has been obliterated, the underlying calcic or petrocalcic horizons become diagnostic for classification and the soils are Calciorthids or Paleorthids. Continuity of the calcic or petrocalcic horizon beneath the shift from the argillic to the cambic horizon shows the close genetic connection between the Argids and the Orthids. The boundary between them occurs between stable ridge crests that are level or nearly level transversely, and less stable areas such as drainageways and rounded ridge crests. Extensive areas of Calciorthids and Paleorthids have developed as a result of landscape dissection. With continued dissection, even the calcic and petrocalcic horizons may be truncated and the resultant soils are Entisols.

Landscape dissection has also caused the development of structural benches adjacent to relict basin floors along the river valley. The benches are caused by erosion of low-gravel materials and exposure of high-gravel materials beneath. The boundary between Aridisols of the basin floor and Entisols of the dissected terrain is commonly abrupt and is marked by a scarp where the entrenched flood plain is close and slopes descending to it are steep.

Differences in moisture movement in the past have caused soil differences resulting in boundaries between Typic Haplargids and Petrocalcic Paleargids. During Pleistocene pluvials, soil moisture deeply penetrated reddish-brown pipes, moving carbonate to depths substantially greater than in adjacent petrocalcic horizons. In contrast the petrocalcic horizons adjacent to the pipes markedly slowed vertical water movement and funneled water into them. Typic Haplargids occur in the pipes and lack petrocalcic horizons within 1-m depth. Petrocalcic Paleargids occur adjacent to the pipes and have petrocalcic horizons within 1-m depth. This boundary is not apparent at the land surface since the slope and land form is the same across both.

Runoff from fan-piedmonts onto toeslopes and basin floors increases vegetation and organic carbon in these areas. This commonly results in changes from the Typic to Ustollic subgroups, depending upon organic carbon and sand/clay ratios. These boundaries are usually apparent and occur along the margin of the basin floor or the adjacent toeslope.

Faunal activity has obliterated the argillic horizon in some areas but not in others. This activity has resulted in erratic distribution of silicate clay and the presence of carbonate in all subhorizons of the B horizon. This has caused a change from an argillic to a cambic horizon, and the soils are Orthids instead of Argids. The boundary is not visible at the land surface.

LITERATURE CITED

1. Dunham, K. C. 1935. The geology of the Organ Mountains with an account of the geology and mineral resources of Dona Ana County, New Mexico. New Mexico Bur. Mines and Min. Res. Bull. 11. Socorro, N.M.
2. Gile, Leland H. 1966. Coppice dunes and the Rotura soil. Soil Sci. Soc. Amer. Proc. 30:657–660.
3. Gile, Leland H. 1975. Causes of soil boundaries in an arid region: I. Age and parent materials. Soil Sci. Soc. Amer. Proc. 39:316–323. (This issue.)
4. Gile, L. H., J. W. Hawley, and R. B. Grossman. 1970. Distribution and genesis of soils and geomorphic surfaces in a desert region of southern New Mexico. Guidebook, Soil-Geomorphology Field Conferences. Soil Science Society of America, and New Mexico State University, University Park, N.M.
5. Hawley, J. W., and F. E. Kottlowski. 1969. Quaternary geology of the south-central New Mexico border region. New Mexico Bur. Mines and Min. Res. Cir. 104:89–115. Socorro, N.M.
6. Herbel, C. H., and L. H. Gile. 1973. Field moisture regimes and morphology of some arid-land soils in New Mexico. p. 119–152. *In* R. R. Bruce et al. (ed.) Field soil water regime. Special Pub. No. 5. Soil Science Society of America, Madison, Wis.
7. Lee, K. E., and T. G. Wood. 1971. Termites and soils. Academic Press, New York.
8. Ruhe, R. V. 1964. Landscape morphology and alluvial deposits in southern New Mexico. Ann. Ass. Amer. Geog. 54:147–159.
9. Ruhe, R. V. 1967. Geomorphic surfaces and surficial deposits in southern New Mexico. New Mexico Bur. Mines and Min. Res. Memoir 18. Socorro, N.M.
10. Soil Survey Staff. 1975. (In press.) Soil taxonomy, a basic system of soil classification for making and interpreting soil surveys. Soil Conservation Service, USDA. Washington, D.C.
11. Thornbury, W. D. 1969. Principles of geomorphology. John Wiley & Sons, New York.

Use of Satellite Imagery to Delineate Soil Associations in the Sand Hills Region of Nebraska[1]

David T. Lewis, Paul M. Seevers, and James V. Drew[2]

ABSTRACT

Published soil association maps of counties within the Sand Hills region of Nebraska were used to establish relationships between satellite imagery and soil associations mapped by conventional methods. Soils formed in the eolian sand of this region range from somewhat excessively drained soils formed on major dunes to poorly drained soils of subirrigated valleys. These soils represent a hydrosequence; soil patterns are closely associated with differences in topography, near-surface hydrology, and rangeland vegetation. In view of these relationships, multispectral satellite imagery acquired during the growing season was useful in stratifying soil associations including subirrigated soils, whereas imagery obtained during periods of continuous snow cover and relatively low solar elevation angles was useful in stratifying soil associations characterized by differences in topography. Relationships established between published soil associations and satellite imagery were used to stratify soil associations at the mesosociation level of cartographic generalization in an adjacent area within the Sand Hills region.

Additional Index Words: remote sensing, soil survey, range management, snow enhancement.

Soil association maps of counties within the Sand Hills region of Nebraska delineate groups of polypedons that occur together in individual and characteristic patterns. These maps are published at scales of 1:100,000 to 1:300,000 and group polypedons into soil associations at the level of cartographic generalization proposed for the mesosociation (Simonson, 1971), a soil assocation for a land area of county size. The purpose of this study is to test the use of multitemporal imagery from the first Earth Resources Technology Satellite (ERTS-1) in visually stratifying soil associations in the Sand Hills region at the level of generalization used in county soil surveys.

Geographically, the Sand Hills region occupies approximately 32,000 km^2 of rangeland in northcentral Nebraska. The landscape is characterized by several generations of sand dunes interspersed with nearly level valleys (Smith. 1965). Major dunes 30- to 90-m high and 0.5- to 1-km wide often form long ridges that extend for as much as 20 km. Lakes and marshes occur in many intervening valleys where the land surface intercepts the ground-water table. Within the dunes and in certain valleys, the gound-water

---

[1] Contribution from the Dept. of Agronomy, Univ. of Nebraska-Lincoln. Published with the approval of the Director as paper no. 3778, Journal Series, Nebraska Agr. Exp. Sta. Research reported was conducted under NASA Contract NAS5-21756. Investigation results released according to NASA ERTS-1 Data User Investigation Publication and Information Release Policy in Weekly Government Abstracts as "Proposal to Evaluate the Use of ERTS-1 imagery in Mapping Soil and Range Resources in the Sand Hills Region of Nebraska," NASA-CR- 128412. Received 2 May 1974. Approved 24 Oct. 1974.

[2] Assistant Professor Postdoctoral Fellow and Professor of Agronomy, respectively.