SEQUENCE OF SOIL PROFILES IN LOESS.

B. H. WILLIAMS.

ABSTRACT. The time factor or age of soils developed from loess in western Nebraska appears to be expressed in the character of the present soils. There is sufficient evidence to suggest that the soils on the tableland south of Chappell, Nebraska, have developed from loess of two distinct periods of deposition. The Dawes soils developed from the older loess or silty, loess-like alluvium apparently had reached the stage of mature normal soils before the second or last loess deposit was made. Evidence supporting this belief is contained in the fossil soils buried beneath the last loess from which the present zonal soils (Keith series) have developed.

Where the old soils were not buried and have remained at the surface through the second period of loess deposition and soil formation they have developed strong claypan subsoils, an indication of their antiquity or of accelerated soil-forming processes. The compact claypan subsoils of the Dawes soils are in contrast with the friable, medium-textured subsoils of the Keith soils which contain only slightly more clay than their surface soils. Since the Dawes and Keith soils south of Chappell have developed from similar friable, silty materials and occupy comparable physiographic and topographic positions, and since the soil-forming influences on them probably have been the same during the period which has given rise to the normal Keith soils, it seems reasonable to suppose that the claypan of the Dawes soils is a result of soil-forming processes operating over longer periods than necessary for the formation of Keith soils. The soils buried beneath the most recent loess have characteristics much like those of the Holdrege series (Chernozem). Where these soils have not been buried they appear to have been advanced to the development of claypan soils (Dawes series).

THE Peorian loess of Nebraska, as stated by Condra and Reed (1) includes all the dust deposits of post-Loveland age. It comprises the initial Peorian (post-Iowa) and probably also equivalents of loess substages found between the Wisconsin drift sheets in South Dakota, Iowa, and Illinois. Some study of the loess substages has been made, but these have not been correlated as yet.

It is the current opinion of both soil scientists and geologists that the dark bands or buried soils—fossils soils—in the Peorian loess mark more humid climatic intervals separating the more xeric loess substages. The buried soils represent all stages of soil development from the youngest, most immature soils to the normal zonal soils and Planosols (claypan soils) of the present.

No attempt is made in this paper to correlate the buried soils with the established Pleistocene stages or substages, or loess depositions, or to estimate the amount of time required for development of these soils. The purpose is to record some observations on similarities and differences between these and the present soils, and also, where the old soils have not been buried, to bring out their relationships to the soils that have developed on the younger loesses.

The observations recorded here were made over a three-day period in November, 1943 in the course of a routine inspection of the soil conservation survey of Deuel County, Nebraska. They are taken from field notes compiled for later use in correlating the soils of the county. The observations are more or less applicable to all of Deuel County, but they relate more specifically to an area of 10 or 12 square miles around a point about three miles southwest of Chappell, Nebraska. This area represents the undissected part of the tableland which Wolfanger (2) calls the south divide and describes as an ancient terrace built at the confluence of the South Platte River and Lodgepole Creek.

The terrace lies about 150 feet above the flood plains of these streams and 25 to 50 feet below the top of the Ogallala which outcrops a short distance to the west and forms the westward extension of the table. The outcrop of the Ogallala includes the Kimball member of this formation, and the algal (*Chlorellopsis*) limestone described by Elias (3) as the topmost bed of the Tertiary in Kansas and adjoining states.

The high elevation of the terrace in relation to the top of the Tertiary column places it as the first or second post-Ogallala terrace and probably of early or middle Pleistocene age.

With the great amount of dust being deposited in western Nebraska near the close of the terrace-forming period, it is reasonable to assume that considerable wind-borne material was deposited on the terrace in the later stages of its formation when it was covered by grasses. This would account in part for the silty texture of the soils and the loess-like character of the three to five feet of fine-earth material immediately above the gravelly alluvium over which the oldest soils are developed.

During the more humid cycle following the formation of the terrace, the soils that formed on the nearly level areas of the tableland apparently were undisturbed for a long period of time and they developed profiles equivalent to the present Chernozem soils and associated weak Planosols. The relatively dry period following the first soil-forming period was one of erosion, and much of the area of the original soils was eroded to varying depths. In some places the soils are entirely removed and the underlying gravelly alluvium was exposed. Some of the old soils, however, remained intact and most of these remnants were buried by later deposits of loess in which the present soils are forming. This loess deposit had the effect of partially smoothing out the inequalities of the previous erosional surface and is of unequal thickness. It rests disconformably on the old soils and Pleistocene gravel beds.

On the basis of the above we have a composite Pleistocene geological column from the youngest to the oldest as follows:

1. Post-loess soils.
2. Loess.
3. Fossil soils.
4. Thin loess or silty loess-like alluvium.
5. Alluvium, chiefly arkosic sand and gravel.

Figure 1 presents a hypothetical composite cross section showing the geological and soils relationships on the tableland south of Chappel, Nebraska.

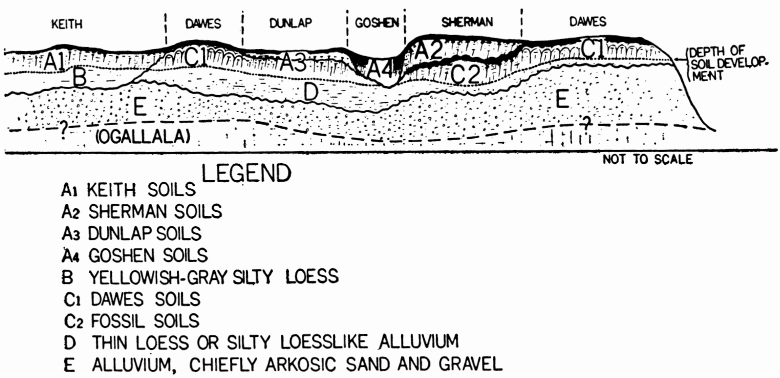

Fig. 1. Hypothetical cross section on tableland south of Chappell, Nebraska.

The fossils soils (C2) (see Fig. 1) bear evidence of a more humid climate than that of western Nebraska at the present time. They have thicker and darker organic-bearing layers, more compact clayey subsoils with more pronounced structural development than the present normal soils, and they are leached of their carbonate of lime to a greater depth. These fossil soils are about representative of the Chernozem group of soils of central Nebraska, and include profiles that correspond to those of the Holdrege and Hastings series, normal soils and Half-Planosols, respectively.

In places where the old soils were not buried (or were buried only to slight depths) by the later loess, weathering and soil-forming processes have continued to operate on them through two periods of soil formation and one period of erosion and loess deposition. Much clay has been formed and accumulated in their subsoils to produce strongly developed claypans with columnar structure characteristic of Solonetz soils. It seems possible that these Solonetz-like soils may have developed without the sodium saturation and the imperfect drainage generally considered necessary for the formation of Solonetz soils.

The claypan soils were included with the soils of the Dawes series (C1) in the original classification of the soils of Deuel County and they are retained in this classification, at least tentatively, in the present soil conservation survey. As a whole, these soils have nearly level relief, but in places they are on slopes of two or three per cent gradient and occupy more sloping areas than some of the adjoining normal Chestnut soils of the Keith series (A1) which have been developed in a relatively short period, during and since the deposition of the most recent loess.

The formation of the Dawes soils on slopes is in contrast with the Dawes silt loam in Kimball County, Nebraska, described by Jackson, Hayes, and Weldon (4), regarding which they state: "The Dawes soils occur in position where external drainage is poorly developed but where water seldom stands . . . The topographic position of this soil shifts the balance between the other developmental factors, giving, in a sense, an old soil." From the above it is assumed that the Dawes soils described by Jackson, Hayes, and Weldon have developed under a soil climate (soil moisture and biological relationships) different from that of the normal soils of the same general area, and that the processes of soil development either were speeded up sufficiently to give a soil of much more advanced stage of development than would be expected for the time the processes were operating or the processes operated longer than assumed.

The Dawes soils south of Chappell are in a position no more favorable, and in places less favorable, for rapid development than the associated normal soils. Therefore, it would seem logical to conclude that soil-forming processes operating slowly over long periods, as in the Dawes soils south of Chappell, would tend to give very similar or like profiles on the same kinds of parent materials that the processes would give if operating rapidly for a much shorter period, as in the Dawes silt loam of Kimball County, Nebraska.

The Keith soils include friable granular silt loam soils developed from yellowish-gray silty loess (B) in areas where the loess is four or more feet thick. In the upper part, their subsoils are friable silty clay loam, having cloddy or prismatic structure, and in the lower part they are friable silt loam and have little structure development. The increased heaviness in the upper part of the subsoils can be determined in the field only through close comparison with the other layers; whereas, the corresponding layer in the Dawes soils contains a very notable increase in content of clay.

The upper parts of the profiles of the Sherman soils (A2), Dunlap soils (A3), and Goshen soils (A4) have developed from the most recent loess, and in this respect they are like the present normal Chestnut soils but the lower parts of their profiles include the old fossil soils (C2) or have developed in part from the fossil soils.

The Sherman soils do not differ from the Keith soils to a depth of 20 to 36 inches, but below this depth they rest on or include the fossil soil and their lime-carbonate horizons have formed in part, if not entirely, in the dark organic-bearing layer of the fossil soil. The subsoils of the buried soils may be within the zone of influence of the soil-forming processes now operating, but in many places they lie deeper than this.

The morphology of the Dunlap soils is not so easily explained as that of the Sherman soils. From their general make-up, they appear, however, to include the old soils which were more or less eroded and then received a thin layer of younger loess—about 12 inches thick—all of which has become darkened with organic matter. This addition to the dark layers of the fossil soil gives the Dunlap soils thicker organic-bearing layers than the Keith and Sherman soils.

Although the Dunlap soils are comprised largely of the old soils, and the weathering and soil-forming processes have continued in the old soils as long as in the Dawes soils, their subsoils show only semiclaypan development about equal to that of the fossil soils that are buried deeply. The writer thinks that the strong claypan did not develop in the subsoils of the Dunlap soils because the thin mantle of late loess in the soils above them absorbed all or nearly all the impacts of weathering and soil-forming processes, and thus little weathering and alluviation of the lower layers have taken place. This explanation would seem plausible because just as in the Keith soils which have developed entirely from late loess, there has been little downward movement of clays from the surface layers.

The Goshen soils are comprised largely of dark-colored local alluvium that has accumulated in depressions and swales in the undissected uplands and at the foot of slopes along the drainages. The soils are dark and of rather uniform texture and consistence. They have little structure development except where the local alluvium is thin, and the lower parts of their subsoils include the heavy layers of the fossil soils.

DISCUSSION.

BRYAN: I am much pleased to see the principles of stratigraphy applied to the study of soil phenomena and am glad to know that soil scientists realize that soils as we now find them are the result of different sets of soil-forming processes operating at different times. One set of soil-forming processes may be superimposed on soils formed under another set of processes and the results are far from simple. I feel that there is a good possibility that a fairly definite chronology can be developed for glacial and post-glacial deposits, using soil profiles as an important means of determining this chronology.

THORP: Mr. Pate and I have been making some field observations on the growth of gullies in loess and in soils developed from it. In many instances, a deep vertical-walled gully is formed at first and the walls of the gully gradually recede uphill in a sort of wave. As the walls recede they become progressively lower and the land below each wall is a fairly smooth slope. New gullies form in the gentle slopes below the old gully walls and wave after wave of the walls can be traced uphill from intermittent drainageways. The resultant slopes of the drainageways comprise a series of smooth slopes and "cat-steps." We recognize, of course, that some "cat-steps" in the loess region are due to other causes. A parallelism may be drawn between the phenomenon here described and the superimposition of one set of soil-forming factors on another set. Many of our old soils as we now find them are the products of several "waves" of combinations of soil-forming processes. The effects of the earlier waves may be and usually are obscured by the effects of later waves and it becomes very difficult to reconstruct the history of many of these old soils. The interpretation of buried or fossil soils is somewhat less difficult. It seems fairly safe to assume that each of three buried post-Tertiary soils and the present soil have been subject to less complicated sequences of soil development than one early post-Tertiary soil that may have been exposed at the surface continually since, perhaps, Kansan times.

PATE*: Regarding buried soil profiles—most examples of this are in the western part of the loess belt. Buried profiles have a tendency to be quite local and occur in areas of erratic or frequently changing climate. As to the equilibrium of profile development, there is a wonderful opportunity to study this in North Dakota where we have soils developed on the residual parent material west and south of the Missouri River and on the younger glacial material north and east of river. Within short distances of each other and under similar climatic environment soils appear to have reached very similar stages of maturity indicating they have reached an equilibrium.

* Soil Conservation Service, U. S. Dept. of Agriculture.

REFERENCES.

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2 Wolfanger, Louis A., et al.: 1921. Soil Survey of Deuel County, Nebraska; U. S. D. A., Bureau of Soils in Coop. Univ. of Nebraska; Adv. Sheets—Field Op. Bur. Soils; pp. 707-755, Fig. 1, Map.

3 Elias, Maxim K.: 1931. The Geology of Wallace County, Kansas, Geol. Survey of Kansas, Bul. 18, Univ. of Kansas, Vol. 32, No. 7, p. 254, fig. 7, pl. 42.

4 Jackson, M. L., Hayes, F. A., and Weldon, M. D.: 1937. Some Chemical and Morphological Relationships Between Soil Profiles of the Rosebud and Associated Soil Series in Southeastern Kimball County, Nebraska. Soil Science Soc. of America, Proceedings, Vol. II, pp. 437-445, Fig. 3.

U. S. DEPT. OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
SOILS AND AGRICULTURAL ENGINEERING,
WASHINGTON, D. C.