ORIGIN OF "SLICKSPOT" SOILS OF NORTH CENTRAL OKLAHOMA. A PRELIMINARY REPORT

Daryoush Bakhtar and Fenton Gray

Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma

Large numbers of "slickspots," which usually support short grasses in a tall grass area, are found in soils of north central Oklahoma. Soil samples, taken from a typical area 30 miles west of Pawhuska, Osage County, were analyzed for sodium content. Resulting data, together with vegetation differences, were used to locate sampling pedons for further study. Ground water levels in sampling sites were noted, and water samples were analyzed for cation and anion content. Nitrates were found to be within the level normally permissible for drinking water; sodium and bicarbonates accounted for most of the dissolved solids.

Localized "slickspots" may occur in arid, semi-arid, and humid regions and on varying topography. They are common in the central to western part of Oklahoma. It is estimated that, in the state of Oklahoma, 897,750 acres are affected by high concentrations of soluble salts (1). Such soils present important problems since they do not support good plant growth. Knowledge of the origin of sodium in these soils is necessary for their improvement and, hence, for effective reclamation programs.

Sodium salts in the soil may originate in material either above or below the solum. Water, particularly water containing carbon dioxide, removes soluble salts from parent materials when drainage is poor and rainfall is insufficient. When water evaporates, salts remain in the soil. Occasionally rains redissolve the salts and carry them to lower areas or depressions. If the solution contains mostly sodium salts, sodium replaces other cations and saturates colloidal particles as it moves downward. As a consequence, the pH and permeability of the soil are affected. Slickspots may result from sodium accumulation in the soil.

The objective of this study was to learn the origin of sodium in the slickspot soils that are typical of north central Oklahoma. The area selected for study is located in NW¼ of section 17, T. 25 N., R. 5 E., 30 miles west of Pawhuska, Osage County.

SOIL-FORMING FACTORS

Jenny (2) defines soil formation as "the transformation of rock into soil." He considers the soil to be mature when the transformation of the rock has been completed and a state of equilibrium is reached. The genesis and morphology of any pedon are based on the assumption that the pedon has changed as a result of variations in climate, topography, parent material, vegetation, and time.

Climate. Soils in the study area developed under a warm temperate, subhumid, continental climate which influences morphological losses, gains, and transformation. The mean annual temperature for Osage County is approximately 60.8 F. The average annual evapotranspiration is about 34 inches.

Topography. The area displays a surface of maturely dissected relief. The highest point of NW¼, section 17, is in the northeast part, which has an elevation of 1,060 ft. The lowest is the southwest part with an elevation of 999 ft (Figure 1).

Parent material. Rocks that crop out and underlie soils of the transect are early Per-

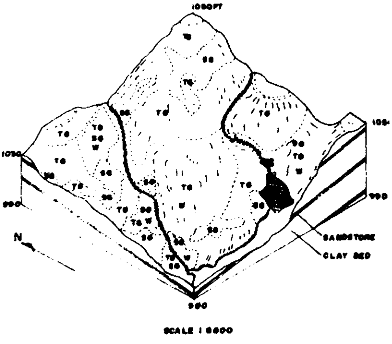

FIGURE 1. Parent material, topography, and vegetation of the study area. TG, tall grass; SG, short grass; W, weeds.

Proc. Okla. Acad. Sci. 51: 93-96 (1971)

mian and belong to the Wellington-Admire unit (3), which consists of interbedded shale, sandstone, and siltstone. Most of the unit is reddish colored shale or silty shale. The clayey material contains lenses of beds of sandstone and also thin siltstone beds (Figure 1). The study area soils may be formed either from Wellington-Admire unit or from the colluvium above.

Vegetation. The section is covered with tall, short, and mixed grasses. Weeds, *e.g.*, ironweeds, are mixed with grasses in many places. Short grass spots are associated with slickspots (Figure 1).

Time. The study area is within the Reddish Prairie Zone. Some of the processes of soil formation may be related to those that form Mollisols.

TABLE 1. *Chemical and physical properties of soil samples.*

Sample No.	Sand %	Silt %	Clay %	Conductivity EC X 10^3 25 C	pH H_2O[a]	pH KCl[b]	Presence of Carbonate (CO_3^{2-})	Soluble sodium ppm	Total sodium ppm
1	14.55	50.45	35.00	.07	7.4	6.4	+	43.70	4520
2	14.50	50.50	35.00	.10	7.1	6.4	—	47.50	4250
3	13.52	51.48	35.00	.09	7.6	6.6	—	40.00	4050
4	14.57	52.93	32.50	.06	7.4	6.3	—	30.00	3820
5	62.12	12.58	26.00	.07	7.5	6.8	—	45.00	3500
6	13.10	50.65	36.25	.60	8.1	7.0	—	612.50	7750
7	23.92	44.83	31.25	.50	8.0	6.9	+	510.00	6150

[a] 1:1 soil-water mixture.
[b] 1:1 soil-KCl mixture.

TABLE 2. *Chemical and physical properties of ground water samples.*

	Sample number 1	2	3	6	7
Depth (inches)	65	67	75	92	92
pH	8.7	8.5	8.3	—[a]	8.3
Conductivity (EC x 10^6, 25 C)	790	508	547	—[a]	1,454
Soluble sodium (%)	90.5	88.3	46.4	61.5	93.7
Sodium adsorption ratio	13.1	5.6	2.4	3.2	21.7
Residual sodium carbonate (%)	9.2	6.0	3.0	2.4	10.0
Ionic content (M.E./liter)					
SO_4^{2-}	.638	.580	.406	.348	1.624
CO_3^{2-}	1.080	.840	.660	.600	.840
HCO_3^{1-}	9.030	9.930	5.790	3.810	10.050
NO_3^{2-}	.112	.097	.112	.241	.112
Cl^{1-}	.520	.380	.300	.800	2.380
Ca^{2+}	.300	.800	1.950	1.250	.400
Mg^{2+}	.600	1.000	1.500	.750	.500
K^{1+}	.010	.007	.020	.012	.045
Na^{1+}	8.772	5.160	3.010	3.225	14.061

[a] Undetermined

MATERIALS AND METHODS

In a preliminary study, chemical and physical analyses were made of soil samples taken from the cut along the road on the west side of section 17, from 1,300 ft to 2,292 ft south of its northwest corner. Resulting data, together with observations on vegetation, were used to locate typical pedons. Seven deep pits were dug, with a backhoe digger, for detailed study (Figure 2). Soil samples were taken from all horizons and subhorizons of the solum and parent material. Five of the pits were dug below the ground water table, which was from 65 to 92 inches deep, and water samples were taken from each of these pits.

FIGURE 2. Cross section of the transect showing sites from which samples (1 - 7) were taken.

Soil samples were air dried and processed to pass a 2 mm sieve. Hydrometer determinations were made. Soil pH was determined by using Corning Model 7 pH meter on a 1:1 soil-water mixture and a 1:1 soil-KCl mixture. The electrical conductivity of a 1:1 soil-water extract was measured. The resistivity reading was taken on a model RC-1B Industrial Instrument Inc. conductivity bridge. Total sodium content was determined by treating the soil with sulfuric acid, hydrofluoric acid, and nitric acid (4).

Water samples were filtered through Whatman No 42 filter paper and pH and conductivity were measured. Carbonate and bicarbonate were titrated against sulfuric acid (5); chloride was determined by titration with silver nitrate (5). Nitrate was measured by micro Kjeldahl procedure. Sulfate determination involved passage of the aliquot through an exchange column which contained hydrogen - saturated Dowex - 50 resin (6). Sodium and potassium were determined with an atomic absorption spectrophotometer. Calcium and magnesium were determined by the Versenate titration method (5).

RESULTS AND DISCUSSION

Tables 1 and 2 show the data resulting from the chemical and physical analyses. The amount of soluble sodium in soil samples varied in the same direction as their total sodium content (Figure 3). Samples from short grass spots showed higher sodium content than did those from tall grass areas.

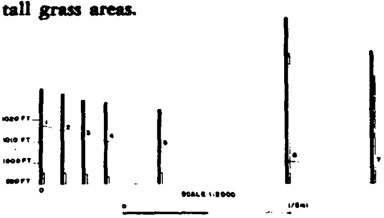

FIGURE 3. Variation of total sodium, soluble sodium, and relief in the road cut west of the study area. The solid black bar represents total sodium (½ inch = 1,000 ppm). The open bar represents soluble sodium (½ inch = 100 ppm).

The study area is under natural vegetation and has never been fertilized. The presence of nitrate in the water samples was interesting. The range of NO_3^{1-} varied from 6 to 15 ppm, less than the highest concentration recommended for drinking water (45 ppm) by the U.S. Public Health Service (7). The data do not show a relation between the amount of NO_3^{1-} and grass or relief. The presence of NO_3^{1-} may be related to naturally occurring organisms or to lightning, which may produce the equivalent of 2 lb/acre of nitric acid per year. Precipitation might also contribute NO_3^{1-} to the soil. In Virginia, the NO_3^{1-} content of the soil is reported to be in the range of 0 to 6 ppm (8).

The data do not show a high concentration of sulfate and chloride, nor, in general, was the conductivity of water samples found to be very high. The ground water under short grass contained more sodium than did that under tall grass. More than 88% of the total bases were sodium compounds. Sodium bicarbonate was found to be the predominant salt, whether the sample was taken from ground water under short, mixed, or tall grass. However, residual sodium carbonate was much greater in samples taken from under short grass than in those from under tall grass. This finding suggests the possibility of upward movement of ground water through capillary action and accumulation of sodium bicarbonate in the solum, which forms the black alkali. Development of black alkali is due to reaction between H-humus and $NaHCO_3$ to form Na-humus which moves downward and gives a dark color to profile.

REFERENCES

1. B. Steward, *Morphology, genesis, and classification of saline-sodic soils in North Central Oklahoma,* M.S. Thesis, Oklahoma State University, Stillwater, 1969.
2. H. Jenny, *Factors of Soil Formation,* McGraw-Hill Book Co., New York, 1941.
3. Research and Development Division, Oklahoma Highway Department, *Engineering classification of geologic materials,* Division 8 Res. Proj. 61-01-1, 1965.
4. L. Webber and J. Shivas, Soil Sci. Soc. Amer. Proc. 17: 96-99 (1953).
5. United States Salinity Staff, *Diagnosis and Improvement of Saline and Alkali Soils,* U.S.D.A. Handbook 60, L. A. Richards, Ed., U.S. Govt. Printing Office, Washington, D. C., 1954.
6. J. Fritz and S. Yamanura, Anal. Chem. 27: 1461-1464 (1955).
7. U. S. Public Health Service, *Drinking Water Standards,* Federal Register 27: 2152-2154 (1962).
8. A. W. Gambell, *Sulfate and Nitrate Content of Precipitation over Parts of North Carolina and Virginia,* U. S. Geol. Survey Prof. Paper 475C: C209-C211, 1963.