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Variations in Vegetation and Soil on Three Breaks-Sites Overlying Three Different Limestone Formations

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VARIATIONS IN VEGETATION AND SOIL ON THREE BREAKS-SITES OVERLYING THREE DIFFERENT LIMESTONE FORMATIONS

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by

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THESIS ABSTRACT

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The purpose of this study was to compare vegetation and soils occurring on breaks-sites overlying three distinct limestone formations. Three limestone formations, Ogallala, Niobrara, and Greenhorn outcrop in Ellis County, Kansas, as the Ash Hollow, Fort Hays and Fencepost limestone members, respectively.

Three line transects were established across each breaks-site. Vegetative composition and basal cover were determined by taking points along each transect.

Each breaks-site was divided into smaller units termed edaphic communities. These edaphic communities were named according to the dominant grasses present. Forage yields were determined for each edaphic community by clipping six one-square-foot plots in each community at the end of the growing season. Forage yields were divided into forbs, shortgrass and midgrass and calculated as total grass and total vegetation.

Soil samples were taken from each edaphic community and mechanical analysis, pH, and chemical analyses for total exchangeable metallic cations and exchange capacity were run on each sample.

Analysis of variance was used to compare grass yields from each edaphic community while the Fisher T Test was used to compare vegetative composition on the breaks-sites.

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INTRODUCTION

The Mixed Grass Prairie, extending from the southern coast of Texas north through the central plains states into the southern provinces of Canada, is one of the most productive agricultural regions in the world. Soils are deep and fertile and the topography is rolling to flat. Because of the fertile, level soils much of the original prairie grassland has been cultivated and often only land unfit for cultivation remains in native vegetation.

The term Mixed Prairie refers to the intermingling of tall, mid and short grasses. This relationship results in a tri-level layering of vegetation, tall grasses forming the overstory, midgrasses forming an intermediate layer and short grasses forming a mat-like understory.

Grasses are not the only form of vegetation present in Mixed Prairie as various forbs are also present. Along with both grasses and forbs many shrubby species are found where conditions are favorable, such as on protected steep slopes and in the valleys.

The Mixed Prairie of Central Kansas extends westward from the True Prairie to the Short Grass Plains west of the 100° meridian. Grasses in the climax vegetation for the West Central Mixed Prairie includes big bluestem (Andropogon gerardi), little bluestem (Andropogon scoparius) switch grass (Panicum virgatum), indian grass (Sorghastrum nutans), tall dropseed (Sporobolus asper), sand dropseed (Sporobolus cryptandrus), western wheat (Agropyron smithii), side-oats grama (Bouteloua curtipendula), red and purple three-awn (Aristida longiseta and Aristida purpurea), hairy dropseed (Sporobolus pilosus), blue grama (Bouteloua gracilis), buffalo grass (Buchloe dactyloides), and hairy grama (Bouteloua hirsuta). Forbs in the climax include western ragweed (Ambrosia psilostachya), maximilian sunflower (Helianthus maximiliani), prairie coneflower (Ratibida columnifera), blazing star (Liatrus punctata), stiff-leaf goldenrod (Solidago rigida), Missouri goldenrod (Solidago missouriensis), ashy goldenrod (Solidago mollis), many flowered scurfpea (Psoralea tenuiflora var. floribunda), heath aster (Aster ericoides), black sampson (Echinacea angustifolia), babywhite aster (Aster arenosus), and cat-claw sensitive brier (Schrankia nuttallii). Some of the woody species found in the climax are lead plant (Amorpha canescens), smooth sumac (Rhus glabra), small soapweed (Yucca glauca), sandhill plum (Prunus besseyi), flowering currant (Ribes odoratum), and poison ivy (Rhus toxicodendron).

Although these species form the total climax for the Mixed Prairie all will not be found associating together over the entire area. Rather each range site will have a particular vegetative climax as determined by soil, topography, precipitation and other climatic factors.

The Mixed Prairie, because of its vastness and economic importance has received much attention and research. Ecologists such as Clements, Weaver, and Albertson have aided in explaining and understanding this vast area of grassland.

All of the research accomplished has been or great value to rangemen and ranchers but there still exists considerable need for more detailed and exacting studies. Additional research is necessary if the full potential of the Mixed Prairie grassland is to be recognized, harvested, and at the same time conserved for future generations. The purpose of this paper is to report the findings of a study comparing the soils and vegetation on breaks-sites overlying three different limestone formations.

RELATED LITERATURE

Several important studies have been conducted in recent years on the West Central Mixed Prairie. Albertson (1937) described the vegetation, topography, soils and underlying parent material and divided the prairie into three major communities in Ellis County, Kansas. Deep heavy clay soils of the upland covered with buffalo grass and blue grama were called short grass types. Thinner soils on slopes and rocky outcroppings were dominated by little bluestem and were termed the little bluestem type. In moist lowlands big bluestem was dominant and such areas were termed big bluestem types.

Changes in vegetation brought about by the great drought and the subsequent recovery was investigated by Albertson (1938, 1940, 1941, and 1943), and Albertson and Weaver (1942). Little bluestem was found to be the dominant grass on the shallower soils of the breaks-sites before the drought; however, as the drought continued, much of the little bluestem was replaced by hairy grama, side-oats grama, and hairy dropseed.

Studying a moderately grazed pasture Tomanek et al. (1958) found the breaks-site dominated by side-oats grama with big bluestem and blue grama about equal in composition as subdominants. Little bluestem made up only a very small percent of the total composition.

Linnell (1961) studying the Chalk Flats in Gove County, Kansas, found that the pH varied from 7.1 to 7.8 in the surface two horizons and the organic matter ranged from 0.2 to 3.2 percent.

From studies on the little bluestem type Martin (1960) found little bluestem dominant with big bluestem the only other important grass. Fifty-four species of forbs were identified and recorded with stiff-leaf goldenrod, cat-claw sensitive briar, stemless tetraneuris (*Tetraneuris stenophylla*), and narrow-leafed houstonia (*Houstonia angustifolia*) most common.

Dietz (1953) divided the prairie into the upland, gentle slopes, steep slopes and lowland with each major division further divided. The steep slope, or breaks-site, was divided into both closed and open sites. The closed and open sites were subdivided into dense, moderate, and sparse areas, depending upon the abundance of vegetation present. Basal cover on the closed site was 30 percent on the dense area, 17 percent on the moderate area, and 9 percent on the sparse area. Yields ranged from 3522 pounds per acre on the dense area, to 2765 pounds on the moderate area, and 1800 pounds on the sparse area. On the open site the dense area had a basal cover of 33 percent, the moderate area 11 percent and the sparse area 4 percent. Seasonal yields were 1934 pounds for the dense area, 1506 pounds for the moderate area, and 796 pounds per acre for the sparse area. Side-oats grama, blue grama, hairy grama, and little bluestem were the dominant grasses found on the steep slopes.

From a study conducted on the Dakota Sandstone formation, Blair (1949) found basal cover on the little bluestem type was 17.2 percent. Little bluestem was the dominant grass with 12.7 percent cover and big bluestem was the subdominant grass with only 2.8 percent cover. Seasonal yield for the little bluestem type was 760 pounds per acre when clipped monthly and 710 pounds per acre when clipped at the end of the growing season.

Patel (1960) found the vegetative cover on the breaks-site to vary from 22.5 percent on the east-facing slope to 9.8 percent on the west-facing slope. Big bluestem was the dominant grass composing 86.4 percent of the composition on west-facing slopes and 84.5 percent on the east-facing slopes. Little bluestem composed 10.1 percent of the composition on the west-facing slopes and 11.3 percent on the east-facing slopes. Side-oats grama comprised 4.0 percent on the west-facing slopes and 4.2 on east-facing slopes. Grass production on west-facing slopes was 2102.5 pounds per acre and 1325 pounds per acre on east-facing slopes.

DESCRIPTION AND HISTORY OF STUDY AREAS

The general area of the Mixed Prairie studied was the breaks-site as described by the Soil Conservation Range Guide Classification (1961). Specifically, breaks-sites originating from three different limestone parent material were investigated.

Near Hays in Ellis County, Kansas three distinct limestone formations occur. These formations are the Ogallala, from the Tertiary system, and the Niobrara and Greenhorn from the Cretaceous system (Moore, et al. 1951).

The Ogallala formation outcrops in Ellis County as the Ash Hollow member and is commonly referred to as the mortar beds due to the cementing together of sand, gravel and silt constituents (Moore, et al. 1951). Mortar beds form an impermeable layer through which water penetrates very slowly. Outcroppings of Ash Hollow limestone are found in the northwest part of the county on either side of the Saline River and again along the Smoky Hill River in the southwest corner of the county (Fig. I).

The Niobrara formation makes an appearance in Ellis County in the form of the Fort Hays member (Fig. I). Fort Hays limestone is a chalky limestone overlaid by Smoky Hill Chalk and underlaid by Blue Hill Shale (Fig. II). Fort Hays limestone does not form an impermeable layer as does the Ash Hollow limestone. Instead numerous large faults and cracks allow water to penetrate down to the Blue Hill Shale.

The third limestone formation in Ellis County is the Greenhorn

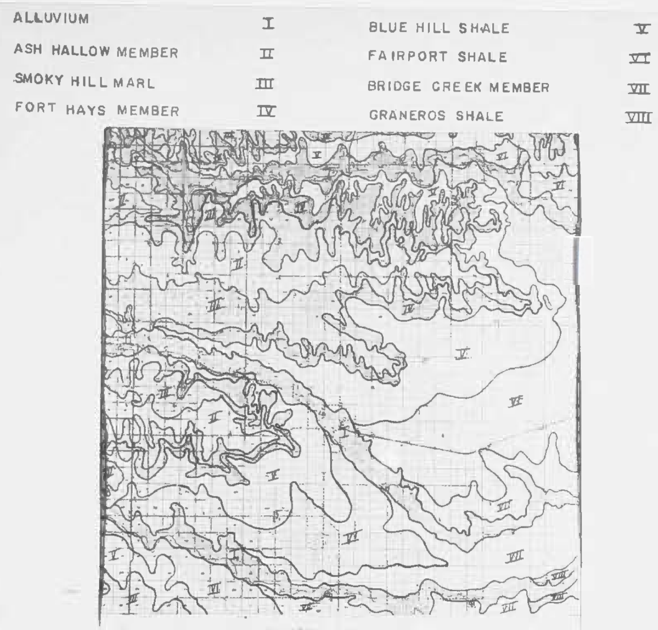

Fig. I. Map showing underlying formations in Ellis County.

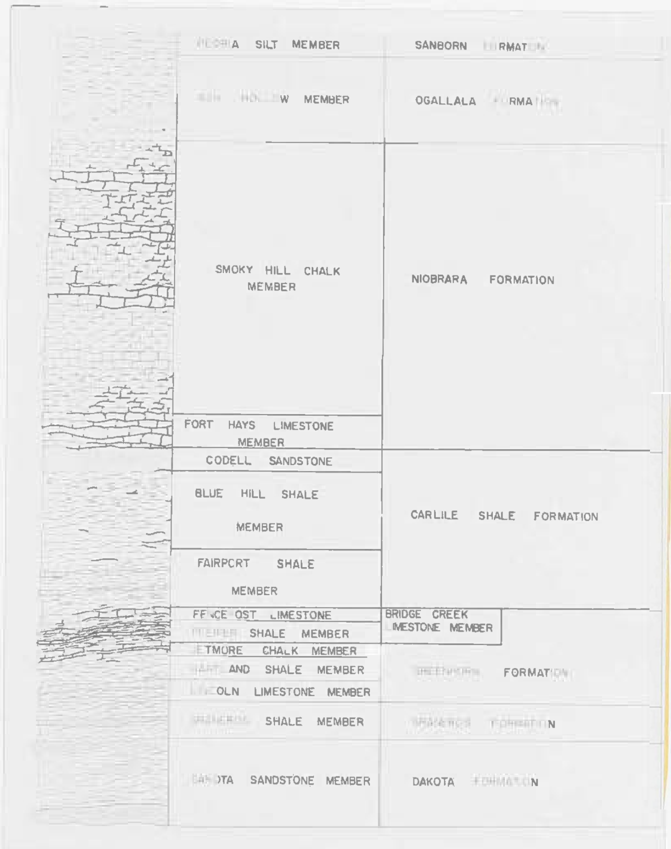

Fig. II. Rock column in Ellis County.

composed of chalky limestone and calcareous shales (Moore, et al. 1951). The formation outcrops in the southeast part of the county along the Smoky Hill River as Fencepost limestone, a constituent of the Pfeifer Shale member (Fig. I). The Pfeifer Shale is overlaid by Fairport Chalky Shale, a member of the Carlile Shale, and underlaid by Jetmore Chalk, a member of the Greenhorn (Fig. II). Fencepost limestone is criss-crossed with numerous faults and cracks which allows water to percolate through to underlying chalk and shale layers.

All three limestone formations, Ogallala, Niobrara and Greenhorn, have great water-holding capacities because of shale and chalk layers. Where soil is deep good stands of mid and tall grasses are common. In many areas where shale outcroppings occur springs are common, many of which flow all year. Others run only during wet periods.

The Soil Conservation Service has divided range land of the Mixed Prairie into various range sites according to the characteristic soil and soil depth. Sites which have a soil mantle of less than 20 inches or a slope of 30 percent or more are classed as breaks-sites. Breaks-sites occurring on the three limestone formations interested the investigator and are the subject of this paper.

Although the Soil Conservation Service has divided the range land into range sites for easier identification and as an aid in determining grazing rates, little work has been done to determine variations in vegetation which occur within each range site. The breaks-site will serve as an example. The basic distinction between types of breaks-sites is the large underlying geological formations. All breaks-sites originating from limestone formations are classed as limestone breaks disregarding variations due to different limestone parent materials. A detailed study of variations in vegetation on breaks-sites overlying different limestone formations should aid better understanding of limestone breaks-site so that its full potential can be recognized and utilized.

Vegetation on the three study areas had not been grazed or otherwise disturbed, except by native animal population, for over 30 years. From the vegetation present the three areas were concluded to be at or very near a climax state for this section of the Mixed Prairie.

One area of study was located two and one-half miles west and eight miles north of Ellis, Kansas, on the Ellis and Trego county line. Underlying parent material is Ash Hollow limestone originating from the Ogallala formation (Moore, et al. 1951). Due to the impermeability to water the Ash Hollow limestone area of study was characterized by a larger percentage of short grass, predominantly drought resistant blue grama, in the climax.

Topography of the Ash Hollow limestone is rolling and broken by steep gorges and ravines (Fig. III). The particular breaks-site under study had a one to three percent east-facing slope. Soil varied from less than one to 18 inches in depth with numerous limestone fragments on the surface. The thin top soil was underlaid by a layer of coarse gravel extending down to bed rock. Soils were very immature possessing only an AC profile. Throughout the area were large outcroppings of bare limestone which had sparse vegetation in cracks and crevices where

Fig. III. General view of breaks-site over Ash Hollow Limestone.

soil had accumulated (Fig. IV).

Dominant vegetation was blue grama and little bluestem. Blue grama dominated the upper slopes with little bluestem occupying the lower slopes. Dominant forbs on the area were james' whitlow wort (*Paronychia jamesii*), babywhite aster, Texas sandwort (*Arenaria stricta* var. *texana*) and resinous skullcap (*Scutellaria resinosa*). Several woody species were found growing on the very steep slopes and in the ravine bottoms (Fig. V).

Another breaks-site studied originated from Fort Hays limestone and was located two miles west and one mile south of Hays. The grassland was removed from grazing in 1902 and has been allowed to return to its original climax vegetation. Topography is rolling with numerous ravines throughout, giving a broken appearance (Fig. VI). The particular study location was on a two to five percent west-facing slope with soil varying from one to 16 inches in depth. The community on which the soil mantle was one inch in depth was covered with many limestone fragments and concretions (Fig. VII). Soil on the Fort Hays limestone as on the Ash Hollow was immature possessing only an AC profile.

Vegetation on breaks-site was dominated by little and big bluestem. These two species intermingled on the deeper soils in about equal proportion with little bluestem occupying the shallower soils almost exclusively. Dominant forbs on the site were james' whitlow wort, babywhite aster, stemless tetraneuris and Texas sandwort. Woody species were not as abundant as on the Ash Hollow area.

Fig. IV. Close-up showing bare limestone with scattered vegetation on the Ash Hollow breaks-site.

Fig. V. Looking down the ravine on the Ash Hollow breaks-site showing several species of woody plants.

Fig. VI. General view of study area over Fort Hays Limestone.

Fig. VII. Close-up of the breaks-site over the Fort Hays Limestone showing shallow soil with limestone fragments and concretions and sparse vegetation.

Another area of study was located seven miles south and eight miles east of Hays on the north bank of the Smoky Hill River. Parent material was Fencepost limestone from the Greenhorn formation. Topography of the general area is rolling except where the river and deep gorges formed steep sharp breaks which give a rough, rugged appearance to the terrain (Fig. VIII). The specific breaks-site studied varied from a two to 15 percent east-facing slope and the soil varied from two to 20 inches in depth. The areas of shallow soils were covered with limestone fragments and concretions (Fig. IX). Soil was immature having only an AC profile.

Dominant vegetation was little and big bluestem. The upper slopes with a deeper soil mantle supported both species with big bluestem most abundant. Little bluestem occupied the shallower, steeper soils. Forbs dominating the area were james' whitlow wort, Texas sandwort, stiff-leaf goldenrod and babywhite aster. Several woody species were found on the steeper slopes and ravines (Fig. X).

Fig. VIII. View showing rugged terrain of the Fencepost Limestone study area.

Fig. IX. Close-up on Fencepost Limestone breaks-site showing shallow soil with limestone fragments and concretions.

Fig. X. Looking down steep slope on the Fencepost Limestone breaks-site at various woody species.

METHODS OF STUDY

The breaks-site is a complex site due to variations in soil depth and chemical composition of soil. These soil variations produce a variety of vegetation patterns. In order to investigate the breaks-site thoroughly the site was divided into smaller areas which were termed edaphic communities. These edaphic communities were named according to the dominant vegetation present.

The study area on Ash Hollow limestone was divided into six edaphic communities:

Little bluestem - shallow soil

Blue grama - side-oats grama

Little bluestem - hairy grama

Blue grama - hairy grama

Little bluestem - deep soil

Little bluestem - side-oats grama

The area of study on Fort Hays limestone was divided into six edaphic communities:

Little bluestem - shallow soil

Little bluestem - blue grama

Little bluestem - deep soil

Big bluestem

Little bluestem - indian grass

Little bluestem - big bluestem

The breaks-site over Fencepost limestone was divided into nine edaphic communities:

Little bluestem - big bluestem

Little bluestem - hairy grama - hairy dropseed

Little bluestem - switch grass - big bluestem

Little bluestem - shallow soil

Little bluestem - deep soil

Big bluestem

Hairy grama - hairy dropseed

Little bluestem - indian grass - big bluestem

Side-oats grama

Soils and vegetative yields for each edaphic community was determined and compared.

Vegetation: Vegetation on the three areas was sampled by using the point frame (Levy and Madden 1933). Three line transects were established across each study area. Transects started on the deeper soil of each area and extended down over shallow soil on the break to a point where the soil depth again reached 20 inches or until the bottom of the ravine was reached. Transects averaged 1000 feet in length making approximately 3000 feet of transect for each area.

Vegetation was sampled by taking 500 sets or a total of 5000 points with the point frame. Points were taken down the entire length of each transect by placing the point frame end to end. Percent composition and basal cover of vegetation was calculated for each breaks-site.

Forbs were sampled by simple reconnaissance and listing. The author walked over the study areas recording all forbs encountered. Forbs were numbered in order of importance and a final list was made in descending order of abundance.

Forage yields were obtained by clipping the vegetation at the end of the growing season during the last week in September and the first week in October. Six random one-square foot plots were clipped on each edaphic community making a total of 78 square feet for the three areas. Vegetation was clipped at the ground level and separated according to short grasses, mid grasses and forbs. Forage was air-dried, and recorded in pounds per acre.

Forbs, grasses and woody species were identified by using keys by Hitchcock (1950) and Rydberg (1932). Common names were obtained from Anderson (1961).

<u>Soils</u>: Soil was sampled by digging bisects in each edaphic community. Soil profiles were identified by distinct color changes and a sample was taken from each color zone. Soil was air-dried, and mechanical analysis, chemical analysis and pH were determined on each sample.

Mechanical analysis was accomplished by using the method described by Bouyoucos (1936).

Soil pH was determined by using a Beckman electronic pH meter. The soil was mixed in a 1:10 paste according to McGeorge (1938). Two replications for each sample were run and an average taken for the final pH.

Chemical analyses were made to determine total exchangeable cations and exchange capacity by a modified method of the one used by the Association of Official Agricultural Chemists (1951) and Jackson (1958) for highly calcareous soils (Appendix A). Three replications of each sample were run and an average taken for the total exchangeable cations and exchange capacity.

RESULTS

OGALLALA FORMATION ASH HOLLOW MEMBER

Percent composition and basal cover: Total basal cover of the Ash Hollow Limestone breaks-site was 10.51 percent (Table I). Blue grama and little bluestem were the dominant grasses making up 3.61 and 3.30 percent basal cover and 34.37 and 31.42 percent, respectively, of the total vegetation. Side-oats grama and hairy grama were found to comprise 2.06 and 1.24 percent basal cover. Big bluestem, hairy dropseed and red three-awn made up the remaining 0.29 percent basal cover.

Forage yield: The Ash Hollow site was the lowest producing area, yielding only 2427.86 pounds per acre total vegetation and 2017.16 pounds per acre of grass (Table II). The highest yielding edaphic community on the Ash Hollow site was the little bluestem-deep soil community which produced 5151.68 pounds per acre. The little bluestem-shallow soil community was the lowest yielding community, producing only 586.26 pounds per acre (Table III).

NIOBRARA FORMATION FORT HAYS MEMBER

Percent composition and basal cover: Basal cover on the Fort Hays Limestone breaks-site was 18.91 percent of which 13.58 percent was little bluestem (Table I). Big bluestem and side-oats grama together made up 4.96 percent basal cover. The remaining 0.38 percent basal cover was furnished by hairy dropseed, red three-awn, blue grama

Table I Percent composition and basal cover on three breaks-sites originating from three limestone formations.

Species	Ash Hollow Limestone Percent Composition	Ash Hollow Limestone Percent Cover	Fort Hays Limestone Percent Composition	Fort Hays Limestone Percent Cover	Fencepost Limestone Percent Composition	Fencepost Limestone Percent Cover
Age*	.69	.07	20.59	3.90	31.02	4.09
Asc	31.42	3.30	71.78	13.58	33.33	4.39
Bcu	19.62	2.06	5.64	1.07	18.21	2.40
Spi	1.39	.15	.10	.02	4.63	.61
Alo	.69	.07	.10	.02	.31	.04
Bda					3.86	.51
Bgr	34.37	3.61	1.68	.32		
Sas					.62	.08
Snu					1.24	.16
Pvi					.93	.12
Bhi	11.81	1.24	.10	.02	5.86	.77
Total	100.00	10.51	100.00	18.93	100.00	13.17

*Symbols for each grass species are taken from the first letter of each genus and the first two of the species. These symbols occur in all tables used throughout this paper. Age--big bluestem, Asc--little bluestem, Bcu--side-oats grama, Spi--hairy dropseed, Alo--red three-awn, Bda--buffalo grass, Bgr--blue grama, Sas--tall dropseed, Snu--indian grass, Pvi--switch grass, Bhi--hairy grama.

Table II Forage production on three breaks-sites expressed in pounds per acre.

Parent Materials	Forbs	Shortgrass	Midgrass	Total Grass	Total Veg.
Ash Hollow	410.76	457.60	1559.56	2017.16	2427.92
Fort Hays	118.78	122.17	3067.78	3189.95	3308.73
Fencepost	284.67	58.13	2374.61	2432.74	2717.41

Table III. Forage production from each edaphic community found on the Ash Hollow Limestone breaks-site expressed in pounds per acre.

Edaphic Communities	Forbs	Shortgrass	Midgrass	Total Grass	Total Veg.
Asc shallow soil	326.70	29.09	230.47	259.56	586.26
Asc deep soil	422.53	33.21	4695.94	4729.15	5151.68
Asc - Bcu	489.75	220.86	2443.17	2664.03	3153.78
Bgr - Bhi	297.69	1085.14	57.81	1142.95	1440.64
Bgr - Bcu	662.61	743.52	1305.75	2049.27	2711.88
Asc - Bhi	265.28	633.80	624.19	1257.99	1523.27

and hairy grama.

Forage yield: The breaks-site located on the Fort Hays Limestone was the highest producing site, yielding 3308.73 pounds per acre total vegetation and 3189.95 pounds per acre of grass (Table II). The highest producing edaphic community on the Fort Hays site was the big bluestem community, yielding 5282.83 pounds per acre. The lowest yielding community was the little bluestem-shallow soil community, producing only 416.60 pounds per acre (Table IV).

GREENHORN FORMATION FENCEPOST MEMBER

Percent composition and basal cover: Basal cover on the Fencepost Limestone was 13.17 percent (Table I). Dominant species were big and little bluestem which together constituted 8.48 percent cover and 64.35 percent of the vegetation. Side-oats grama made up 2.40 percent of the cover and 18.21 percent of the vegetation. Hairy grama, hairy dropseed, red three-awn, tall dropseed, switch grass, indian grass and blue grama made up the remaining 2.30 percent cover and 17.44 percent composition.

Forage yield: The breaks-site located on Fencepost Limestone was an intermediate producing site compared to the Ash Hollow and Fort Hays breaks-sites, yielding 2717.41 pounds per acre total vegetation and 2432.74 pounds per acre of grass (Table II). On the Fencepost site, as on the Ash Hollow site, the little bluestem-deep soil community was the highest producing, yielding 5665.95 pounds per acre. The lowest yielding community, as on the Ash Hollow and the Fort Hays, was the little bluestem-shallow soil community, producing only 426.21 pounds

Table IV. Forage production from each edaphic community found on the Fort Hays Limestone breaks-site expressed in pounds per acre.

Edaphic Communities	Forbs	Shortgrass	Midgrass	Total Grass	Total Veg.
Asc shallow soil	120.14	12.80	403.32	416.12	536.26
Asc deep soil	192.06		2352.76	2352.76	2544.82
Asc - Age	67.22		4782.47	4782.47	4849.69
Asc - Snu	220.86		3889.26	3889.26	4110.12
Age	42.12		5240.71	5240.71	5282.83
Asc - Bgr	70.25	720.23	1738.17	2458.40	2528.65

per acre (Table V).

A complete list of all plants identified on the three breaks-sites may be found in Appendix B.

Table V. Forage production from each edaphic community found on the Fencepost Limestone breaks-site expressed in pounds per acre.

Edaphic Communities	Forbs	Shortgrass	Midgrass	Total Grass	Total Veg.
Asc shallow soil	235.07		191.14	191.14	426.21
Asc deep soil	768.25		4897.70	4897.70	5665.95
Asc - Pvi - Age	91.22		3745.23	3745.23	3836.45
Asc - Snu - Age	221.16		4417.45	4417.45	4638.61
Asc - Bhi	206.50	333.10	312.09	645.19	851.69
Age	86.42		3219.04	3219.04	3305.46
Asc - Age	329.76		2881.18	2881.18	3210.94
Bhi - Spi	335.60	190.06	238.06	428.12	763.72
Bcu	288.09		1469.57	1469.57	1757.66

SOILS

The importance of exchangeable cations lies in the fact that plants obtain soil nutrients partially through the exchangeability of cations. The property of cation exchange is also important in the application of fertilizers. An example of this principle can be seen in the application of lime to a soil which is acidic. Calcium in the lime exchanges places with hydrogen on the soil particles thus producing an alkaline or neutral soil. Another example of the exchange property of soils is shown by nutrients which are leached from the soil very easily. Many nutrients when added as fertilizer would soon be leached below the root zone and would thus be lost to plants. The exchange property of these nutrients allows the cations to exchange places with other cations in the soil to thus form insoluble complexes.

Exchange capacity of a soil is the ability of the cations present to exchange with one another. The exchange process, among soil particles, organic material and plant roots enables plants to utilize nutrients available in the soil.

OGALLALA FORMATION

On the areas where the soil depth was less than five inches a coarse textured top soil was underlaid by a layer of coarse gravel. Limestone fragments were found in the lower depths of the deeper profile and throughout the profile in the shallower soils.

Textural analysis and pH determination: The Clark soil over the Ash Hollow limestone had the highest average percent sand of the three areas studied (Table VI). The sand fraction varied from 27 to 41 percent. The silt fraction varied from 36 to 55 percent. Percent clay ranged from 16 to 32 (Table VI). From results obtained by mechanical analysis soil on the Ash Hollow site would be classified as a loam.

The average pH on the Ash Hollow site was the lowest (7.68) of the three sites studied (Table VI). The pH range was from 7.34 to 7.86.

Total exchangeable metallic cations and exchange capacity: Samples used in mechanical analysis were also analyzed chemically. Total exchangeable metallic cations on the Ash Hollow site ranged from a low of 25.36 m.e.[1] per 100 grams of soil to a high of 49.63 m.e. per 100 grams (Table VI). The average exchangeable cations for the site was 44.07 m.e. per 100 grams of soil.

Exchange capacity ranged from 7.08 m.e. per 100 grams of soil to 12.00 m.e. (Table VI). Average exchange capacity for the site was 8.72 m.e. per 100 grams of soil.

NIOBRARA FORMATION

Textural analysis and pH determination: Soil on the Fort Hays

[1] m.e. is the abbreviation used to designate milli-equivalents. One m.e. is equal to one milligram of hydrogen or its equivalent which will combine with or displace it.

Table VI. Results of mechanical analysis, pH determination, chemical analysis of total exchangeable metallic cations and the exchange capacity of soil from each edaphic community on the Ash Hollow Limestone breaks-site.

Edaphic communities	Percent Sand	Clay	Silt	pH	Exchangeable cations m.e./100 grams	Exchange capacity m.e./100 grams
Asc deep soil						
0- 8	41	16	43	7.78	43.40	10.03
8-16	31	32	37	7.78	46.58	11.43
Bgr						
0- 4	30	17	53	7.68	25.36	8.27
4-10	41	23	36	7.80	30.69	10.87
Bgr - Bcu						
0- 5	27	19	54	7.68	48.99	7.08
5-14	42	20	38	7.86	49.63	12.09
Bgr - Bhi						
0- 5	33	19	48	7.58	49.45	9.68
5-11	39	25	36	7.34	49.17	9.07
Asc - Bcu						
0- 6	31	18	51	7.69	44.51	9.15
6-12	40	24	44	7.71	47.62	10.21
Asc - Bhi						
0- 5	35	17	55	7.59	49.32	8.07

breaks-site had the lowest sand content of any site studied (Table VII). The sand fraction varied from two percent to 20 percent. The clay fraction ranged from 25 to 63 percent. The silt content varied from 23 to 65 percent. From the mechanical analysis soil over the Fort Hays limestone would be a silty clay loam.

Soil pH ranged from 7.84 to 8.31 with an average of 8.07.

Total exchangeable metallic cations and exchange capacity: Total exchangeable metallic cations on the Fort Hays site ranged from a low of 22.51 m.e. per 100 grams of soil to 49.84 m.e. (Table VII). Average exchangeable cations for the site was 34.02 m.e. per 100 grams of soil.

Exchange capacity for the Fort Hays soil ranged from 1.34 m.e. per 100 grams of soil to 10.66 m.e. (Table VII). Average exchange capacity for the site was 5.33 m.e. per 100 grams of soil.

GREENHORN FORMATION

Textural analysis and pH determination: Soils on the Fencepost breaks-site were intermediate in sand content in relation to soils of Ash Hollow and Fort Hays breaks-sites. The sand fraction varied from seven to 29 percent (Table VIII). The clay fraction ranged from 14 to 63 percent. The silt content varied from 23 to 59 percent (Table VIII). Results obtained from mechanical analysis indicate soil over the Fencepost limestone would be classified as clay.

Soil pH ranged from 7.90 to 8.33. The average pH was 8.07.

Total exchangeable metallic cations and exchange capacity: Total exchangeable cations on the Fencepost breaks-site ranged from 36.53 m.e.

Table VII. Results of mechanical analysis, pH determination, chemical analysis of total exchangeable metallic cations and the exchange capacity of soil from each edaphic community on the Fort Hays Limestone breaks-site.

Edaphic communities	Percent Sand	Clay	Silt	pH	Exchangeable cations m.e./100 grams	Exchange capacity m.e./100 grams
Asc shallow soil						
0- 6	2	50	39	8.31	30.92	10.66
Asc deep soil						
0- 9	7	33	60	8.00	34.76	2.80
Asc - Age						
0- 7	18	50	32	7.84	33.90	5.83
7- 9	20	57	23	8.07	31.16	8.63
9-15	4	45	51	8.20	43.37	2.97
15-20	1	43	56	8.24	49.84	3.18
Asc - Snu						
0- 3	4	38	58	7.98	22.51	6.03
3- 6	10	63	27	8.08	31.81	6.91
6-10	4	60	36	8.23	31.28	7.76
Asc - Bgr						
0- 7	10	25	65	8.01	31.60	2.54
Age						
0- 9	7	30	63	7.96	33.02	1.34

Table VIII. Results of mechanical analysis, pH determination, and chemical analysis of total exchangeable metallic cations and the exchange capacity of soil from each edaphic community on the Fencepost Limestone breaks-site.

Edaphic communities	Percent Sand	Percent Clay	Percent Silt	pH	Exchangeable cations m.e./100 grams	Exchange capacity m.e./100 grams
Asc shallow soil						
0- 6	28	40	32	8.33	45.89	3.80
Asc deep soil						
0- 8	13	36	51	7.90	46.23	11.49
8-16	18	14	38	8.00	42.35	3.15
Asc - Age						
0- 6	24	38	38	8.10	47.01	2.15
6-12	14	63	23	8.28	48.17	3.28
12-14	14	61	25	8.30	48.69	3.24
Bcu						
0- 2	29	32	39	8.09	38.00	7.69
Asc - Pvi - Age						
0- 4	9	32	59	8.01	41.17	6.87
4- 9	23	39	38	8.00	36.53	4.70
Asc - Snu - Age						
0- 5	7-	54	39	7.90	39.18	3.31
5-15	9	53	38	7.90	40.03	6.61
Age						
0- 6	15	38	47	8.23	45.52	3.25
6-14	17	60	33	7.95	48.60	4.40
Asc - Bhi						
0- 5	23	40	37	8.00	41.60	6.00
Bhi - Spi						
0- 4	28	38	46	8.05	39.31	5.59

per 100 grams of soil to 48.69 m.e. Average exchangeable cations for the area was 43.22 m.e. per 100 grams of soil.

Exchange capacity ranged from 2.15 to 11.49 m.e. per 100 grams of soil. Average exchange capacity is 4.74 m.e. per 100 grams.

DISCUSSION

Vegetation on the three breaks-sites were found to be composed of the same species but composition, basal cover and yield were highly variable (Tables I and II). Statistical analysis was applied to the vegetative results to aid in understanding and explanation. Analysis of variance and Duncan's Multiple Range Test (Duncan 1955) were applied to the grass yields on each edaphic community within each breaks-site. Significant differences were found among sites, at the one percent level of probability, but no difference were found between replications (Table IX, X, and XI).

ASH HOLLOW

Statistically there was a significant difference between grass yields on the little bluestem-deep soil community and grass yields on the remaining five communities (Table IX). No significant difference was found among the grass yields from the little bluestem-side-oats grama, blue grama-side-oats grama, little bluestem-hairy grama and the blue grama-hairy grama communities. Grass yield from the little bluestem shallow soil community was significantly lower than all other communities.

FORT HAYS

No significant difference was found among grass yields from the big bluestem, little bluestem-big bluestem or the little bluestem-

Table IX. Analysis of variance table and Duncan's Multiple Range Test for yields on the Ash Hollow breaks-site.

Source of variation	Degrees of freedom	Sums of squares	Mean square	F
6 sites	5	7875.45	1575.09	8.20**
6 reps	5	438.22	87.64	.46
error	25	4892.42	192.10	
36 total	35			

Site $\bar{X}$[1]	A	B	C	D	E	F
	2.73	11.98	13.23	21.03	26.37	49.43

[1] Site $\bar{X}$ the mean yields from six one-square-foot plots expressed in grams. Significant at the 99 percent level.

Communities

A Little bluestem shallow soil

B Blue grama - hairy grama

C Little bluestem - hairy grama

D Blue grama - side-oats grama

E Little bluestem - side-oats grama

F Little bluestem deep soil

Table X. Analysis of variance table and Duncan's Multiple Range Test for yields on the Fort Hays breaks-site.

Source of variation	Degrees of freedom	Sums of squares	Mean square	F
6 sites	5	9200.41	1840.08	4.23**
6 reps	5	1289.82	257.96	.59
error	25	10871.23	434.85	
36 total	35			

Site $\bar{X}$[1] the	A	B	C	D	E	F
	4.35	24.47	25.63	40.50	41.50	54.47

1 Site $\bar{X}$ the mean yields from six one-square-foot plots expressed in grams. Significant at the 99 percent level.

Communities

A Little bluestem shallow soil

B Little bluestem deep soil

C Little bluestem - blue grama

D Little bluestem - indian grass

E Little bluestem - big bluestem

F Big bluestem

Table XI. Analysis of variance table and Duncan's Multiple Range Test for grass yields on the Fencepost breaks-site.

Source of variation	Degrees of freedom	Sums of squares	Mean square	F
9 sites	8	16722.38	2090.30	8.63**
6 reps	5	1339.61	267.92	1.11
error	40	9684.47	242.11	
54 total	53			

Site $\bar{X}$[3]	A	B	C	D	E	F	G	H	I
	1.92	4.36	6.72	15.29	30.40	33.64	38.07	45.98	51.18

[3] Site $\bar{X}$ the mean yields from the six one-square-foot plots expressed in grams. Significant at the 99 percent level.

Communities

A Little bluestem shallow soil

B Hairy grama - hairy dropseed

C Little bluestem - hairy grama

D Side-oats grama

E Little bluestem - big bluestem

F Big bluestem

G Little bluestem - switch grass - big bluestem

H Little bluestem - indian grass - big bluestem

I Little bluestem deep soil

indian grass communities, although a significant increase in yield was found on the above communities over the remaining communities (Table X). Grass yields from the little bluestem-blue grama and the little bluestem deep soil communities showed no significant difference. Yield from the little bluestem shallow soil community was significantly lower than other communities on the Fort Hays breaks-sites.

FENCEPOST

The two highest producing communities, little bluestem-deep soil and little bluestem-indian grass-big bluestem produced 51.18 and 45.98 grams of grass per plot, respectively (Table XI). Statistically there was no difference in grass yields from these communities. The little bluestem-switch grass-big bluestem community produced 38.07 grams of grass per plot. No difference in grass yields were indicated when comparing this community with the little bluestem-indian grass-big bluestem community; however, there was a significant decrease in grass yield when comparing the little bluestem-switch grass-big bluestem community to the little bluestem deep soil community. The big bluestem and little bluestem-big bluestem communities produced 33.64 and 30.40 grams of grass per plot, respectively. There was no difference in yields between big bluestem-little bluestem-big bluestem communities or among these and the little bluestem-switch grass-big bluestem community, but a significant decrease did exist among the big bluestem, and little bluestem-big bluestem communities and the two highest producing communities, little bluestem deep soil and the little bluestem-indian grass-big bluestem. The side-oats grama community produced 15.29 grams of grass per plot. No difference in yields were shown when comparing the side-oats grama community with the little bluestem-hairy grama community, which produced 6.72 grams of grass per plot. A significant decrease in grass yields was shown, however, when comparing the side-oats grama and little bluestem-hairy grama communities with all higher producing communities. The two lowest producing communities, hairy grama-hairy dropseed and little bluestem shallow soil, produced 4.36 and 1.92 grams of grass per plot, respectively. No difference in grass yields occurred between these two communities. A significant decrease in grass yields was evident when comparing the two lowest producing communities with all other communities.

The Fisher T Test (Fisher 1954) was used to compare the vegetative composition of the three breaks-sites (Table XII). Composition of the four major species, little bluestem, big bluestem, side-oats grama, and hairy grama, which occurred on all three sites were used to compare the breaks-sites. Composition of little bluestem on the Fort Hays site (71.78 percent) was found to be significantly higher than on the Fencepost (33.33 percent) and Ash Hollow sites (31.42 percent) (Table XII). Little bluestem composition of the Fencepost site was significantly higher than the little bluestem composition on the Ash Hollow site. Big bluestem composition on the Fort Hays (20.59 percent) and Fencepost (31.02 percent) sites was significantly greater than the big bluestem composition on the Ash Hollow site (.69 percent). No significant difference was found between the big bluestem composition on the Fort Hays and Fencepost sites.

Table XII. Percent composition of four grasses found on all three breaks-sites. Breaks-sites indicated as parent material.

	Ash Hollow	Fort Hays	Fencepost
Asc	31.42	71.78	33.33
Age	.69	20.59	31.02
Bcu	19.62	5.64	18.21
Bhi	11.81	.10	5.86

Side-oats grama composition on the Ash Hollow site (19.62 percent) was significantly higher than on the Fort Hays site (5.64 percent). No significant difference in side-oats grama composition occurred between the Ash Hollow and Fencepost sites (18.21 percent) however, a significant increase did exist between the Fencepost and Fort Hays sites. Hairy grama composition on the Ash Hollow site (11.81 percent) was significantly greater than on the Fencepost (5.86 percent) and Fort Hays sites (.10 percent). Hairy grama composition on the Fencepost site was significantly higher than the composition on the Fort Hays site.

SOILS

Soils on the three sites were highly variable in texture. Over the Ash Hollow limestone the soil was a loam high in both sand and silt and relatively low in clay (Table VI). On the Fort Hays limestone the soil was high in both silt and clay and low in sand and was classed as a silty clay loam (Table VII). Soil over the Fencepost limestone was classed as a clay, due to the high percent of clay (Table VIII).

Total exchangeable cations on the three breaks-sites varied from 44.07 m.e. per 100 grams of soil on the Ash Hollow, to a low of 34.02 m.e. on the Fort Hays, to 43.22 m.e. on the Fencepost site. Total exchangeable cations alone does not indicate what nutrients are available for plant use. Neither does total exchangeable cations indicate which of the four metallic cations, (sodium, calcium, potassium, or magnesium) are present and in what quanitity. Without continuing the soils analysis and determining which of the four metallic cations are present, amounts and availability of each, no conclusions are indicated concerning the relationship between chemical content of the soil and the vegetation present on the three breaks-sites.

No relationships between pH, exchangeable cations, and exchange capacity were apparent. The exchange capacity for the Ash Hollow site with a pH of 7.68 was 8.72 m.e. per 100 grams of soil. On the Fort Hays and Fencepost sites the pH was 8.07 and the exchange capacity was 5.38 m.e. and 5.12 m.e. per 100 grams of soil, respectively.

A definite relationship was shown between vegetative composition and forage yield.

SUMMARY

Due to the complexity of the breaks-site additional research on this particular range site was attempted. Three breaks-sites occurring over three distinct limestone formations were selected for study. The three limestone formations studied were the Ogallala, Niobrara, and the Greenhorn. Specific members studied of these formations were the Ash Hollow limestone, Fort Hays limestone, and the Fencepost limestone. Vegetation on each site had been undisturbed for more than 30 years and was close to climax condition.

Each breaks-site was divided into smaller sites called edaphic communities. Edaphic communities were determined by variations in soil and vegetative cover and were named according to the dominant species present.

The Ash Hollow breaks-site was divided into six edaphic communities:

Little bluestem - shallow soil
Little bluestem - deep soil
Little bluestem - hairy grama
Side-oats grama - blue grama
Little bluestem - side-oats grama
Blue grama - hairy grama

The Fort Hays breaks-site was also divided into six edaphic communities:

Little bluestem - shallow soil
Little bluestem - deep soil

Little bluestem - indian grass

Little bluestem - blue grama

Little bluestem - big bluestem

Big bluestem

The Fencepost breaks-site was divided into nine edaphic communities:

Little bluestem - shallow soil

Little bluestem - deep soil

Little bluestem - switch grass - big bluestem

Little bluestem - indian grass - big bluestem

Little bluestem - big bluestem

Little bluestem - hairy grama

Side-oats grama

Hairy grama - hairy dropseed

Big bluestem

Three line transects were established across each breaks-site with emphasis placed on passing through each edaphic community. A total of five thousand points were recorded on each transect using a point frame. Composition and cover of grass was calculated from the data collected. Forbs were sampled by simple reconnaissance.

Basal cover ranged from 10.51 percent on the Ash Hollow site to 18.91 percent on the Fort Hays site. Little bluestem was the dominant grass on all three sites but varied in composition from 31.42 percent on the Ash Hollow site, 71.78 percent on the Fort Hays site and 33.33 percent on the Fencepost site.

Forage yields were collected at the end of the growing season. Six square feet were taken on each edaphic community. Yields for each edaphic community and each breaks-site were calculated. Forage was divided into forbs, shortgrass, and midgrass and calculated as total grass and total vegetation. Forage yields for the edaphic communities were highly variable, ranging from 5665.21 pounds per acre to 416.60 pounds per acre. Yields for the breaks-sites ranged from 3308.73 pounds per acre on the Fort Hays limestone, to 2717.14 pounds on the Fencepost limestone to 2427.14 pounds on the Ash Hollow limestone.

Soils on the three breaks-sites were also highly variable. Soil samples were taken in each edaphic community according to distinct color changes in the profiles. Soils ranged from a loam on the Ash Hollow site, to a silty clay on the Fort Hays site, to a clay on the Fencepost site. Mechanical analysis, pH, total exchangeable cations and exchange capacity were determined on each sample. The pH was 7.68, 8.07 and 8.07 on the Ash Hollow, Fort Hays and Fencepost sites, respectively. Total exchangeable cations varied from 44.07 m.e. per 100 grams of soil on the Ash Hollow site to 34.02 m.e. on the Fort Hays site and 43.69 m.e. on the Fencepost site. The exchange capacity ranged from 4.74 m.e. per 100 grams of soil on the Fencepost site to 5.33 m.e. on the Fort Hays site and to 8.72 m.e. on the Ash Hollow site.

Analysis of variance was run on the grass yields of each edaphic community within each breaks-site. Grass yields from the little bluestem deep soil community on the Ash Hollow site showed a significant increase over all other communities. The little bluestem shallow soil community on the Ash Hollow site showed a significant decrease in grass yield from all other communities on the site.

Grass yield from the three highest producing communities on the Fort Hays site showed a significant increase over the three lower producing communities.

A significant increase in grass yield was found to exist when comparing the highest producing community with all communities below the little bluestem-switch grass-big bluestem community on the Fencepost site. A significant decrease in grass yield occurred between the two lowest producing communities and the remaining communities on the sites.

The Fisher T Test was used to compare the vegetative composition between the three breaks-sites. The four major species little bluestem, big bluestem, side-oats grama and hairy grama, which occurred on each site were compared. Composition of little bluestem was significantly different on all sites. No significant difference was evident between big bluestem composition on the Fort Hays and Fencepost sites, although big bluestem composition was significantly lower on the Ash Hollow site. Side-oats grama composition on the Ash Hollow and Fencepost sites showed no significant difference; however, side-oats grama composition on the Fort Hays site was significantly lower. Hairy grama composition was significantly different on all three areas.

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APPENDIX A

CHEMICAL ANALYSIS

TOTAL EXCHANGEABLE METALLIC CATIONS

REAGENTS

(a) Neutral normal ammonium acetate solution. Prepared by mixing 2 N NH_4OH and 2 N acetic acid and adjusting the pH to 7.0.

(b) 0.1 N HCl

(c) 0.1 N NaOH

DETERMINATION

Place ten grams of air-dried, finely ground soil in a 500 ml Pyrex erlenmeyer flask and add 100 ml of NH_4 acetate solution. Stopper the flask and shake vigorously for three seconds. Agitate the solution every fifteen minutes for one hour. Filter solution on a buchner funnel with light suction. Leach the residue with NH_4 acetate solution until 250 ml of filtrate is obtained. Save residue for exchange capacity determination. Transfer filtrate to a 250 ml Pyrex beaker and evaporate to dryness on a hot plate. Place the beaker in a muffle furance and heat at 550^{o} C for fifteen minutes to remove any organic matter.

Dissolve the residue with 50 ml 0.1 N standard HCl using brom cresol purple as an indicator. Place the beaker on a warm hot plate for complete dissolution. If the brom cresol purple changes from a yellow to a purple, indicating an alkaline condition, add more 0.1 N HCl. Filter the solution and rinse residue with deionzed water. Back titrate with standardized 0.1 N NaOH to a distinct purple coloration.

The results are recorded in terms of net 0.1 N acid used. In calculating the total exchangeable bases each ml of net acid used equals one milli-equivalent exchangeable cations per 100 grams of soil on the basis of a 10 gram charge.

FORMULA

Milli-equivalent exchangeable metallic cations per 100 grams of soil. = V-T

Where V equals the volume of 0.1 N HCl added and T is the back titer of 0.1 N NaOH.

EXCHANGE CAPACITY

REAGENTS

(a) Ninety-five percent ethyl alcohol which reacts alkaline to phenolphthalein upon addition of 0.1 ml 0.1 N NaOH per 100 ml.

(b) 0.1 N HCl

(c) 0.1 percent aquatic methyl orange solution.

(d) Anti-foam -- a mixture of mineral oil and capryl alcohol.

STEAM DISTILLATION APPARATUS

Three liter Pyrex boiling flask, 500 ml Pyrex, long-neck Kjeldahl flask, 150 ml separatory funnel, 14 inch coil condenser and connections of 7 mm glass tubing. The boiling flask is connected to three Kjeldahls with rubber and glass tubing. The Kjeldahls in turn are fixed with a separatory funnel and connected to the coil condensers.

DETERMINATION

Wash the residue, obtained from the total exchangeable cation process, with 15 ml portions of alcohol until a total volume of 250 ml is reached. Drain off excess alcohol and transfer residue to Kjeldahl flasks. Add a few drops of anti-foam solution and begin heating. Place a 250 ml beaker containing 1.0 ml 0.1 N HCl and two drops of methyl orange solution under the condenser. Pass steam through the Kjeldahls until all air is displaced, release steam pressure and add 15 ml of normal NaOH from the separator then continue distillation. Stir the acid frequently during the first two minutes of distillation to assure that the ammonical liquid does not rise to the surface. Collect 200 ml of distillate and make distinctly alkaline with 0.1 N NaOH. Back titrate with 0.1 N HCl until first signs of color change from yellow to orange.

APPENDIX B

The following is a list of grasses found on the Ash Hollow breaks-site:

Common Name:	Scientific Name:
Little bluestem	*Andropogon scorparius* Michx.
Side-oats grama	*Bouteloua curtipendula* (Michx.) Torr.
Blue grama	*Bouteloua gracilis* (H. B. K.) Lag.
Hairy grama	*Bouteloua hirsuta* Lag.
Red three-awn	*Aristida longiseta* Steud.
Hairy dropseed	*Sporobolus pilosus* Vasey

Forbs found on the area listed in descending order of abundance were:

Common Name:	Scientific Name:
James whitlow wort	*Paronychia jamesii* T. & G.
Babywhite aster	*Aster arenosus* Blake
Texas sandwort	*Arenaria stricta* Michx, var. texana Robins
Oval-leaf bladder pod	*Lesquerella ovalifolia* Rydb.
Stiff-leaf goldenrod	*Solidago rigida* L.
Black sampson	*Echinacea angustifolia* DC.
Hairy evolvulus	*Evolvulus pilosus* Nutt.
Prairie ragwort	*Senecio plattensis* Nutt.
Western ragweed	*Ambrosia psilostachya* DC.
Wavey-leaf thistle	*Cirsium undulatum* (Nutt.) Spreng.
Stemless tetraneuris	*Tetraneuris stenophylla* Rydb.
Broom snakeweed	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby.
Purple prairie clover	*Petalostemum purpureum* (Vent.) Rydb.
Slender greenthread	*Thelesperma gracile* (Torr.) Gray
Serrateleaf evening primrose	*Oenothera serrulata* Nutt.
Blazing star	*Liatris punctata* Hook.
Prairie coneflower	*Ratibida columnifera* (Nutt.) Woot. & Standl.
Stinging spurge	*Tragia ramosa* Torr.
White milkwort	*Polygala alba* Nutt.
Heath aster	*Aster ericoides* L.
Prickly pear cactus	*Opuntia macrorhiza* Engelm.

Woody species found on area were:

Common Name:	Scientific Name:
Small soapweed	Yucca glacua Nutt.
Wild grape	Vitis vulpina L.
Poison ivy	Rhus radicans L.
Skunk brush	Rhus trilobata Nutt.
Flowering currant	Ribes odoratum Wendland f.
Smooth sumac	Rhus glabra L.

The following grasses were located on the Fort Hays breaks-site.

Common Name:	Scientific Name:
Big bluestem	Andropogon gerardi Vitman
Little bluestem	Andropogon scoparius Michx.
Side-oats grama	Bouteloua curtipendula (Michx.) Torr.
Hairy grama	Bouteloua hirsuta Lag.
Blue grama	Bouteloua gracilis (H. B. K.) Lag.
Switch grass	Panicum virgatum L.
Indian grass	Sorghastrum nutans (L.) Nash
Hairy dropseed	Sporobolus pilosus Vasey
Red three-awn	Aristida longiseta Steud.

Forbs found on area in order of descending abundance were:

Common Name:	Scientific Name:
James whitlow wort	Paronychia jamesii T. & G.
Babywhite aster	Aster arenosus Blake
Stemless tetraneuris	Tetraneuris stenophylla Rydb.
Texas sandwort	Arenaria stricta Michx. var. texana Robins
Oval-leaf bladderpod	Lesquerella ovalifolia Rydb.
Stiff-leaf goldenrod	Solidago rigida L.
Narrowleaf hustonina	Hustonia angustifolia Michx.
Serrateleaf evening primrose	Oenothera serrulata Nutt.
Prairie ragwort	Senecio plattensis Nutt.
Hairy evolvulus	Evolvulus pilosus Nutt.
Many flowered scurfpea	Psoralea tenuiflora Push. var. floribunda (Nutt.) Rydb.
Purple prairie clover	Petalostemum purpureum (Vent.) Rydb.
Black sampson	Echinacea angustifolia DC.
Western ragweed	Ambrosia psilostachya DC.
Slender greenthread	Thelesperma gracile (Torr.) Gray
Resinous scullcap	Scutellaria resinosa Torr.
Ashy goldenrod	Solidago mollis Bartl.
Broom snakeweed	Gutierrezia sarothrae (Pursh.) Britt. & Rusby
Stinging spurge	Tragia ramosa Torr.

Wavey leaf thistle	*Cirsium undulatum* (Nutt.) Spreng.
Cat-claw-sensitive brair	*Scharankia nuttallii* (DC.) Standl.
Prairie coneflower	*Ratibida columnifera* (Nutt.) Woot. & Standl.
Maximilian sunflower	*Helianthus maximiliani* Schrad.
Yellow stemed dalea	*Dalea enneandra* Nutt.
Heath aster	*Aster ericoides* L.
Golden dalea	*Dalea aurea* Nutt.
False prairie boneset	*Kuhnia glutinosa* W.
Prickle pear cactus	*Opuntia macrorhiza* Engelm.
Tall evening primrose	*Stenosiphon linifolius* (Nutt.) Britt.
Blazing star	*Liatrus punctata* Hook.

Woody species found on the area were:

Common Name:	Scientific Name:
Small soapweed	*Yucca glacus* Nutt.
Poison ivy	*Rhus radicans* L.

The following list includes all grasses found on the Fencepost breaks-site:

Common Name:	Scientific Name:
Little bluestem	*Andropogon scoparius* Michx.
Big bluestem	*Andropogon gerardi* Vitman
Side-oats grama	*Bouteloua curtipendula* (Michx.) Torr.
Hairy grama	*Bouteloua hirsuta* Lag.
Hairy dropseed	*Sporobolus pilosus* Vasey
Indian grass	*Sorghastrum nutans* (L.) Nash
Switch grass	*Panicum virgatum* L.
Buffalo grass	*Buchole dactyloides* (Nutt.) Engelm.
Tall dropseed	*Sporobolus asper* (Michx.) Kunth

Forbs present on the area in order of descending abundance were:

Common Name:	Scientific Name:
James whitlow wort	*Paronychia jamesii* T. & G.
Texas sandwort	*Arenaria stricta* Michx. var. texana Robins
Stiff-leaf goldenrod	*Solidago rigida* L.
Babywhite aster	*Aster arenosus* Blake
Narrowleaf hustoniana	*Hustonia angustifolia* Michx.
Stemless tetraneuris	*Tetraneuris stenophylla* Rydb.
Oval-leaf bladderpod	*Lesquerella ovalifolia* Rydb.

Resinous scullcap	Scutellaria resinosa Torr.
Purple prairie clover	Petalostemum purpureum (Vent.) Rydb.
Fendlers aster	Aster fendleri Gray
Black sampson	Echinacea angustifolia DC.
Serrateleaf evening primrose	Oenothera serrulata Nutt.
Aromatic aster	Aster oblongifolius Nutt.
Broom snakeweed	Gutierrezia sarothrae (Pursh.) Britt. & Rusby
Many flowered scurfpea	Psoralea tenuiflora Pursh. var. floribunda (Nutt.) Rydb.
Slender greenthread	Thelesperma gracile (Torr.) Gray
Hairy evolvulus	Evolvulus pilosus Nutt.
Maximilian sunflower	Helianthus maximiliani Schrad.
Ashy goldenrod	Solidago millis Bartl.
Fremonts evening primrose	Oenothera fremontii S. Wats.
White milkwort	Polygala alba Nutt.
Heath aster	Aster ericoides L.
Blazing star	Liatrus punctata Hook.
Prairie coneflower	Ratibida columnifera (Nutt.) Woot. & Standl.
Prairie ragwort	Senecio plattensis Nutt.
Wavey leaf thistle	Cirsium undulatum (Nutt.) Spreng.
Tall evening primrose	Stenosiphon linifloius (Nutt.) Britt.
Canada lettuce	Lactuca canadensis L.
Texas croton	Croton texensis (Klotzsch) Muell. Arg.
Stinging spurge	Tragia ramosa Torr.
Shorts loco	Astragalus shortianus (Nutt.) Rydb.

Woody species found on area were:

Common Name:	Scientific Name:
Green ash	Fraxinus pennsylvanica Marsh.
Chokecherry	Prunus virginiana L.
Skunk brush	Rhus trilobata Nutt.
Poison ivy	Rhus radicans L.
Small soapweed	Yucca glacua Nutt.
Flowering currant	Ribes odoratum Wendland F.
Wild grape	Vitis vulpina L.
Hackberry	Celtis occidentalis L.
Smooth sumac	Rhus glabra L.