

PRAIRIE MOUNDS
in
BRYCE CANYON NATIONAL PARK

by

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In his dissertation on the plant ecology of Bryce Canyon National Park, Buchanan (1960) describes the occurrence of slightly elevated mounds within sagebrush flats on the plateau area of the park. These mounds were first noticed on aerial photographs of the upper tributaries of East Creek. The mounds appeared superficially inconspicuous on the ground and were distinguished chiefly by differences in the height and composition of vegetation on mounds and between mounds. Buchanan identified the mounds as "mima mounds" and suggested that they were constructed by Prairie Dogs.

Mima mounds were named after the type locality of their occurrence, the Mima Prairie in western Washington. There exists a considerable literature on mima mounds and correspondingly a great range and variety of opinions as to their origin. They are, in most recent studies however, considered a geomorphic or pedologic phenomena not a biological one as Buchanan suggests.

It is the purpose of this paper to further examine the mounds Buchanan identified in Bryce Canyon National Park, with particular regard to 1) geographic distribution in and around the plateau area of the park, 2) their morphology, 3) their spacing with respect to each other, 4) the differences in the height of vegetation on mounds and between mounds, and 5) the soil depth and profile in and adjacent to mounds. We hope that a summary of these characteristics will eventually assist in narrowing speculation concerning the origin of mounds in Bryce Canyon.

It is a pleasure to acknowledge the assistance of Mr. John Bezy, Chief Naturalist of Bryce Canyon National Park in directing our attention to the existence of Bryce's prairie mounds and in arranging accommodations during the period of field work. This project is likewise indebted to

the members of the University of Arizona, Department of Geography 1980 field class and their unstinting labors and also to our ever helpful instructors Dr. Richard Reeves and Dr. Lay James Gibson.

THE MOUND LITERATURE

Prairie mounds have a wide geographic distribution. Mound "fields" of low, naturally occurring hillocks distributed over level or sometimes sloping terrain occur extensively in Arkansas and eastern Oklahoma where they are called Prairie mounds. In the Gulf Coastal Plain similar features are called "pimples", and in California, Oregon, and western Washington the term "mima mounds" is usually applied.

Theories on the origin of mounds are numerous. Human manufacture has been suggested (Wilkes, 1845). The role of some biological agent such as ants (Hilgard 1873), or burrowing mammals like gophers or prairie dogs has been considered crucial (Dalquest and Scheffer 1942, Koons 1948). Quinn (1961) proposed construction by wind deposition of loess at the base of clumps of vegetation during a more arid climate.

The bulk of the literature deals with description of mounds and their geographic extent yet has failed to provide a cogent theory of mound genesis. Certainly a sound and convincing theory of origin must have as its base an objective and meticulous description of the phenomena. The widespread availability of aerial photography has aided in a better understanding of mound distribution and has frequently enabled features not easily discernable on the ground to be illuminated.

"Mima" mounds are certainly the most thoroughly discussed and perhaps the most well understood of all the various mound forms.

A brief review of the literature concerning them requires consideration.

Mima mounds were first described in detail and named by Bretz (1913).

The typical mound consists of a lens shaped or biconvex spheroidal segment of black unstratified pebbly silt which rests upon a cobbly outwash surface. They range in diameter from 10 to 70 feet and in height from barely discernable features to a maximum of 7 or 8 feet. In cross-section their form is flatly hemispheroidal and in plan-view they are roughly circular. Mound spacing is quite regular and in general intermound distance is less than the diameter of adjacent mounds. Intermound surfaces are characterized by outcroppings of the submound gravels.

Bretz reviewed a number of earlier hypothesis and concluded that origin was not fully explicable on the basis of data then available. He did, however, suggest a tentative hypothesis involving modification of washed drift deposited in the holes of a melting ice sheet.

The hypothesis of gopher construction of mima mounds was proposed by Dalquest and Scheffer (1942) and restated later by Scheffer (1947). This notion sparked a lively exchange of ideas as to origin and attracted the attention of T. L. Pewe a periglacial geomorphologist who noted the similarity between mima mounds and mounds formed by ice wedges near Fairbanks, Alaska (1948). Pewe suggested a theory of slumping of polygonal patches of earth into ditches left by thawed polygonal-fissure ice.

Newcomb (1952) made more detailed observations of the mounds than had Dalquest and Scheffer and pointed out that the gopher theory contained internal disharmonies and agreed with the Pewe theory. Later Ritchie (1953) refined the hypothesis to include subsequent erosion of an ice network after thawing. This he argued would account for the

distribution of cobbles between mounds, the enhanced alignment of mounds, and the fact that the steep side of mounds on slopes faced up-gradient.

PRAIRIE MOUNDS IN BRYCE CANYON NATIONAL PARK

The Physical Setting

Bryce Canyon National Park extends approximately 20 miles along the eastern rim of the Paunsaugunt Plateau in south central Utah. In contrast with the spectacularly rugged eastern rim which rises as much as 1500 feet above the adjacent lowlands, the plateau area of the park is a region of low and rolling relief. At an elevation of about 8000 feet the plateau slopes gently northward from the southern rim area. Intermittent streams flowing east and northeast out of the park are tributaries of the perennial East Fork of the Sevier River which drains the Paunsaugunt Plateau.

Climate records for the plateau have been maintained at Bryce Canyon National Park since 1933. The climate of the plateau area is characterized by long cold winters and mild summers. The mean annual temperature for the coldest month, January is 8.2°F. Each year the soil is frozen to a depth of 1-4 feet and ice forms on reservoirs and streams. The mean annual temperature for the warmest month, July, is 64.5°F. Great diurnal ranges in temperature are common and reflect the influence of topographic setting, and elevation. The maximum average annual range of temperature for Bryce Canyon is 111°F (86°F - - 25°F):

The precipitation of the plateau area also shows great annual and seasonal fluctuations. Bryce Canyon receives an annual average precipitation of 18.82" but amounts have ranged from as little as 14"

to a maximum of 22". Droughts occurred throughout the Paunsaugaut Plateau in 1902-1904, 1916, 1918 and 1922-1924, yet exceptionally great amounts of precipitation fell between 1905-1915.

Most summer rainfall occurs infrequently in brief and localized thundershowers. Many monthly rainfalls consist of a single shower which supplies an inch or more of rain. The most important source of water which feeds springs and maintains the flow of streams is not rainfall but snow. Snow may occur in all months except July, August, and September and provides the majority of the annual total precipitation. The average annual snowfall at Bryce Canyon is 103".

Land Use History

The first scientific exploration of the plateau region of what is now Bryce Canyon National Park was conducted in 1872 by members of the Wheeler survey (1870-76). Mapping and further investigation continued in 1875 under the supervision of Capt. C. E. Dutton. Although the surveys were brief and gave scant attention to the region they nevertheless outlined the major geographic and geologic features which were previously unknown. Trappers and prospectors may have visited the region between 1830-1866, but no written account remains.

Cattle were first introduced into the plateau area during the summer of 1873 by the Kanarra Cattle Company. The first sheep were introduced in the summer of 1877 and were wintered at Sheep Flat east of the plateau. By 1892 the first homestead on the plateau was established near the present day Ruby's Inn northwest of the Park (see figure 1). John L. Sevy maintained the 160 acre homestead as a headquarters for sheep ranging. Grazing on the plateau was probably

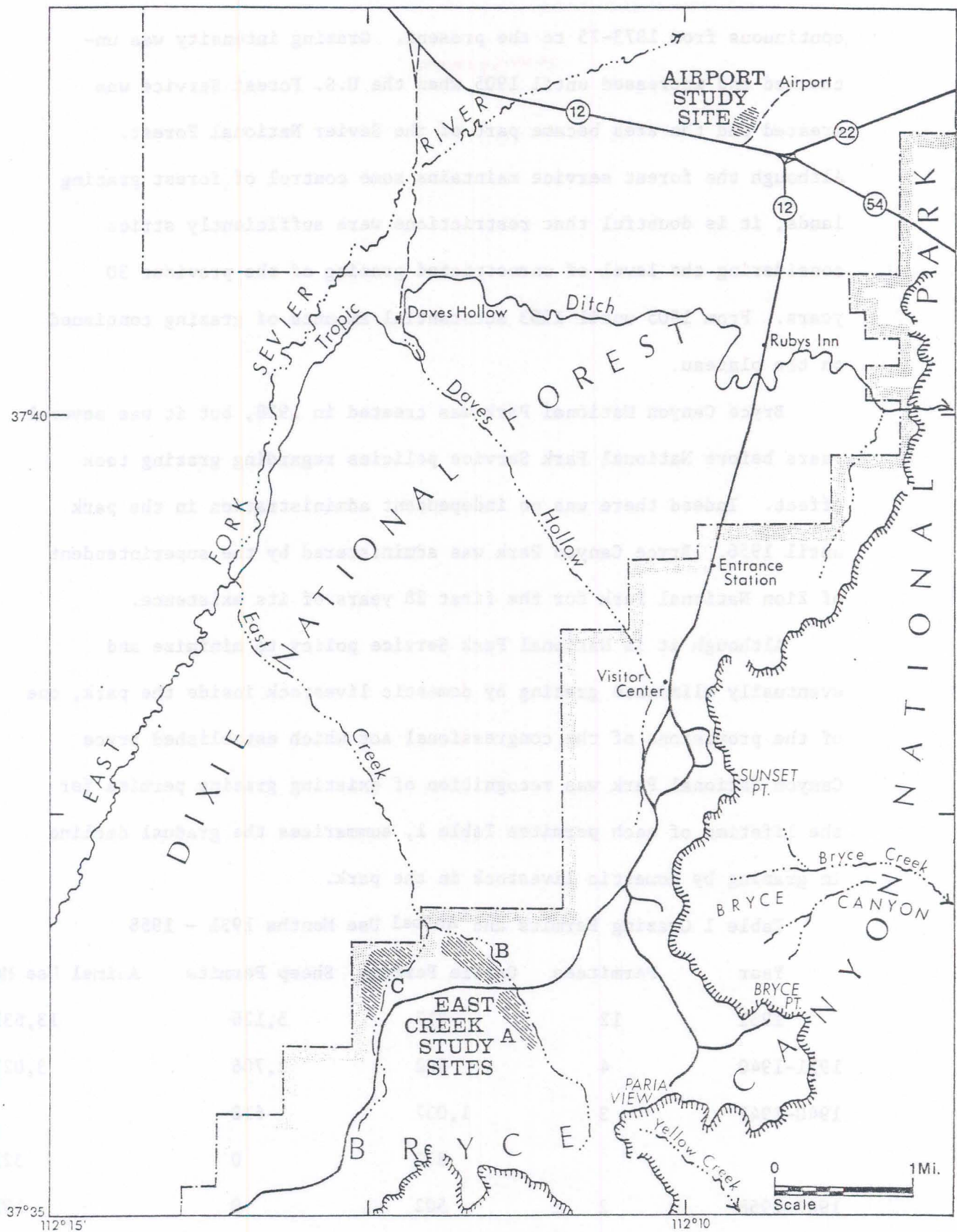


Figure 1. Location of mound study sites within Bryce Canyon National Park and northeast of the park near Bryce Canyon Airport.

continuous from 1873-75 to the present. Grazing intensity was unchecked and increased until 1905 when the U.S. Forest Service was created and the area became part of the Sevier National Forest. Although the forest service maintains some control of forest grazing lands, it is doubtful that restrictions were sufficiently strict considering the level of unrestricted grazing of the previous 30 years. From 1905 until 1953 substantial amounts of grazing continued on the plateau.

Bryce Canyon National Park was created in 1928, but it was several years before National Park Service policies regarding grazing took effect. Indeed there was no independent administration in the park until 1956. Bryce Canyon Park was administered by the superintendent of Zion National Park for the first 28 years of its existence.

Although it is National Park Service policy to minimize and eventually eliminate grazing by domestic livestock inside the park, one of the provisions of the congressional act which established Bryce Canyon National Park was recognition of existing grazing permits for the lifetime of each permittee Table 1, summarizes the gradual decline in grazing by domestic livestock in the park.

Table 1 Grazing Permits and Animal Use Months 1931 - 1958

Year	Permittees	Cattle Permits	Sheep Permits	Animal Use Months
1931	12	717	5,126	13,631
1931-1940	4	802	2,706	3,027
1940-1947	3	1,037	618	
		872	0	322
1947-1958	2	502	0	191

Data from Buchanan 1960

Lumbering has been an important industry since the earliest days of settlement. On the Paunsaugunt Plateau mills were located east of the present day Ruby's Inn on the canyon rim and northwest of the park in Daves Hollow (established 1896), and elsewhere on the East Fork of the Sevier and its tributaries. Although no cutting has occurred within the park since 1907 prior to that time there were no restrictions on cutting and many trees were cut from what is now the headquarters area of the park (Buchanan 1960).

Since 1960 when the photograph in figure 2 was taken the mound areas which are clearly discernable outside the park in the Sevier National Forest have been substantially altered. In an effort to improve grazing the sagebrush has been removed, and the ground surface appears to have been either deep plowed or harrowed and seeded with grass. Figure 3 illustrates the changes in vegetation and reduction in cover which has occurred. The mound forms are still discernable.

The Mound Sites

The Prairie mounds in Bryce Canyon National Park occur on low terraces in the relatively flat depressions carved by intermittent streams which are tributaries of the East Fork of the Sevier River, the vegetation of these broad valleys is a high plateau sagebrush community. The dominant shrub is Black sage (*Artemisia arbuscula*). Various other shrubs and subshrubs occur with sagebrush, such as Southwest Rabbitbrush (*Crysothamnus pulchellus*), Colorado Rubberweed (*Hymenoxys richardsonii*), Broom Snakeweed (*Gutierrezia sarothrae*) and Gray

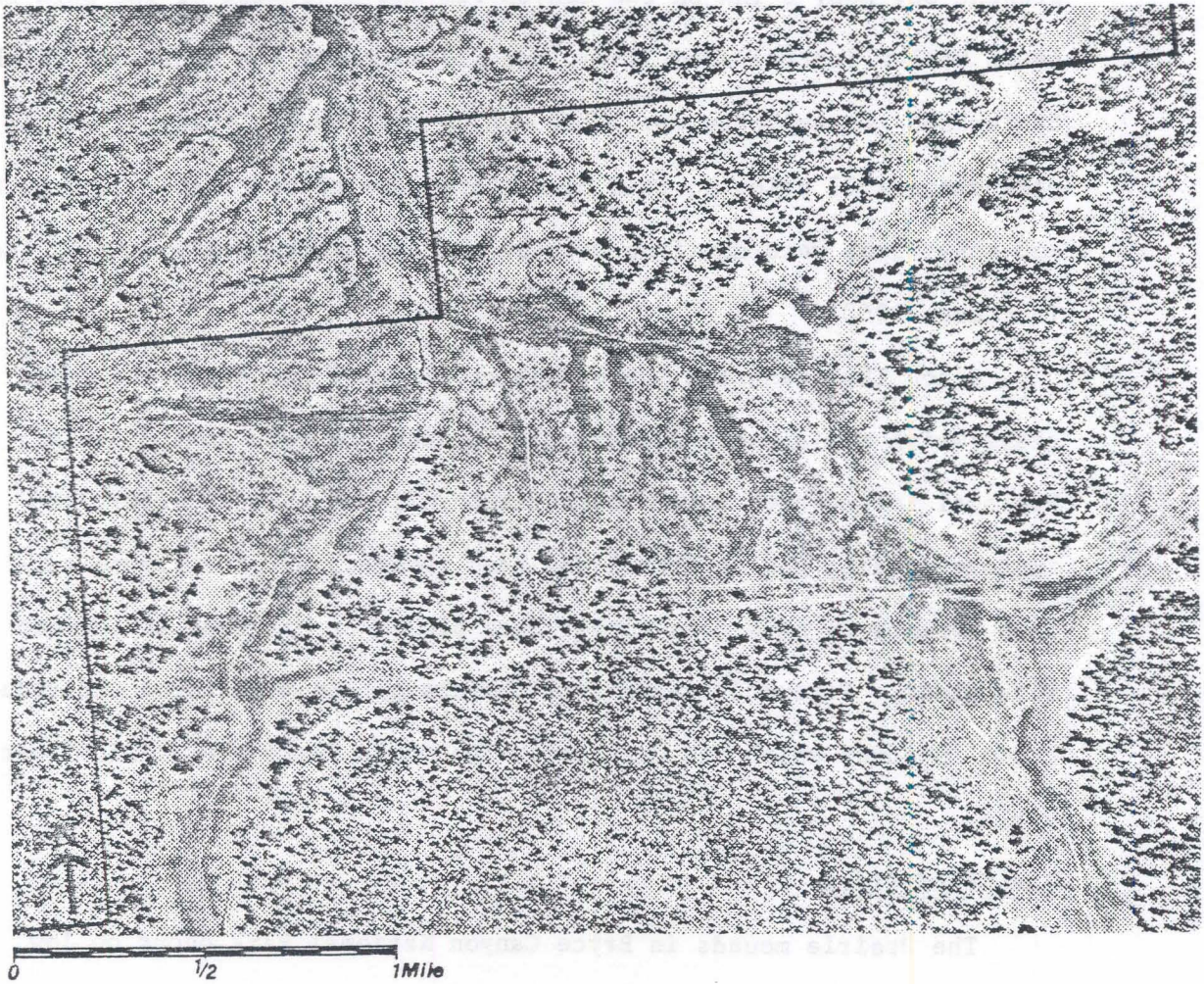


Figure 2. Aerial photo of the East Creek Drainage. Polka-dot pattern on stream terraces are prairie mounds.

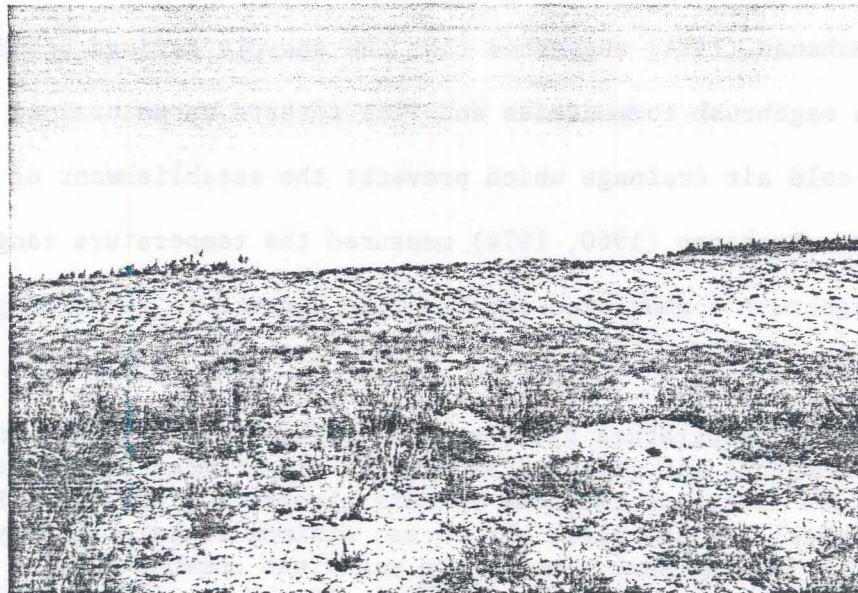
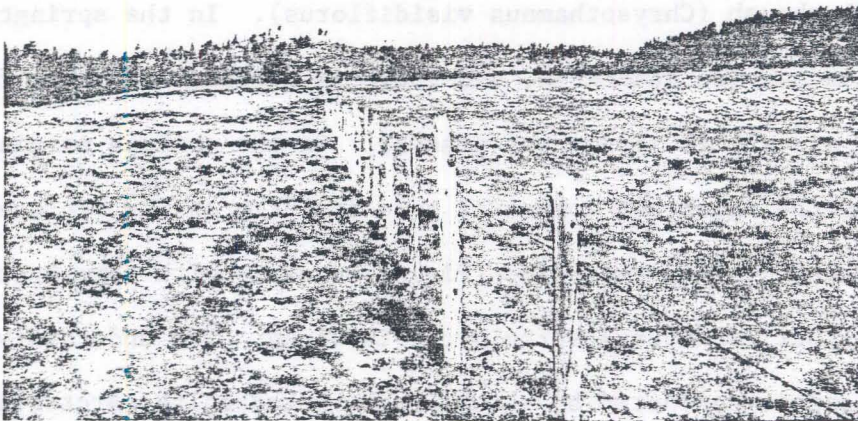


Figure 3. Mound areas in the Dixie National Forest have been deep plowed, probably to remove shrubs.

Horsebrush (*Tetradymia canescens*). Bunch grasses and forbes are also found in association with the shrubs.

The flat valley floors below the terraces are occupied by dry meadows, where the dominant species are June grass (*Koeleria cristata*) and yellowbrush (*Chrysothamnus viscidiflorus*). In the springtime these meadows are saturated, and there is abundant moisture for other annuals as well as sedges and grasses. On the upslope margin of the terraces the sagebrush community ends abruptly and is replaced by an open forest of Ponderosa Pine (*Pinus ponderosa* with some Rocky Mountain Juniper (*Juniperus serpyllifolius*) is found. The understory is sparse and is dominated by shrubs such as Manzanita (*Arctostaphylos patula*) Snowberry (*Symphoricarpos oreophilus*) and Bitterbrush (*Purshia tridentata*). Grasses and forbes comprise the shrub understory.

Buchanan (1974) suggested that the sharply defined boundary between sagebrush communities and Pine forests is maintained by winter season cold air drainage which prevents the establishment of tree species. Buchanan (1960, 1974) measured the temperature range between sagebrush communities and the Pine forests in Bryce Canyon and states that:

"Daily temperature fluctuations in the lowest depressions are tremendous and minimum temperature differences between the sagebrush flats and the pine forests may be as great as 30°F. On a typical January night the forest minimum temperature may be 60°F, at the same time as the sagebrush community has a minimum temperature of minus 30°F." (Buchanan 1974, p. 26) It appears that low growing shrubs are insulated by snow cover where as young trees are killed by such low temperatures.

Two study sites were chosen for examination of mounds (see figure 1). The first was the East Creek sage flat, the most extensive mound area

within the park located about 2 miles southwest of park headquarters Buchanan (1960) has carefully described the vegetation communities both on and between mounds in this area. The map in Figure 4 shows the location of the aerial photo of the East Creek area and the location of study sites. Mounds occur on low alluvial terraces with slopes of between 1° and 12° with an average slope of 5° . The mounds are chiefly distinguishable by the height of Black sage which grows on them while intermound areas have only very sparse grasses and forbes and frequently have a thin "pavement" of gravel. The lowest areas adjacent to East Creek comprise a dry meadow community and show no mound development. The samples were taken from three areas labeled A, B and C in Figure 4. A considerable change in the composition of the sagebrush community has probably occurred in the last century. Heavy grazing prior to the establishment of the park has contributed to the erosion of top soil with a subsequent decline in the density of grass species and an increase in more xerophytic species. Erosion check dams were installed in the mid 1930's to help control gully development along the intermittent stream channels but the present volume of sediments behind the dams indicates a continued high level of sheet erosion. Many areas between mounds have a lag surface or deflation pavement of gravels which remain after finer sediments are removed.

An additional study site was located near the airport about 3 miles north of the park entrance. This was primarily a soil sampling site located on a nearly level terrace with slopes between 0° and 4° . The vegetation of mounds here was also dominated by Black sage but some mounds also had Winter Fat (*Eurotia lanata*) as a dominant. Intermound areas had sparse vegetation with only stunted bunch grasses and Spreading Phlox (*Phlox diffusa*). Gravel pavement was extensive.

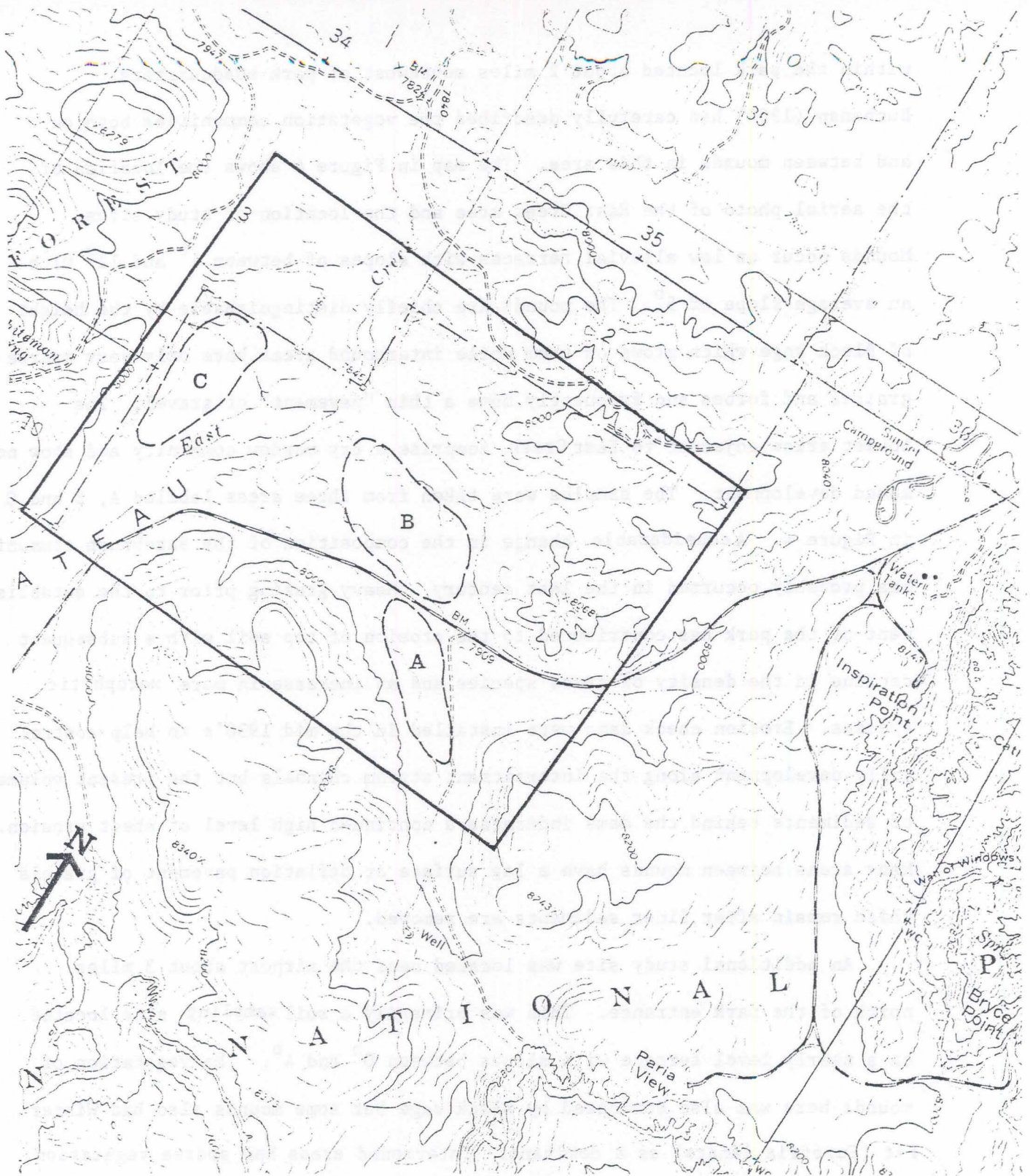


Figure 4. Topography of the East Creek Study sites. The box indicates the position of the photo in Figure 2.

The sampling was comprised of two parts. One was the measurement of mound morphology and plant distributions. The second was sampling of soils.

The methodology for mound sampling consisted of measuring the downslope dimension (called length), the cross slope dimension perpendicular to the length (called width) and measurement of the difference between the top surface of the mound and the adjacent terrace surface (called height). Slopes were measured adjacent to the sample mounds and the slope of the mound top was also measured. Samples were taken of the height of Black sage both on and between mounds. In all, 50 mounds were sampled. Table 2 summarizes the data collected for mounds. Additional notations were made as to the presence, absence and pattern of gravel pavements for mounds and intermound areas. The distance between the base of mounds was also measured. Some measurements were made randomly while other samples consist of the radial distance from one mound to all adjacent mounds. These data are summarized in Table 3.

By far the best developed mound features, that is the true hillocks with distinct elevations on all sides above the surrounding intermound areas were found on nearly flat surfaces. Mounds which occurred on slopes were lobe-like in form with the upslope margin merging smoothly with the adjacent intermound area. As such mound margins were distinguished as much by changes in the height and composition of vegetation as by their form.

The "typical mound" is a roughly circular or slightly elongate flat surfaced lobe averaging 36 feet in length and 34 feet in width with a height at the downslope lip of 12 inches. There was considerable variation from this average however. Lengths ranged from 25-57 feet, widths from 22-48 feet and height from 4-22 inches. Where heights could be distinguished on all sides of the mound the down slope margin always had the greatest height. In general mounds tended to be longer than they were wide as demonstrated in Figure 5 where mound length is plotted against width.

TABLE 2

	"Down Slope" Length	Width	Ht.*	Mound Slope (Degrees)	Area Slope (Degrees)	Max Ht. Black Sage (inches)	Average Ht. Black Sage (inches)
Study Area A	35	26	26	9	8	27	18
	32	33	17	5	8	18	14
	48	48	13	4	8	18	14
	32	29	20	8	8	22	16
	46	29	12	6	5	18	12
	29	24	8	2	5	15	-
	40	40	6	3	5	18	12
	37	48	10	4	5	18	14
	25	22	7	3	5	-	12
	56	39	8	5	5	15	12
	36	35	7	-	-	15	12
	48	38	12	6	5	15	12
	36	31	8	4	4	24	15
	34	36	22/8	5	5	20	14
	35	23	12	4/8	4/8	22	15
	28	26	7	6	8	22	15
	26	26	6	5	12	24	21
	36	33	6	9	8	-	12
	27	31	7	5	5	18	12
	29	31	10	4	5	21	16
	39	47	12	2/2	5	18	15
	33	32	10	3	5	21	15
Study Area B	36	32	9	0	1	26	16
	33	44	12	3	6	30	21
	32	31	16	3	5	27	18
	26	36	12	0	1	24	18
	29	25	11	2	6	30	20
	36	26	19/8	3	4	21	-
	36	-	19	3	5	24	18
	37	35	11/6	0	5	27	12
	57	52	16/9	2	6	-	22
	42	36	18	1	7	25	12
	36	47	14	3	5	21	15
	35	35	16	1	6	23	15
	37	35	14	3	6	27	17
	29	31	13	0	6	18	12
	45	44	13	1	2	17	16
	37	33	14/3	1	4	28	20
Study Area C	34	38	5	2	3	15	12
	51	41	5	3	15	15	12
	41	39	4	3	3	18	15
	40	35	14	3	3	20	14
	44	29	9	4	3	22	15
	31	33	11	3	3	-	14
	35	33	11	3	3	21	14
	32	32	8	3	3	18	14
Study Area D	38	37	10	3	3	18	14
	42	39	8	5	3	-	12
	44	57	8	0	0	15	14

*where two measurements of height are given the first indicates height downslope; the second is the uphill height.

TABLE 3

Intermound Measurements Distance from Base to Base

	Intermound Measurement (feet)	Average Distance (feet)	Maximum Height of Black Sage (inches)	Average Height of Black Sage (inches)
Area A	126	59	10-21	4-12
	43			
	49			
	63			
	62			
	49			
	107			
	34			
	44			
	48			
	47			
	84			
	50			
Area B	29	26	14-16	8-12
	32			
	14			
	30			
	23			
	22	32		
	51			
	42			
	26			
	39	36		
	38			
	86			
	56			
	52	64		
	61			
	49			
	43			
	45			
	32	40		
	31			
	28			
	20			
	17	28		
	48			
	49			
	100			
	56	59		
	31			
	32			
	60			
	38	39		
	13			
	52			

TABLE 3 continued

	Intermound Measurement (feet)	Average Distance (feet)	Maximum Height of Black Sage (inches)	Average Height of Black Sage (inches)
Area C	66	58	8-15	3-12
	57			
	68			
	43			
	39			
	85			
	51			
	111			
	56			
	45			
	63			
	59			
	137			
	51			
	89			
	85			
Airport Site	61	46		
	54			
	41			
	50			
	52			
	32			
	48			
	26			

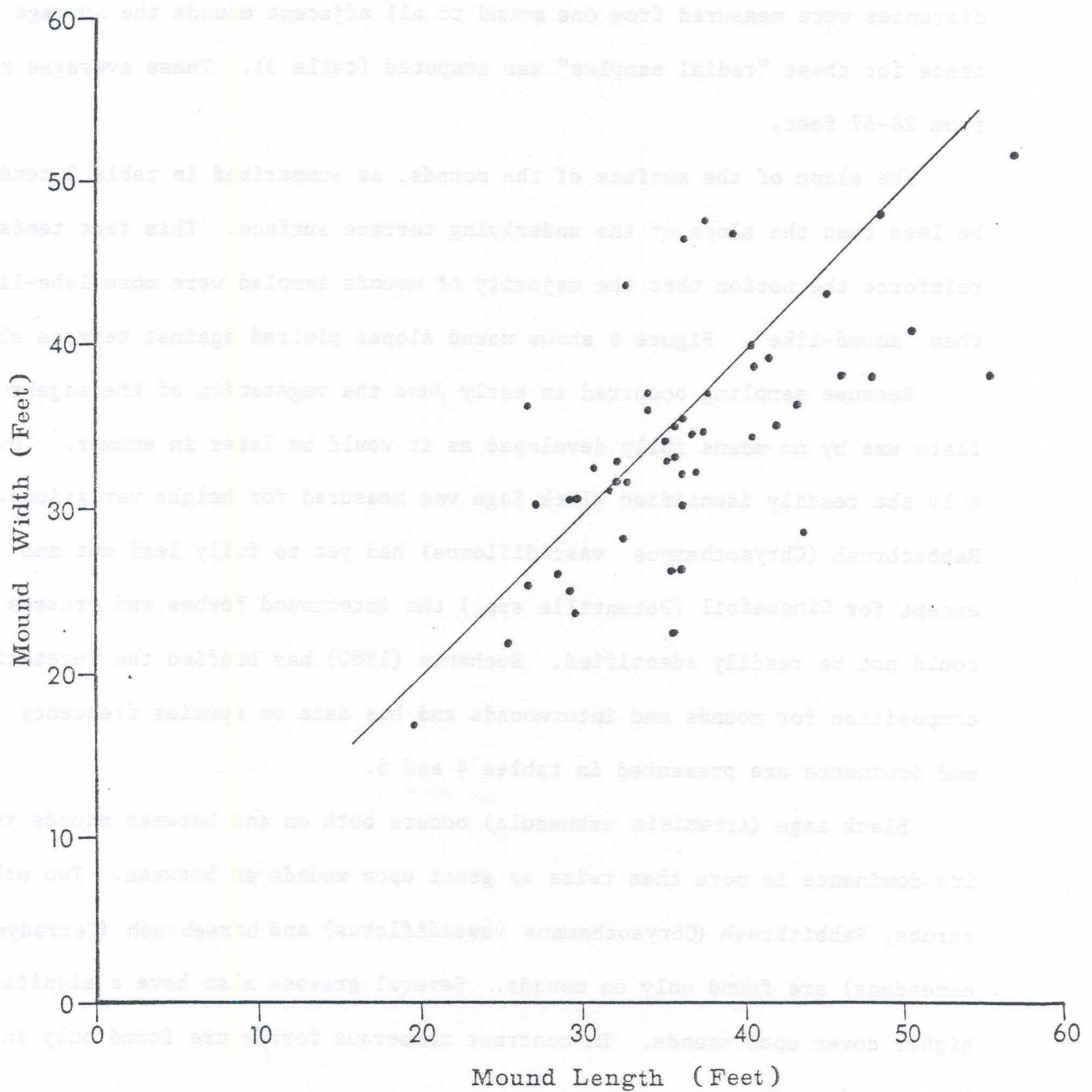


Figure 5. Mound length plotted against width. The line indicates mounds with equal length and width.

Intermound distances averaged 57 feet but the variation was far greater than for mound size. The range of intermound distance was 13-137 feet. Wherever distances were measured from one mound to all adjacent mounds the average distance for these "radial samples" was computed (table 3). These averages range from 28-67 feet.

The slope of the surface of the mounds, as summarized in table 2 tend to be less than the slope of the underlying terrace surface. This fact tends to reinforce the notion that the majority of mounds sampled were more lobe-like than "mound-like". Figure 6 shows mound slopes plotted against terrace slopes.

Because sampling occurred in early June the vegetation of the sagebrush flats was by no means fully developed as it would be later in summer. Thus only the readily identified Black Sage was measured for height variations. Rabbitbrush (*Chrysothamnus viscidiflorus*) had yet to fully leaf out and except for Cinquefoil (*Potentilla* spp.) the intermound forbes and grasses could not be readily identified. Buchanan (1960) has studied the vegetation composition for mounds and intermounds and his data on species frequency and dominance are presented in tables 4 and 5.

Black sage (*Artemisia arbuscula*) occurs both on and between mounds yet its dominance is more than twice as great upon mounds as between. Two other shrubs, Rabbitbrush (*Chrysothamnus viscidiflorus*) and horsebrush (*Tetradymia canescens*) are found only on mounds. Several grasses also have a significantly higher cover upon mounds. In contrast numerous forbes are found only in intermound areas.

As indicated in tables 2 and 3, there is a significant difference in the height of Black sage upon mounds and between mounds. The average height of individuals on mounds sampled ranges from 12-22" with a maximum of 30" while in the various intermound areas averages ranged between 3 and 12" with a

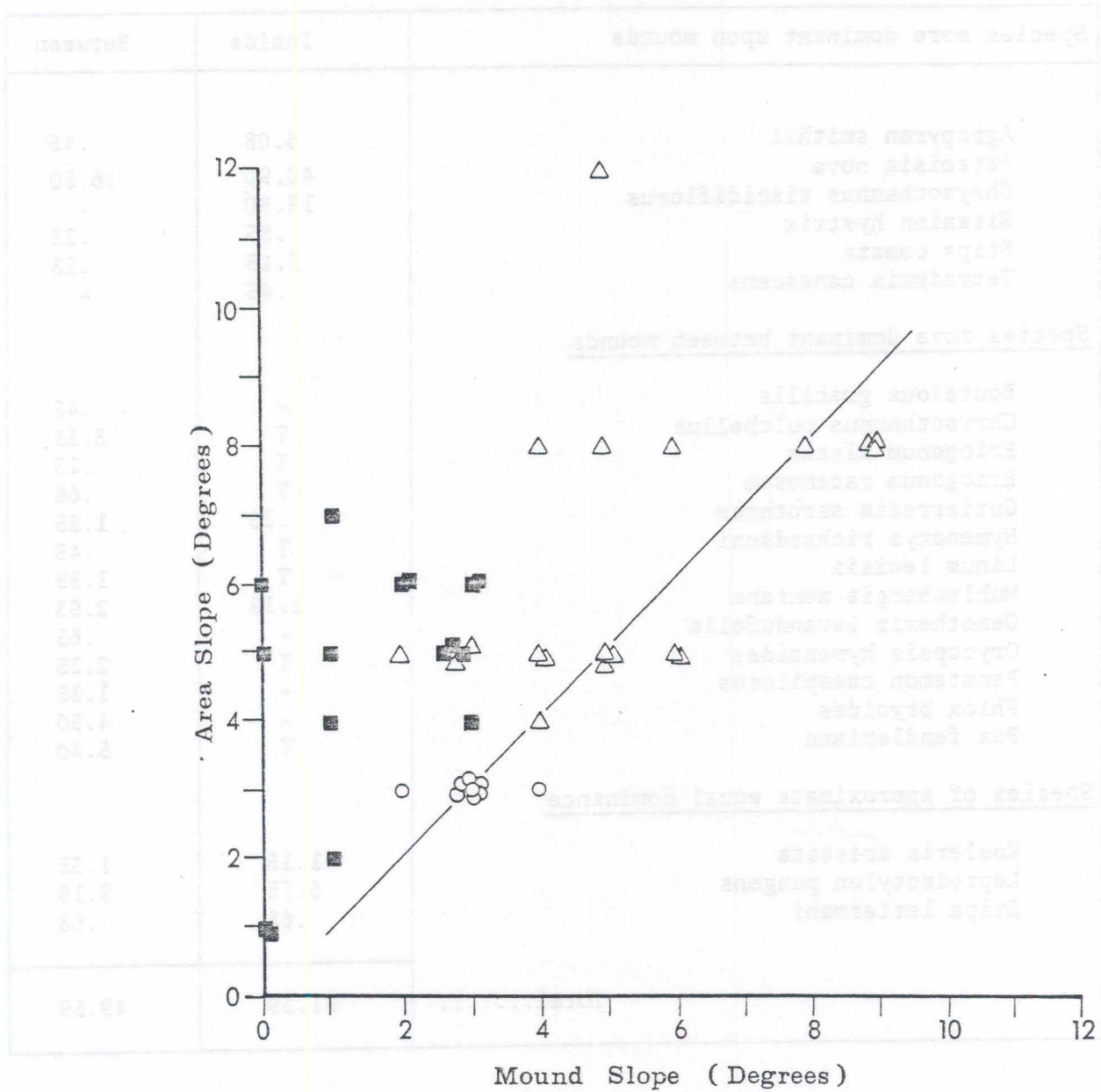


Figure 6. Mound slope plotted against general slope of the area. Δ indicates study area A, $\blacksquare$ - study area B, and $\circ$ - study area C. The line indicates mound slope equal to area slope.

Table 4

DOMINANCE STUDY OF MIMA MOUNDS

Species more dominant upon mounds	Inside	Between
Agropyron smithii	6.08	.45
Artemisia nova	40.90	16.50
Chrysothamnus viscidiflorus	19.80	-
Sitanion hystrix	.85	.23
Stipa comata	3.15	.23
Tetradymia canescens	.45	-
<u>Species more dominant between mounds</u>		
Bouteloua gracilis	-	.45
Chrysothamnus pulchellus	T	3.38
Eriogonum alatum	T	.23
Eriogonum racemosum	T	.68
Gutierrezia sarothrae	.23	1.35
Hymenoxys richardsoni	T	.45
Linum lewisii	T	1.35
Muhlenbergia montana	1.35	2.93
Oenothera lavandufolia	-	.65
Oryzopsis hymenoides	T	2.25
Penstemon caespitosus	-	1.35
Phlox bryoides	-	4.50
Poa fendleriana	T	5.40
<u>Species of approximate equal dominance</u>		
Koeleria cristata	1.15	1.35
Leptodactylon pungens	6.75	5.18
Stipa lettermani	.68	.68
Total.....	81.39	49.59

Table 5

FREQUENCY STUDY OF MIMA MOUNDS

Species more frequent upon mima mounds	Inside	Between
<i>Agropyron smithii</i>	60%	15%
<i>Chrysothamnus viscidiflorus</i>	90	0
<i>Stipa lettermani</i>	35	15
<i>Tetradymia canescens</i>	15	0
<u>Species more frequent between mima mounds</u>		
<i>Bouteloua gracilis</i>	0	25
<i>Chrysothamnus pulchellus</i>	5	95
<i>Eriogonum alatum</i>	5	40
<i>Eriogonum racemosum</i>	5	60
<i>Gutierrezia sarothrae</i>	5	80
<i>Hymenoxys richardsoni</i>	5	45
<i>Linum lewisii</i>	5	40
<i>Muhlenburgia montana</i>	5	15
<i>Oenothera lavandulifolia</i>	0	50
<i>Penstemon caespitosus</i>	0	65
<i>Poa fendleriana</i>	5	20
<u>Species of approximate equal frequency</u>		
<i>Artemisia nova</i>	100	100
<i>Koeleria cristata</i>	45	35
<i>Leptodacylon pungens</i>	80	75
<i>Oryzopsis hymenoides</i>	30	45
<i>Phlox bryoides</i>	0	5
<i>Sitanion hystrix</i>	45	40
<i>Stipa comata</i>	45	45

maximum of 21", in addition there are numerous areas where sage is sparse or nearly lacking entirely from intermound areas.

Shallow gravel pavements were distributed only on terraces and were found both on mounds and between mounds. On mounds the pavements areas were not continuous and occurred in very small patches in depressions between shrubs. Soil was often mounded or held by the roots at the base of shrubs. In intermound areas the pavements were far more extensive in area and in one instance a large, oval slightly depressed area, perhaps a "blow-out" was covered with pavement and lacking vegetation. These pavements are almost certainly deflation or lag surfaces left when finer sediments are removed by wind and running water.

A brief survey was conducted to ascertain the distribution of mounds in and around Bryce Canyon National Park. Although the extent of coverage of available aerial photographs for the area was extremely limited, mound patterns can be distinguished in a number of localities all with similar characteristics. Mounds are commonly found on terraces between streams and the pine forest, within sagebrush communities, they have apparently never developed in low areas of meadow vegetation. Accessibility by auto to many mound areas was limited by muddy or washed out roads, however, a brief survey of areas easily accessible by auto confirmed that mounds though a subtle feature in the landscape are widespread throughout the Bryce Canyon area of the Paunsaugunt Plateau.

ANALYSIS OF SOILS

Soils occurring under and around prairie mounds at two sites were examined in the hope that the pedological data could be of use in understanding prairie mound genesis. One trench was dug through a mound near East Creek in study

area C to observe a continuous section of soil profile and to collect samples for laboratory analysis. This is referred to as the "trench site." Sites were excavated at a second site adjacent to the access road to Bryce Canyon Airport, north of the park boundary. This second site is referred to as the "pit site." (see figure 1)

Trench Site

The trench site is located in a transition zone between a ponderosa pine forest and a sage/grass prairie at the northwestern corner of the park. This location was selected in order to minimize aesthetic disturbance and to avoid disturbance in areas where Utah Prairie Dog had been reintroduced. The mound sectioned is somewhat atypical since it is nearly within the forest, while the majority of mounds in this locality are adjacent to the creek on open sage and grass covered stream terraces.

Soils were water saturated almost to the surface which severely handicapped the examination of the profile. Weathered rock (Wasatch Formation) apparently underlies these shallow soils and may inhibit infiltration of water. Numerous springs occur where the soil cover is thin. The trench itself was approximately forty feet long and ran from an upslope intermound area, through the apex of a mound, to a downslope intermound area. Depth of the trench corresponded roughly with the depth at which the soils were waterlogged and varied from about 15 to 30 inches. The shallowest depth was at the downslope intermound area where water had a tendency to accumulate in the trench (see figure 7).

The soil was very moist at all depths making hand texturing and visual observations concerning the profile difficult, however some characteristics were obvious. Medium textured soils appeared in the upper 2 to 8 inches of the profile and graded downward to fine textured materials. The color of

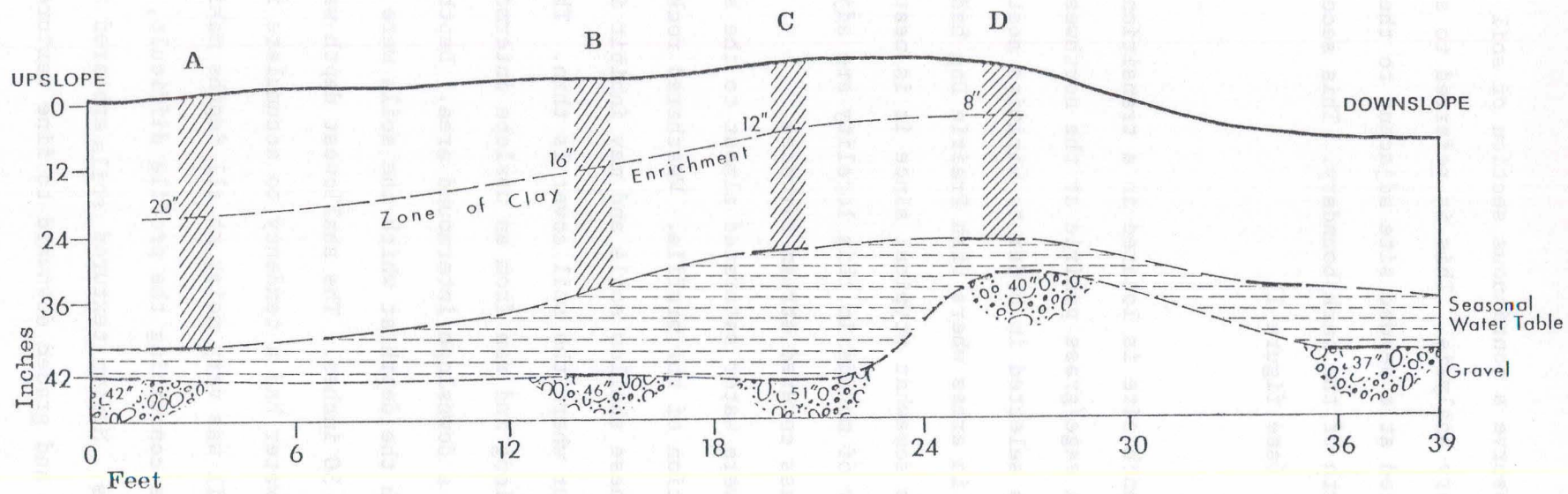


Figure 7. East Creek - Trench Site.

the soil was brown to dark brown with little apparent change of color with increasing depth. Roots were fairly abundant and extended to the weathered rock.

Pit Site

The pit site is located on mildly dissected alluvial terraces which overlay the Kaiparowitz formation near Bryce Canyon Airport (Figure 1). A pit was dug at the apex of a mound to a depth of 46 inches where a layer of gravel inhibited further digging. These gravels possess a thin, clay coating which is orange in color and probably rich in iron oxides. Above this gravel zone, the soil profile appears remarkably homogeneous in texture, structure, and color, with the only observable deviation being a thin, discontinuous layer of gravel and pebbles occurring at approximately 6 inches below the surface. Soil color varies from 10YR5/3 to 10YR5/6 on the Munsell Color Chart.

A second pit was dug in the intermound area approximately 50 feet downslope from the apex pit (figure 8). The basal gravel layer in this pit is located from 11 to 20 inches below the surface and has a white to grey color, while the soil above is light brown. A third pit was dug between the apex and intermound pits to determine presence and depth of the basal gravel. The average depth of gravel at this third pit is 36 inches. No soil samples were taken from this pit.

Both trench and pits were sampled vertically at four inch intervals for laboratory analysis of texture. Four profiles were sampled at the trench site and labeled profiles A, B, C and D (figure 7). Profile A is located in the intermound zone at the upslope end of the trench and the other three profiles are on the mound with profile D being under the apex.

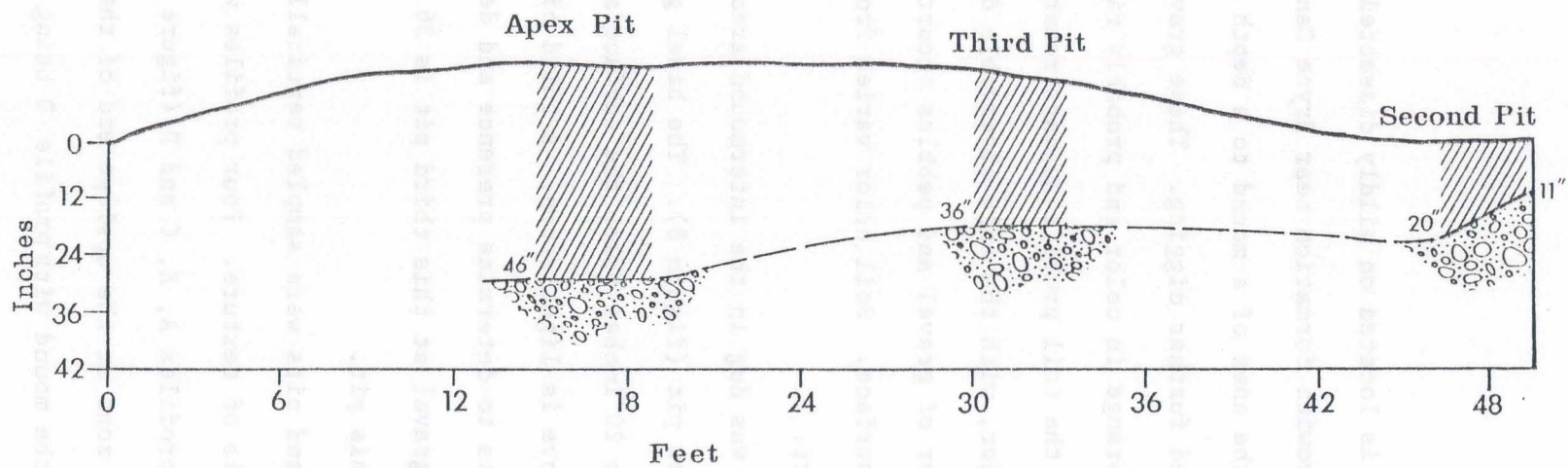


Figure 8. Bryce Canyon Airport - Pit Site.

Texture Analysis

The samples were taken to the soils laboratory at the University of Arizona for mechanical analysis. The method used for determination of sand, silt, and clay content of each sample is based on dispersion and sedimentation of individual soil particles. Each air dry sample was first run through a two millimeter sieve to remove coarse fragments larger than sand, 10 ml of 0.5 normal sodium pyrophosphate, a dispersing agent, and approximately 1,000 ml of water were added to each sample before blending to separate aggregates. This thoroughly mixed solution enables a hydrometer to measure grams of soil in solution. Using Stokes Law of sedimentation rates, sand settles out within 40 seconds, thus a hydrometer reading taken 40 seconds after mixing indicates the amount of clay and silt remaining in suspension. Sand content is found by subtracting the 40 second reading (with a slight temperature correction factor) from the total sample weight. Similarly, after two hours silt settles out of solution and a hydrometer reading will indicate grams of clay in solution. Silt content is then determined by subtracting clay and sand fractions from the total weight. For comparability all measurements were converted to percent sand, silt, and clay.

Results

Table 6 shows the results of the mechanical analysis. Trench profiles all show increasing clay content with increasing depth. Surface samples are sandy loams ranging in clay content from 2 to 6.4 percent. Distinct clay enrichment occurs at different depths in different profiles; in profile A enrichment is at 20 inches, profile B at 16 inches, profile C at 12 inches, and profile D has distinct clay enrichment at 8 inches below the surface. The clay buildup at depth is consistent with standard thought, that is clay

Table 6

Prairie Mound Profile 1

	Sand (%)	Silt %	Clay (%)	Textural Class
0"	50	48	2	sandy loam
4"	54	38	8	sandy loam
8"	45.6	44	10.4	loam
12"	46.8	38.8	14.4	loam
16"	50.4	35.6	14	loam
20"	34.4	35.6	30	clay loam
24"	36	38	26	clay loam

Prairie Mound Profile 2

0"	46.8	46.8	6.4	sandy loam
4"	48.4	39.6	12	loam
8"	54	28	18	sandy loam
12"	56	30.4	13.6	sandy loam
16"	38	38	24	loam
20"	44.8	28.8	26.4	loam
24"	40	34	26	loam

Prairie Mound Profile 3

0"	50.8	45.2	4	sandy loam
4"	49.6	42.4	8	loam
8"	48.8	36.8	14.4	loam
12"	42	34	24	loam
16"	47.6	28.4	24	loam
20"	39.6	30.4	30	clay loam
24"	25.6	40.4	34	clay loam

Prairie Mound Profile 4

0"	51.6	46.4	2	sandy loam
4"	48	44	8	loam
8"	41.6	32	26.4	loam
12"	45.6	32.4	22	loam
16"	46.8	24.8	28.4	sandy clay loam
20"	41.2	26.8	32	clay loam
24"	47.6	20.4	32	sandy clay loam

Airport Intermound Profile

0"	68.4	22.8	8.8	sandy loam
4"	58.8	25.2	16	sandy loam
8"	67.6	20.8	11.6	sandy loam
12"	52.4	28	19.6	sandy loam
16"	64.4	32.8	2.8	sandy loam

Table 6 (cont'd)

<u>Airport Prairie Mound Profile</u>	<u>Sand (%)</u>	<u>Silt (%)</u>	<u>Clay (%)</u>	<u>Textural Class</u>
0"	70.4	23.6	6	sandy loam
4"	66.8	29.6	3.6	sandy loam
8"	70.4	22.4	7.2	sandy loam
12"	68.4	26	5.6	sandy loam
16"	64.4	28	7.6	sandy loam
20"	77.6	14.8	7.6	sandy loam
24"	69.6	18	12.4	sandy loam
28"	67.6	24.4	8	sandy loam
32"	67.6	22.8	9.6	sandy loam
36"	69.2	22.8	8	sandy loam
40"	72	20	8	sandy loam
44"	68.8	18.8	12.4	sandy loam

is translocated from upper layers of the profile to a lower zone of accumulation. Removal of clay from upper layers is illustrated by the presence of coarser textures (sandy loams) in these layers. Perhaps the abundance of clay in lower layers may also be partly due to hydrolysis weathering in water saturated zones. The zone of clay accumulation (B horizon) at the trench site is illustrated in Figure 7. The B horizon gradually approaches the soil surface as it nears the apex of the mound, indicating that much of the surface material (A horizon) at the apex has been removed by erosion.

Airport prairie mound soils and intermound soils are strikingly homogeneous in texture with all samples being sandy loams. There is a difference in gravel content at varying depths; generally gravel content in the samples increased with sample depth. The small amount of clay at depth in the profile is surprising because clay coated gravels are present in the basal gravel layer indicating some downward movement of clays in the soil.

DISCUSSION

Any hypothesis for the origin of mounds must account for several important features: 1) the regularity of spacing 2) the similarity in form, size and height of mounds, 3) the distribution of mounds from forest boundary to terrace edge and 4) the occurrence of a developed soil profile in some mound areas and not in others.

Prairie mounds have been attributed by various authors to ants, termites, pocket gophers and other rodents, gas and water boils, permafrost and frost action, stagnant ice melting in glacial moraines, uprooted trees, dessication cracking, wind deposits and vegetation dunes, erosion and or deposition by running water, fish nests, and shrink-swell of expansive clays. The majority of hypothesis tend to reflect the training and experience of the individual

investigator. Because mounds occur in such a variety of environments it seems likely that prairie-type mounds may form by different processes and produce similar appearing hillocks.

Of the origins proposed for mounds in general, fish nests, ants and termites, gas and water boils and glacial moraines are clearly not applicable to the Bryce mounds. The general absence of clays in the profiles of both soil sample sites would rule out the shrinking and swelling of expansive clays (Paton 1974). Mounds formed by tree throw should produce an irregular mound-submound contact, and would not explain the regularity of size and form of mounds, nor their distribution upon terrace surfaces throughout the Bryce Canyon area.

Construction of mounds by animals, in particular the pocket gopher, has been advocated by Arkley (1948) for mounds in the central valley of California. This hypothesis was further developed by Koons (1948) for mounds in Texas and independently for mima mounds in Washington by Dalquest and Scheffer (1942). As presented by these authors, pocket gophers are theorized to move earth laterally into their nest area by filling old burrows and tunnels in areas where a thin soil overlies an impermeable substrata which is seasonally waterlogged. Thus mounds develop and provide a refuge during the wet season, in addition looser soil on mounds produces more forage than intermound areas (Allgood and Gray, 1973). Thus each mound represents the territory of a pocket gopher.

There is no question that pocket gophers live in prairie mounds and modify their internal characteristics. Ants, ground squirrels, prairie dogs, badgers and toads (Ross ^{et al.} and others 1968) also live in mounds. The internal features in the mounds cited as evidence of construction by gophers could also be produced by habitation activities, and no one has documented

that pocket gophers preferentially move materials laterally toward their nest sites.

The suggestion by Buchanan that mounds were constructed by prairie dogs has not been documented by any published field investigation. The Utah Prairie Dog (*Cynomys parvidens*) flourished within the plateau areas of Bryce Canyon National Park following the years of heavy grazing between 1905 and 1930 (Stebbins, 1971). Data from employees of the park show that several active prairie dog towns were recorded in the East Creek Area as recently as 1958 and early 1959. However the towns were mysteriously abandoned later in that year.

Buchanan (1960) and others (Elmore et al., 1976) have presumed that the mounds represent the work of the Utah Prairie Dog, and have estimated their population by counting mounds, yet there is no evidence that Prairie Dogs of any species construct mounds which have an average diameter of 36 feet. Flath and Paulick (1976, p. 396) have recorded a maximum size of 20 feet for mounds of maternity burrows of the White-tailed Prairie Dog, even so the mounds of maternity burrows were significantly larger than other types of mounds and many burrows show little or no excavated soil. The Utah Prairie Dog is closely related to the White-tailed Prairie Dog (see Pizzimenti and Collier 1975) and Elmore et. al (1976, p. 4) has noted that many holes utilized by the Utah Prairie Dog are also moundless.

The presence of a soil profile at the East Creek soil trench site argues against a prairie dog genesis of mounds since mounds of Prairie Dogs are composed entirely of excavated materials. If mounds were constructed by Prairie Dogs more mixing of soil layers would be expected (Tileston et. al., 1966).

There is no doubt that Prairie Dogs live on mounds. The Utah Prairie dog was reintroduced into the East Creek Area in 1974 and 1975 and there was

evidence of numerous old and recent burrow excavations. Because of the seasonally high water table in the area the mounds offer a refuge from areas of high moisture which can promote harmful bacteria or virus. In addition the shallow depth of the gravel layer may inhibit sufficient depth of burrowing except on mounds. A critical soil depth is required for hibernating animals to maintain vital body processes during winter months (Elmore et. al., 1976). In addition shallow burrow systems may enhance the chances of predation by terrestrial enemies like coyotes and especially badgers.

CONCLUSIONS

The differences in soil profiles between the airport prairie mound area and the trench prairie mound area make definitive conclusions about the origins of the mounds difficult. The removal of clays in suspension from upper layers of the profile (eluviation) and the subsequent clay enrichment at depth (illuviation) is the dominant pedological process associated with the East Creek site soils within the park. This accumulation of clay (approximately 30 percent of the soil) at depth is the result of a long term translocation process that has undergone no extreme mixing by prairie dogs or any other agent. The similarity between the mound and intermound profiles at the trench site suggests that identical processes are operating in both profiles. Based on the presence and depth of illuvial clay throughout the trench, the prairie mound at this location appears to be a residual landform and has not been created by relatively recent processes. Although the soil data is inconclusive with respect to mound genesis at the trench site, advanced illuvial horizon development indicates that at least a few thousand years have passed since the genesis of the mound.

At the airport site, there is a paucity of clay at all depths. Three possible explanations for the lack of translocated clay and the striking homogeneity of the pit profiles are 1) excessive mixing in the profile by biological or physical processes; 2) some process has inhibited the eluviation and subsequent illuviation of clay; and 3) the alluvial materials that compose the soil have not had sufficient time to undergo the clay translocation process. The continuous areal distribution of a sandy loam texture at the airport pit site makes further pedologic and geomorphic study necessary to adequately explain the presence of mounds there.

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