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ANALYSIS OF THE RAINBASIN DEPRESSIONS
OF CLAY COUNTY, NEBRASKA

A Thesis

Presented to the
Department of Geography/Geology
and the
Faculty of the Graduate College
University of Nebraska

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
University of Nebraska at Omaha

by
Patrick J. Starks

July 1984

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THESIS ACCEPTANCE

Accepted for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts University of Nebraska at Omaha.

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Chapter 1

INTRODUCTION

The state of Nebraska has an area of 76,612 square miles and is divided into thirteen distinct physiographic regions (Figure 1). In recent years, attention has been focused upon one particular portion of the Central Loess Plains--the "rainbasin area" or, as it is sometimes called, the "rainwater basin."

The rainbasin area (Figure 2) of Clay County has numerous surficial depressions, each of which is underlain by claypan soils. Lahee (1961) defines a depression as a basin which is "rimmed round on all sides." More accurately defined, a depression is:

A low place of any size on a plain surface, with drainage underground or by evaporation; a hollow completely surrounded by higher ground and having no natural outlet for surface drainage (The American Geological Institute, 1976).

The claypan soils tend to impede the percolation of rain-water, therefore creating a "temporary" wetland in the form of a marsh, pond or small lake--thus the term rainbasin.

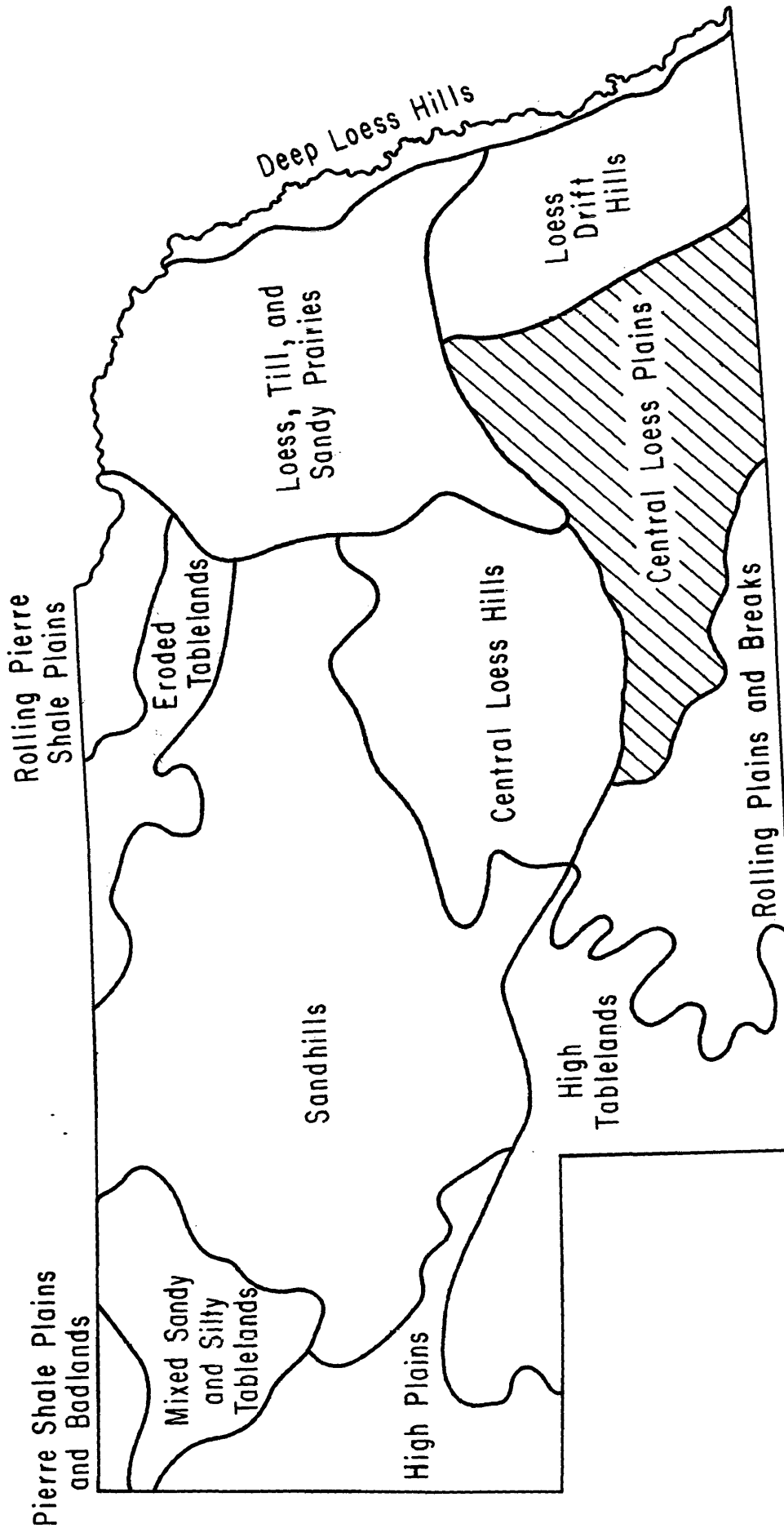


FIGURE 1. PHYSIOGRAPHIC REGIONS OF NEBRASKA
 (ADAPTED FROM SEARCY AND LONGWELL, 1964)

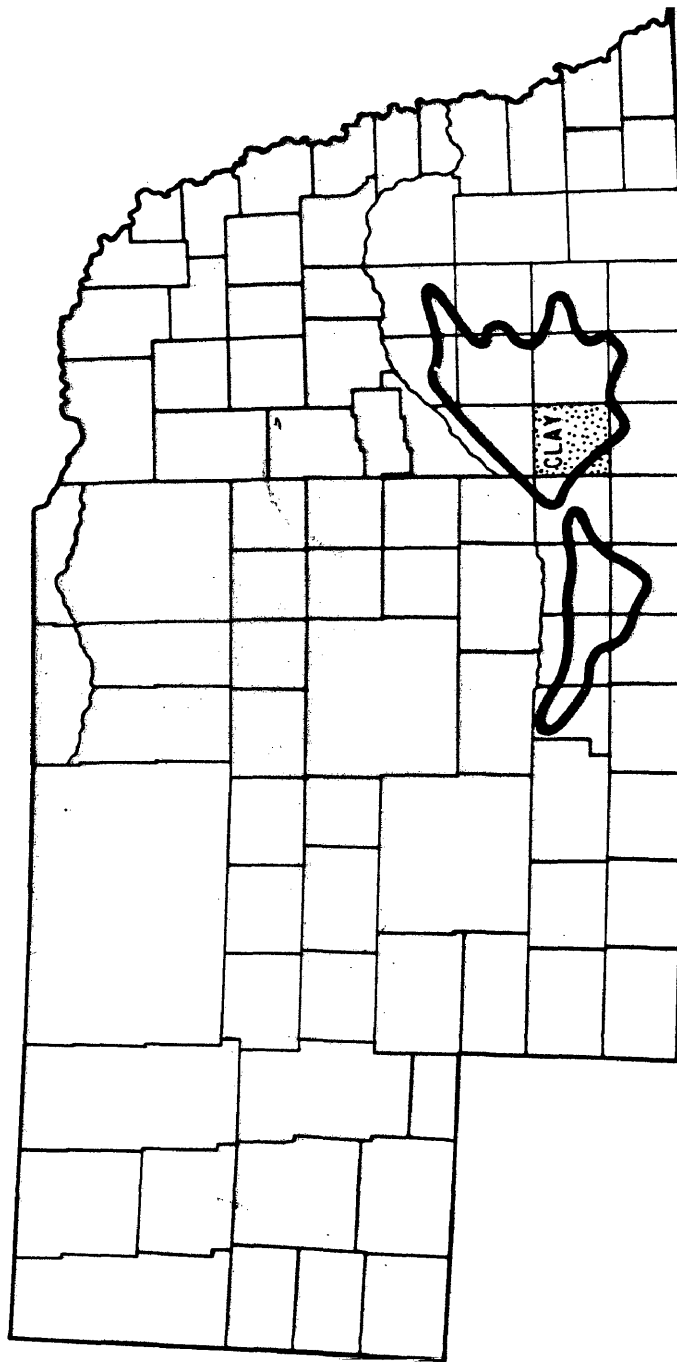


Figure 2. The Rainbasin Area of Nebraska and the study area.
(Rainbasin boundaries adapted from McMurtrey, Craig, and
Schildman; 1972).

In the field, of course, these depressions are most recognizable when water is standing in them (Figure 3) or when a heavy growth of lush green vegetation is present because of the moist conditions (Figure 4). In some instances, the presence of some depressions is so subtle that it is difficult to depict them on topographic maps because of the map scale.

The only published map that delineates the boundaries of the rainbasin area is found in the Nebraska Game and Parks Commission report, Survey of Habitat, Work Plan K-71 (McMurtrey, Craig, and Schildman; 1972), and the approximate boundaries have been reproduced in Figure 2. According to the Survey of Habitat, the boundaries of the rainbasin area encompass 4,200 square miles and contain 3,907 natural, irregularly distributed fresh water wetlands (McMurtrey, Craig, and Schildman; 1972, p. 2).

Research in the rainbasin area has mainly been concerned with wetland habitat (McMurtrey, Craig, and Schildman; 1972) or wetland loss (Denney, 1982; Farrar, 1982). Recently (1982), the Department of Environmental Control (DEC) provided funding to the Nebraska Remote Sensing Center at the University of Nebraska-Lincoln for a project aimed at analyzing and classifying wetlands by means of color-infrared aerial photography in a portion of the rainbasin area (Walter and Buckwalter, 1982). Additionally, wetland acreages were computed and maps produced for

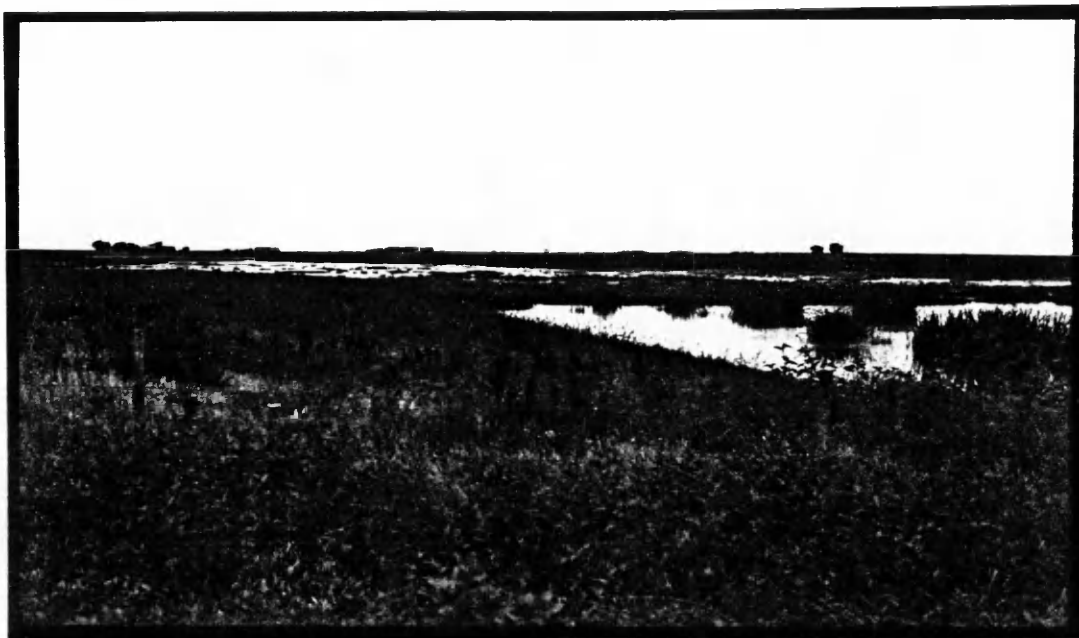


Figure 3. Standing water in a Rainbasin depression of Clay County.



Figure 4. Lush green vegetation due to the moist conditions in the depression.

selected years. It was reported that some categories of wetlands experienced a decline in number of acres, while other categories showed an increase.

In years of low rainfall, some of the depressions may dry up. However, some of the depressions have been artificially drained for the specific purpose of converting what was once wetland into cropland (Figure 5). It is this activity that has captured the attention of many environmentalists as well as the state's wildlife managers in recent years.

Even though the rainbasin area has been studied in terms of its ecological importance, the depressions that give this area of Nebraska its uniqueness have yet to be described, let alone studied in terms of their genesis. Therefore, the objectives of this investigation are to i) pool the existing knowledge of the rainbasin area into one document, ii) describe the physical attributes of the depressions, iii) describe the geographic distribution and patterns of the depressions, and iv) combine the findings of (ii) and (iii) in order to make suggestions as to how the depressions of Clay County may have originated.

From Figure 2 it can be seen that the rainbasin area occupies parts of seventeen counties in Nebraska. However, the present research has focused on only one county, Clay, which was chosen for the initial research because: i) it possesses a greater number of depressions than any other

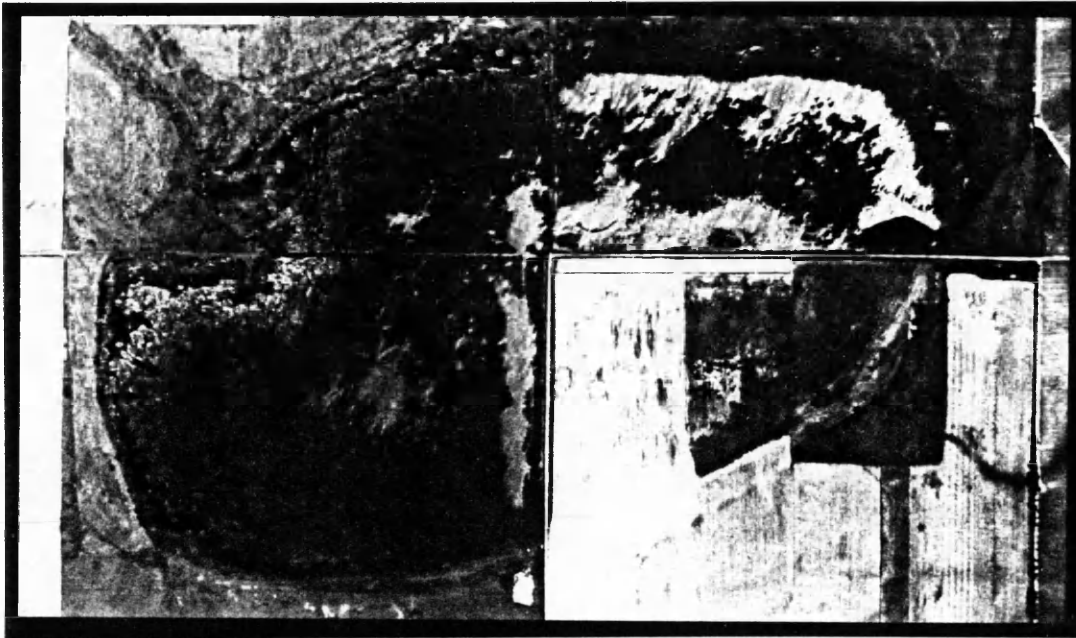


Figure 5. Color-infrared aerial photograph of Smith Lagoon in Clay County. The southeast portion of the lagoon is being drained to suit agricultural purposes.

county in the region; ii) soil surveys from both 1927 and 1981 are available; iii) 1981 color-infrared aerial photography, as well as a considerable amount of black-and-white aerial photography taken between 1938 and 1968, is available; and iv) 7½-minute topographic maps are available for the whole county.

To summarize, the depressions of Clay County, Nebraska, are analyzed in this report both cartographically and quantitatively in order to gain a better understanding of the whole rainbasin area. In addition, existing data and the findings of this research will be pooled in anticipation of providing some cohesive knowledge of what is presently known of the rainbasin area. It is hoped that this study will provide some direction for future investigation, and to pose questions that may prompt research in the future.

Chapter 2

LITERATURE

Rainbasin

Little written material aimed directly at the rainbasin area exists. The few reports that do exist, however, center on wetland loss or the reduction of wildlife habitat (Denney, 1982; Farrar, 1982; Walter and Buckwalter, 1982; McMurtrey, Craig, and Schildman, 1972).

Nevertheless, some indirect references to what is now called the rainbasin area were located by the author. For example, Condra (1906) when discussing the topography of the loess plain of southeastern Nebraska, stated that:

In some places the surface contains shallow undrained basins filled by the rainfall at wet-weather times. Most of these small lakes dry up entirely during the summer. The lakes occur principally in York, Fillmore, Clay and Phelps counties.

Thirty years later, Condra again mentioned the depressions in his writing, but little additional information was presented (Condra, 1936).

Although references pertaining to the whole rain-basin area are lacking, citations for certain portions of the rainbasin area are more numerous. In particular, these citations concern the depressions of Clay County, Nebraska--the study site for this thesis.

Clay County, Nebraska

The 1927 Soil Survey of Clay County, Nebraska mentions the presence of numerous depressions throughout the county (Roberts and Gemmell, 1927). The first substantive information concerning any characteristic feature of the depressions comes from this report. In this document, it was noted that three principal types of soils are associated with the depressions of Clay County; Butler, Fillmore, and Scott silt loams. These soils are described as having true claypans, and as occurring in depressions (Roberts and Gemmell, 1927). However, it is not suggested that the presence of the Butler, Scott, and Fillmore soils define the areal extent or absolute location of the depressions. Rather, these soils are indicators of where to look first for the occurrence of the depressions. A more thorough discussion on depressions and associated soils is found in Chapter 4.

From the soil maps supplied with the soil report (Map 1, map pocket), one can obtain a "general" impression of the geographic distribution of the depressions in Clay County.

On the soil map, the areas in yellow, striped-pink, and solid pink denote the Scott silt loam, Fillmore silt loam, and Butler silt loam, respectively. Due to the scale of the map, however, many other areas were too small to be represented on the map. Clay County is noted as containing numerous depressions of varying sizes.

Figure 6 is a generalized schematic of the depressional soils according to topographic position as suggested by the 1927 soil survey. Here, it can be seen that the Butler silt loam occupies the highest relative topographic position, followed by the Fillmore and Scott silt loams, respectively. Figure 7 is a generalized schematic as suggested by the more recent Soil Survey of Clay County, Nebraska (Hammer, Ragon, and Buechle, 1981). In this case, an additional soil, which occurs in a lower topographic position than the Scott silt loam, is mapped. This soil is the Massie silty clay loam, which occupies the lowest, wettest parts of some depressions (Hammer, Ragon, and Buechle, 1981).

When discussing the geology of Clay County, Keech and Dreeszen acknowledged the presence of the depressions but added that little is known about them (Keech and Dreeszen, 1959).

Although the existence of the depressions in southeastern Nebraska has been long recognized, virtually no scientific knowledge has accumulated. A major question

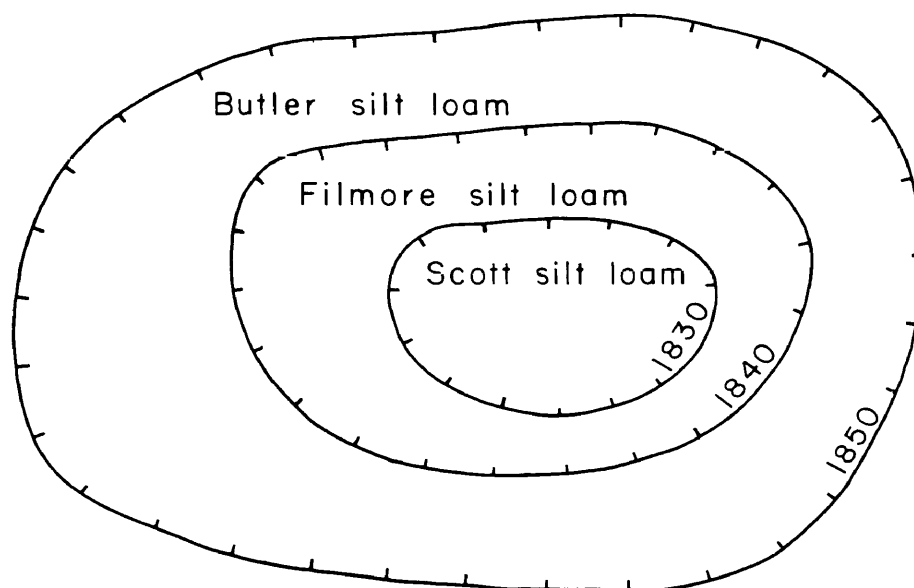


Figure 6. Generalized schematic of the poorly drained soils usually associated with depressions in Clay County. (Source: Roberts and Gemmell, 1927).

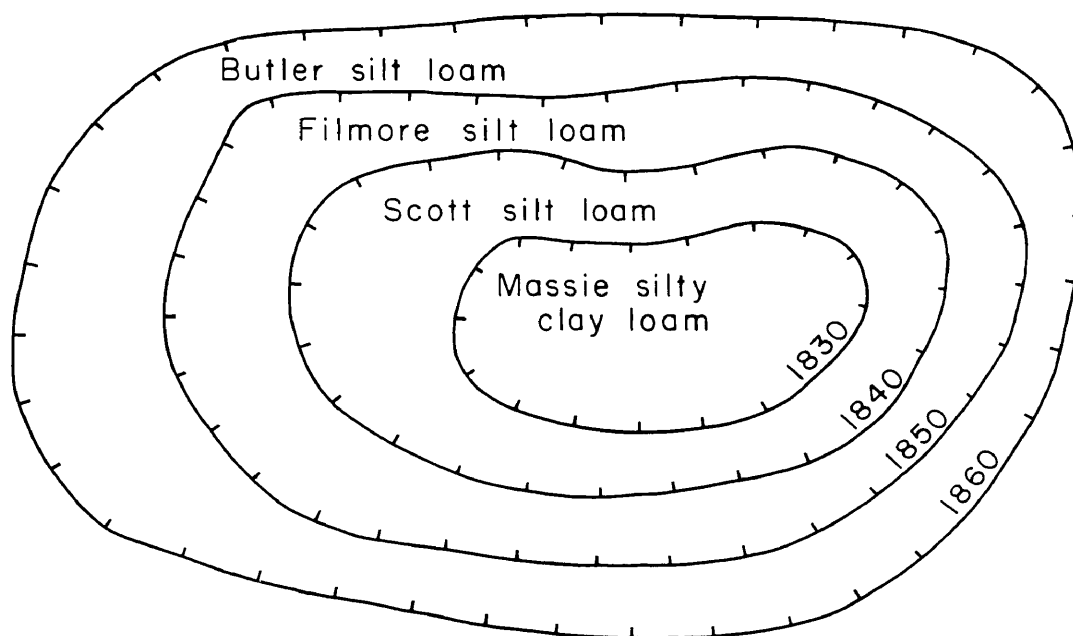


Figure 7. Generalized schematic of the poorly drained soils usually associated with depressions in Clay County. (Source: Hammer, Ragon, and Buechle; 1981).

still remains--how did these depressions form? Even though this research is not designed specifically to answer this question, it is anticipated that by reviewing the various depression-forming processes, some light will be shed on the problem.

Depression Formation

There is no single process by which all depressions on the earth's surface are formed. Indeed, there are many processes by which depressions may be created. In some cases, the formational process is obvious. For example, sinkholes generally found in limestone areas are formed when the roof of a limestone cavern collapses. In other cases, depression formation is not well understood--as in the rainbasin area. Several of the processes effecting development are listed and explained below.

Animal action

Gilbert believed that the depressions found on the plains of the western United States were formed by buffaloes (Gilbert, 1895). Depressions formed in this manner are termed "buffalo wallows." Darton more fully described how buffalo wallows were created. He reported that:

They were started by buffaloes either in wet spots or at places where there is salt or alkali, which the animals lick. The trampling of the hoofs of the heavy

animals wears the sod thin, and then the wind soon blows out a cavity, or if water collects in it the mud is carried out in large amounts in the shaggy coats of the buffaloes, who delight to wade or roll in a water hole (Darton, 1916).

Frye felt that the buffalo was more of a modifying agent in depression development, and that burrowing rodents would have a greater effect on depression development. However, animal action was not considered important by Frye (Frye, 1950) who went on to describe several processes which could have formed many of the depressions in the High Plains of Kansas.

Schoff, like Frye, reported that the buffalo was probably not an important factor in the creation of depressions. Some reasons for his conclusion are the rather large size of some depressions, and depression density (Schoff, 1939).

It is highly unlikely that the buffalo, or any other animal, is solely responsible for the creation of all the depressions in the Rainbasin. One major reason for this conclusion relates to the enormity of some of the depressions in Clay County. Figure 8 is a topographic representation of a rather large depression found in northwestern Clay County. This depression is in excess of 1500 acres in size and there are several others in Clay County that are comparable in size.

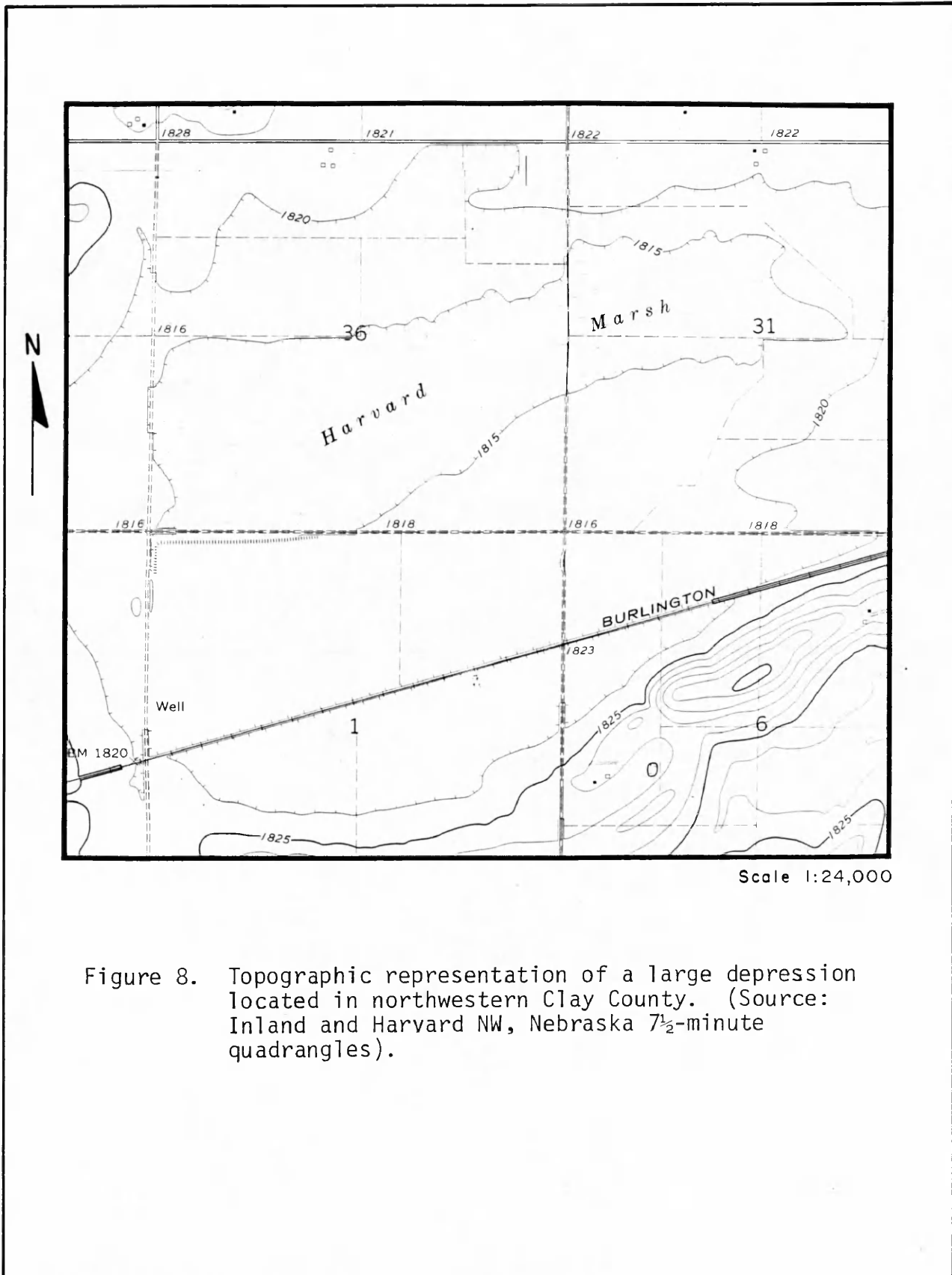


Figure 8. Topographic representation of a large depression located in northwestern Clay County. (Source: Inland and Harvard NW, Nebraska 7½-minute quadrangles).

Caliche karst

Caliche was described by Price (1940) as an accumulation of soil lime well above the water table in the lower soil zones. Price, Judson (1950), and Havens (1961) have attributed the creation of some depressions in Texas and New Mexico to the breaching of the caliche caprock by stream action, leaching, or some other erosional process.

A caliche caprock is not found in Clay County; therefore the depressions of Clay County are not believed to be caliche karst.

Deep-seated solution

Johnson (1901) and Frye (1950) both wrote of St. Jacob's Well and the Meade Salt Well of Kansas. It was their opinion that the solution of gypsum or salt at great depth (approximately 1000 feet) had caused the surface to collapse forming these rather large sinkholes. Other large depressions in the same vicinity, such as Big Basin, are believed to have formed the same way. These latter sinkholes are circular in shape and often very deep. Big Basin is approximately one mile in diameter and one hundred feet deep (Johnson, 1901).

Most of the existing well logs for Clay County are less than 500 feet deep and do not show the existence of deposits of salt or gypsum. However, two wells were located by the

author that were in excess of 3000 feet deep (Conservation and Survey Division, 1984). Limestone and dolomite deposits were found in the lower reaches, and were for the most part dense and not very permeable or porous. Therefore, it is not thought that deep-seated solution has been responsible for depression formation in Clay County.

Compaction

Johnson (1901) suggested that depressions could form when rain water accumulates in the initial but faint unevenness of a plain surface. The rain water percolates down to the groundwater causing settling of the ground thus forming a depression. Johnson referred to the above process as compaction.

Frye (1950) recognized that the mechanism of compaction was important in forming depressions in the High Plains of Kansas. However, Frye felt that Johnson's compaction theory was not clearly defined. Frye suggested that:

...the small sinks have developed where the surface layer of alluvium is composed of silt, about 12 feet thick, which rests on well-sorted, unconsolidated sand and gravel. Rain water flows through openings which develop in the surficial silt so as to reach the sands and gravels below. This flow washes silt from the sides of passageways in the surficial material into the interstices of the coarser deposits beneath. Such inwashing of silt can continue as long as the

passageways remain open or until enough silt has been carried into the coarse materials below to reduce their permeability and inhibit further inwash. After termination of silt inwash into the gravels the cavity is slowly filled and the initially steep sides of the sink reduced in slope. Localization of the initial point of inwash may be due to burrowing by rodents, decay of roots, or holes made by man. In the Hutchinson area the sinks were observed to be localized in an alfalfa field and were not found in adjacent wheat fields. As the water table in the area was about 15 feet below the surface, it seems probable that the dehydrating effect of alfalfa on the silt produced contraction joints which permitted inflow of rain water to the previous sands and gravel below. The shallow root system of wheat had little effect at depth (Frye, 1950).

The process described above is Frye's differential silt infiltration concept.

It is entirely possible that some of the depressions of Clay County have formed in this way. However, no conclusive evidence exists to prove or disprove Frye's theory.

Similar to Frye's differential silt infiltration hypothesis is the process of "piping and compaction." Elder (unpublished) noted that piping is responsible for depressions frequently found in fields where alfalfa has grown for a number of years. Apparently the deep and extensive rooting of the alfalfa reduces the moisture content of the soil causing deep cracks to develop. Rainwater flowing into the cracks saturates the loess

causing it to settle and occupy less space--thus, enlarging the crack. Elder stated that "once settlement and compaction has started it progresses until the surface has slumped and formed a depression or pit on flat land areas..." (Elder; Circa, 1970).

Alfalfa is of recent introduction to Clay County. It is possible, however, that some similar plant communities have been responsible for initiating depression development in parts of Clay County. However, no evidence exists that clearly points to any depressions in Clay County having formed by piping.

Deflation

Deflation is described as the removal of material from the land surface by wind action (The American Geological Institute, 1976). Of course wind has long been recognized as a powerful erosive agent capable of wearing down mountains and scooping out hollows on a plain surface.

Gilbert (1895) was among the first to advance the notion that wind was the mode of origin for many of the depressions found in the American West. Gilbert came to his conclusion because the other proposed hypotheses "seemed barred by some insuperable obstacle" (Gilbert; 1895, p. 47). Judson (1950), Frye (1950), and Reeves (1966) felt that deflation was responsible for the origin of some depressions

in the United States. Deflation is likely to have created certain depressions in Clay County, though it is not known which ones.

Meteors

In some instances, depressions have been created by the impact of meteorites upon the earth's surface. Reeves noted that several depressions near Odessa, Texas, had been formed in this way (Reeves; 1966, p. 280). The Carolina Bays, most notably those found in the Myrtle Beach area of South Carolina, were long believed to have been created by a shower of meteorites (Johnson, 1936). However, there has been some doubt cast on this mode of origin for the Carolina Bays by Johnson (1936).

Though some depressions in Nebraska may have been formed by the impact of meteors, it is doubtful that the depressions of Clay County were created in this manner.

Thermokarst

Thermokarst is described as the "settling or caving of the ground due to melting of ground ice" (American Geological Institute, 1976).

Pewe and Journaux (1983) described a number of distinctive surface features in south-central Yakutia, Siberia, U.S.S.R., that they called thermokarst topography. This

type of topography contains mounds, sinkholes, tunnels, caverns, and short ravines which form when large ground-ice masses in the permafrost begin to thaw. The thaw can be initiated by a general climate change or by a disturbance of insulating vegetation (Pewe and Journaux, 1983).

Alases are thermokarst landforms and are described as "steep-sided depressions that form as small depressions coalesce and sediment is washed into the bottom." (Pewe and Journaux; 1983, p. 11). Pewe and Journaux indicated that the alases can be from three to forty meters deep and from one-tenth of a kilometer to fifteen kilometers in diameter.

Clay County is located well away from any areas that might have experienced the effects of ground ice. Therefore, the rainbasin depressions of Clay County are probably not thermokarst landforms.

Glaciation

Kettles, sometimes called kettleholes, are depressions found in ground moraine or outwash plains. Kettles form when drift is deposited around a block of ice that has become detached from the main body of the glacier. When the block of ice melts away, a pit or depression is left behind.

The eastern border of Clay county is located approximately ten miles from the maximum glacial advance in south-

eastern Nebraska (Dreeszen, 1970); therefore, it is not likely that the depressions of Clay County are kettles.

Solution of carbonate rocks

Solution of carbonate rocks is similar to that of deep-seated solution. In this case, however, the rocks involved are limestones and chalk and are located only a few hundred feet below the surface (Frye, 1950). Frye noted several places in Kansas where solution of carbonate rocks had taken place.

There are several places outside the High Plains region of the United States where this process has created depressions. For example, the states of Florida, Kentucky, and Indiana are dotted with sinkholes that have formed when slightly acidic water caused the limestones of subterranean caverns to weaken and collapse. The data gleaned from the well logs of Clay County suggests that the depressions probably did not form by the solution of carbonate rocks.

Summary of Depression-Forming Processes

There are numerous processes by which depressions may be created. These processes may be mechanical or chemical in nature, or they may work in concert with one another to form a depression. While it is clear that some depression-forming processes are not likely to have operated in Clay County, it is difficult to say which ones have.

The present research will try to ascertain (indirectly) the process(es) by which the depressions were created by looking at the arrangement and distribution of the depressions in Clay County. The areal association of depressions with other landforms may be helpful in the analysis.

Landforms Found In
Association With Some Depressions

As noted earlier, Gilbert believed that many of the depressions in the Great Plains owed their existence to the wind. His reasoning included the fact that some of the depressions he had observed had a raised rim on one side sufficient to deflect drainage elsewhere (Gilbert, 1895). Gilbert attributed the rim's presence to materials being blown out of the depression and deposited on the upper edges.

Coffey described the existence of many "clay dunes" in south Texas (Coffey, 1909). He observed that some of "these ridges were sometimes several miles long, thirty feet high, and not over 200 or 300 yards in width" (Coffey; 1909, p. 754). He observed further that these clay dunes were almost always associated with a lagoon--or depression. In addition, he discovered that these ridges were found principally on the northwest side of the lagoon; the prevailing winds

being from the southeast. Coffey also suggested that if the material from the ridges were placed in the depressions, that it "would be sufficient to bring them to the level of the surrounding country" (Coffey; 1909, p. 755). The presence and location of the ridges led Coffey to conclude, like Gilbert, that the depressions were created, or at least enlarged, by the wind.

Price (1963), Reeves (1966), Marrs and Gaylord (1982), and Kolms (1982) are among many American authors who have written of clay dunes, sediment plumes, and ridges found on the downward side of playas, lagoons, and other depressions. Their research ranges from ridge genesis to determining windflow characteristics from the ridges.

Many Australian writers have noted the presence of ridges on the lee sides of depressions in Australia. Hills noted that:

Along the eastern shores of almost every lake and swamp in the plains of northern Victoria there occurs a crescentic ridge of silty clay or clay loam whose smooth and regular outlines, rising above the plains, at once catch the eye in an otherwise monotonous landscape (Hills, 1940, p. 7).

Because of the unique characteristics of these ridges, Hill coined a new term--lunette, which he defined as a crescent-shaped ridge found on the lee side of lakes, swamps, and similar depressions.

Other Australian writers have discussed the lunette in terms of form, composition, and theories of origin (Bowler, 1966, 1968, 1973, 1976; Twidale, 1972). In addition, lunettes have been analyzed in order to reconstruct past climate conditions (Bowler, 1976).

Ridges and The Rainbasin Depressions in Clay County

A number of the depressions in Clay County do indeed have a ridge located on one side. In some cases, these ridges may be classified as lunettes because of their shapes (Figure 9).

Since ridges appear to be associated with the depressions in Clay County, and the ridges seem to be genetically linked to the depressions, parameters for the ridges were defined, measured and analyzed as part of this study.

Breached Basins-A Variation on the Rainbasin Depressions of Clay County

At the outset of the study, a depression was defined as a low place of any size on a plain surface which exhibits no natural outlet for surface drainage. It was discovered that landforms similar in almost every respect to depressions (circular or oval in shape, ridge on the southeast side,

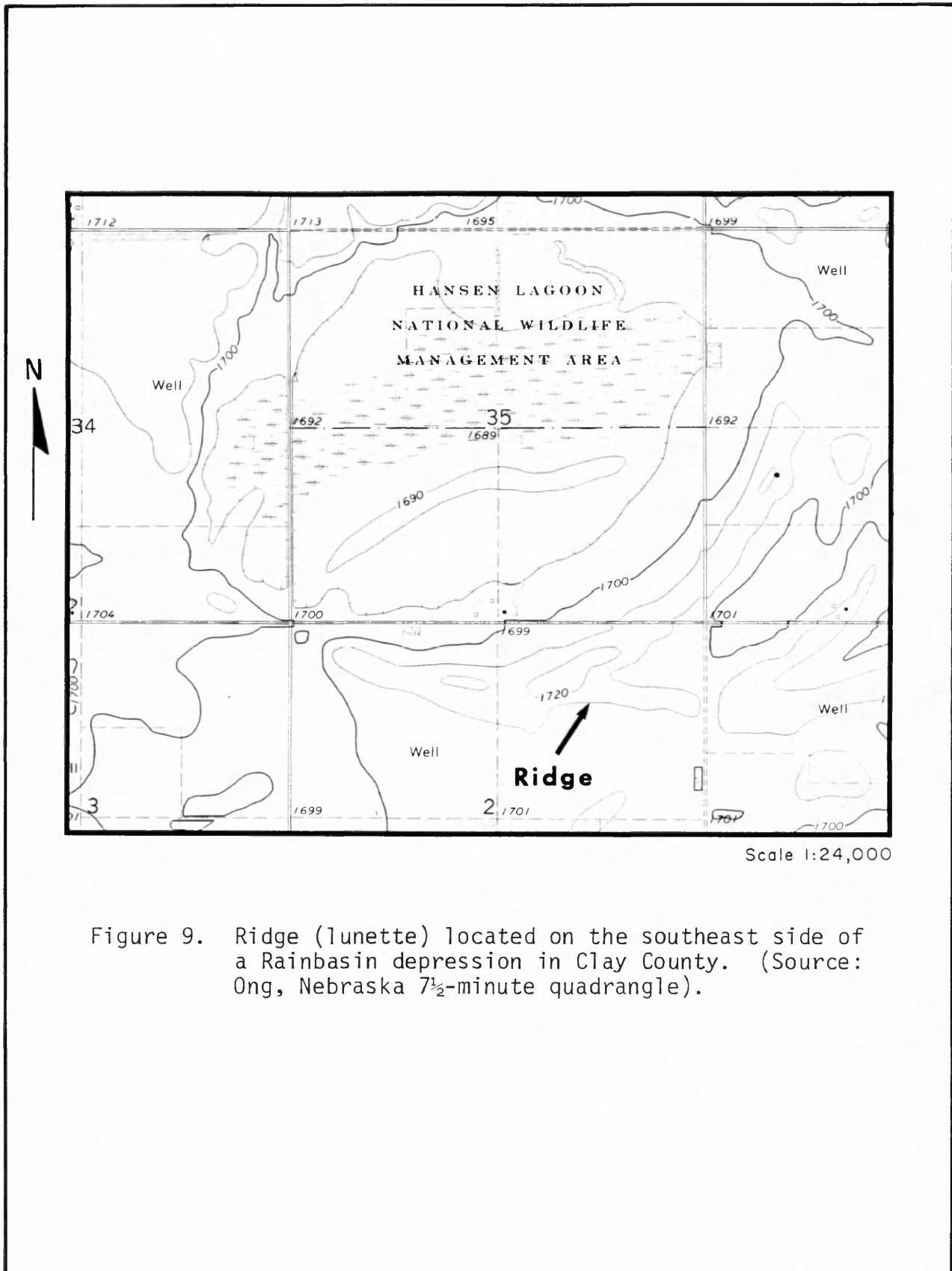
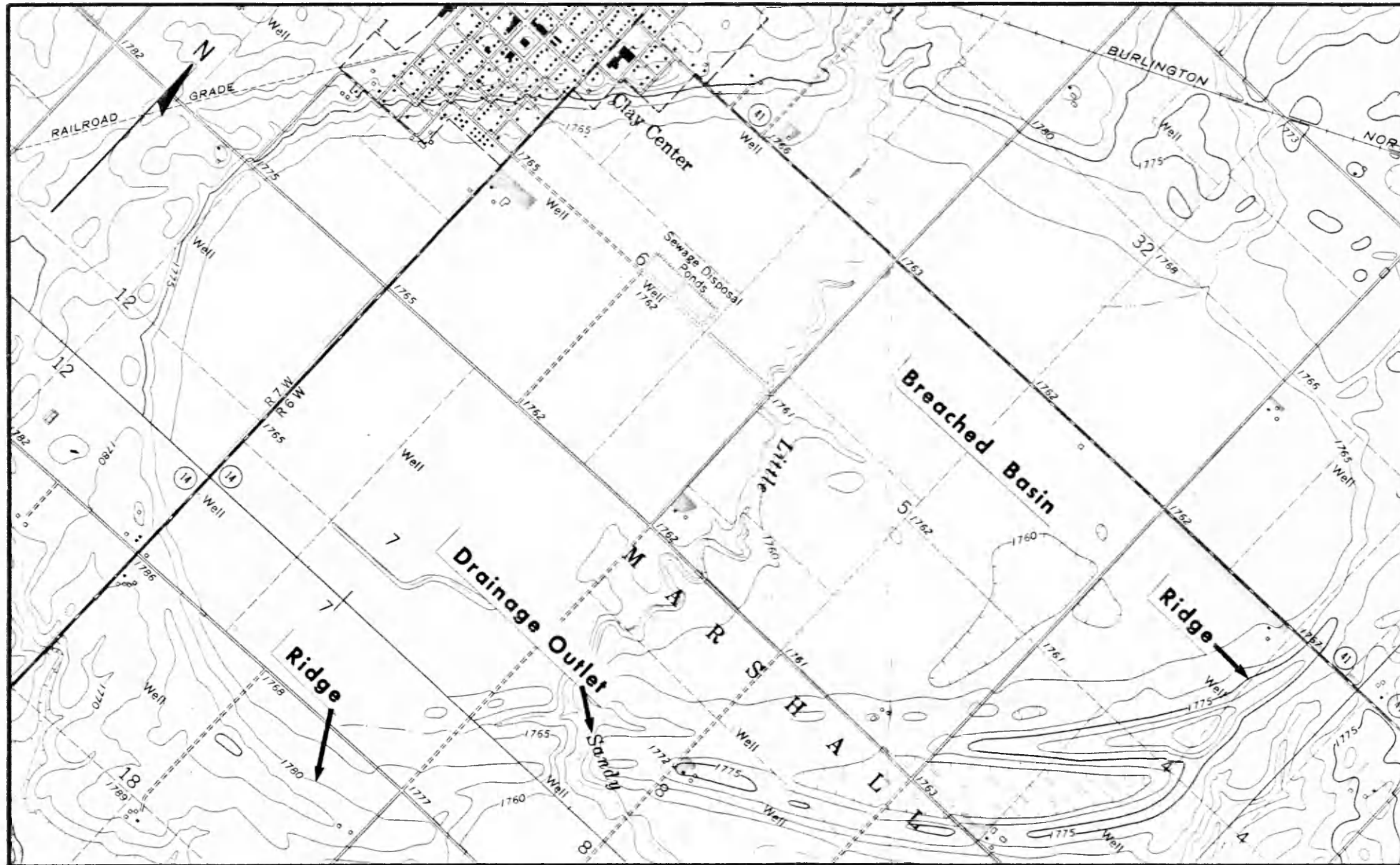


Figure 9. Ridge (lunette) located on the southeast side of a Rainbasin depression in Clay County. (Source: Ong, Nebraska 7½-minute quadrangle).

generally flat bottom with upward sloping sides) existed in Clay County. These landforms are here termed "breached basins". The breached basins are similar to the depressions except that they display a drainage outlet (Figure 10). In some cases the breached basins manifest a terraced floor which is due to the effects of a stream or streams flowing through the basin. Thirteen breached basins were discovered in Clay County.

Only one reference relating to breached basins was found. Judson (1950) stated that the San Jon site of his study area in the southern High Plains of eastern New Mexico "is an obvious depression breached by the relatively recent recession of the Escarpment." The Escarpment referred to is the Northern Escarpment of the High Plains facing the Canadian Valley. Judson used this breached depression, and others like it, to study exposures along the Escarpment so that the internal structure of the depressions could be analyzed.

The breached basins of Clay County may be indicative of an older generation of depressions that have been breached by the erosive force of streams. However, it is not the purpose of this paper to deal at length with the breached basins of Clay County. But, because the basins are so similar to the depressions, the basins are treated in the same manner as the depressions in the quantitative analysis of the present study.



Scale 1:24,000

FIGURE 10. BREACHED BASIN LOCATED IN CENTRAL CLAY COUNTY,
 (SOURCE: FAIRFIELD AND HARVARD, NEBRASKA
 7½-MINUTE QUADRANGLES).

Chapter 3

METHODOLOGY

Locating The Depressions

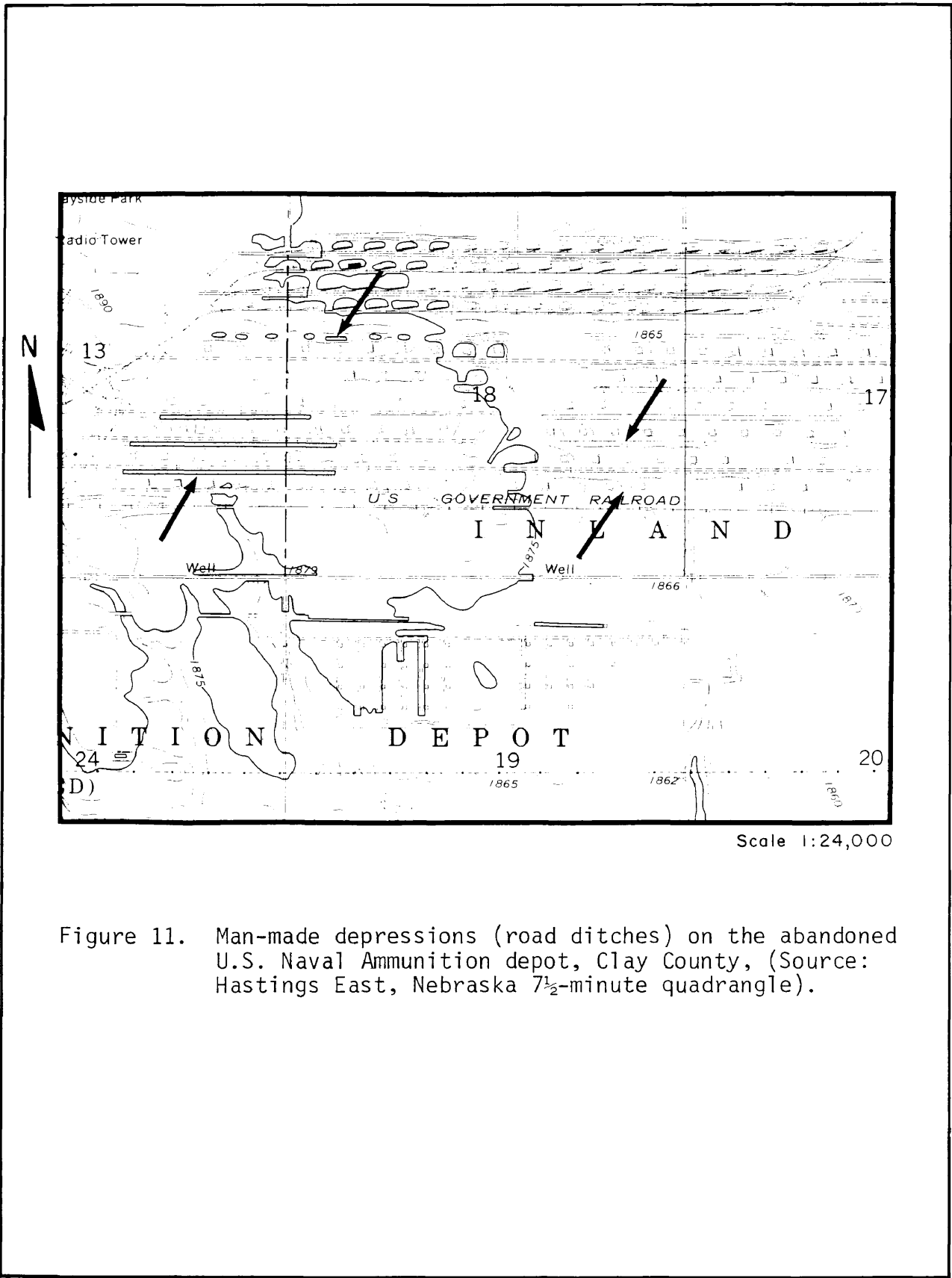
In order to carry out the analysis on the rainbasin depressions of Clay County, the depressions first had to be located. Stereo-pairs of aerial photographs were initially considered for this phase of the project, but because of the inadequate scale of the available photography and the subtleties of the depressions, this process was soon abandoned. It was then decided that the 7½-minute topographic maps of Clay County would be most useful for the locational aspect of this study. Twenty topographic maps at 1:24,000 scale were required for complete coverage of Clay County. These topographic maps are fairly new (1960-1969), and the contour intervals are five and ten feet depending upon the map being used.

Tracing paper was placed over each topographic map so that each depression and its drainage area could be transferred from the base map. This process allowed for less visual confusion between the contours and any mark that might be made during the measurement of the depression parameters.

Depressional areas are depicted on topographic maps as closed, hachured contour lines. However, not everything appearing in this manner is a naturally occurring depression. In light of this fact, it became evident that certain decisions had to be made regarding which depressions would be included in the study and which ones would not. It was found that, in Clay County, several depressions were indeed man-made. These man-made depressions include road ditches, silage pits, and gravel pits. Figure 11 illustrates several man-made depressions located on the abandoned United States Naval amunition depot in west-central Clay County. The area within the boundary of the ammunition depot was virtually eliminated from study because an overwhelming majority of the depressions found here were man-made. Figure 12 is another example of man-made depressions. In this instance a depression was created when an earthen dam was built across the stream for water conservation. When the earthen dam was constructed, the contours became "trapped"; therefore depicting the area as a depression by hachured contours.

In some areas, the rainbasin depressions have been so greatly modified in shape and size by man, that these too were rejected from study (Figure 13). In most instances this modification is due to land leveling or construction.

By the end of the locational phase of the project, 120 natural depressions were selected for analysis.



Scale 1:24,000

Figure 11. Man-made depressions (road ditches) on the abandoned U.S. Naval Ammunition depot, Clay County, (Source: Hastings East, Nebraska 7½-minute quadrangle).

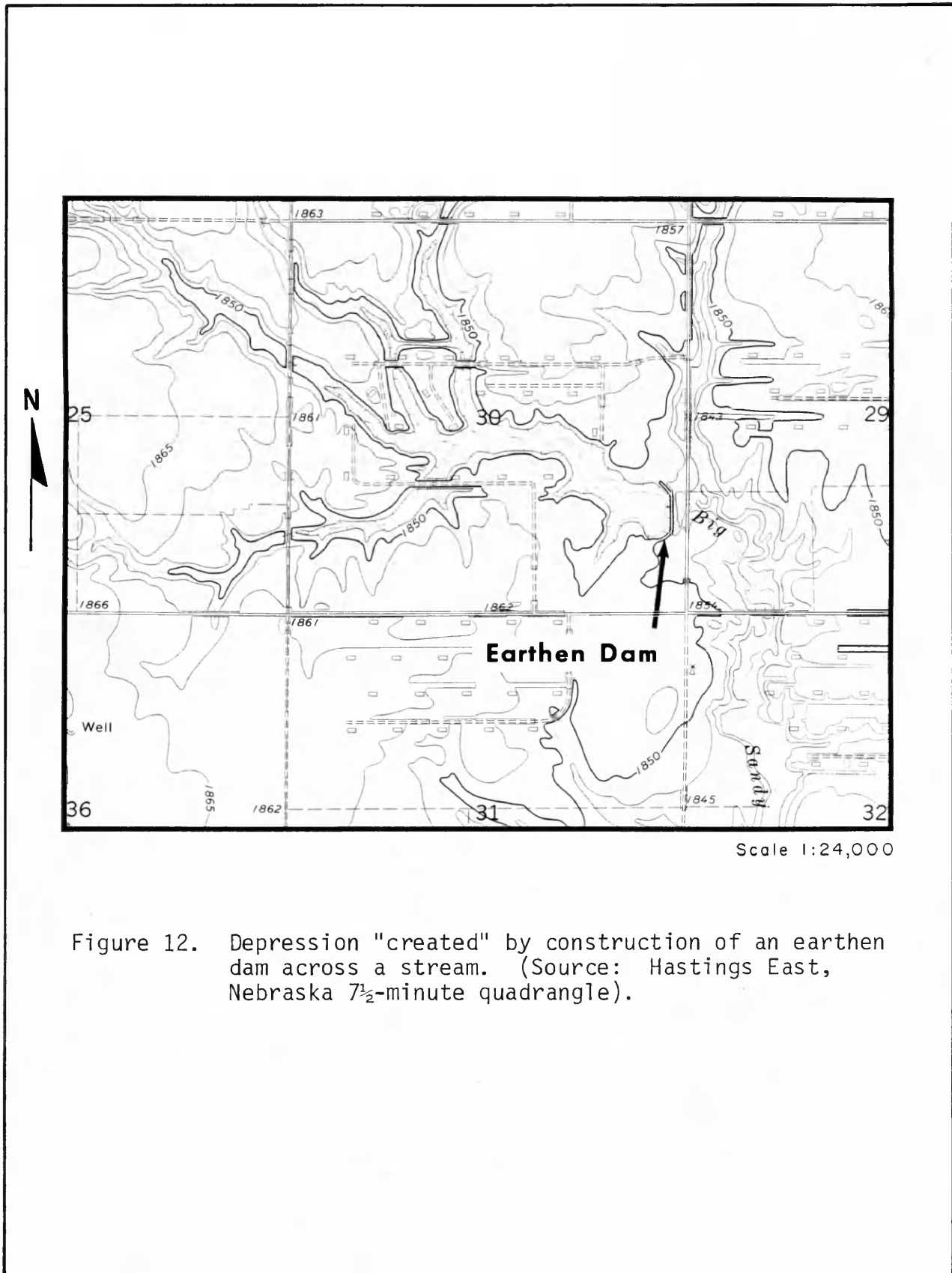
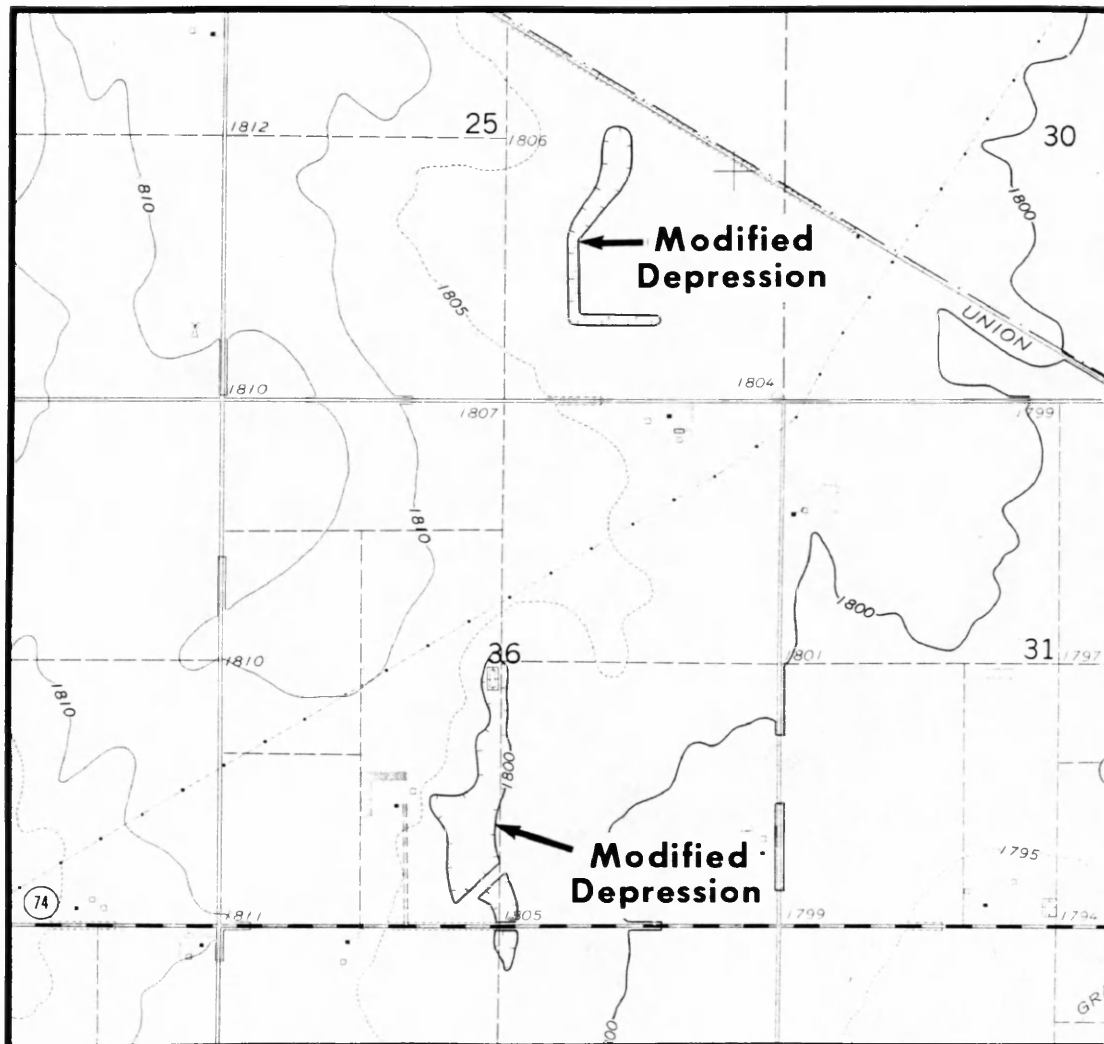


Figure 12. Depression "created" by construction of an earthen dam across a stream. (Source: Hastings East, Nebraska 7½-minute quadrangle).



Scale 1:24,000

Figure 13. Modified depressions. (Source: Fairfield NW, Nebraska 7 $\frac{1}{2}$ -minute quadrangle).

Ridges

As noted in Chapter 2, many of the depressions possess a ridge or "lunette" on their southeast sides. These ridges were transferred to the tracing paper along with the depressions and drainage area of the depressions.

For the purpose of clarity and consistency, the lower limit of the ridge is defined as that contour that clearly delimits the ridge; i.e., the one that closes on itself. Once this guideline was established, delimiting a ridge became rather straightforward.

Depression Parameters and Their Measurement

A series of ten parameters (nine quantitative and one qualitative) were defined and measured for each of the 120 depressions studied in Clay County. The measurements were taken either from the tracing-paper transfers or directly from the map. The selected parameters included surface area, depth, volume, perimeter, azimuth of the major and minor axes, length of major and minor axes, and the drainage area of the depression. The measurements were all recorded on a coding form (Figure 14) for easy retrieval. After all measurements were recorded, the data were then key-punched on cards for computer analysis.

DEPRESSION PARAMETER
Coding Form

Quadrangle: _____ County: _____
Depression identifier: _____
Survey description: _____
Depression or breached basin?
Surface area: _____
Depth: _____
Volume: _____
Perimeter: _____
Azimuth of the major axis: _____
Azimuth of the minor axis: _____
Length of the major axis: _____
Length of the minor axis: _____
Drainage area: _____
Comments:

Figure 14.

Surface and drainage areas

The surface area for each depression and its drainage area were calculated by means of a NUMONICS electronic planimeter. Each depression and drainage area was measured three times with the average value recorded on the coding form.

Depth

The depth of each depression was determined by subtracting the bottom elevation of each depression from the highest depression (hachured) contour exhibited by each depression (Figure 15). The bottom elevation for each depression was calculated by dividing the contour interval for each topographic map in half and subtracting that figure from the lowest hachured contour for the respective depression.

Perimeter

The distance around each depression was measured through the use of the NUMONICS electronic planimeter. Measurements were to the nearest foot in length.

Azimuth and length of the major axes

The major axis of a given depression is defined as the longest axis exhibited by the depression. Because most of the depressions in Clay county are oval or elliptical in plan, it was a rather straightforward procedure to determine

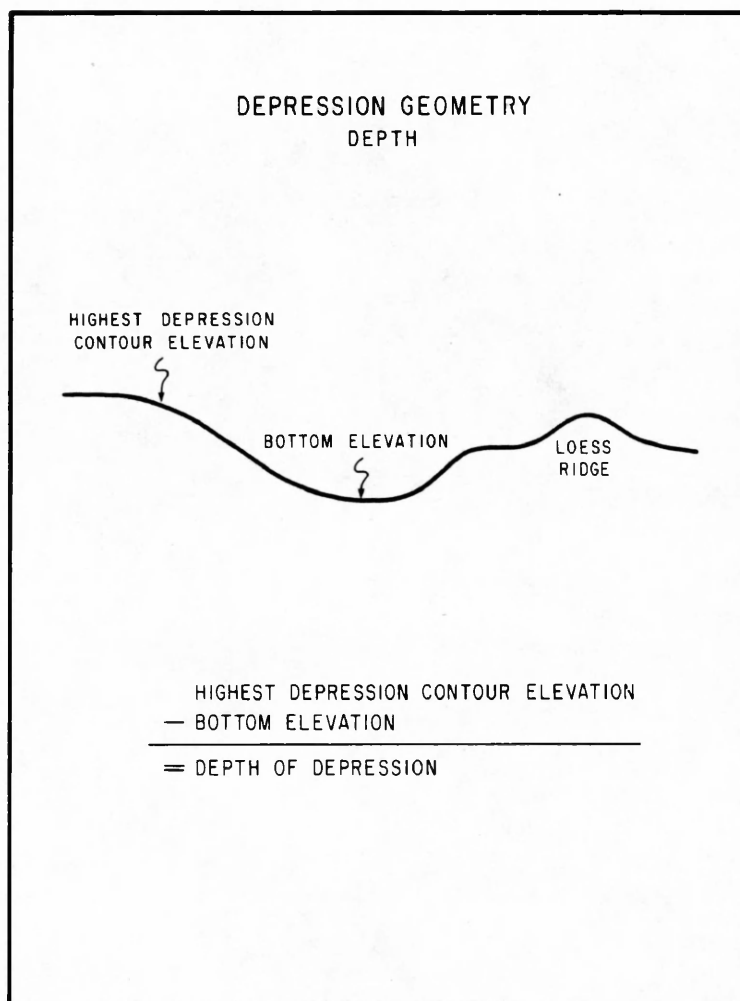


Figure 15.

where the major axis lay. The length of the major axis was measured by an engineering scale to the nearest ten feet.

Azimuths of each major axis were determined by drawing a north-south line through the most westerly point of the major axis (Figure 16), and then measuring the angle between the major axis and the north-south line. The above procedure provided a systematic method for angle measurement. This statement is best explained by example. A given depression, like the one in Figure 16, has two possible azimuths for the major axis. If the plan above is followed, the selected azimuth will be approximately fifty five degrees. If the north-south line was drawn through the most easterly point instead, the azimuth would be 335 degrees. Even though the major axis has the same trend, its azimuths (55° and 335°) are quite different. Therefore, the systematic plan for azimuth measure outlined above was adapted.

Azimuth and length of the minor axes

The minor axis of a depression was determined by finding the longest length which can be drawn perpendicular to the major axis. The measurements for the minor axis were carried out in similar fashion to that for the major axis; the only difference being that the north-south line was drawn through the most easterly point of the minor axis (Figure 16). This distinction became useful when a depression was of small size or irregularly shaped.

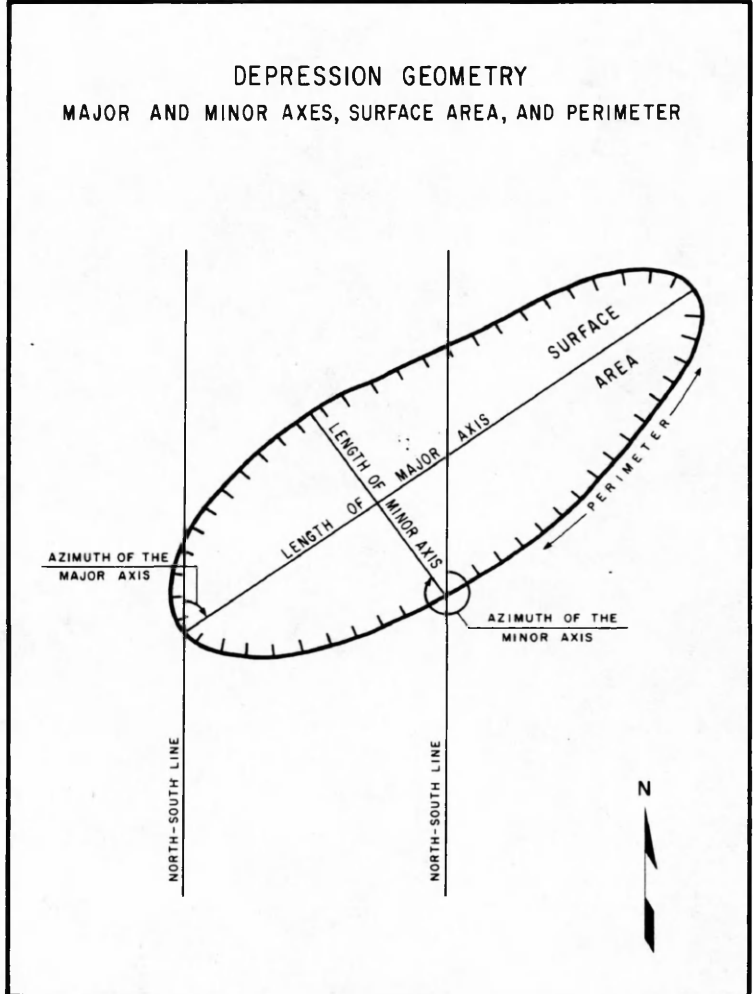


Figure 16.

Volume

The volume for each depression was calculated by the average end-area method (Figure 17). According to Figure 17, the surface area within the 1860 contour line is determined and added to that of the area within the 1850 contour line. An average surface area is then calculated and multiplied by the contour interval of the topographic maps-- in this example, ten feet. The resulting figure is the volume (V_1) between the 1860 and 1850 contour lines. After the volume has been calculated for each pair of contour lines, the volumes are summed to yield the total volume of the depression.

Other Data

In addition to the various quantitative data accumulated for each depression, a certain amount of qualitative data was also gathered. From Figure 14, it can be seen that a depression was given an identifying number, a survey description, quadrangle or topographic map location, and a place for comments about the depression. The locational information was useful when questions concerning specific depressions arose.

Another useful piece of information was whether or not a depression was breached (i.e. is the landform a depression or breached basin?). This aspect is relevant to the study only in a descriptive sense. Measurements were made on the

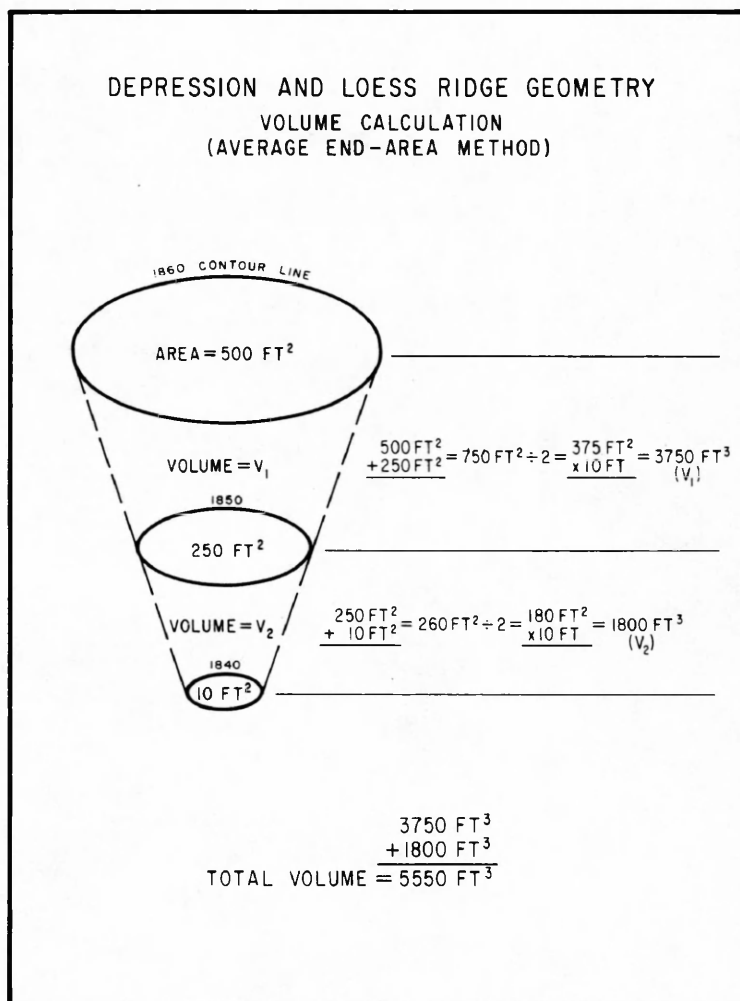


Figure 17.

breached basins in the same fashion as those for the closed depressions except that the areal extent of a breached basin was not determined by a hachured contour. Rather, soils information and topographic data were used to delimit the boundary of the breached basins.

Ridge Parameters and Their Measurement

The ridge parameters closely parallel those of the depressions and include surface area, height of the ridge above the plain, volume, perimeter, azimuth of the major and minor axes, length of the major and minor axes, and the distance from ridgeline to the depression. Figure 18 is the coding form used for recording the measurements of the ridge parameters.

Measurement of the ridge parameters followed, for the most part, the scheme developed for the depression parameters. Nevertheless, a few exceptions should be noted.

Height

Height of a ridge or lunette is calculated by subtracting the highest hachured depression contour from the elevation of the ridge top (Figure 19). The ridge top elevation is determined in the same manner as that for the depression bottom elevation.

Azimuth and length of the major axes

From Figure 20, it can be seen that the ridges are

RIDGE PARAMETER
Coding Form

Quadrangle: _____ County: _____

Ridge identifier: _____

Associated with: depression of breached basin?

Surface area: _____

Height: _____

Volume: _____

Perimeter: _____

Azimuth of the major axis: _____

Azimuth of the minor axis: _____

Length of the major axis: _____

Length of the minor axis: _____

Distance from the ridgeline to nearest edge of the
depression: _____

Comments:

Figure 18.

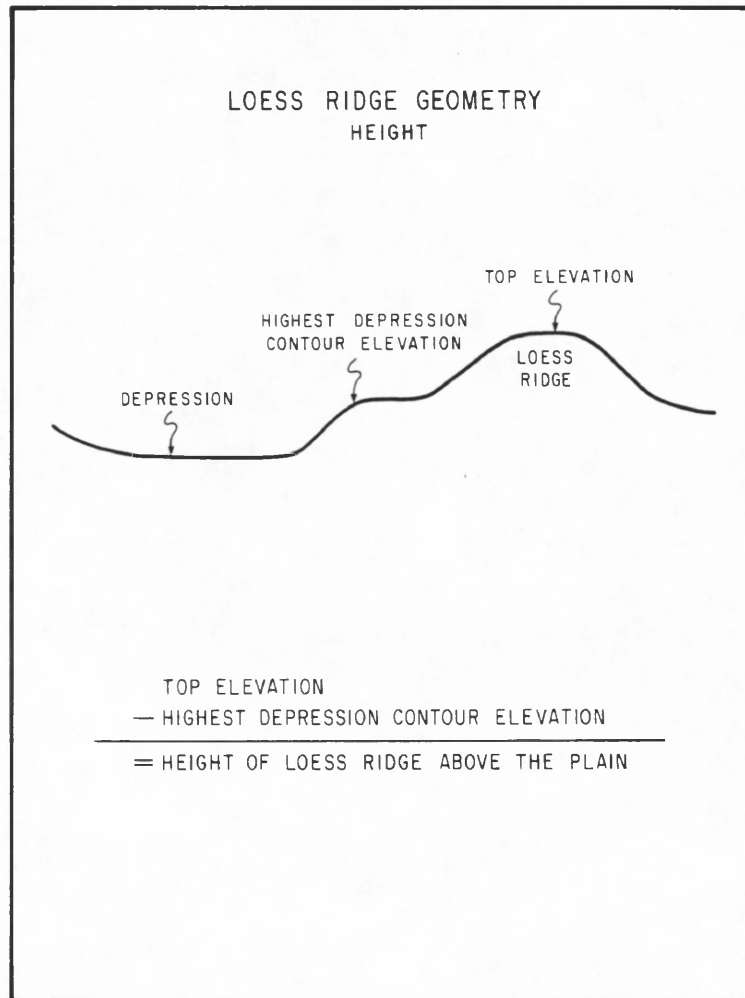


Figure 19.

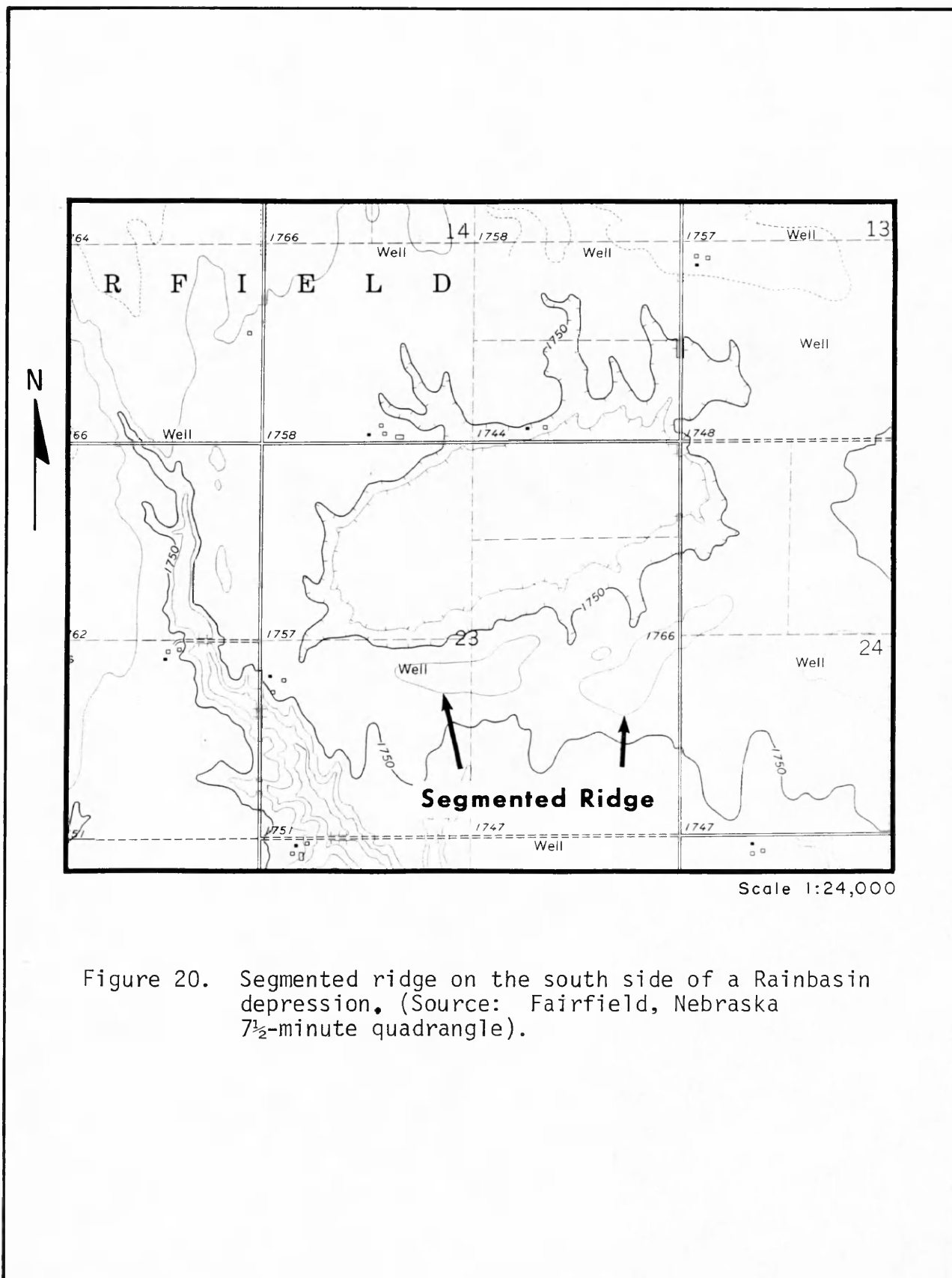


Figure 20. Segmented ridge on the south side of a Rainbasin depression. (Source: Fairfield, Nebraska 7½-minute quadrangle).

crescentic in shape, and may be broken up into separate segments. This fact necessitated an alternate method for measuring the azimuth and length of the major axes of the ridges.

The length of the major axis was determined to be the length of the ridgeline. In the case of two or more segments, a composite length was calculated by adding the length segments of the various ridgelines together (Figure 21).

The azimuth of a ridge was determined by drawing a line between the opposing ends of the ridge. Where the ridge is broken up into segments, a line was drawn between the opposing ends of the most distant segments (Figure 21). Thus, the azimuth of the major axis represents an "average" azimuth.

Azimuth and length of the minor axes

The method used in calculation of these parameters, is the same as that used for the depression parameters.

Surface area, perimeter, and volume

Surface area, perimeter, and volume parameters were measured in the same manner as the corresponding depression parameters. Where a ridge consists of two or more segments, the various measurements were made for each segment and summed to create a composite measurement.

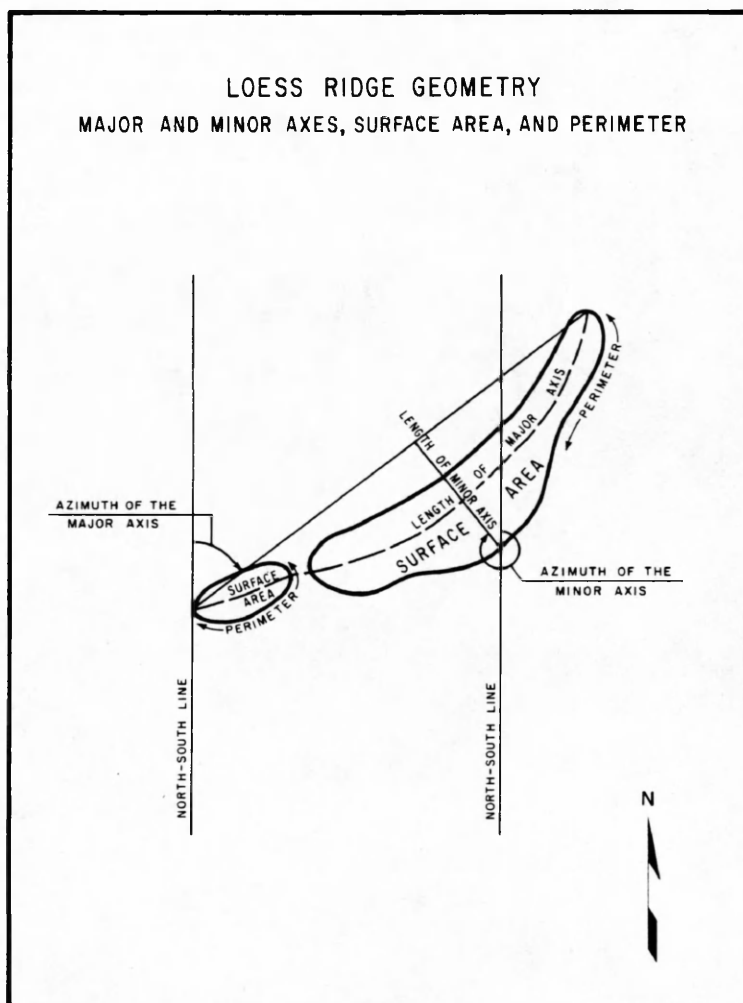


Figure 21.

Distance from ridgeline to edge of depression

The ridge-depression distance measurement represents an average distance from the ridgeline to the nearest edge of the depression. Three locations along the ridgeline were chosen for measurement. Two of the three points were located at opposite ends of the ridge while the third point was located halfway between the first two points. A perpendicular line was drawn from these locations to the first hachured contour of the depression (Figure 22). The lengths were then summed, averaged, and recorded on the coding form.

Qualitative Analysis

The depressions in Clay County are analyzed cartographically as well as quantitatively. The cartographic investigation comprises the qualitative component of the thesis. A map of all rainbasin depressions, and their associated ridges has been reproduced in Chapter 4. From this map, several inferences as to depression origination, modification, and location are possible. Additionally, a map depicting the poorly drained soils in relation to the depressions has been produced. The main purpose of this map is to determine if soils information can be used to accurately define the occurrence and areal extent of the depressions of Clay County.

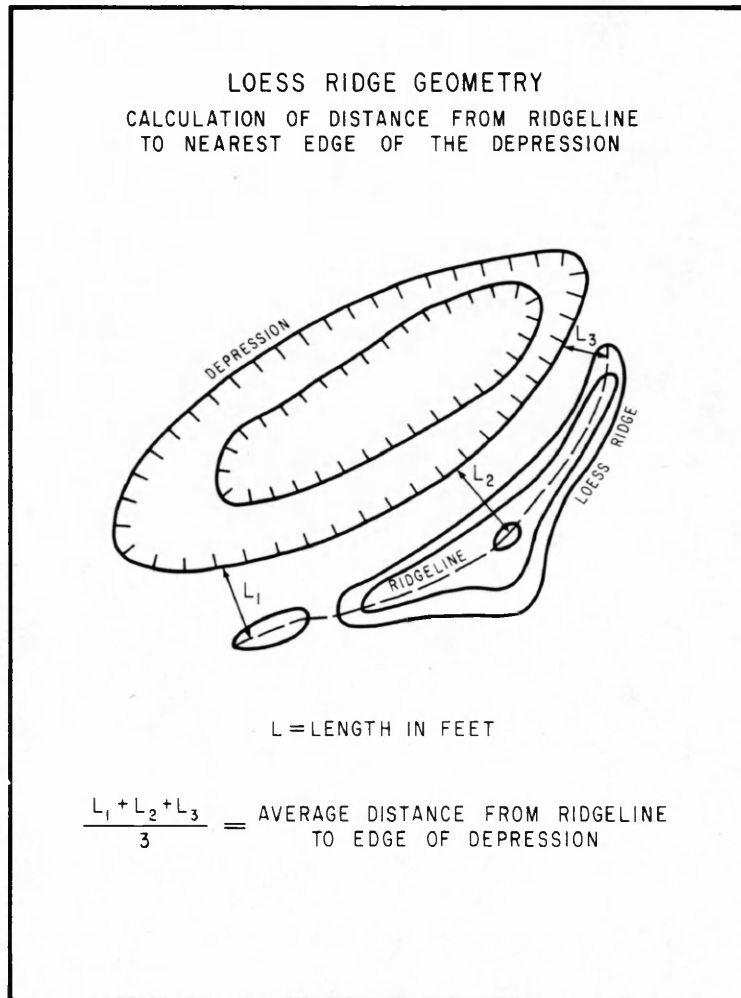


Figure 22.

Quantitative Analysis

The various parameters and their measures were subjected to statistical analysis via the SPSS (Statistical Package for the Social Sciences) routines, Condescriptive Pearson Correlation, Regression, and Discriminant. Pearson's Correlation was used to determine if strong relationships exist between the parameters of the ridge and depression categories (between group relationships), and to determine if relationships exist between parameters for a given group (within group relationships). Regression is similar to Pearson's Correlation except that Regression may be used as an inferential tool. Discriminant analysis was used to see if the ridge and depression parameters could be used to predict membership of a given depression into predetermined groups. If this latter procedure is successful, it might suggest that spatial order does exist in the Rainbasin of Clay County--that is, the depressions are of the same genetic process.

The SPSS routine "Condescriptive" was also employed to yield descriptive statistics of the depressions and ridges. This aspect of the study (quantitative analysis) is the first such analysis of the depressions in Clay County known to this writer. The results are reported in Chapter 4.

CHAPTER 4

ANALYSIS

General Comments

The rainbasin depressions of Clay County are analyzed both cartographically and statistically. The depressions are characterized in terms of their physical attributes, trends and patterns, and their relationship to other land forms. Some results of the field trips taken to the study area, coupled with subsurface information, aerial photographs, and personal interviews with geologists, form a part of this chapter. The knowledge gleaned from the above is not meant to be exhaustive, but rather to be suggestive of what has happened in certain specific locations.

Cartographic Analysis

The need for visualization of the trends, distribution, and patterns of the rainbasin depressions of Clay County, necessitated all of the depressions being incorporated into one map. Figure 23 represents all naturally occurring,

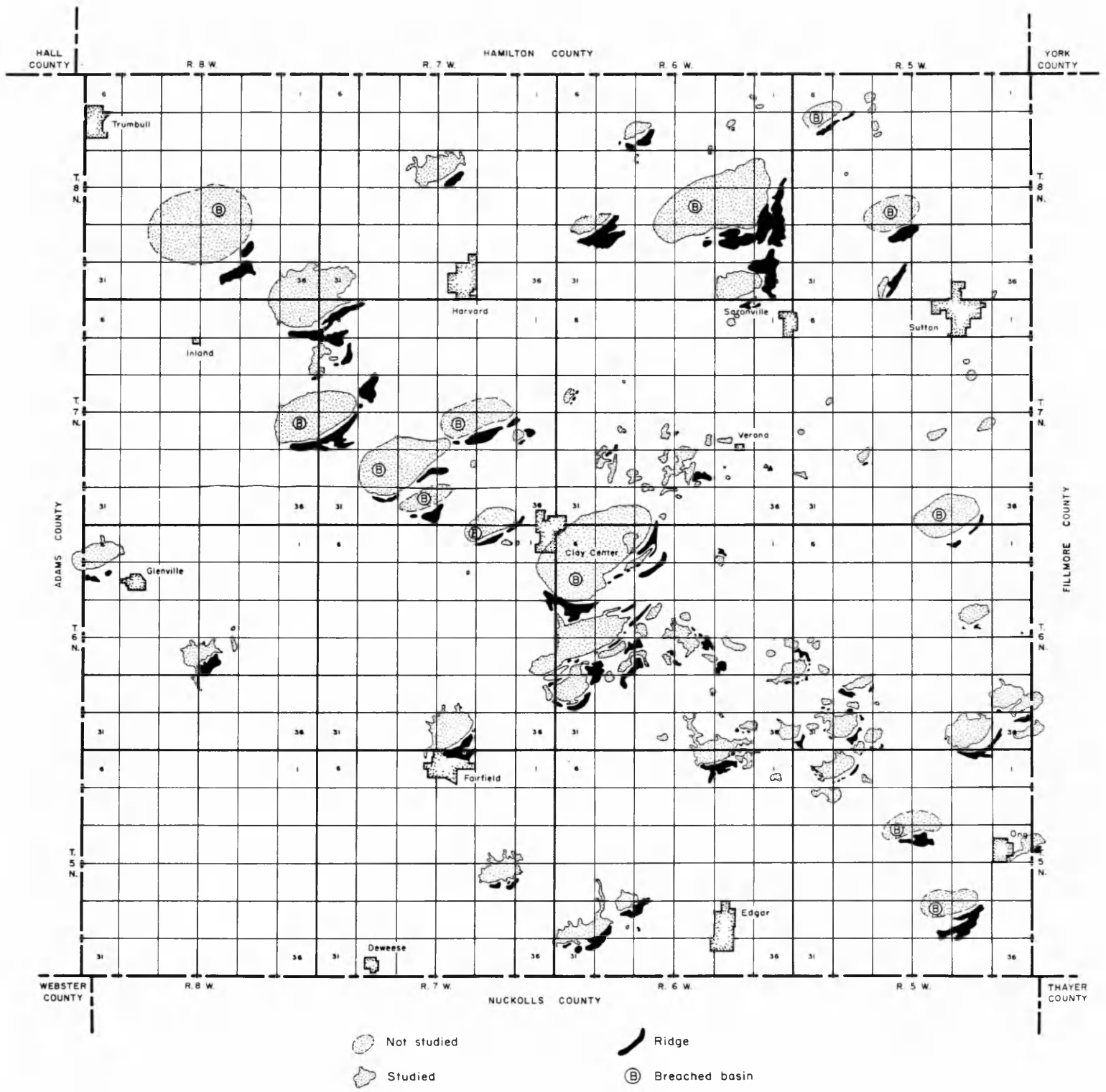


Figure 23. Location of the depressions, breached basins, and ridges of Clay County.

unmodified depressions and breached basins, along with their respective ridges, as depicted on the 7½-minute quadrangles of Clay County. Some of the depressions and associated ridges were initially (and unintentionally) overlooked and, therefore, were not included in the statistical analysis. However, these depressions are noted in Figure 23 and are included in the cartographic analysis.

Depression distribution

Rainbasin depressions are found throughout Clay County with the exception of Township 5-North, Range 8-West (Figure 23). This is not to say that this township has no depressions, but rather that the scale and contour interval of the topographic maps may have not been sufficient to delineate any possible depressions located there.

Some of the depressions in Clay County appear to be grouped together in linear trends. For example, some seem to be located along a diagonal line from Trumbull, in northwestern Clay County, to Ong in southeastern Clay County (Figure 23). A similar trend can be noticed along a line from Glenville, to Fairfield, to Edgar.

Reeves (1966) noted that large depressions often occurred in groups in his study area in west Texas. He suggested that these depressions may have been "part of an interconnected, open-lake system which formed along old river systems" (Reeves; 1966, p. 150). It is entirely

possible that the linear trends noted above, could have originated in the way Reeves described. It is also possible that another factor, such as wind, may be responsible for this linear trend. Drill core samples taken through some of the depressions within the linear trends would be useful in addressing the theory suggested by Reeves.

Physical characteristics

As can be noted in Figure 23, the size of the depressions is quite variable. The larger depressions are found, for the most part, along the diagonal line from Trumbull to Ong. The smaller depressions are scattered throughout the county.

The shape of the depressions, when taken as a whole, varies greatly. However, it appears that the larger depressions tend to be more elliptical in shape, while the smaller depressions may be elliptical, circular, or even irregular in plan.

Figure 24 depicts the length and azimuth of the depressions found in Figure 23. The larger depressions (long arrows) seem to possess a similar azimuth while the smaller depressions exhibit a wide range of azimuths.

A general evolutionary scheme may be suggested from Figures 23 and 24: As the smaller, randomly-oriented depressions become larger, they tend to become more elliptical in shape and they tend to possess similar major-axis azimuths.

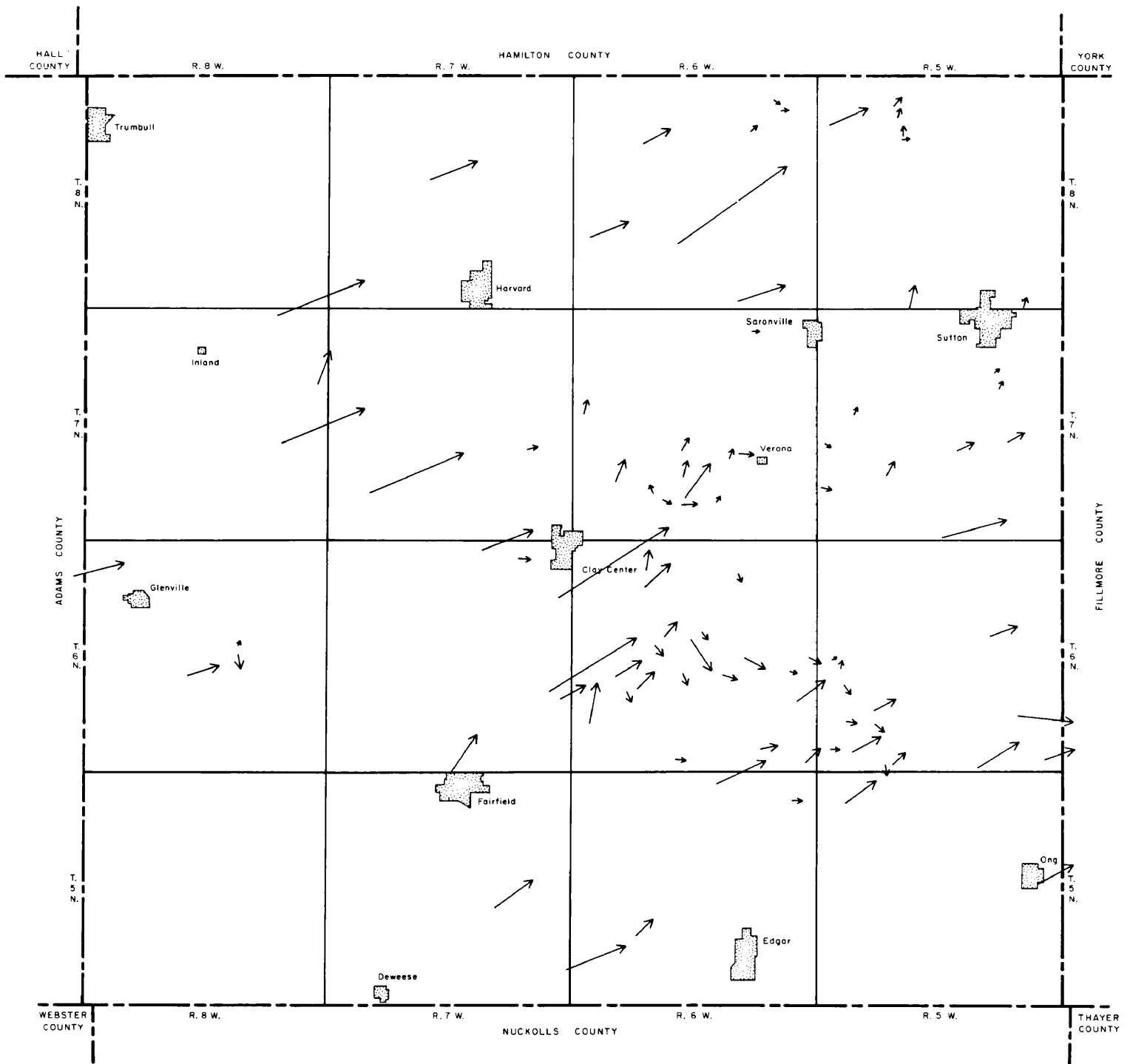


Figure 24. Length and azimuth of the major axes of the depressions.

At this point, one might ask how the depressions become enlarged, or how the larger depressions attain their elliptical shape and orientation. To address the first question, it would seem that deflation would be a logical factor in enlarging the depression. Wind would erode materials out of the depressions and transport them elsewhere, whereas water would tend to fill the depressions in and diminish their size. The orientation and ellipticity of the larger depressions appears to be wind induced as well. Judson (1950), who studied lake basins in eastern New Mexico, postulated that deposition of eolian materials on the lee side of the lake basins should tend to elongate them perpendicular to the wind. Judson added that "quantitative data were insufficient to make a more definite statement" (Judson; 1950, p. 266). Price (1968), Marrs and Gaylord (1982), and Kolm (1982) found that oriented lakes, lake basins, playas, and other depressions tend to be aligned orthogonal to the wind.

The months November through April are the months with the strongest winds in Nebraska. These strong winds prevail from the north to the northwest. In addition, very little precipitation occurs during the months November through April (Lawson, Dewey, and Neild; 1977). If the present climate conditions are indicative of past events, it would appear that eolian action is responsible for orienting the depressions in Clay County.

Reeves (1966) presented two hypotheses for depression orientation: 1) formation along a stream channel, and 2) end-current erosion. A third hypothesis would be a combination of 1 and 2. Nevertheless, Reeves felt that the large Class IV (lake basins produced along streams during Pleistocene pluvials) basins, and playas, of his study area owed their orientation to end-current erosion.

Livingstone (1954) derived a theoretical model that he felt might explain the parallelism of the oriented lakes of Alaska--end-current erosion. The orientation of the lakes on the coastal-plain of northern Alaska has been described by various writers (Black and Barksdale, 1949; Carson and Hussey, 1962), and different orienting agents have been discussed; all using wind as an agent in one form or another. Livingstone found that the oriented lakes of Alaska were aligned perpendicular to the wind--unlike Black and Barksdale who felt the lakes were oriented parallel to the wind.

Using a circular lake basin as his starting point, Livingstone accounted for lake orientation in the following way: as the wind blows across the lake, longshore currents set up in the lake. The longshore currents then attack the ends of the circular lake; the ends being points perpendicular to wind flow at a maximum distance from the center of the lake. The erosive power of these end-currents were hypothesized, by Livingstone, to be more effective than

other currents that are prevalent in the lake. Thus, the lakes tend to attain an elliptical to sub-elliptical shape and the azimuths of the major axes are similar.

Many of the depressions in Clay County now contain water. It is not unreasonable to think that all contained water centuries ago. Therefore, the mechanism described by Livingstone could have operated on the depressions of Clay County--indeed, it is probable that end-current erosion may be operating at present in the depressions. However, quantitative work concerning end-current erosion in the depressions of Clay County is not known to exist; clearly, research in the area of end-current erosion would be useful in analyzing the shape and orientation of the depressions in the Rainbasin.

Ridges

From Figure 23 several features can be noted, but, the most apparent is the presence of a ridge on the south and east sides of some depressions in Clay County. Also, many of these ridges are crescentic in plan and, thus, conform to Hills' description of a lunette (Hills, 1940).

Gilbert (1895) and Coffey (1909) felt that the presence of ridges, found in association with depressions, could only be explained in terms of wind action; i.e., the wind deflates materials from the depression and deposits those materials

on the lee side of the depression. Because the ridges are consistently found on the south and east sides of the depressions, it would seem that Gilbert and Coffey are correct in their appraisal of ridge development. Thus, a question is raised: Are the ridges and depressions genetically linked? Statistical analysis of the ridges and depressions is expected to be an aid in attempting to answer this question.

Field Observation

During the summer of 1983, a series of field trips were taken to Clay County. These trips were designed to gain first-hand knowledge of the character of the depressions in Clay County. In addition, many questions were asked which served to give direction to the research.

From the field observations, and visual analysis of the topographic maps of the study area, it became obvious that the depressions and ridges had to be analyzed concurrently. It was felt that the ridges might be particularly revealing. One depression, and its associated ridge, is especially noteworthy and is discussed below.

Theesen Lagoon

Theesen Lagoon, located on the Adams-Clay County line and approximately one-half mile northwest of Glenville,

is 7½ feet deep, occupies a depression having a surface area of about 390 acres, and has a ridge on the south side. The lagoon was visited on a field trip to Clay County, and served to reinforce the deflation theory as the mode of origin for at least some of the depressions in Clay County.

Logs of test holes drilled by the Conservation and Survey Division, University of Nebraska-Lincoln and the U.S. Geological Survey are listed and the geology is described in various reports. Information suggests that Peoria Loess mantles the land surface in the uplands of the Blue River Basin. Typically a "buried" soil referred to as the Gilman Canyon Formation underlies the loess. Underlying the Gilman Canyon is the Loveland Formation and older geologic units. Studies in the last 15 to 20 years suggest that the Loveland Formation is the upper unit of a complex sequence of brown to gray silts, clays, sandy silts and sands. The names of Loveland (youngest) Beaver Creek and Grafton (oldest) formations have been applied to this complex. A basal sandy gravel may be associated with any of the three pre-Gilman Canyon formations (Dreeszen, 1984; personal communication). Only one test hole has been drilled in a depression site in Clay County or in counties near by. That test was drilled along the road in the Theesen Lagoon and the log indicates a different geologic section from that described above.

Thirty-seven feet of clays and clayey silts lying directly above sand and gravel were drilled in the Theesen Lagoon depression. The Gilman Canyon and older Loveland, Beaver Creek, or Grafton formations were not recognized in the samples. The sand gravel may be a part of either the Beaver Creek or Grafton samples. The full thickness of clays and clayey silts may represent a Peoria Loess equivalent plus younger sediment. Erosion has exposed sand on the north-facing slope of the ridge on the south side of Theesen Lagoon. Whether the sand occurs as a lens or as a core is not known. From the evidence at hand, it would appear that wind lifted materials out of the area now called Theesen Lagoon and deposited those materials on the lee side--thus forming a ridge. However, the sand, being a heavier material, was transported only to the north face of the ridge. A suspected origin of the sand on the ridge is from deposits once underlying Theesen Lagoon. Subsequent to the creation of the depression by deflation or other means, dust and silts and clays washing in from surrounding lands filled Theesen Lagoon to its present depth.

The scenario described above for Theesen Lagoon may be applicable to other depressions in Clay County. One way to test the deflation theory would be to see if any other ridges have sand on their north and west sides. Testing ridges for sand may be done by a variety of methods; however, color-infrared aerial photography may prove useful.

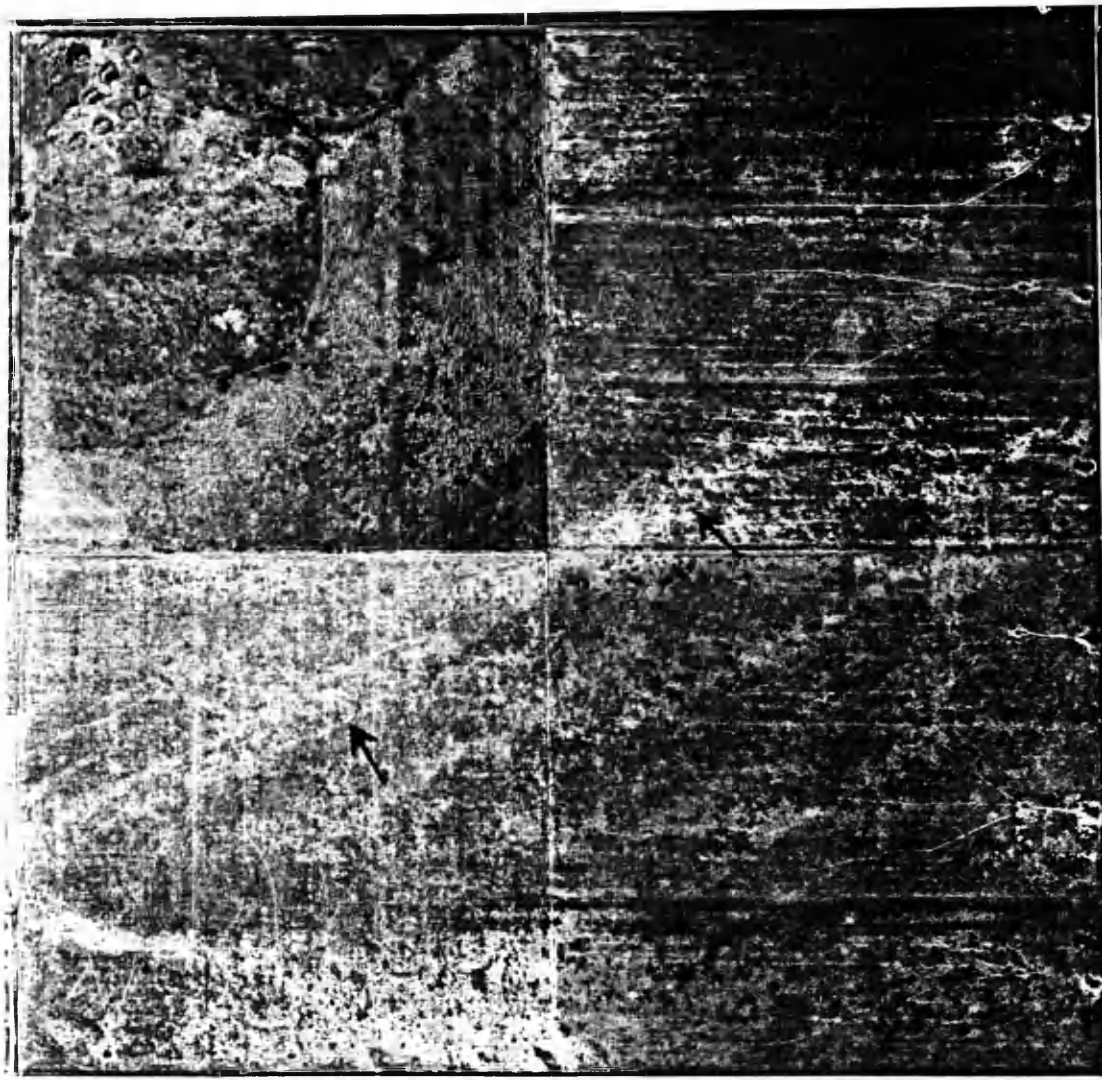


Figure 25. Aerial color-infrared photograph of the ridge on the south and east sides McMurtrey Marsh, Clay County.

Figure 25 is an aerial color-infrared (CIR) of the ridge on the south and east sides of McMurtry March (Section 28, Township 7-North, Range 7-West). The arrows point to lighter tones along the ridge. It is suspected that the lighter tones are due to the presence of sand in the ridge-- sand being more reflective of infrared radiation than the surrounding soil or vegetation in the area. If the lighter tones on Figure 25 are due to the presence of sand in the ridge, CIR may prove to be useful in further analyses of the ridges.

Poorly Drained Soils and Depressions

Map 2 (map pocket) was compiled from the 1981 Soil Survey of Clay County, Nebraska and registered to an overlay of the depression map of Clay County. This map shows the relationship between depression location (as depicted on the 7½-minute topographic maps) and the occurrence of the poorly drained soils (Butler, Fillmore, Scott, and Massie silt loams). Each soil type is discussed separately concerning the relationship of depressions and the specific soil.

Butler silt loam

From Map 2 it can be ascertained that the Butler silt loam occurs widely over Clay County. When the Butler soil

is found in association with the depressions, it usually occurs in linear or curvilinear strands. However, not all of the depressions of Clay County possess the Butler soil. Some of the breached basins display extensive areas of Butler soil, but, again, not all breached basins. The Butler silt loam is not a good indicator of the absolute location, or areal extent of depressions in Clay County.

Fillmore silt loam

Like the Butler soil, the Fillmore can be found throughout Clay County, but it does not occur as often as the Butler nor is it as extensive in areal extent. Fillmore soils can be found, on occasion, in depressions occurring in linear or curvilinear patterns. The Fillmore soil does not indicate the areal extent or absolute location of depressions in Clay County.

Scott silt loam

The Scott silt loam is truly a depressional soil, occurring in marshes, ponds, stream bottoms, and the like. However, not all depressions in Clay County display a Scott silt loam. Where the Scott soil does appear in conjunction with a depression, the soil may occupy a large part of the depression or only be found in a small part of the depression. Therefore, the Scott silt loam cannot be used by itself to indicate the areal extent of a depression.

Massie silt loam

The Massie silt loam, like the Scott, is a true depressional soil. But, again, not all of the depressions exhibit a Massie soil. However, where the Massie soil does occur, it normally covers a relatively extensive area within the depression. Because the Massie soil does not occur in all depressions it cannot be used as a locational device to seek out other depressions.

Summary of the Poorly Drained Soils

The Butler and Fillmore silt loams occur throughout Clay County, with the Butler occurring most often and more extensively. Even though these soils are considered poorly drained, they are not good indicators of depression size, shape, or location.

Scott and Massie soils are true depressional soils, but, not all of the depressions exhibit these soils. Therefore, these soils cannot be used to accurately locate the depressions of Clay County, nor can these soils be used to define the areal extent of a depression.

It is suggested by Map 2 that the four poorly drained soils under consideration do not accurately, define the size, shape, or absolute location of a depression when considered either individually or in concert. The Butler, Fillmore, Scott, and Massie soils, when used in concert,

usually define the relative location of a depression, but not its size or shape.

Statistical Analysis

Four statistical (SPSS) algorithms were utilized to: i) provide a numerical description of the physical attributes of the depressions and ridges; ii) evaluate the relationships between groups (the groups are the depressions and ridges and the relationships refer to the parameters within the groups); iii) determine if a ridge parameter's dimensions can be predicted by one or more of the depression parameters, and if so which depression parameter(s) is/are the most important; and iv) see if it is possible to predict the presence of absence of ridge based upon the physical attributes of the depressions.

The four algorithms employed in the statistical analysis are SPSS CONDESCRIPTIVE, PEARSON CORR, REGRESSION, and DISCRIMINANT. These SPSS algorithms are described below in conjunction with the results.

Descriptive statistics

CONDESCRIPTIVE provides the researcher the mean, range, maximum, minimum, etc., values of the measurements recorded per parameter (Nie, et. al.; 1970). All parameters for the ridges and depressions were analyzed and the results are listed in Table I.

TABLE I

DESCRIPTIVE STATISTICS OF DEPRESSION AND RIDGE PARAMETERS

Depression ^A Parameters	Maximum	Minimum	Mean	Range	Standard Deviation
AREA	2866.9 acres	0.1	173.2	2866.9	431.6
DEPTH	15.0 feet	2.5	5.4	12.5	3.6
PERIMETER	47679.0 feet	254.0	9816.3	47425.0	11164.4
ALAB	242.0 degrees	2.0	76.3	240.0	45.8
ASAC	359.0 degrees	183.0	281.6	176.0	61.4
LLAD	17800.0 feet	100.0	3167.3	17700.0	3378.0
LSAE	9400.0 feet	90.0	1663.8	9310.0	1817.4
DRNARF	7663.2 acres	0.0	639.1	7663.2	1370.4
VOLUME	15398057.0 yard ³	403.0	1042032.8	15397654.0	2436391.5
Ridge ^G Parameters					
AREA	653.9 acre	0.8	81.9	653.1	123.7
HEIGHT	45.0 feet	3.0	22.6	42.0	10.5
PERIMETER	56878.0 feet	860.0	12570.9	56018.0	12478.7
ALA	141.0 degrees	3.0	63.1	138.0	31.2
ASA	355.0 degrees	184.0	305.4	171.0	49.4
LLA	17935.0 feet	300.0	4614.6	17635.0	4241.5
LSA	5000.0 feet	110.0	119.0	4890.0	1004.3
RLDH	1667.0 feet	117.0	739.6	1550.0	325.7
VOLUME	5478073.0 yard ³	1613.0	686167.4	4791905.6	1107295.4

A120 Depressions studied CAzimuth of minor axis ELength of minor axis G51 Ridges studied

BAzimuth of major axis DLength of long axis FDrainage area HDistance from ridgeline to depression

The depressions are found to vary quite significantly in size, with the maximum recorded size being approximately 2867 acres, and the minimum 0.1 acres. On the other hand, the depth of the depressions does not exhibit a wide range, and the standard deviation is quite small. The deepest depression is fifteen feet, but the mean depth is close to five and one-half feet. The perimeter, and lengths of the major and minor axes of the depressions exhibit large standard deviations. These large standard deviations are to be expected because the perimeter, and major and minor axes are related to surface area. Volume of the depressions is also quite variable, but it, too, is related to surface area.

Azimuths of the major and minor axes were recorded and analyzed to determine whether or not the depressions are oriented in a "preferred" direction. When considered enmasse, the depressions show no dominant directional bias. However, when the azimuth parameter is analyzed via linear or multiple regression with other parameters, some interesting relationships occur.

The ridges do not show as great a variability in terms of surface area as do the depressions--the maximum surface area being approximately 654 acres, and the minimum being 0.8 acres. Some ridges reach a height of forty-five feet above the surrounding plain, but the average height is only about twenty three feet. The azimuth of the major axes of the ridges also exhibits less variability than do the

depressions. The apparent difference in the variability of the ridge and depression azimuths (major axis), probably is due to the manner in which differing landform processes affect them. The volume of the ridges also varies greatly, but on the average is 1613 cubic feet. The ridges are found to be located anywhere from 177 feet to 1667 feet from the edge of the depression. Size of the depressions may affect the distance between the depression and the ridge -- again, the depressions were not broken into size groups and statistically analyzed.

Correlations between depression parameters

The SPSS subroutine PEARSON CORR (Nie, et. al.; 1970) is a statistical algorithm which yields a coefficient that measures the strength and direction of the linear relationship between two variables.

Table II is a summary of the r (correlation coefficients) values between the various depression parameters. As might be expected, there are relatively strong positive relationships between the variables relating to surface area (area, perimeter, length of the major and minor axes, etc.). A strong positive relationship is also seen to exist between the surface area of the depression and its drainage area (0.93). The coefficient of determination (r^2) is calculated to be approximately 0.86 or 86%, meaning that 86% of the variation in surface area of the depressions can be explained by the variation in the depression drainage

TABLE II

CORRELATION BETWEEN DEPRESSION VARIABLES

Variables	Depth	Perim	ALA	ASA	LLA	LSA	DRNAR	Volume
Area	0.34	0.78	-0.12	0.27	0.89	0.88	0.93	0.76
Depth		0.59	-0.03	0.15	0.48	0.50	0.38	0.67
PerimA			-0.15	0.35	0.94	0.90	0.87	0.84
ALAB				-0.51	-0.12	-0.11	-0.13	-0.14
ASAC					0.34	0.32	0.31	0.26
LLAD						0.94	0.89	0.81
LSAE							.87	0.79
DRNARF								0.79

Aperimeter CAzimuth of minor axis ELength of minor axis

BAzimuth of major axis DLength of major axis FDrainage area

area. The r and r^2 can be taken to mean, in the case of surface area vs. drainage area, that as the surface area of the depression becomes larger its drainage area is increased; this is what one would expect in a flat area such as Clay County.

Correlations between ridge parameters

As was the case with the depression parameter correlations, the ridge parameters relating to surface area are strongly correlated (Table III). The correlation coefficient for surface area of the ridge versus the volume of the ridge is 0.97, and the coefficient of determination is 0.94 (94%). The surface area of the ridge and ridge volume are strongly related--even more so than the comparable coefficients calculated for the depressions. In the case of the ridge surface area and volume correlation, it would seem that the factors affecting the ridge surface area have the same affect upon the ridge volume; i.e., the larger the ridge becomes in terms of its surface area, the more its volume is increased. In the case of depression surface area versus depression volume, the correlation is not as strong as that for comparable ridge correlations. This "weaker" correlation may be due to the inwashing to sediments into the depression, thus weakening the relationship between depression surface area and volume of the depression.

TABLE III

CORRELATION BETWEEN RIDGE VARIABLES

Variables	Height	Perim	ALA	ASA	LLA	LSA	RLD	Volume
Area	0.23	0.94	-0.22	0.15	0.89	0.91	0.60	0.97
Height		0.33	-0.01	0.13	0.35	0.32	0.44	0.31
Perim ^A			-0.22	0.19	0.98	0.89	0.62	0.91
ALAB				-0.29	-0.23	-0.26	-0.22	-0.23
ASAC					0.21	0.16	0.25	0.15
LLAD						0.84	0.60	0.85
LSAF							0.60	0.92
RLDF								0.59

Aperimeter CAzimuth of minor axis ELength of minor axis

BAzimuth of major axis DLength of major axis FDistance from ridgeline to depression

Correlations between depression and ridge parameters

Of the 120 depressions analyzed in the study, only 51 were found to have ridges. Therefore, correlations between ridge and depression parameters were performed only on those depressions having ridges. As part of the correlation process, it was felt that it would be useful to determine if selected ridge parameters could be predicted or explained by the depression parameters. REGRESSION is an SPSS multiple regression algorithm which enables the analysis of relationships between a dependent variable and a set of independent variables. Unlike the SPSS subroutine PEARSON CORR, REGRESSION may be used as an inferential (predictive) tool (Kim and Kohout, 1970).

Lunettes and ridges found on the south and east sides of some depressions in Clay County, are felt to be genetically linked to the depressions. That is, some of the ridge parameters should be correlated to some depression parameters. Table IV lists the dependent variables, and the independent variables that were used to explain them.

Surface area of the ridges was used as a dependent variable, and depression surface area, drainage area, and volume were used as independent variables that might explain ridge surface area. Table IV shows that of all three independent variables, surface area of the depressions is the most important predictor of ridge surface area. When depression drainage area and volume are entered into the

TABLE IV

CORRELATION BETWEEN DEPRESSION AND RIDGE PARAMETERS

(Ridge) Dependent Variables	(Depression) Independent Variables	Multiple r	r ²
Surface area	Surface area	0.79531	0.63252
	Drainage area	0.79554	0.63288
	Volume	0.79753	0.63606
Distance from ridgeline to the depression	Surface area	0.12795	0.01637
	Depth	0.14886	0.02216
	Azimuth of major axis	0.89797	0.80635
	Drainage area	0.89805	0.80649
Volume	Volume	0.90104	0.81187
	Surface area	0.78128	0.61040
	Depth	0.78244	0.61221
Height	Volume	0.78331	0.61358
	Surface area	0.18248	0.03330
	Depth	0.25051	0.06275
Azimuth of major axis	Volume	0.29441	0.08668
	Azimuth of major axis	0.94229	0.88791

multiple regression formula, the r is increased from 0.795 to only 0.797 and the percent of variance shared is raised from approximately 63 percent to 64 percent. Ridge volume too appears to be best explained by depression surface area.

The height of the ridges does not correlate well with depression surface area, depth, or volume. Correlations between ridge height and other depression variables revealed similar weak relationships. Reasons for these weak relationships may be accounted for by erosional processes working on the ridges, inwashing of materials into the depressions, or other landform processes working on the ridges and depressions.

One important finding from the REGRESSION algorithm is the correlation between the distance from ridgeline to the depression and several depression parameters. The question raised here is--What depression parameter (if any) is a good predictor of the distance between the depression and the ridge line? Surprisingly, the azimuth of the major axis of the depression is the statistical answer. At first glance, one questions the relationship between azimuth and distance between ridge and depression. However, a closer look reveals that, in general, as the major axis of the depression becomes longer, the further the ridgeline is from the depression. A look back at Figure 23 would seem to substantiate the azimuth - distance relationship; and would

tend to support an evolutionary or developmental theory concerning the depressions--as the depressions become larger, the azimuths of the major axes become similar, more material is taken from the depression and deposited on the ridge, the ridge enlarges and its crest becomes located further away from the edge of the depression. Additionally, from Table IV, we find that the azimuths of the major axes of the depressions and ridges are strongly correlated ($r = 0.94$) and that the depression azimuth strongly influences the ridge azimuth ($r^2 = 0.89$). Therefore, it is evident that the depressions affect the characteristics of the ridges; that is, the variances of the depression parameters explain the variances in most ridge parameters.

Discriminant analysis

Earlier a question was raised concerning the presence or absence of a ridge based upon the physical attributes of a depression. More precisely stated, can the depressions be correctly placed into a ridge-present or ridge-absent category based solely upon the depression parameters.

DISCRIMINANT, an SPSS discriminant analysis procedure, was employed to determine if the above mentioned question can be answered.

Discriminant analysis is a statistical technique which is used to distinguish between two or more groups of cases. In order to distinguish between the groups, a collection of

discriminating variables developed, each measuring characteristics on which the groups are expected to differ. "The mathematical objective of discriminant analysis is to weight and linearly combine the discriminating variables in some fashion so that the groups are forced to be as statistically distinct as possible" (Klecka, 1975). The present study employs two groups (ridge absent, ridge present) for the DISCRIMINANT algorithm, and the discriminating variables are the depression parameters. Therefore, the depressions are to be placed into one of the two ridge groups based upon the physical parameters of the depressions.

The standardized canonical discriminant function coefficients listed in Table V show the relative importance (ignoring the signs) of the discriminating variables. Depression surface area, and length of the major and minor axes figure prominently in the discriminant function. DISCRIMINANT was more accurate at detecting depressions without ridges (classification accuracy or 89.9%) than those that possess ridges (68.6%). However, the DISCRIMINANT routine achieved an overall classification of almost 81 percent. The relatively good classification results of DISCRIMINANT indicate that the ridges and depressions are genetically linked.

Summary of the Cartographic and Statistical Analysis

The rainbasin depressions in Clay County were analyzed

TABLE V

MULTIVARIATE LINEAR DISCRIMINANT ANALYSIS

(Groups defined by presence or absence of a ridge)

<u>Discriminating variables (Depression Parameters)</u>	<u>Standardized Canonical Discriminant Function Coefficients</u>
Surface area	-1.13832
Depth	0.36948
Perimeter	-0.14719
Azimuth of the major axis	-0.24081
Azimuth of the minor axis	-0.01388
Length of the major axis	0.95375
Length of the minor axis	0.76024
Drainage area	0.42086
Volume	-0.26761

Classification Results:

<u>Actual group</u>	<u>Number of cases</u>	<u>Ridge Present</u>	<u>Ridge Absent</u>
Ridge present	51	35 (68.6%)	16 (31.4%)
Ridge absent	69	7 (10.1%)	62 (89.9%)

Percent of "grouped" cases correctly classified: 80.8%

both cartographically and statistically. It was discovered that of the 120 depressions analyzed, fifty one displayed a ridge or lunette in close proximity. Moreover, these ridges are consistently located on the south and east sides of the depressions.

When considered en masse, the depressions manifest a linear trend that runs along a diagonal line from northwest to southeast across Clay County. It is not understood at present what mechanism is responsible for this trend. The larger depressions exhibit a preferred orientation of the major axis, yet the smaller ones display a random orientation.

Surface area of the depressions is quite variable, with the smallest one measured at 0.1 acres and the largest 2866.9 acres. The depth, however, is not as variable, with a range of only a little over twelve feet. On the other hand, the surface area of the ridges is not as variable as it was for the depressions. However, the height of the ridges has a range of almost forty three feet.

The SPSS algorithm REGRESSION revealed some interesting relationships between selected ridge (dependent) and depression (independent) variables: i) the surface area of the ridges is relatively strongly correlated with the surface area of the depressions, with the r^2 value revealing that sixty three percent of the variation in the surface area of the ridges is explained by the surface area of the

depressions; ii) the volume of the ridges is most significantly affected by the surface area of the depressions; and iii) it is revealed that as azimuth of the major axis of the depression increases, the further the ridgeline is from the depression. Given the above relationships from the REGRESSION routine, it would appear that the presence and condition of the ridges is dependent upon the presence and condition of the depressions. DISCRIMINANT appears to support this hypothesis, because the depressions were placed into one of two groups (ridge-absent or ridge-present) based solely upon the depression parameters with an accuracy of approximately eighty-one percent.

CHAPTER 5

CONCLUSIONS

The present study was undertaken to: i) pool the existing knowledge concerning the rainbasin area into one document, ii) describe the physical attributes of the depressions, iii) describe the geographic distribution and patterns of the depressions, and iv) make suggestions as to how the depressions of Clay County may have originated.

During the literature-search phase of the project it was discovered that little material explicitly concerning the rainbasin area of Nebraska exists. However, some literature describing the existence of depressions in a portion of the Central Loess Plains--the rainbasin area--was located (Condra, 1906, 1936; Reed and Dreeszen, 1959). In recent years, the rainbasin area has attracted some attention under the theme of wetland habitat evaluation and enumeration (McMurtrey, Craig, Schildman, 1972; Denney, 1982; Farrar, 1982; Walter and Buckwalter, 1982). However, very little information directly concerning the physical attributes and characteristics of the depressions is available. The 1927 and 1981 soil surveys for Clay County, the study site, yield little data regarding the depressions except for

the soils that have been generally associated with the depressions. Nevertheless, it was discovered that the soil types associated with depressions were not always indicative of a depression's areal extent or absolute location. Rather, the soils information tells the investigator where to look first for the occurrence of depressions.

Topographic maps of the 7½-minute series were found to be most useful in defining the location and areal extent of the depressions in Clay County. From the topographic maps, two important landforms were noticed that were included in the analysis of the depressions--ridges (lunettes) and breached basins. The lunettes are crescent-shaped ridges found on the south and east sides of fifty one of the 120 depressions studied. Breached basins are similar to depressions in every respect except that they exhibit external drainage. Once the depressions, breached basins, and ridges were delineated on the 7½-minute quadrangles, a single composite map was made of these three landforms.

From the composite map, several interesting features are noticed: i) ridges are consistently found on the south and east sides of some of the depressions and breached basins; ii) a rather striking linear trend of depressions can be seen extending diagonally from the north west corner to the southeast corner of Clay County; iii) the larger depressions tend to be elliptical in shape, while the smaller depressions have varied shapes; and iv) the larger depressions' major

axes are lined up along a similar azimuth; the smaller depressions show no directional bias.

Statistical analysis of the depressions revealed that the surface area of the depressions is quite variable. The largest depression was measured to have a surface area of 2866.9 acres, the smallest was measured at 0.1 acres. The depth of the depressions was fairly uniform with a range of only twelve feet. Additionally, statistical analysis of the ridges show that the surface area of the ridges is not as variable as it is for the depressions. However, the height of the ridges ranges almost forty three feet.

Because the ridges were thought to be linked to the depressions, two statistical routines (REGRESSION and DISCRIMINANT) were employed to analyze the relationships between selected ridge and depression parameters, and to determine if the depressions could be placed into a ridge-absent or ridge-present group based solely upon the depression parameters. The SPSS algorithm REGRESSION revealed that the surface area of the ridges was strongly correlated with the surface area of the depressions. The r^2 value for the ridge surface area-depression surface area relationship reveals that sixty three percent of the variation in the surface area of the ridges is explained by the surface area of the depressions. An interesting relationship between the azimuth of the major axis of the depression and the distance from the ridgeline to the depression also became apparent. The rather high correla-

tion coefficient reveals that as the azimuth of the major axis of the depression increases, the further the ridgeline becomes from the edge of the depression. The REGRESSION routine reveals that the "condition" of the ridges are dependent upon the condition of the depressions.

DISCRIMINANT appears to support the hypothesis that the ridges are genetically linked to the depressions. The support of this theory is suggested by the fact that eighty three percent of the time DISCRIMINANT correctly placed the depressions into the ridge-present or ridge-absent category based solely upon the depression parameters.

The cartographic and statistical analysis suggest that the ridges (their presence and condition) is highly dependent upon the presence and condition of the depressions.

Nevertheless, it is difficult to say what force(s) is/are responsible for depression genesis in Clay County. The REGRESSION and DISCRIMINANT analysis, coupled with the Theesen Lagoon example, seem to suggest that the depressions owe their existence to the wind. The cartographic analysis would also appear to support the theory of depression origin by deflation. However, it is entirely possible that the ridges may have been formed subsequently to depression development--that is to say that the depressions were formed by some other means and that the materials making up the ridge are not related to depression sediments.

A puzzling question arises concerning the linear trend

of depressions across Clay County. Namely, what has caused this trend? It is possible that this trend is structurally controlled. In order to determine if structure is responsible for the linear trend a series of geologic samples will have to be taken. Wind may be another force that is responsible in producing the alignment. However, it is difficult to say how the wind may have been channeled in such a way as to cause this rather striking trend. A study of the geomorphology and geology of the Clay County area seems to be in order in answering the question of how the wind might have been channeled to produce this alignment of depressions. Water should also be considered as a possible agent in effecting depression development along the linear trend. These depressions may have been part of an interconnected, open-lake system which was once part of an old river system. Drilling through several of the depressions might enable investigators to determine if the depressions were created by fluvial systems. There are many questions yet to be answered concerning depression development in Clay County.

The present research was not intended to prove conclusively which process(es) is/are responsible in forming the depressions of Clay County. However, it can be stated that, at the very least, wind played a major role in depression modification, and that the ridges (lunettes) are genetically linked to the depressions. Future analysis of the depressions and ridges might include:

1. Test holes drilled through a depression and its associated ridge with subsequent lab analysis for the purpose of comparing the core samples. This should provide a better indication of what materials truly make up the ridge and whether or not they are related to the depression deposits.
2. Analysis of pollen in the lunettes and depressions may reveal the climate conditions prevailing during formation.
3. Mapping the depressions and ridges in the remaining Rainbasin counties should elucidate the trends and distributions of the wider region.
4. Detailed geomorphic analysis of both the closed and breached depressions, and the lunettes is needed.

The rainbasin area offers research opportunities to geologists, geographers, geomorphologists, climatologists, pedologists, as well as many others. Indeed, it is suggested that these various groups undertake research in the rainbasin area in order to increase our knowledge of the genesis and evolution of this region.

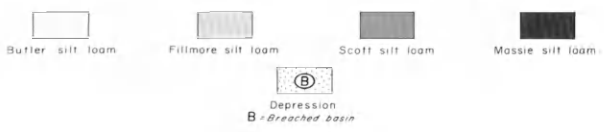
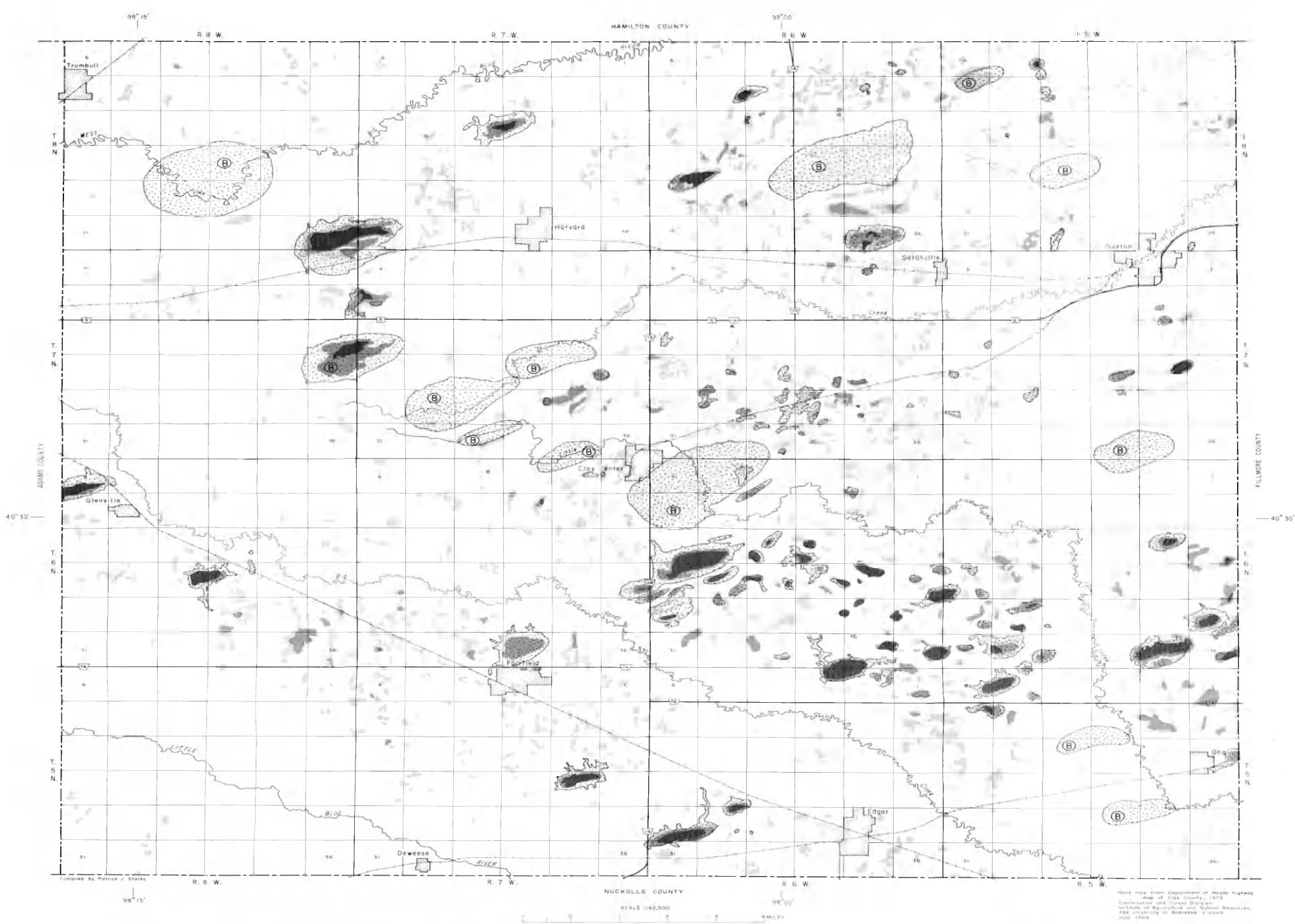
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RELATIONSHIP BETWEEN POORLY DRAINED SOILS AND
RAINBASIN DEPRESSIONS - CLAY COUNTY, NEBRASKA

