"Morning Fair, Roads Bad:" Geology, Topography, Hydrology, and Weather on the Iowa and Nebraska Mormon Trails, 1846-1847

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Introduction

Many stories are told of the physical rigors and toils experienced by the many pioneers who crossed the Mormon Trail over present-day Iowa, Nebraska, Wyoming, and Utah to reach the valley of the Great Salt Lake. Especially prolific are accounts of the great sufferings and hardships experienced by the "advance company," the group that led the first wave of pioneers across the Mississippi River in February 1846.

Cold, rain, snow, ice, and mud made the initial trek across Iowa especially difficult. The advance company took about four and a third months to reach the Missouri River on 14 June 1846, over three hundred miles from Nauvoo, making an average of less than two and a half miles per day. Spring weather conditions during an El Niño year hampered the journey across the territory; the company had to stop often because of weather and sometimes could manage only a quarter mile per day when attempting to travel. Heavy rains, flooded streams, cold weather, and muddy prairies slowed the progress of the trek across Iowa considerably.

On the other hand, the 1847 journey of the advance company across present-day Nebraska, Wyoming, and Utah (1,032 miles) took only three and a third months (Figure 1). The 1847 trek across Nebraska was much easier than the 1846 trek across Iowa.

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The geology, *geomorphology* (study of landforms and their origins), topography, hydrology, and weather of Iowa and Nebraska had much to do with this. On these subjects, a large amount of scientific data are available that have not been previously compiled and studied for the benefit of understanding physical conditions on the Mormon Trail. This paper summarizes information on these topics in a manner that the layperson can understand and that will deepen his or her knowledge and appreciation of the Mormon pioneer experience in Iowa and Nebraska in 1846 and 1847.

This paper does not represent an exhaustive researching of all available scientific and historical information. Although some of the scientific sources are dated, the material referenced is still relevant and accurate for the purposes of this paper. The geologic studies of Iowa counties obtained and researched are dated between 1900 and 1916. These were used for their historical as well as scientific merit.

United States Geological Survey (USGS) 1:100,000-scale metric mapping was used for the topographic study. The approximate location of the Mormon Trail on these maps was supplied by Karla Gunzenhauser of the Iowa Mormon Trails Association and by Dr. Stanley B. Kimball of Southern Illinois University. The Mormon Trail had many variants; the topographic study presented in this paper is generally representative of all these variants.

Overview of Regional Geomorphology of Iowa and Nebraska

The present terrain and landforms existing in Iowa and Nebraska are the result of a number of geologic processes caused by or related to *glaciation*. A glacier is a body of ice, snow, and frozen meltwater, lying wholly or mostly on land, and showing evidence of present or former motion.[1] Glaciers accumulate great thicknesses of snow and ice at high altitudes and move great distances under gravity and under the stresses caused by their own weight.

During the era known as the Ice Age, all of Iowa and eastern Nebraska was covered by glacial ice that moved south from Canada in extensive sheets. Glacial episodes are basically grouped into four time periods known (from oldest to youngest) as the Nebraskan, Kansan, Illinoisan, and Wisconsinan periods. Figure 2 shows the maximum extent of glaciation in the central United States during the four general glacial periods. As glacial ice moved south from Canada, it scraped up huge amounts of soil and rock in its path that became mixed and carried with the moving ice sheet.[2]

At the end of each glacial episode, the ice generally melted from the southern end toward the north, and thus the glacier would "retreat." All the soil and rock that had been mixed in with, and carried by, the glacier dropped out and was left behind. The soil and rock dumped from the glacial ice is called *till* or *drift* and is a couple of hundred feet thick in Iowa and eastern Nebraska. Large vol-

umes of sand and gravel were deposited in east-central Nebraska to the west of the glacial ice.[3] In succeeding glacial episodes, new glacial ice overran and buried the till that had been left after previous episodes.

Following glaciation in Nebraska and southern Iowa, all of Iowa and roughly the eastern one-fifth of Nebraska were covered by thick sheets of till. During the interglacial periods and after the Ice Age, erosion by rain, streams, and frost cut down through the accumulated tills. Rivers and streams were cut into the till, and a topsoil developed on its surface. Kay (1916)[4] referred to this developed soil layer as a *gumbotil*, described by Gow and Tilton (1916)[5] as "a sticky, tenacious clay." This type of soil becomes very sticky and slippery when wet. Wind and water attacked exposed sand and gravel deposits in central and western Nebraska and redeposited them eastward and southward. The finer silts and clays were carried out, leaving behind the coarser sands that later served as a source material for the Sand Hills region.[6] Blankets of *loess* (a wind- blown silt and clay soil) were laid down across southern and eastern Nebraska and all of southern Iowa during Illinoisan and Wisconsinan time. The splendid bluffs seen rising near the Iowa shore of the Missouri River are composed of loess, blown in by wind to thicknesses of several hundred feet.

The loess was deposited on a dissected and eroded till surface and completely or partially blanketed the hills and valleys that had been eroded in the till. Following loess deposition, rain, wind, ice, and streamflow continued to wear away at the exposed soils. As a result, the loess and till are thick in some places and thin or absent in others, thus forming a landscape in Iowa and Nebraska composed of bedrock, alluvial sand and gravel, till, gumbotil, and loess, which gave diversity to the land surface crossed by the pioneers.[7,8,9,10,11] All of southern Iowa and all of Nebraska east of about Columbus lie within a geologic regime known as the *dissected till plains* (Figure 1), in which the till and loess have been dissected by streams and drainageways and formed into low, rolling hills and ridges.

Beyond a general north-south line running roughly through Columbus, the dissected till plains give way to the geologic regime known as the *Great Plains* (Figure 1). The Great Plains extends westward from the dissected till plains. Cutting across both geologic regimes is the Platte River basin, which runs east-west across Nebraska. Parent materials for the soils in the Platte River basin are alluvial sands and gravels that filled in the river basin after Nebraskan and Kansan glaciers blocked its drainage to the east.

The Platte River and its valley dominated the Mormon Trail experience in Nebraska. The Platte was very different from any river the westering pioneers had encountered before and is a unique and curious feature of the Mormon Trail. Although the dissected till plains geologic regime extended westward as far as about present-day Columbus, the Mormon Trail geology changed significantly once the pioneers crossed the Elkhorn River.

Figure 4 shows a geologic cross section through the present-day Platte River

valley at Fremont.[12] This figure shows typical variations in topography and geologic materials that made up the landscape that the Mormon Trail crossed in eastern Nebraska. Preglacial drainage in Nebraska flowed east through valleys cut into shale and sandstone bedrock. When glacial ice moved into eastern Nebraska during Nebraskan and Kansan time (Figure 2), bedrock valley drainages to the east were dammed by ice and cut off. The drainage water filled and overtopped the valleys, which were then completely filled in with sands and gravels, shown on Figure 4 as the David City and Grand Island Sand and Gravel. Following ice retreat, the Nebraskan and Kansan tills were left behind in the uplands while topsoils formed on the surfaces of the sands and gravels. The entire Platte River valley in Nebraska is cut into the Grand Island Sand and Gravel (Figures 4 and 5). Loess was deposited following glaciation and blanketed the till and the downcut valleys.

The Platte River is a *braided stream*. West of Fremont, braiding increases markedly with distance (Figure 6). Braided streams have complex mazes of channels that thread their way among bars deposited on the river bottom.[13] These streams are characterized by fast currents, general instability of their bars and channelways, and caving of channel walls. Once channel islands are formed, more bars form in one or both of the divided channels. To the east of Columbus, the river enters the dissected till plains, where it accumulates a huge quantity of drainage from the Loup and Elkhorn river systems, becomes a more restricted channel carrying more water, and generally becomes a single-trunk river (Figure 7).

Although wide, the Platte is generally less than one or two feet deep. Emigrants referred to the Platte as being "a mile wide, a foot deep, too thin to plow and too thick to drink."[14] Most of the flow in the Platte occurs through the beneath-the-surface sands and gravels that fill the buried valley (Figure 4). It was perhaps this characteristic that led westering Americans to describe it as a river that "flowed upside down."[15] During low-flow periods, surface flow can disappear over long stretches of the Platte, and flow occurs completely below the surface of the riverbed. The Platte River is dangerous to cross on foot, however, because of swift currents and shifting, quick sands and meandering channels in the river as much as twenty feet deep that shift position with time. Even strong swimmers have drowned when encountering these channels, in which the water moves very fast.

In the central part of the Great Plains of Nebraska, the Sand Hills region rises north of the Platte River (Figure 3). The region is composed of fine-grained, wind-blown sand dunes formed into low hills and ridges and is the largest area of wind-blown sand dunes in the Western Hemisphere, being ten times larger than the state of Delaware.[16] The dunes begin between Columbus and Grand Island and extend as far west as Morrill County, Nebraska. The sand dunes are stabilized by a grass cover.

Figure 5 shows a cross section of the subsurface geology along the Platte River between Keith and Kearney Counties. The cross section shows the Ogallala Sandstone near the surface; as is evident from the figure, the Ogallala has a generally "smooth" and constant gradient across Nebraska. The smooth, constant gradient of the Ogallala is a geologic feature known as the "Gangplank," which extends across Nebraska and Wyoming. The Platte River gradient mimics that of the Gangplank.

In Keith County, Nebraska, the Platte River valley begins its incision into the sandstone bedrock of the Ogallala Formation. Here the valley bottom constricts to a width of about three miles (Figure 8). As the Platte proceeds west of present-day Lake McConaughy, its incision depth decreases with distance; and the river valley widens into a long, narrow, funnel shape.

Nebraska Mormon Trail Geography

The geography of the Nebraska Trail is studied in great detail in Steele's 1933 M.A. thesis.[17] Her work studies the evolution of the trail, the locations of the "main trail" and its variants south of the Platte River and their relationships to the topography they traversed, and the significance of the Nebraska Trail's location from geographic, geomorphologic, and economic perspectives. I am unaware of any similar work for the Iowa Trail.

Topography

A common misconception is that of Iowa's "flatness." Iowa is a Great Plains state and is relatively "flat" topographically compared to the Rocky Mountain states of Wyoming and Utah. The topography appears flatter than it really is when viewed from a car on Interstate 80. One gains a different perspective traveling along two-lane roads in southern Iowa. From the point of view of an 1846 pioneer, the Iowa Mormon Trail was not flat.

Figure 9 presents a cross section of the Mormon Trail across Iowa and Nebraska. The cross section is based on USGS mapping having ten- and twenty-meter (thirty-two to sixty-four foot) contour intervals. The present-day Iowa shore at the Mormon Trail's Mississippi River crossing is at an elevation of about 525 feet above mean sea level (msl). (The 1846 Iowa shore was about thirty-one feet lower.) The present-day Iowa shore at the trail's Missouri River crossing is at an elevation of about 968 feet msl. The high points of the Iowa trail are in Union and Adair Counties at elevations of about 1,362 feet msl.

The high point of the Iowa trail in Union County was first reached about 202 miles from Nauvoo, near present-day Spaulding. At this point, the pioneers had traveled vertically through about 837 feet in elevation, making an average gradient of a little over four feet per mile. The average gradient across the Great Plains region of Nebraska (west of the Elkhorn River) was a little over six feet

per mile. However, the "average" Iowa gradient is deceiving in light of a more careful study of the cross section shown on Figure 9.

The rivers and streams along the Iowa Mormon Trail are cut into loessial soils, which tend to stand vertically in open cut and which can erode steep-sided stream channels and valleys. Several stream valleys in succession between Farmington and Bonaparte, Iowa, have grades between about 120 to 205 feet per mile (2.3 to 3.9 percent grades). Comparison of the Iowa and Nebraska trail cross sections shown on Figure 9 shows that although the Nebraska trail west of the Elkhorn was steeper overall, the Iowa trail reversed grades far more often and more dramatically, lending a "roughness" to the Iowa trail that was not encountered across most of present-day Nebraska. Moreover, although the 1846 pioneers used established trails as much as possible, these essentially ended a little over halfway across Iowa. Indian trails were largely being used across unfamiliar terrain by the time the Trail reached the Thompson River in present-day Union County. Figure 9 shows that the Trail's "roughness" increased markedly just west of Garden Grove and continued until the Trail reached the Elkhorn River.

Figure 10 shows a typical map view of the Mormon Trail through Iowa, the Thompson River crossing in Union County. (The Mt. Pisgah settlement was on the east bank of the Thompson, known then as the Grand River.) The contour interval on Figure 10 is ten meters (thirty-two feet). Comparison to a typical map view of the trail in the Platte River valley near Columbus, Nebraska (Figure 7) gives another sense of the Trail's "roughness" between Nauvoo and the Elkhorn River.

The reason for the stark difference in roughness seen on Figure 9 is twofold. First, Iowa's western border is completely formed by the Missouri and Big Sioux Rivers, and its eastern border is completely formed by the Mississippi River (Figure 3). Once the Missouri River reaches the Kansas City area, the river heads east across Missouri to its confluence with the Mississippi River at St. Louis. One hundred percent of Iowa's drainage crossing the Mormon Trail either flows southwest or south to the Missouri River, or southeast to the Mississippi River. In Iowa, the pioneers had to *cross* all of the drainages, which intersected the trail across the entire state rather than paralleling it.

Second, the Mormon Trail *followed* the main drainageway across most of Nebraska (i.e., the Platte River), and thus the Mormon Trail followed the "Gangplank" geologic feature (Figures 3, 5, and 9). Although the trail's average gradient along the Platte (a little over six feet per mile) was steeper than its average gradient between Nauvoo and Union County, Iowa (a little over four feet per mile), it did not reverse grades and was easier to negotiate.

Hydrology

Because of the enormous areas drained by the Mississippi and Missouri river

systems, they flood when accumulated snowfalls melt along their northern and mountainous reaches. When the Mississippi and Missouri rivers flood, Iowa and northern Missouri experience flooding as well because all of Iowa's drainage essentially flows to these rivers. River stages in Iowa are affected to some degree by spring rains and/or snowmelts in Wyoming, Colorado, Nebraska, Kansas, Montana, the Dakotas, Minnesota, Missouri, and Illinois, in addition to spring rains and snowmelt in Iowa itself.

River and stream systems can handle increased flows in three ways: by increasing their velocities and gradients to move water faster; by increasing their stages—that is, by flooding and carrying greater depths of water; and by storing more water within the streambanks—that is, by raising the water table and storing excess water in the ground. If most or all of the void spaces become filled with water, the ground becomes saturated and can accept no more runoff, snowmelt, or floodwater. In addition to aggravating the drainage situation, saturation near the surface can make loess and till soils untrafficable.

Weather

Iowa and Nebraska have humid, continental climates characterized by warm to hot, humid summers and cold, dry winters. Springtime brings snowmelt as well as frequent and often-heavy rain to Iowa and Nebraska. Adding to the complications of traveling on foot or by wagon across Iowa in the spring was the wide variation in springtime temperatures.

Temperature data for 1846 and 1847 were recorded and are available for the following locations: St. Paul, Minnesota; St. Louis, Missouri; and Muscatine, Iowa (Figure 1 and Tables 1 and 2).[18] Harry J. Hillaker, Iowa State climatologist, reported the following concerning these data:

> The only temperature averages available are for St. Paul, MN and St. Louis, MO; however, their readings are fairly consistent. 1845-1846 was an El Niño year and the beginning of 1846, as is usually the case with El Niño, was exceptionally mild. January 1846 in particular was very mild, and to a lesser degree March of 1846 was mild as well. Temperatures were below normal in only June and October [and in February] during 1846. At both St. Paul and St. Louis this was the warmest year on record up to that point in time (mainly because of very mild conditions in the winter months). The year 1847 was just the opposite as temperatures averaged above normal in only February and April.[19]

Temperature records date back to 1839 for Muscatine. Monthly high and low temperatures for the period 1845-47 are presented in Table 2,[20] along with average monthly highs and lows for available years between 1839 and 1974.[21] The Muscatine data in Table 2 correlate to Hillaker's observation that the spring of 1846 was mild overall. Muscatine's highs and lows were above average in January, March, and April 1846, and the lows were above average in May and

June.

The advance company left Nauvoo on 4 February 1846. Brigham Young had originally planned to leave Nauvoo on 1 June 1846,[22] which would have avoided winter and springtime travel and which would have provided for more grass cover for the livestock. Low temperatures in Iowa during February and March are mostly below freezing—and often below zero. Grasses begin to grow in earnest following the end of the killing frosts; the recommended start date for planting in Iowa is after 15 April. It is possible that "very mild" weather in January 1846 influenced the decision to leave in February.

John D. Lee and Orson Pratt kept some records of daily temperatures.[23] Lee and Pratt noted early-morning temperatures of five degrees to twenty-eight degrees between 23 February and 3 March. Between 4 March and 28 April, they recorded morning temperatures between a low of twenty-one degrees on 21 March and a high of sixty-one degrees on 18 March. As late as 28 April, Pratt recorded a temperature of twenty-eight degrees at 1:30 p.m., with rain. When temperatures hover near freezing during precipitation events, the miserable phenomenon of "freezing rain" occurs. When the weather begins to warm up in March, temperatures are commonly below freezing at night, which freezes the ground from the surface down, and above freezing during the day, causing the ground to thaw the same way—from the surface down. These conditions tend to make the loess and till soils untrafficable; adding rain or freezing rain makes the situation even more miserable (Figure 11).

Table 2 indicates that 1847 was the opposite of 1846 in Muscatine, with the monthly lows being below average every month and the highs being below average during six months, including January and March. William Clayton's journal consistently noted "cold" and "very cold" mornings through the end of May 1847. Tables 1 and 2 suggest that January 1847 was a colder-than-normal month in the midwestern United States.

The statewide average precipitation for Iowa totals nearly thirty-two inches per year. However, the average conditions are rarely experienced, with variability seen in both time and location.[24] For example, while Muscatine (Figure 1) received the highest yearly precipitation in Iowa history in 1851 (74.50 inches, or about thirty-eight inches above average), Farmersburg (108 miles north) received 37.94 inches (over six inches above its average).

The statewide average precipitation for Nebraska totaled almost twenty-three inches between 1876 and 1995.[25] Nebraska's climate is described as semiarid in the western part and subhumid in the eastern part and becomes drier from east to west. Greater climatic variation exists west to east across the state than from Nebraska to the Atlantic coast. Usually, more than three-fourths of the annual precipitation falls between April and September.[26]

Precipitation data for 1846 and 1847 were recorded and are available for the following locations in the midwestern United States (Figure 1): Fort Scott and

Leavenworth, Kansas; Council Bluffs, Iowa; Farmersburg, Iowa; Muscatine, Iowa; St. Louis, Missouri; and Athens, Illinois. Monthly, annual, and average precipitation data for these locations for the period of 1845-47 are summarized in Table 3 and indicate above-average precipitation overall in the year 1846 in Farmersburg, Iowa; Athens, Illinois; and St. Louis, Missouri.[27] Muscatine, Iowa, received close to its average precipitation.

Table 4 indicates that total precipitation during the period of February-June 1846 was well above average in Farmersburg, Muscatine, and Athens (10.3 percent to 44.1 percent). Total precipitation during the period of February-April 1846 was even higher above average at these locations (37.3 percent to 77.0 percent). The data suggest that the Iowa Mormon Trail experienced a wet spring in 1846. The records of Lee, Pratt, Patty Sessions, Eliza R. Snow,[28] and William Clayton[29] document precipitation on 52 of the 124 days (42 percent) between 14 February and 17 June 1846. The latest records of snow were on 5 and 7 April 1846.

Effects of Natural Processes on Travel Across Iowa and Nebraska, 1846-47

Many factors related to geology, topography, hydrology, and weather made the spring of 1846 a very poor time for the advance company and its accompanying wave of exiled humanity to have to cross Iowa. The 1847 journey across present-day Nebraska was much easier for the advance company. The Nebraska Trail was about five hundred miles long. The company left Winter Quarters on 14 April 1847 and had traveled about 514 miles by 29 May (about 11 miles per day). The company did little or no traveling on Sundays.

Soils—Loess is unique among silt and clay soils in that it prefers to stand vertically in open cut. Loess has a tremendous vertical strength, and if cut on a slope, will eventually tend to erode in vertical banks. This great vertical strength lent itself well to the making of loess dugouts in western Iowa and eastern Nebraska, in which some of the pioneers found temporary shelter. Clayton described large underground cachets excavated in the loess by the Pawnee Indians near present-day Fullerton, Nebraska.[30]

Where the steep-cut tendency of loess did not lend itself well to the pioneers was in the cutting of steeply sided stream banks. The author has walked through drainages west of the Omaha area that were cut with vertical sides up to about fifteen feet deep; vertical cliffs can be viewed in the Council Bluffs area that are at least a hundred feet high. The combination of steep loess streambanks, trees and thick vegetation along the streambanks, precipitation, and the tendency of loess to lose its vertical strength and rut deeply under foot and vehicle traffic when wet made the journey across Iowa very difficult for the advance company.

Tills are noted for their very hard, dense condition. The drawback of till and

gumbotil when they are wetted is that they become very slippery and very sticky and "mucky" when softened by traffic. Any combinations of loess, gumbotil, and till on a streambank during or after a rain would have presented a horse- or ox-drawn wagon with rutting and muck problems and slippery surfaces. Double- and triple-teaming wagons was common in Iowa in the spring of 1846 and greatly slowed progress since one-half to two-thirds of the wagons were idle while their teams were being double- or triple-teamed elsewhere.

Soil conditions were much better for the 1847 Nebraska trek than they had been in Iowa the previous spring. The advance company only had to deal with the loess soils of the dissected till plains for a distance of about thirty-five miles; they departed Winter Quarters at 2:00 p.m. on 14 April and finished crossing the Elkhorn River at noon the next day. Once they were across, the dissected till plains were left behind for good.

Travel across the sand and gravel (Figure 4) along the Platte River was easier. Clayton noted on 16 April 1847: "From these bluffs a little above the [Elkhorn] ferry you can see the . . . Platte River; and the beautiful level bottom on the north of it, about fifteen miles wide for many miles up the river." On 19 April, he wrote: "The roads very good and . . . very level on these flat bottoms of the Platte River which . . . appear to be from ten to fifteen miles wide."[31] Beyond the Elkhorn, roads had already been established on the north side of the Platte.[32] Except for the portion of the Trail extending into the uplands along the north bank of the Loup, which crossed over the loess deposits of the uplands, the journey would continue over the Grand Island Sand and Gravel until the trail entered the portion of the Platte River valley incised into the Ogallala Sandstone in present-day Keith County.

Beyond the confluence of the North and South Platte Rivers, the river was no longer cut into the deposits of the Grand Island Sand and Gravel but was now incised into sandstone bedrock. The valley became constricted down to widths of as little as three miles (Figure 13) and was filled with alluvium transported by the river. The pioneers generally encountered three types of geologic materials over which to travel. The first was over the steep sandstone bluffs, over which they had to pass wherever the Platte River channel abutted the north wall of its valley. The second was a loose, wet sand nearest the river, which was at the lowest elevation within the valley and which remained saturated. This material was an alluvial river deposit and likely contained much silt. Clayton described this saturated material near the river as "soft and swampy"[33] and as "soft and wet."[34] On 17 May 1847, he wrote: "The whole of this bottom seems full of springs and we have to keep near the bluffs to make a good road to travel, and in fact, we find it more or less soft and springy even close to the bluffs."[35] Although the sandstone bedrock was permeable, it likely provided some confinement (a kind of "bathtub effect") for the water in the valley beneath the riverbanks. Close to the river, the sand always remained saturated and soft—and

not a good travel surface.

Steele noted that "[t]he sand hills are the source of many springs all along their front, the porosity of the sand preventing runoff and the hills acting as reservoirs of ground water. Surface streams fed by the bluff springs are inclined to spread out over the flat bottom land. The water table is high, a second factor deterring proper drainage. Consequently the road tended to shun the bottom land."[36]

The third type of geologic material encountered in the valley was an intermediate zone or terrace of sand that was not a part of the steep, rough, sandstone bluffs but was also high enough above and far enough from the river so as not to be saturated and soft like the sands at the bank. When the pioneers camped as far as about a mile from the river, Clayton reports that they were able to obtain water in holes dug about four feet deep. It was this "intermediate" zone that the pioneers sought out for their roads, and they did not always find it. From the time the advance company entered the sandstone valley in Keith County, Clayton discussed their attempts to remain both off of the sandstone bluffs and away from the softer, wet terrain near the riverbank. These conditions continued through the rest of the journey across present-day Nebraska.

Weather—Weather-related problems in Iowa, including rain, cold, and mud, were described by Clayton. He made many notes of "bad roads" and "very bad roads" between Nauvoo and Garden Grove; he spent eleven days traveling between Garden Grove and Mt. Pisgah and mentioned rainfall on five of those days.

A particularly trying time occurred between 22 March and 15 April 1846. Clayton's company crossed the Chariton River on 22 March. Clayton estimated that the bottoms were about four miles wide. The company spent all day traveling those four miles, having to let the wagons down the east bluff on ropes and having to pull them up the west bluff on ropes as well. Clayton "spent the day helping the teams till I was so sore and tired I could scarcely walk." Church leaders decided to stop to organize the camp.

Rains fell on 24 and 25 March and between 3 and 6 April. Clayton noted on 3 April that they decided to try to move on:

> We started . . . about 8:00 o'clock. The roads were very bad and when we had traveled about three miles it began to thunder and rain. . . . We then started again in the heavy rain and bad roads and traveled about three miles. . . . We had a very bad bluff to rise and had to double teams to get up. . . . It was about 5:00 o'clock before all our teams got up and it rained heavily all the time. . . . It continued to rain all night very hard.[37]

Clayton's company was then a few miles beyond the Chariton River and about fifty miles from Garden Grove, which would have put them at about Shoal Creek, about three miles east of present-day Cincinnati, Iowa. On 6

April, William noted the following:

> It has rained again the last night and continued to rain all day very heavily. The camp is very disagreeable and muddy. . . . [A]t 8:00 o'clock . . . the wind arrived and soon blew a perfect gale with heavy rain, hail, lightning and thunder. It continued for an hour and then abated some. All the tents in our company except mine and Pack's were blown down. The rain beat through the wagon covers and drenched the families and effects. It was the most severe storm we have experienced.[38]

He noted on 7 April: "This morning it is fair but cold and windy. The ground is frozen stiff and considerable ice. Many of the tents are still lying flat and everything around shows that the storm was very severe. . . . The day continued fine but roads almost impassable."[39] Orson Pratt recorded early-morning temperatures of thirty-nine degrees on 6 April and twenty-nine degrees on 7 April.[40] On 8 April, Clayton wrote: "[W]e concluded to move on a little farther west about a quarter of a mile. It took the company all day to move, it being almost impossible to move the loads[41] even with tripling teams."[42]

The following day brought more rain. Clayton records the following on 9 April:

> This morning we concluded to pursue our journey. . . . The roads were very bad indeed. About noon it commenced raining heavily which made the roads still worse. . . . [A]fter toiling till about four o'clock and having traveled only about five miles and our teams being entirely worn down we turned out of the road to a little branch of water to camp. Several of my teams stuck and we had to work till dark to get part of them to camp and two wagons we were compelled to leave over night. Quite a number were obliged to stay back on the prairie and Charles Hale did not come more than a quarter of a mile from where we started this morning. . . . It continued to rain very heavily until night. We could not make a fire and had little for supper, our provisions being in one of the wagons back. This is the most severe time we have had but yet the camp seems in good spirits.[43]

April 10 brought more rain. Clayton wrote:

> The weather is yet very wet and gloomy. . . . At seven o'clock a gale struck up and blew our tents over. We then concluded to move . . . out of the wind. Before we got moved . . . it grew very cold. . . . It rains and blows very badly and is very severe on our women and teams. . . . Our teams fare hard with wet and cold.[44]

Orson Pratt recorded temperatures on 11 April of twenty-five degrees at sunrise and thirty-three degrees at 8:00 a.m., with frozen mud.[45] Clayton wrote: "This morning rode . . . to help to get Brother Peart's wagon out of the slough. It took five yoke of oxen and twelve men to draw it out. The roads are yet very bad but it is fair and very cold. We sent twelve yoke of oxen to bring up Peck's . . . wagon."[46]

Pratt reported an early-morning temperature of twenty-nine degrees on 13

April. Clayton's company traveled the four remaining miles to Locust Creek on that day. Pratt reported early-morning temperatures of forty-five degrees on 14 April and thirty degrees on 15 April. On 15 April, William Clayton was told of the birth of his new son in Nauvoo, "a fine, fat boy," and wrote, "This morning I composed a new song—'All is well.'"[47]

Another effect of low temperatures and rain on people is that people do not work well in wet and cold conditions when unprepared for them. The exposure likely had the pioneers moving sluggishly.

The advance company enjoyed better weather on the Nebraska Mormon Trail than they had had in Iowa the previous spring. Clayton recorded precipitation on sixteen of the forty-six days (about one-third) the advance company spent in present-day Nebraska; one of those days had "a slight shower of snow" (18 April), and nine of those days occurred during the last two weeks of May 1847. On none of these sixteen days did the rainfall stop travel. The pioneers traveled eight miles on 19 May 1847, the day Clayton described as the "most uncomfortable day we have had and the hardest on our teams," over the "worst road we have had from Winter Quarters."[48] That particular day was an exception. Starting the last week of April, phrases such as "morning fine and pleasant" became common in Clayton's journal. April and May 1847 were good months for travel.

Toward the end of April, Clayton began noting very cold overnight temperatures and warm to very hot daytime temperatures. On 26 April, while still less than twenty miles west of the Loup River ford, Clayton first noted the effects of the progressively drier climate: "The sun is very hot and not much wind. I find it has a great tendency to make sore lips, parched up and feverish." On 27 April: "The land today has been very rolling and uneven. It is also very sandy and dry. . . . The sun is very hot but there is a nice west wind although it is dry and parches our lips." On 29 April: "One of Orson Pratt's horses is very sick, supposed to be the bots. . . . I am not astonished, as the wagons and everything else is shrinking up, for the wind is perfectly dry and parching; there is no moisture in it. Even my writing desk is splitting with the drought." On 18 May: "The weather very hot."[49]

Yet the nights continued cold. On 2 May: "This morning is fine but cold. Ice about half an inch thick." On 15 May: "This morning is very cloudy and very cold, more like a January morning than a May morning." On 24 May: "The morning very cold indeed. . . . The evening fine but cold enough to freeze clothing stiff when laid on the grass to dry."[50]

Clayton notes the effects of the weather on the teams. The oxen teams appear to have adapted well to the drier conditions; the horse teams fared more poorly. The quality of the feed varied from day to day; some days the feed was good, and some days the grass was either not growing because of the climate or had been eaten away by the large buffalo herds. Clayton mentioned on 6 and 7 May that horses and cattle were "giving out," but the hardships on the teams

caused by the weather did not prevent the advance company from generally traveling ten-plus miles per day. They generally made less than ten miles per day when having to cross over the bluffs in the sandstone valley.

Clayton began to note airborne dust on 28 April: "The roads are extremely dusty and the strong wind blows it into the wagons and everything is covered." On 29 April: "The clouds of dust were almost sufficient to suffocate everyone." On 30 April: "The wind blows strong from the north and the dust is very bad." On 12 May: "We have passed over vast beds of salt, or rather dust with a salt taste. It looks something like dirty flour. . . . Considerable strong wind from southeast covering everything in the wagons with dust and sand."[51] This was the same phenomenon that caused the "dust bowl" of the early nineteenth century. The pioneers traveled 15, 18, 16, and 12 miles, respectively, on the dates mentioned above.

Topography and Geography—Mention is made again of the never-ending and dramatic grade reversals caused by having to cross 100 percent of the streams encountered (Figures 3 and 9), the natural tendency of loess soils to form steep streambanks, and the lack of established, well-traveled roads. These conditions necessitated lowering wagons down steep streambanks on ropes and hauling them up the opposite banks the same way, double- and triple-teaming when necessary.

The steepness of present-day streambanks and the depths of present-day channels cut into the loess can perhaps be misleading when we consider conditions encountered by the pioneers of 1846. In comparing the topographic conditions of 1850s Pottawattamie County to those existing in 1900, Udden (1900) reported the following:

> At the time the government land surveys were made [1850s], a good many bottoms of the larger streams as well as of small upland creeks, were less well drained than they are today and were marked as swampy tracts on the survey charts. . . . These lands have become dry pastures or fields, either by artificial means or by the natural cutting of channels by the streams below the surface of the flat bottoms, induced by the destruction of a rank native vegetation through pasturing. Many small creeks which now have well established furrows twenty feet deep, requiring good bridges for the wagon roads, could be crossed by teams and heavy vehicles almost anywhere in the early days before the country was settled.[52]

Based on this evidence, it appears that to some extent, streambank steepnesses and channel depths in the loesses of Iowa were not as severe in 1846 as they are today. Present-day observations may give some misleading impressions of the degree of difficulty the pioneers faced in locating fording places and in actually crossing the drainages.

Steele wrote that on arrival "[a]t the bend of the Platte just south of the present city of Fremont . . . people from the East were at once struck with the uni-

formity of the landscape that spread out before them: a wide lazy island-spotted river, meandering over a broad flat valley floor inclined gently to the bordering uplands. That broad valley supported the great migration. It made a good road. Monotony of relief favored expedience of transportation."[53] Clayton wrote in his *Emigrants' Guide* that

> from here, you have before you near five hundred miles travel over a flat, level country, and a good road, with the exception of several sandy bluffs mentioned herein. The road generally runs from one to two miles from the Platte river, but not too far to turn off to camp in case of necessity. . . . You will find nearly two hundred miles without timber, but in that region you will find plenty of buffalo chips, which are a good substitute for fuel.[54]

The trail departed from the relative flatness of the Platte River valley in only two areas (Figure 9). The first was west of present-day Columbus. The pioneers continued to follow the north bank of the Loup River west of its confluence with the Platte (Figures 1 and 13). Major Stephen D. Long had followed this route on a federal exploration expedition in 1820 and had traveled west up the north bank of the Loup River for about fifty miles, crossing the river about fourteen miles southwest of present-day Fullerton (Figure 1).[55] Steele noted:

> In most years it was impossible to ford across the mouth of the Loup with wagons, and very little travel attempted to cross there until the ferry was organized in 1858. . . . The Loup Valley resembles the Platte Valley, only in smaller terms: generally sandy soil near the river, land of low relief for two or three miles on either side of the river, and then the bluffs rising abruptly twenty to one hundred feet high. In places the hills advance almost to the river. The road up the valley was generally good.[56]

The Loup River is situated along the northern edge of the Platte River valley. Just north of present-day Grand Island, travel along its north bank began to take the pioneers out of the flat valley and into the uplands (Figures 9 and 13). The company began traveling northwest along the Loup on the afternoon of 21 April, and Clayton noted at the end of the day that "[w]e are now within three miles from the bluffs on the north."[57] Clayton noted on 22 April that "[t]he country this afternoon was more uneven, there being many steep pitches and rises."[58] The next day, a fording place was sought.

Crossing the Loup was not easy. The Loup shares the characteristics of the Platte: although not as wide, it is generally about two feet deep and dangerous to cross on foot or in a wagon because of shifting quicksands and meandering, deep channels that shift position with time. The advance company's initial crossing of the Loup began on 24 April 1847.

> [T]he prospect looks dull for rafting on account of sandbars and very rapid current. . . . Luke Johnson was the first who went over, . . . and although he had no load, . .

> . it was with difficulty he got over. When [Orson Pratt] had got in about a rod, his horses began to sink some in the sand and they could not draw. A number of the brethren jumped in and lifted at the wheels, etc., till they got him to the bar in the middle. He then started for the other bar and about half way across his horses sank in the quicksand. . . . A number of the men . . . took them off the wagon and led them across to the sand bar. The carriage was drawn to the sand bar by men with a long rope. . . . The river is not more than two feet deep, but there are a great many beds of quicksand which are dangerous to teams, and calculated to shake a wagon to pieces.[59]

The rest of the company crossed about one-quarter mile up the river the next day.

> After a few wagons had gone over, it was perceived that they went over with less difficulty, and by doubling teams they soon took over the loaded wagons without much difficulty. . . . I found the current strong indeed, and about as much as a horse could do to ford it without a load. . . . [T]he wagons started on to find a better place to camp and feed for our teams . . . and give the teams a chance to rest, for they as well as the men are very tired by wading against the strong current on the quick sand. The bottom land on this side is more sandy than on the other side.[60]

The second place where the trail departed from the relative flatness of the Platte River valley was near the vicinity of present-day North Platte (Figures 1 and 9). By this point on the trail, the Platte River valley was incised into sandstone bedrock and was less than three miles wide. The river was braided within the valley and meandered between the north and south valley walls. Where the river was at the northern edge of its valley, the only alternatives were to continue traveling along the north bank, which would take them out of the flat valley and into the bluffs at the north edge of the valley, or to cross the river, which would appear to have been generally impractical for wagons because the braided Platte was about a mile wide and because the meanders extended to the south valley wall as well.

Other Factors—Other factors that prolonged (or may have prolonged) the advance company's journey across Iowa in 1846 include the following:

> Because of the cold weather and killing frosts well into April in Iowa, grass does not begin to grow in earnest until after mid-April. There was little food for the teams before that time. Clayton's first mention of sufficient grazing for the teams was on 22 April, when he wrote that they "found good grass and much of it."[61]

> Clayton's journal indicated a lack of sufficient teams. The cattle and horses they had were overworked because there were not enough and because of all the double- and triple-teaming that had to be done. Clayton made frequent complaint of the poor condition of the animals. Complicating the matter was the lack of grazing and feed.

Clayton mentioned rattlesnakes for the first time on 22 April. Rattlesnakes hibernate during the winter months and are of a poor disposition when they come out of hibernation with hunger in the spring. Their young are born in the spring, and their bites are more dangerous than those of adult snakes because the young snakes have not yet learned to hold back their venom when they strike. The animals may not have been accustomed to the great number of rattlesnakes on the prairie or may not have been careful enough while grazing after being famished for so long a time. Clayton wrote on 22 April that "[w]e have seen many rattlesnakes today" and on 23 April that "[a] number of the horses have been bitten by rattlesnakes and one is dead. There are a great number of these snakes on these prairies."[62] A horse belonging to one of Clayton's teamsters was bit on its nose on 25 April and died overnight.[63]

The advance company stopped for days at a time in Iowa on more than one occasion to organize the camp—for example, at Sugar Creek, Garden Grove, and Mt. Pisgah. On some of these days, the travelers would not have moved anyway because of weather.

Clayton was in charge of moving the Church property as well as his own. He reports the weight of the property at about three thousand pounds.[64] This burden no doubt slowed his group.

Faster Iowa Travelers—On 19 May, Clayton made this entry while a few miles west of Garden Grove: "Some teams returned from camp [believed to be Mt. Pisgah] and said that some from Nauvoo had arrived there which started two weeks ago last Saturday [2 May]." Mt. Pisgah was about two hundred miles from Nauvoo, meaning this particular group would have traveled an average of about twelve miles per day. The combined records of Lee, Sessions, Pratt, Snow, and Clayton[65] indicate rain on the Iowa Mormon Trail on eleven of those seventeen days. The circumstances are unknown to me, but it is evident that relatively rapid travel was possible by that time.

William Reynolds Terry left Nauvoo on 8 May 1846 and made the three-hundred-mile journey to Council Bluffs in "two months and eight days" with the group from Macedonia, Iowa, which was large enough to have been organized into companies of hundreds, fifties, and tens. If we assume seventy calendar days, they journeyed an average of almost four and a half miles per day. Terry wrote that he "Riged up one Wagon two yoke Oxen a fore cows one yearling and two Calf and foore Sheep lodid my Famuly in and set out for the wildernis we travild a west cors this beeing the 8 day of May AD 1846 our Rode was weet and mody we feriad and briged and forded many a dangers streeam of water and in counterd many A heard ship . . . two numeris to mention. . . . [W]ee traveld two months and eight days . . . [to] Counsial Bluffs."[66]

Travel on the North Bank of the Platte River—On 4 May 1847, within a few days of reaching the Platte River south of the Loup ford,

> three wagons were discovered on the opposite bank of the river. . . . The river is about two miles wide and no person here acquainted with it, consequently, no one attempted to go over. . . . [O]ne of the men from . . . the other side [of] the river overtook us. . . . He says the road is good on the other side and easily forded, being not more than knee deep in the deepest place and a good bottom. . . . When [he] went back over the river, [three men] accompanied him on horses. . . . They returned soon after . . . and say that the river is very good to cross, not being more than two feet deep in the deepest place, and the bottom good. The horses broke through but very little. The traders say . . . that if we continue on this side, we shall have to cross the river twice where the water is much deeper and cannot be crossed only in a ferry. There is a good traveled road also, which would be an advantage we have not got on this side.[67] . . . Brother Brown reported what the traders said about the route. . . . [W]hen it was considered that we are making a road for thousands of saints to follow, and they cannot ford the river when the snow melts from the mountains, it was unanimously voted to keep on this side as far as Fort Laramie at least.[68]

Previous authors have said that the pioneers chose to travel on the north side of the Platte to keep themselves separated from Oregon Trail travelers on the south side. Allen noted that "[t]he main difference between their path and the well-traveled Oregon Trail was that, until they got into Wyoming, they traveled on the north side of the river while the Oregon pioneers were on the south. They simply wanted to avoid unnecessary contact with possibly unfriendly people."[69] Steele wrote that "[t]he Mormon policy of segregation led them to shun the Omaha ferry [across the Missouri River], and most Gentiles kept away from the Florence ferry."[70] Regarding the Mormons' deviation from the later Oxbow Variant south of the Platte, Steele remarked that "the Mormons thought in terms of the same philosophy that prompted them to blaze their own road north of the Platte—that wherever separation . . . was possible, it was more satisfactory for the discipline of the Saints."[71]

Although the Latter-day Saint pioneers did recognize the advantages of separation from potentially unfriendly migrating parties, Clayton did not mention this as either a cause or a potential benefit of the decision made on 4 May to keep the Trail on the north side of the Platte. The concern he mentioned was that future pioneers would not be able to "ford the river when the snow melts from the mountains." The advance company had just completed the Loup crossing on 24 April and may have been leery of having future pioneers cross the then-two-mile-wide Platte River once the snowmelt made it wider, deeper, and faster.

By the time Clayton's *Emigrants' Guide* was published in March 1848, it was obvious that the character of the braided streams changed with time. Regarding the Loup crossing, Clayton's *Guide* stated that "[i]n this river the channels often change—the old ones fill up, and new ones are made—hence, the wisdom and necessity of . . . find[ing] the best route, before you attempt to take wagons over. . . . [Y]ou may plunge your wagons from a sand-bar into a deep hole, and do much damage."[72] The advance company was aware that there were places the

Platte could be crossed but apparently decided on 4 May that they did not want to depend on having to. Clayton did not relate the company's thoughts on the traders' report that staying on the north side would necessitate two crossings farther along the Trail. The advance company may have decided that the Platte River's shape, morphology, and dynamics would have made any long-term crossing points undependable.

By the time the advance company reached the Salt Lake valley on 24 July 1847, they knew that other emigrating companies would be well on their way. On 2 August, Ezra T. Benson left the Salt Lake Valley to return east to meet the next company. Clayton noted on 3 August that he was working on a "table of distances" between Winter Quarters and the Great Salt Lake Valley.[73] Having discovered a route that worked well and did not depend on a Platte River crossing, the Saints organized themselves to use it in the coming years.

TABLE 1
AVERAGE TEMPERATURES IN ST. PAUL, MINNESOTA, AND ST. LOUIS, MISSOURI, 1845-1847

City	Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
St. Paul, MN	1845	19.5	25.6	34.6	47.6	60.8	67.6	74.2	69.5	59.8	45.6	29.5	14.1	45.7
	1846	28.0	19.5	38.4	46.4	63.6	66.8	74.2	73.9	62.8	42.9	39.8	21.6	48.2
	1847	4.2	19.7	23.9	46.2	52.6	65.2	71.9	66.7	58.0	46.7	30.4	16.4	41.8
	1820-1930	12.3	16.4	29.1	45.5	58.0	66.5	72.3	69.3	59.7	47.6	31.7	17.7	43.9
St. Louis, MO	1845	40.6	44.1	45.4	64.3	64.7	74.7	79.8	77.6	70.9	55.3	42.7	27.4	57.3
	1846	38.7	31.4	47.2	59.0	69.3	70.8	81.4	78.6	74.0	56.3	46.4	39.7	57.7
	1847	27.2	36.2	41.4	59.3	63.5	72.0	78.6	74.7	69.1	57.1	45.1	34.8	54.9
	1837-1930	31.8	34.9	44.6	56.4	66.1	74.8	79.4	77.3	70.1	57.8	44.6	34.7	56.0

TABLE 2
MONTHLY HIGH AND LOW TEMPERATURES, MUSCATINE, IOWA, 1845-1847

Year	J	F	M	A	M	J	J	A	S	O	N	D
1845	58/6	66/6	77/8	86/16	82/34	88/54	98/50	93/48	92/30	72/16	60/-7	42/-12
1846	56/12	50/-8	72/20	82/28	86/38	82/54	94/44	94/54	92/42	80/16	62/2	54/6
1847	40/-23	56/-10	66/0	86/13	87/30	86/40	92/42	86/42	84/36	86/8	74/7	63/-10
Average*	51/-12	55/-7	70/7	81/24	87/35	92/46	95/51	94/48	90/37	81/25	67/10	53/-5

* Averages calculated by author based on data for available years between 1839-1974.

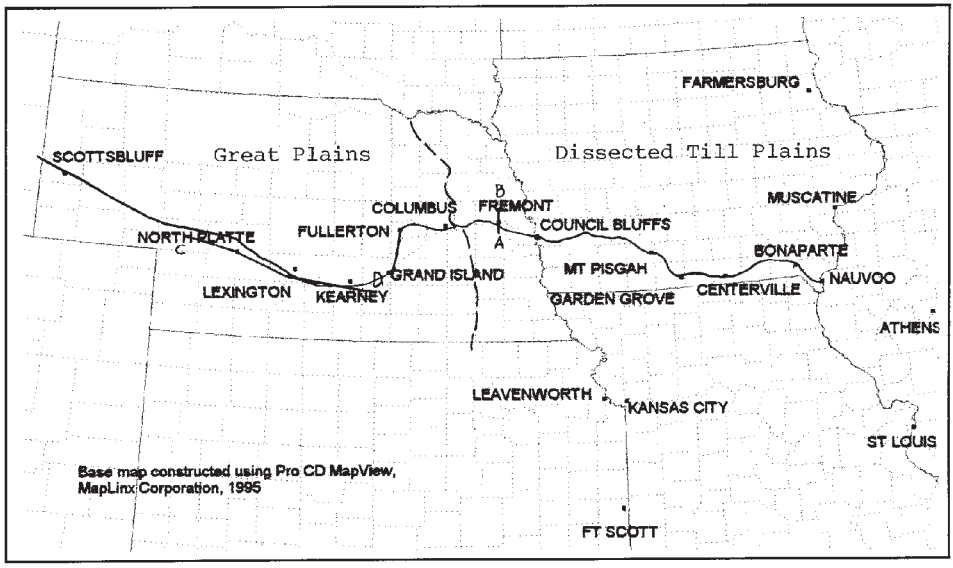
TABLE 3
MONTHLY, ANNUAL, AND AVERAGE PRECIPITATION, 1845-1847

City	Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Fort Scott, KS	1845	0.70	2.33	0.94	5.39	8.16	24.56	4.57	7.18	3.35	3.05	0.97	0.39	61.59
	1846	1.27	0.92	1.61	2.64	1.76	7.03	1.17	3.09	5.53	2.56	2.97	3.49	34.04
	1847	1.25	1.24	1.10	4.22	3.12	4.63	5.84	1.79	1.50	2.48	5.86	1.61	34.64
	1843-1930	1.77	1.85	2.27	4.21	5.41	6.19	4.28	3.62	4.05	3.10	2.35	1.72	40.82
Leavenworth, KS	1845	0.60	2.20	0.73	2.40	2.30	15.80	0.01	1.70	6.70	1.30	0.82	0	34.56
	1846	0.40	0.20	1.10	3.90	3.20	4.16	2.61	0.08	3.88	1.03	1.14	2.05	23.75
	1847	0.69	1.30	0.48	2.79	7.18	5.15	1.20	0.50	0.32	0	0.27	1.15	21.03
	1836-1930	1.06	1.35	1.93	3.07	4.51	4.97	4.01	4.06	3.98	2.50	2.08	1.30	34.82
Des Moines, IA	1845	1.00	1.32	1.42	3.83	1.61	5.50	0.51	2.34	3.04	--	--	--	--
	1846	0.92	0.02	--	--	--	--	--	--	--	--	--	--	--
Farmersburg, IA	1845	1.10	2.79	2.73	3.36	2.40	5.50	3.90	1.35	3.27	1.22	0.15	0.35	28.12
	1846	1.00	0.03	3.12	6.53	6.33	3.65	3.10	2.15	3.90	1.90	1.95	1.0	34.66
	1847	0.55	0.60	1.70	1.90	4.25	3.65	2.40	2.90	3.05	0.80	2.60	0.85	25.25
	1836-1930	1.20	1.14	1.76	2.57	3.82	4.35	3.95	3.69	3.69	2.31	1.77	1.42	31.67
Muscatine, IA	1846	2.80	4.50	2.10	5.40	3.40	4.20	1.30	0.50	5.50	1.30	1.80	1.75	34.55
	1847	0.79	1.11	2.94	3.30	3.50	4.60	1.20	3.30	2.10	1.21	3.45	1.00	28.50
	1846-1930	1.79	1.88	2.59	3.33	4.18	4.49	3.72	4.11	3.78	2.68	2.26	1.91	36.72
St. Louis, MO	1845	1.83	1.07	3.18	2.28	4.42	10.01	4.75	6.23	1.03	1.16	1.10	0.93	37.99
	1846	2.98	1.27	1.27	4.84	3.75	5.21	0.84	4.73	4.84	2.71	2.11	10.90	45.45
	1847	2.12	3.58	2.28	3.98	4.36	8.61	5.37	0.90	3.26	8.74	8.63	0.89	52.72
	1837-1930	2.29	2.50	3.52	3.76	4.53	4.54	3.54	3.45	3.22	2.87	2.84	2.49	39.55
Athens, IL	1845	1.95	0.46	2.20	6.50	2.55	13.68	2.62	1.63	4.14	2.48	3.35	1.48	43.04
	1846	4.87	1.83	2.55	7.84	3.96	5.28	2.33	1.13	7.44	1.16	1.55	4.96	44.90
	1847	2.27	3.47	1.51	2.09	3.12	1.07	2.01	2.64	3.76	4.62	4.80	1.25	32.61

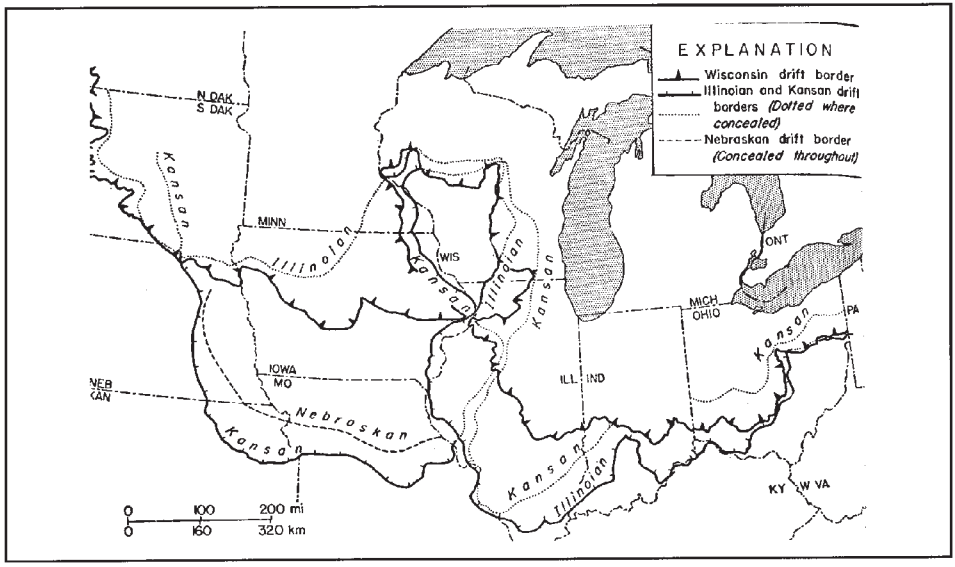
TABLE 4
MONTHLY PRECIPITATION, FEBRUARY-JUNE 1846

City	Feb-Apr 1946 Precipitation (in)	Feb-Apr Average Precipitation (in)	% Above/Below Average	Feb-Jun 1946 Precipitation (in)	Feb-Jun Average Precipitation (in)	% Above/Below Average
Farmersburg, IA	9.68	5.47	+77.0	19.66	13.64	+44.1
Muscatine, IA	12.00	7.80	+53.8	19.60	16.47	+19.0
St. Louis, MO	7.38	9.78	-24.5	16.34	18.85	-13.3
Athens, IL	12.22	8.90	+37.3	21.46	19.46	+10.3

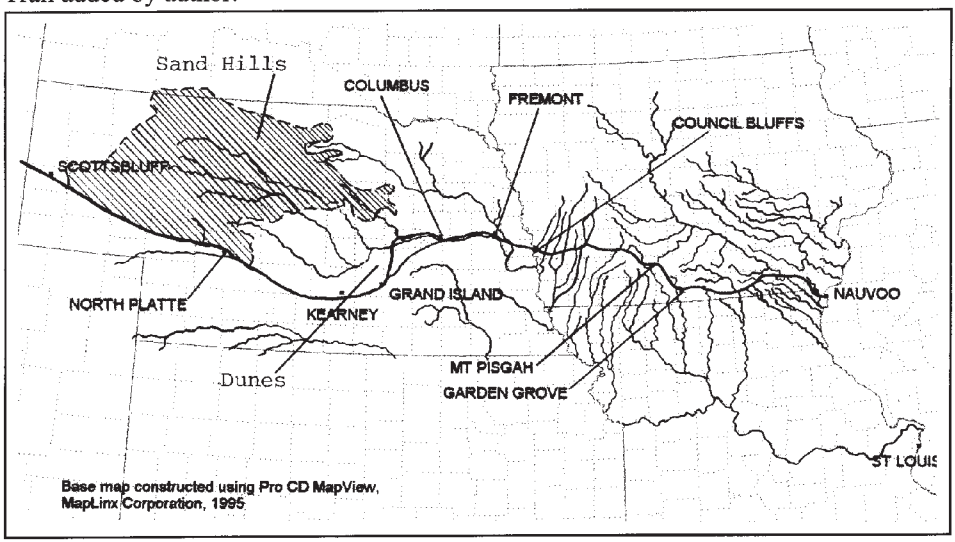
1 -The Mormon Trail in Iowa and Nebraska.



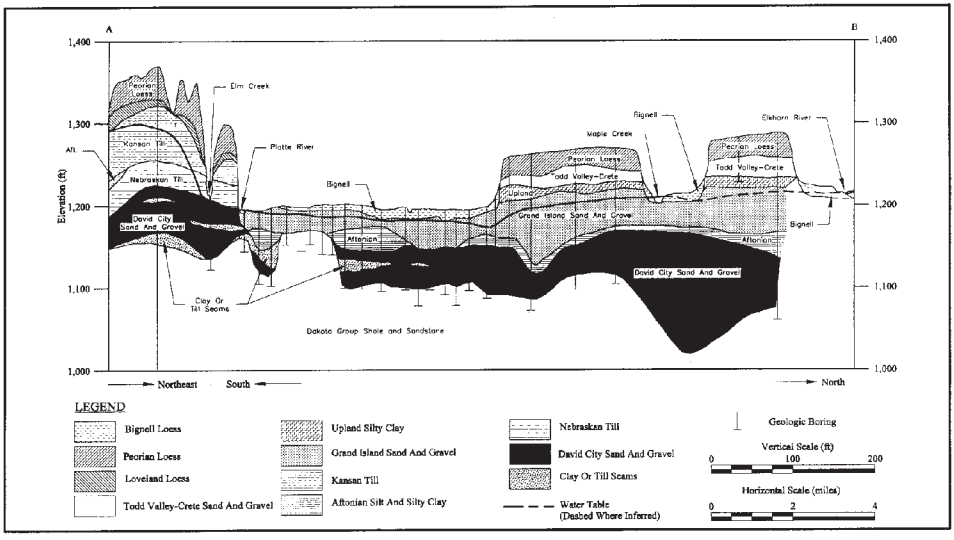
2 - Maximum limits of Nebraskan, Kansan, Illinoisan, and Wisconsinan glaciation in the central United States, where identified or inferred. From Flint (1967)[74].



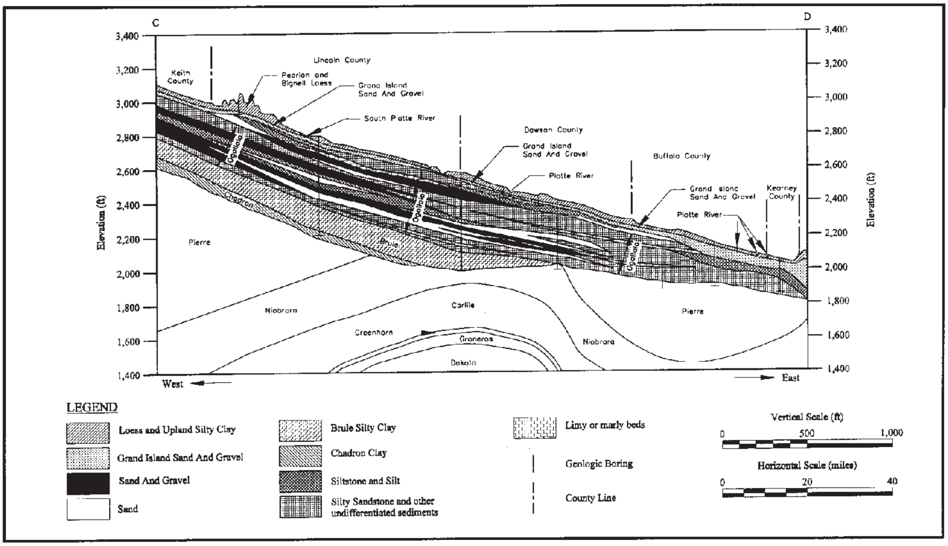
3 - Map showing Iowa and Nebraska drainage to the Missouri and Mississippi rivers. Map does not show all Nebraska, Iowa, and Missouri streams. Approximate location of Mormon Trail added by author.



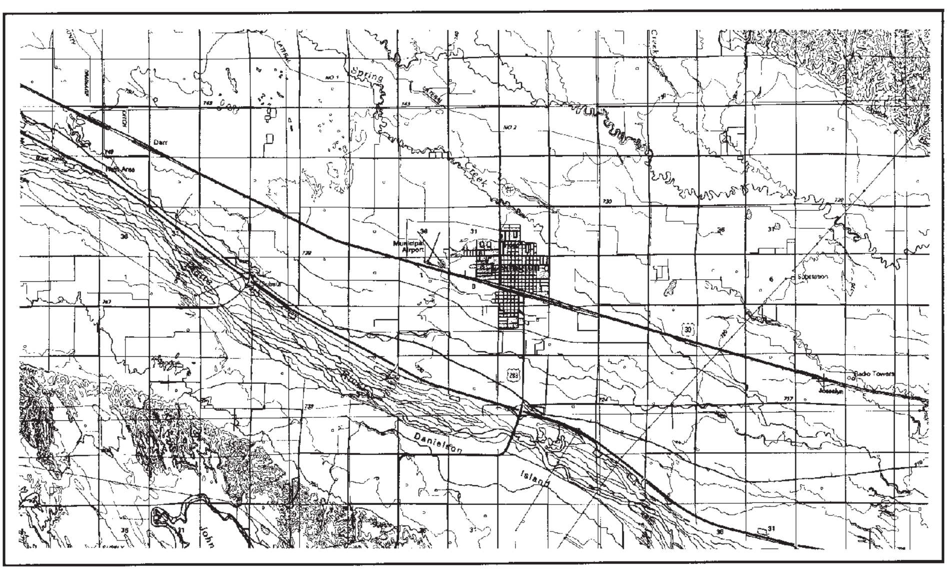
4 - Cross-section A-B northward across Elm Creek, Platte River, Maple Creek, and Elkhorn River valleys near Fremont, based on geologic borings and surface exposures. Buried valleys were cut to much larger sizes needed to carry away glacial meltwater. After Condra et.al (1947)[75]. See Figure 1 for location of cross section.



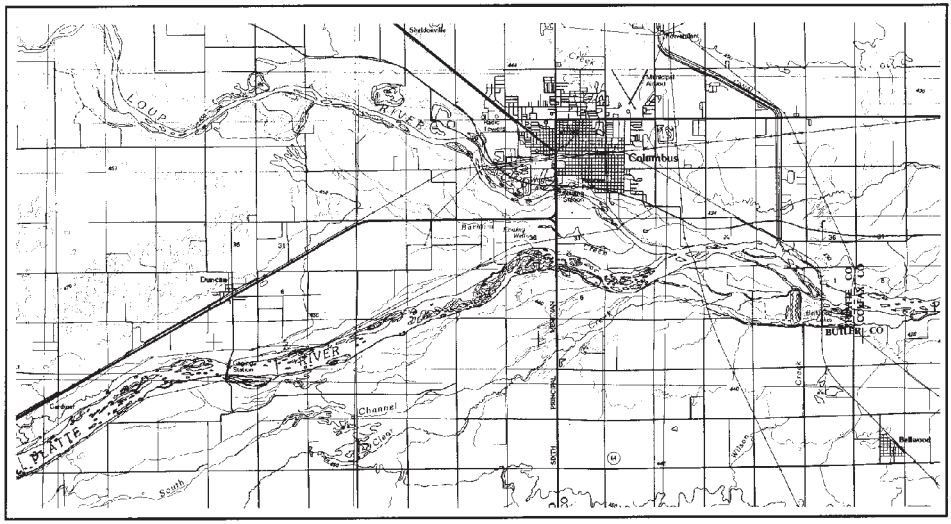
5 - Cross-section C-D from Keith County eastward along Platte River in south-central Nebraska. Note the "Gangplank" feature formed by the Ogallala Formation. See Figure 1 for location of cross section. After Condra et.al (1947)[76].



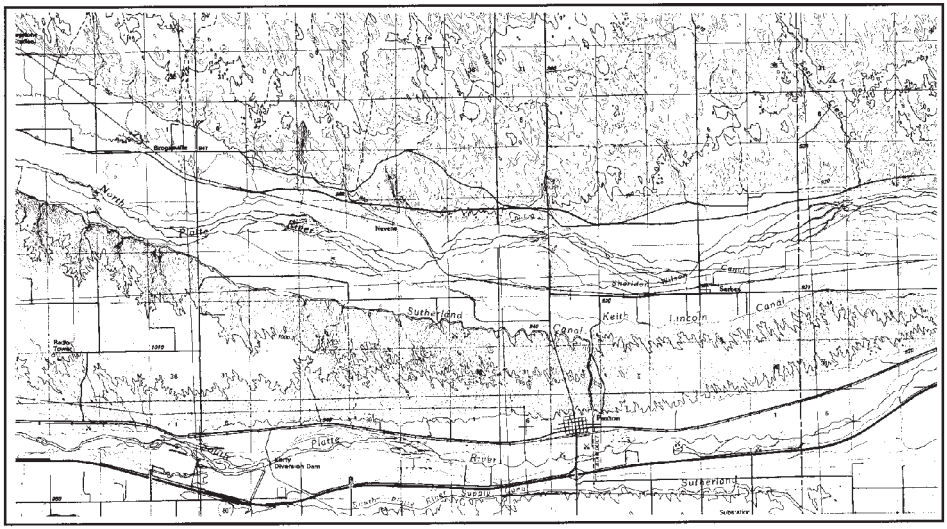
6 - 1:200,000-scale topography[77] (reduced to 50% of original size) showing spectacular braiding of Platte River at Lexington, Dawson County, Nebraska (Figure 1). Contour interval = 10 meters (32 feet). Squares on map are surveyed sections, 1 mi².



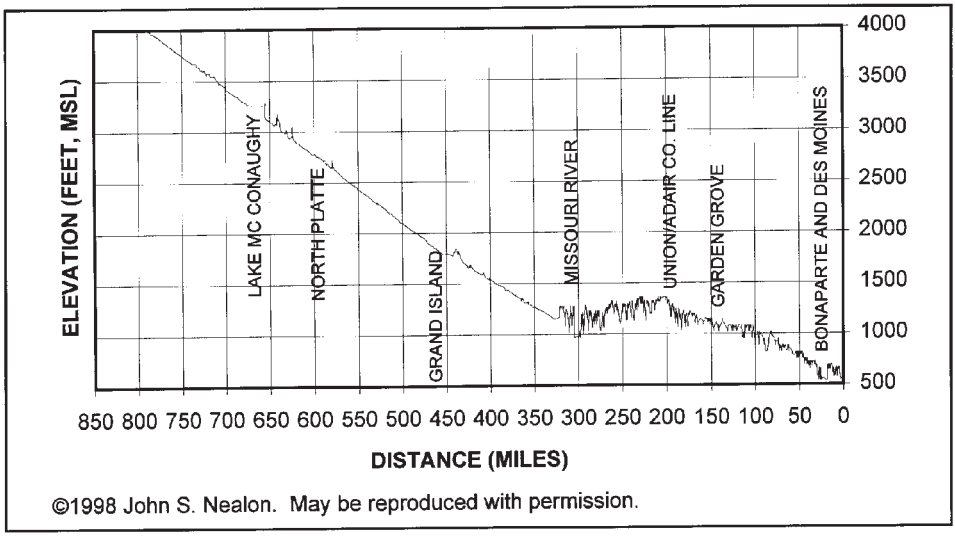
7 - 1:200,000-scale topography[78] (reduced to 50% of original size) showing Platte River as a single-trunk stream near Columbus, Platte County, Nebraska (Figure 1). Contour interval = 10 meters (32 feet). Squares on map are surveyed sections, 1mi².



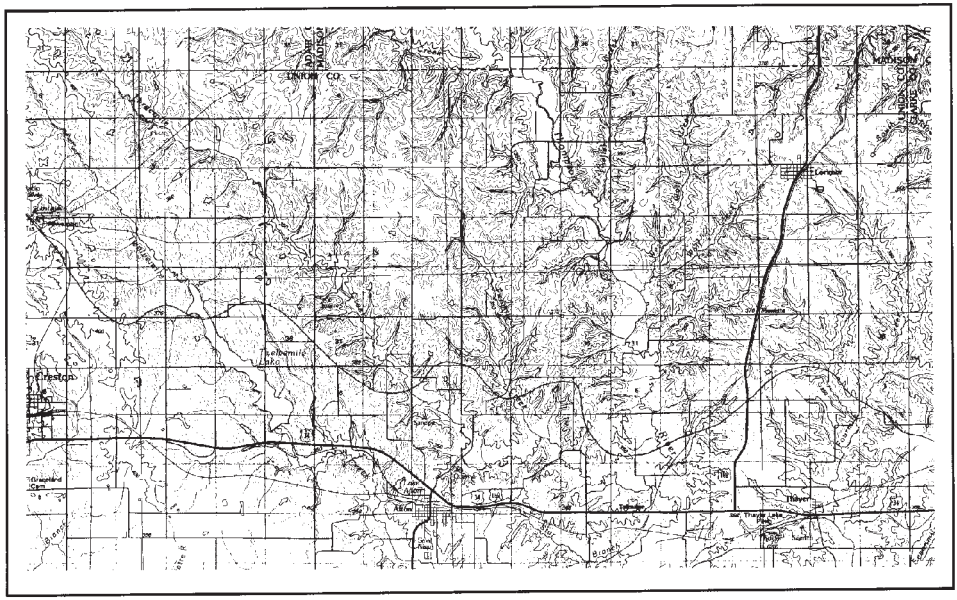
8 - 1:200,000-scale topography[79] (reduced to 50% of original size) showing constriction of Platte River valley to less than 3 miles in width between North Platte to the east and Lake McConaughy to the west, Keith County, Nebraska. Note the necessity of either crossing the Platte River or of ascending into the Sand Hills. Contour interval = 10 meters (32 feet). Squares on map are surveyed sections, 1mi².



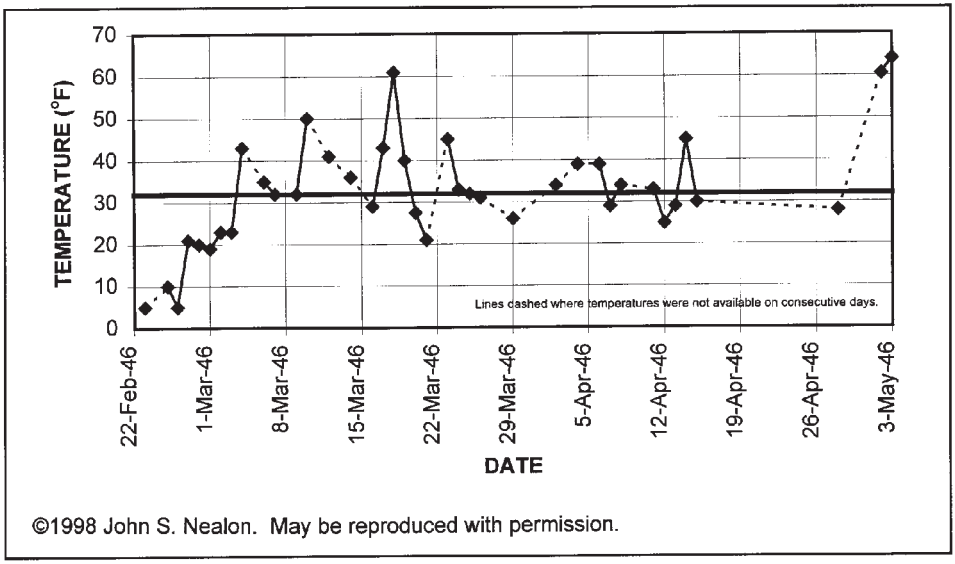
9 - Cross-section of the Iowa and Nebraska Mormon Trails. Note the abrupt end to the trail "roughness" west of the Elkhorn River as the trail ascends the "Gangplank".



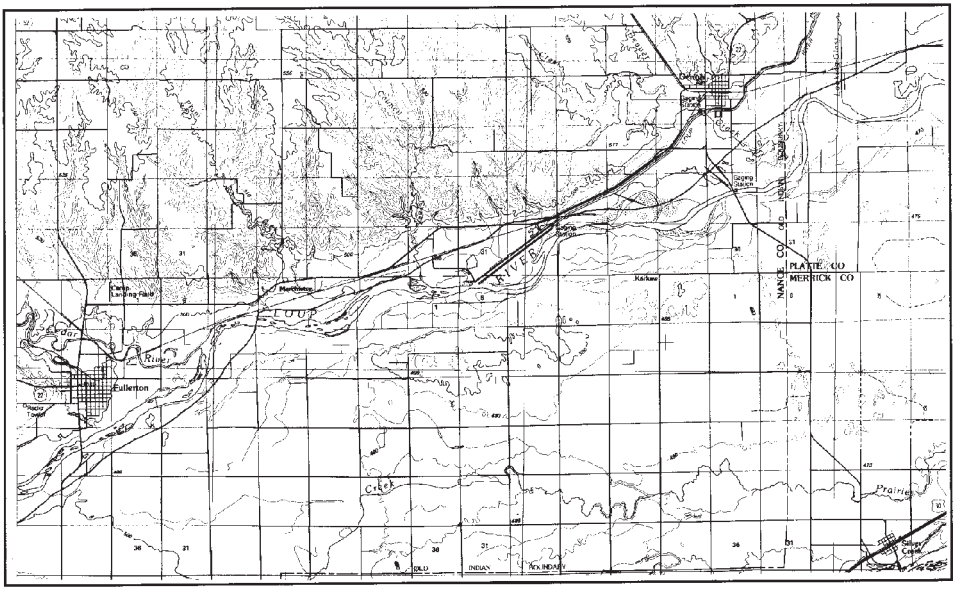
10 - 1:200,000-scale topography[80] (reduced to 50% of original size) showing typical southern Iowa topography. Contour interval = 10 meters (32 feet). Squares on map are surveyed sections, 1 mi^2. Compare to Nebraska Mormon Trail topography shown on Figures 6 and 7. The Mt. Pisgah settlement was on the east side of the Thompson River crossing.



11 - Variation of early-morning temperature (6:00 to 9:30 a.m.) with time, Spring 1846.



12 - 1:200,000-scale topography[81] (reduced to 50% of original size) showing the Loup river crossing near Fullerton, Nebraska (Figures 1 and 9). Note that the Loup is at the north wall of the Platte River valley. Contour interval = 10 meters (32 feet). Squares on map are surveyed sections, 1mi^2.



Notes

1. Richard Foster Flint, *Glacial and Pleistocene Geology* (New York: John Wiley & Sons, Inc, 1967), 11.

2. Marvin P. Carlson, *Geology, Geologic Time and Nebraska* (Educational Circular No. 10, Conservation and Survey Division, University of Nebraska-Lincoln, Lincoln, Nebraska, 1993), 49-50.

3. Ibid., 50.

4. George F. Kay, *Gumbotil, a New Term in Pleistocene Geology,* Science, new series, 44, 3 November 1916; James E. Gow and John L. Tilton, *Geology of Adair County*, from Iowa Geological Survey, 27, Annual Report, 1916, 308.

5. Gow and Tilton, 308.

6. Carlson, 51.

7. Gow and Tilton, 277-344.

8. John L. Tilton, *Geology of Cass County*, from Iowa Geological Survey, 27, Annual Report, 1916, 171-276.

9. John L. Tilton, *Geology of Clarke County*, from Iowa Geological Survey, 27, Annual Report, 1916, 105-170.

10. Melvin F. Arey, *Geology of Davis County*, from Iowa Geological Survey, 20, Annual Report, 1909, 487-524.

11. J. A. Udden, *Geology of Pottawattamie County*, from Iowa Geological Survey, 11, Annual Report, 1900, 201-77.

12. Condra et al., 13-29.

13. Marie Morisawa, *Streams: Their Dynamics and Morphology* (New York: McGraw-Hill, 1968), 80.

14. Stanley B. Kimball, ed., *The Latter-day Saints' Emigrants' Guide* (Gerald, Missouri: The Patrice Press, 1983), 47.

15. Ibid., 46.

16. C. F. Keech and R. Bentall, *Dunes on the Plains: The Sand Hills Region of Nebraska* (Resource Report No. 4, University of Nebraska, Conservation and Survey Division, Lincoln, 1982), 1.

17. Olga Sharp Steele, *The Geography of the Mormon Trail Across Nebraska*, M.A. Thesis, University of Nebraska, Lincoln, 23 May 1933.

18. Climatic Summaries, Bulletin W, United States Department of Agriculture, provided by Harry J. Hillaker, Iowa State Climatologist, Iowa Department of Agriculture and Land Stewardship, 30 April 1998.

19. Letter from Hillaker, 30 April 1998.

20. Henry F. Diaz, *A Long Record of Weather Observations in Southeastern Iowa, 1839-1979*, National Climatic Center, Asheville, North Carolina, July 1980, 42, 48.

21. Generally, 60 to 62 data points were available for averaging for each month, including the periods of 1839-60 and 1936-74.

22. From the journal of William Reynolds Terry, provided by William G. Hartley of Brigham Young University.

23. Unpublished data provided by Karla Gunzenhauser, Historian, Iowa Mormon Trails Association, 26 August 1997.

24. Paul J. Waite, Jayne M. Harbaugh, and Marie R. Klugman, *Drought in Iowa: The Pattern, Frequency, and Intensity*, Iowa Water Resources Data System Report Series, Report 79- 1, December 1979, 5-7.

25. *Annual Precipitation in Nebraska* (1850-1995), University of Nebraska-Lincoln, Conservation and Survey Division, Institute of Agriculture and Natural Resources, 1995.

26. John A. Elder, *Soils of Nebraska*, University of Nebraska, Conservation and Survey Division, Lincoln, May 1969, 2.
27. Climatic Summaries.
28. Gunzenhauser.
29. Clayton, 2-47.
30. Ibid., 100-101.
31. Ibid., 78, 81.
32. Steele, 11-12.
33. Clayton, 146.
34. Ibid., 149.
35. Clayton, 153.
36. Steele, 121.
37. Clayton, 12.
38. Ibid., 14.
39. Ibid., 15.
40. Gunzenhauser.
41. Clayton's company was responsible for moving the Church property in addition to his personal property. He estimated the weight at three thousand pounds.
42. Clayton, 15.
43. Ibid., 16.
44. Ibid., 16-17.
45. Gunzenhauser.
46. Clayton, 17.
47. Ibid., 19.
48. Ibid., 161-62.
49. Ibid., 105, 108, 112, 158.
50. Ibid., 124, 149, 180-81.
51. Ibid., 111, 113, 114-15, 143-44.
52. Udden, 216-17.
53. Steele, 58-59.
54. Kimball, 83.
55. Steele, 10, 78.
56. Ibid., 66.
57. Clayton, 88.
58. Ibid., 90.
59. Lawrence Clayton, 92-93.
60. Lawrence Clayton, 101-02.
61. Clayton, 22.
62. Ibid., 23.
63. Ibid., 25.
64. Ibid.
65. Gunzenhauser.
66. William Reynolds Terry, personal journal, provided by William G. Hartley of Brigham Young University.
67. After crossing the Loup, the advance company had to make its own road until about Scottsbluff.
68. Clayton, 128-30.
69. Kimball, 3.
70. Steele, 39.
71. Ibid., 163.
72. Kimball, 83.

73. Clayton, 341.
74. Flint, 338.
75. Condra et.al., 29.
76. Condra et.al., 14.
77. United States Geological Survey, Kearney, Nebraska. 1:100,000-scale metric topographic map, 30x60 minute quadrangle, 1985.
78. United States Geological Survey, David City, Nebraska. 1:100,000-scale metric topographic map, 30x60 minute quadrangle, 1988.
79. United States Geological Survey, Ogallala, Nebraska. 1:100,000-scale metric topographic map, 30x60 minute quadrangle, 1990.
80. United States Geological Survey, Creston, Iowa. 1:100,000-scale metric topographic map, 30x60 minute quadrangle, 1993.
81. United States Geological Survey, David City, Nebraska. 1:100,000-scale metric topographic map, 30x60 minute quadrangle, 1988.