Kansas Geological Survey

Midcontinent Meeting for the National Karst Map Project- Field Trip Notes

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GEOHYDROLOGY

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Introduction

These notes pertain to a day long fieldtrip from the Kansas Geological Survey into the Flint Hills region and central Kansas with stops planned at Florence, the Hutchinson area, and Cheyenne Bottoms, just outside Great Bend (Figure 1). Lunch and dinner stops are planned at Hutchinson and the Brookville Hotel in Abilene, respectively. Should you have special needs or concerns please do hesitate to discuss them with the field-trip leaders.

Lawrence to Emporia

This section of the road log is taken from Buchanan and McCauley (1987). Figures 2-5 show the surficial geology along the first segment of the field-trip route through Douglas, Shawnee, Osage, and Lyon counties. Outbound, travel is on Interstate 70 from Lawrence to Topeka and Interstate 335 from Topeka to Emporia.

Mile Marker	Description
201.9	West Lawrence interchange.
199.7	Baldwin Creek.
198.6-199.0	Oread Limestone, one of the most prominent formations in eastern Kansas, averages about 52 feet in thickness in the northern part of the state. The Oread was named for Mount Oread, the hill that overlooks downtown Lawrence.
198.1	Plattsmouth limestone. The Oread Formation is made up of four smaller limestone layers. The Plattsmouth limestone is the thickest of those limestones.
197.2	K-10-Interstate 70 interchange
196.3	Oakley Creek.
195.6-196.8	Numerous outcrops of Lecompton Limestone.
195.0	Tecumseh Shale, overlain by Deer Creek Limestone.
193.8	Tecumseh Shale, overlain by Deer Creek Limestone. The Tecumseh is up to 65 feet thick.
193.3	Deer Creek Limestone.
188.5	US Highway 40 overpass
188.3	Topeka service area
184.6	Deer Creek Limestone. Exposed near the top of the cut, the Ervine Creek Member is the uppermost member of the Deer Creek.
183.7-184.0	Calhoun Shale overlain by Topeka Limestone.
183.4	Stinson Creek
183.3	Ervine Creek limestone is exposed on the south side of the eastbound lane of Interstate 70.
182.8	Topeka Limestone is exposed on the north side of west-bound Interstate 70.
182.0	East Topeka Interstate 335 – Intestate 70 interchange.
180.9	Deer Creek.
180.0-180.2	Topeka Limestone.

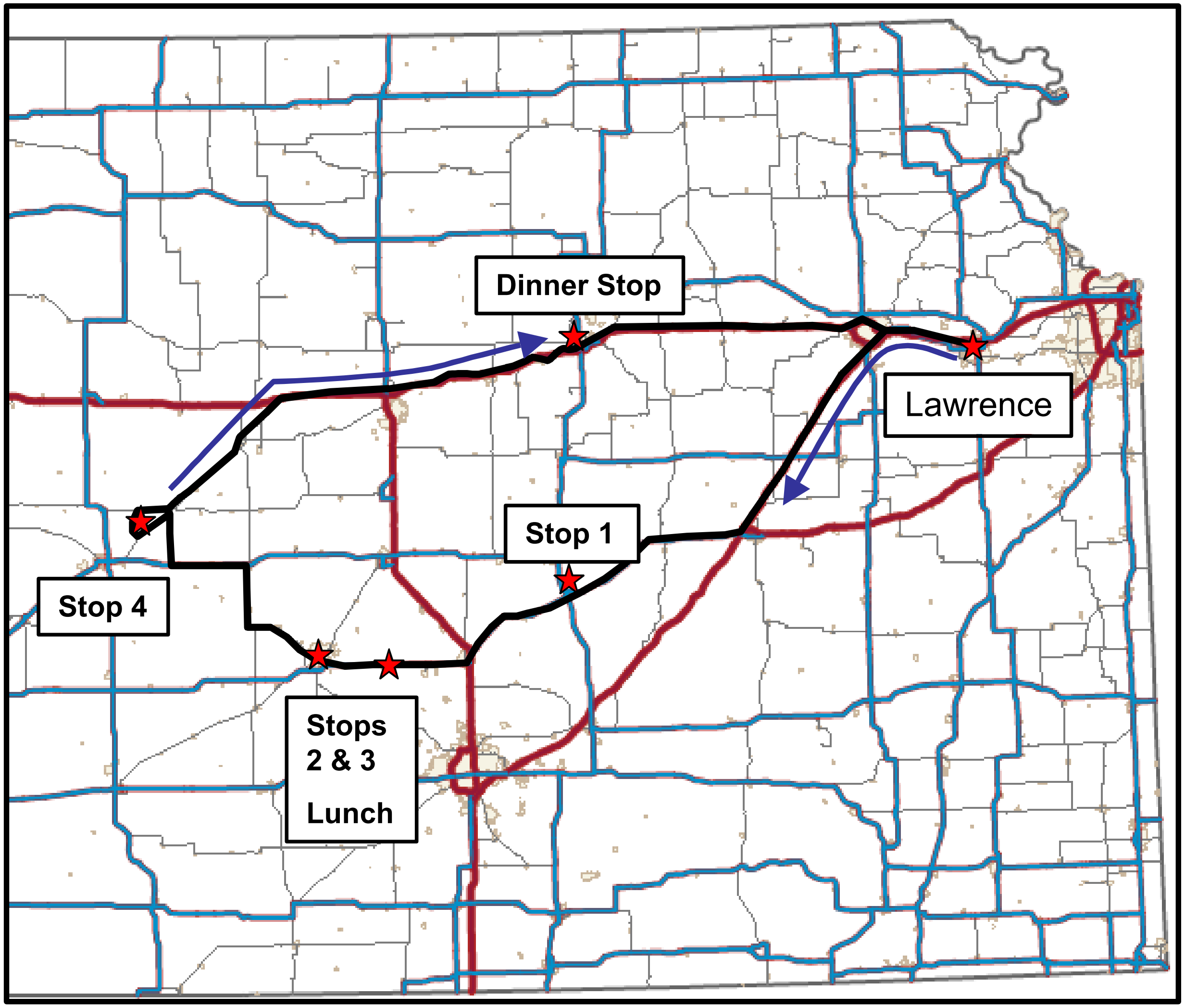

Figure 1. The field trip route from the West Lawrence entrance onto Interstate 70 (the Kansas Turnpike) and return by way of the dinner stop at Abilene on Interstate 70. Stop 1 is at Crystal spring near Florence, Kansas; Stop 2 is at the IMC subsidence in Hutchinson; Stop 3 is at the US-50 and Victory Road subsidence east of Hutchinson; and Stop 4 is at Cheyenne Bottoms near Great Bend.

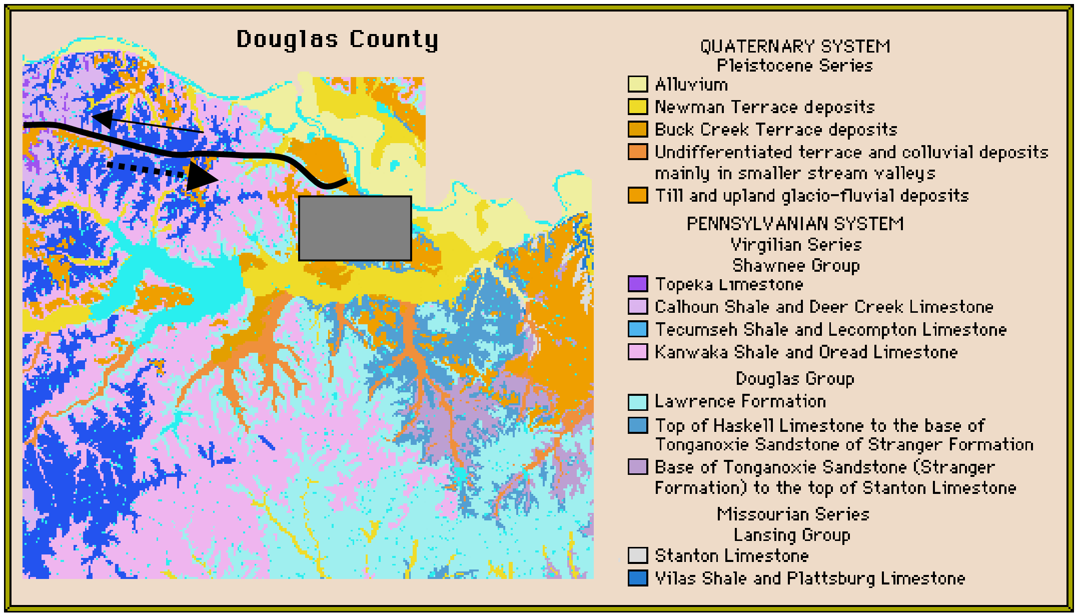

Figure 2. Surface geology of Douglas County. Solid arrows indicate the outbound route and dashed arrows, the inbound route back to Lawrence.

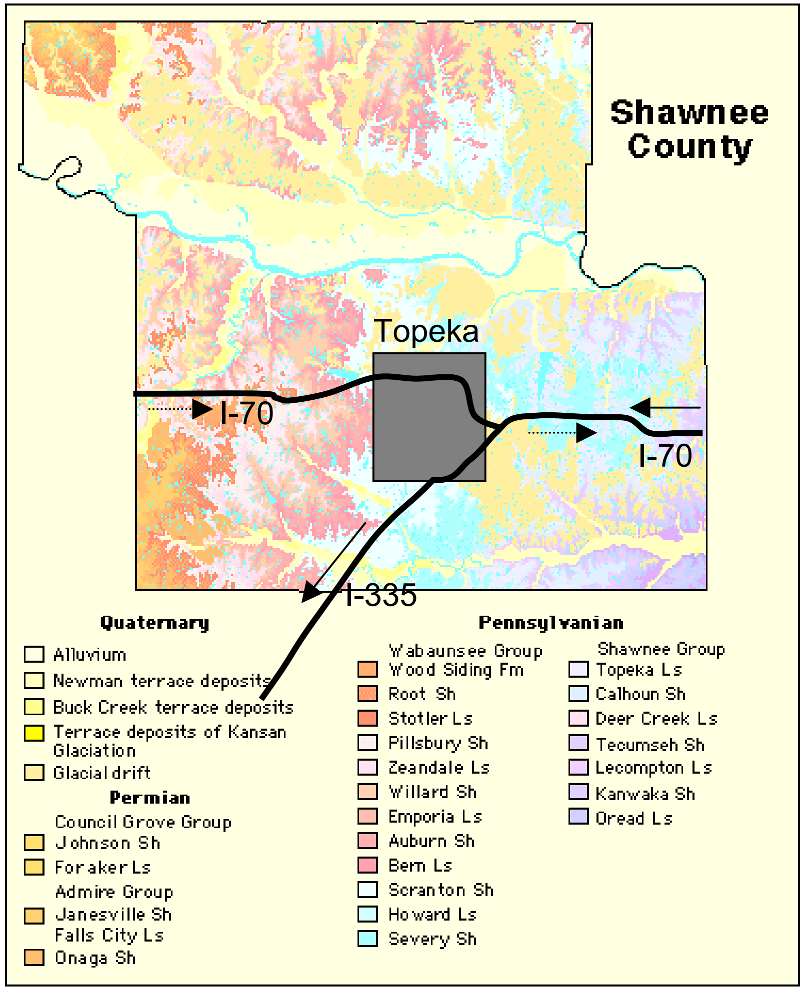

Figure 3. Surface geology of Shawnee County. Arrows with solid lines indicate the outbound route and those with dashed lines indicate the inbound route back to Lawrence.

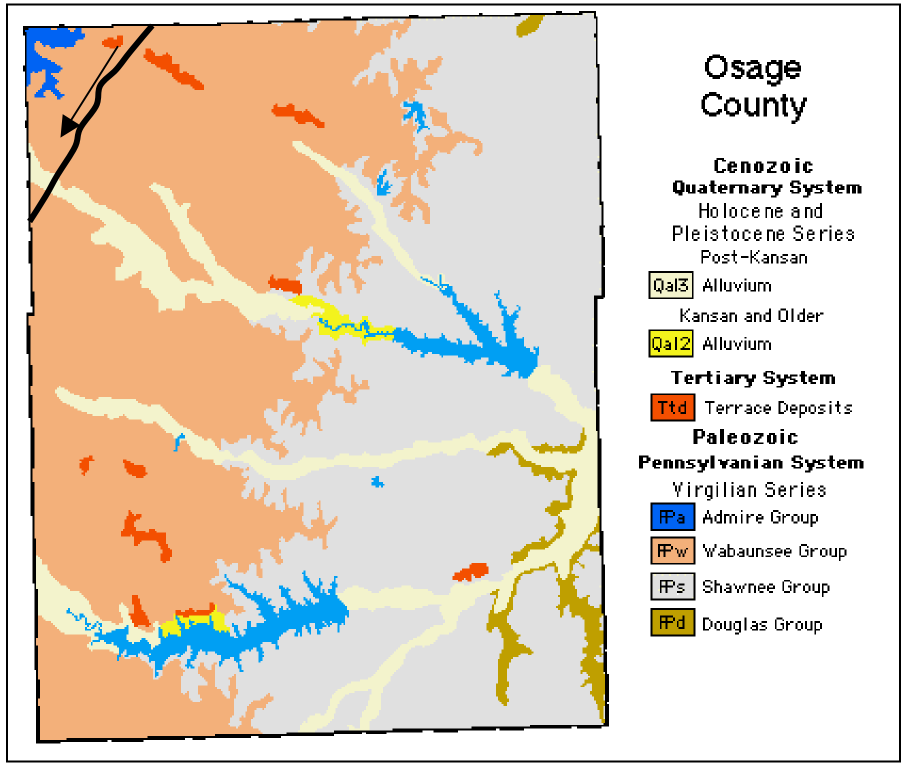

Figure 4. Surface geology of Osage County. Arrows with solid lines indicate the outbound route from Lawrence.

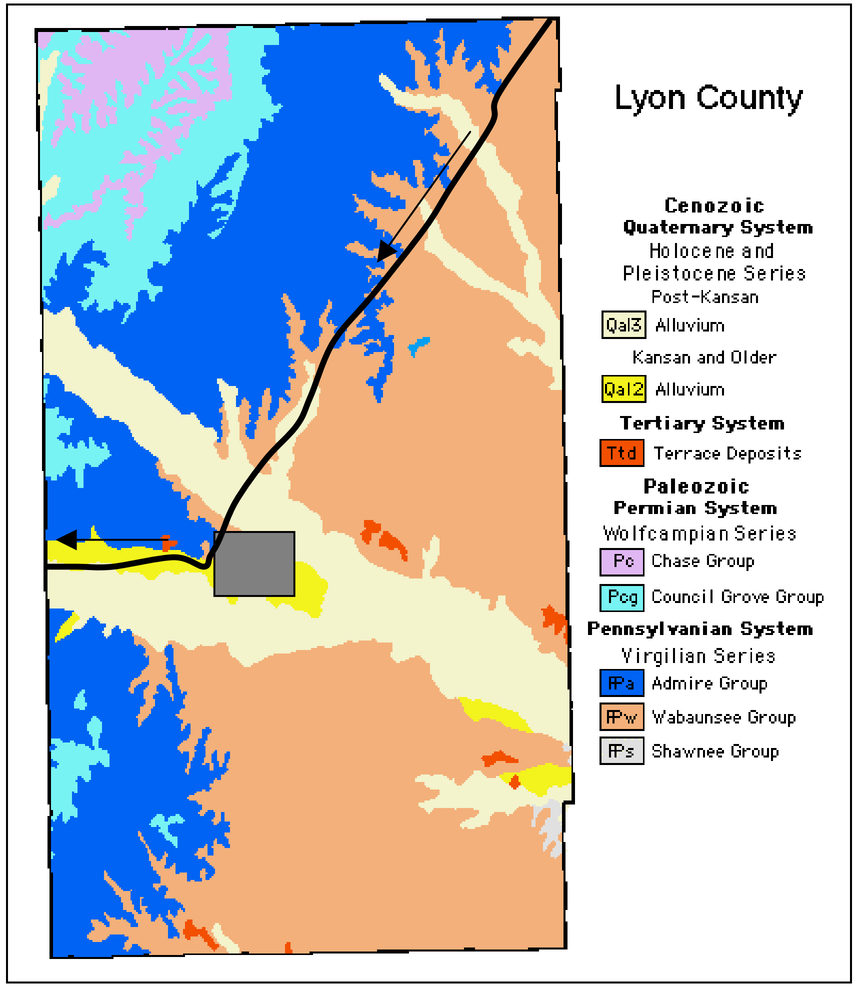

Figure 5. Surface geology of Lyon County.

Mile Marker	Description
178.0	Howard Limestone, including an exposure of the Nodaway coal bed. Though coal deposits are common in the eastern third of Kansas, few outcrops are visible along the turnpike. This coal bed, which ranges from a few inches to 2 feet in thickness, has been mined extensively in the past, producing nearly 12 million tons from underground and surface diggings. More than 97 percent of the Nodaway coal mined in Kansas came from Osage County. Today the market for coal from this formation is hindered by the coal's high sulfur content-as much as 6 to 8 percent.
177.0	South Topeka Interstate 335 – US Highway 75 interchange
176.0	The turnpike passes through a small area of partially obscured orange glacial deposits that contain pink Sioux quartzite boulders, which were carried from South Dakota and Minnesota into Kansas by glaciers. This location is near the southern boundary of the glaciers' movement into Kansas less than one million years ago.
175.8	South branch of Shunganunga Creek.
173.7	Burlingame Limestone Member of the Bern Limestone east of the road.
172.3	White Cloud Shale Member of the Scranton Shale on the east side of the road. The White Cloud ranges in thickness from 30 to 80 feet.
170.8	Sixmile Creek.
167.7	Wakarusa River.
167.3	Soldier Creek Shale, which is overlain by the Burlingame Limestone.
165.5	Osage/Shawnee county line.
165.2	Elmont Limestone Member of the Emporia Limestone, overlain by Willard Shale.
164.6	Willard Shale and overlying Zeandale Limestone.
163.4	Tarkio Limestone Member of the Zeandale Limestone.
160.5	Switzler Creek.
159.9	Sandstone layer in the Pillsbury Shale.
157.8	Dover limestone.
157.0	Dragoon Creek.
156.7	Dover limestone on the east side of the road.
155.7	Approximate crossing of the Santa Fe Trail.
155.3	Soldier Creek, which flows into Dragoon Creek.
154.8	Osage-Wabaunsee county line.
154.3	Lyon-Wabaunsee county line.
153.3	Pillsbury Shale and overlying Dover limestone.
151.4	Salt Creek.
148.0	Elm Creek.
147.9	Pillsbury Shale and overlying Dover limestone.

146.7	Admire Interstate 335 – US Highway 56 interchange.
144.8	Dover limestone.
144.1	One Hundred and Forty-Two Mile Creek. Creeks named by distance are common in Kansas-from One Mile Creek, east of Fort Riley, all the way up to this creek, which received its name because it was about 142 miles from the beginning of the Santa Fe Trail in Independence, Missouri.
143.9	Pillsbury Shale and overlying Dover Limestone Member of the Stotler Limestone.
143.2	Hill Creek.
142.9	Dry shale and Grandhaven limestone, members of the Stotler Limestone.
141.8	Duck Creek.
141.4	Nebraska City Limestone Member of the Wood Siding Formation.
140.7	Grayhorse limestone, overlain by the Brownville limestone, both members of the Wood Siding Formation.
139.0-140.0	For a mile to the northeast the turnpike passes over rocks of Permian age in the lower part of the Admire Group. The road then returns to rocks of Pennsylvanian age.
135.8	Dow Creek.
132.2	Stillman Creek. This is one of several area creeks that drain southeastward into the Neosho River.
131.8	Emporia service area.
130.3	Allen Creek.
130.0	Troublesome Creek.
129.2	The Neosho River
128.8	Nebraska City Limestone Member of the Wood Siding Formation.
126.8	Emporia Interstate 335 – US Highway 50 interchange.

Emporia to Florence

A published road log of the geology is not available for this segment on the field trip that passes through westcentral Lyon and central Chase counties (Figures 5-6). We are traveling upstream along US Highway 50 along the north side of the Cottonwood River valley through the central part of the Flint Hills region. The Flints Hills is a distinct physiographic region in Kansas mantled by tall grass prairie. The vast expanse of the grassland makes it ideal for grazing. Raising cattle is the primary agricultural activity in the region because of the high food value of the grasses that form the basis for the prairie ecosystem. Note the location of the Tall Grass Prairie National Preserve in Chase County. The surficial geology consists of lower Permian interbedded limestones and shales assigned to the Council Grove and Chase Groups. In the valleys, the bedrock is overlain by thin alluvial and terrace deposits, generally less than 50 feet in thickness. Figures 5-7 show the surface geology of Lyon, Chase, and Marion counties, respectively, along US 50. The thicker limestones are sources of ground water for domestic and stock wells and for most of documented springs in Chase and Lyon counties. Well yields tend to be low, but in the case of the springs discharge depends entirely on the frequency and intensity of precipitation events. Springs and sinkholes commonly occur in this region and the springs that reportedly have a higher discharge issue from the thicker limestone units (Figure 8).

Mile Marker	Description
344	US 50 exit ramp from Interstate 335. The route of US 50 is predominantly over terrace and alluvial deposits on the north side of Cottonwood River from this exit to Florence.
337.7	Lyon-Chase County line.
335.9	Buckeye Creek crossing
332.7	Outcrops of Permian Council Grove Group rocks.
329.4	Kansas State Historical Society board on south side of the highway providing information on the settlement of the Cottonwood River Valley.
328.2	The highway passes through a roadcut that exposes strata assigned to the Blue Rapids Shale, Funston Limestone, and Speiser Shale formations of the upper Council Grove Group.
327.9	Strong City. The church south of US 50 was built using stone from the Cottonwood Limestone, a formation within the Council Grove Group.
326.7	US Highway 50 - Kansas Highway 177 interchange. The Tallgrass Prairie National Preserve is located approximately 1 mile north of the interchange. The Preserve is over 10,894 acres of tall grass prairie in size and was formerly known as the Z-Bar Ranch.
326.6	Just beyond this interchange, the highway passes over strata assigned to the Blue Rapids Shale. Exposed in the roadcut to right are the Funston Limestone and Speiser Shale units of the uppermost Council Grove Group. At the top of the hill is the Wreford Limestone, the lowermost unit of the Chase Group.

324	Typical Flint Hills landscape can be viewed to the north and south of the Cottonwood River valley for the next several miles.
322.6	Diamond Creek crossing. The creek receives discharge from Diamond Spring in Morris County. The spring's source is ground water from the Permian Barneston Limestone , a unit in the Chase Group.
321.1	Middle Creek crossing
319.8	Junction with Kansas Highway 150. The bedrock units that form the valley sides consist of upper Council Grove on the lower slopes capped by lower Chase Group rock units.
316.5	Clover Cliff Bed and Breakfast is a 5,000-acre working ranch that offers overnight or extended stay accommodations in the main ranch house, in nearby satellite buildings, or in a chuckwagon out on the prairie.
314	Turn-off for the Clements natural stone bridge over the Cottonwood River.
312.7	The bedrock forming the valley sides consists of uppermost Council Grove Group rock outcropping on the lower slopes and capped by the rock units belonging to the lower Chase Group, primarily Wreford Limestone.
311.2	The highway passes over high terrace deposits.
307.3	Marion-Chase County line
306.8	Bruno Creek crossing
306.3	One-room school house north of the highway and built of native limestone
305.8	The highway passes over high terrace deposits.
305.2	Martin Creek crossing
304.3-302.7	Outcrops of the Matfield Shale overlain by the Florence Limestone and Fort Riley Members of the Barneston Limestone along the north side of the highway.
302.7	Cottonwood River crossing
302.3	Enter the city of Florence
302.1	Turn right on Marion Street and proceed for 1.5 miles. The Florence water treatment plant is on the right. Just beyond this point is the Hillcrest Cemetery. Continue to follow the road across the Cottonwood River bridge. The road veers to the left (west), following a bend in the river. Cross the bridge that spans an unnamed creek. The dominant source for the creek is discharge from Crystal spring. Follow the road west and turn right onto Whitetail Road and proceed north up the hill for 0.2 miles. Turn right into the lane that leads to Crystal spring 0.3 miles away.

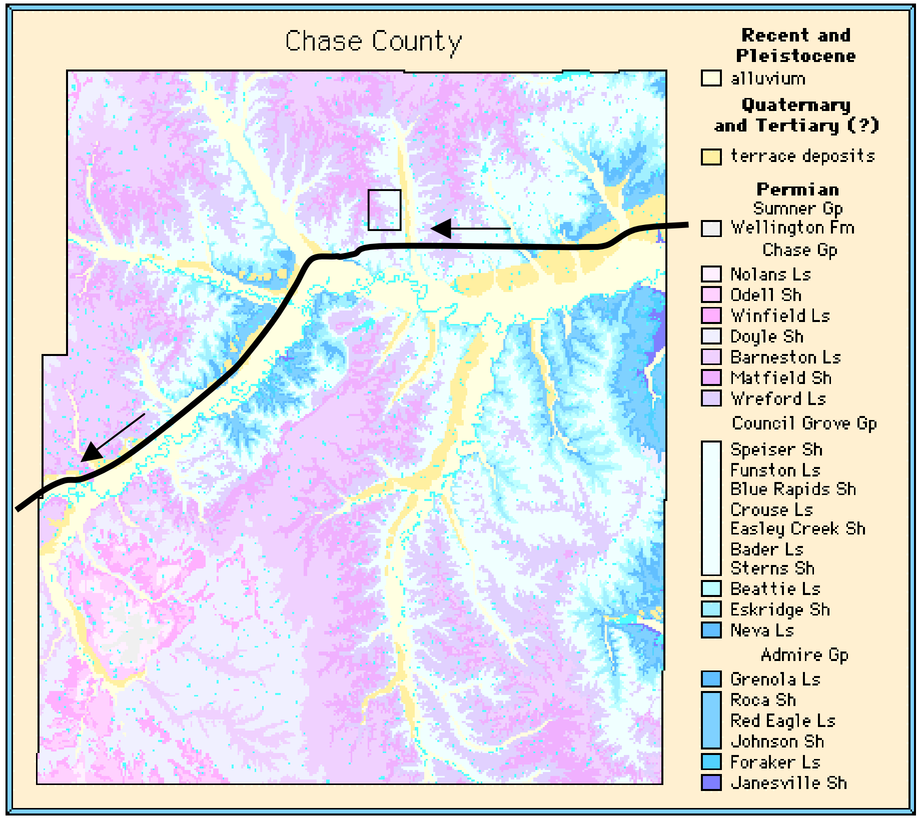

Figure 6. Surface geology of Chase County.

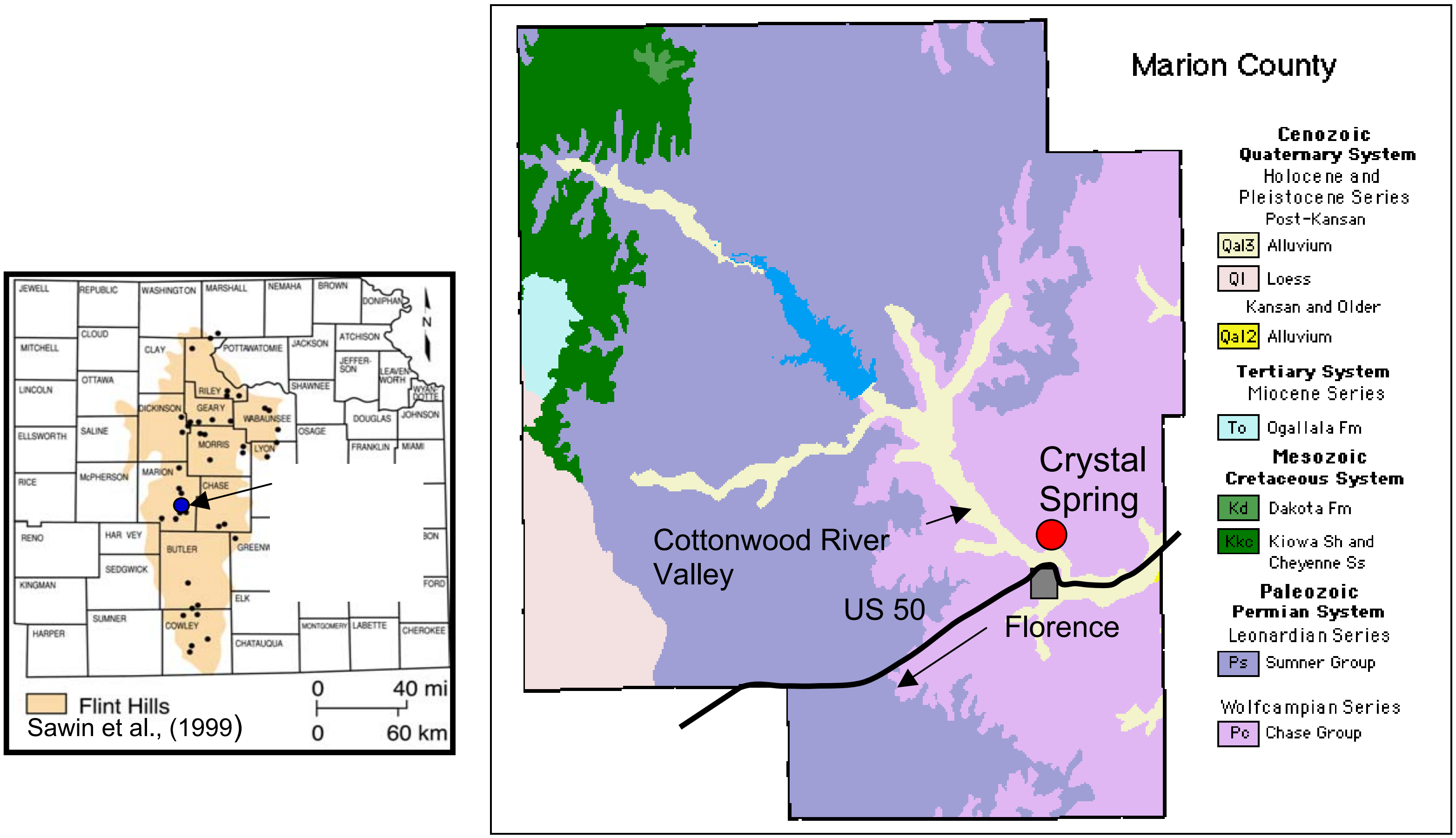

Figure 7. Surface geology of Marion County, showing the location of Crystal spring (Stop 1) with respect to Florence, and the Cottonwood River. The distribution of springs inventoried in Sawin et al. (1999) is shown on the left.

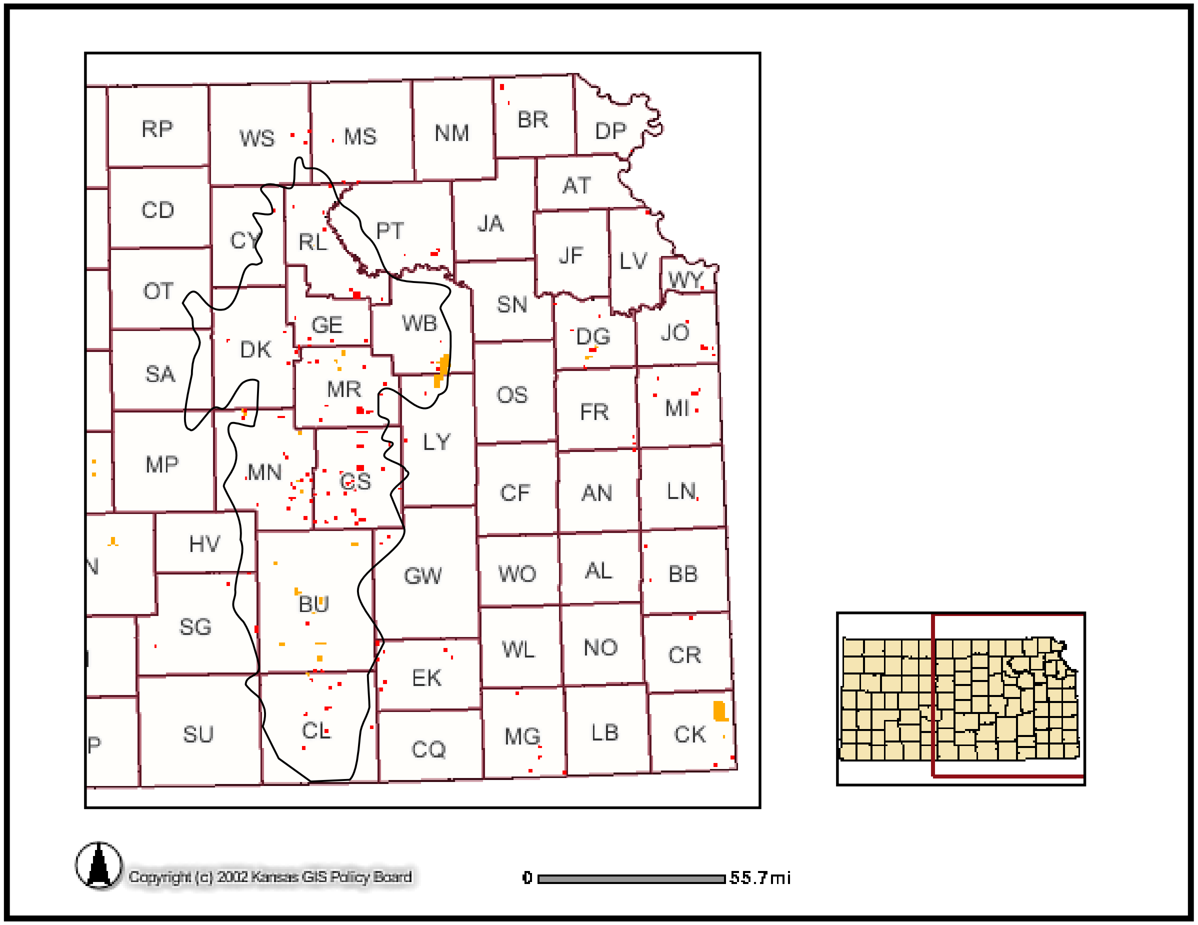

Figure 8. Distribution of karst features in the Flint Hills region (outlined in black) and adjacent areas of eastern Kansas. Plotted on the map are 1-mile square sections of land where spring and sinkhole locations have been documented in the literature. Sections in yellow and red indicate areas the occurrence of sinkholes and springs, respectively. Modified from the Karst Data Viewer (http://www.kgs.ku.edu/geohydro/karst/karst_view.cfm)

Stop 1: Crystal Spring (Carbonate Karst, Figure 7)

This summary is taken from Macfarlane (2003).

Crystal spring is located along the north wall of the Cottonwood River valley, just to the east of where an unnamed tributary drainage enters the valley from the surrounding upland area (Figures 7 and 9). The spring is unique for the Flint Hills region because of its high discharge rates and its use by the city of Florence for water supply. Prior to construction of the spring house by the city, two 7.6-m (25-ft) deep wells were drilled side-by-side into the underlying Florence Limestone and pumps were installed to more easily produce water for the municipal supply. Water is pumped periodically from the spring to replenish water in the storage tower at a maximum rate of 7.6 L/s (0.27 ft^3/s). Otherwise, spring discharge exits from the spring house to a discharge pool before it enters the unnamed tributary drainage leading to the Cottonwood River. Measured spring discharge ranged from slightly less than 28.3 L/s up to more than 510 L/s (1 ft^3/s up to more than 18 ft^3/s) and at least half of the time the discharge was 73.6 L/s (2.6 ft^3/s) (Figure 10).

The near-surface stratigraphy of the Crystal Spring catchment is best characterized as a sequence of alternating limestones and shales belonging to the Lower Permian Chase Group (Figure 11). Based on the occurrence of springs within the Martin Creek drainage, primary aquifer unit is the 80 foot-thick Barneston Limestone, The Barneston consists primarily of carbonate (limestone and dolomitic limestone) rocks assigned to the Fort Riley Limestone and the Florence Limestone members, separated where it is present by a shaley carbonate of the Oketo Shale Member. Downdip of the outcrop belt in Riley County, core samples of the Barneston reportedly contain minor amounts of gypsum and anhydrite that occur as thin partings and nodules.

Acting over long periods of time, the continued movement of ground water through the limestones has created an integrated network of solution-widened fractures and conduits of varying size. The scale of these features ranges widely from fractures with apertures that are tenths of an inch (several millimeters) wide up to master conduits up to several feet (1 m) in diameter. The exposed bedrock around the spring site consists of the thick-bedded limestones of the lower Fort Riley Limestone. The spring house obscures the view of the point of discharge from the bedrock. However, from the surface geology it appears that the ground-water source for the spring is the upper part of the Florence at the same stratigraphic level as a cave passageway exposed in the wall of the nearby Sunflower rock quarry.

Within its catchment ground water is transported through an integrated network of fractures and conduits to Crystal spring. Rapid entry and movement of surface water into solution-widened fractures and conduits is facilitated by sinkhole-like openings in the streambed of a reach of Martin Creek, approximately 2.5 miles to 3 miles (4 kilometers to 4.8 kilometers) north of the spring (Figure 9). A monitoring well was completed through the Barneston Limestone and installed 700 feet (213 meters) east of Martin Creek and the sinkhole furthest downstream to continuously monitor water levels in the Barneston Limestone. Water levels in the Barneston Limestone fluctuate over several 10s of feet (up to 10 meters) depending on the occurrence and duration of wet and dry periods (Figure 12). Periods of high water levels in the aquifer coincide

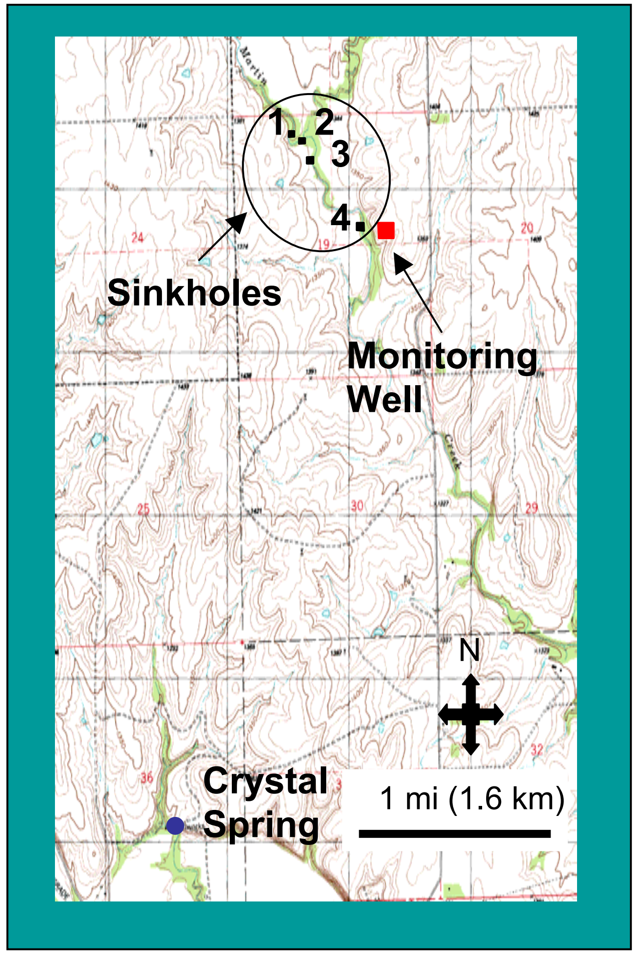

Figure 9. Location of the sinkholes and monitoring well in the Martin Creek drainage with respect to Crystal spring located along the north wall of the Cottonwood River valley.

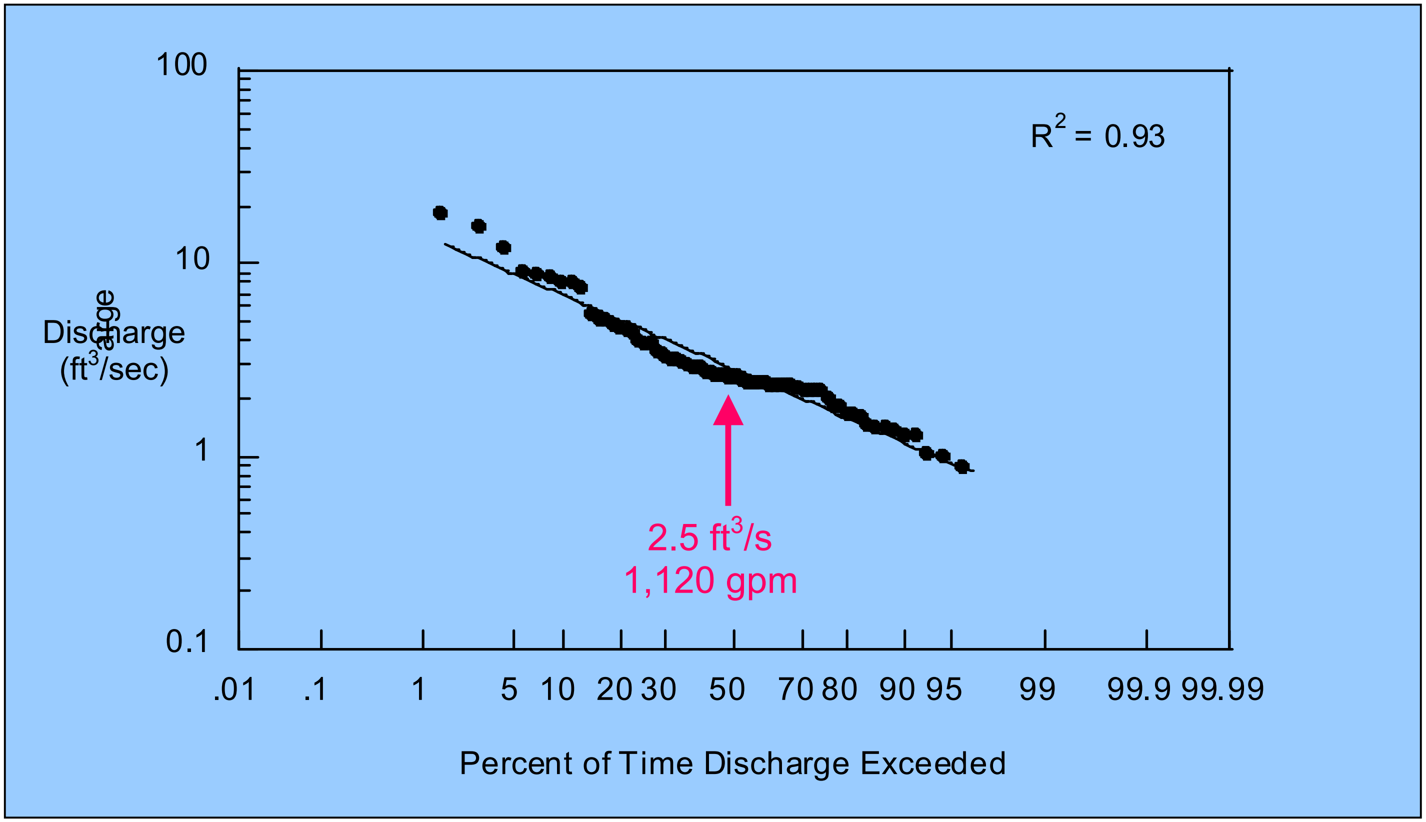

Figure 10. Crystal spring discharge values measured during 2000 and 2002-03.

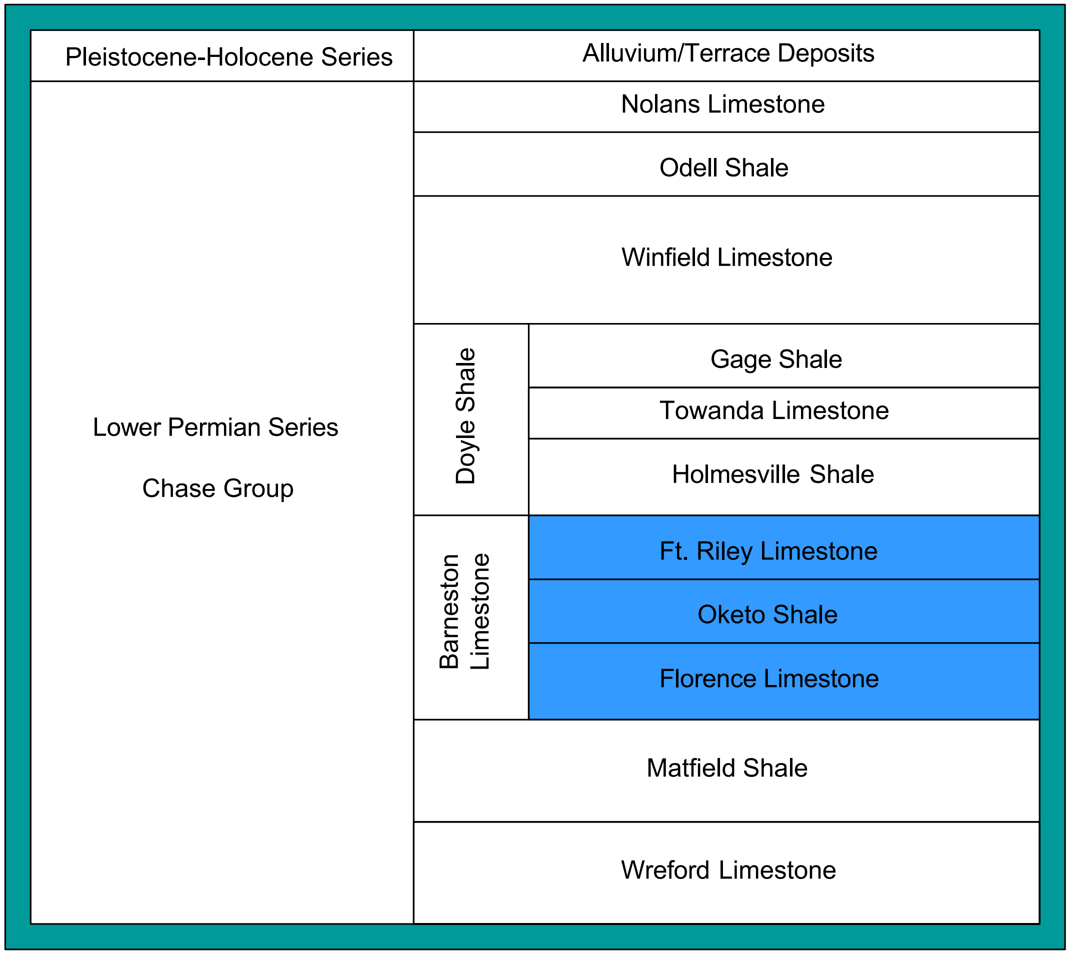

Figure 11. Stratigraphy of the lower Permian Chase Group. The units that comprise the Barneston aquifer are highlighted in blue. Other aquifers of regional significance include the Wreford Limestone, the Towanda Limestone Member of the Doyle Shale, the Winfield Limestone, the Nolans Limestone, and the Alluvium/Terrace deposits.

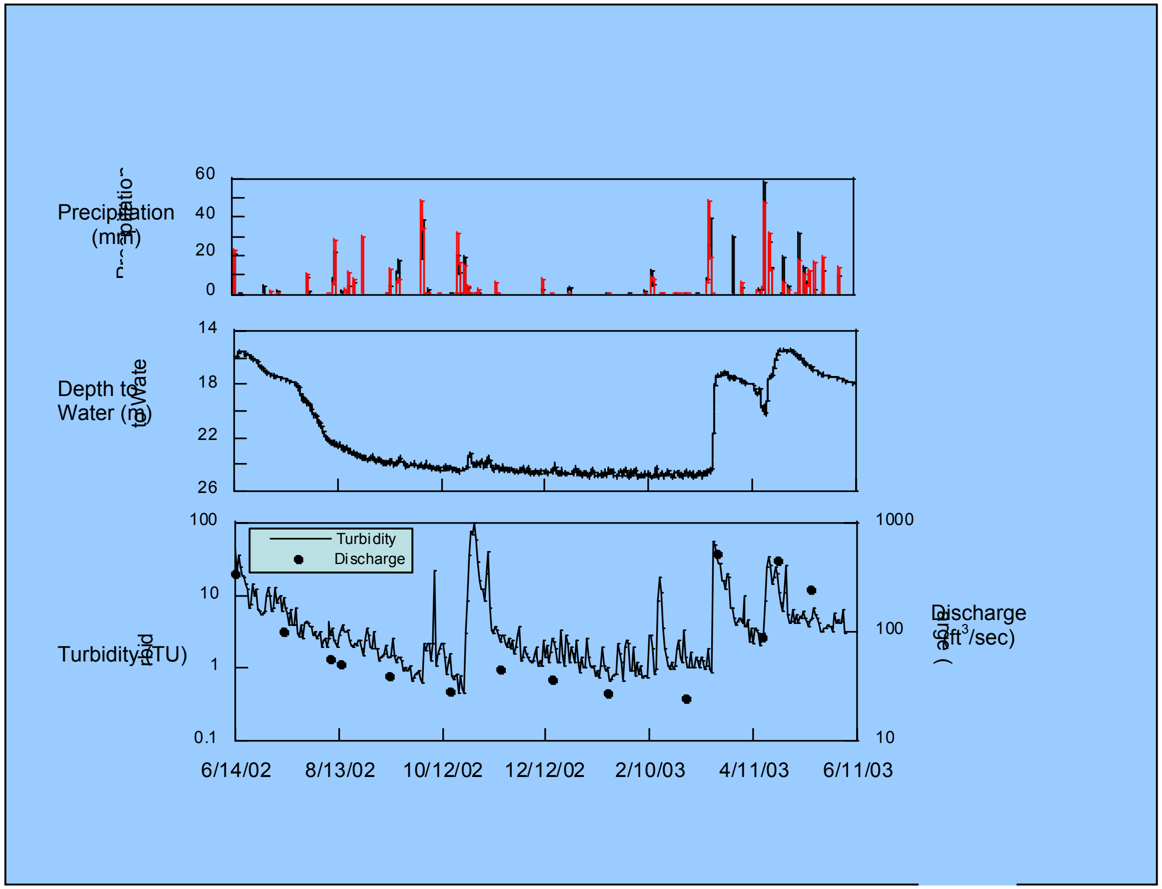

Figure 12. Relationship between precipitation (for two nearby stations shown in black and red), depth to water in the monitoring well, and turbidity and discharge at Crystal spring.

with streamflow events. Water levels are generally low during extended dry periods, such as occur during the summer, fall, and winter seasons and are high during the spring season.

Dye-trace experiments conducted during a relatively dry period indicated travel times through the ground-water system of approximately 60 hours from sinkholes to the spring, indicating dye travel velocities of approximately 1 mi per day (1,500 m per day).

Spring discharge and turbidity are lower but dissolved solids concentrations are higher during dry than during wet periods. Spring discharge water quality reflects geochemical interactions between the ground water and a limestone aquifer (Figure 13). Calcium and bicarbonate dominate the dissolved ionic constituents. Dissolved solids concentrations ranged from 311 mg/L to 410 mg/L in samples of Crystal spring collected during the Winter and Spring 2002 water sampling events. To monitor changes in water quality, samples of water were collected from Crystal spring monthly from April 2002 to June 2003 and analyzed for sulfate, chloride, and nitrate concentrations. Sulfate, chloride, and nitrate ranged from 12 mg/L to 42.4 mg/L, 4.5 mg/L to 8.5 mg/L, and 2 mg/L to 9 mg/L, respectively.

The relationships between precipitation events and spring discharge, turbidity, and chemistry, precipitation and water levels in the aquifer near Martin Creek, and the short travel time between the sinkholes and the spring indicate that the creek is a major contributor of water to Crystal spring during wet periods (Figure 14). The other major contributor is the drainage from the part of the aquifer where the solution openings are small scale and less well connected. This source sustains spring discharge during drier periods.

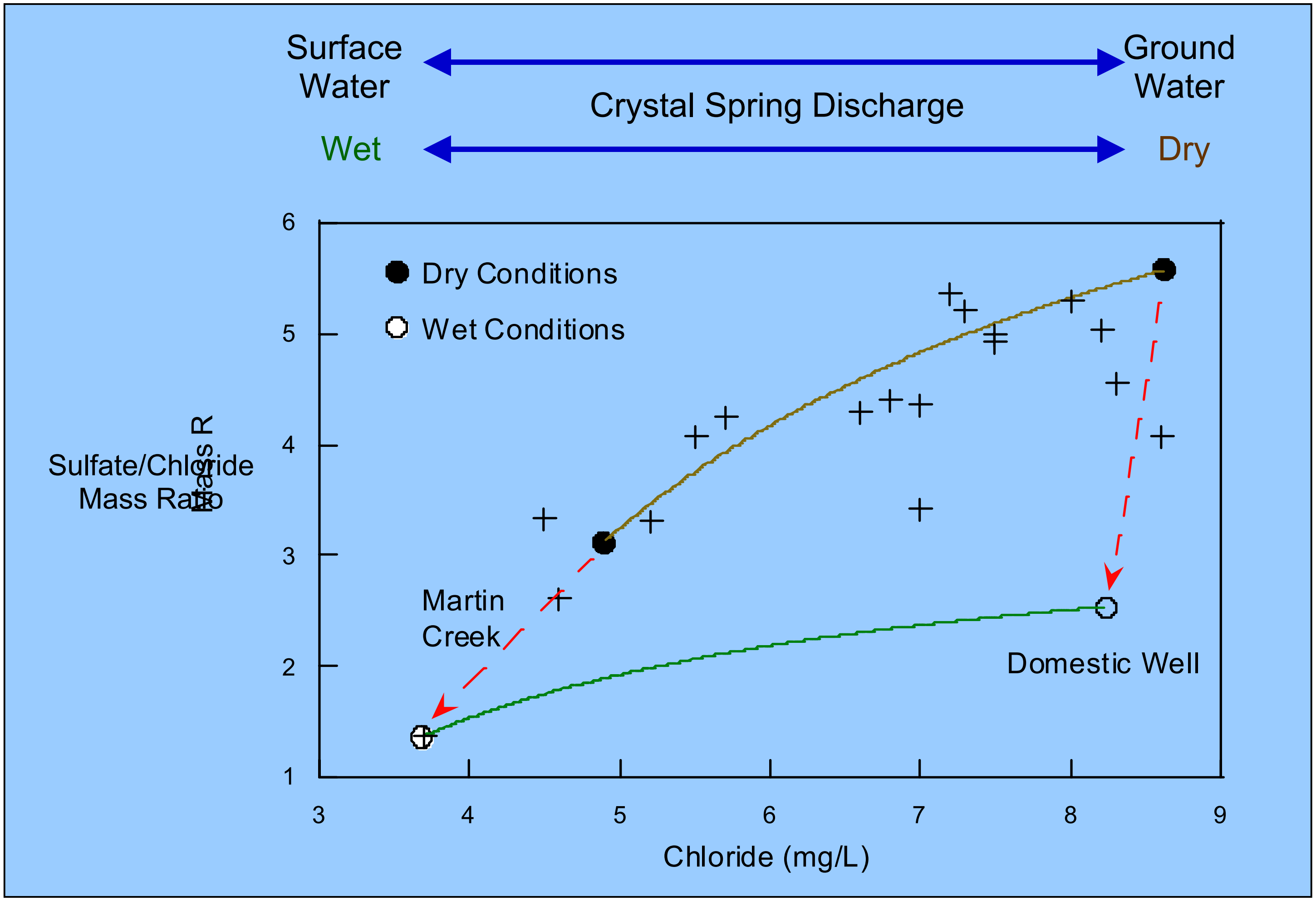

Figure 13. Wet and dry period mixing curves plotted on a graph of chloride *vs.* the sulfate/chloride mass ratio for the end members, Martin Creek, and a nearby domestic well (SE NE NE Sec. 18, T. 20 S., R. 5 E.). Martin Creek represents the surface water that enters the sinkholes in Martin Creek. The domestic well represents the regional ground-water chemistry in the Barneston aquifer. The points plotted on the graph are for the water samples collected from Crystal spring in 2000 and 2002-03.

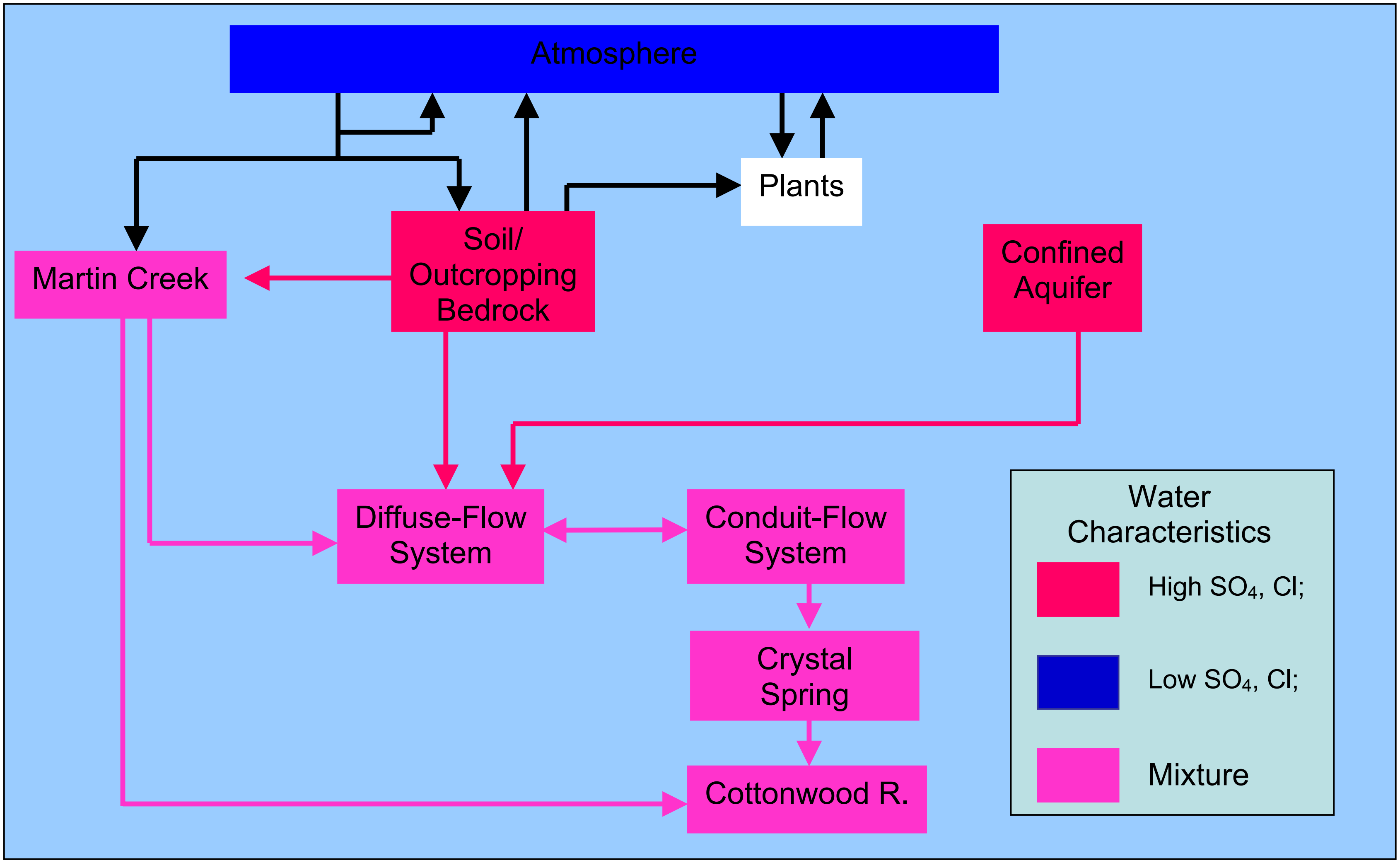

Figure 14. Schematic showing the flow of water and its geochemical character as it flows through the Crystal spring catchment to the Cottonwood River.

Natural Evaporite Dissolution in Central Kansas

The following discussion of natural evaporite dissolution in central Kansas is taken from a number sources, including Merriam (1963), Lane and Miller (1965), Watney and Paul (1980), Gogel (1981), Gillespie and Hargadine (1981, 1986), Sadeghipour et al. (1987), Walters (1991) Anderson et al. (1995), and Watney et al. (2003).

Evaporite dissolution has impacted the Lower Permian Herrington Member of the Nolans Limestone, the Wellington Formation, and the Ninnescah Shale and overlying Lower Cretaceous bedrock units and Cenozoic deposits (Figure 15). The Herrington consists of dolomitic limestones and thin interbedded tan shales. The limestones tend to be vuggy where dissolution has removed gypsum and other evaporites from the rock. The Wellington consists of a lower unnamed member, the middle Hutchinson Salt Member, and an upper unnamed member. The Hutchinson Salt is present in the subsurface under much of central and southcentral Kansas and adjacent northcentral Oklahoma (Figure 16). The Hutchinson is almost entirely bedded salt with minor interbedded shales, anhydrite, and gypsum. The upper member of the Wellington and the overlying Ninnescah consist primarily of gray shale and siltstone with minor amounts of gypsum and anhydrite. Lower Cretaceous units consist of shales, siltstones, and sandstones that belong to the Kiowa and Dakota formations. Unconsolidated Tertiary and Quaternary deposits overlie the bedrock surface over much of this part of central Kansas, including the *Equus* beds, and alluvium and terrace deposits associated with the Smoky, Saline, Solomon, and Arkansas river valleys. Dip on the bedrock units is westward, and the updip edge of the Hutchinson Salt Member trends from Salina southward through Newton, Wichita, and Wellington.

Evolution of the Smoky Hill and the Arkansas drainages is intimately tied to subsidence along the updip edges of the Permian bedrock units due to evaporite dissolution, primarily in the Hutchinson Salt Member of the Wellington Formation (Figure 17). Recurrent deep-seated structural movement of basement blocks has activated new and reactivated existing fracture sets, which allowed small downward flows of fresh ground water across dominantly shaly rocks. Throughout the Cenozoic, erosion has been actively stripping off the overlying Cretaceous and Permian bedrock units, bringing the updip edge of the evaporite-bearing rocks closer to land surface and within the realm of circulating fresh ground water. Unloading associated with erosion of the overburden changed the stress field and resulted in the development of joint and fracture systems in the Permian shale and siltstone units above the evaporite deposits. These joint and fracture systems facilitated greater downward flows of ground water across the low permeability shales and siltstones of the upper Wellington and Ninnescah. Within the shale units, volume expansion associated with the conversion of anhydrite to gypsum would have also opened up new fractures in the shales and siltstones. Thus, the shallow fresh ground-water system began to dissolve the evaporites and initiate subsidence of the overlying strata. Dissolution removed evaporites causing fracturing of the overlying shale and siltstone units and subsidence of the land surface, all of which helped to localize the river drainage and alluvial deposition along the developing dissolution zone. Consequently, *Equus* beds sediments now fill a 50-mile long trench along a corridor more than 300 square miles in extent from McPherson to Wichita created by the dissolution of more than 200 feet of halite. Collectively, the fractured shale and karstified underlying Chase Group limestone units form a zone eastward of the

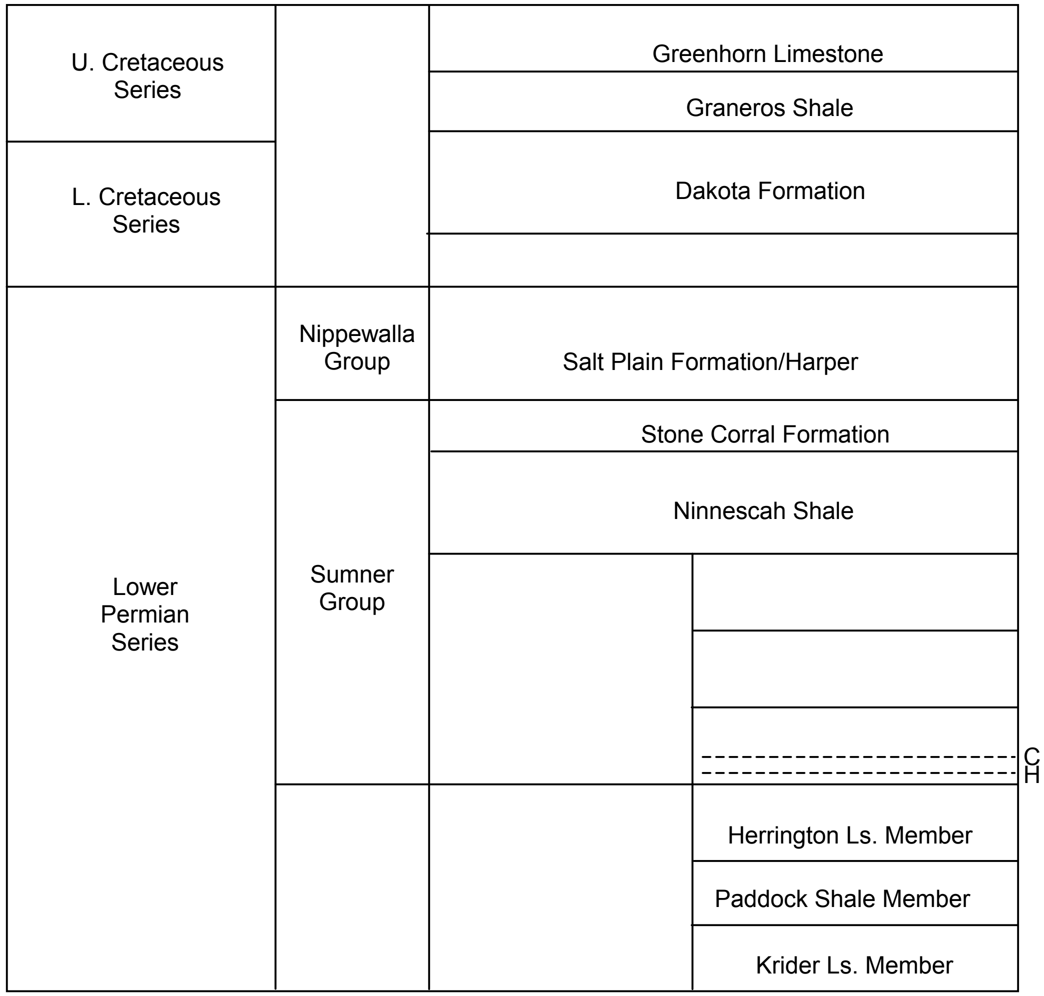

Figure 15. Stratigraphic column showing the bedrock units in the central Kansas region. In the lower part of the Wellington Formation, H marks the base of the Hollenberg Limestone and C marks the base of the Carlton Limestone Members of the Wellington Formation.

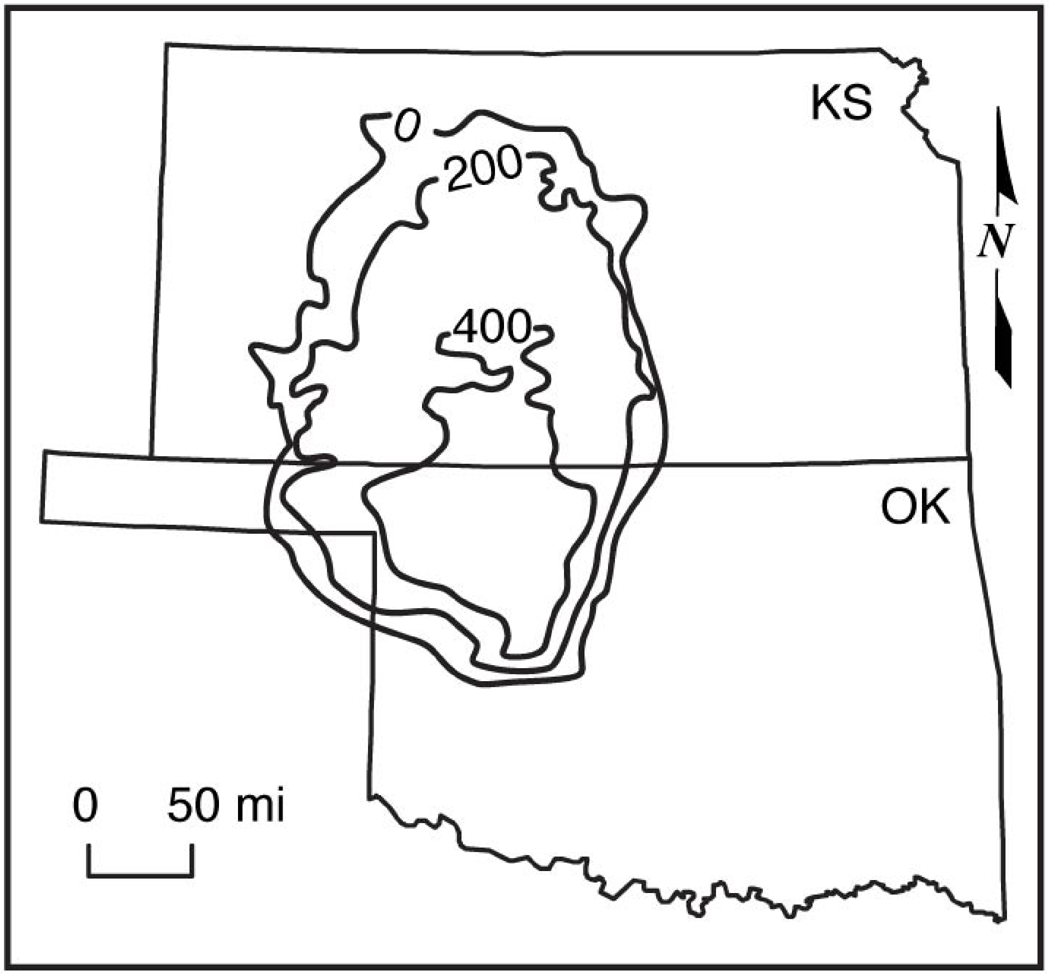

Figure 16. Extent and thickness of the Hutchinson Salt Member, Wellington Formation.

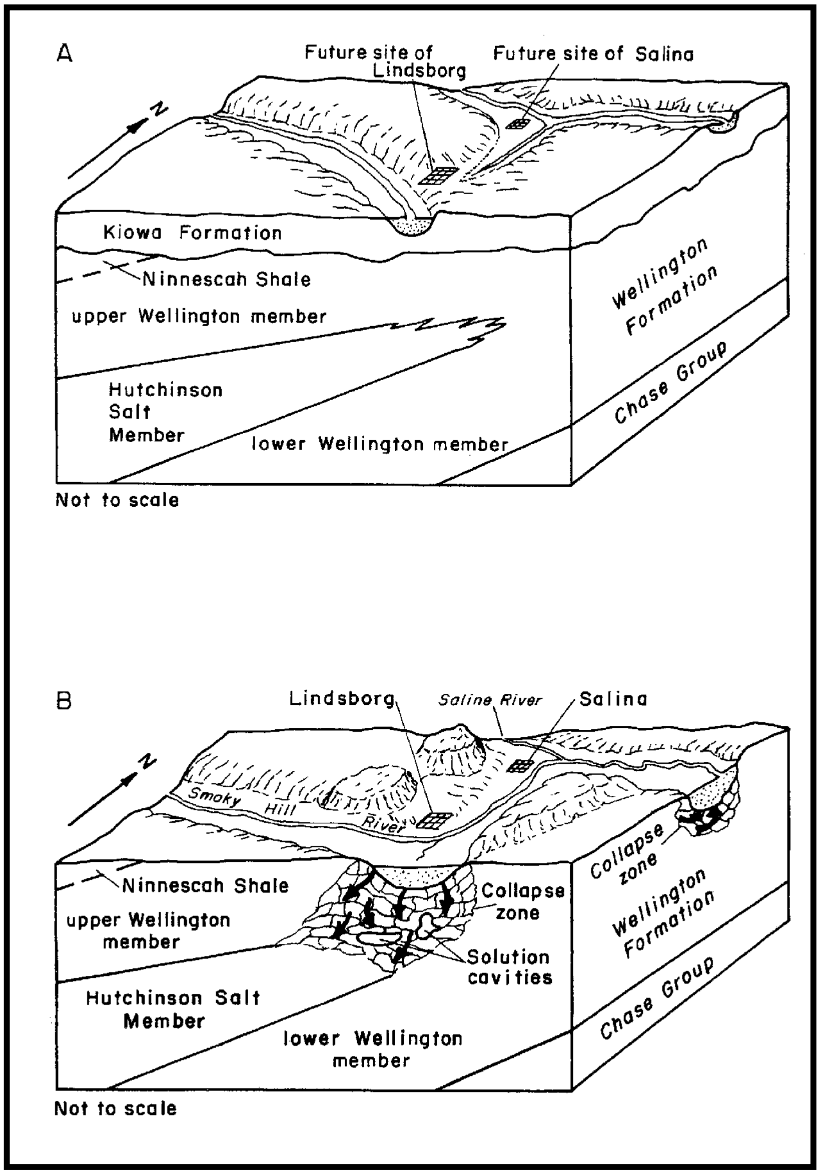

Figure 17. Development of the evaporite dissolution zone at the up-dip edge of the Hutchinson Salt Member of the Wellington Formation in central Kansas.

dissolution front extends from Salina southward to the Kansas-Oklahoma border and is referred to as the Wellington aquifer (Figure 18). With the drainage localized above the dissolution zone, fracturing and subsidence of overlying shales and siltstones accelerated due to increased flushing by local ground-water flow systems. In some cases overlying, permeable sand and gravel deposits filled open fractures and solution channels to enhance permeability of the brecciated bedrock. These fracture fillings resulted in a more integrated network of permeable fractures that increased the flow rate of the shallow ground-water system and the intensity of the evaporite dissolution. Increased intensity of dissolution has resulted in coalescence of sinkhole and closed depression features into subsidence basins and has further enhanced fracture and solution channel permeability. The formation of sinkholes and subsidence features at the surface is a reminder that the dissolution front and adjacent dissolution zone continue develop naturally and in many cases, enhanced by human activity.

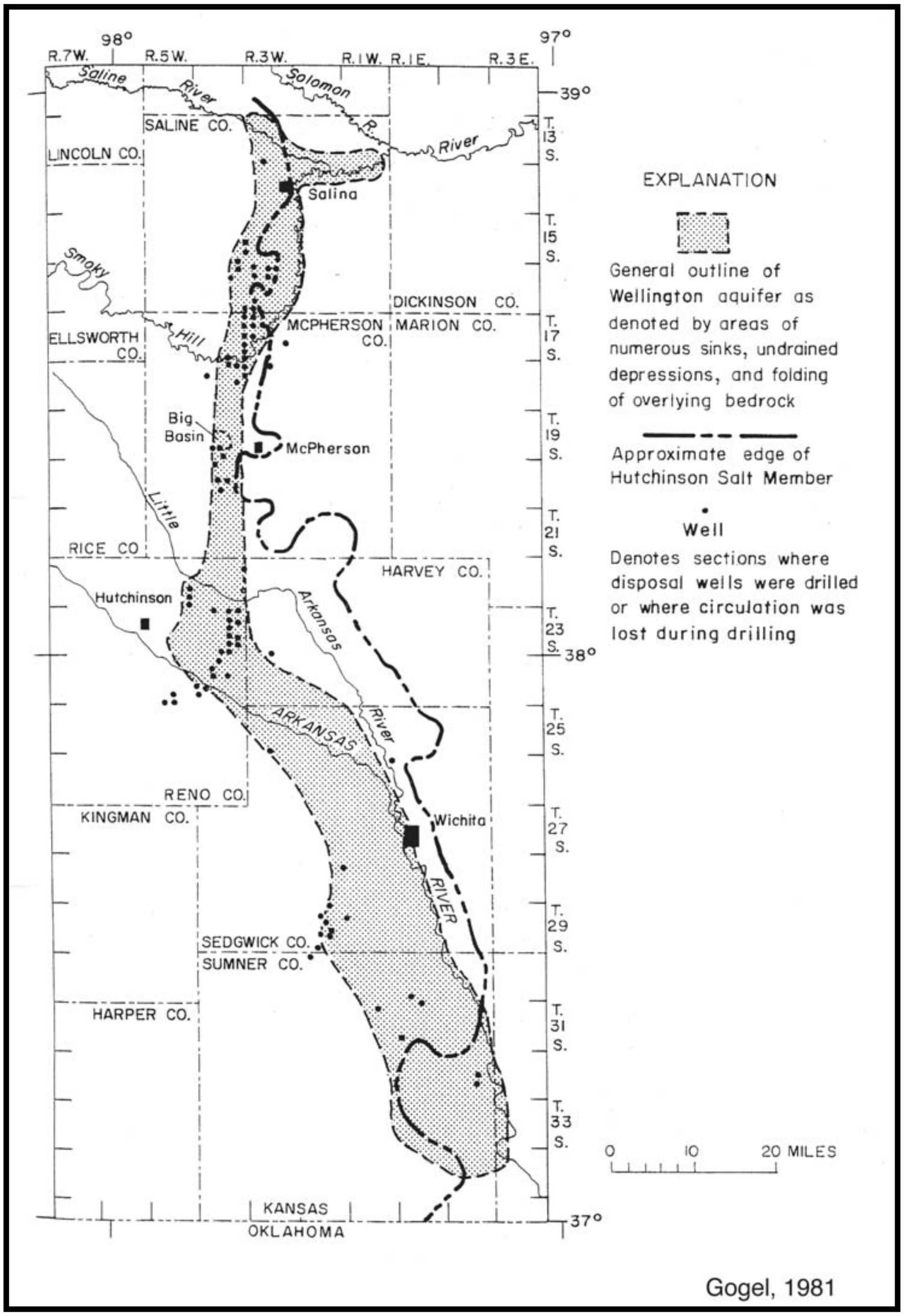

Figure 18. Extent of the Wellington aquifer and the current, updip edge of the Hutchnson Salt Member of the Wellington Formation. Also shown are the locations of wells that formerly were used to dispose of oil-field brines into the aquifer.

Florence to Hutchinson

Figures 7, and 19 show the surface geology in Marion and Harvey and Reno counties, respectively. This segment of the fieldtrip takes us from the Flint Hills and through the Wellington-McPherson Lowland to the Arkansas River Lowland region of Kansas (Figure 19). Within this segment of the trip we pass over upper Chase Group and Sumner Group rock units. The character of the bedrock units changes from interbedded shales and limestones to interbedded fractured and slumped shales and solutioned evaporates. Variable thicknesses of Pliocene to Recent sediments mantle the bedrock in much of the Wellington-McPherson and Arkansas River Lowland regions. At the surface closed depressions mark subsidence features resulting from natural or anthropogenically-induced dissolution in western Harvey and Reno counties.

Mile Post	Description
302.1	Turn right on US 50 and proceed towards Newton, continuing up Doyle Creek drainage.
301.5	Junction US 77. The bedrock is Ft. Riley Limestone.
299.5	The Towanda Member of the Doyle Shale and the Winfield Limestone form the south valley wall of Doyle Creek.
297.2	Crossing the Doyle Shale/Winfield Limestone contact
293.7	Crossing the outcrop of the Herrington Member of the Nolans Limestone.
293	Crossing the poorly exposed outcrop of the Hollenberg Limestone Member of the Wellington Formation. Stratigraphically, the Hollenberg is located near the bottom of the Wellington Formation.
290.4	Cross the bridge over the BNSF railroad tracks at Peabody.
288.2	Marion-Harvey County line.
284.5	Crossing the outcrop of the poorly exposed Carlton Limestone Member of the Wellington Formation.
281.5	US Highway 50 overlies Quaternary loess deposits.
281.3	Enter the town of Walton
275.4	US Highway 50 - Interstate 135 Interchange. Interstate 135 loops around the eastern and southern sides of the city of Newton. Take Exit 30 to Hutchinson on US Highway 50.
271.7	Sand Creek crossing.
268.2	East Emma Creek crossing
266.4	West Emma Creek crossing. Note the hummocky topography typical of an area of stabilized sand dunes. In this area, ground water in the *Equus* Beds aquifer has high nitrate (above 10 mg/L) due to dairy and calf feeder operations. There is a thin, permeable vadose zone above the aquifer, and the aquifer begins to pinch out in this area.
264.5	Access road to the city of Halstead, offices of the *Equus* Beds Groundwater Management District 2.
263.3	Black Kettle Creek crossing

262.3	Little Arkansas River crossing
255.4	Enter the city of Burrton. In the surrounding area, surface evaporation pits and the injection wells in the Wellington aquifer have been used to dispose of oil-field brines, resulting in significant contamination of the *Equus* Beds aquifer. Oil production has also resulted in dissolution of evaporites within the Wellington, which has resulted in the formation of subsidence at the surface in the form of sinkholes.
252.8	Harvey-Reno County line.
249.7	Victory Road-US Highway 50 intersection. Note surface subsidence as you drive across the Victory Road sink.
248-247.7	Water filled depression caused by natural subsidence of unconsolidated sediments and shallow bedrock from natural salt dissolution.
241.8	Take the exit ramp from US Highway 50 to Kansas Highway 61 and proceed north 2.6 miles to 11th Avenue in the city of Hutchinson. Turn right into the China Star parking lot. In 2005 the options for lunch include the China Star buffet, Fazoli's Italian fast food, or McDonald's. Following lunch, turn left onto 11th avenue and into the left turn lane. Proceed to Avenue G on Kansas Highway 61 for approximately 1.15 miles, just beyond the overpass. Make a left turn onto Avenue G and proceed east to Charles Street for a distance of 0.75 miles. Turn left on Charles Street to the intersection with Carey Street, a distance of 0.4 miles. Proceed through the fenced area to the IMC subsidence.

Stop 2: Hutchinson Salt Plant[1] (Human-induced Evaporite Karst, Figure 19)

In and near the city of Hutchinson, where salt has been mined continuously since 1888, four documented areas of land subsidence developed prior to the most recent 2005 event (Walters, 1977; Table 1).

Table 1. Documented salt-sink collapses in the Hutchinson area related to solution mining. Taken from Walters (1977).

Year	Company	Area	Remarks
1914	Morton Salt Co.	Southwest of the city	Rapid surface collapse
1925	Carey Salt Co.	Downtown	Minor slow subsidence
1952	Barton Salt Co.	Southeast of the city & northeast of the plant	Ground subsidence with fresh ground water entering the associated brine well
1974	Cargill Inc.	Barton Salt Co. plant & south of the plant	Rapid surface collapse. Sinkhole grew in size from 200 to 300 feet in diameter. Partially filled with fresh ground water to a maximum depth of 39 feet. Water level at 21.5 feet below ground surface.

Underlying the city of Hutchinson, below 8 feet of loess-like soil, are 50 feet of coarse cross-bedded loose sands and gravels that form the shallow aquifer. The underlying bedrock is Lower Permian reddish brown shale belonging to the Ninnescah Shale and Wellington Formation with a total thickness of 350-400 feet. Beneath the shale are 350 feet of salt beds belonging to the Hutchinson Salt Member of the Wellington Formaation.

All of the events cited in Table 1, including the most recent, are associated with the old method of solution mining using casing set at or near the top of the salt, which results in uncontrolled dissolution. In the older method (practiced from 1888 to the 1960s), the brine well casing was set at the top of the salt and a string of tubing was inserted and lowered to the bottom of the salt section to be mined. Fresh ground water was injected down the tubing and the brine was allowed to flow back to the surface under the pressure of the injected flow. A pressure-tight cavity was required, a condition usually prevailing in the early life of the well. By this method of operation salt was dissolved upward from the bottom in the salt zone with extended operation due to the buoyant rise of fresher water in the growing cavity. This in turn caused breakage of the tubing as a result of the dislodgement and falling of undermined ledges of shale and anhydrite, which in turn, exposed shallower salt beds. Dissolution and removal of shallower salt beds allowed the

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[1] Stop 2 is on private property any visitors should check with the plant owners or their representatives before proceeding with a site visit. Also, the order of the stops was changed to accommodate meeting with a site guide after lunch on the day of the fieldtrip. Thus, the lunch stop was made at Hutchinson prior to visiting Stop 2.

circulating water access to the shale roof rock. Ultimately, the cavities would merge to create what was referred to as a gallery and thus tremendously increasing the span of the unsupported roof. The end result of this method is considered to the directly related to roof collapse and ultimately to localized surface subsidence, including sinkhole formation. The most recent sinkhole formed in early January 3, 2005, near the old Carey Salt plant site and the Burlington Northern-Santa Fe railroad tracks (Figure 20).

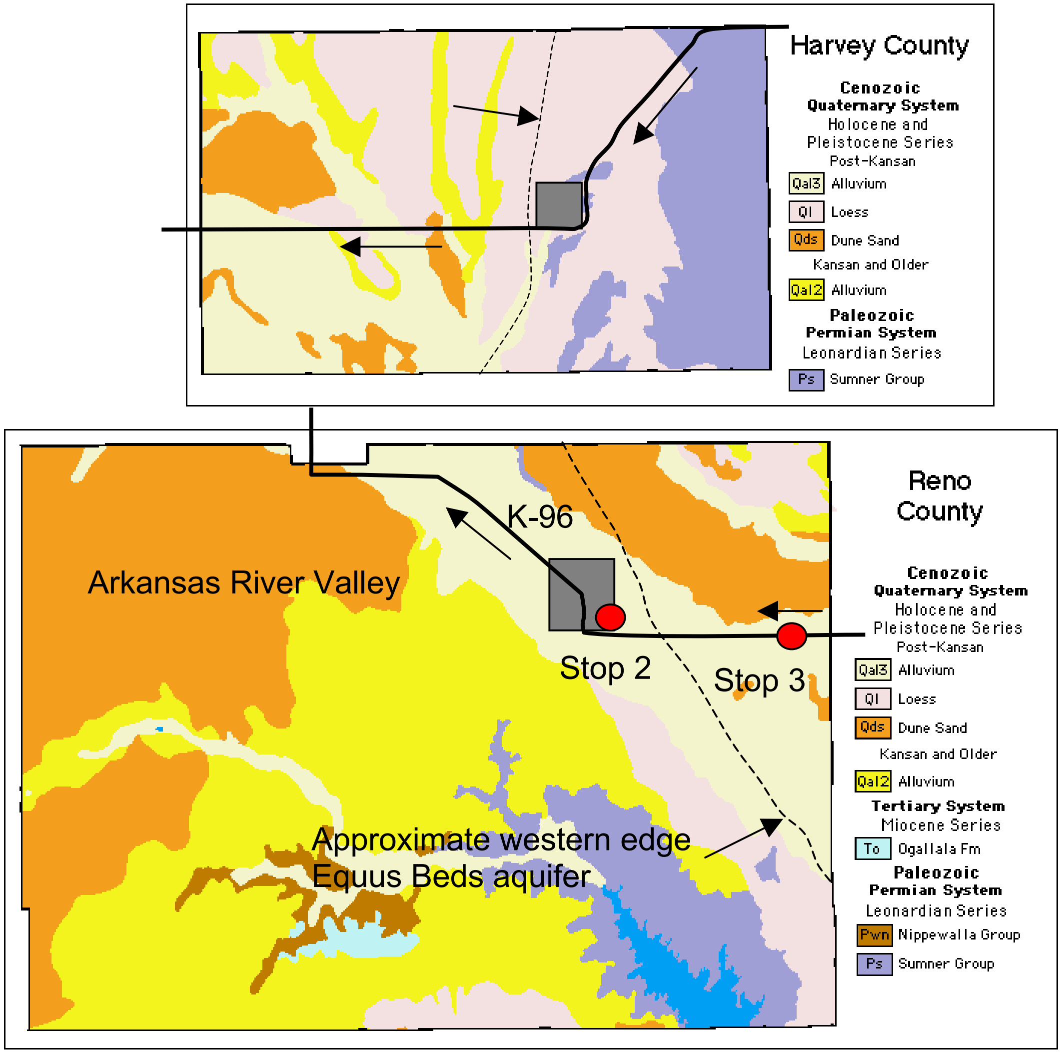

Figure 19. Surface geology along the fieldtrip route through Harvey (above) and Reno (below) counties. Note the approximate eastern and western extents of the *Equus* beds aquifer.

Figure 20. Panoramic view of the sinkhole that developed at the Carey Salt plant site in Hutchinson, January 2005 as it appeared near the time of its formation. The sinkhole has continued to grow undermining the railroad spur on the right side and encroaching on the main line of the Burlington Northern-Santa Fe main line in the background.

From Stop 2 to Stop 3 (the US Highway 50-Victory Road Subsidence Feature)

Mile Post	Description
	From Stop 2 proceed south to Carey Blvd. across the plant site. Turn left on Carey Road and proceed for a distance of 0.75 miles. Turn right onto South Halstead Street for 1.4 miles. Turn left onto US Highway 50 and proceed to the intersection with Victory Road, a distance of 7 miles.
249.7	Stop 3 at the intersection of Victory Road and US Highway 50.

Stop 3: Hutchinson Area- US 50 & Victory Road (Natural Evaporite Karst, Figure 21)

The Wellington aquifer is defined as a discontinuous zone of solution cavities and collapsed beds in the Wellington Formation behind an advancing salt-dissolution front at the up-dip eastern edge of the Hutchinson Salt and vuggy carbonates of the Nolans Limestone in the Smoky Hill River valley near Solomon, Kansas (Gogel, 1980; Gillespie and Hargadine, 1981, 1986). Conceptual numerical models of the flow system in the Wellington aquifer indicate that ground-water flow is controlled by the combined effects of topographic relief, regional variations in aquifer permeability and thickness, and the effects of underground disposal of oil-field brines. Model results show that ground-water in the Wellington aquifer moves southward from an area of higher fluid potential located north of this field stop toward regions of lower fluid potential in the Arkansas River valley near the Kansas-Oklahoma border. Local flow systems associated with the river valleys are believed to the primary cause of salt dissolution and the local development of the Wellington aquifer framework. Previous investigations indicate that dissolution has occurred throughout the Quaternary. However, in the last half century the rate of dissolution has accelerated locally as a result of extensive oil and gas drilling and related activities. The following is taken from Miller (2003).

Most of the upper 2,300 feet of the subsurface consists of Lower Permian shales and evaporates. The Sumner Group base (top of the Chase Group) is 750 feet below surface. The base and top of the Hutchinson salt are 375 feet and 525 feet below surface, respectively. These horizons are indicated as easily recognizable seismic reflectors within the shallow bedrock at this site. Bedrock is defined as the top of the Ninnescah Shale, with the unconsolidated Pliocene-Pleistocene *Equus* beds making up most of the upper 90 feet of sediment.

Figures 22 and 23 are the processed and interpreted reflection seismograms from seismic data acquired along two orthogonal kilometer-long profiles of this field site taken from Miller (2003). Line 1 is an east-west line that stretches along US Highway 50 east of Hutchinson and Line 2 is a north-south line along Victory Road (Figure 20). The lines intersect where the roads cross and near the center of the sinkhole's surface expression.

Mechanisms and gross chronology of structural failures, as interpreted from stacked seismic sections, suggest that initial subsidence and associated bed offsets occurred at high strain rates and were confined to a cone defined by reverse-fault planes. This process was active at least twice: once when the current 300-feet wide sinkhole developed and initially as the 1,050-feet wide dissolution feature originally formed as a single, relatively continuous event. This 1,050-feet wide footprint could also be the result of dozens of distinct events that occurred during the last million or so years. Separating each of the periods of rapid subsidence was a long period of gradual subsidence. These episodes of gradual subsidence continued in the subsurface, producing an ever-expanding bowl, the extent of which is defined by normal-fault planes until roof-rock failure above the salt reactivates during a period of high stress-relief. The rate of destabilization and failure, as well as the load-bearing potential of the rock layers above the zones of dissolution, strongly influenced the original subsidence geometries and dimensions as well as the subsequent reactivation of subsidence along the two profiles in Figures 22 and 23. With its history potentially extending back as far as the mid-Tertiary, it is unlikely that subsidence will end within the next millennium at this site. Until the highway started sinking here in 1998, little if any subsidence seems to have been associated with this paleosinkhole throughout late Quaternary time. This long period of inactivity, followed by localized, rapid subsidence observed at this site, makes it reasonable to expect other small sinkholes to develop without warning above this or other similar paleofeatures in this area. Considering the interpreted bed geometries, surface subsidence at the current sinkhole site will continue along its northern and eastern edges, elongating the sinkhole in those directions. Besides the obvious disruption to the road system, this subsidence feature unfortunately provides a pathway between the fresh ground waters in the *Equus* beds and the remnant evaporates within the Hutchinson Salt interval. Surface subsidence will likely continue at a gradual rate for some time in the future. Sufficient bridging and undercompacted rock layers still exist beneath the surface expression of the sinkhole to sustain the current subsidence rate of approximately 1 foot per year for some time to come.

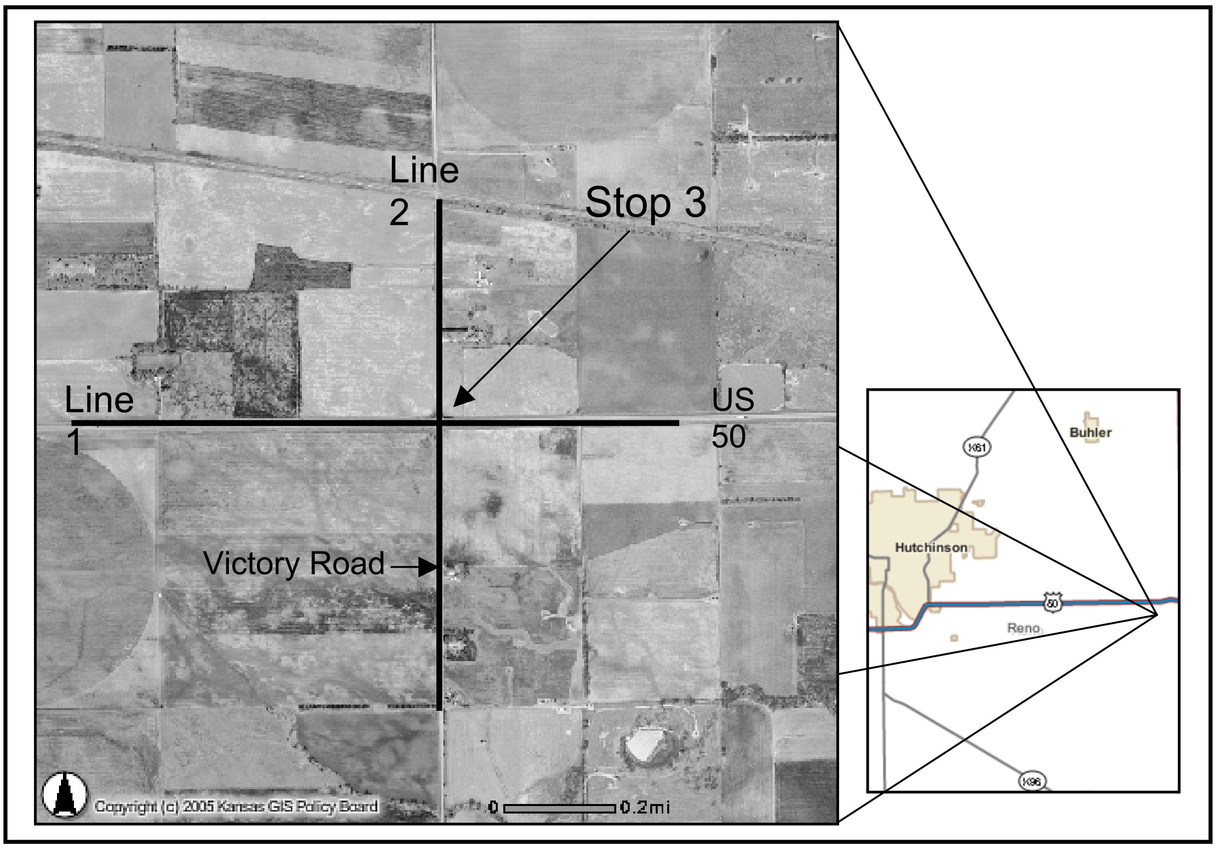

Figure 21. Location of the seismic profiles shown in Figures 22 and 23 at Stop 3.

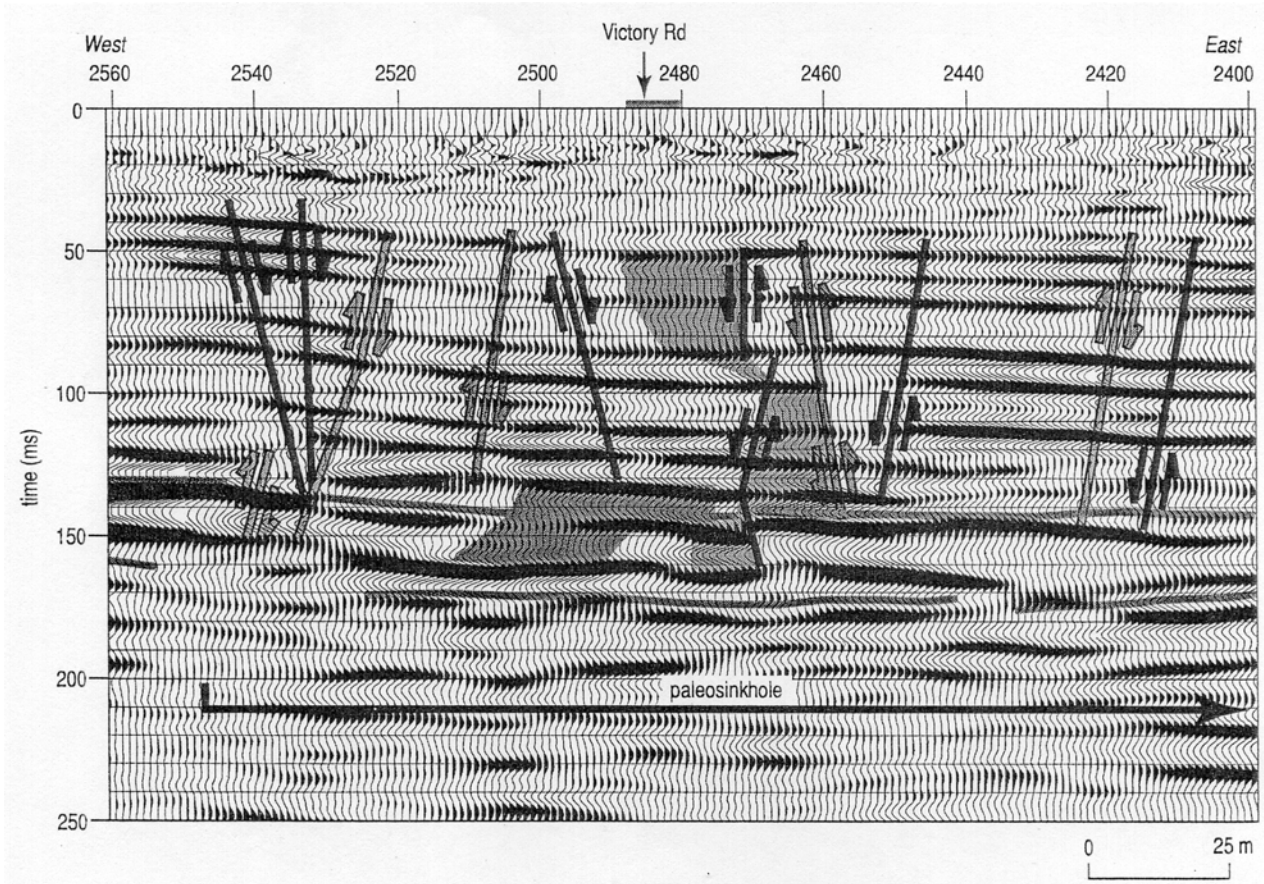

Figure 22. An interpreted seismic section along the segment of Line 1 near the US 50 – Victory Road intersection. The figure shows two different paleosinkhole margins as reverse-oriented faults (light gray) that formed after rapid strain release in a brittle-rupture fashion. This was followed by a low-velocity, low-stress release that formed a synform (bowl-shaped depression) bounded by normal-type faults (black). The most recent subsidence was again the result of rock failure and rapid strain release that formed the tensional dome resulting in bed subsidence along reverse-fault planes (darker gray, toward the center). Lighter shading (above) represents areas currently active, whereas darker shading (below) indicates areas for future concern. Taken from Miller (2003).

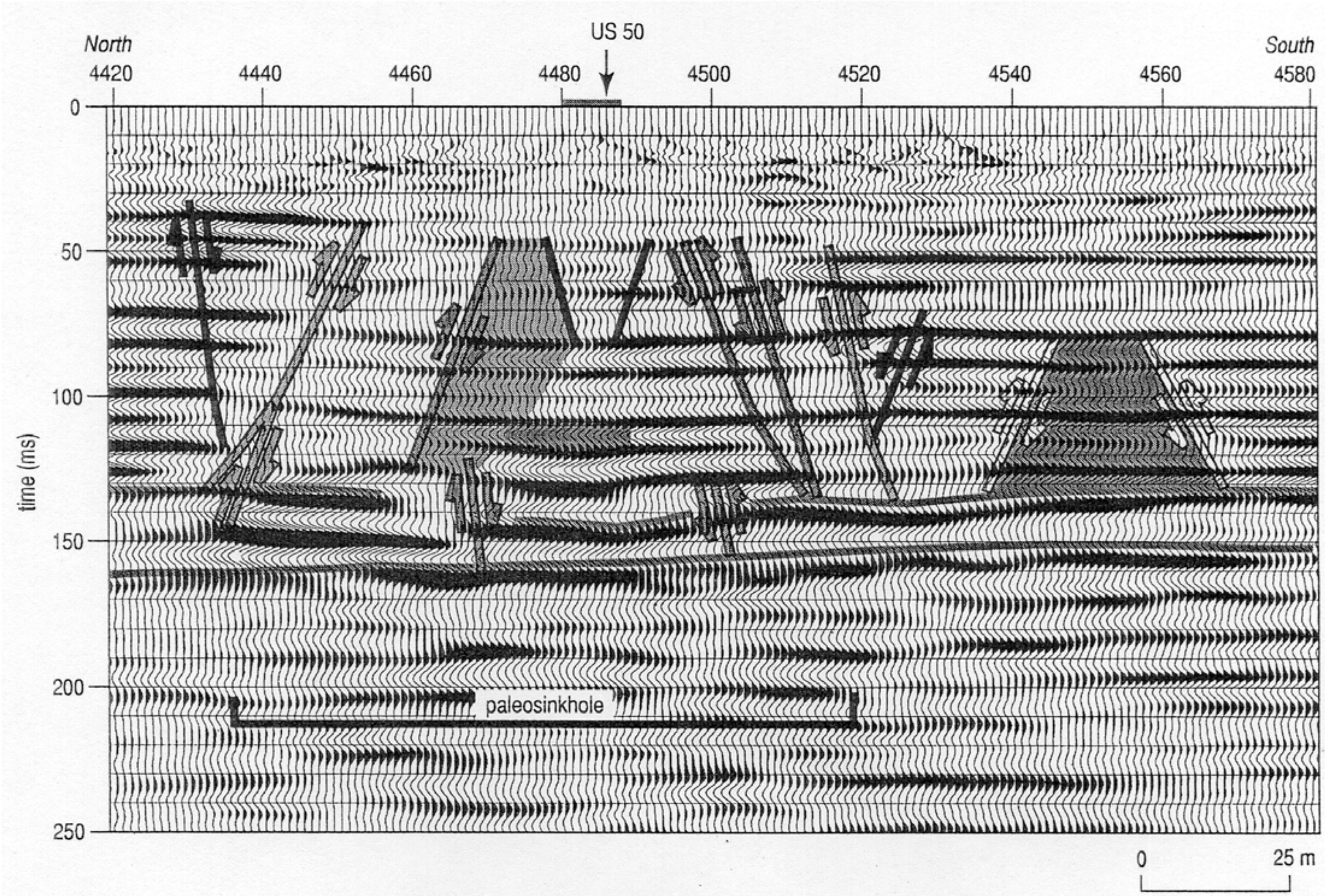

Figure 23. An interpreted seismic section along the segment of Line 2 near the US 50 – Victory Road intersection. The original sinkhole margins are indicated by reverse-oriented faults (light gray), which formed during rapid stress release from brittle-rock failure. This was followed by low-velocity, low stress release forming a synform (bowl-shaped depression) bounded by normal-type faults (black). The most recent subsidence was again the result of rock failure and rapid stress release that formed the tensional dome resulting in bed subsidence along reverse-fault planes (darker gray, toward center). Darker shading bounded by white reverse faults indicates an area for future concern. Taken from Miller (2003).

Hutchinson to Cheyenne Bottoms

Figures 19, 24, and 25 are maps showing the surface geology of Reno, Rice, and Barton counties, respectively, along the fieldtrip route. After crossing the Arkansas River on Kansas Highway 96, the road follows the Arkansas River up to Sterling and then north across the valley to Lyons. The surface geology from Hutchinson to Lyons consists of Arkansas River alluvium, terrace deposits, and dune sands that overlie bedrock units belonging to the Lower Permian Sumner and Nippewalla Groups and the Lower Cretaceous Kiowa Formation (Figure 15). From Lyons to Cheyenne Bottoms the bedrock units underlying variable thicknesses of Quaternary deposits are the Cretaceous Kiowa and Dakota formations along most of the route.

Mile Post	Description
249.7	Leave Stop 3 and proceed west on US 50 back to Hutchinson and Kansas Highway 61 junction.
241.8	Junction with Kansas Highway 61. Follow US Highway 50 - Kansas Highway 61.
240.9	Arkansas River
239	US Highway 50-Kansas Highway 61 – Kansas Highway 96 interchange
238.1	Junction with Kansas Highway 96. Exit and proceed towards Lyons.
238.3	Burlington Northern-Santa Fe railroad overpass
236.9	Yaggy gas storage field. It is believed that this is the source of the gas that caused the explosions in Hutchinson in 2001. Watney et al. (2003) hypothesized that gas migrated from the storage field along fracture planes in thin, dolomite layers above the Hutchinson Salt Member of the Permian Wellington Formation to abandoned and poorly plugged or unplugged wells in Hutchinson.
240.7	Enter the city of Nickerson and follow Kansas Highway 96 through town.
231.2	Cross the Arkansas River.
227.5	Kansas Highway 96 – Kansas Highway 14 junction.
115.4	Reno-Rice County line.
116	Cross the Arkansas River.
119.2	Enter the city of Sterling.
126.6	Cow Creek crossing.
128.4	Enter the city of Lyons.
129.4	Junction of Kansas Highway 96 and Kansas Highway 14 with US 56.

This section of the road log from taken from Buchanan and McCauley (1987).

234.4	Little Cow Creek crossing. This point marks the approximate boundary along US 56 between the Arkansas River Lowlands, to the west, and the southernmost extent of the Smoky Hills to the east. Alluvium, terrace deposits, and eolian sand underlie

	most of the area to the west; to the east, Cretaceous sandstones and shales have been eroded to form a rolling, upland topography.
232.5	This cross on the south side of the road is a monument to Father Juan de Padilla, who accompanied Coronado on his expedition to Kansas in 1541.
231.4	Cow Creek crossing.
230.9	Spring Creek crossing.
230	East edge of the Chase-Silica oil field.
229	Here the highway passes over Chase Channel, a buried river valley. The valley was formed by a southeasterly flowing stream that emptied into the McPherson Channel, buried valley beneath the *Equus* beds.
228.5	Enter the town of Chase.
228.4	This is the east edge of the sand hills. The town of nearby town of Chase is 0.2 miles north of the highway. A series of hills called Plum Buttes are 3 miles to the south.
226.3	Spring Creek crossing.
221.4	The Barton-Rice County line.
220	One mile south of the highway is the Panning sink, which developed as a result of the dissolution of evaporates in the Hutchinson Salt Member of the Wellington Formation. The sinkhole developed on April 24, 1959, around an oil well that had been converted to a disposal well for oilfield brines. Because of its construction, the well allowed disposed brines to come in contact with and dissolve out evaporites in the Hutchinson interval, which caused the subsidence at the surface.
217	West edge of the Chase-Silica oil field.
215.2	Enter the town of Ellinwood.
216.2	At the west edge of Ellinwood turn right onto NE 100 Avenue and proceed north approximately 7.5 miles to Kansas Highway 156. Proceed north 4.1 miles to Kansas Highway 4.
133.4	Turn left onto Kansas Highway 4 and proceed west.
131.9	Pull off the highway and into the turnout on the south side of the highway and proceed to the overlook, Stop 4

From Stop 4 follow the directions on the map (Figure 26) through Cheyenne Bottoms to the observation tower and the exit to Kansas Highway 156.

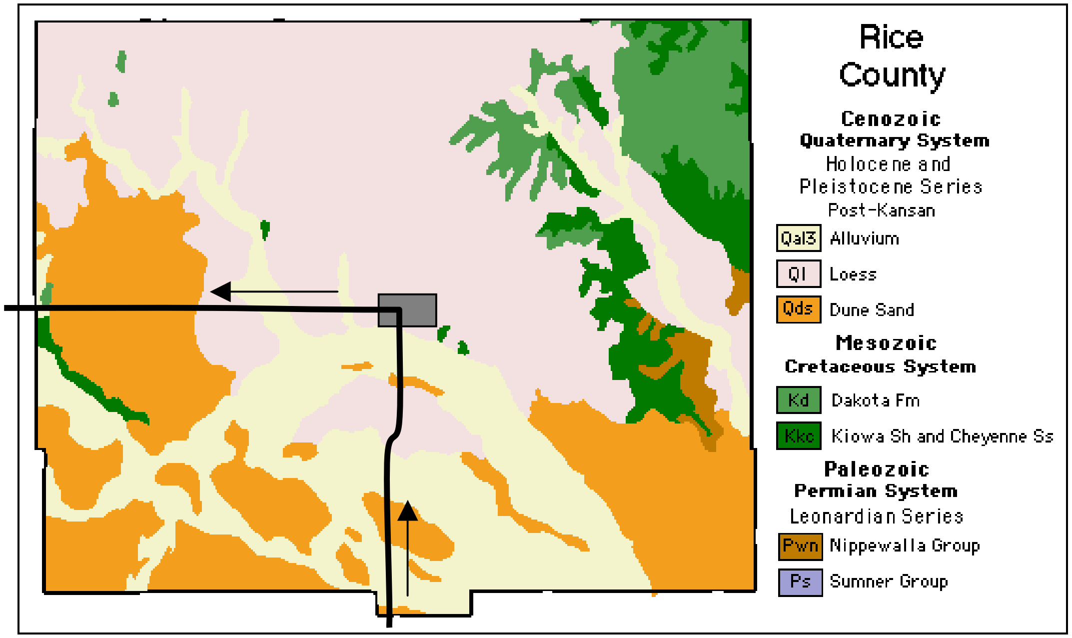

Figure 24. Surface geology of Rice County.

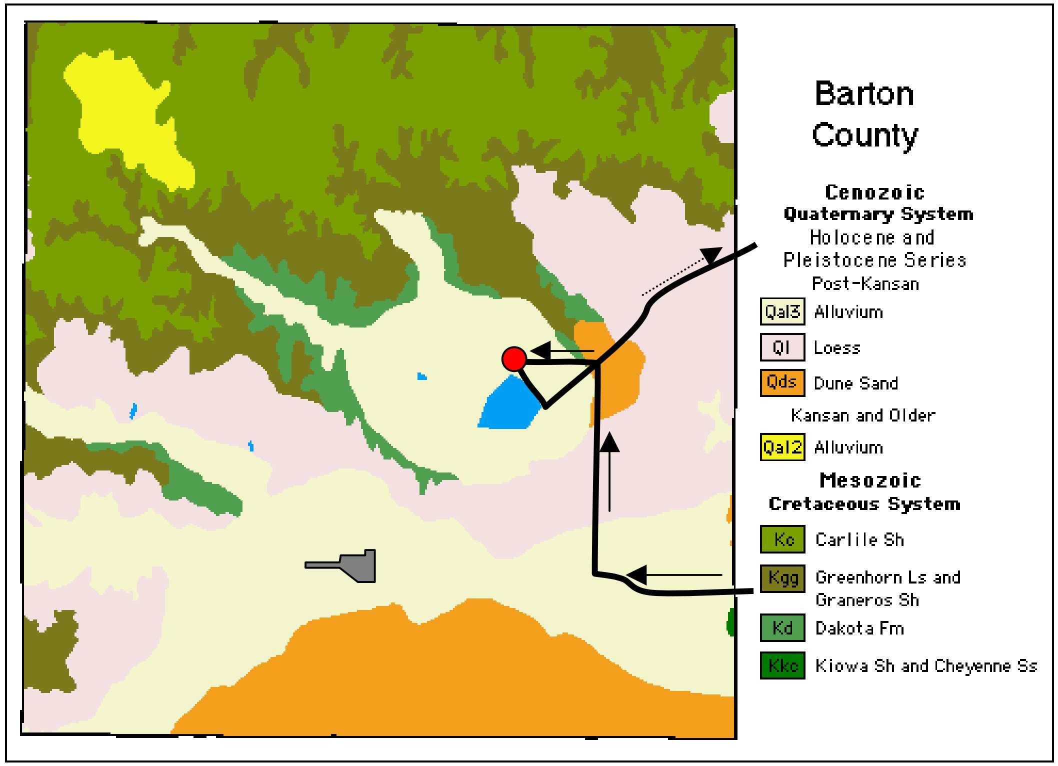

Figure 25. Surface geology of Barton County showing the fieldtrip route. The dashed arrow shows the return trip to Lawrence.

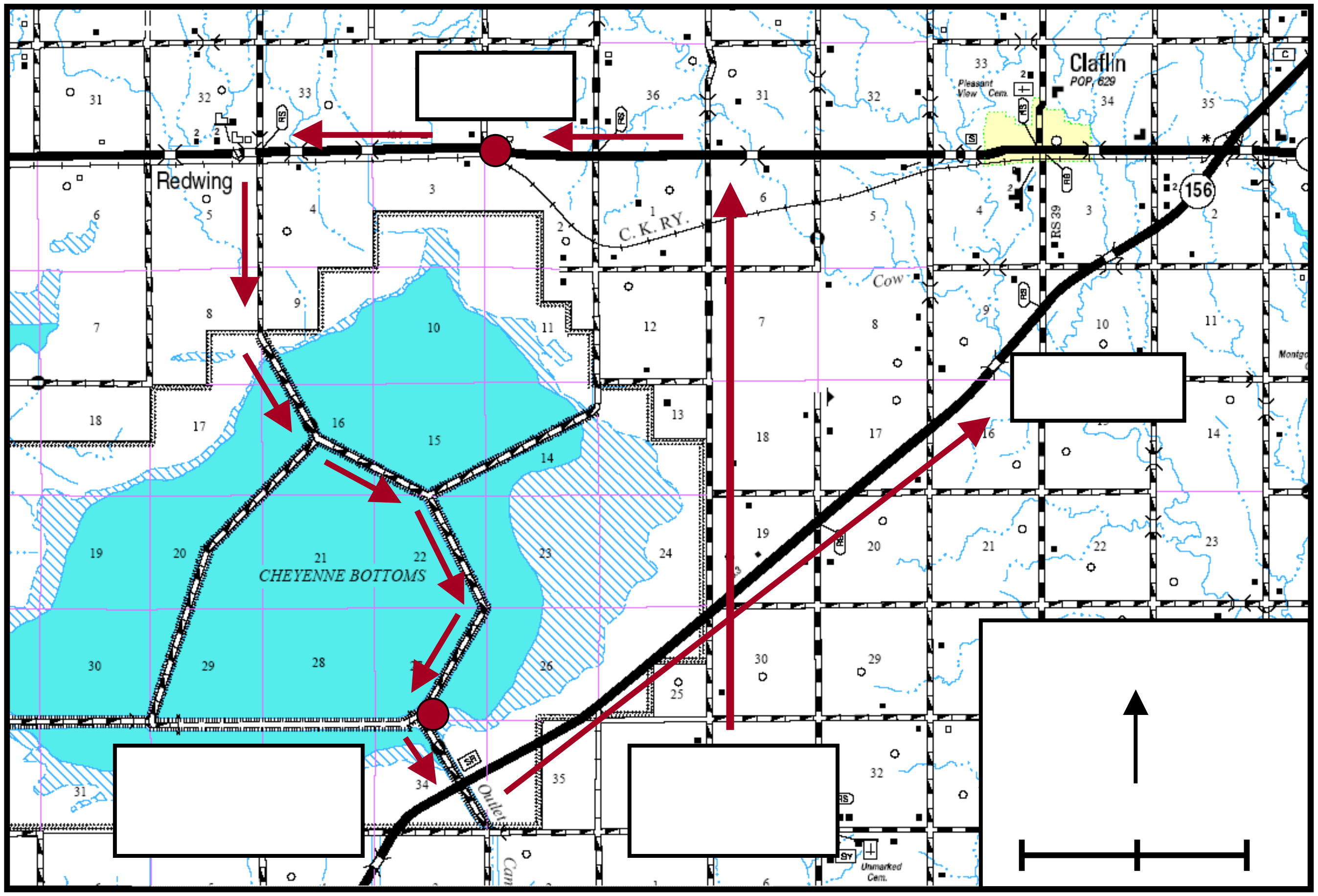

Figure 26. The field trip route to Stop 4, through Cheyenne Bottoms, and to Interstate 70.

Stop 4: Cheyenne Bottoms (paleokarst feature)

Stop 4 is located on a ridge overlooking Cheyenne Bottoms to the south. The shallow bedrock consists of Cretaceous Greenhorn Limestone. This overview of Cheyenne Bottoms is taken from Aber (2004; http://academic.emporia.edu/aberjame/geomorph/project/summary.htm) and Bayne (1977).

Cheyenne Bottoms is the premier wetland of Kansas. Located in the center of the state, it is considered to be the most important wetland site for shorebird migration in the central United States (Figure 28). Cheyenne Bottoms occupies approximately 64 square miles (166 square kilometers) in Barton County near Great Bend and Hoisington (Figure 27). It is managed in part by the Kansas Department of Wildlife and Parks and partly by The Nature Conservancy.

The basin is developed in lower Cretaceous bedrock overlying upper Permian salt-bearing strata. Subsurface solution of halite within the Hutchinson Salt or dissolution and collapse of deeper carbonate rock in the Lower Paleozoic section are possible causes for subsidence of the basin, and wind erosion may have further scoured the basin. The record in the sediment fill beneath Cheyenne bottoms encompasses the past 100,000 years. During this interval, the bottoms has alternated between wet and dry conditions many times. Since the end of the Pleistocene Epoch 10,000 years ago, a distinct drying trend developed and culminated in the *hypsithermal* or *altithermal*, a period of warmer and drier conditions across the western United States a few 1,000 years ago. More recently the world's climate has cooled slightly during the past three millennia. Cheyenne Bottoms has continued to experience wet and dry cycles until the present.

On the ground, Cheyenne Bottoms appears essentially flat with almost no relief across the basin. However, the Bottoms does have distinct geomorphic zones (Figure 27). The state wildlife area includes the "downstream" end of the enclosed drainage system, which occupies an oval depression in the southeastern end of the larger basin (Figure 28). Water drainage in this portion is closely managed via inlet/outlet canals along with numerous levees, gates, and water pumps. The Nature Conservancy lands include delta complexes of Blood and Deception creeks in the "upstream" end of the bottoms. The small deltas and associated marshes resemble the geomorphic pattern of the Mississippi Delta.

Nine man-made, interconnected pools each cover more than 700 acres. Roughly 50 percent of the bottoms is privately owned and consists of native-grass pasture and cropland planted with wheat, milo, and alfalfa (Figure 28). Areas set aside for wildlife include the Cheyenne Bottoms Wildlife Area. These 20,000 acres in the southeast corner of the bottoms are adjoined by 6,772 acres owned and managed by The Nature Conservancy since 1990.

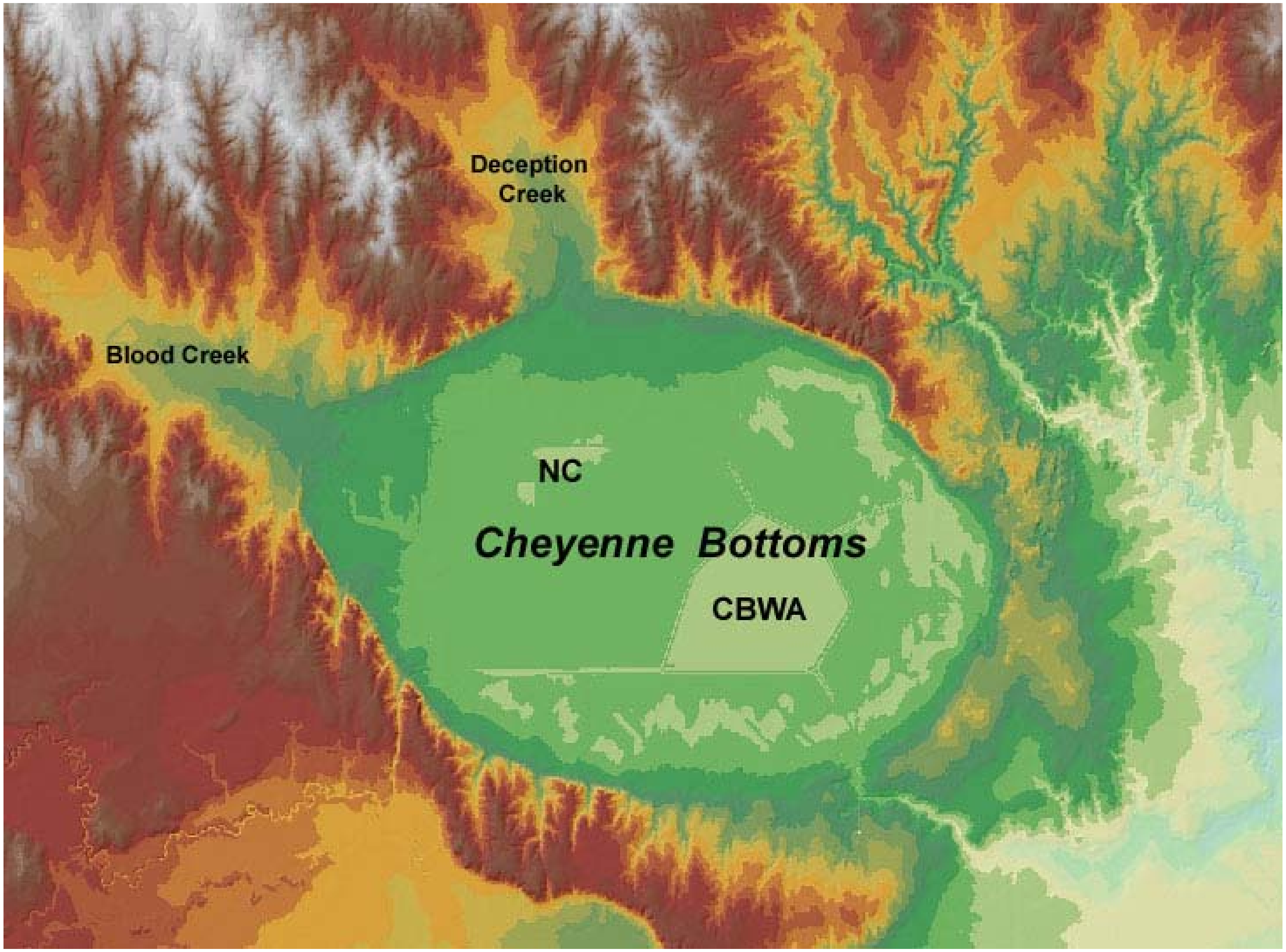

Figure 27. Digital elevation model for Cheyenne Bottoms and surroundings. NC = Nature Conservancy, CBWA = Cheyenne Bottoms Wildlife Area. http://www.emporia.edu/nasa/epscor/chey_bot/chey_bottom.htm.

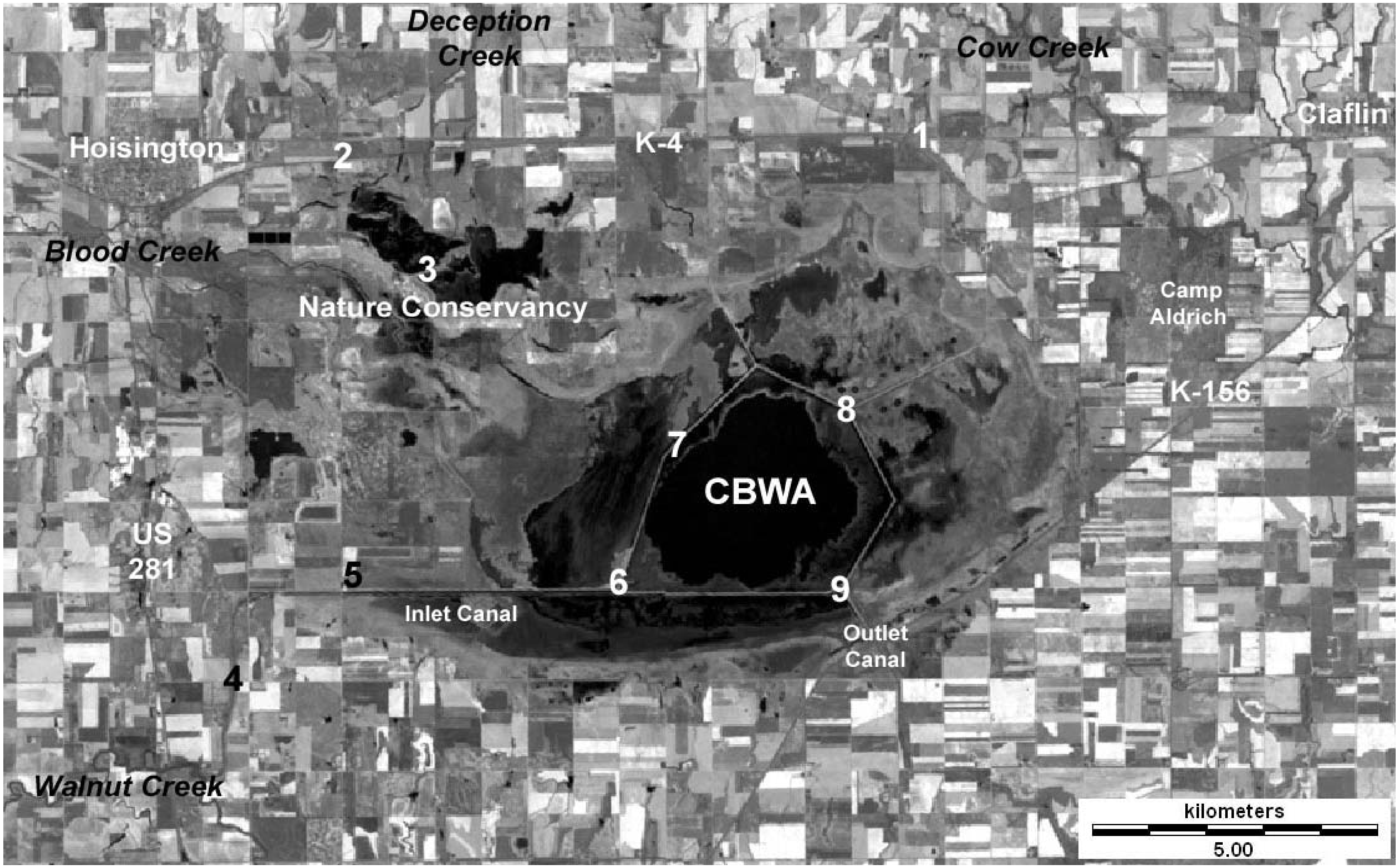

Figure 28. Photomosaic of the Cheyenne Bottoms and adjacent areas. CBWA = Cheyenne Bottoms Wildlife Area. 1 = Stop 4; 2 = Entrance road leading to the CBWA headquarters building; 3 = Areas managed by the Nature Conservancy; 4 = Ditch leading from the Wet Walnut Creek to the Inlet canal; 5 = CBWA Headquarters building; 6, 7, and 8 = Observation Points; and 9 = Observation tower. http://academic.emporia.edu/aberjame/geomorph/project/summary.htm.

Cheyenne Bottoms to Lawrence

Figures 25, 29-34, 3, and 2 show the surface geology of the fieldtrip route through Barton, Ellsworth, Lincoln, Saline, Dickinson, Geary, Riley, Wabaunsee, Shawnee, and Douglas counties. The route passes through the Smoky Hills, Flint Hills, and the Glaciated regions of Kansas.

Mile Post	Description
134.75	Entrance onto Kansas Highway 156 from the observation tower in Cheyenne Bottoms (Figure 26). Alluvial fill underlies the entrance onto Kansas Highway 156.
138.75-141.65	An area of stabilized sand dunes.
140.9	Cow Creek crossing. From this point onward almost to the city of Holyrood in Ellsworth County, the surficial geology consists of eolian and alluvial undifferentiated Quaternary deposits.
143.6	Junction with Kansas Highway 4. The town of Claflin is a few miles west of the road intersection (Figure 26).
145.6	Ellsworth-Barton County line.
148.4-149.2	The shallow bedrock here is upper Cretaceous Greenhorn Limestone, a unit consisting of 80 feet of interbedded marl, chalk, and chalky limestone.
150.5	Enter the city of Holyrood.
151.2	Plum Creek crossing.
154.5	Crossing the approximate drainage divide between the Arkansas and Missouri River basins.
155.2	Bedrock is the Cretaceous Greenhorn Limestone. Note the rock fence posts on the east and west sides of the road. This and areas of central Kansas to the north are locally referred to as Post-rock country. The limestone that forms the fence posts is quarried locally and comes from a very persistent one-foot thick layer within the Greenhorn Limestone.
156.5-156.7 & 157-157.1	The outcropping bedrock unit is the Cretaceous Graneros Shale
157.8	Outcrops of sandstones and mudstones of the upper Dakota Formation.
159.3	Note the panoramic view of the Smoky Hill River valley below. Note the exposures of Dakota Formation sandstone in the hillsides.
163.5	Junction with Kansas Highway 14.
164.1	Smoky Hill River crossing; enter the city of Ellsworth.
165.7	Junction with Kansas Highway 140. From this point to the Oak Creek crossing, Kansas Highway 156 passes over high terrace deposits of the Smoky Hill River.
166.8	Oak Creek crossing.
166.8-169.7	The bedrock is the Dakota Formation.
169.3	Spring Creek crossing.
170.6	East Spring Creek crossing.

170.8-172.3	The bedrock is Graneros Shale-Greenhorn Limestone
172.3	Dakota Formation bedrock. Note the roadcuts through the upper and middle Dakota Formation in the Elkhorn Creek drainage from this point to Interstate 70 on the west side of the highway. The cuts provide classic views illustrating the stratigraphic complexity of the Dakota Formation at the outcrop scale.
172.3-172.5	Landslide slumping in upper Dakota Formation, west side of road.
173.5	Elkhorn Creek crossing.
176.3	Entrance onto Interstate 70.

Road log from the Kansas Highway 156 – Interstate 70 junction to the Interstate 70 - Kansas Turnpike (Interstate 335) interchange at Topeka taken from Buchanan and McCauley (1987).

225.7	East Elkhorn Creek.
226.5	Dakota Formation sandstone south of the highway.
228.2	Ellsworth-Lincoln County line.
228.5	Graneros Shale, overlain by the Greenhorn Limestone
229.0	The Smoky Hills dominate the view to the east, as Interstate 70 crosses the eastern edge of the uplands, which are capped by the Greenhorn Limestone.
235.5	Lincoln/Saline County line.
237.0	Mulberry Creek.
238.5	Brookville exit. Many of the buildings in Brookville, 7 miles to the south, are built out of the Dakota sandstone. This town used to be the site of the Brookville Hotel, a well-known Kansas eatery, which opened in the 1870's. Due to excessive popularity and lack of central wastewater treatment, the hotel moved to Abilene in the late 1990s.
248.0	The Smoky Hill Buttes are on the horizon the south. Capped by the Dakota Formation.
250.8	U.S. 81/Interstate 135 interchange. Enter the city of Salina.
254.1	Saline River crossing.
259.0	Kiowa Formation.
259.9	This is the approximate boundary between the Permian and Cretaceous formations in Kansas.
264.3	Solomon River. In this area, upwelling brines from the Wellington aquifer discharge into the river.
266.0	Saline-Dickinson County line.
269.0-272.0	Sand-dune topography. Sand blown out of the valley of the Smoky Hill River.
274.3	Mud Creek crossing.
275.2	Kansas Highway 15 interchange and Abilene. Our dinner stop is at the Brookville Hotel north of the interstate on a drive off of Kansas Highway 15.
278.5	Wellington Formation shale (poorly exposed).

280.0	Sand-dune topography.
281.8	Nolans Limestone on the north side of Interstate 70.
282.1	Lone Tree Creek.
285.8	Winfield Limestone.
286.4	Chapman Creek.
289.5	Geary/Dickinson county line.
290.6	Fort Riley member of the Barneston Limestone.
295.0	Exit of U.S. 77. Junction City and Milford Reservoir. Milford is the largest lake in Kansas.
298.7	Smoky Hill river.
299.8	Franks Creek.
308.2	McDowell Creek. About 20 miles north kimberlite pipes crop out at the surface.
311.0	Konza Prairie. Tall-grass prairie preserve owned by The Nature Conservancy and used for research by Kansas State University.
312.7	Swede Creek.
316.0	Riley/Geary County line.
322.0	Riley/Wabaunsee County line.
333.3	Mill Creek.
346.0	Wabunsee/Shawnee County line.
355.2	Interstate 70 - Interstate 470 interchange.
368	Interstate 70 and Interstate 335 interchange.

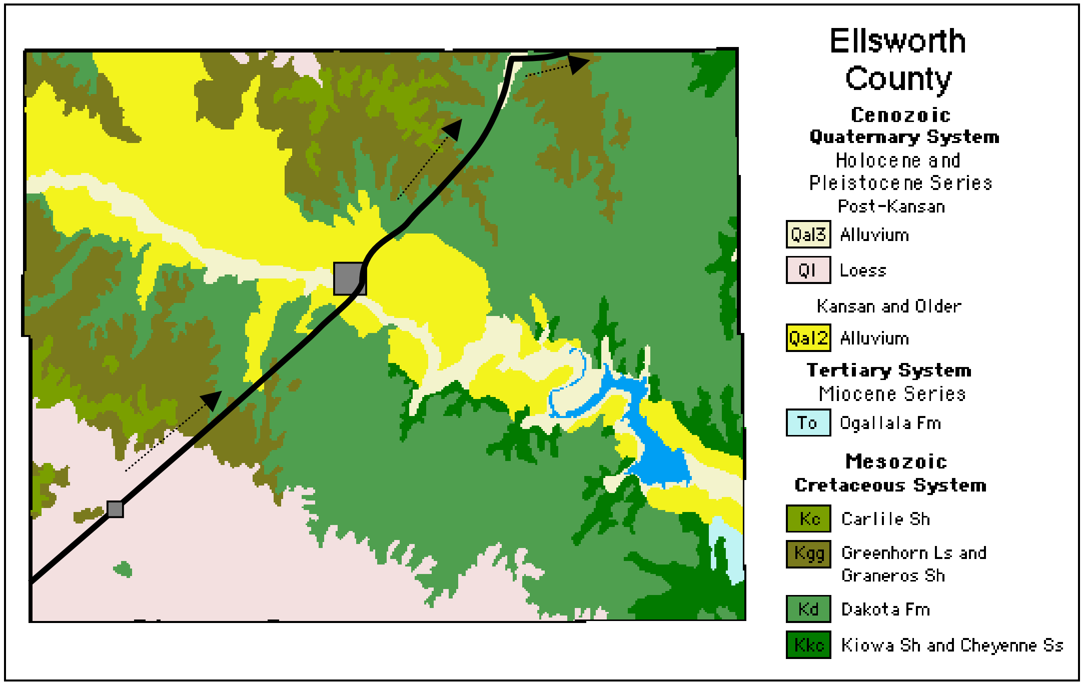

Figure 29. Surface geology of Ellsworth County.

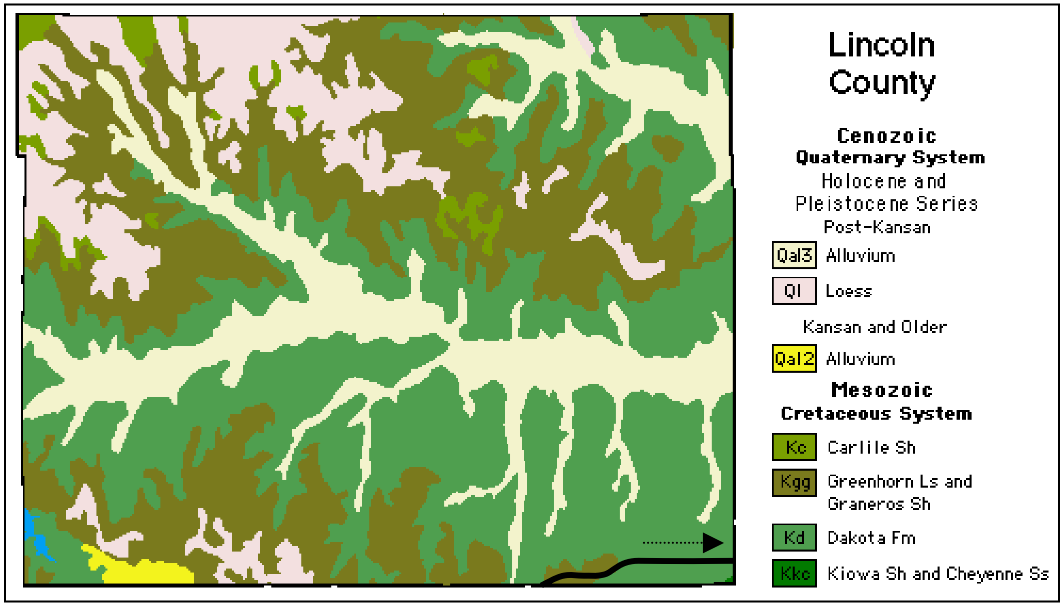

Figure 30. Surface geology of Lincoln County.

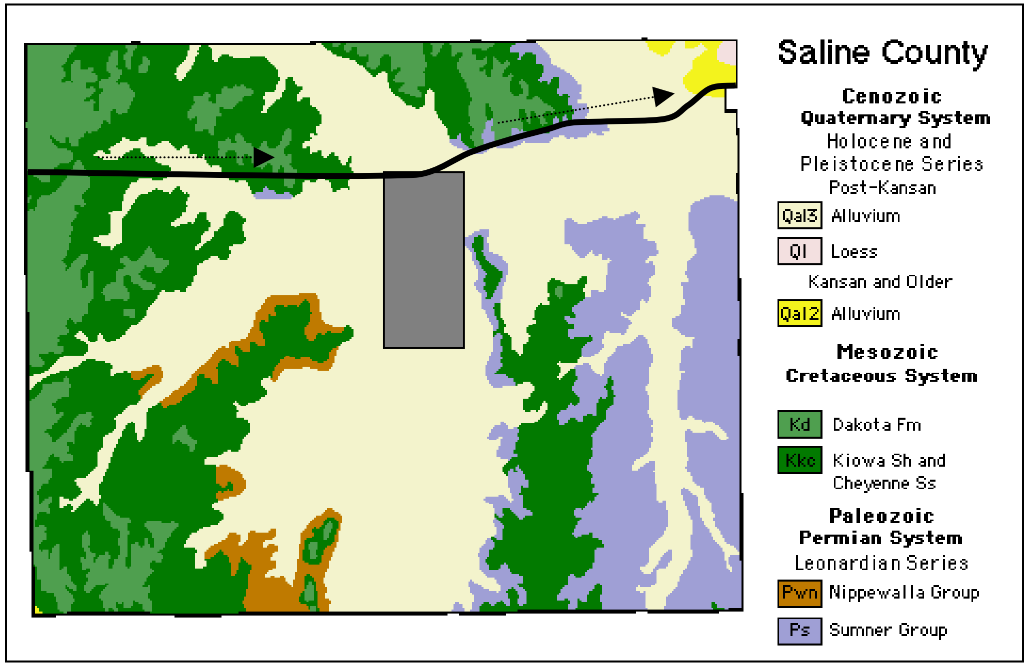

Figure 31. Surface geology of Saline County.

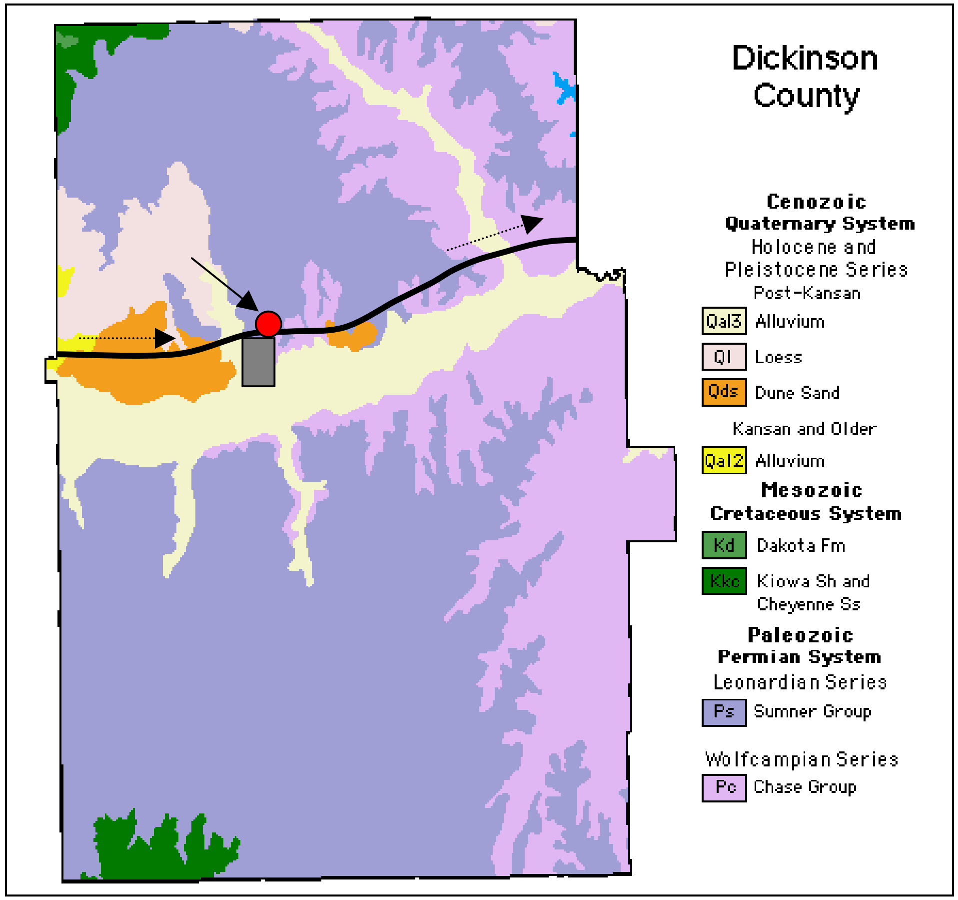

Figure 32. Surface geology of Dickinson County.

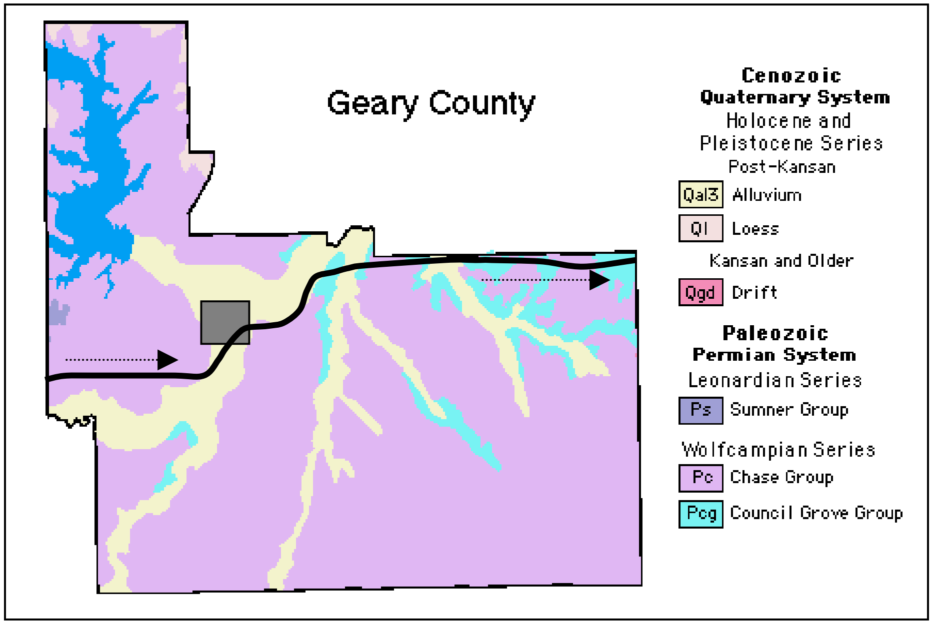

Figure 33. Surface geology of Geary County.

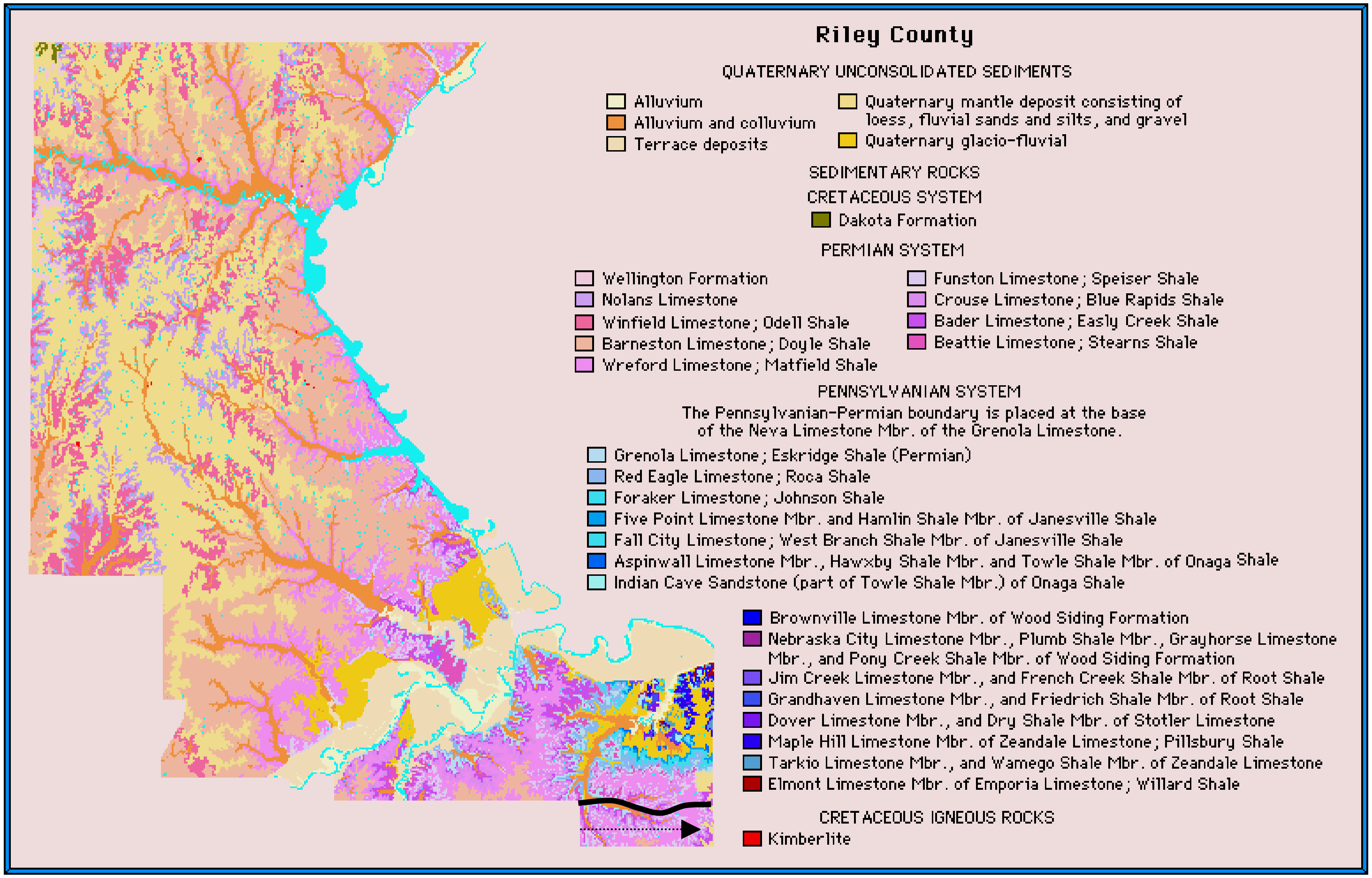

Figure 34. Surface geology of Riley County.

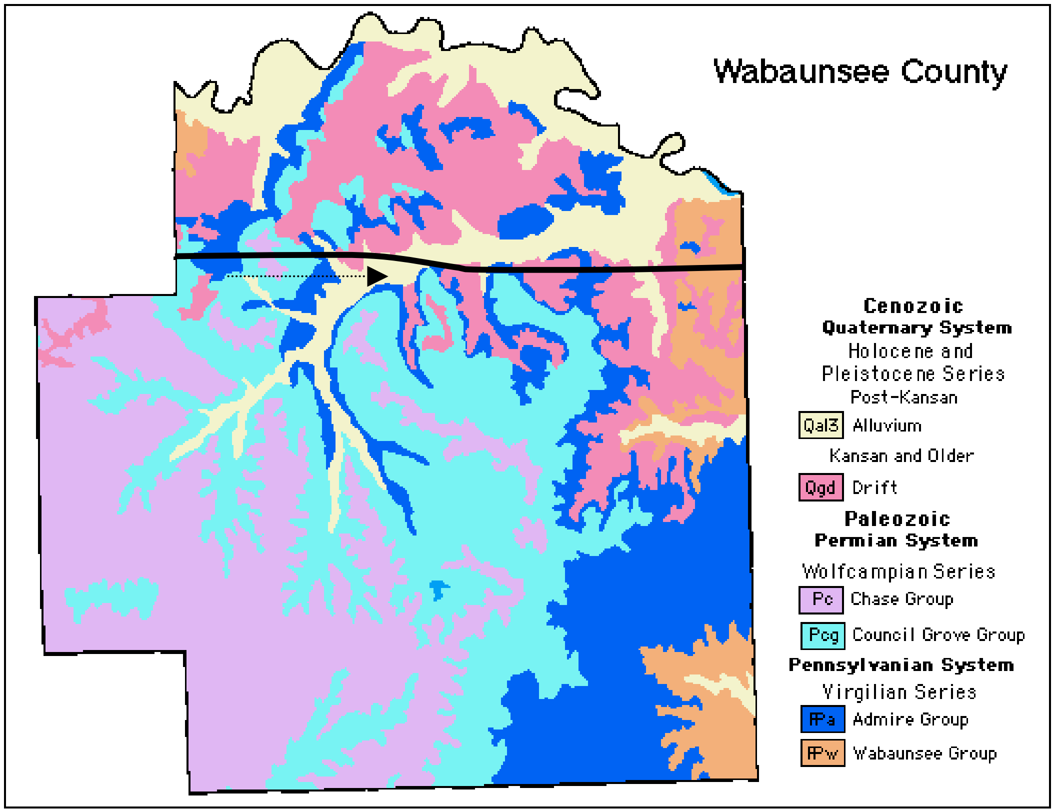

Figure 35. Surface geology of Wabaunsee County.

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Midcontinent Meeting for the National Karst Map Project

Photographs

Stop 1. Florence, Kansas

Florence, KS, Crystal Springs well house. S. Ausbrook, August 2005

Karst presentation, Crystal Spring, Florence, KS. S. Ausbrook, August 2005

Karst field trip presentation, Crystal Spring, Florence, KS, S. Ausbrook, August 2005.

Crystal Spring overflow discharge point, S. Panno, August 2005.

Crystal Spring natural discharge point.

Crystal Spring discharge point from well house. S. Ausbrook, August 2005

Florence (lower) and Fort Riley (upper) Limestone units, Crystal Spring, S. Ausbrook, August 2005.

Stop 2. Hutchinson, KS. Carey Salt plant. Private property.

Hutchinson sinkhole, S. Panno, August 2005.

Hutchinson old Carey salt plant sinkhole. Looking north towards Burlington Northern-Santa Fe railroad tracks. S. Ausbrook, August 2005.

Cross-section of sinkhole at old Carey Salt plant, Hutchinson, KS. M. Townsend, August 2005.

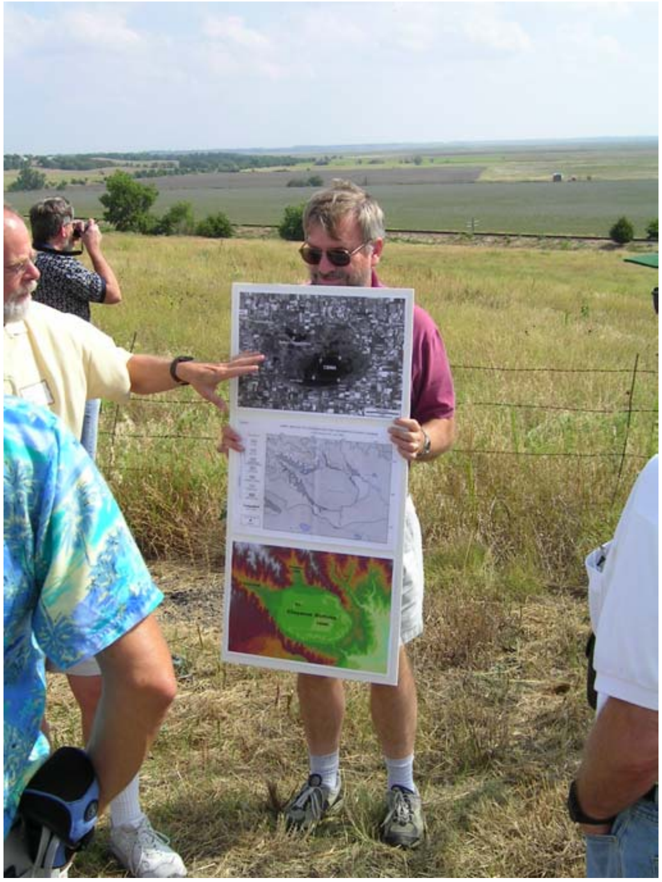
Installed framing used by consulting firm for filling sinkhole. Looking north towards Burlington Northern-Santa Fe railroad tracks. S. Ausbrook, August 2005.

East of Hutchinson, KS Highway 50. Well drilling for new disposal well for salt water. S. Ausbrook, August 2005.

Stop 3: US Highway 50 – Victory Road

US Highway 50-Victory Road Subsidence Feature, Greg Olmacher (KGS) giving presentation. S. Ausbrook, August 2005.

Stop 4. Cheyenne Bottoms



Kansas Highway 4 overlook at Cheyenne Bottoms. Looking south. Photos of geology and land use of the area presented at site. D. Weary, August 2005.

Abandoned farmstead north of overlook on Kansas Highway 4. S. Panno, August 2005.

Cheyenne Bottoms panorama looking from southwest to southeast. Taken at overlook. S. Panno, August 2005.

Karst field trip participants at Cheyenne Bottoms overlook. D. Weary, August 2005


Cheyenne Bottoms observation tower, southeast corner of area. D. Weary, August 2005.


Looking west across Cheyenne Bottoms from observation tower in southeast corner of area.
D. Weary, August 2005.

Looking west across Cheyenne Bottoms near overlook. S. Ausbrook, August 2005.

Cheyenne Bottoms looking south along outlet ditch from area. S. Ausbrook, August 2005.


Mudcracks, Cheyenne Bottoms. S. Panno, August 2005.