SUBSURFACE GEOLOGY OF SALINE COUNTY, KANSAS

by

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INTRODUCTION

Purpose of Investigation

The purpose of this investigation was to determine the relationship between subsurface stratigraphy, structure, geologic history and petroleum accumulation in Saline County, Kansas.

Location and Physiography

Saline County is located in Central Kansas. It is bounded on the north by Ottawa County; on the east by Dickinson County; on the south by McPherson County; and on the west by Lincoln and Ellsworth Counties.

Geologically, the area is situated in the Salina basin, a structural basin bordered on the east by the Nemaha anticline, on the west by the Central Kansas uplift and on the south by the Central Kansas uplift and the Chautauqua arch. Saline County lies in the south part of this basin. It is a hilly region with well developed drainage. The western upland declines gently eastward at an average rate of 17 feet to the mile. The highest point in the county(1680 feet) is in the westernmost part in T. 15 S., R. 5 W., near Ellsworth County, and the lowest point (about 1150 feet) is at the eastern border near the junction of the Solomon and Smoky Hill rivers. Thus the maximum relief is about 530 feet.

The Smoky Hill, Salina and Solomon rivers are the three main streams in the county. They meander over broad flood plains. The Smoky Hill river runs from south to north in the central part of the area, and then turns eastward in the vicinity of Salina. About five miles east of Salina, the Smoky Hill river receives the Salina river which flows southeastward in the

area north of Salina. From this point the Smoky Hill continues east to receive Gypsum Creek in the north part of T. 14 S., R. 1 W. and the Solomon river at the eastern border of the county. The Solomon river flows southeastward across the northeastern corner of the county. Gypsum Creek, running from south to north, and its tributaries drain the southeastern part of the area. The western part of the county is drained by Mulberry Creek and its tributaries. This stream joins the Salina river about two miles north of Salina.

REVIEW OF LITERATURE

Twenhofel (1924) reported on the geology and invertebrate paleontology of the Comanchean and Dakota formations of Kansas including Saline County. An annual report of oil and gas exploration in the county has been published by the Kansas State Geological Survey since 1943, (Ver Wiebe et al.). The areal and subsurface geology and the development of the oil and gas resources of Saline County have been described by Ver Wiebe (1938). Keroher and Kirby (1948) made a detailed description of Upper Cambrian and Lower Ordovician rocks in Kansas. Taylor (1946, 1947a, 1947b) described the stratigraphy and structure of Siluro-Devonian strata, Middle Ordovician limestones and Upper Ordovician shales in Kansas. Lee (1949) presented a subsurface geologic cross section from Barber County to Saline County, Kansas. The stratigraphy and structural development of the Salina basin area were discussed in detail by Lee (1956). All of these references include specific information concerning Saline County.

Moore (1926) discussed early Pennsylvanian deposits west of the Nemaha granite ridge, Kansas. Norton (1939) reported on the Permian red beds of Kansas. Lee (1940) described the subsurface Mississippian rocks of Kansas.

Moore, et al. (1951) compiled the subsurface and outcropping stratigraphic units in Kansas. These references are more indirect than those mentioned previously.

PROCEDURE

To provide a basis for study of the stratigraphic and structural relationships of the area, the writer constructed four structure contour maps, one isopach map and one panel diagram depicting major stratigraphic units penetrated by oil wells. The structural contour maps were drawn on the Arbuckle group of Upper Cambrian and Lower Ordovician age, the Viola limestone of Middle Ordovician age, the Mississippian limestone and the Lansing group of Middle Pennsylvanian (Missourian) age. The isopach map portrays the interval between the top and base of the Viola limestone. These maps were used in conjunction with previously published material in interpreting the structural development and depositional and erosional events in the area. The number of control points on the maps and structural relief of the area justified a contour interval of 25 feet for the structural maps and 20 feet for the isopach map; a smaller interval might have introduced fictitious or nonexistent features, while a larger interval would have sacrificed detail.

The sources for the data used were maps provided by the Herndon Map Service of Oklahoma City, Oklahoma, and drillers' logs obtained from the Kansas Geological Society, Wichita, Kansas.

STRATIGRAPHY

Introduction

The sedimentary rocks in Saline County, attaining a total thickness of

more than 4,000 feet, range from Upper Cambrian to Quaternary in age. Lithologically, they form a section of alternating limestones, sandstones, shales, and some evaporites.

The surface rocks include Permian, Cretaceous and Quaternary sediments. The outcrops of these younger beds largely determine the topographic pattern of the area. The hilly regions of the county are underlain by Cretaceous sandstones and shales, while the floors of the stream valleys are covered by Quaternary alluvium. The rocks of Permian age outcrop mainly along the narrow zones between the hill sides and the edges of the valleys and are also exposed in the eastern part of the county, where the surface has very low relief.

Subsurface strata range from Upper Cambrian to Pennsylvanian in age. Rocks of the Arbuckle group, of Upper Cambrian and Lower Ordovician age, are the oldest formations found in the subsurface of Saline County. The Arbuckle group is overlain by rocks of the Simpson group which are of Lower and Middle Ordovician age. The Middle Ordovician Viola limestone, overlying the Simpson group, is very irregular in thickness in this area. The Viola is overlain by the Sylvan shale of Upper Ordovician age, which is absent in the central part of the county. The Hunton limestone of Siluro-Devonian age is underlain by the Ordovician strata; it is absent in the southwestern part of the area. The Siluro-Devonian Misener sandstone which overlies the Hunton limestone is found in only a few wells of Saline County. The Mississippian rocks covering the older strata are thick and widespread, and are overlain by another thick sequence of Pennsylvanian strata.

The stratigraphic nomenclature used in this report is that proposed by Moore, et al., (1951).

The name of a rock unit often varies from state to state in midcontinent

area. To further complicate nomenclature, different rock names are often applied to the same stratigraphic unit, even within the limited area of the Salina basin. To provide a basis for resolving discrepancies in nomenclature encountered in the literature of this report, correlation chart has been included with the discussinn of each geologic period.

Pre-Cambrian Rocks

Pre-Cambrian rocks of Kansas are not exposed at the surface, but crystalline rocks of this age are present beneath the sedimentary formations and are encountered by wells drilled to sufficient depth.

Farquhar (1957) presented a generalized description of lithology of Pre-Cambrian rocks in Kansas. He stated that the Pre-Cambrian rocks of Kansas include a metamorphic group composed of quartzite, granulite, schist, phyllite, and gneiss (some granitic). This has been intruded by a suite of igneous rocks consisting not only of granite, but also of some darker magmatic rocks. The intrusive granite is of batholithic dimensions and, like the metamorphic rocks it intrudes, is overlain by Upper Cambrian and later sediments (Farquhar, 1957).

No Pre-Cambrian rocks have been reported in Saline County.

Lower and Middle Cambrian Rocks

Rocks of Lower and Middle Cambrian age are not present in Kansas.

Upper Cambrian and Lower Ordovician Rocks

The oldest rocks encountered in the wells of Saline County were designated the "Arbuckle group" which consists of late Cambrian and early Ordovician

deposits. The subdivisions of these rocks are tabulated in Fig. 1.

Upper Cambrian Rocks. Three Upper Cambrian formations outcropping in the Ozark region of Missouri, where these beds are described in detail, are present in the subsurface of Kansas. In Missouri they are, in ascending order, the Lamotte sandstone, the Bonneterre dolomite and the Eminence dolomite. Neither the Lamotte sandstone nor the Eminence dolomite has been reported in the subsurface of Saline County.

Bonneterre Dolomite. The Bonneterre dolomite is exposed at the surface in the St. Francois Mountain region of southeastern Missouri and has been found by deep drilling throughout most of Missouri. It lies conformably below the Elvins group and above the Lamotte dolomite. In Missouri the Bonneterre dolomite consists of a light to dark, finely crystalline dolomite with thin partings of light green and brown shale. It has a high percentage of glauconite.

The Bonneterre dolomite is present in eastern and western Kansas but is absent in many parts of the state. It is thin or missing over the Central Kansas uplift and the Nemaha anticline. In eastern Kansas the unit is medium finely crystalline and commonly dark gray or brown. In northeastern and western Kansas the dolomite generally is buff to white and coarsely crystalline. The maximum thickness in eastern Kansas is 198 feet noted in a well in eastern Crawford County. The formation becomes thinner to the north and wedges out to the west against the Central Kansas uplift. In western Kansas, a maximum thickness of 125 feet has been recorded for this unit. In Saline County the Bonneterre dolomite varies from zero in the northwest to about 150 feet in the southeast (Keroher and Kirby, 1948).

Lower Ordovician Rocks. The Lower Ordovician rocks in Kansas have been

		Iowa	Kansas Subsurface		Missouri	Oklahoma Subsurface
Ordovician	Lower	Willow River (Shakopee) dol.	Arbuckle Group	Cotter dol. and Jefferson city dol. Undifferentiated	Smithville limestone Powell dol. Cotter dol. Jefferson City dol.	Arbuckle "lime" (Siliceous lime")
		Root Valley sandstone		Roubidoux dolomite	Roubidoux formation	
		Oneota dolomite		Gasconade dolomite and Van Buren formation Undifferentiated Gunter sandstone member	Gasconade dolomite Van Buren formation Gunter sandstone member	
Cambrian	Upper	Trempealeau formation		Eminence dolomite	Proctor dol. Eminence dol. Potosi dol.	
		Franconia sandstone			Elvins group	Honey Creek limestone
		Dresbach sandstone		Bonneterre dolomite	Bonneterre dolomite	Cap Mountain formation
				Lamotte sandstone	Lamotte sandstone	Reagan sandstone
Pre-Cambrian						

Fig. 1. Subdivision of Upper Cambrian and Lower Ordovician rocks at the outcrop and in the subsurface of Kansas and adjacent states (Modified from Keroher and Kirby, 1948).

subdivided, in ascending order, into the Van Buren formation, the Gasconade dolomite, the Roubidoux formation and the Jefferson City and Cotter dolomite. Only the Roubidoux dolomite and the Jefferson City-Cotter sequence have been recognized in Saline County,(Keroher and Kirby, 1948).

Roubidoux Dolomite. The Roubidoux crops out over much of the central and northwestern parts of the Ozark Plateau in Missouri, where it consists of massive beds of sandstone near the top and base and beds of cherty dolomite in the middle. It is conformable with the Jefferson City dolomite and the Gasconade formation.

In Kansas the Roubidoux dolomite consists of sandy dolomite and fine subangular sand, with cherty dolomites near the middle of the formation in some areas. For the most part, the arenaceous character of the dolomite is not obvious in untreated samples. In both eastern and western Kansas the Roubidoux dolomite is characteristically white and very coarsely crystalline at the base, but becomes fine-grained near the top. Over a large area in the southeastern part of the state the thickness of the Roubidoux dolomite is relatively constant within limits of 150 to 200 feet. Keroher and Kirby (1948) report that the dolomite in Saline County is restricted to the northwestern part of the county.

Jefferson City-Cotter Sequence. The Roubidoux dolomite in Kansas is conformably overlain by beds correlated by Keroher and Kirby (1948) with the Jefferson City and Cotter dolomites of Missouri. The same authors stated that the dolomite of those formations at the outcrop is chiefly of two kinds: a fine-grained argillaceous earthy-textured variety and a more massive dolomite with a hackly surface. These dolomites commonly contain intercalated beds of sandstone, chert and green shale. In the subsurface of Kansas the dolomites

of the Jefferson City-Cotter sequence are variable in character. Beds that are only a few feet thick may differ greatly from those above and below both in color and in texture. The lithological character changes rapidly in a lateral direction, also. This lateral and vertical variability is a characteristic that serves to distinguish the dolomites of the Jefferson City-Cotter sequence from those of earlier formations of Late Cambrian and Early Ordovician age. A white to gray, dense, somewhat argillaceous, soft dolomite, which probably is the equivalent of the "cotton rock" of Missouri geologists, is the most common type of dolomite in the Jefferson City-Cotter sequence in Kansas. A light-tan coarsely crystalline dolomite is also very common. Brown dolomite occurs in the lower part of the sequence above the contact with the Roubidoux dolomite in most wells in Kansas. It is commonly very dark and very coarsely crystalline. However, light-brown, gray-brown, or buff fine-grained dolomites occur in this zone in some areas.

The Jefferson City and Cotter dolomites are reported to be 210 feet thick in Jackson County, in western Missouri.

Thicknesses of 350 to 400 feet prevail in the southernmost part of Kansas. A maximum thickness of 667 feet of these beds is found in Cowley County. Thinning is rapid to the north, (Keroher and Kirky, 1948).

Ordovician System

Rocks representing the Lower, Middle and Upper Ordovician are present in Kansas. These subdivisions and their relation to those of neighboring states are tabulated in Fig. 1 and Fig. 2. The lower part of the Lower Ordovician has been included in the "Arbuckle group" described in the previous paragraphs.

		Kansas		Iowa	Missouri	Oklahoma
		Siluro-Devonian		Silurian	Silurian	Silurian
Ordovician	Upper	Maquoketa-Sylvan shale		Maquoketa formation	Maquoketa shale	Sylvan shale
		Viola limestone		Prosser formation	Kimmswick limestone	Viola limestone
	Middle			Decorah formation		
		Rocks of Simpson age	Platteville formation	Platteville formation	Decorah shale	Simpson group
	Lower		St. Peter sandstone	St. Peter sandstone	St. Peter sandstone	
		Arbuckle group				

Fig. 2. Subdivision of the Ordovician system in Kansas and neighboring states (Modified from Leatherrock, 1945).

The terms, Sylvan shale, Viola limestone, and Simpson group are used in Saline County.

Simpson Group. Rocks of the Simpson group in north-central Kansas have been divided into two formations: the lower St. Peter sandstone and the upper Platteville formation.

St. Peter Sandstone. The St. Peter sandstone in north-central Kansas consists of three zones: an upper and a lower zone of sandstone characterized by rounded and frosted grains, and a middle zone composed of green clay shale containing varying amounts of finer and less rounded grains than that of the upper and lower zones. The middle zone is also characterized locally by

disseminated grains of glauconite. This middle zone of the St. Peter does not seem to be present in the Salina basin, (Leatherock, 1945).

The usual thickness of the upper zone is 15 to 45 feet, of the middle zone 10 to 30 feet, and of the lower zone 15 to 50 feet, (Leatherock, 1945).

The St. Peter sandstone lies unconformably beneath the Platteville formation. A low angular unconformity separates the St. Peter and associated Simpson beds from underlying rocks, (Moore et al., 1951).

Platteville Formation. The Platteville formation is unconformable below the Viola limestone. At the base of this formation in north-central Kansas is a very persistent bed of dolomite. The bed is composed mainly of sucrose or granular dolomite, but in some wells it is interbedded with earthy limestone of lithographic texture. The thickness of the basal dolomite ranges from 5 to 35 feet. In most of the wells in north-central Kansas the Platteville above the basal dolomite is composed mainly of green clay shale and minor amounts of interbedded limestone, dolomite and sandstone, (Leatherock, 1945). The maximum known thickness of the formation in Kansas is 100 feet in Brown county; from here it wedges out southward and southwestward on the flanks of the Chautauqua arch and the Central Kansas uplift, (Moore et al., 1951).

Viola Limestone. The Viola limestone of Kansas, which represents only part of the Viola of Oklahoma, consists of dolomite and limestone containing some cherty beds characterized by black flecks and spicular and tubelike fragments of microorganisms. In deep parts of the North Kansas basin, the carbonate rocks of the Viola are almost entirely dolomite, but toward margins of the basin earthy and granular limestone appears, especially at the base. An unconformity between Viola and Platteville rocks in Kansas is revealed by northward thickening of the Platteville formation. The Viola occurs throughout

the state except on the Central Kansas uplift, the Chautauqua arch, and the northern end of the Nemaha anticline, (Moore et al., 1951).

Taylor (1947) divided the Viola of Central Kansas, on the basis of lithology, into six cherty, calcitic and dolomitic limestones. This sequence attains a total thickness exceeding 250 feet in Mitchell County.

The uppermost limestone member, Zone 1, is thin, commonly under 20 feet, and is distinguished by an abundance of coarse dolomite rhombs and crystals.

The upper cherty limestone member (Zone 2) underlies the coarsely crystalline dolomitic beds of Zone 1. It carries large amounts of brown or gray, sharp-edged, rather smooth chert which is irregularly splotched with white or gray microfossils.

The middle limestone member (Zone 3) is a tan or gray, dense to finely crystalline calcitic limestone which normally contains less than 10 per cent of insoluble material.

The middle cherty member (Zone 4) is differentiated from other zones by dark-specked, microfossiliferous, rough and smooth chert, which is dolocastic in residues. This chert is mixed with tan crystalline limestone that is calcitic in the north and becomes partially dolomitic toward the south.

The lower limestone member (Zone 5) is the most widespread of the Viola zones; it is brown or gray crystalline limestone, calcitic in the north but more dolomitic in the south. This one resembles zones 3 in that it contains only small amounts of insoluble material.

The lower cherty or basal clastic member (Zone 6) is a mixture of limestone, chert, and sand. The chert is microfossiliferous and unevenly brown colored, presenting a stippled or minutely mottled appearance with numerous tiny dark brown dots in a lighter brown matrix. It occurs in north central

Kansas but is not present south of southern McPherson County.

Viola Limestone in Saline County. The Viola limestone is well developed in the north part of the state and frequently attain a thickness of 250 feet but thin gradually to the south. In Saline County the Viola limestone ranges from 40 to 180 feet in thickness as shown in the isopach map (Plate 5 in appendix).

Here a thin, coarsely crystalline, dolomitic limestone, interpreted as the upper limestone member (Zone 1), appears in rotary samples from the Central Oil and Gas Company's Crawford well No. 1 NE 1/4, Sec. 26, T. 13 S., R. 3 W.) at 3,390 feet, but has not been recognized elsewhere in the county. The upper cherty member (Zone 2) likewise is missing in Saline County. Five to ten feet of the middle limestone (Zone 3) occur in parts of eastern Saline County. The middle cherty member (Zone 4) is widespread and has a maximum thickness exceeding 100 feet. The chert of this zone contains more black specks here than to the north and east, and is separable into two divisions on the basis of chert characteristics. The upper part contains black-specked gray chert, some of which is smooth and solid, in residues, and the rest rough and dolocastic. The lower part is also black-specked, but is ordinarily tan or brown, smooth, and solid with many tiny indistinct microfossils packed so closely together as to give the fragments a somewhat mottled or lace-like appearance. This lower chert resembles some of the chert in the lowermost cherty member (Zone 6). The lower limestone (Zone 5) is 35 to 50 feet thick in Saline County, and consists of buff or gray crystalline calcitic limestone. The basal beds (Zone 6) are chiefly brown calcitic and dolomitic limestones with minor amounts of chert, sand, and shale. This zone is less than 25 feet thick in Saline County. In many wells the distinctive chert in this lowest

unit is missing, and the zone is recognized by the change from calcitic limestone to calcitic and dolomitic strata containing small amounts of sand and shale. In other wells some cherty material is present, and overlies a Simpson sand characterized by gray, dark-specked, smooth chert which, in insoluble residues, displays large dolocasts, (Taylor, 1947).

A section of more than 150 feet of Viola limestone occurs in the southernmost part of T. 16 S., R. 3 W. on the axis of the northeast-southwest trending Lindsborg-Salina anticline in central Saline County. Downdip about six miles east there are only 95 feet of limestone. The thickening occurs in the middle cherty member (Zone 4), with Zones 5 and 6 remaining normal. Two wells which illustrate this relationship are Stanolind Oil and Gas Company's Martin No. 1 (SE 1/4 Sec. 3, T. 16 S., R. 3 W.) which is near the crest of the anticline, and the Lario et al. Fulton No. 1 (NW 1/4 Sec. 14, T. 16 S., R. 2 W.) in a syncline on the east,(Taylor, 1947a).

Log of Martin No. 1, Saline County, Kansas

Depth (Feet)	Description of Zones
3,295	Base of Maquoketa-Sylvan shale. Top of Viola limestone .
3,295-3,395	Middle cherty member (Zone 4). Black specked chert mixed with brown and tan dolomite and calcitic limestone. Gray in upper part.
3,395-3,430	Lower limestone (Zone 5). Tan calcitic limestone containing brown dolomite rhombs.
3,430-3,450	Lower cherty member (Zone 6). Brown calcitic limestone with dolomite rhombs and a few pieces of brown-stippled chert.
3,450	Top of Simpson group. Green waxy shale with a little limestone.

Log of Fulton No. 1, Saline County, Kansas

Depth (feet)	Descriptions of Zones
3,445	Base of Maquoketa-Sylvan shale. Top of Viola limestone.
3,445-3,452	Middle limestone member (Zone 3). Tan crystalline calcitic limestone.
3,452-3,485	Middle Cherty member (Zone 4). Black-specked, tan chert mixed with tan calcitic limestone.
3,485-3,525	Lower limestone member (Zone 5). Tan or gray, crystalline to dense limestone.
3,525-3,539	Basal clastic member (Zone 6). Buff to brown limestone mixed with some sand.
3,539	Top of Simpson group. Greenish black waxy shale.

Sylvan Shale. Taylor (1947b) stated that two different types of shaly strata comprise the Maquoketa-Sylvan formation over much of Central Kansas. The upper shale member is normally hard gray shale containing varying amounts of dolomite crystals and rhombs whose molds cause insoluble residues to be very dolocastic. In parts of Central Kansas this member contains sufficient siliceous material to produce hard gritty fragments and some wells even show dirty gray silty cherts with the dolomitic shales. These silty chert-like pieces are commonest in the northeastern and southwestern parts of the Central Kansas area.

The lower shale member underlies the upper dolomitic shale, and is soft, silty and gray in the north part of Central Kansas, but grades into darker gray, brown and black shale in the south. It is relatively non-dolomitic, and residues are only sparingly dolocastic.

Neither of these shale members breaks into long, slender, angular fragments as do some beds in the Chattanooga, nor do they have the green waxy appearance

typical of much of the Simpson shale. Either member may be missing from wells in which the other is represented. Sharp contacts between them are rare, but holes drilled in shale are subject to considerable caving, and contacts may be sharper than is indicated by the samples. In a few wells the change from dolomitic to non-dolomitic strata is sharply defined, but in most tests it is spread over at least a 20-foot interval. Large fragments collected near the contact in some wells show silty chert layers or thin dolomitic, siliceous shale seams interfingering with soft non-dolomitic shale layers, suggesting a gradual merging of the upper and lower strata.

Sylvan Shale in Saline County. In Saline County the Sylvan shale normally consists, as in the area on the east, of two zones; an upper dolomitic gray shale which, in residues, forms many dolocastic pieces, and a lower, comparatively non-dolomitic, flaky, gray or brownish gray shale which is sparingly dolocastic in residues. The siliceous shale and silty chert of upper beds in areas to the east are gone, having graded into a softer shale which retains its gray and pink dolomite rhombs, but ordinarily lacks the hardness to scrape bits of steel from a needle which scratches it. The lower non-dolomitic shale exhibits no major change, although brownish-colored layers thicken somewhat in the west and south parts of the county, (Taylor, 1947b).

A typical section is exhibited by the Lario et al. Fulton No. 1 well (SW 1/4 NW 1/4 Sec. 14, T. 16 S., R. 2 W.) in Saline County, in which 92 feet of Sylvan beds are logged as follows, (Taylor, 1947b):

Log of Fulton No. 1, Saline County, Kansas

Depth (feet)	Description of Zones
3,353	Top of Maquoketa-Sylvan shale.
3,353-3,383	Upper dolomitic shale member. Light gray shale with many embedded tan and gray dolomite crystals and rhombs. Residues very dolocastic.
3,383-3,445	Lower shale member. Gray and brownish gray soft flaky shale containing a few widely scattered dolomite crystals and rhombs. Residues sparingly dolocastic.
3,445	Top of Viola limestone.

In the Fulton well, as in most holes, the contact between the upper dolomitic shale and the lower non-dolomitic beds as seen in samples, is not as sharp as it appears on an electric log, and samples show fragments of both dolomitic and non-dolomitic shales for some distance on both sides of the contact (Taylor, 1947b).

Siluro-Devonian System

The Siluro-Devonian strata in central Kansas are represented by the Hunton limestone and the Misener sandstone. These names are borrowed from Oklahoma.

Hunton Limestone. Crystalline dolomitic limestones containing three prominent chert bands comprise the thickest sections of the Hunton formation in the Salina basin. The chert is microfossiliferous, and light tan to frosty white. The limestone is uniformly crystalline, dolomitic, and light tan to light gray. Some beds, especially near the southern and western edges of the basin, contain crystalline calcitic limestone, (Taylor, 1946).

Hunton strata occur in all but the southwestern part of Saline County.

A typical section for this area is shown by the Kinney et al. Bell No. 1 well (NW 1/4 Sec. 23, T. 14 S., R. 5 W.) which is logged as follows (Taylor, 1946):

Log of Bell No. 1, Saline County, Kansas

Depth (feet)	Descriptions of Zones
3,595	Top of Hunton.
3,595-3,618	Middle cherty zone. Light tan, finely crystalline to dense, calcitic and dolomitic limestone, with up to 50 per cent light tan, smooth or slightly rough chert.
3,618-3,645	Light tan, buff or brown, dense to finely crystalline calcitic limestone.
3,645-3,680	Medium gray, finely crystalline, dolomitic limestone, with up to 20 per cent dirty gray and rough chert. A little angular quartz sand appears in lowest 10 feet of samples.
3,680	Base of Hunton.

Misener Sandstone. The Misener formation is impure limy or shaly sandstone, ordinarily not more than 10 feet thick. The sand normally is fine and angular, but contains small amounts of coarser grains, some of them frosted. It lies unconformably beneath the Chattanooga shale. Its thinness, irregular distribution and superposition on various formations, above which is a black or gray shale, indicate a long pre-Chattanooga erosion interval (Leatherock and Bass, 1936). In central Kansas it lies on Viola, Sylvan, and Hunton beds. Kansas oil geologists have applied the term "Misener sand" to this unit. Some have correlated it with the Lower Mississippian Sylamore sandstone, (Taylor, 1946). The Misener formation has only been recorded in a few wells in Saline County. It ranges from 3 to 19 feet thick.

Mississippian System

Outcrops of Mississippian rocks occur in a large area in Iowa, Missouri, and Oklahoma. In Kansas, outcrops are confined to a small part of Cherokee County in the extreme southeastern part of the state. The subsurface units of the Mississippian and their relation to the subdivisions of the exposed rocks in Missouri and Iowa are shown in Fig. 3 (Lee, 1943).

Kansas (subsurface)	Iowa (surface)	Missouri (surface)
Rocks of Chester age	Chester group	Chester
Rocks of Meramec age	Meramec group	Meramec
Rocks of Osage age	Osage group	Osage
Rocks of Kinderhook or Osage age	Kinderhook group	Kinderhook
Rocks of Kinderhook age		

Fig. 3. The subsurface units of the Mississippian of Kansas and their relation to subdivisions used in the exposed rocks in Missouri and Iowa (Modified after Lee, 1943).

Rocks of Mississippian age in Kansas consist mostly of limestone and dolomite, with varying amounts of chert. Some units are non-cherty while others contain chert in great abundance. Shale is represented at the base of the section by the Chattanooga shale (base of the Kinderhook), which is as much as 250 feet thick and by the Northview shale, a thin, calcareous, silty unit slightly higher in the section. Some shale also occurs in the lower part of the St. Joe limestone (base of the Osage) in south-central Kansas. Some dark and very shaly limestones are also present. Sandstone is conspicuously absent except at the base of the Mississippian where sandstone or sandy shale sometimes occur.

In Saline County the Mississippian rocks range from about 200 feet to more than 400 feet in thickness.

Pennsylvanian System

Pennsylvanian rocks in Kansas have been divided into five series. They are, in ascending order, the Morrow, Atoka, Desmoines, Missouri and the Virgil. The Morrow and the Atoka have not been reported in Saline County. Subdivisions of these rocks in Kansas and in neighboring states are shown in Fig. 4.

Desmoinesian Series. The lowermost Pennsylvanian rocks in Saline County are those of the Desmoinesian series which have been divided into the Cherokee and the Marmaton groups.

Cherokee Group. The Cherokee group is composed of dark-colored, finely crystalline, cherty limestones interbedded with black shales. The basal part of the Cherokee group consists of thin lenses of detrital chert and quartz grains interbedded with varicolored shale. This detrital zone is generally referred to as the Pennsylvanian basal conglomerate, but has been called Sooy

	Kansas	Iowa	Missouri	Oklahoma
	Permian	Permian	Permian	Permian
Virgilian series	Wabaunsee group	Wabaunsee group	Wabaunsee group	Wabaunsee group
	Shawnee group		Shawnee group	
	Douglas group		Douglas group	
Missourian series	Pedee group	Pedee group	Pedee group	Ochelata group
	Lansing group	Lansing group	Lansing group	
	Kansas City group	Kansas City group	Kansas City group	
	Pleasanton group	Pleasanton group	Pleasanton group	Skiatook group
Desmoinesian series	Marmaton group	Appanoose group	Henrietta group	Marmaton group
	Cherokee group	Cherokee group	Cherokee group	Cherokee group
Atokan series	Atokan series			Atokan series
Morrowan series	Morrowan series			Morrowan series

Fig. 4. The subsurface units of the Pennsylvanian in Kansas and their relation to subdivisions used in neighboring states, (Moore, 1949).

conglomerate, (Wilmarth, 1938). It rests on beds ranging from Pre-Cambrian to Mississippian and is overlain by beds ranging from Cherokee age in Central Kansas to possible Permian age in northwest Kansas. The Gorham sand of Russel County is a near-shore phase of the Sooy conglomerate, (Koester, 1935). In Saline County the Cherokee group ranges from 117 feet to 180 feet in thickness.

Marmaton Group. The Marmaton group consists of alternating shales and thin gray limestones containing gray to tan chert. It seems to lie conformably upon the Cherokee group when the latter is present. As a whole the Marmaton group is more calcareous and more dominantly marine than the underlying Cherokee shale, (Moore et al., 1951). The Marmaton group ranges from 100 to 140 feet in thickness in Saline County.

Missourian Series. The Missourian series is divided into four groups. These are, in ascending order, the Pleasanton, the Kansas City, the Lansing and the Pedee. The Pleasanton group has not been recognized in Saline County.

Lansing-Kansas City Group. The Lansing and Kansas City groups are treated in this paper as one lithologic unit because there seems to be no reliable horizon to enable distinction between the two in the subsurface. These groups have a combined thickness of about 500 feet in Saline County. They have a composition characterized mainly by limestones, alternating with thinner shales, (Moore et al., 1951).

Pedee Group. The Pedee group is about 50 to 75 feet thick in Saline County. It includes the Weston shale and the overlying Iaton limestone. The Weston shale is dark bluish to bluish-gray clay shale, and is usually unfossiliferous. The Iatan limestone is called the "Brown Lansing" by many drillers in Kansas. It is nearly white or bluish-gray in color and very fine

and dense, (Moore, et al., 1951).

Virgilian Series. The three groups representing the Virgilian series are, in ascending order, the Douglas, the Shawnee, and the Wabaunsee groups.

Douglas Group. The Douglas group is composed mainly of green shale and tan sandstone with minor amounts of limestone, (Moore, et al., 1951). It has a thickness ranging from 70 to 120 feet in Saline County.

Shawnee Group. The Shawnee group consists of limestones, and calcareous shales. The limestone is dense, massive and sometimes cherty. The shale is bluish gray to dark gray in color, and is usually calcareous. It has thickness of about 350 feet, with the Topeka limestone marking the top and the Oread limestone marking its base, (Moore, et al., 1951).

Wabaunsee Group. The Wabaunsee group consists of limestones and shales interbedded with sandstone and siltstone. It has a total thickness of about 500 feet, (Moore, et al., 1951). The Wabaunsee group has been recognized in the subsurface of Saline County but usually has not been logged in the wells drilled.

Permian System

The Permian rocks in Kansas are divided into three series. They are, in ascending order, the Wolfcampian, the Leonardian, and the Guadalupian. The Guadalupian and the upper part of the Leonardian have not been reported in Saline County.

Wolfcampian Series. This series is composed of the Chase, the Council Grove, and the Admire groups, in ascending order.

Admire Group. The Admire group lies unconformably upon Pennsylvanian rocks. It consists predominately of shale with thin limestones and is about

130 feet in thickness, (Moore et al., 1951).

Council Grove Group. The Council Grove group consists of alternating limestones and shales. It is about 330 feet in thickness. The limestones are light gray to buff and fossiliferous. The shales are varicolored and some are quite calcareous, (Moore, et al., 1951).

Chase Group. The Chase group contains beds of limestone and dolomite alternating with red and green shale. There are some cherty limestones and calcareous shales in this group. The thickness is about 330 feet. The top of the Chase group is marked by the Herington limestone, (Moore et al., 1951).

Leonardian Series. The Leonardian series is divided into the Sumner group and Nippewalla group, in ascending order. The latter has not been recognized in Saline County.

Sumner Group. The Sumner group, about 1,000 feet thick, is composed chiefly of shale with some limestone and evaporite. The upper part of this group contains dolomite, anhydrite, and gypsum with some gray shale. Both the middle and the lower parts are predominantly silty shale. In the subsurface of Kansas, the lower part, known as the Wellington formation, is characterized by the Hutchinson salt member in the middle portion, (Moore, et al., 1951).

Jurassic and Triassic Systems

Rocks of Jurassic and Triassic age occur in the subsurface of western Kansas and outcrop in southern Morton County. The Jurassic rocks are represented by the Morrison formation. The underlying Dockum group is tentatively assigned to Triassic age. Neither of these two units has been recognized in Saline County, (Moore, et al., 1951).

Cretaceous System

The Cretaceous rocks in Saline County consist of two units: the Mentor formation and the Dakota formation. The relationship between these formations and those of the adjacent areas is indicated in Fig. 5.

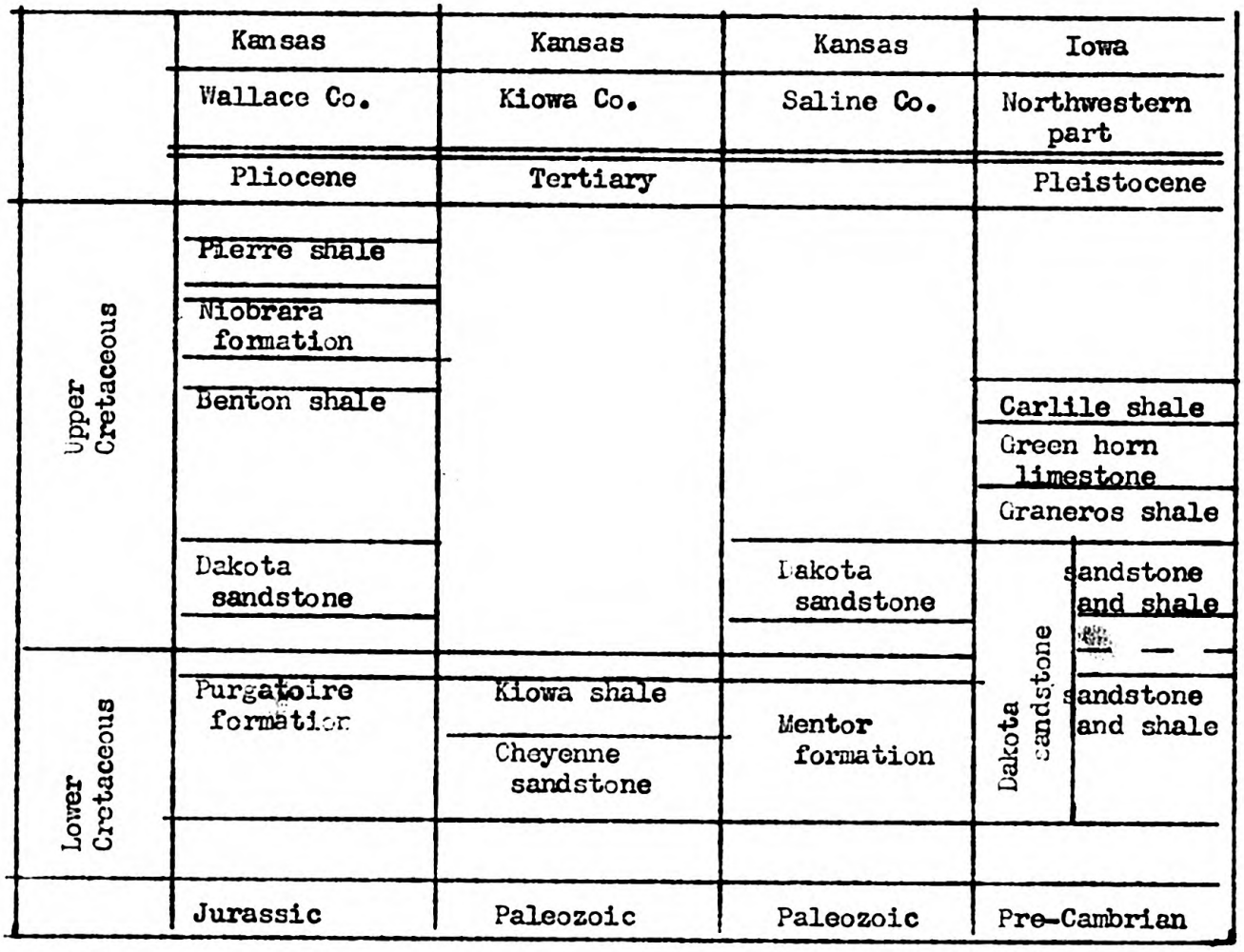

Fig. 5. The relationship between Cretaceous formations of Saline County, Kansas, and those of adjacent areas, (Cobban and Reeside, 1952).

Mentor Formation. The type section of the Mentor formation is at Mentor, Saline County, Kansas; unfortunately, erosion has destroyed the originally described section, but several good exposures are found in the vicinity of Natural Corral, a box canyon about five miles southwest of Marquette, McPherson County, Kansas. Here the Mentor beds are composed chiefly of sandstone with some shale and limestone. The sandstone is red to yellow in color, and coarse- to fine-grained. The shale is gray to dark blue; sometimes it is gypsiferous. The limestone is gray and consists almost wholly of shells. The most common species represented are Ostrea kiowana, Cyprimeria kiowana, Cardium kansasensis and Turritella seriatim-granulata belviderii. The Mentor formation is about 150 feet thick in the Natural Corral section.

Dakota Formation. The Dakota formation consists of clay, silt, and shale with some lenticular sandstone and lignite. Clay is the dominant material of the formation. Generally the clay is massive and is ordinarily gray in color, but has irregular red hematite-stained zones. The thickness of the formation is estimated to be 100 to 300 feet, (Moore, et al., 1951). A section of 79.5 of Dakota formation has been measured in Saline County (Plummer and Romary, 1947).

Tertiary System

Rocks of Tertiary age have not been recognized in Saline County.

Quatenary Deposits

A large part of Saline and McPherson Counties and a part of western Marion, Harvey, and eastern Reno Counties are covered by a formation of Quaternary deposits called the Equus beds. These beds consist of alternating

layers of sand, silt, clay and gravel with a bed of volcanic ash in some places. A section of the Equus beds more than 150 feet thick has been found in McPherson County, (Haworth and Beede, 1897).

In Saline County these beds, which were deposited as stream channels, lie upon an uneven eroded surface of Permian rocks, (Ver Wiebe, 1938).

STRUCTURE

Saline County is located in the southern part of the Salina basin, a structural basin in north-central Kansas. For convenience, the major regional structures related to the Salina basin are here divided into two categories: pre-Mississippian structures and post-Mississippian structures. The geographic distribution of these structures is shown in Fig. 8.

Pre-Mississippian Structures

North Kansas Basin. The North Kansas basin was named by Rich (1933). This basin, situated in the northeastern part of Kansas, was formed by subsidence of the Nebraska arch during the Cambrian and Ordovician periods, (Lee, 1948).

Ellis Arch. The Ellis arch, trending northwesterly in central and northwestern Kansas, was named by Moore and Jewett (1942). They stated that in the region presently defined as belonging to the Central Kansas uplift, Mississippian rocks are absent and Lower Pennsylvanian strata rest directly on Ordovician, Cambrian, or locally on pre-Cambrian rocks. Lee, et al., (1948) called the structure the Ancestral Central Kansas uplift.

Chautauqua Arch. The Chautauqua arch was first described by Barwick (1928). He stated that it was an extension of the Ozark uplift into

southeastern Kansas.

In pre-Mississippian time the Ellis arch joined with the Chautauqua arch to form the Central Kansas arch. This positive element divided the North Kansas basin and South Kansas basin. This structural element has been referred to by Jewett (1951) as the Ozark monocline.

Post-Mississippian Structures

Salina Basin. The Salina basin was defined by Barwick (1928) as the pre-Pennsylvanian syncline bounded on the east by the Nemaha anticline, on the southwest by the Central Kansas uplift and on the south by the saddle between the Chautauqua arch and the Central Kansas uplift. It extends for an undetermined distance into Nebraska.

Lee (1956) indicated that the Salina basin lies on the western margin of an earlier structural basin named the North Kansas basin. This earlier basin was subsequently divided during Mississippian time by the Nemaha anticline, forming the Salina basin on the west and the Forest City basin to the east.

Nemaha Anticline. The Nemaha anticline, trending northeastly, is a major post-Mississippian element that crosses Kansas from Nemaha County to Sumner County. The northern end of this structure extends into Nebraska, and it has been traced southwestward to the area of Central Oklahoma. In many papers the Nemaha anticline has been referred to as "Nemaha mountains", "the Nemaha granite ridge", or "the granite ridge". The anticline was formed during late Mississippian or possibly early Pennsylvanian time when this positive element was uplifted about 1,000 feet higher than the surrounding region. Mississippian and older rocks were eroded from the crest and the

anticline was reduced to the level of the surrounding region, (Ley, 1926). After peneplanation, an eastward facing escarpment was formed when the area west of the anticline was uplifted, (Lee, 1943).

Central Kansas Uplift. The term Central Kansas uplift has been used to refer to both a major post-Mississippian structural uplift and its ancestral structure in north-central Kansas (Jewett, 1951). It was called the Russel arch by Denison (1926) and was later named the Baron arch by Barwick (1928). Koester (1935) stated that the uplift was a buried, oft-rejuvenated structural feature trending northwest - southeast across west-central Kansas. It originated in pre-Cambrian time as a series of parallel batholiths and persisted as a positive element throughout much of Paleozoic time. Several periods of broad warping and erosion occurred during the Paleozoic and Mesozoic eras. Lee and Merriam (1954) stated that by the end of Dakota time the area of the former Central Kansas uplift had become a northerly sloping surface scored by northerly and northwesterly plunging local anticlines.

Abilene Anticline. The Abilene anticline is a rather pronounced fold west of, and nearly parallel to, the Nemaha anticline. Lee, et al., (1948) reported that the prominent Abilene anticline on the northeast side of the Salina basin was recognized in the surface rocks in Riley County and extended southward into Dickinson County. It resembles the Nemaha anticline in that the beds dipped steeply on its southeastern side and very gently to the northwest. The Abilene anticline is interrupted on the south by the Salina basin syncline. Lee and his associates showed that the Voshell anticline farther south lies approximately in the trend of the Abilene anticline, but the two probably are not connected, (Jewett, 1951).

Voshell Anticline. The Voshell anticline occurs in McPherson and Harvey

Counties and is approximately parallel to the Nemaha anticline. Bunte and Fortier (1941) indicated that the anticline extended in a northeasterly direction and plunged southwest. It appeared that the major structural uplift took place in post-Mississippian time with minor movements following in late or post-Permian time and that no structural movement had taken place here before Kinderhookian deposition. In all probability the Voshell anticline was formed contemporaneously with the Nemaha anticline.

Subsurface Structures in Saline County

Geologic structures in Saline County are dominated by narrow, elongate, northeast-trending anticlines and synclines, generally parallel to larger structures to the east. The strata are very gently undulating. The general strike of subsurface rocks in the area is north 55 degrees east which is in accord with the regional trend. Regional dip ranges from 20 feet to 50 feet per mile. The major structure in the county is the Lindsborg-Salina anticline trending north-easterly in a narrow area from T. 16 S., R. 3 W. to T. 13 S., R. 1 W. Up to the present, no faults have been mapped in the area.

To study the structural character of the area the writer constructed four structure contour maps on the tops of the Arbuckle group, the Viola limestone, the Mississippian and the Lansing group of Pennsylvanian age. These horizons were selected for contouring because they are easily recognized and are recorded in most wells.

No wells have been drilled in the northwestern corner of the area, hence, no control points are available for contouring. Therefore contours are not projected into this part of the county.

Structure Contours on Top of the Arbuckle Group. The top of the Arbuckle

group is the oldest horizon recorded in wells of Saline county. Structural contours on this horizon clearly depict the Lindsborg-Salina anticline and two closed synclines, one lying to the northwest and one to the southeast of the anticline.

The Lindsborg-Salina anticline can be divided into two parts. The axis of the north part plunges to the south at the rate of 17 feet per mile. The dip on both flank is about 45 feet to the mile except in the central portion of T. 14 S., R. 2 W. In this part of the anticline the dip steepens to 360 feet per mile. There is a closure of 50 feet on its eastern flank. The south part of the Lindsborg-Salina anticline has an approximately horizontal axis. The northwest flank dips at a rate of about 50 feet per mile, while the southeast flank dips at a rate of nearly 35 feet to the mile.

On the crest of the southern part of the anticline in T. 16 S., R. 3 W. there is a closure of about 10 feet covering an area of nearly two square miles. In the east part of T. 15 S., R. 3 W. a closure of three feet covers an area of one square mile.

The linear syncline to the southeast of the anticline trends in the same direction as the anticline. The syncline to the northwest of the anticline lacks the linear character of the other structures. It is ovate, with a large and nearly flat central portion. A narrow, linear, north-plunging syncline, with a north-south trend extends to the south from this ovate syncline. This linear extension can be traced southward to the southern boundary of Saline County. It becomes progressively narrower to the south, and probably disappears a short distance south of the county boundary. A second linear syncline, trending southwest from the northeast corner of T. 16 S., R. 4 W. lies adjacent to the northwest flank of the Lindsborg-Salina anticline

and parallels this major structure. This small syncline opens to the south, in McPherson County.

A second linear anticline, subparallel to the Lindsborg-Salina structure is located in the southeast corner of the county. Its northwest flank dips 40 feet per mile. The southeast flank extends outside of the area and its dip can not be determined. There is a saddle on this fold in the area between T. 16 S., R. 1 W. and T. 15 S., R. 1 W. Probably this anticlinal folding is a structure connected with the Abilene anticline of Dickinson County and the Voshell anticline to the south in McPherson County.

Structure Contours on Top of the Viola Limestone. The Viola limestone is the most important oil producer in Saline County. Because of this, more information is available for this unit which facilitates subsurface study. The structural elements depicted by the contour map of the Viola limestone are similar to those of the Arbuckle, with some minor modification. The Lindsborg-Salina anticline has a broader crest on the Viola than on the Arbuckle. The axis of the anticline plunges to the south at an average rate of 10 feet per mile. Generally the dip on both flanks of the anticline is 80 feet to the mile. There are a few small depressions and highs on the crest of the anticline. A closure of 50 feet is located in the central portion of T. 14 S., R. 2 W. In the west part of T. 14 S., R. 2 W. there is an elongate closure of four feet, and two small depressions to the north of this closure. In the east part of T. 15 S., R. 3 W. is an elongate closure of five feet and a rounded depression to its north. In the south part of T. 15 S., R. 3 W. there is an elongate closure of 15 feet.

A rounded closure of one foot and an elongate depression occur to the northwest of this closed structure. In the west part of T. 15 S., R. 3 W.

two elongate depressions are mapped. There are two ovate closures of 50 feet and 35 feet in the north part of T. 16 S., R. 3 W. A closure of 50 feet is found in the south part of the same township. A depression and a closure of two feet are mapped in the northeast corner of T. 16 S., R. 4 W. Between T. 16 S., R. 4 W. and T. 15 S., R. 4 W. and elongate closure of 40 feet occurs on the northwest flank of Lindsborg-Salina anticline.

The two linear synclines, northwest and southeast of the Lindsborg-Salina anticline, and the minor one at the southwest end of this anticline persist with the same configurations they showed on the structure contour map of the Arbuckle.

In the southeast corner of the county in the position of the anticline depicted on the Arbuckle map, the anticlinal structure persists. A closure of 10 feet is mapped on the crest of this anticline in the south part of T. 16 S., R. 1 W.

Structure Contours on Top of the Mississippian System. Mississippian rocks are also productive of oil in Saline County. Structure contours on top of the Mississippian are similar to those of older horizons with respect to the major structures. The axis of the Lindsborg-Salina anticline plunges to the south at an average rate of 12.5 feet per mile. The flanks of the anticline dip less steeply than on earlier horizons. The west flank of the anticline has an average dip of 40 feet to the mile. The east flank has an irregular surface and dips still more gently. The maximum closure for the highs on the crest of the anticline is about 55 feet. To the east of the Lindsborg-Salina anticline is a syncline, located between T. 14 S., R. 1 W. and T. 16 S., R. 3 W., and depicted on the Arbuckle and Viola horizons. It again assumes a northwest-trend. It is linear and plunges to the southwest. This

syncline probably continues south of the county boundary. A small depression occurs in the center of this syncline. It is located in the northeast part of T. 15 S., R. 2 W.

The syncline to the northwest of the Lindsborg-Salina anticline is clearly defined in the Arbuckle and Viola horizons. A saddle, located in the northwestern part of T. 16 S., R. 4 W., divides this syncline into two parts. The syncline to the north of the saddle is ovate, closed, and trends north-south, while the southern syncline is linear and trends northeast. The latter plunges to the southwest and its southern limit is probably defined a short distance beyond the south boundary of Saline County.

The high in the south part of T. 15 S., R. 4 W. has a closure of about 70 feet with an abrupt northwestward dip of 500 feet per mile. In the southeast part of T. 15 S., R. 5 W. an ovate anticline, not present in earlier horizons, has developed with a closure of 85 feet.

In T. 16 S., R. 1 W., at the position of the anticline depicted by earlier horizons, a few small highs and depressions have developed on the flat anticlinal crest. A subrounded closure of ten feet and an elongate closure of 15 feet are mapped in the northwestern part of the township. An ovate closure of 10 feet is located in the western part of the township. Two depressions are present in the central and north part of the township. Another high is located close to the southern boundary of the county. It probably achieves a closure in McPherson County.

<u>Structure Contours on Top of the Lansing Group</u>. Structure contours on the top of the Lansing group vary greatly from those of earlier horizons. The Lindsborg-Salina anticline is crossed by two northwest-trending synclines: one is located in the central part of the anticline, the other on the north part of the anticline. Between these two synclines there are four closures

and one depression on the crest of the Lindsborg-Salina anticline. An ovate north-south trending closure of 20 feet is mapped between T. 13 S., R. 2 W. and T. 14 S., R. 2 W. An ovate east-west trending closure of 10 feet is located in the central part of T. 14 S., R. 2 W. In the southwestern part of T. 14 S., R. 2 W. occurs a subrounded closure of 20 feet, and an ovate closure of 25 feet with a small depression lying between the two.

The south part of the anticline has developed into an elongate dome covering an area of about 40 square miles in T. 16 S., R. 3 W. and T. 15 S., R. 3 W. The north part of the elongate dome has developed into an ovate closure of 85 feet, which covers an area of about 25 square miles. Two elongate closures cover the south part of the dome: a closure of 20 feet located between T. 16 S., R. 3 W. and T. 15 S., R. 3 W., and another closure of 15 feet found in the central part of T. 16 S., R. 3 W.

The high in the south part of T. 15 S., R. 4 W., depicted by the Viola and Mississippian structural maps, has a closure of about 55 feet with an abrupt northwestward dip of about 75 feet per mile.

The syncline to the northwest of the Lindsborg-Salina anticline and other structural features in the west part of the county depicted by structure contours on the top of the Mississippian have disappeared. A nearly flat surface covers Range 5 and the west of Range 4 in all four townships on the west edge of the county. In the east-central part of T. 16 S., R. 4 W. a small linear depression has developed.

To the southeast of the Lindsborg-Salina anticline, the syncline depicted by earlier horizons is deformed into two synclines. These two synclinesplunge to south and are connected by a monoclinal structure. This monoclinal structure, trending northwest-southeast, is located in the central part of T. 15 S.,

R. 2 W. and dips to the southwest at a rate of about 17 feet per mile. The syncline at the northeast side of the monocline is fan-shaped and has a flat central portion. The syncline at the southwest side of the monocline is linear and approximately north-south trending. It extends to the south from the monocline and has asymmetrical flanks. The west flank has a more gentle dip than the east. Along the southern boundary of the county both flanks of the syncline tend to close. The syncline is probably closed a short distance south of the county boundary.

The southeast corner of the area remained as an anticlinal high. There is a depression in the central part of T. 16 S., R. 1 W. A small closure and a depression is shown in the northwest part of the same township. Another very small closure occurs at the eastern border of T. 16 S., R. 2 W.

GEOLOGIC HISTORY

The area under investigation is characterized by a thick stratigraphic section with evidence of many interruptions in sedimentation. During the course of geologic development of the area deposition predominated over erosion.

The relationships and character of stratigraphic units within the Arbuckle group indicate that during Cambro-Ordovician time, Saline County was part of a relatively high area which was alternately invaded by the Cambro-Ordovician sea and exposed to subaerial erosion. Of the six formations of the Arbuckle group described in Kansas, only the Bonneterre dolomite, the Roubidoux dolomite and the Jefferson City-Cotter sequence are present in Saline County,(Keroher and Kirby, 1948). The absence of the other three units may be due to either nondeposition or erosion.

In north central Kansas, after Arbuckle time, rocks of Simpson age were deposited upon the locally channeled surface of the Arbuckle limestone. The top of the Simpson is also an eroded surface (Leatherock, 1945). Evidence of this is found in the southwestern part of T. 14 S., R. 4 W. of Saline County, where the Simpson group is locally absent.

After interruption of sedimentation at the end of Simpson time, the Viola sea covered the area. More than 100 feet of Viola rocks, predominantly limestone, were deposited over most of the county. The isopach map of the Viola limestone (Plate 5 in appendix) shows that the thickness of the unit varies irregularly from place to place; this irregularity is most obvious along the Lindsborg-Salina axis where the thickness varies from 180 to 80 feet within a distance of a few miles. Elsewhere the change in thickness is gradual, and ordinarily six or seven miles are required to show an average difference of 40 feet. This suggests a relationship between the thickness of the limestone and the anticlinal folding. Since other parts of the county have not been heavily drilled, the apparent regularity of thickness in these areas might be due to less abundant data. At present it is impossible to establish a cause and effect relationship between structure and thickness. Evidence available indicates that either the limestone was deposited on an uneven surface or that the top of the unit has been subjected to post-depositional erosion.

In Upper Ordovician time the sea was shallow and muddy, (Taylor, 1947b). During this time, the Sylvan shale was deposited unconformably on the Viola limestone, (Taylor, 1947a). At the end of Ordovician time the sea withdrew, and slight tilting, followed by peneplanation, locally removed Sylvan deposits, (Taylor, 1947b). The shale is absent in the central part of Saline County

(Plate 6 in appendix).

In Siluro-Devonian time the sea trangressed from the northeast, indicated by gradually overlapping sediments. The Hunton formation was deposited in the area. After deposition, seas withdrew and the formation was truncated, (Taylor, 1946). The Hunton is absent in the southwest part of the county (Plate 6 in appendix). Upon this erosional surface seas advanced and the Misener sandstone was deposited. Its thinness, irregular distribution and superposition on various formations, indicate a long pre-Mississippian erosional interval, (Leatherock and Bass, 1936). This sandstone occurs mainly in the east part of the area (Plate 6 in appendix).

During Mississippian time, the sea advanced and covered the entire area. A section of more than 400 feet of limestone with some shale and sandstone was deposited on the pre-Mississippian erosional surface. During and at the end of the period tectonic activity was intensified in Kansas. During this time the Nemaha anticline was uplifted to bisect the North Kansas basin, forming the Forest City basin and the Salina basin. The Central Kansas uplift was re-elevated. At the same time, Mis issippian and pre-Mississippian rocks of Saline County were folded intensively.

During Pennsylvanian time the sea advanced and retreated repeatedly and tectonic activity was renewed, as evidenced by alternating clastic and non-clastic sediments and the revived movement of the Nemaha anticline, (Lee, 1956). The close of the Pennsylvanian was marked by the unconformity at the top of the Wabaunsee group that separates Permian and Pennsylvanian rocks, (Moore, et al., 1951).

There are two types of local folding, northwest-trending and northeast-trending. These are depicted on the structure contour maps (Plates 1, 2, 3, 4

in appendix). Both northwest and northeast-trending folds are revealed by the structure contour map of the Lansing group. Only the northeast-trending folds are clearly revealed by structure contour maps of the earlier horizons, i.e., the Arbuckle group, the Viola limestone and the Mississippian system. It may be that the northwest-trending folds are not clearly revealed by structure contour maps of the earlier horizons because of the scale of the maps and the contour intervals used.

Following post-Pennsylvanian erosion, the Permian sea advanced and deposited a sequence of alternating limestones and shales unconformably upon the eroded Pennsylvanian rocks. In Kansas, Permian rocks are separated from the overlying Cretaceous formations by an angular unconformity representing a long hiatus, during which hundreds of feet of Permian rocks were eroded, (Lee, 1956). Consequently, only the Wolfcampian series of Lower Permian age and the lower part of the Leonardian series (Sumner group) of Middle Permian age were preserved in Saline County.

The geologic history between Permian and Cretaceous times in Kansas is only partly known. In northwestern Kansas, Permian rocks are overlain unconformably by the Morrison formation of Jurassic age. During the hiatus that separates them, deposition and erosion of Triassic sediments occurred in other areas of the state, (Lee, 1956). Rocks of Jurassic and Triassic age are not present in Saline County. Lee (1956) stated that preceding Cretaceous deposition, rocks of these age, if ever present, were eroded away. By the beginning of Cretaceous time Permian rocks had been roughly truncated, (Lee, 1956).

The Mentor formation of Lower Cretaceous age, which has been correlated with the Cheyenne sandstone and Kiowa shale, overlies the truncated surface

of the Permian rocks. An unconformity separates the Mentor formation from the overlying Dakota formation of Upper Cretaceous age, (Cobban and Reeside, 1952). In other parts of central Kansas the Upper Cretaceous rocks consist of two groups: the upper Montana group and the lower Colorado group. Only the Dakota formation, which is the basal part of the Colorado group, is preserved in Saline County. The rocks of the younger formations of the Upper Cretaceous were removed by erosion, (Lee, 1956).

During Cenozoic time deposits in central Kansas were all continental in origin and were deposited mostly by streams on the eroded surface of older rocks. The Emma Creek formation, tentatively assigned to Tertiary age, is widespread in McPherson and adjacent counties. The lower part of this unit is probably equivalent in part to the Ogallala formation of western Kansas, (Moore, et al., 1944). This formation has not been found in Saline County. Probably Emma Creek sediments were deposited in the county and later removed by erosion.

Sediments of Saline County representing Quaternary deposition are: the Equus beds, a stream channel deposit having wide distribution in major valleys in the area; and recent alluvial terraces bounding present stream channels.

PETROLEUM EXPLORATION AND DEVELOPMENT

During more than 20 years of exploration there were many oil pools discovered in Saline County, with two periods of sudden increase in production: during 1943, and during the years from 1951 to 1953.

According to Folger and Hall (1933) the history of development of oil pools in Saline County can be dated to 1929. In this year three dry holes

were drilled and another one was completed as a producer on December 8, 1929. This fourth well was on the Olsson farm in Sec. 10, T. 16 S., R. 3 W. It opened the Olsson pool which was the first commercial production in the county.

Landes (1937) and Ver Wiebe (1938) reported that from 1930 to 1937 few tests were drilled in Saline County. All were unsuccessful. These were all located in the eastern half of the county.

In the years from 1938 to 1942, drilling was continued without productive results, (Ver Wiebe, et al., 1948).

During 1943 three oil pools were discovered in Saline County. These were the Hunter, the Salina and the Pliny pools. This successful drilling created renewed interest in exploration. Since then, the search for oil in Saline County has continued with varying degrees of success. By 1956 the existing pools were the Salina, Salina South, Mentor, Smolan, Swenson, Olsson, Salemsborg, Bachofer, Hunter North, Hunter and Gypsum Creek. All oil in the Salina, Salina South, Mentor, Smolan, Swenson, Olsson, and Salemsborg pools is produced from the Viola limestone. The oil from the Hunter, Hunter North, Gypsum Creek and Bachofer pools is found in the Mississippian limestone. The oil from the Pliny pool which is located in T. 16 S., R. 1 W. was produced from the Lansing-Kansas City Limestone, but the production did not last very long. The Pliny pool was abandoned during 1947. The location of the oil pools in Saline County is shown in Fig. 6. The total annual production from all pools is listed in Table 1.

Table 1. Annual oil production in Saline County, Kansas, 1930 to 1956, (State Geological of Kansas Bull. 1938-1957).

Year	Oil production	bbls
1930 to 1942	1,400	
1943	74,750	
1944	194,398	
1945	214,662	
1946	308,758	
1947	336,161	
1948	266,252	
1949	242,290	
1950	361,030	
1951	683,262	
1952	1,071,522	
1953	1,517,070	
1954	1,429,923	
1955	1,126,475	
1956	811,834	
Total	8,639,787	bbls

RELATION OF PETROLEUM TO STRUCTURE AND STRATIGRAPHY

Most of the oil pools of Saline County, including the Salina, Salina South, Mentor, Smolan, Swenson, Olsson, and Salemsborg are located along the crest of the Lindsborg-Salina anticline from township 14 south to 16 south. All oil in these pools is produced from the Viola limestone (Fig. 6 and Plate 3 in appendix). Other pools, including the Hunter, Hunter North and Gypsum Creek are located on another anticlinal structure in T. 16 S., R. 1 W. The oil from these pools is found in the Mississippian limestone. The remaining producing pool, the Bachofer, is located in the center of the syncline between the two anticlines just mentioned. The oil in this pool is produced from the Mississippian limestone (Fig. 6 and Plate 2 in appendix). The oil from an abandoned pool, the Pliny, was found in the Lansing-Kansas City limestone. The area within all these pools has been intensely drilled.

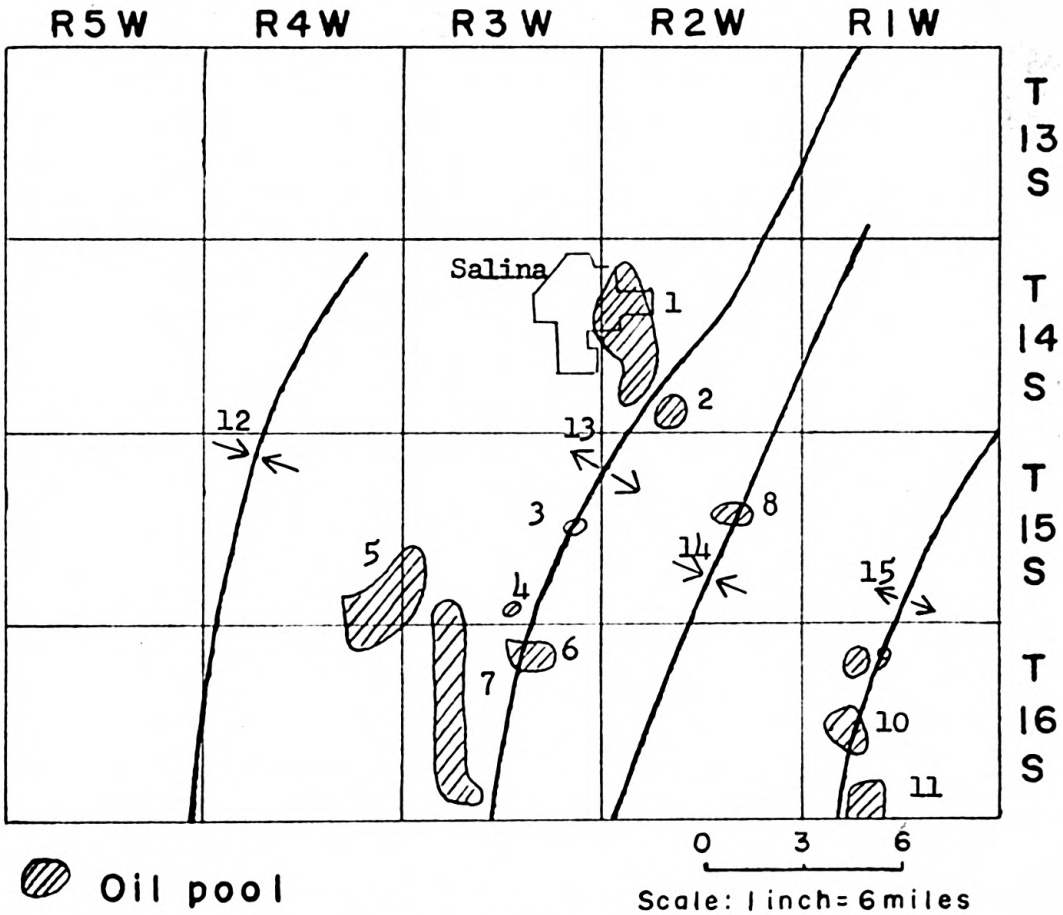

Fig. 6. Oil pools in Saline County, Kansas. (Goebel, E. D., et al., 1957).

1. Salina
2. Salina south
3. Mentor
4. Swenson
5. Smolan
6. Olsson
7. Salemsborg
8. Bachofer
9. Hunter North
10. Hunter
11. Gypsum Creek
12. Unnamed west-flanking syncline
13. Lindsborg-Salina anticline
14. Unnamed east-flanking syncline
15. Probable extension of Abilene anticline

The Lindsborg-Salina anticline is the major structure of the area. The other significant anticlinal structure is in the southeastern part of the county. It lies in the trend of, and is probably related to, the Abilene anticline to the north and the Voshell anticline to the south. Petroleum accumulation is primarily controlled by anticlinal structures. The limestones serve as reservoirs. Whether the source bed lies within the area or petroleum has migrated from some other area remains to be determined.

SUMMARY AND CONCLUSIONS

Saline County is located in the south part of the Salina basin which is a major structural basin in north-central Kansas. The county is underlain by a stratigraphic sequence of more than 4,000 feet of limestones, sandstones, shales and some evaporites, ranging from Upper Cambrian to Quaternary in age.

The strata are gently folded. The major structure in the area is the Lindsborg-Salina anticline trending northeast-southwest. The axis of the anticline extends from the north border of T. 13 S., R. 1 W. to and beyond the south border of T. 16 S., R. 3 W. It plunges to the southwest. On the map of the Arbuckle group the north part of the axis plunges to the southwest at an average rate of 17 feet per mile and levels out so that the south part of the axis is horizontal. On the map of the Viola limestone the axis plunges to the southwest at an average rate of 10 feet per mile. On the map of the Mississippian rocks the axis plunges to the southwest at an average rate of 12.5 feet to the mile. On the map of the Lansing group the anticline is crossed by northwest-trending depressions, which divide the anticline into three parts. The average dip of the flanks of the Lindsborg-Salina anticline

is less than 50 feet per mile toward the southeast and northwest. The present attitude of the rocks is the result of many structural movements that occurred in post-Mississippian and pre-Desmoinesian times. The amount of information available and the scale used in map preparation in this study are such that an exact statement regarding the effect of each structural movement can not be made.

During its geologic history the area experienced several periods of submergence and emergence and was repeatedly subjected to subaerial erosion. Many of the stratigraphic units were locally thinned or entirely removed.

During more than 20 years of exploration there were many oil pools discovered in the county. Most of these pools were found either along the Lindsborg-Salina anticline or associated with a linear anticline in T. 16 S., R. 1 W. in the southeastern part of the county. The latter is a structural high lying in the trend of, and probably related to, the Abilene anticline to the north and the Voshell anticline to the south. Petroleum production of the area is obtained mainly from the Middle Ordovician Viola limestones and the Mississippian limestones. Petroleum accumulation is primarily structurally controlled with limestones serving as the reservoirs. Although production is obtained from structural highs, not all highs are productive. Contrarily, one pool, the Bachofer, is not located on an anticline. This particular pool is found in the flat center of a syncline. In all pools production was initially flush, but rapid depletion usually followed. The characteristics of Saline County oil pools are similar to the structural types as discussed by Russell (1951) "oil and gas accumulation in fractures". In this type of pool, production is obtained from fractures in limestone caused by deformation associated with folding. All folds are not uniformly

fractured, and thus not all highs will be uniformly productive. Initial production is usually high but declines very rapidly. Because production depends upon fractures, which are irregularly distributed, the number of barrels of recoverable oil per acre-foot can not be predicted.

ACKNOWLEDGMENTS

The writer is indebted to Mr. William K. Clark for advice and timely suggestions while preparing this thesis and also to Dr. J. R. Chelikowsky for suggestions and editing this manuscript. Thanks are also extended to other members of the staff of the Department of Geology for assistance and suggestions.

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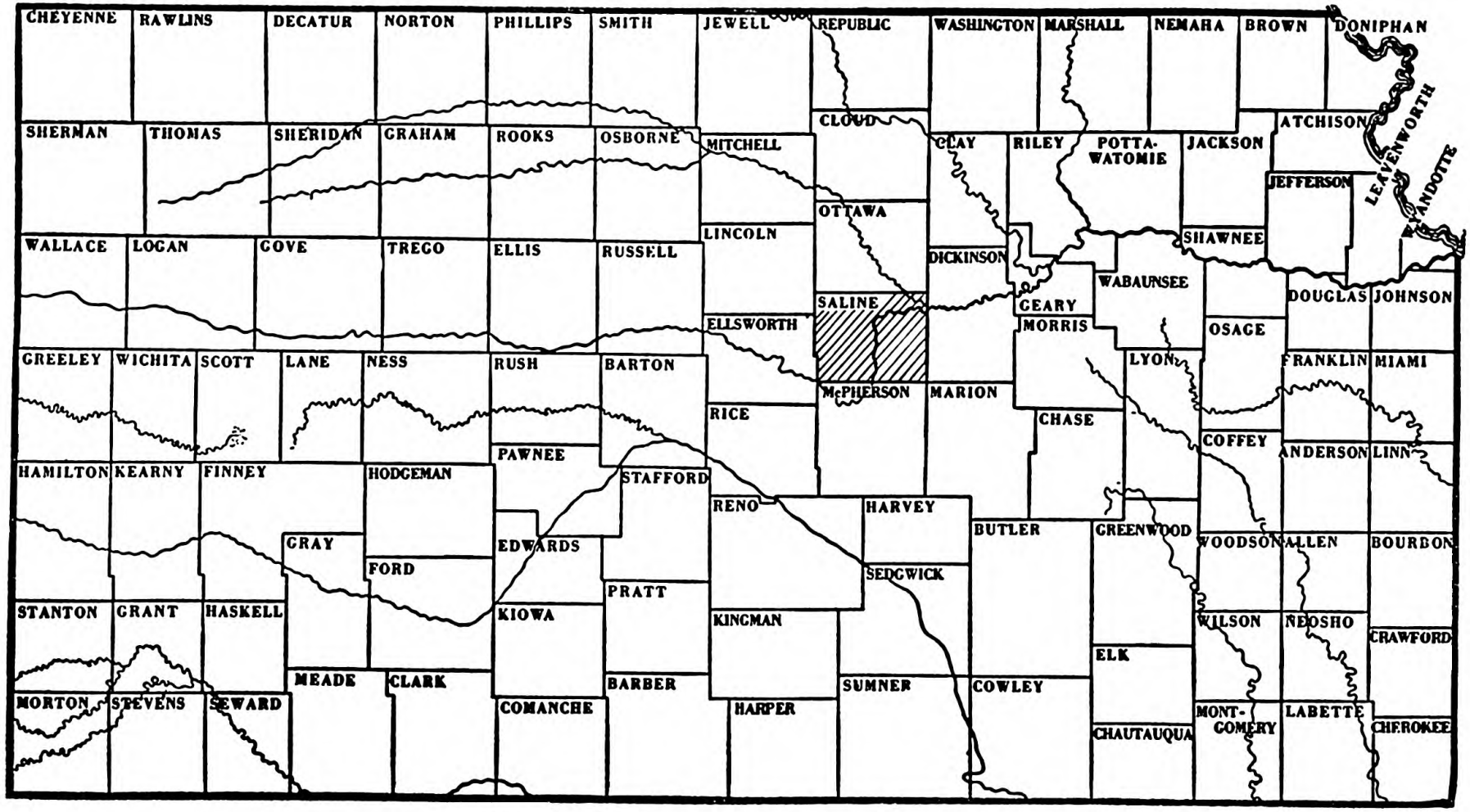
APPENDIX



Area covered by this report

Fig. 7. Map of Kansas showing the location of Saline County.

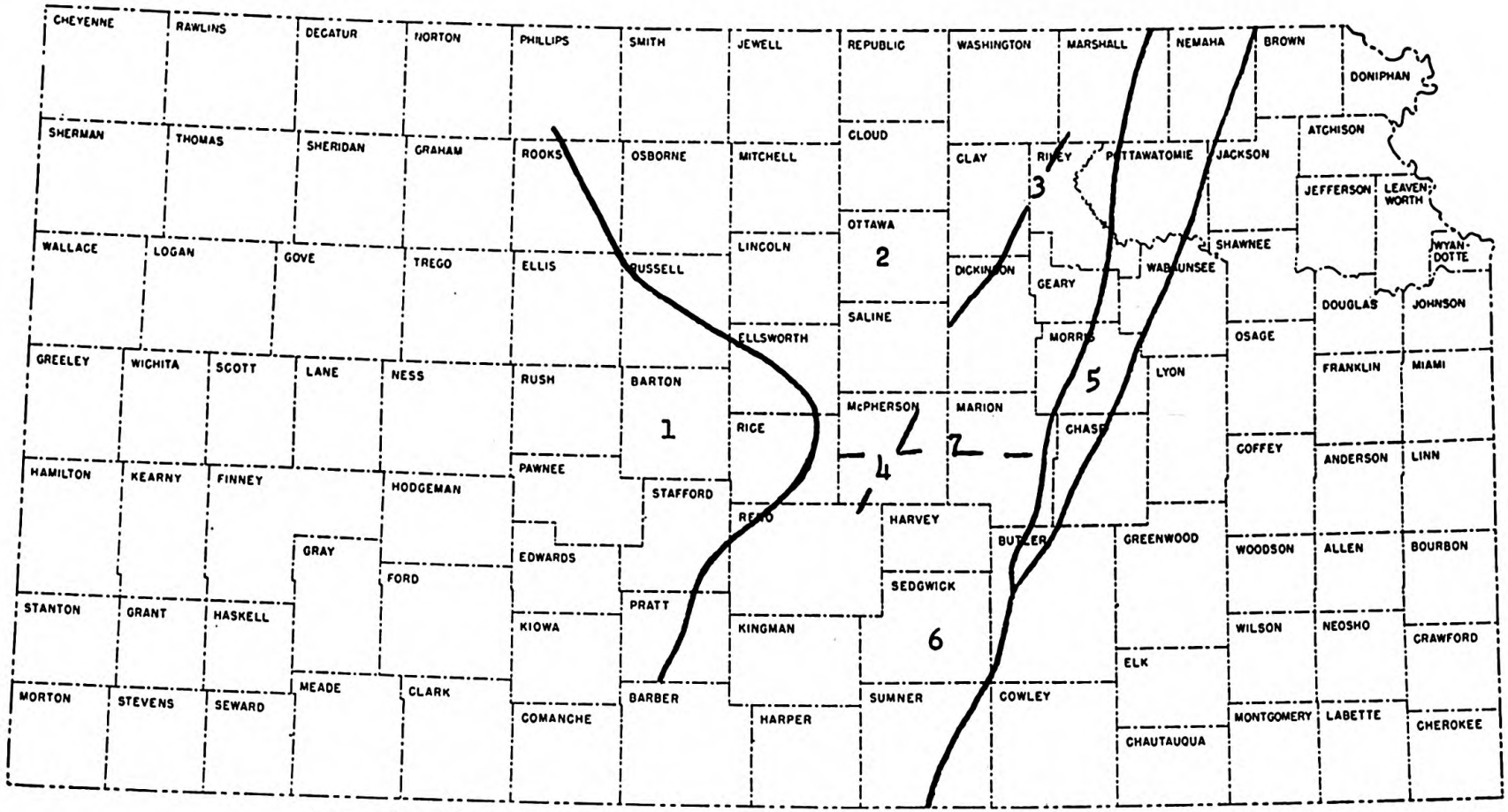


Fig. 8. Major structures in Central Kansas (Jewett, 1951)

State Geological Survey of Kansas

1. Central Kansas uplift, 2. Salina basin, 3. Abilene anticline,
4. Voshell anticline, 5. Nemaha anticline, 6. Sedgwick basin,
7. approximate boundary between Salina and Sedgwick basins.

1. Unnamed west-flanking syncline

2. Lindsborg-Salina anticline

3. Unnamed east-flanking syncline

4. Probable extension of Abilene anticline

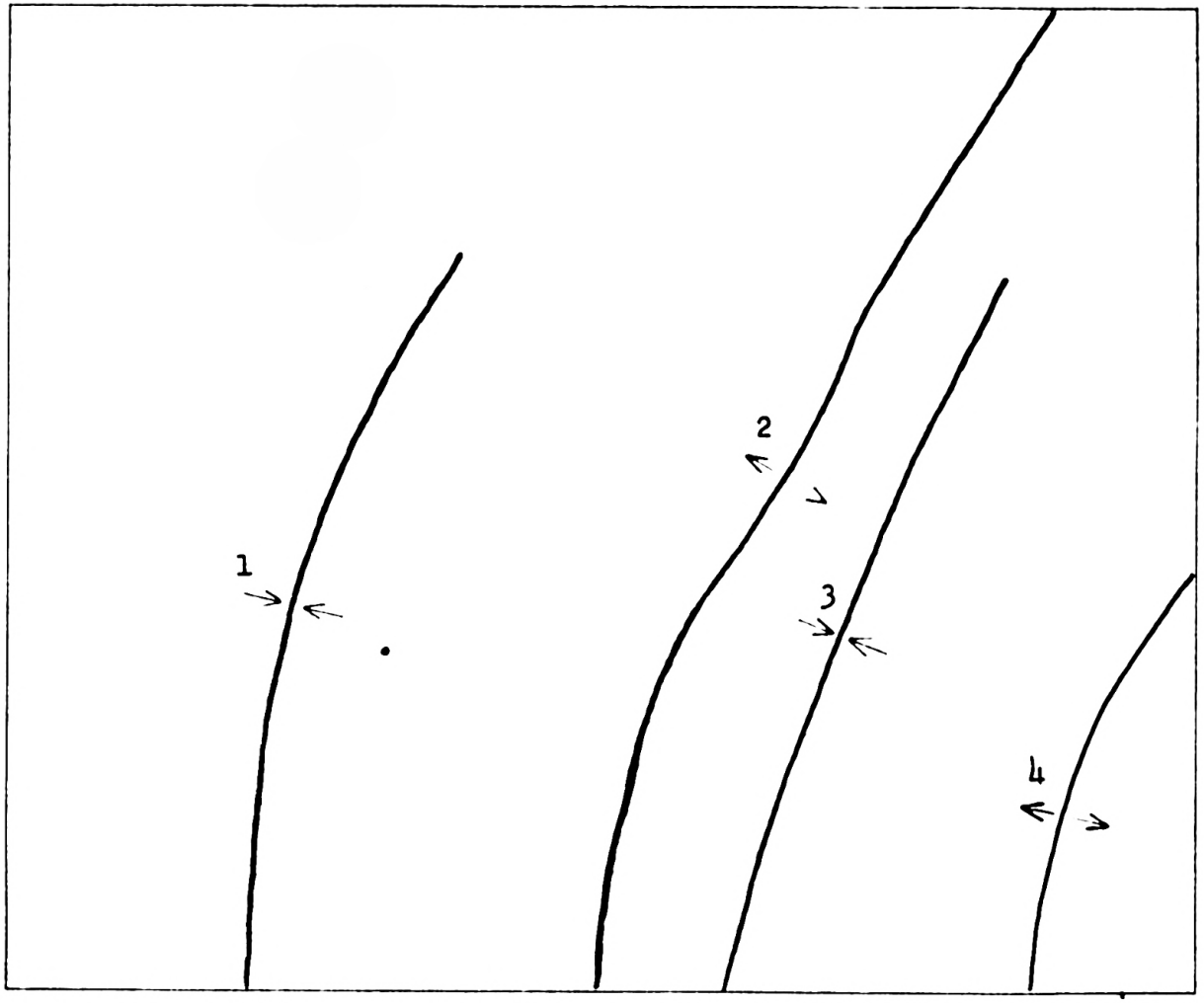


Fig. 9. Local subsurface structures in Saline County, Kansas

Plates 1 through 6

in accompanying plate box

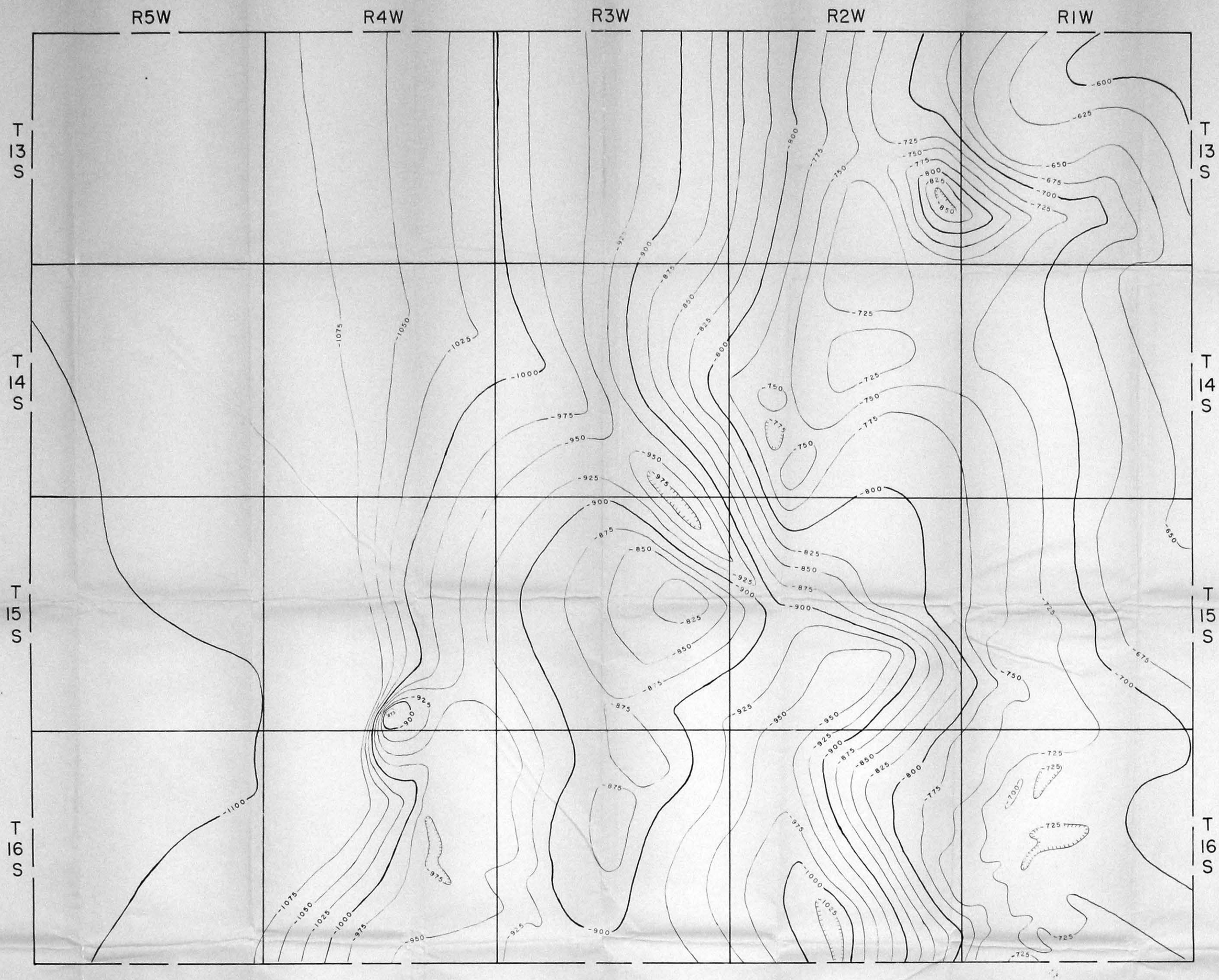


Plate I

STRUCTURE CONTOURS ON THE TOP OF THE LANSING GROUP
SALINE COUNTY, KANSAS

Contour interval: 25 feet Scale: 1 inch=1 mile

Datum: sea level

Chih-wei Pan

January, 1959

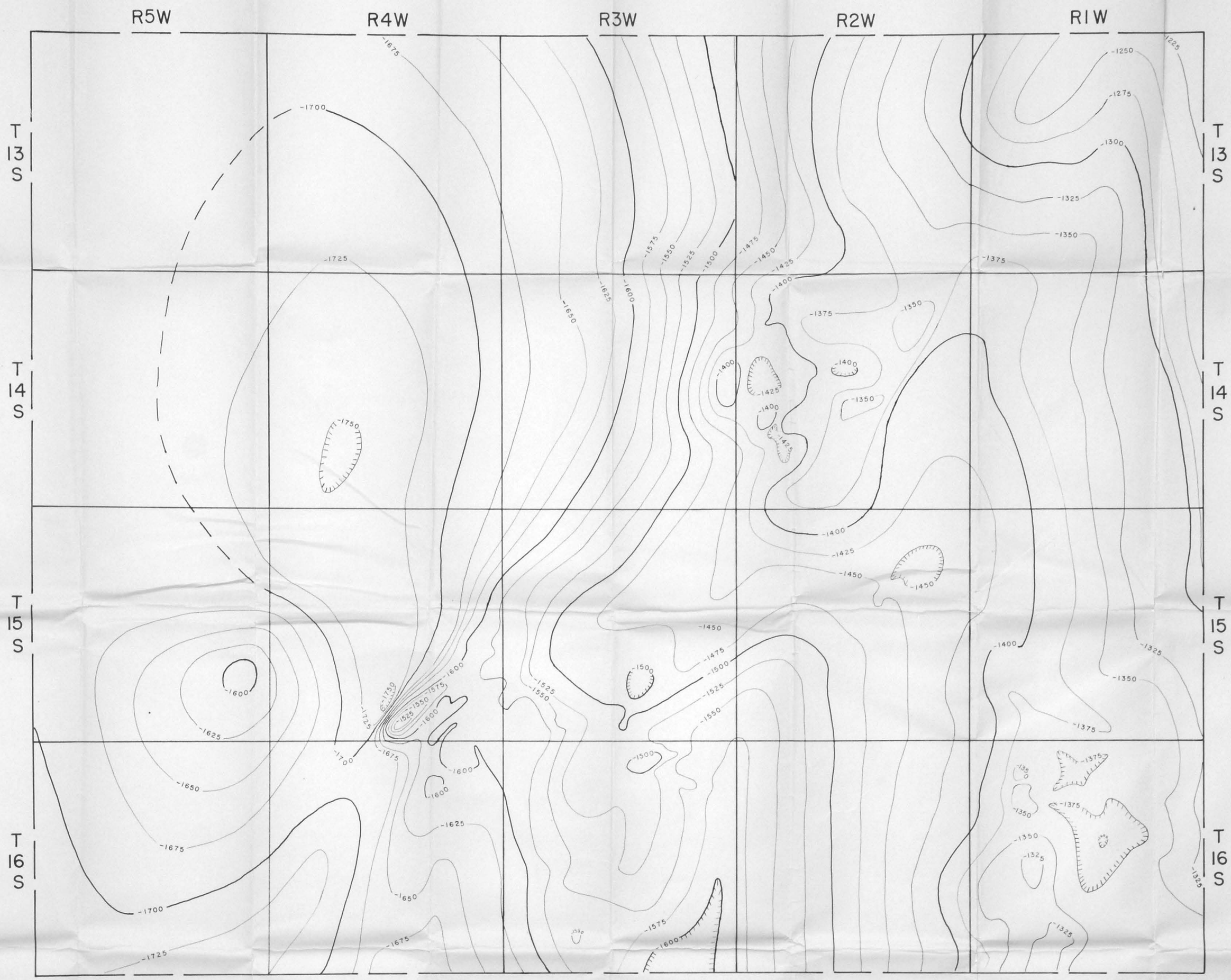


Plate 2

STRUCTURE CONTOURS ON THE TOP OF THE MISSISSIPPIAN ROCKS

SALINE COUNTY, KANSAS

Contour interval: 25 feet Scale: 1 inch=1 mile

Datum: sea level

Chih-wei Pan

January, 1959

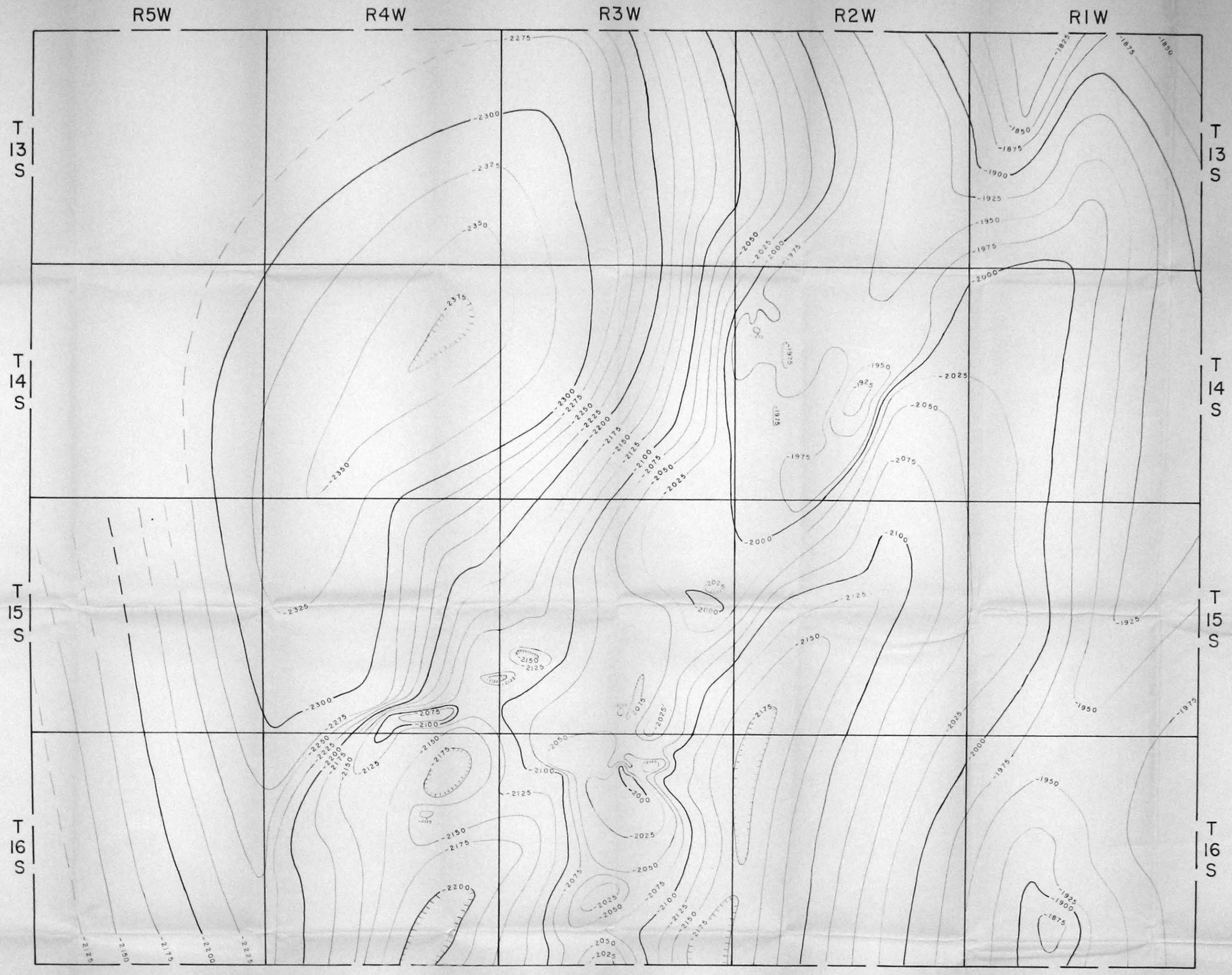


Plate 3

STRUCTURE CONTOURS ON THE TOP OF THE VIOLA LIMESTONE
SALINE COUNTY, KANSAS

Contour interval: 25 feet Scale: 1 inch=1 mile

Datum: sea level

Chih-wei Pan

January, 1959

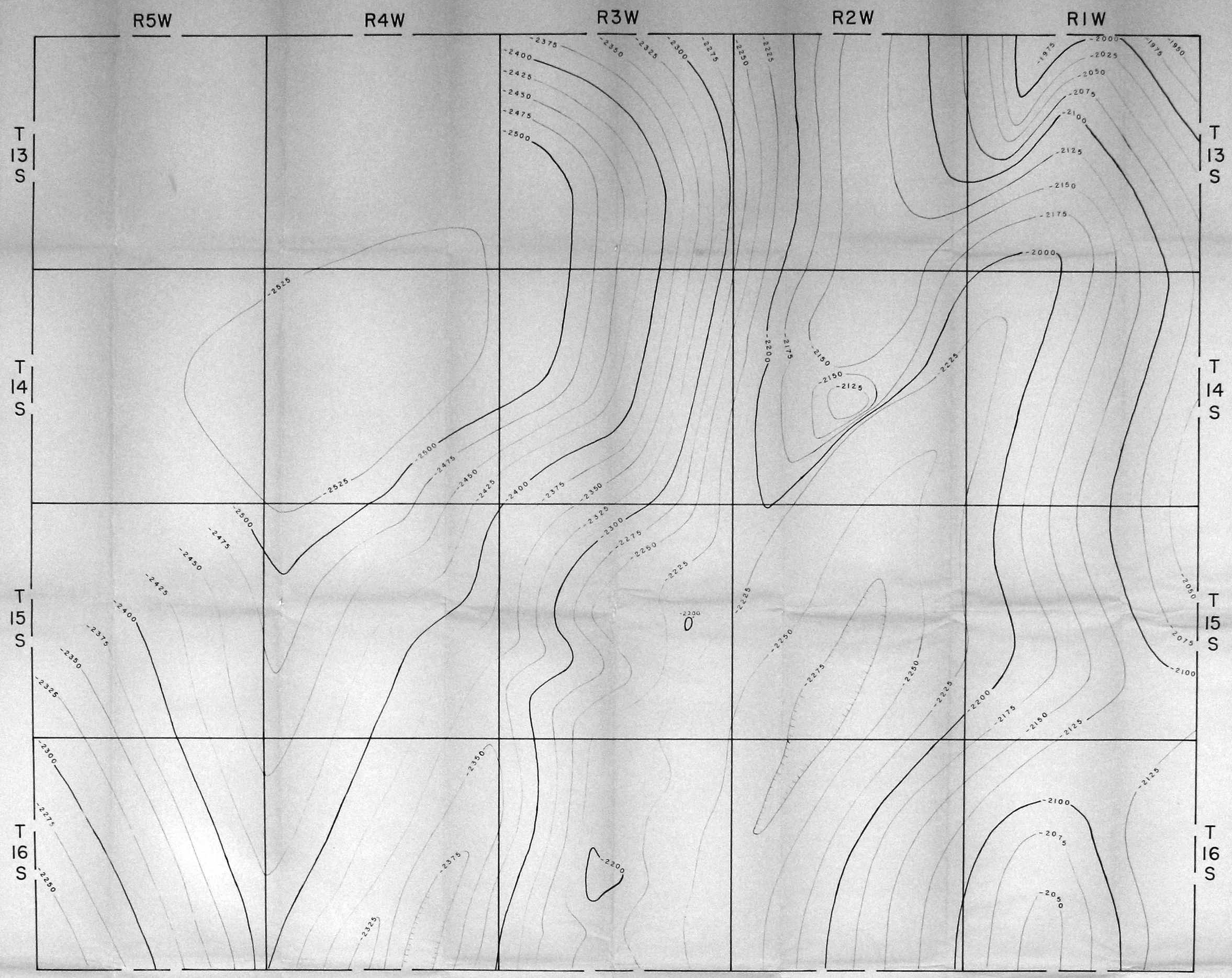


Plate 4

STRUCTURE CONTOURS ON THE TOP OF THE ARBUCKLE GROUP

SALINE COUNTY, KANSAS

Contour interval: 25 feet Scale: 1 inch=1 mile

Datum: sea level

Chih-wei Pan

January, 1959

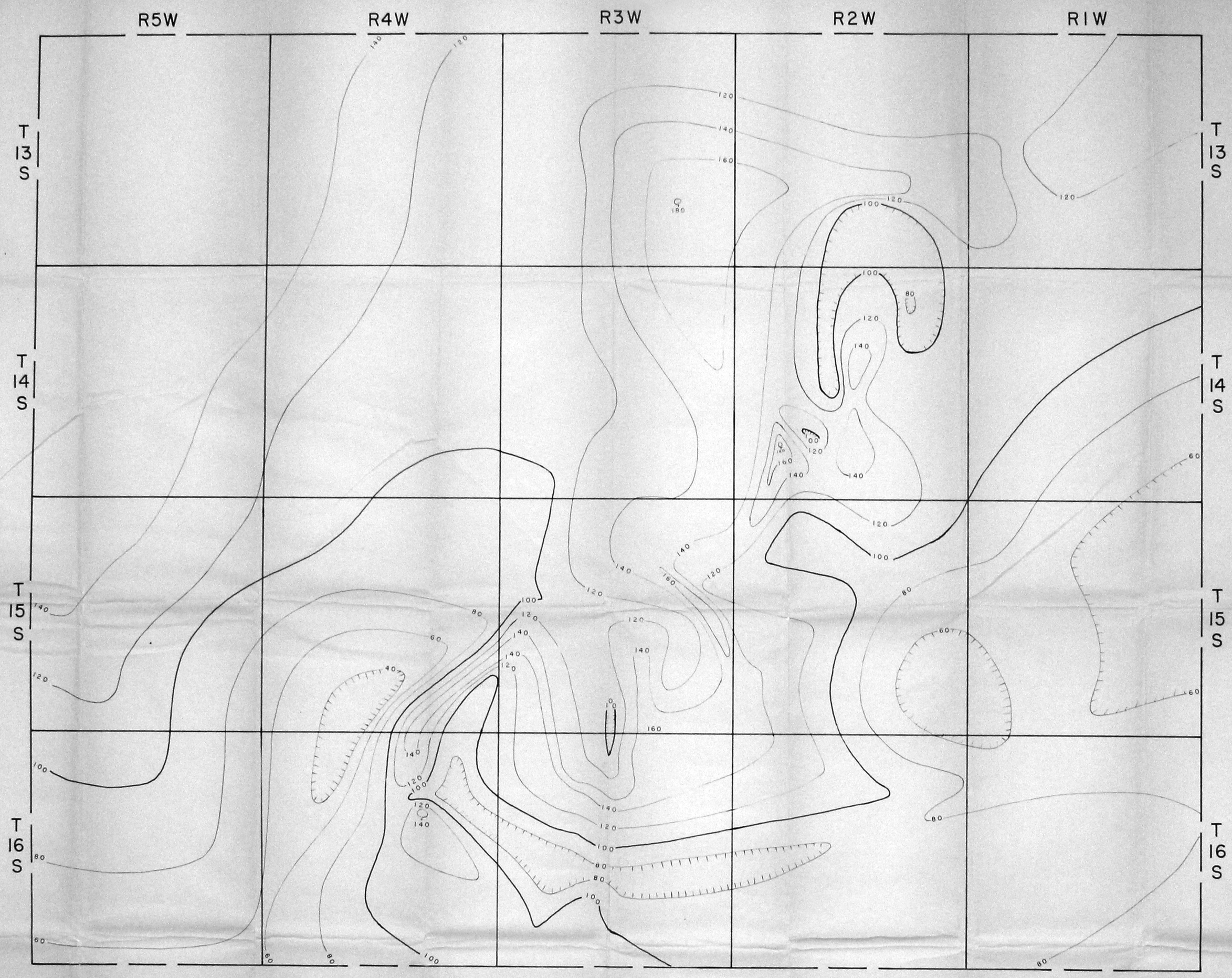


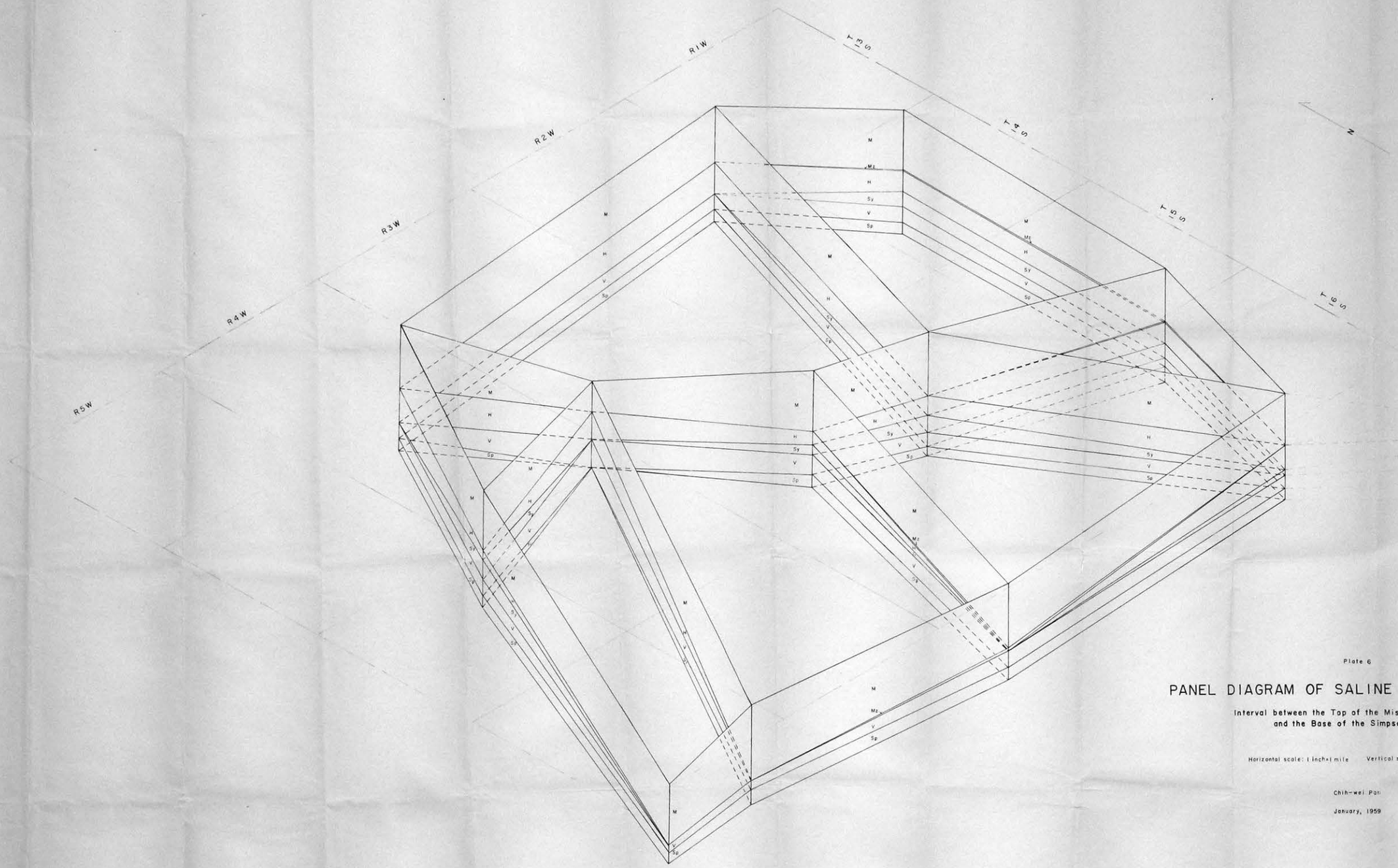
Plate 5

ISOPACH MAP OF THE VIOLA LIMESTONE
SALINE COUNTY, KANSAS

Isopach interval: 20 feet Scale: 1 inch=1 mile

Chih-wei Pan

January, 1959



Symbols	Formations	Periods
M	Mississippian Rocks	Mississippian
Mz	Misener Sandstone	Silura-Devonian
H	Hunton Limestone	
Sy	Sylvan Shale	
V	Viola Limestone	Ordovician
Sp	Simpson Group	

Plate 6

PANEL DIAGRAM OF SALINE COUNTY, KANSAS

Interval between the Top of the Mississippian Rocks and the Base of the Simpson Group

Horizontal scale: 1 inch=1 mile Vertical scale: 1 inch=200 feet

Chih-wei Pan

January, 1959

SUBSURFACE GEOLOGY OF SALINE COUNTY, KANSAS

by

CHIH-WEI PAN

B.S., National Taiwan University, Taipei, China, 1950

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1959

It was the purpose of this study to attempt to relate the subsurface stratigraphy, structure and geologic history with petroleum accumulation in Saline County, Kansas. Four structural contour maps, an isopach map and a panel diagram were constructed in order to interpret the structural development and the depositional and erosional history of the area as it is related to petroleum accumulation.

Geologically, the area is situated in the southern part of the Salina basin. The county is underlain by a stratigraphic sequence of more than 4,000 feet of alternating limestones, sandstones, shales and some evaporites. Subsurface strata range from Upper Cambrian to Pennsylvanian in age and the surface rocks include Permian, Cretaceous and Quaternary sediments.

The strata are gently folded. The general trend of the folds is northeast-southwest. There are some that cross this trend. The major structure in the county is the northeast trending Lindsborg-Salina anticline. The present attitude of the rocks is the composite effect of structural movements that occurred at different times. The major tectonic disturbance appears to have occurred in post-Mississippian and pre-Desmoinesian times. During its geologic history, the area experienced several periods of submergence and emergence and was repeatedly subjected to subaerial erosion. Many of the stratigraphic units were thinned or entirely removed.

During more than 20 years of exploration many oil pools were discovered in the county. Most of these oil pools are presently located along the crest of the Lindsborg-Salina anticline. Others are found on another anticline in southeast part of the area. Petroleum accumulation is primarily restricted to anticlinal structures. Ordovician and Mississippian limestones serve as reservoirs. The characteristics of the pools are similar to those described

by Russell (1951) "oil and gas accumulation in fractures". In this type of pool, production is obtained from fractures. Initial flush production is usually followed by rapid depletion. The number of barrels of recoverable oil per acre-foot can not be predicted reliably.