UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

FEDERAL LANDS ASSESSMENT PROJECT (FLAP): SALINA BASIN PROVINCE: PHASE I

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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(Plate in pocket)

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INTRODUCTION

The Federal Lands Assessment Project (FLAP) of the U.S. Geological Survey has been established to develop resource estimates of undiscovered onshore oil and gas on Federally owned lands. In order to accomplish this goal the project was divided into two phases of which Phase I consisted of a) division of the United States into structural provinces, b) identification of Federally owned lands and, c) identification of regional oil and gas plays. Phase II consists of analysis of the plays identified in Phase I.

Structural provinces divisions follow the resource assessment areas previously established by AAPG and USGS (Cram, 1971; Varnes, et al, 1980; Dolton, et al, 1981) and are defined by county outlines. Federal lands were identified from records held by the General Services Administration (GSA, 1983a, 1983b) and state and county offices. Play analysis is a method of resource assessment which takes into consideration all significant geologic factors (Baker, et al, 1984; Bird, 1984; Procter, et al, 1984; Galloway, et al, 1982; Mast, et al, 1980). For the purposes of this study an oil and gas play is defined as follows: "A play consists of a group of prospects and/or discovered fields [or accumulations] having common geological characteristics such as source rock, trapping mechanism, structural history, etc., [which] may contain oil and/or gas (Proctor, Lee and Taylor, 1982)."

LOCATION

The Salina basin (Fig. 1) is located in the Midcontinent region and is comprised of the eastern half of Nebraska and the north-central portion of Kansas. Plate 1 shows the structural setting for the basin which lies between the Central Kansas Uplift-Cambridge Arch on the west and the Nemaha Anticline to the east, Siouxana Arch to the north and a poorly defined structural saddle between the Sedgewick basin to the south (Berg, 1983). In addition to the structural boundaries, the basin is further defined by the zero isopach of Mississippian rocks (Lee, 1956; Berg, 1983) (Plate 1). Note that the political (county) boundaries of the Salina Basin Province differ in places from the stratigraphic limits, particularly along the southern margin of the basin.

STRATIGRAPHY

The Salina basin stratigraphic section extends from Precambrian basement to Quaternary alluvium, however, Paleozoic rocks, Ordovician through Pennsylvanian, represent the bulk of the section and contain the known hydrocarbon reservoirs (Fig. 2). Lee (1956) has provided the most detailed discussion of Salina basin stratigraphy and structural history, to date, however, the Kansas Geological Survey is currently preparing major reevaluation of this area (Paul and Beene, 1985). Based on the distribution of these reservoirs relative to structural features within the basin, two hydrocarbon plays for estimating undiscovered oil hydrocarbon reserves have been identified: Ordovician and Mississippian.

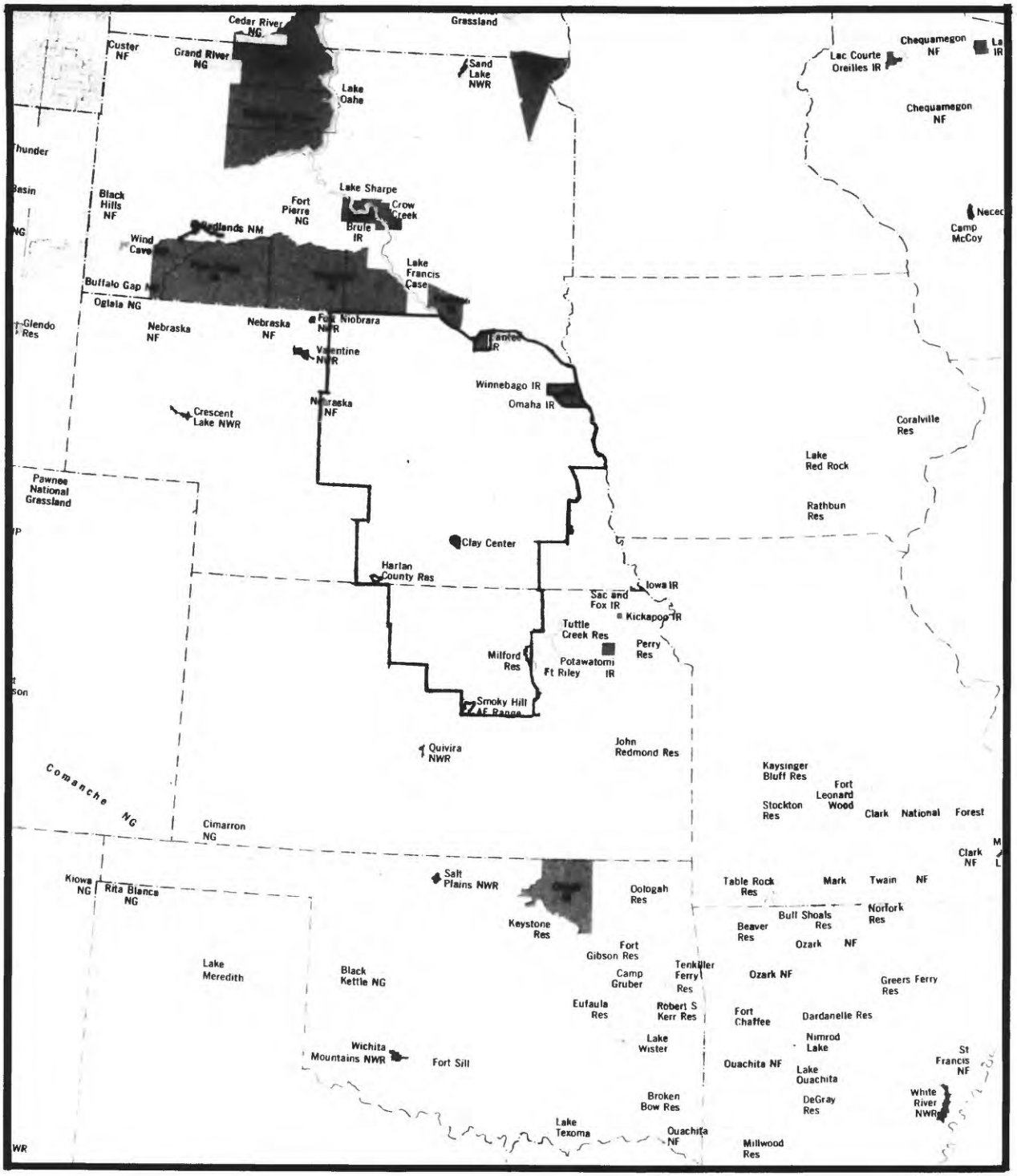

Figure 1. Index map showing the location of the Salina basin by county outline and the locations of the largest parcels of Federal lands (USGS, 1970).

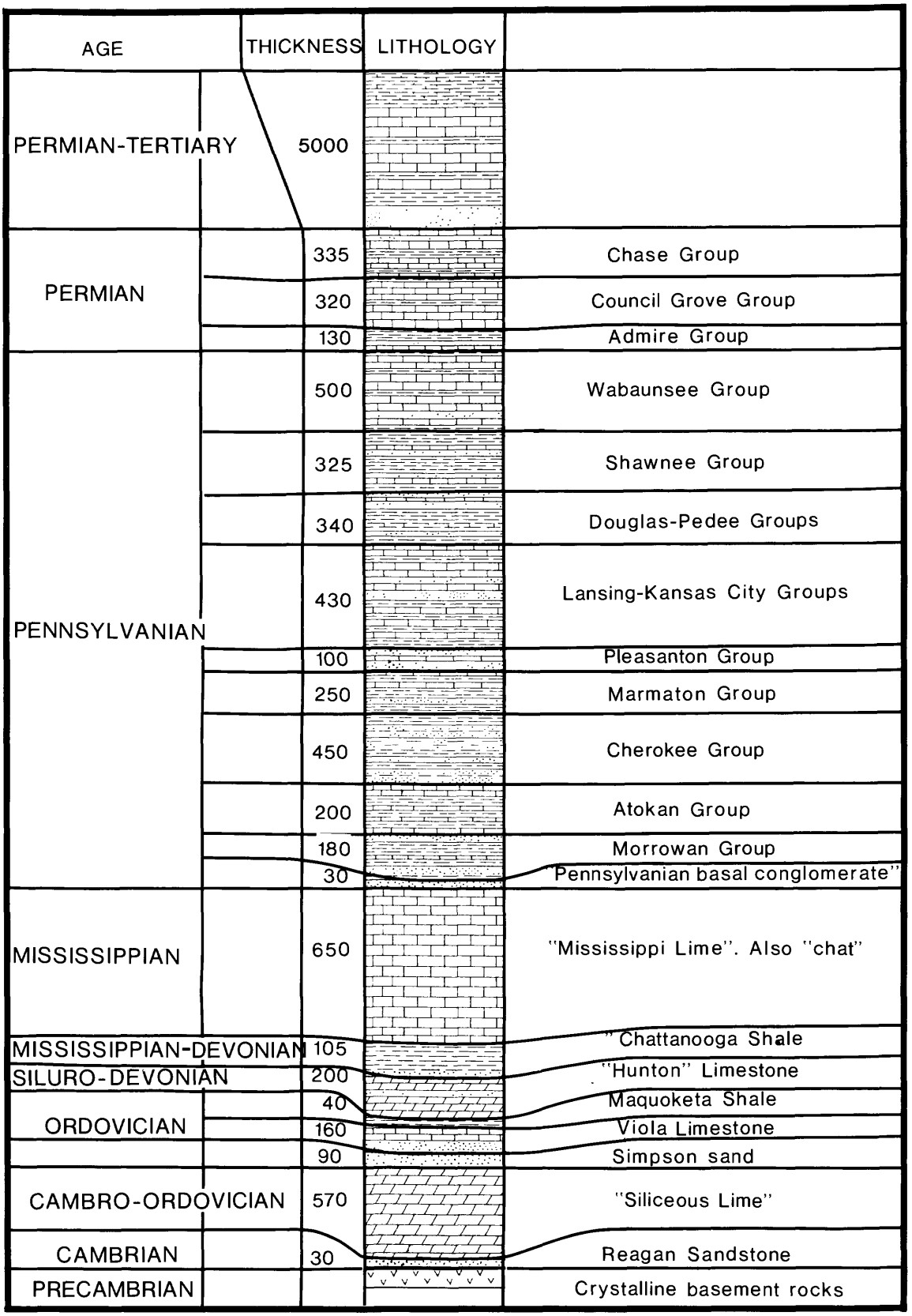

Figure 2. Generalized stratigraphic column for the Salina basin (not to scale) (after Landes, 1970).

Ordovician (Simpson, Viola, Maquoketa) Play

A. Geologic Characterization

Locally sourced oil is trapped in low relief anticlinal closures where porosity has developed in one or more Middle and Upper Ordovician reservoirs within the Simpson Group, Viola Limestone or Maquoketa Shale. Anticlinal traps occur along the southern margin of the Salina basin trending north and northeast both adjacent and parallel to the the Nemaha anticline. These anticlines are secondary features (fourth and fifth order of Merriam, 1963) located between the two primary structures (third order of Merriam, 1963) which form the southwest (Central Kansas Uplift (CKU)) and southeast (Nemaha anticline) basin margins (Plate 1). The traps were created during the Late Mississippian-Early Pennsylvanian deformation which produced the CKU and Nemaha anticline (Lee, 1956). Stratigraphic variations which provide the porosity development are strongly controlled by paleostructure (Salgat, 1983). The Simpson sandstones are best developed in paleolows while reservoir porosity in the Viola dolomite is best developed on paleohighs (Salgat, 1983) which permitted karst development (Caldwell and Boeken, 1985). Ordovician reservoir lithologies consist of a) poorly cemented, well rounded quartz St. Peter Sandstone (Simpson Group), b) sucrosic and cherty dolomite (Viola Limestone), c) cherty dolomite (Maquoketa Shale) (Hilpman, 1958) (Fig. 2). Reservoir porosity ranges from 14%-18% for Simpson sandstones to 6%-12% for Viola dolomite (Salgat, 1983).

The Ordovician play includes stratigraphic traps along the western margin of the basin (the eastern flank of the CKU) where the Ordovician pinches out against the basal Pennsylvanian unconformity (Lincoln and Osborne Counties) (Plate 1). A small possibility also exists that low relief anticlinal features paralleling the CKU, some of which are productive at younger horizons (e.g., Ruggels field, Ellsworth County, produces from Pennsylvanian Lansing-Kansas City) may be productive in the deeper Ordovician (Lee, 1956) since structural relief seems to increase with depth (Merriam, 1963).

Ordovician oil in the Salina basin may be sourced locally by Simpson shales (J. Hatch, pers. comm.). Ordovician production occurs in Kansas in the deepest part of the basin where the present geothermal gradient is about 3.1 ^{o}C/km (Kansas Geological Survey, 1982). The Salina and Forest City basins comprised the North Kansas (Iowa) basin and had similar depositional histories until the Late Mississippian when uplift of the Nemaha anticline resulted in the separation. There is definite indigenous Simpson production in the Forest City basin (W. L. Watney, pers. comm.) where Late Mississippian-Early Pennsylvanian faulting and subsidence resulted in a thicker section and deeper burial depths (Lee, 1956). In addition, organic richness of the Simpson increases northwest from the Forest City basin to the Kansas portion of the Salina basin and, if a sufficient heat source was available, these sediments could have attained thermal maturity (J. Hatch, pers. comm.). Oil migration and entrapment in the Salina basin post-dates the Late Mississippian development of the structures.

Lower Ordovician (Arbuckle) production is absent in the Salina Basin although there is signficant production on the adjacent CKU. Walters (1958) and Price (1980) predict that there will be no Arbuckle production in the

Salina Basin because the CKU served as a barrier to the northward migration of Arbuckle oil from the Anadarko Basin.

The Nebraska portion of the Salina basin is bounded on the northwest by the Siouxana Arch, on the west by the Cambridge Arch (CKU) and on the east by the Nemaha anticline. Although stratigraphic traps may exist below the Pennsylvanian unconformity on both the west and southeast margins, lack of an organic-rich facies and sufficent burial depths or heat source resulted in thermally immature rocks.

B. Exploration Status

Drilling within the Salina basin has been light overall. In Kansas, as of December 1984 (Petroleum Information, 1984) a total of 2,000 wells have been drilled within the 9,750 mi^2 of the 12 county area (Plate 1). However, more than half the wells are in a single county along the southern margin of the basin (Saline, 1,080 wells) and drilling in basin interior has been sparse. Additional wells drilled within the stratigraphic boundary but outside the political boundary in northern McPherson and Marion Counties would add 1,000-3,000 wells to the total. Most wells have tested the section at least through the Upper Ordovician (Simpson) and many, particularly in recent years, through the Lower Ordovician (Arbuckle). Around the shallow margins of the basin, wells have tested through the Precambrian. Drilling depths are generally less than 4,500 feet. In Nebraska, drilling has been even sparser than in Kansas. Most counties have fewer than 10 wells and some have never been drilled (Plate 1). As of December 1984 (Petroleum Information, 1984) only 544 wells have been drilled within the 36,200 mi^2, 54 county area.

The Ordovician play is demonstrated along the southern margin of the Salina basin. There are 7 fields, four with cumulative production exceeding 1 MMBO, producing from the Ordovician within the political basin boundary and all are in Saline County, Kansas (Table 1, Plate 1). There are an additional 7 fields in northern McPherson and Marion Counties. Cumulative production per field ranges from 86 MBO to 5,530 MBO (Smolan field). Average depth to production is 3,350 feet. Cumulative Ordovician production from the Salina basin (county outline) is 14,347 MBO and no gas. Inclusion of the production from the 7 fields in McPherson and Marion Counties raises the basin totals to 27,276 MBO and 146 MMCF.

Table 1. Cumulative oil and gas production from Ordovician reservoirs, Kansas portion of the Salina basin (Paul and Beene, 1985).

Field	County	Oil (BBL) @ 1/1/84	Gas (MCF) @ 1/1/84
Amerson	McPherson	620	
Bonaville	McPherson	19,662	
Hogland	McPherson	56,900	
Lindsborg	McPherson	12,193,403	
Reuben	McPherson	34,468	

Table 1. Cumulative oil and gas production from Ordovician reservoirs, Kansas portion of the Salina basin (Paul and Beene, 1985)--continued.

Field	County	Oil (BBL) @ 1/1/84	Gas (MCF) @ 1/1/84
Durham	Marion	351,791	145,816
Ratzlaff	Marion	58,584	320,670
Scully	Marion	272,226	
Gillberg	Saline	220,118	
Lindsborg	Saline	2,592,748	
Olsson	Saline	1,428,635	
Salina	Saline	4,377,376	
Shultz	Saline	112,738	
Smolan	Saline	5,529,612	
Swenson	Saline	85,773	
		27,334,654	466,486

The only production in the Nebraskan part of the Salina basin (county boundaries) is in Harlan County (Table 2) and this production, 857 MBO through 1984, is from Pennsylvanian Lansing-Kansas City reservoirs. These fields are more properly assigned to the Central Kansas Uplift structural province.

Table 2. Cumulative oil and gas production for Nebraska Portion of the Salina basin (Nebraska Oil and Gas Conservation Commission, 1985, pers. comm.).

Field	County	Producing Zone	Oil (BBL) @ 10/84
South Alma	Harlan	Kansas City-Lansing	804,281
Hausserman	Harlan	Kansas City-Lansing	26,907
Prairie Dog Creek	Harlan	Kansas City-Lansing	25,989

C. Resource Potential on Federal Land

Known federal lands in the Salina basin province total 58,898 acres in Kansas and 138,312 acres in Nebraska (see Tables 2 and 3 for a list of major parcels, Fig. 1 and Plate 1 for location). The federal acreage in Nebraska is located primarily in the non-prospective northeastern and central portions of the province (Plate 1).

Table 3. Significant land parcels (>2,500 acres) of Federal ownership in Kansas portion of the Salina basin (General Services Administration, 1983a, 1983b).

Administering Agency	Property	Area (acres)
Corps of Engineers	Milford Reservoir (approx)	22,000
Department of the Air Force	Smoky Hills Weapons Range	33,878

Table 4. Significant land parcels (>2,500 acres) of Federal ownership in Nebraska portion of the Salina basin (General Services Administration, 1983a, 1983b).

Administering Agency	Property	Area (acres)
Corps of Engineers	Harlan County Lake	30,257
	Lewis and Clark Lake	15,258
Department of Agriculture	Hruska Meat Animal Research Center	34,355
Department of the Army	Cornhusker Ordnance Center	11,936
	Hastings National Guard Base	3,211
Department of Interior	Omaha Indian Reservation	27,092
	Santee Indian Reservation	9,278
	Winnebago Indian Reservation	27,524
	Desoto Wildlife Refuge	4,324
	Clay County WPA	4,098
	Fillmore County WPA	2,511
	Kearney WPA	2,874
	(WPA - Waterfowl Production Area)	

In Kansas the only federal land in a prospective area is the 33,900 acre Smoky Hill Weapons Range in Saline County (Plate 1). This acreage is adjacent to the Smolan field which has produced 5,508 MBO and to the Lindsborg field which has produced 2,600 MBO (14,800 MBO if the portion in McPherson county is included). No wells have been drilled to date on this property (Petroleum Information, 1984; Kansas Geological Survey, pers. comm.). If subsurface anticlinal features are present in the Ordovician section on the Smoky Hills Weapons Range, there is a good probability that hydrocarbon accumulations may be present. Resource potential assigned for this play is small.

Mississippian Play

A. Geologic Characterization

Structural and stratigraphic traps in the Mississippian surface below the basal Pennsylvanian unconformity. During the time represented by the Pennsylvanian unconformity the carbonate rocks of Mississippian age were exposed to prolonged erosion and freshwater diagenesis which resulted in the development of residual cherts ("Mississippi chat") and reworked cherts ("Pennsylvanian basal conglomerate"), which are virtually indistinguishable (Lee, 1956; Hilpman, 1958; Nodine-Zeller, 1981), and in the development of secondary porosity in underlying limestones. Traps are primarily stratigraphic (porosity changes) with secondary low relief structural closure (Shenkel, 1955; Curtis, 1960; Salgat, 1983). Stratigraphic traps are common along the flanks of the basin, particularly along the flanks of the CKU (Harris and Larsh, 1979), where Mississippian rocks are truncated by the Pennsylvanian unconformity. Structural traps are present along the southern margin of the basin as localized anticlinal closure a) within the Mississippian Warsaw or Spergen Limestones below the unconformity and, b) as paleotopograhical erosional features at the unconformity (Carlson, 1971; Harris and Larsh, 1979; Salgat, 1983). Porosity variation is related to subaerial exposure and weathering of the limestone surface and which resulted in a) fracturing of the chert (Shenkel, 1955; Ebanks, et al, 1979) and, b) to the development of a saccarhoidal porosity 30-50 feet below the "chat" (Hilpman, 1958).

Oil trapped in the Mississippian rocks is most probably Devonian Woodford oil that has migrated northward from the Anadarko and Arkoma basins in Oklahoma (J. Hatch, pers. comm.). Migration is post-Middle Pennsylvanian, the age of the basal Pennsylvanian unconformity which serves as a seal. Pennsylvanian rocks are definitely not within the oil generation "window" (W.L. Watney, pers. comm.).

B. Exploration Status

Drilling history is covered under the Ordovician play description. There are 16 fields in Clay, Dickinson and Saline Counties producing from the Mississippian (Table 5), 3 of which have cumulative production exceeding 1,000 MBO. Cumulative production ranges from 1 MBO to 2,000 MBO (Lost Springs field). An additional 38 fields in McPherson and Marion Counties can be included in the geologic basin boundaries. The single largest field, Lost Springs, covers portions of Dickinson, Marion and Morris Counties and has a cumulative production of 25,200 MBO. Three small, now abandoned, fields (Bateham, Griffith and Wakefield) along the northeast margin of the Kansas portion were situated on the Abilene anticline. Cumulative Mississippian production from the Salina basin (county outlines) is 8,400 MBO and 61,900 MBO if portions of McPherson and Marion Counties are included.

The Mississippian, with 17.4 BCFG cumulative production, is the primary gas producing interval in the Salina basin (Merriam and Goebel, 1968). However, production of associated gas is from outside the county outline for the basin (Marion and McPherson Counties). The portion of Lost Springs field in Marion County, has alone produced 9.8 BCFG. Average depth to production is 2,650 feet.

Table 5. Cumulative oil and gas production from Mississippian reservoirs for Kansas portion of Salina basin (Paul and Beene, 1985).

Field	County	Oil (BBL) @ 1/1/84	Gas (MCF) @ 1/1/84
Bateham	Clay	992	
Griffith	Clay	95,053	
Ash Grove	Dickinson	467,600	
Holland Creek	Dickinson	2,233	
Lost Springs	Dickinson	2,010,783	
Battle Hill	McPherson	179,132	
Bitikofer	McPherson	220,615	16,050
Bitikofer N.	McPherson	124,515	2,952,803
Burch	McPherson	190,481	
Canton N.	McPherson	1,222,506	387,332
Crowther	McPherson	4,460,534	
Fanska S.	McPherson	5,372	
Georob	McPherson	5,251,541	
Georob E.	McPherson	76,687	
Gypsum Creek	McPherson	673,709	
Henne	McPherson	2,116,244	
Henne S.	McPherson	115,590	
Maxwell	McPherson	211,189	
Paden	McPherson	8,198,948	
Round Hill	McPherson	189,743	
Roxbury	McPherson	4,225,466	
Roxbury S.	McPherson	763,564	
Bitikofer N.	Marion	13,596	863,582
Canton N.	Marion	2,349	107,868
Durham Center	Marion	163,235	27,897
Durham E.	Marion	-------	2,125,632
Durham S.	Marion	20,391	11,788
Fanska	Marion	339,758	-------
Fanska S.	Marion	99,029	-------
French Creek	Marion	119,395	723,826
Hillsboro	Marion	425,795	71,541
Hillsboro W.	Marion	-------	97,166
Lehigh	Marion	154,413	109,140
Lehigh N.	Marion	57,871	63,634
Lost Springs	Marion	23,109,754	9,783,793
Penner	Marion	9,790	3,397
Penner E.	Marion	-------	3,006
Penner N.	Marion	-------	19,322
Burdick	Morris	62,804	
Grandview	Morris	41,753	
Grandview S.	Morris	17,503	
Lost Springs	Morris	57,100	
3 Mile Creek	Morris	109,250	
3 Mile Creek S.	Morris	178,198	

Table 5. Cumulative oil and gas production from Mississippian reservoirs for Kansas portion of Salina basin (Paul and Beene, 1985)--continued.

Field	County	Oil (BBL) @ 1/1/84	Gas (MCF) @ 1/1/84
Ash Grove	Saline	2,136	
Bachofer	Saline	317,556	
Bachofer SE	Saline	20,741	
Gillberg	Saline	220,118	
Gypsum Creek	Saline	1,745,585	
Hunter	Saline	1,865,475	
Hunter N.	Saline	563,459	
Hunter NW.	Saline	28,4332	
Mortimer	Saline	272,045	
Peterson	Saline	118,608	
Pihl	Saline	682,179	
		61,876,715	17,367,777

C. Resource Potential on Federal Lands

The known federal lands in the Salina basin (county outline) that fall within the play are 540 acres of BLM land (Clay and Saline counties) and the 33,900 acres of the Smoky Hill Weapons Range. The Mississippian section thins rapidly under this acreage as it onlaps the southeastern flank of the CKU. This is the same situation which exists 40 miles to the east where the Mississippian section thins as it onlaps the Nemaha anticline in the Lost Springs field (Lee, 1956, plate 6). If trapping structures similar to those at Lost Springs or Hunter fields are present there is a reasonable chance for hydrocarbon accumulation. Resource potential assigned to federal lands for this play is small.

References Cited

Baker, R. A., Gehman, H. M., James, W. R., and White, D. A., 1984, Geologic field number and size assessments of oil and gas plays: AAPG Bulletin, v. 68, p. 426-437.

Berg, R. J., 1983, A Mid-Continent basin--A reappraisal [Abs.]: AAPG Bulletin, v. 67, p. 1323.

Bird, K. J., 1984, A comparison of the play-analysis technique as applied in hydrocarbon resource assessments of the National Petroleum Reserve in Alaska and of the Arctic National Wildlife Refuge: USGS Open-File Report 84-78, 18 p.

Caldwell, C. D. and Boeken, R., 1985, Wireline log zones and core description of upper part of the Middle Ordovician Viola Limestone, McClain and McClain SW fields, Nemaha County, Kansas: Lawrence, Kansas Geological Survey Subsurface Geology Series 6, p. 17-35.

Carlson, M. P., 1971, Eastern Nebraska and north-central Kansas in I. H. Cram, ed., Future petroleum provinces of the United States--Their geology and potential: AAPG Memoir 15, p. 1103-1108.

Cram, I. H., 1971, [ed.], Future petroleum provinces of the United States--Their geology and potential: AAPG Memoir 15, 1496 p.

Curtis, G. R., 1960, [ed.], Kansas oil and gas fields--Volume III, northeastern Kansas: Wichita, Kansas Geological Society, 219 p.

Dolton, G. L., Carlson, K. H., Charpentier, Coury, A. B., et al, 1981, Estimates of undiscovered recoverable conventional resources of oil and gas in the United States: USGS Circular 860, 87 p.

Ebanks, W. J., Jr., Brady, L. L., Heckel, P. H., et al, 1979, The Mississippian and Pennsylvanian (Caboniferous) Systems in the United States--Kansas: USGS Professional Paper 1110-Q, p. Q1-Q30.

Galloway, W. E., Hobday, D. K. and Magara, K., 1982, Frio Formation of Texas Gulf Coastal Plain--Depositional systems, structural framework, and hydrocarbon distribution: AAPG Bulletin, v. 66, p 649-688.

General Services Administration, 1983a, Detailed listing of real property owned by the United States and used by civil agencies throughout the world as of September 30, 1982: Washington, D.C., U.S. Government Printing Office, 1737 p.

_____1983b, Detailed listing of real property owned by the United States and used by the Department of Defense for military function throughout the world as of September 30, 1982: Washington, D.C., U.S. Government Printing Office, 469 p.

Harris, R. L. and Larsh, H. A., 1977, Kansas--Its geology, economics and current drilling activity: Oil and Gas Journal, v. 77, April 30, p. 323.

Hilpman, P. L., 1958, Producing zones of Kansas oil and gas fields: Geological Survey Kansas Oil and Gas Investigations no. 16, 10 p.

Kansas Geological Survey, 1982, Geothermal resources of Kansas, [Map] 1:500,000.

Landes, K. K., 1970, Petroleum geology of the United States: New York, John Wiley & Sons, Chapter 16, p. 116-121.

Lee, W., 1956, Stratigraphy and structural development of the Salina Basin area: Geological Survey of Kansas Bulletin 121, 167 p.

Merriam, D. F., 1963, The geologic history of Kansas: Kansas Geological Survey Bulletin 162, 317 p.

Merriam, D. F. and Goebel, E. D., 1968, Natural gas in Kansas in B. W. Beebe and B. F. Curtis, eds., Natural gases of North America: AAPG Memoir 9, p. 1548.

Nebraska Conservation and Survey Division, 1982, Geothermal resources of Nebraska, [Map] 1:500,000.

_____1963, Distribution of the pre-Pennsylvanian in Nebraska, GMC-5, [Map] 1:1,000,000.

Nodine-Zeller, D. E., 1981, Karst-derived Early Pennsylvanian conglomerate in Ness County, Kansas: Lawrence, Kansas Geological Survey Bulletin 222, 30 p.

Paul, S. E. and Beene, D. L., 1985, 1983 oil and gas production in Kansas: Lawrence, Kansas Geological Survey Energy Resources Series 24, 253 p.

Petroleum Information, 1984, Well history control system, digital records: Denver, Petroleum Information.

Price, L., 1980, Shelf and shallow basin oil as related to hot-deep origin of petroleum: Journal of Petroleum Geology, v. 3, p. 91.

Procter, R. M., Taylor, G. C., and Wade, J. A., 1984, Oil and natural gas resources of Canada: Geological Survey of Canada Paper 83-31, 59 p.

Procter. R. M., Lee, P. J. and Taylor, G. C., 1982, Methodology of petroleum resource evaluation--Petroleum resource assessment workshop and symposium, Circum-Pacific energy and mineral resource conference, Honolulu, 1982: Geological Survey of Canada [unpublished manual], 60 p.

Salgat, B. R. J., 1983, Scully Field--Marion County, Kansas [Abs.]: AAPG Bulletin, v. 67, p. 1327.

Shenkel, C. W., Jr., 1955, Geology of the Lost Springs pools area, Marion and Dickinson Counties, Kansas: Geological Survey of Kansas Bulletin 114, part 6, p. 168.

U.S. Geological Survey, 1975, Federal Land Ownership, Hutchinson, Kansas: USGS Open-File Report 76-106-5, 1:250,000, [Map] 1 sheet.

_____1970, Federal lands--Principal lands administered or held in trust by Federal agencies, January 1, 1968 in The national atlas of the United States of America: USGS, p. 272.

Varnes, K. L., Coury, A. B., Dolton, G. L., Frezon, S. E., et al, 1980, Oil and gas resource assessment areas, lower 48 United States, regions 2 through 11, 2A, 6A, 11A: USGS Open-File Report 81-84C, 1 sheet.

Walters, R. F., 1958, Differential entrapment of oil and gas in Arbuckle dolomite of central Kansas: AAPG Bulletin, v. 42, p. 2133.