STRATIGRAPHIC FRAMEWORK OF KANSAS PART I: EAST-WEST CENTRAL KANSAS

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Summary

Twenty-six gamma-ray logs were machine correlated to prepare what eventually will be a collection of computer correlated cross-sections in Kansas. The logs are along a west-east profile through the Hugoton Embayment, Central Kansas Uplift, Salina Basin, Nemaha Anticline, and Forest City Basin across Kansas in the North American Midcontinent. Correlations were made for successive one-half foot (15 cm) intervals for the entire stratigraphic section employing more than 40,000 correlations, resulting in a resolution that would be impossible to duplicate using manual methods. Three cross-sections graphically summarize the findings.

Introduction

The objective of this study was to start a collection of machine-correlated cross-section to enhance knowledge about the subsurface geology of the state by processing gamma ray logs starting at least as the Arbuckle and ending close to the surface.

The log processing was done using *Correlator*, an interactive computer system for the lithostratigraphic correlation of borehole wireline logs (Olea, 1988). The system has been used extensively and successfully in the detailed characterization of aquifers (Olea, 1996) and oil reservoirs (Olea and Davis, 1986).

Methodology

The search for correlations operates on pairs of wells that ideally have the same pair of digitized wireline logs: a shale log (gamma ray or self-potential) and a correlation log (typically a high-resolution resistivity log). In the absence of a correlation log—or lacking an appropriate correlation log—a shale log can be used both as shale and correlation log.

For easy reference, the well to the left of a display can be termed "reference well" and the one to the right, "matching well." Given an elevation at reference well z_i, *Correlator* automatically selects as the correlating elevation that level in the matching well that maximizes the weighted correlation coefficient. If the log sampling interval is h, the weighted correlation coefficient $\omega_{1,2,3,4}(i,k;n)$ is defined as the product of the normalized shale similarity coefficient $\alpha_{1,3}(i,k;n)$ for the shale logs and the Pearsonian correlation coefficient $r_{2,4}(i,k;n)$ for the correlation logs:

$$\omega_{1,2,3,4}(i,k;n) = \alpha_{1,3}(i,k;n)\, r_{2,4}(i,k;n)$$

$$\alpha_{1,3}(i,k;n) = 1 - \frac{1}{2n+1} \sum_{j=i-n}^{i+n} \left| \frac{y_1(j) - y_{\min 1}}{y_{\max 1} - y_{\min 1}} - \frac{y_3(j+k) - y_{\min 3}}{y_{\max 3} - y_{\min 3}} \right|$$

$$r_{2,4}(i,k;n) = \frac{\mathrm{cov}_{2,4}(i,k;n)}{s_2(i;n)\, s_4(k;n)}.$$

The normalized shale similarity, the covariance $\mathrm{cov}_{2,4}(i,k;n)$, and the standard deviations $s_2(i;n)$ and $s_4(k;n)$, are calculated over correlation intervals of $(2n+1)$ readings each. Interval centers z_i and z_j differ by an offset or lag $\lambda = (j-i)h = kh$ in the common index set of sequential sampling numbers along the depth scale. The correlation coefficient is sensitive to the matching of the signatures of the correlation logs and the other coefficient is sensitive to the discrepancy in the relative proportions of shale as given by the shale logs. The maximization of the weighted correlation coefficient comprises an additional parameter, the interval $k_{\min} \le k \le k_{\max}$ of search for the best match.

The automatic maximization of the weighted correlation coefficient always yields one largest value $\omega_{1,2,3,4_{\max}}(i,k_m;n)$ for every elevation z_i in the reference well, so a correlating elevation z_{k_m} is always found in the matching well . However, not all correlations are saved. In a first step, the system discards all weak correlations below a threshold. In a final stage an expert system checks for global consistency and interactively suggests to the user the discarding of crossing or inconsistent correlations.

By combining the correlations obtained from several pairs of wells, *Correlator* is capable to display cross-sections showing top and bottoms of lithostratigraphic units, correlations present in all wells for the same lithostratigraphic level, and cross-sections showing the spatial variation in the amount of shale. By solving the three-point problem—determining the dip and azimuth of every plane defined by lithostratigraphically equivalent points in three wells located in the vertices of a triangle, preferably close to equilateral—the system is also able to generate dips representing the regional inclination of the strata (Olea, 1994). Such dip plots are extremely useful for detecting faults and unconformities and summarizing the geological evolution of any portion of a basin through geologic time.

Study area

Only gamma-ray logs were used because they are widely available and have good vertical resolution showing variation in the amount of shale in the subsurface. The studied interval extends from surface to at least the Ordovician. Figure 1 and Table 1 show the location of 26 wells selected for the evaluation, of which only the top 17 were directly used to produce the results in this report. The remainder wells were employed to prepare results presented at the Barcelona Conference of the IAMG mostly dealing with the interpretation of synthetic dip plots (Olea et al., 1997). The wells are located approximately along 39° parallel that roughly coincides with highway US I70. The digitization interval was 2 readings per foot.

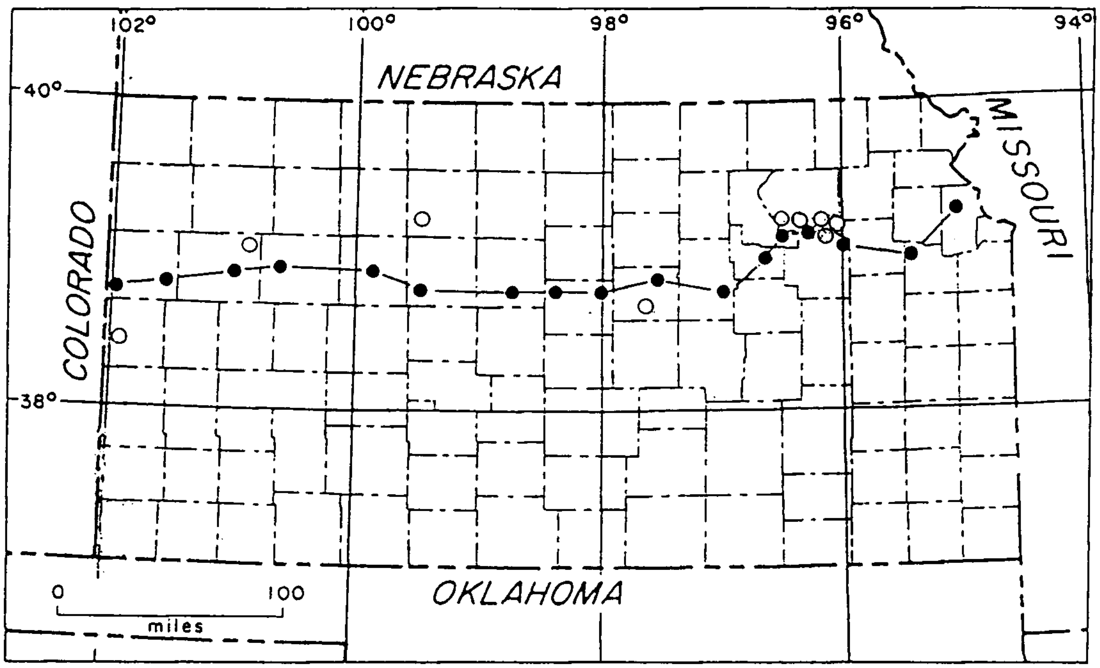

Figure 1. Map of Kansas with county outlines. Solid dots denote locations of wells on cross-section in Figure 3. Open circles are additional wells used to produce dip plots not included in this report.

Selected results

Three plates summarize the results:

1. Cross-section with all correlations produced by the *Correlator* processing.

2. Cross-section with false color rendition for the vertical and horizontal variation in the amount of shale.

3. Tracing of 26 major rock units, with an interpretation of the anomaly between wells Schepp No. 1 and Pageler No. 1 as a normal fault. Tables 2 and 3 list all correlations.

Table 1. The East-West Central Kansas data set.

	Well	Location	County
1.	Phillips No. 1 Wallace Prospect	C SW SW sec. 7, T 15 S, R 42 W	Wallace
2.	Texaco No.1 Pearce	C NE NE sec 18, T 14 S, R 38 W	Wallace
3.	J. S. Carter No. 1 Ross	SE SE SE sec 36, T 13 S, R 34 W	Logan
4.	Wycoff Brothers. No. 1 Eklna	C SE NW sec 27, T 13 S, R 30 W	Gove
5.	WBCO & Plains Res. No. 1 Delaney	C NW sec 7, T 13 S, R 23 W	Trego
6.	Grand Mesa No. 1-11 Befort	NW SE SE sec 11, T 14 S, R 20 W	Ellis
7.	Shields No. 1-A Niedenthal	SE SW SE sec 14, T 14 S, R15 W	Russel
8.	Frankfort No. 1 Kuck	SE SW NE sec 8, T 14 S, R 10 W	Ellsworth
9.	Rupp-Ferguson No.1 Allan	SE SE SW sec 28, T 14 S, R 6 W	Ellsworth
10.	USCG No. 1 Geis	SW C sec 32, T 13 S, R 2 W	Saline
11.	Frontier No. 1 Deines	NE NW NW sec 27, T 14 S, R 4 E	Dickinson
12.	Cimarron No. 1 Simpson	C SW NW sec 15, T 12 S, R 7 E	Geary
13.	Bedell-Dunne No. 1 Schepp	SE SE SE sec 35, T 10 S, R 8 E	Riley
14.	Venus et al. No. 1 Pageler	SW SE NW 24, T 10 S, R 10 E	Wabaunsee
15.	Kaiser et al. No. 1A Adams	C SE NW sec 20, T 11 S, R 13 E	Wabaunsee
16.	USGS No. 1 DCL & FA	SE NW NW sec 13, T 12 S, R 17 E	Douglass
17.	Anadarko et al. No 1A Christy	C NE NW sec 33, T 8 S, R 21 E	Leavenworth
18.	Amoco No. 1 Bounds	NE SE NE sec 17, T 18 S, R 24 W	Greeley
19.	L. M. Mai et al. No. 1 Foos	NE NE NE sec 16, T 11 S, R 32 W	Logan
20.	AFG Energy No. 12 Rathbun	E/2 SW NE sec 27, T 9 S, R 20 W	Rooks
21.	Penn West No. 1A Borg	NE NE NW sec 29, T 16 S, R 3 W	Saline
22.	McCulloch-Venus et al. No. 1 McCoy	SW NE NW sec 26, T 9 S, R 8 E	Pottawatomie
23.	Kansas No. 1 Burgess	SE NE SE sec 31, T 9 S, R 10 E	Pottawatomie
24.	Anadarko et al. No. 1A Straub	SE SE SE sec 29, T 9 S, R 11 E	Pottawatomie
25.	Roxy No. 1-26 Arand	SW SW sec 26, T 10 S, R 11 E	Pottawatomie
26.	Rains & Williamson No. 1 Virgin Mary	NW SW SW sec 4, T 10 S, R 12 E	Pottawatomie

All these cross-sections employ the gamma ray log for the seventeen wells marked with solid dots in Figure 1. It extends for more than 400 miles (644 km), is up to 5,500 feet (1,676 m) deep, and is based on more than 40,000 correlations. All main architectural elements of Kansas geology are evident. The depression on the West is the Hugoton Embayment of the Anadarko Basin and the positive area in the center of the cross-section is the Central Kansas Uplift. Farther east is the Salina Basin with the Humbolt fault bounding the east flank of the Nemaha Anticline. The area to the East of the Nemaha Anticline is the Forest City Basin.

Each unit was checked against sample and driller logs, scout tops, type logs, and continuous core descriptions in the westernmost well represented by open circle in Figure 1. *Correlator* proved particularly helpful for correlating intervals that did not contain marker beds and intervals whose petrophysical characteristics were repetitive. Some of the geological features are subtle even in large color plates.

Conclusions

In cratonic areas with laterally persistent lithologies such as Kansas, computer-aided wireline log correlation is feasible even when the distances between correlated wells is on the order of 20-25 miles (32-40 km). The information that can be extracted from these correlations allows high-resolution modeling of the surface and the study of geologic events that are not possible to detect or model with the resolution and accuracy of manual correlation, let alone from the perspective of classical simple visual inspection of wireline logs.

Table 2. Tracing of the eastern portion of the cross-section.

TRACING STARTED FROM WELL 1 (WALLACE 1)
ALL LOGS ARE GAMMA RAY LOGS
(I) DENOTES INTERPOLATION
THE DATUM IS SEA LEVEL
ALL RESULTS ARE IN FEET

	1 Wallace 1	2 Pearce 1	3 Ross 1	4 Elkna 1	5 Delaney 1	6 Bef.1-11	7 Nied.1A	TOPS
	-3936	-3559	-2849	-2879	-2472	-2170	-1840	KB
1	-2796.0	-2570.0	-2287.0	-2240.5	-2132.0 I	-2151.5		Carlile
2	-2604.5	-2385.5	-2057.0	-1983.5	-1866.0	-1885.0		Greenhorn
3	-2525.0	-2293.0	-1977.0	-1900.5	-1776.0	-1790.0		Graneros
4	-2406.0	-2201.5	-1919.5	-1862.5	-1760.5	-1779.0		Dakota
5	-2178.0	-1961.0	-1598.5	-1518.0	-1444.5	-1516.0	-1771.5	Kiowa
6	-2061.0	-1856.0	-1549.5	-1469.5 I	-1393.5	-1457.5 I	-1689.5	Cheyenne
7	-1955.0	-1737.0	-1418.0	-1131.0 I	-1265.0	-1369.0	-1609.0	Jurassic
8	-1793.0 I	-1658.0 I	-1367.5 I	-1131.0 I	-1265.0	-1369.0	-1609.0	Permian
9	-1588.5	-1467.5	-1249.5 I	-1131.0 I	-1265.0	-1369.0	-1609.0	Nippewala
10	-1105.0	-879.0	-641.0	-588.0	-516.0	-717.0	-959.5	Sumner
11	-914.5	-601.0	-252.5	-151.0	105.5	-4.5	-175.0	Chase
12	-656.0	-339.5	13.5	140.5	427.5	312.0	140.0	C. Grove
13	-278.0	45.0	367.0	483.0	736.5	634.5	427.5	Admire
14	-237.5 I	88.5	408.5	519.5	802.0	718.0	509.5	Wabaunsee
15	13.0	317.5	642.5	763.5	1082.0	1009.0	889.5	Shawnee
16	231.5	539.0	868.0	980.0	1307.0	1246.0	1111.5	Heebner
17	275.0	583.0 I	908.0	1010.5	1334.5	1280.5	1147.0	Douglas
18	290.0	598.0	922.0	1023.0 I	1347.0	1293.0	1168.5	Lan-KC
19	645.0	969.5 I	1271.0 I	1323.5 I	1626.0	1536.5 I	1400.0	Pleasanton
20	686.0	1003.0	1304.0	1344.0	1647.0	1548.5 I	1400.0	Marmaton
21	840.0	1145.5	1434.0	1485.5	1797.5 I	1612.5 I	1400.0	Cherokee
22	1037.0	1248.5 I	1520.5 I	1572.5	1917.0 I	1612.5 I	1400.0	Atoka
23	1110.0	1337.0	1587.0 I	1572.5	1917.0 I	1612.5 I	1400.0	Morrow
24	1266.0	1533.5	1629.0 I	1572.5	1917.0 I	1612.5 I	1400.0	Upper Miss
25	1442.0	1757.5	1890.5	1606.0	1961.5 I	1612.5 I	1400.0	Lower Miss
26	1627.0	1988.5	2121.0	1799.5	2059.5 I	1612.5 I	1400.0	Viola
27	1720.0	2065.0	2166.5 I	1845.0 I	2111.0	1626.0	1403.0	Arbuckle

Table 3. Tracing of the western portion of the cross-section.

TRACING STARTED FROM WELL 9 (ALLAN 1)
ALL LOGS ARE GAMMA RAY LOGS
(I) DENOTES INTERPOLATION
THE DATUM IS SEA LEVEL
ALL RESULTS ARE IN FEET

	7 Nied.1A	8 Kuck 1	9 Allan 1	10 Geis 1	11 Deines 1	12 Simpson 1	TOPS
	-1840	-1803	-1576	-1224	-1300	-1313	KB
1	-959.5	-1186.0	-1406.5				Sumner
2	-175.0	-372.5	-606.0 I	-981.5			Chase
3	140.0	-45.0	-253.5	-628.5	-1007.5 I	-1241.5 I	C. Grove
4	425.5	262.0	68.0	-309.5 I	-710.5	-944.5 I	Admire
5	510.0	329.5	127.0	-250.0 I	-657.0	-893.5 I	Wabaunsee
6	889.5	739.5	630.5	267.0	-153.0	-385.0	Shawnee
7	1111.5	1032.0	904.0	542.0	135.5	-98.0	Heebner
8	1148.0	1068.5	944.5	581.5	169.5	-64.0	Douglas
9	1167.5	1152.0	1075.0	740.0	352.0	84.0	Lan-KC
10	1402.0 I	1405.0	1396.5	1047.5	653.5	376.5	Pleasanton
11	1402.0 I	1423.0	1420.0	1086.0	690.0	415.0	Marmaton
12	1402.0 I	1533.0 I	1538.0	1251.0 I	816.5	511.0	Cherokee
13	1402.0 I	1533.5 I	1658.0	1394.5 I	851.0	562.0 I	Upper Miss
14	1402.0 I	1534.0 I	1773.0	1606.5	928.0	658.5 I	Chattanooga
15	1402.0 I	1534.0 I	1866.0	1770.0	1096.0	844.0	Hunton
16	1402.0 I	1535.0 I	2013.0	1959.0	1401.5	1252.0	Viola
17	1404.5	1645.5	2201.5	2146.0	1596.5	1471.0 I	Arbuckle

	13 Schepp 1	14 Pageler 1	15 Adams 1A	16 DCL&FA 1	17 Chris. 1	TOPS
	-1183	-1145	-1038	-1115	-1070	KB
4	-1117.5 I	-1046.0				Admire
5	-1066.5 I	-995.0				Wabaunsee
6	-586.0	-454.0	-614.0			Shawnee
7	-300.5	-125.0	-308.5	-803.0 I	-934.5	Heebner
8	-270.0	-83.5	-265.0	-751.0	-887.0	Douglas
9	-158.5	85.5	-45.5	-511.0	-681.0	Lan-KC
10	135.5	409.0	290.0	-165.5	-367.0	Pleasanton
11	170.0	469.0 I	367.0	-74.5	-299.0	Marmaton
12	251.5	605.5	524.5 I	94.0	-119.5	Cherokee
13	297.0	1082.0	1074.0	593.5	388.0	Upper Miss
14	297.5	1259.0	1284.0	900.0	743.5	Chattanoog
15	298.0	1476.5	1493.0	990.0	800.0	Hunton
16	806.0	1902.0	1786.0	1115.5	1065.0	Viola
17	1029.0 I	2130.0 I	1989.0	1295.5 I	1259.5	Arbuckle

References

Olea, R. A., 1988, Correlator, an interactive computer system for the lithostratigraphic correlation of logs: Kansas Geological Survey Petrophysical Series 4, 85 p.

Olea, R. A., 1994, Expert systems for automated correlation and interpretation of wireline logs: Mathematical Geology, vol. 26, No. 8, p. 879-897.

Olea, R. A., 1996, Use of wireline logs for the quantitative characterization of the Dakota aquifer, Hodgeman County, Kansas (abst.): Abstracts of the 30th International Geological Congress, Beijing, vol. 3, p. 495.

Olea, R. A. and J. C. Davis, 1986, An artificial intelligence approach to lithostratigraphic correlation using geophysical well logs: Society of Petroleum Engineers paper SPE 15603 presented at the 61st Annual Conference and Exhibition held in New Orleans, 12 p.

Olea, R. A., J. C. Davis, and D. F. Merriam, 1997, Automatic regional wireline log lithostratigraphic correlation in Kansas using CORRELATOR: Proceedings of the Third Anual Conference of the International Association for Mathematical Geology, International Center for Numerical Methods in Engineering (CIMNE), Barcelona, Spain, p. 343-348.

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