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The Blaine And Related Formations Of
Northwestern Oklahoma And Kansas

VOLUME II

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1961

STATE GEOLOGICAL SURVEY
OF KANSAS
METROGRAPHY DIVISION

THE BLAINE AND RELATED FORMATIONS OF NORTHWESTERN
OKLAHOMA AND KANSAS

VOLUME 11

by
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APPENDIX A - TABLES

Table 1. Mineralogic composition of members within the upper 100 feet of the Flowerpot Shale, based on minerals from the sand-size portion of the insoluble or washed residue, in percent.

Units and Measured Sections	Light Minerals						Heavy Opaque Minerals				
	Total lights	Quartz	Chert	Orthoclase	Plagioclase	Microcline	Total heavies	Sphene and Leucoxene	Ilmenite and Magnetite	Orange opaque	Pyrite
Unit J (2)	99.95	66.23	28.20	3.28	0.66	1.64	0.05	27.19	5.26	2.19	-
Unit E (4)	99.93	78.80	13.92	4.75	0.63	1.90	0.07	26.95	15.26	7.79	-
(5)	99.83	81.07	13.33	2.13	1.07	2.40	0.17	20.27	17.28	9.97	-
(10)	99.87	84.33	8.48	5.64	0.94	0.63	0.13	61.24	0.56	0.56	-
Unit C (1)	99.83	85.04	12.61	1.17	0.29	0.88	0.17	6.78	4.72	1.47	-
(7)	99.95	78.20	11.42	6.92	1.38	2.08	0.05	28.63	12.55	7.84	-
(8)	99.93	79.13	13.01	5.96	0.81	1.08	0.07	28.75	15.63	8.75	-
(10)	99.96	80.27	13.24	4.59	0.54	1.35	0.04	30.82	11.01	10.38	-
(12)	99.94	86.22	7.05	5.45	0.96	0.32	0.06	26.96	16.81	8.70	-
(15)	99.95	79.04	12.58	5.16	2.25	0.97	0.05	15.54	10.14	33.78	-
Unit A ₃ (10) -	10 feet below Unit C.										
	99.99	86.75	4.64	6.62	0.99	0.99	0.01	27.51	4.76	1.59	-
(14) -	15 feet below Unit C.										
	99.97	81.14	8.42	8.08	1.68	0.67	0.03	43.33	9.09	3.64	0.30
Unit A ₂ (5)	99.96	79.93	11.04	6.69	1.00	1.34	0.04	28.20	2.30	34.43	-
Unit A ₁ (5) -	56 feet below Unit C.										
	99.92	75.59	18.53	3.53	0.88	1.47	0.08	17.98	3.54	24.25	-
(6) -	49 feet below Unit C.										
	99.97	81.40	12.79	2.91	1.16	1.74	0.03	17.20	1.27	67.50	-
(12) -	54 feet below Unit C.										
	99.98	77.92	12.93	7.57	0.63	0.95	0.02	42.90	5.74	6.01	0.27
(13) -	62 feet below Unit C.										
	99.63	84.21	10.20	4.28	0.99	0.33	0.37	13.92	0.51	70.62	-
Average clastic	99.94	80.25	12.58	4.91	0.96	1.23	0.06	27.30	8.03	17.62	0.03

Table 1. (continued)

Units and Measured Sections	Heavy Non-Opaque Minerals											
	Zircon	Garnet	Rutile, red	Rutile, yellow	Tourmaline, gray to brown	Tourmaline, blue	Biotite	Chlorite and Muscovite	Epidote	Apatite	Anhydrite	Fluorite
Unit J (2)	0.88	17.98	-	0.44	26.75	0.88	12.28	4.39	1.32	0.44	-	-
Unit E (4)	1.30	29.87	-	-	8.44	0.32	5.52	0.65	3.90	-	-	-
(5)	2.33	34.88	-	0.66	8.97	0.33	2.33	0.33	2.66	-	-	-
(10)	0.56	3.65	-	-	16.85	0.56	7.02	0.84	0.28	1.40	6.46	-
Unit C (1)	-	2.06	-	-	1.18	0.29	0.88	82.60	-	-	-	-
(7)	1.96	12.16	-	-	15.69	-	3.92	12.55	3.14	1.18	0.39	-
(8)	1.88	25.94	-	-	9.38	-	4.69	1.88	1.88	-	1.25	-
(10)	1.89	9.43	-	-	13.21	2.20	5.66	12.58	1.26	0.94	-	0.63
(12)	2.32	14.78	0.29	0.90	11.59	0.29	6.09	3.19	1.74	4.06	1.16	1.16
(15)	-	5.07	-	-	1.35	0.34	1.69	22.97	0.68	2.36	5.41	0.68
Unit A ₃ (10)	-	5.29	-	0.53	6.35	-	2.65	47.09	2.12	0.53	1.59	-
(14)	0.61	15.76	-	0.30	6.36	0.30	3.33	11.52	1.82	2.73	0.61	0.30
Unit A ₂ (5)	-	8.52	-	0.33	18.69	0.33	4.59	0.98	1.31	-	0.33	-
Unit A ₁ (5)	0.82	8.17	-	-	3.81	0.27	1.36	16.89	-	1.36	21.53	-
(6)	0.64	3.50	-	-	4.78	-	0.64	2.55	1.27	-	0.64	-
(12)	0.55	7.10	-	-	6.56	-	4.10	10.66	0.82	1.91	13.39	-
(13)	2.58	2.84	-	-	2.06	0.26	0.51	-	1.55	-	5.15	-
Average clastic	1.08	12.18	0.02	0.18	9.53	0.37	3.96	13.63	1.51	0.99	3.47	0.16

Table 2. Lithologic composition and statistical parameters of units within the upper 100 feet of the Flowerpot Shale.

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Unit J shale (26)					8.90	2.83	-0.51	0.86
Unit I siltstone (2)	13.20	3.70	76.40	6.70				
(4)	23.20	4.50	61.90	10.40				
(7)	23.10	2.90	65.70	8.30				
(8)	19.00	3.90	72.10	5.00				
(12)	8.50	7.70	80.90	2.90				
(13)	8.60	15.40	72.90	3.10				
dolomite (20)	77.78	0.03	10.58	11.61				
(22)	85.70	0.10	5.90	8.20				
(23)	67.40	1.10	23.30	8.20				
Unit H dolomite (14)	77.59	0.08	16.95	5.38				
Unit G dolomite (11)	87.94	0.03	5.93	6.10				
(12)	64.00	2.00	26.90	7.10				
(13)	91.20	0.01	4.64	4.15				
(14)	91.57	0.04	5.98	2.41				
(15)	87.97	0.02	8.89	3.12	6.90	1.82	0.28	0.88
(16)	83.84	0.02	10.29	5.95	7.20	2.09	0.22	0.74
Unit E siltstone and shale (5)	2.60	29.50	64.10	3.80				
(6)	33.20	0.40	55.40	11.00				
(10)	15.30	8.80	70.20	5.70				
(11)	28.77	0.05	44.52	26.66				
(12)	14.30	0.20	63.20	22.30				
(13)					8.62	2.60	0.34	0.78
Unit C siltstone (1)	20.00	3.70	65.50	10.80				
(4)	7.90	25.10	63.00	4.00				
(5)	9.50	14.60	72.20	3.70				

Table 2. (continued)

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Unit C siltstone								
(7)	10.20	6.60	76.30	6.90				
(8)	10.10	18.80	65.90	5.20				
(9)	6.10	5.30	85.70	2.90				
(9)	5.10	1.80	85.20	7.10				
(10)	14.10	14.40	65.60	5.90				
(10)	12.10	7.80	73.80	6.30				
(11)					6.23	2.59	0.91	1.59
(12)	9.62	21.94	63.01	5.53				
(15)	18.42	11.30	58.00	12.27				
Unit B dolomite								
(12)	46.00	1.80	44.60	7.60				
siltstone								
(13)					5.61	4.19	0.41	0.52
Unit A ₃ dolomite								
(5) reddish-brown, 24 feet below Unit C.								
	45.60	0.40	41.60	12.40				
(14) greenish-gray, 15 feet below Unit C.								
	43.70	8.50	40.80	7.01				
(14) reddish-brown, 36 feet below Unit C.								
	65.40	0.80	22.30	11.50				
siltstone								
(5) greenish-gray, 26 feet below Unit C.								
	9.00	2.10	84.10	4.80				
(6) greenish-gray, 9 feet below Unit C.								
	2.70	2.70	89.90	4.70				
(6) greenish-gray, 34 feet below Unit C.								
	11.40	7.40	75.70	5.50				
(7) greenish-gray, 8 feet below Unit C.					6.59	3.01	0.74	0.71
(7) greenish-gray, 13 feet below Unit C.								
	28.10	10.90	48.60	12.40				
(7) greenish-gray, 28 feet below Unit C.								
	19.40	2.20	75.80	2.60				
(8) greenish-gray, 26 feet below Unit C.								
	22.00	3.30	63.50	11.20				
(9) greenish-gray, 21 feet below Unit C.								
	12.80	5.70	73.40	8.10				
(10) greenish-gray, 10 feet below Unit C.								
	13.70	9.00	65.50	11.80				

Table 2. (continued)

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Unit A ₂ siltstone								
(5) greenish-gray 20.30	19.80	58.20	1.70					
(6) greenish-gray 18.30	13.90	59.10	8.70					
(7) greenish-gray 6.30	5.00	83.70	5.00					
(9) greenish-gray 6.50	10.70	77.00	5.80					
(10) reddish-brown (12) greenish-gray 6.80	8.60	65.90	18.70	7.70	3.40	0.60	0.60	
(13) greenish-gray 30.00	31.20	30.90	7.90					
Unit A ₁ siltstone and shale								
(5) greenish-gray, 56 feet below Unit C. 6.30	7.90	70.90	14.90					
(5) brown, 79 feet below Unit C. dolomite				8.23	3.07	0.18	0.82	
(5) 82 feet below Unit C. 63.20	0.30	24.90	11.60					
siltstone and shale								
(6) greenish-gray, 41 feet below Unit C. 8.33				8.33	3.39	0.34	0.56	
(6) greenish-gray, 49 feet below Unit C. 8.30	21.60	66.70	3.40					
(6) greenish-gray, 77 feet below Unit C. 20.30	4.90	69.20	5.60					
(8) greenish-gray, 50 feet below Unit C. 4.85				4.85	2.36	0.76	2.08	
(12) greenish-gray, 54 feet below Unit C. 9.00	9.60	75.00	6.40					
(13) ", 50 feet below Unit C. (13) ", 55 feet below Unit C.				5.39	2.54	0.44	0.89	
(13) red-brown, 57 feet below Unit C. (13) greenish-gray, 62 feet below Unit C.				8.77	2.80	-0.23	0.75	
19.30	19.90	55.90	4.90	8.53	3.25	0.11	0.65	
(13) greenish-gray, 82 feet below Unit C. 18.80	2.10	74.90	4.20					
(13) red-brown, 84 feet below Unit C. 7.60				7.60	2.39	-0.45	0.93	

Table 3. Mineralogic composition of members within the Blaine Formation, based on minerals from the sand-size portion of the insoluble or washed residue, in percent.

Members and Measured Sections	Light Minerals						Heavy Opaque Minerals				
	Total lights	Quartz	Chert	Orthoclase	Plagioclase	Microcline	Total heavies	Sphene and Leucoxene	Ilmenite and Magnetite	Orange opaque	Pyrite
Altona Dolomite											
(1)	99.84	75.25	12.87	9.90	0.99	0.99	0.16	36.48	14.47	7.23	0.31
(5)	96.92	72.39	9.92	15.28	0.80	1.61	3.08	13.87	18.06	37.17	-
(7)	99.95	80.17	5.31	12.57	0.56	1.40	0.05	40.31	6.81	0.52	-
(9)	99.73	76.43	7.32	13.38	1.27	1.59	0.27	23.37	24.56	-	-
(11)	99.94	84.41	5.76	7.45	1.02	1.36	0.06	49.51	6.51	0.33	-
(18)	96.77	89.63	6.35	3.34	-	0.67	3.23	9.61	6.91	30.93	-
(21)	98.65	83.50	8.08	7.07	0.67	0.67	1.35	9.98	3.02	26.22	-
(28)	99.83	85.05	13.04	1.09	0.27	0.54	0.17	71.66	0.64	9.24	-
Shale and Siltstone below Altona											
(2)	99.99	70.74	10.61	8.04	0.96	0.32	0.01	17.01	23.47	2.38	0.68
(5)	99.93	81.67	9.32	7.72	0.64	0.64	0.07	26.05	14.79	12.54	-
Maggie Dolomite											
(9)	95.54	86.76	4.71	6.18	0.88	1.47	4.46	5.77	14.17	-	-
Cedar Springs Dolomite											
(11)	68.87	84.00	10.86	3.71	1.43	-	11.13	2.18	81.11	-	-
Average Dolomite	99.88	77.94	6.83	11.43	0.79	1.11	0.12	21.23	19.51	11.38	0.03
Average Shale and Siltstone	99.97	80.14	10.28	6.18	0.81	0.54	0.03	21.53	19.13	7.46	0.34

Table 3. (continued)

Members and Measured Sections	Heavy Monopaque Minerals											
	Zircon	Garnet	Rutile, red	Rutile, yellow	Tourmaline, Gray and brown	Tourmaline, blue	Biotite	Chlorite and Muscovite	Spidote	Apatite	Anhydrite	Niebeckite
Altona Dolomite												
(1)	1.26	19.81	-	0.63	5.35	-	2.52	6.60	-	1.26	4.09	-
(5)	10.73	14.14	-	-	0.52	-	0.26	0.26	0.26	-	4.71	-
(7)	1.57	16.23	-	0.52	17.80	0.52	8.90	1.57	3.14	0.52	-	1.57
(9)	8.28	32.54	-	0.59	5.03	0.30	0.89	2.37	1.48	0.30	0.30	-
(11)	0.98	20.20	-	0.98	13.36	0.65	5.21	-	1.95	-	0.33	-
(18)	3.30	33.03	-	-	5.71	-	1.50	-	8.11	-	0.90	-
(21)	1.86	40.14	-	-	5.80	0.23	2.78	0.23	6.58	0.23	0.93	-
(28)	0.32	0.64	-	-	0.64	-	0.32	3.18	1.91	-	11.15	0.32
Shale and Silt stone below Altona												
(2)	4.42	23.47	-	0.34	8.16	0.34	4.08	7.14	-	5.44	2.72	0.34
(5)	7.72	8.68	-	-	11.90	-	1.61	12.86	0.32	-	3.54	-
Magpie Dolomite												
(9)	13.65	33.86	-	0.26	1.31	0.26	1.31	-	1.05	-	28.35	-
Cedar Springs Dolomite												
(11)	9.69	4.60	-	-	0.73	-	0.48	0.24	0.24	-	0.73	-
Average Dolomite	5.70	23.84	-	0.33	6.18	0.22	2.65	1.25	2.76	0.26	4.48	0.17
Average Shale and Silt stone	6.07	16.08	-	0.17	10.03	0.17	2.85	10.00	0.16	2.72	3.13	0.17

Table 4. Lithologic composition and statistical parameters of units
in the Blaine Formation.

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Altona Dolomite								
(1)	95.15	2.25	2.21	0.49				
(2)	89.90	3.60	3.90	3.60				
(4)	78.80	5.40	11.40	4.40				
(5)	95.00	0.30	2.90	1.80				
(6)	94.10	0.30	3.20	2.40				
(7)	84.90	3.80	8.50	2.80				
(8)	72.20	3.10	19.30	5.40				
(9)	96.50	1.60	1.20	0.70				
(10)	97.50	0.10	1.10	1.30				
(11)	88.60	7.10	4.20	0.10				
(12)	96.10	0.50	2.40	1.00				
(13)	96.10	0.50	2.00	1.40				
(14)	89.84	0.06	3.24	6.86				
(15)	92.82	0.06	3.71	3.41				
(16)	93.90	0.40	3.80	1.90	6.50	2.05	0.23	0.61
(18)	93.20	1.80	3.40	1.60	6.00	2.88	0.35	0.89
(20)	95.40	0.20	2.30	2.10				
(21)	92.20	1.60	4.50	1.70	6.20	2.54	0.38	1.05
(22)	93.57	0.08	2.51	2.84	8.20	2.36	-0.29	0.46
(23)	91.38	0.08	4.66	3.88				
(24)	93.30	0.20	3.70	2.80	7.80	2.83	0.35	0.75
(25)	91.80	0.10	5.20	2.90				
(26)	92.60	0.10	3.50	3.80				
(27)	92.61	0.06	3.66	3.67	8.70	2.94	-0.16	0.69
(27) Reno	80.50	0.11	10.37	9.02	7.83	3.04	0.30	0.63
(28)	32.00	2.90	52.40	12.70				
Shale and Siltstone below Altona								
(1) siltst.	5.00	0.70	83.40	10.90				
(2) reddish-brown shale					7.63	3.22	1.03	0.77
(5)	13.80	6.90	71.00	8.30				
(9)					7.87	3.27	0.43	0.84

Table 4. (continued)

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Maggie Dolomite								
(4)	18.60	8.10	69.90	3.40				
(5)	25.60	5.50	67.50	1.40				
(6)	17.60	0.50	79.30	2.60				
(7)	39.40	5.20	24.30	31.10				
(8)	10.50	18.90	65.10	5.50				
(9)	92.50	2.40	2.50	2.60				
(10)	73.10	0.80	26.20	0.10				
(11)	87.30	0.70	10.80	1.20				
(12)	95.60	0.10	2.80	1.50				
(13)	86.13	0.02	4.47	9.38				
(14)	93.50	0.50	2.90	3.10				
(15)	90.37	0.01	6.76	2.86	6.50	2.19	0.42	0.64
(16)	90.71	0.02	6.89	2.38	6.70	2.13	0.54	1.27
(18)	91.06	0.03	5.77	3.14	6.90	2.50	0.43	0.69
(20)	95.12	0.06	1.44	3.38				
(21)	92.20	1.60	4.50	1.70	6.20	2.54	0.38	1.05
(22)	95.46	0.03	3.17	1.34	6.20	2.15	0.50	0.69
(23)	90.49	0.02	3.39	6.10				
(24)	89.80	0.40	6.20	3.60	6.90	2.48	0.30	0.62
(25)	92.25	0.04	3.47	4.24				
(26)	46.10	0.90	47.10	5.90				
Shale and Siltstone below Maggie								
(2)					7.67	3.25	0.55	0.96
(5)	16.50	2.40	75.80	5.30				
(6)					8.43	3.20	0.40	0.85
(7)	13.70	1.20	77.20	7.90				
(9)					9.07	2.93	0.82	0.61
(12)	greenish-gray shale at top.							
	55.70	0.40	22.40	21.50				
(22)	dol. 54.50	0.20	33.90	11.40	6.60	1.73	0.06	0.78
(23)					6.17	2.93	0.42	0.86
(25)	reddish-brown shale.				8.47	3.59	0.25	0.96
(27)	dol. 78.18	0.02	6.49	15.31				
(27)	dol. 54.30	0.20	20.90	24.00				
(27)	greenish-gray silt stone.							
	5.20	0.50	62.60	31.70				

Table 4. (continued)

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Cedar Springs Dolomite								
(1)	70.00	4.70	21.80	3.50				
(2)	83.10	0.90	8.20	7.80				
(4)	80.80	5.80	6.50	6.90				
(5)	96.40	0.03	1.33	2.22				
(6)	97.88	0.03	0.85	1.24				
(7)	95.50	0.30	2.07	2.40				
(8)	97.10	0.40	1.70	0.80				
(9)	88.00	0.20	7.70	4.10				
(10)	97.90	0.30	0.90	0.90				
(11)	92.30	0.60	3.90	3.20				
(12)	97.56	0.04	1.10	1.30				
(13)	94.84	0.05	2.33	2.78				
(14)	91.94	0.03	4.02	4.01				
(15)	83.30	6.70	7.00	3.00	5.40	2.89	0.13	0.87
(18)	83.33	0.03	12.39	4.25	7.20	2.16	0.18	1.02
(20)	88.92	0.01	2.03	9.04				
(22)	87.24	0.06	7.38	5.32	7.50	1.82	0.06	1.05
(23)	79.30	1.30	12.50	6.90				
(24)	82.30	0.10	10.30	7.30	7.80	2.40	0.28	1.14
(25)	73.11	0.02	7.39	19.48	9.40	2.19	-0.04	0.86

Table 5. Lithologic composition and statistical parameters of units in the Dog Creek Shale.

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Upper Shale and Siltstone								
(1)	3.20	60.80	32.30	3.70				
(6)	3.30	16.20	77.50	2.90				
(7)	18.10	2.20	75.80	3.90				
(7)	14.30	4.70	77.10	3.90				
(9)					8.07	3.04	0.36	0.74
(11)	29.40	29.40	36.00	5.20				
(24)					7.40	3.09	0.40	0.74
(28)					7.13	3.10	0.48	0.61
Unit I								
(14)	6.40	6.50	80.60	6.50				
(16)	76.75	0.07	18.91	4.27				
Unit H								
(10)	23.80	6.20	60.90	9.10				
(11)	25.20	30.40	37.90	6.50				
(13)	61.20	0.50	31.90	6.40				
Between Units G and H								
(15)					6.33	1.74	0.46	1.27
Unit G								
(14)	74.90	0.10	17.60	7.40				
(15)	54.00	2.20	30.90	12.90	6.70	2.20	0.32	0.91
Between Units G and F ₂								
(14)					5.97	2.47	0.68	1.67
Unit F								
(1)	14.60	52.40	31.10	1.90				
(2)	13.80	56.60	27.00	2.60				
Unit F ₂								
(6)	7.60	37.90	52.50	2.00				
(9)	7.50	3.10	85.50	3.90				
(10)	23.20	1.30	71.60	3.90				
Between Units F ₁ and F ₂								
(7)	15.60	8.30	72.70	3.40				

Table 5. (continued)

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Unit F ₁ (11) ₁ (12) (12)	7.30 3.10 10.30	2.50 36.60 12.90	83.80 59.20 71.40	6.40 1.10 5.40				
Between Units F ₁ and E (8) (12) (12) (14)	6.10 10.40 13.40 17.00	1.60 20.90 23.10 1.10	81.80 65.00 58.90 68.70	10.50 3.70 4.60 13.20				
Unit E (5) (6) (7) (7) (7) (8) (11) (12) (14) (15)	88.30 64.30 14.20 88.54 44.10 10.10 31.20 32.10 22.10 68.71	0.03 0.80 9.30 0.06 0.30 1.20 1.60 1.30 0.90 0.08	6.41 18.20 74.30 4.70 34.10 81.30 62.70 58.90 68.30 25.93	5.26 16.70 2.20 6.70 21.50 7.40 4.50 7.70 8.70 5.28	6.10	1.66	0.39	0.93
Between Units D and E, or C and F (1) (12) (12)	6.60 9.60 26.80	0.24 1.30 3.20	75.00 86.90 60.90	18.10 2.20 9.10	6.47	1.92	0.47	1.21
Unit D (7) (8) (8) (10) (12) (12) (14)	80.22 43.70 65.60 72.80 65.50 76.99 20.30	0.01 0.60 0.20 0.30 2.70 0.05 1.60	7.28 39.10 25.10 21.20 27.80 15.31 72.70	12.49 16.60 9.10 5.70 4.00 7.65 5.40				
Unit C (1) (4) (5) (6) (7) (8) (9) (14)	1.50 78.80 82.30 78.12 71.46 65.80 84.32 48.90	0.70 0.90 0.01 0.02 0.02 0.10 0.02 1.90	88.50 14.20 11.10 13.31 17.09 24.90 6.21 39.50	9.30 6.10 6.62 8.55 11.43 9.20 9.45 9.70				

Table 5. (continued)

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Between Unit C and Southard Dolomite								
(12)	13.40	0.80	56.70	29.10				
(20)	27.70	2.10	55.20	15.00				
Southard Dolomite								
(1)	46.20	0.30	45.60	7.90				
(2)	64.09	0.06	24.36	9.49				
(5)	85.00	0.02	7.10	7.88				
(6)	60.17	0.03	23.12	16.68				
(7)	51.05	0.03	35.97	12.95				
(8)	75.82	0.03	13.90	10.25				
(10)	83.10	0.20	7.80	8.90				
(12)	81.30	0.002	8.80	9.90				
(13)	81.26	0.03	11.48	7.23				
(14)	93.03	0.08	4.04	2.85				
(15)	86.38	0.06	4.72	8.84				
(16)	58.80	0.10	35.20	5.90	6.10	1.56	0.43	1.07
(18)	80.94	0.08	12.57	6.41	6.70	1.92	0.24	0.75
(20)	83.22	0.05	11.99	4.74				
(21)	74.70	0.20	19.60	5.50	6.50	1.83	0.37	1.03
(24)	95.20	0.10	2.50	2.20	8.00	2.78	0.51	0.73
Unit B								
(1)	13.40	10.90	72.10	3.60				
(4)	23.10	0.40	37.30	39.20				
(4)	37.70	3.40	54.20	4.70				
(5)	84.00	0.03	6.43	9.50				
(5)	86.70	0.05	4.49	8.72				
(6)	55.95	0.03	27.68	16.34				
(6)	58.10	0.80	32.30	8.80				
(7)	33.00	0.10	44.10	22.80				
(7)	67.40	0.30	20.60	11.70				
(8)	18.00	0.40	66.00	15.60				
(9)	55.50	1.20	39.20	4.00				
(10)	25.28	0.07	52.17	22.49				
(11)	50.90	1.50	42.50	5.10				
(12)	54.60	1.40	37.10	6.90				
(12)	70.90	1.90	19.60	7.60				
Between Units B and A								
(4)	16.60	57.60	22.50	3.30				
(7)	12.90	4.80	79.90	2.40				
(12)	2.70	39.40	56.70	1.20				
(12)	2.40	47.50	48.70	1.40				
(14)	17.60	28.00	47.70	6.70				
(14)	14.40	6.30	72.00	7.30				

Table 5. (continued)

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Unit A								
(1)	9.90	62.90	24.70	2.50				
(1)	13.10	11.40	71.80	3.70				
(4)	18.00	0.20	76.40	5.40				
(5)	12.40	39.80	46.30	1.50				
(6)	8.10	51.90	38.10	1.90				
(6)	26.40	0.70	68.10	4.80				
(7)	12.90	30.90	55.50	0.70				
(7)	18.50	2.20	77.50	1.80				
(8)	7.30	3.00	87.20	2.50				
(10)					4.43	1.63	0.60	5.15
(12)					3.67	1.76	0.68	4.10
(13)	31.70	0.90	54.20	13.20				
Between Unit A and Watonga Dolomite								
(4)	8.40	59.50	28.00	4.10				
(6)	44.44	0.07	48.67	6.82				
(7)	6.70	21.60	69.70	1.90				
(25) dol.	88.58	0.03	6.54	4.85				
(25) dol.	65.90	0.10	28.20	5.80				
(26) dol.	76.94	0.03	10.57	12.46				
(26)	41.20	1.30	47.40	10.10				
(26) dol.	77.42	0.02	15.11	7.45				
Watonga Dolomite								
(1)	8.40	64.80	25.40	1.40				
(1)	15.70	11.20	70.20	2.90				
(2)					4.00	1.88	0.71	3.93
(4)	3.90	18.50	75.70	1.90				
(7)	4.10	9.10	83.90	2.90				
(8)	30.77	0.05	62.65	6.53				
(12)	64.98	0.02	28.81	6.19				
(13)	75.30	0.20	17.80	6.70				
(15)	31.53	0.03	60.91	7.53	6.00	1.40	0.36	1.31
(16)	40.00	0.80	54.50	4.70	6.00	1.17	0.28	0.02
(18)	81.68	0.07	11.71	6.54	7.40	2.14	0.29	0.76
(20)	79.98	0.04	10.60	9.38				
(20)	31.10	1.10	51.70	16.10				
(21)	29.40	0.20	54.70	15.70	6.60	1.94	0.38	0.97
(22)	43.00	0.70	38.30	18.00	7.30	2.17	0.19	0.76
(23)	75.96	0.02	13.33	10.69				
(24)	63.20	0.20	32.90	3.70	5.70	1.61	0.53	1.41
(25)	75.10	0.03	14.62	10.25				
(26)	59.10	0.10	33.30	7.50				

Table 5. (continued)

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Between Watongasard Haskeu Members (12)	26.50	3.20	61.70	8.60				
Basal Shale below Haskeu Member (26)					8.30	3.42	0.23	0.68
(26) dol.	93.06	0.01	2.78	4.15				
(26) dol.	76.20	0.06	10.85	12.89				
(28)					7.73	3.13	0.23	0.81

Table 6. Mineralogic composition of members of the Dog Creek Chale,
 based upon studies of minerals from the sand-size portion
 of insoluble or washed residues, in percent.

Units and Measured Sections	Light Minerals						Heavy Opaque Minerals				
	Total Lights	Quartz	Chert	Orthoclase	Plagioclase	Microcline	Total heavies	Sphene and Leucocoxene	Ilmenite and Magnetite	Orange opaque	Pyrite
Upper Shale and Siltstone											
(1)	99.88	72.46	15.41	9.84	1.31	0.98	0.12	12.89	57.86	1.89	-
(7)	-	65.62	10.73	20.50	1.26	1.89	tr.	19.22	24.32	0.90	-
Unit H											
(10)	99.88	83.71	8.47	5.86	0.98	0.98	0.12	6.71	46.06	2.04	-
(11)	99.84	79.68	9.03	8.71	1.29	1.29	0.16	9.23	37.85	0.31	-
Unit G											
(15)	99.01	76.07	9.84	10.82	0.66	2.62	0.89	6.23	60.75	4.36	-
Unit F											
(2)	99.73	75.24	7.52	15.05	0.63	1.57	0.27	13.13	37.71	3.03	-
Unit F ₂											
(6)	99.98	81.61	6.77	10.00	0.97	0.65	0.02	32.25	13.91	4.73	-
Unit F ₁											
(12)	-	72.39	7.98	16.87	0.61	2.15	tr.	49.63	21.48	2.96	-
Between F ₁ and E units											
(12)	99.97	76.55	6.19	15.96	0.65	0.65	0.03	38.05	14.78	1.26	-
Unit B											
(1)	-	75.15	13.94	7.27	1.82	1.82	tr.	26.21	27.83	2.59	-
Between Units B and A											
(4)	99.66	72.70	12.38	13.33	0.63	0.95	0.34	22.10	27.20	1.98	-
Unit A											
(1)	99.92	84.72	5.44	6.74	1.55	1.55	0.08	15.60	34.25	0.61	-
(5)	99.96	84.26	7.87	5.25	1.64	0.98	0.04	29.01	30.86	4.63	-
(6)	99.77	78.63	9.40	8.83	1.71	1.42	0.23	17.21	45.12	4.65	-
(7)	99.96	70.57	9.81	18.35	0.63	0.63	0.04	26.52	31.71	1.83	-
(12)	99.91	64.89	15.99	12.23	2.82	4.08	0.09	10.51	36.36	1.42	-
(14)	99.98	80.00	7.58	11.21	0.61	0.61	0.02	32.57	19.54	1.63	0.33
Between Unit A and Watonga Dolomite											
(7)	99.79	74.85	6.51	15.09	1.48	0.59	0.21	37.64	7.76	2.87	-
Watonga Dolomite											
(1)	99.95	83.15	5.90	7.87	1.69	1.40	0.05	26.87	15.51	0.55	-
Average Dolomite											
	99.75	75.99	9.85	10.82	0.70	2.64	0.25	7.51	48.88	5.26	-
Average Shale and Siltstone											
	99.89	76.47	9.33	11.66	1.14	1.40	0.11	17.84	34.96	2.79	tr.

Table 6. (continued)

Units and Measured Sections	Heavy Nonopaque Minerals										
	Zircon	Garnet	Rutile, red	Rutile, yellow	Tourmaline, gray to brown	Tourmaline, blue	Biotite	Chlorite and Muscovite	Epidote	Anhydrite	Diabeckite
Upper Shale and Siltstone											
(1)	2.52	16.04	-	0.31	4.40	-	2.20	0.31	0.63	0.94	-
(7)	5.41	12.91	-	0.30	1.50	-	3.30	29.73	2.40	-	0.90
Unit H											
(10)	10.50	30.90	-	0.58	1.46	-	0.29	-	1.46	-	-
(11)	14.77	30.46	-	0.31	4.62	-	1.85	-	0.62	0.31	-
Unit G											
(15)	9.35	14.33	-	0.31	1.25	-	0.62	-	5.61	-	0.31
Unit F											
(2)	10.77	25.25	-	0.34	4.04	-	2.02	1.35	1.01	1.35	-
Unit F ₂											
(6)	7.99	1.78	0.59	1.48	3.85	0.30	3.55	25.44	3.25	-	0.89
Unit F ₁											
(12) ¹	5.19	7.41	-	3.70	2.96	0.74	1.48	1.48	5.93	-	-
Between F ₁ and E units											
(12)	2.20	25.79	-	0.31	5.66	-	4.40	2.52	5.03	-	0.31
Unit B											
(1)	2.59	19.09	0.32	0.65	0.97	-	0.32	15.53	2.59	1.29	-
Between Units B and A											
(4)	5.10	27.48	-	0.28	9.63	-	1.13	2.55	1.98	0.57	-
Unit A											
(1)	6.42	34.56	-	0.61	2.45	0.61	1.83	0.92	1.53	0.61	-
(5)	3.09	14.51	-	1.54	9.26	0.31	3.40	1.85	0.31	0.93	0.31
(6)	7.91	15.12	0.23	3.49	2.56	-	1.40	0.70	1.63	-	-
(7)	5.79	23.17	0.30	0.61	3.66	0.30	1.52	1.52	2.74	0.30	0.30
(12)	2.84	35.80	-	0.57	1.70	0.28	1.99	0.85	5.97	1.70	-
(14)	2.61	29.64	-	0.33	5.86	-	2.61	1.63	3.26	-	-
Between Unit A and Watonga Dolomite											
(7)	1.72	12.64	-	-	4.60	-	2.30	27.30	3.16	-	-
Watonga Dolomite											
(1)	3.88	32.13	0.28	0.55	7.76	0.28	3.32	3.60	3.60	1.66	-
Average Dolomite											
	11.30	17.30	-	0.37	1.51	-	0.73	-	6.77	-	0.37
Average Shale and Siltstone											
	7.12	22.44	0.09	0.72	4.41	0.45	1.71	4.14	2.70	0.54	0.09

Table 7. Mineralogic composition of some Chickasha wedges of the Dog Creek and Blaine Formations, based upon studies of sand-size minerals of the insoluble or washed residue, in percent.

Units and Measured Sections	Light Minerals						Heavy Opaque Minerals				
	Total lights	Quartz	Chert	Orthoclase	Plagioclase	Microcline	Total heavies	Sphene and Leucoxene	Ilmenite and Magnetite	Orange opaque	Pyrite
Dog Creek Shale (28) - 70 feet below top.	-	70.98	23.83	3.63	0.26	1.30	tr.	25.48	-	-	-
(28) - 110 feet below top.	-	64.05	30.21	3.93	0.91	0.91	tr.	24.60	6.35	flood	-
(28) - 150-180 feet below top.	-	67.47	28.42	2.74	0.68	0.68	tr.	26.94	6.73	5.39	0.67
Blaine Formation (28) - 35 feet below Altona Dolomite.	95.95	82.65	9.86	3.06	1.02	3.40	0.05	73.40	0.96	1.60	-
Units and Measured Sections	Heavy Nonopaque Minerals										
	Zircon	Garnet	Rutile, yellow	Tourmaline, brown and gray	Biotite	Chlorite and Muscovite	Epidote	Apatite	Anhydrite		
Dog Creek Shale (28) - 70 feet below top.	-	-	-	0.64	-	12.10	-	-	-	61.78	
(28) - 110 feet below top.	-	1.59	0.30	1.59	-	6.35	-	-	-	56.73	
(28) - 150-180 feet below top.	0.67	1.68	-	1.68	0.67	0.67	4.38	-	-	51.18	
Blaine Formation (28) - 35 feet below Altona Dolomite.	0.64	0.96	0.32	3.53	0.32	3.53	10.90	2.56	-	1.28	

Table 8. Lithologic composition of Chickasha Tongues in the Dog Creek, Blaine, and Flowerpot Formations.

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Dog Creek 70 feet below top (28)	33.70	4.80	49.80	11.70	6.26	2.78	0.78	1.09
Dog Creek 110 feet below top (28)	upper portion.				6.20	2.76	0.89	1.89
	lower portion.				6.17	2.47	0.75	0.89
Dog Creek 150-180 feet below top (28)	reddish-brown shale.				7.73	3.13	0.23	0.81
Blaine Formation 35 feet below Altona Dolomite (28)	13.80	10.60	65.10	10.50				
Flowerpot Shale 250 feet below top (20)					6.66	2.77	0.65	0.83

Table 9. Mineralogic composition of the basal part of the Marlow Formation, including Doe Creek Member (Sections 6-7), based upon studies of sand size grains of the insoluble or washed residue, in percent.

Units and Measured Sections	Light Minerals						Heavy Opaque Minerals				
	Total lights	Quartz	Chert	Orthoclase	Plagioclase	Microcline	Total heavies	Sphene and Leucoxene	Ilmenite and Magnetite	Orange opaque	Pyrite
(1)	99.81	87.66	2.54	8.23	0.63	0.94	0.19	12.50	50.30	3.04	-
(4)	99.74	64.49	13.35	19.54	1.30	1.30	0.26	29.85	18.20	1.49	-
(6)	99.58	86.20	6.20	5.63	1.69	0.28	0.42	10.24	52.79	0.93	-
(7)	99.84	82.24	7.47	6.85	1.24	2.18	0.16	13.43	7.81	1.25	5.93
(8)	98.59	74.38	15.08	7.36	2.10	1.05	1.41	12.29	48.54	0.32	-
(9)	99.99	93.66	2.59	2.31	0.86	0.58	0.01	30.90	16.36	7.27	-
(13)	99.22	89.41	4.60	2.97	1.00	1.99	0.78	8.10	40.78	1.95	-
(24)	99.43	88.15	6.21	0.83	1.85	2.36	0.57	19.02	7.06	0.54	-
(28)	99.92	82.72	4.24	9.64	1.41	1.98	0.08	35.71	17.20	3.89	-
Averages											
Marlow	99.54	82.98	6.95	7.28	1.32	1.47	0.46	14.34	36.75	1.06	-
Doe Creek	99.86	83.76	6.98	6.38	1.41	1.47	0.14	11.42	35.40	1.06	2.61
Units and Measured Sections	Heavy Nonopaque Minerals										
	Zircon	Garnet	Rutile, red	Rutile, yellow	Tourmaline, gray & brown	Tourmaline, blue	Biotite	Chlorite and Muscovite	Epidote	Apatite	
(1)	8.53	16.46	-	0.30	0.91	0.30	1.82	-	0.60	-	
(4)	7.16	32.23	0.59	0.29	5.67	1.49	1.79	0.29	0.59	-	
(6)	13.04	17.39	-	1.89	1.55	0.62	0.31	-	1.24	-	
(7)	2.81	53.75	-	0.31	2.18	0.31	0.93	0.31	10.93	-	
(8)	11.00	22.33	0.97	0.97	0.64	0.32	1.61	-	0.32	0.64	
(9)	7.27	3.63	-	10.90	-	-	-	21.81	1.81	-	
(13)	9.21	26.25	-	0.55	4.74	-	1.95	0.55	5.58	0.27	
(24)	19.83	44.83	0.27	0.27	4.07	-	0.81	-	2.71	0.54	
(28)	18.18	0.97	0.32	6.49	8.11	-	3.89	0.97	3.89	0.32	
Averages											
Marlow	11.87	27.13	0.52	0.78	2.77	0.26	1.62	0.17	2.12	0.61	
Doe Creek	9.10	31.24	-	1.27	1.76	0.49	0.56	0.14	4.94	-	

Table 10. Lithologic composition and statistical parameters of the basal part of the Marlow Formation and Doe Creek Member.

Units and Measured Sections	Carbonate	Sand	Silt	Clay	Mean	Deviation	Skewness	Kurtosis
Marlow base								
(1)	4.20	80.40	13.20	2.20				
(4)	5.80	76.20	15.90	2.10				
(5)	9.20	49.40	38.70	2.70				
(8)					3.43	0.51	0.19	1.56
(9)					5.13	1.38	0.41	1.98
(10)					3.53	0.42	0.26	1.31
(11)					3.40	0.41	0.00	1.15
(12)					4.96	1.22	0.32	1.13
(13)					3.30	0.46	0.09	0.25
(14)					3.13	0.71	0.44	1.11
(16)					3.56	0.45	0.40	0.88
(22)					3.13	0.71	0.68	1.70
(24)					3.13	0.52	0.27	1.89
(25)					4.86	1.17	0.27	1.12
(28)					4.16	1.32	0.53	1.34
Doe Creek								
(5)	38.00	48.80	11.60	1.60				
(6)	55.90	22.90	18.70	2.50				
(7)	31.40	68.60	-	-	1.53	0.21	0.54	1.43

Table 11. X-ray data from specimens of the El Reno and Whitehorse

Groups. Only major or important peaks are shown. The letter g means glycerated; i is illite, c is chlorite, and q is quartz.

Formations and Measured Sections	d spacing in Angstrom units					
	3.31-3.34 i, q	3.36-3.58 c	4.21-.27 q	4.93-4.98 i	6.91-7.25 c	9.55-10.05 i 13.40-14.40 c
Flowerpot Shale						
Unit A ₁						
(5) - 45 feet below top.	3.34 3.34g			4.98	7.20	10.04 9.90g
(6) - 4.5 feet below top.	3.32	3.52		4.95	7.03 7.03g	9.90, 13.80 9.80g, 13.60g
(13) - 50 feet below top.	3.33 3.34g		4.25 4.25g	4.98 4.98g	7.13 7.13g	10.03 13.80 10.00g, 14.00
(13) - 51 feet below top.	3.32	3.51	4.23		7.03 6.97g	9.80 13.80 9.80g, 13.80g
Unit C						
(12) - siltstone.	3.32	3.53			7.05	9.80 13.40 13.80
(15) - siltstone.	3.33	3.51			7.00 7.00g	9.80 13.60 9.80g
Blaine Formation						
Below Kingfisher Creek.						
(23)	3.34 3.35g	3.53 3.52g	4.24g	4.98 4.95g	7.13g	10.04 13.40 10.05g
Below Nescatunga.						
(2)	3.33	3.55	4.25	4.93	7.02 7.03g	9.80 13.40 9.80g, 13.65g
Below Magpie.						
(6)	3.31	3.54		4.93	7.02 7.02g	9.80 9.80g, 13.40g
(9)	3.32 3.32g	3.52 3.53g		4.98 4.98g	7.08 7.08g	9.90 14.00 9.90g, 14.00g
(25)	3.33	3.49	4.23	4.93	7.08 6.96g	9.80 9.80g

Table 11. (continued)

Formations and Measured Sections	d spacing in Angstrom units					
	3.31-3.34 i,q	3.36-3.58 c	4.21-4.27 q	4.93-4.98 i	6.91-7.25 c	9.55-10.05 i 13.40-14.40 c
Blaine Formation						
Below Altona.						
(2)	3.32	3.55		4.98	7.13	10.04 13.80
	3.32g	3.55g		4.98g	7.13g	10.04g 14.00g
(9)	3.31	3.55		4.94	7.03	9.80 13.80
					7.03g	9.80g 13.80g
Dog Creek Shale						
Below Matonga.						
(26)	3.32			4.95	7.05	9.80 13.80
					7.01	9.80g 13.80g
Above Unit G.						
(9)		3.52		4.95	7.02	9.90 14.10
	3.32g	3.54g		4.98g	7.02g	9.80g 13.80g
(14)	3.31	3.53		4.95	7.07	9.80 13.80
					7.15g	9.80g 13.80g
(15)	3.32	3.55		4.98	7.10	9.91 13.80
	3.33g	3.55g		4.93	7.14g	9.91g 14.40g
(24)	3.30				7.25	10.04
	3.32g	3.52g	4.22g	4.95g	7.25g	9.80g
(28) - upper 15 feet.						
	3.32				7.00	9.75 13.60
					7.00g	9.75g 14.15g
Chickasha Tongues						
in Dog Creek						
(28) - 70-71 feet below top.	3.31	3.48	4.22	4.93	7.00	9.75 13.40
					6.91g	9.75g 13.80g
(28) - 115-130 feet below top.	3.30			4.90	7.20	9.80 13.50
	3.30g	3.50		4.75		9.60
(28) - 150-180 feet below top.	3.32			4.94	7.07	13.70
						9.80g 13.80g
Marlow Formation						
(9)	3.30	3.54			7.02	9.75 13.40
					7.02g	9.80g 13.80g
(12)	3.34	3.55			7.10	9.91 14.03
					7.03g	9.75g 13.60g

Table 11. (continued)

Formations and Measured Sections	d spacing in Angstrom units					
	3.31-3.34 i,q	3.36-3.58 c	4.21-4.27 q	4.93-4.98 i	6.91-7.25 c	9.55-10.05 i 13.40-14.40 c
Marlow Formation (13)	3.33		4.26		7.13	
(14)	3.33	3.51g	4.21g		7.09	10.04g
(16)	3.31g	3.63g			7.13g	10.05
(25)	3.32	3.55			7.13	9.55
(25)	3.32g	3.55g			7.10g	9.95 13.20
(25)	3.32				7.10	10.04g
(25)	3.32g			4.99g	7.05g	9.91 14.00
(28) - greenish-gray.						9.89g
(28)	3.35	3.55			7.25	10.05
(28)	3.33g		4.27g	4.98g	7.02g	9.95g
(28) - reddish-orange.						
(28)	3.32	3.52	4.25	4.95	7.09	9.91 14.20
(28)	3.34g	3.58g			7.13g	10.03g

Table 12. Average mineralogic composition of parts of the El Reno and Whitehorse Groups, northwestern Oklahoma. The numbers in parentheses indicate recalculated percentages after carbonate and clay is removed. (Figures denote percentage.)

Minerals	Formations								
	Flowerpot	Blaine		Dog Creek		Chickasha		Marlow	
	clastic	dolomite	clastic	dolomite	clastic	Blaine Tongue	Dog Creek Tongue	Base	Doe Creek
LIGHTS									
Quartz	63.78 (80.25)	4.91 (77.94)	52.39 (80.14)	25.06 (75.99)	62.37 (76.47)	62.48 (82.65)	49.06 (67.43)	77.78 (82.98)	45.69 (53.76)
Chert	10.00 (12.58)	0.43 (6.83)	6.72 (10.28)	3.25 (9.85)	7.61 (9.33)	7.45 (9.86)	19.99 (27.47)	6.61 (6.95)	3.81 (6.98)
Orthoclase	3.90 (4.91)	0.72 (11.43)	5.35 (8.18)	3.57 (10.82)	9.51 (11.66)	2.31 (3.06)	2.54 (3.49)	6.83 (7.28)	3.48 (6.38)
Plagioclase	0.76 (0.96)	0.05 (0.79)	0.53 (0.81)	0.23 (0.70)	0.93 (1.14)	0.77 (1.02)	0.45 (0.62)	1.23 (1.32)	0.77 (1.41)
Microcline	0.98 (1.23)	0.07 (1.11)	0.35 (0.54)	0.87 (2.64)	1.14 (1.40)	2.57 (3.40)	0.72 (0.99)	1.37 (1.47)	0.80 (1.47)
Carbonate	13.88	92.22	9.57	53.87	14.10	13.87	-	2.79	44.00
Clay	7.10	1.68	25.08	12.90	4.23	10.50	27.24	2.93	1.79
HEAVIES	0.06	0.12	0.03	0.25	0.11	0.04	tr.	0.46	0.14
Opagues									
Sphene and Leucoxene	27.30	21.23	21.53	7.51	17.84	73.40	25.68	14.34	11.42
Ilmenite and Magnetite	8.03	19.51	19.13	48.28	34.96	0.96	4.37	36.75	35.40
Orange opaque	17.62	11.38	7.46	5.26	2.79	1.60	1.81	1.06	1.06
Fyrite	0.03	0.03	0.34	-	tr.	-	-	-	2.61
Nonopagues									
Zircon	1.08	5.70	6.07	11.30	7.12	0.64	0.23	11.87	9.10
Garnet	12.18	23.84	16.08	17.30	22.44	0.96	1.10	27.13	31.24
Rutile, red	0.02	-	-	-	0.09	-	-	0.52	-
Rutile, yel.	0.18	0.33	0.17	0.37	0.72	0.32	0.11	0.78	1.27
Tourmaline, gray to brown	9.53	6.18	10.03	1.51	4.41	3.53	1.31	2.77	1.76
Tourmaline, blue	0.37	0.22	0.17	-	0.45	-	-	0.26	0.49
Biotite	3.96	2.65	2.85	0.73	1.71	0.32	0.22	1.62	0.56
Chlorite and Muscovite	13.63	1.25	10.00	-	4.14	3.53	6.38	0.17	0.14
Epidote	1.51	2.76	0.16	6.77	2.70	10.90	1.47	2.12	4.94
Apatite	0.99	0.26	2.72	-	-	2.56	-	0.61	-
Anhydrite	3.47	4.48	3.13	-	0.54	1.28	57.24	-	-
Riebeckite	0.16	0.17	0.17	0.37	0.09	-	-	-	-

APPENDIX B

Stratigraphic Sections

The detailed measured sections are here arranged in order from north to south, beginning with those in Barber and Comanche Counties, Kansas, and ending with those in Grady County, Oklahoma, a linear distance of approximately 250 miles. Each section was measured with a ruler and hand-level along cliff faces and road cuts. Almost 1,000 samples were collected for examination in the laboratory, consisting of hand specimens and 500-gram bags of spot and channel samples. Of the above samples, only one-third were studied, consisting of 272 insoluble residues, 325 pipette analyses, 150 light and heavy mineral slides, 64 X-rays, and 80 thin-sections.

The recorded percentages of sand, silt, clay, and carbonate were determined by insoluble residue and pipette methods. Dolomite and calcite are placed together under the term carbonate and the term calcareous refers to the total carbonate content of the rock. The gypsum and hematite portions were not separated from the clay and carbonate portions, taken into solution and therefore the reported percentages of the clay and carbonate are probably high. Quantitative analysis was not attempted.

The heavy- and light-mineral fractions of the sand-size portion were separated by use of bromoform. These mineral grains were then placed upon slides, mounted in Canada balsam, and approximately 300 grains on each slide were identified in order to determine relative

percentages. The "orange opaque" portion of the heavy-mineral fraction is probably a mineral such as sphene or leucoxene with hematite stains. Some of the grains identified as epidote may be staurolite. The microcline portion of the light minerals refers only to that type that shows the characteristic quadrille twinning. The chlorite-muscovite portion is included with the heavy fraction and where this percentage is high there is probably 5 to 10 percent that should be included with the light-mineral fraction.

Minor structures of the rocks were studied by means of thin sections cut at right angles to the bedding. The terms "thin-bedded", "medium-bedded", and "thick-bedded" indicate that the bedding planes are approximately one-fourth, one, and three inches apart, respectively. The term "red-brown" or "reddish-brown" means moderate to dark reddish-brown color, probably due to hematite. Silt comprises a large percentage of the shales and it is understood that the term "shale" means silty shale with as much as 40 percent or more of silt-size particles in it, the silt being composed of quartz and clay aggregates plus at least 25 more minerals.

The clay-size particles, as determined by X-ray studies, consist mainly of minerals of the illite and chlorite group, with minor amounts of quartz and carbonates. The term "clay shale" means a rock with the above-mentioned clay minerals in it comprising a graphic mean diameter of 8 phi or more. Unless complete pipette analyses are determined for each rock it is impossible to distinguish a clay shale from a fine-grained siltstone in the field and therefore the term shale includes

both types. For example, a shale with a graphic mean of 7.4 phi would be classed as a siltstone, but appear as shale, whereas a shale of graphic mean 8.25 would be a clay shale. Both types of rocks would be classed as shale or silty shale in the field and could not be distinguished from each other. The term silty is applied if appreciable amounts of fine-grained silt or grit can be seen, or felt between the fingers or teeth.

In the following detailed measured sections, an asterisk (*) after a rock term indicates that mineralogic, lithologic, or X-ray analyses have been made and the results are included in Tables 1-12.

[The following table contains several rows of text that are extremely faint and difficult to read. It appears to be a list of measured sections with associated rock descriptions and possibly numerical values. Due to the low contrast and blurriness of the image, the specific text within these rows cannot be accurately transcribed.]

Detailed Measured Sections.

Section 1. Dog Creek Section

Barber County, Kansas

Beginning at top in Marlow Formation along State Highway 160, in N $\frac{1}{2}$ N $\frac{1}{2}$ sec. 9, T. 32 S., R. 14 W., ending in the Flowerpot Shale in SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 5, T. 32 S., R. 14 W., Barber County, Kansas.

Thickness
in feet

MARLOW FORMATION (Top not exposed)

Sandstone*, moderate reddish-brown to reddish-orange, fine-grained, quartzose. Exposed thickness 10.0

DOG CREEK SHALE (Type section, total thickness 30.9 feet)

Shale*, red brown, blocky, interbedded with reddish-orange, silty, thin-bedded, weakly indurated sandstone as above..... 1.5

Unit F (Dog Creek):

Sandstone*, reddish-orange, fine-grained, medium-bedded, well-indurated, forming ledge 2.2

Unnamed Units (Dog Creek):

Shale, red-brown, silty, blocky 0.5

Siltstone*, purple-brown, platy, with some greenish-gray streaks 0.2

Shale, purple-brown, blocky, with some satin-spar layers 0.75

Shale, red-brown, silty, blocky 1.0

(Dog Creek Section 1, continued)

Unit C (Dog Creek):

Siltstone*, red-brown, mottled greenish-gray, argillaceous,
thin-bedded, well-indurated, forming ledge 0.9

Unnamed Units (Dog Creek):

Shale, red-brown, silty, blocky 1.0

Southard Dolomite Member:

Dolomite*, red-brown, mottled greenish-gray, silty, well-
indurated 0.1

Unnamed Units (Dog Creek):Unit B:

Shale, purple-brown, platy 0.75

Siltstone*, red-brown, calcareous, arenaceous, massive, well-
indurated, forming ledge 1.65

Unnamed Unit (Dog Creek):

Shale, dark red-brown, silty, blocky to platy, weakly
indurated 4.0

Unit A (Dog Creek):

Siltstone, moderate reddish-orange to reddish-brown,
argillaceous, platy, thin-bedded, weakly indurated 1.0

Sandstone*, greenish-gray, mottled reddish-brown, quartzose,
silty, massive, well-indurated, forming a ledge 1.0

Siltstone, greenish-gray, gypsiferous, massive, well-indurated,
forming ledge 0.2

(Dog Creek Section 1, continued)

Shale, red-brown, blocky	0.2
Siltstone*, greenish-gray, arenaceous, calcareous, fine-grained, dense, well-indurated, forming light-colored ledge	0.2
<u>Unnamed Units (Dog Creek):</u>	
Shale, red-brown, blocky, weakly-indurated	5.25
Siltstone, greenish-gray, nodular, well-indurated	0.2
<u>Watonga Dolomite Member:</u>	
Sandstone*, greenish-gray, mottled reddish-brown, silty, calcareous, medium-bedded, well-indurated, forming ledge ...	2.5
Shale, dark red-brown, silty, platy	0.1
Siltstone*, greenish-gray, arenaceous, calcareous, well-indurated, thinly-laminated, platy, ripple-marked, forming ledge	0.9
<u>Unnamed Units (Dog Creek):</u>	
Shale, red-brown, blocky, silty, mottled greenish-gray	0.8
Siltstone, greenish-gray, calcareous, well-indurated, nodular, massive	0.1
Siltstone, reddish-brown, mottled greenish-gray, well-indurated, massive	0.75
Siltstone, greenish-gray, mottled reddish-brown, well-indurated, massive	0.5
Siltstone, mottled reddish-brown and greenish-gray, argillaceous, well-indurated, massive	0.5
Shale, red-brown, blocky	2.2

(Dog Creek Section 1, continued)

BLAINE FORMATION (Total thickness, 41.4 feet)

Altona Dolomite Member:

Limestone*, light gray to greenish-gray, gypsiferous, fine-grained, dense, well-cemented, grading into a finely laminated, crinkly bedded portion, weathering into box-works, forming prominent mappable escarpment	0.2
Limestone, greenish-gray, silty, massive, as above	0.2
Limestone, light gray to greenish-gray, as above, well-indurated, massive, forming ledge	0.1

Unnamed Units (Blaine):

Siltstone*, red-brown, argillaceous, blocky	1.9
Siltstone, greenish-gray, mottled reddish-brown, argillaceous, blocky, thin-bedded	0.5
Siltstone, mottled red-brown and greenish-gray, argillaceous, well-indurated, massive, forming ledge	0.7
Siltstone, red-brown, mottled greenish-gray, argillaceous, blocky, weakly indurated	1.5
Shale, red-brown, silty, blocky	1.75
Siltstone, red-brown, mottled greenish-gray, argillaceous, massive, blocky, weakly indurated	1.0
Siltstone, moderate reddish-orange, mottled greenish-gray, argillaceous, thin-bedded, well-indurated, forming ledge ...	0.25
Shale, red-brown, mottled greenish-gray, silty, blocky	4.5
Siltstone, greenish-gray, argillaceous, well-indurated	0.1

(Dog Creek Section 1, continued)

Shale, red-brown, silty, blocky, thin-bedded, with many thin greenish-gray siltstone beds	3.0
Gypsum, light pink to white, massive, crinkly, well-indurated, possibly representing the Nescatunga Member	0.4
Shale, green-gray, gypsiferous, blocky	0.1
Shale, red-brown, blocky	1.4
Siltstone, greenish-gray, gypsiferous, dolomitic, argillaceous, well-indurated, massive	0.1
Shale, red-brown, blocky, with much satin-spar	2.5

Medicine Lodge Gypsum Member:

Gypsum, white, fine-grained, mottled light-gray, massive, well-indurated, forming an escarpment	21.0
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Cedar Springs Dolomite Member:

Dolomite*, dark-gray, fine-grained, oolitic, thin-bedded, well-indurated, grading into gypsum above	0.2
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FLOWERPOT SHALE (Exposed thickness, 92.9 feet)

Unit K (Flowerpot):

Shale, greenish-gray, blocky	0.25
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Units H-J (Flowerpot):

Shale, red-brown, blocky	0.6
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Shale, greenish-gray, gypsiferous, blocky	0.2
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Shale, red-brown, blocky; section extrapolated to SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 5, T. 32 S., R. 14 W., in cliff along creek north of road ..	2.0
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(Dog Creek Section 1, continued)

Shale, greenish-gray, gypsiferous, blocky	0.4
Shale, red-brown, silty, blocky, with occasional greenish-gray layers	5.0
<u>Units E-G (Flowerpot):</u>	
Gypsum, mottled reddish-brown and greenish-gray, argillaceous, massive, well-indurated, forming ledge	1.0
<u>Unit D (Flowerpot):</u>	
Shale, red-brown, blocky, gypsiferous, with some nodular gypsum, partly covered	6.25
<u>Unit C (Flowerpot):</u>	
Siltstone and gypsum; red-brown, argillaceous, thin-bedded, crinkly bedded, well-indurated, forming ledge	1.25
<u>Units A-B (Flowerpot):</u>	
Shale, red-brown, gypsiferous, blocky	0.75
Shale, greenish-gray, gypsiferous, blocky	0.1
Shale, red-brown, gypsiferous, blocky	3.2
Shale, greenish-gray, gypsiferous, blocky	0.1
Shale, red-brown, gypsiferous, blocky, with some greenish-gray shale layers	2.75
Gypsum, red-brown, silty, well-indurated, massive	0.25
Shale, greenish-gray, blocky, with much satin-spar	0.2
Shale, red-brown, gypsiferous, blocky, with many thin greenish-gray shale layers	38.0
Gypsum, greenish-gray, mottled red-brown, silty, well-indurated, platy, thin-bedded, forming ledge and base of extremely	

(Dog Creek Section 1, continued)

gypsiferous shale section	1.4
Silt, tone, red-brown, weakly indurated, platy, thin-bedded, with some satin-spar	1.0
Siltstone, red-brown, mottled greenish-gray, gypsiferous, well-indurated, massive	0.4
Shale, red-brown, blocky, with much satin-spar and many thin greenish-gray layers	6.0
Shale, greenish-gray, blocky	0.3
Shale, red-brown, blocky, with much satin-spar and many thin greenish-gray layers, exposed to creek	21.5

Section 2. Cave Creek

Comanche County, Kansas

Measured along Cave Creek (Sand Creek), beginning at top in the Marlow Formation in NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 35, T. 33 S., R. 17 W., ending in the Elaine and Flowerpot Formations at Comanche Cave and east of the cave east of the creek in NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 2, T. 34 S., R. 17 W., which includes type Cave Creek Formation, type Shiner Gypsum, and type Nescatunga Gypsum.

MARLOW FORMATION (Top not exposed)

Sandstone, moderate reddish-orange to moderate reddish-brown, fine-grained, quartzose, massive, grading downward into gypsum
..... 5.0

Gypsum, pink to reddish-brown, arenaceous, well-indurated, thin-bedded, crinkly bedded, becoming greenish-gray in basal 2 inches, forming mappable escarpment 4.75

DOG CREEK SHALE (Total thickness, 25.4 feet)

Shale, red-brown, blocky 2.0

Unit F (Dog Creek):

Sandstone*, moderate reddish-orange to moderate reddish-brown, gypsiferous, silty, well-indurated, platy, forming ledge ... 0.75

Unnamed Units (Dog Creek):

Siltstone, greenish-gray, mottled red-brown, weakly indurated, massive 1.0

Shale, red-brown, blocky 0.9

(Cave Creek Section 2, continued)

Siltstone, red-brown, argillaceous, platy, weakly indurated, with nodular gypsum and satin-spar	1.0
<u>Unit C (Dog Creek):</u>	
Siltstone, greenish-gray, weakly indurated, massive, with much satin-spar	0.75
<u>Unnamed Unit (Dog Creek):</u>	
Shale, red-brown, platy	1.4
<u>Southard Dolomite Member:</u>	
Dolomite, greenish-gray, silty, well-indurated, fine-grained, dense	0.1
<u>Unnamed Units (Dog Creek):</u>	
<u>Unit B:</u>	
Shale, red-brown, blocky	0.2
Siltstone, greenish-gray, mottled red-brown, weakly indurated.	1.4
<u>Unnamed Unit (Dog Creek):</u>	
Shale, red-brown, silty, blocky	2.4
<u>Unit A (Dog Creek):</u>	
Siltstone, red-brown and greenish-gray, argillaceous, weakly indurated	1.6
Siltstone, greenish-gray, argillaceous, well-indurated	0.2
Siltstone, red-brown and greenish-gray, argillaceous, weakly indurated	0.25
<u>Unnamed Units (Dog Creek):</u>	
Shale, greenish-gray, silty, blocky	0.2

(Cave Creek Section 2, continued)

Shale, red-brown, blocky	2.2
Gypsum, white, mottled red-brown, massive to thin-bedded, forming a prominent ledge	0.2
Shale, red-brown, blocky	1.0
Shale, greenish-gray, blocky	0.2
Shale, red-brown, blocky	1.0
<u>Watonga Dolomite Member:</u>	
Sandstone*, greenish-gray, dolomitic, well-indurated, fine- grained, massive, forming ledge	0.5
Siltstone, greenish-gray, mottled red-brown, weakly indurated, partly covered	2.2
<u>Unnamed Units (Dog Creek):</u>	
Shale and gypsum, greenish-gray, selenitic, silty, platy, thin-bedded, well-indurated, grading into siltstone	0.5
Shale, red-brown, blocky	1.0
Gypsum, red-brown and greenish-gray, argillaceous, platy, thin-bedded	0.3
Shale, greenish-gray and red-brown, blocky, with much satin- spar	2.1
BLAINE FORMATION (Total thickness, 63.2 feet)	
<u>Shiner Gypsum Member (Type section):</u>	
Gypsum, white, fine-grained, massive, weathering coarsely selenitic, forming mappable escarpment	14.0

(Cave Creek Section 2, continued)

Altona Dolomite Member:

Dolomite*, light-gray, fine-grained, dense to oolitic, medium-bedded, weathering massive 1.0

Unnamed Units (Blaine):

Shale, greenish-gray, blocky 0.2

Shale† red-brown, blocky, with 1 foot of greenish-gray gypsiferous shale in middle 9.0

Nescatunga Gypsum Member (Type section):

Gypsum, white, fine-grained, well-indurated, massive, becoming dolomitic in basal 1 inch, forming a ledge 2.0

Unnamed Units (Blaine):

Shale, greenish-gray, mottled red-brown, blocky 0.2

Shale*, red-brown, blocky, with some greenish-gray shale layers in middle 9.5

Medicine Lodge Gypsum Member:

Gypsum, white, fine-grained, thin-bedded, well-indurated, with anhydrite lenses in middle portion, weathering massive, forming escarpment and host rock for Comanche Cave 27.0

Cedar Springs Dolomite member:

Dolomite‡ light-gray, fine-grained, oolitic, well-indurated, thin-bedded, grading upward into gypsum 0.25

FLOWERPOT SHALE (Exposed thickness, 7.4 feet)

Unit K (Flowerpot):

Shale, greenish-gray, blocky 0.25

(Cave Creek Section 2, continued)

Unit J (Flowerpot):

Shale, red-brown, blocky, selenitic 0.75

Unit I (Flowerpot):

Shale, greenish-gray, mottled red-brown, selenitic, crinkly
bedded 0.3

Shale, red-brown, blocky 0.25

Shale and gypsum, greenish-gray, mottled red-brown, well-
indurated, crinkly bedded, forming ledge 0.75

Siltstone*, greenish-gray, argillaceous, weakly indurated,
with some nodular gypsum 0.25

Shale, red-brown, blocky 0.75

Shale and gypsum, red-brown, selenitic, blocky 0.4

Shale, red-brown, blocky 0.6

Shale and gypsum, greenish-gray, selenitic, well-indurated,
thin-bedded, crinkly bedded, with some red-brown shale beds. 0.7

Unit H (Flowerpot):

Shale, red-brown, blocky 1.0

Shale and gypsum, greenish-gray, as above, well-indurated,
forming ledge 0.4

Shale, red-brown, blocky, exposed to creek 1.0

Section 3. Redfork Creek

Comanche County, Kansas

Beginning at top in Marlow Formation, section measured along road in SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 30 and SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 29, T. 34 S., R. 16 W., south Comanche County, Kansas.

MARLOW FORMATION (Top not exposed)

Sandstone, moderate reddish-brown to moderate reddish-orange, fine-grained, weakly indurated, exposed to surface	10.0
Gypsum, red-brown, mottled white, fine-grained, well-indurated, thinly laminated	0.75
Sandstone, red-brown, mottled greenish-gray, argillaceous, silty, weakly indurated, partly covered	1.0
Sandstone, greenish-gray, argillaceous, silty, fine-grained, weakly indurated, platy	0.1

DOG CREEK SHALE (Total thickness, 36.1 feet)

Shale, red-brown, blocky, conformable with beds above	1.2
Siltstone, greenish-gray, mottled red-brown, argillaceous, blocky	0.3
Shale, red-brown, blocky	1.0

Unit F (Dog Creek):

Sandstone, greenish-gray, fine-grained, silty, friable to well-indurated, forming ledge	0.25
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Unnamed Unit (Dog Creek):

Siltstone, moderate reddish-brown to reddish-orange, mottled greenish-gray, arenaceous, well-indurated, thin-bedded	2.75
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(Redfork Creek Section 3, continued)

Unit C (Dog Creek):

Siltstone, greenish-gray, thin-bedded, well-indurated 0.9

Unnamed Units (Dog Creek):

Siltstone, moderate reddish-brown to moderate reddish-orange,
argillaceous, weakly indurated 0.25

Shale, red-brown, blocky 0.75

Southard Dolomite Member:

Siltstone, greenish-gray, dolomitic, platy, thin-bedded 0.1

Unit B (Dog Creek):

Shale, red-brown, blocky 0.3

Siltstone, greenish-gray, mottled red-brown, dolomitic, well-
indurated, thin-bedded 0.1

Unnamed Units (Dog Creek):

Shale, red-brown, silty, blocky, partly covered 3.75

Gypsum, greenish-gray and red-brown, selenitic, argillaceous,
well-indurated, thin-bedded, crinkly bedded 0.2

Shale, red-brown, blocky 0.5

Gypsum, as above 0.1

Shale, red-brown, blocky 0.4

Unit A (Dog Creek):

Siltstone, greenish-gray, mottled red-brown, dolomitic, well-
indurated, crinkly bedded 0.2

Siltstone, moderate reddish-brown to moderate reddish-orange,
mottled greenish-gray, argillaceous, massive 0.6

(Redfork Creek Section 3, continued)

Shale, red-brown, silty, blocky, with much selenite	1.5
Siltstone, greenish-gray, mottled red-brown to moderate reddish-orange, dolomitic, well-indurated, massive	0.6
<u>Unnamed Units (Dog Creek):</u>	
Shale, red-brown, blocky, with much satin-spar	1.75
Gypsum, white, mottled red-brown, well-indurated, crinkly bedded to massive	0.1
Shale, greenish-gray, blocky	0.1
Shale, red-brown, blocky, with much satin-spar	2.0
Gypsum, white, mottled red-brown and greenish-gray, well- indurated, massive, wavy bedded, forming prominent ledge ...	0.2
Shale, greenish-gray, blocky	0.2
Shale, red-brown, blocky	2.0
Siltstone, greenish-gray, argillaceous, dolomitic, blocky, well-indurated in places	0.1
Shale, red-brown, blocky, with some greenish-gray siltstone bands	2.0
Siltstone, greenish-gray, well-indurated, massive	0.25
Shale, red-brown, silty, blocky	1.5
<u>Watonga Dolomite Member:</u>	
Siltstone, greenish-gray, argillaceous, dolomitic, gypsiferous, well-indurated, thin-bedded, with many symmetrical ripple marks that strike west, selenitic and red-brown in upper 6 inches, forming ledge	2.0

(Fork of Blaine of Blaine, continued)

Upper Blaine (Dg of Blaine)

Shale, red-brown, blocky, with much satin-spar 2.0

Siltstone, greenish-gray, mottled red-brown, well-indurated.
massive 0.2

Shale, red-brown, blocky, with much satin-spar 0.75

Siltstone, as above, well-indurated 1.7

Shale, red-brown, mottled greenish-gray, silty, blocky 2.0

BLAINE FORMATION (not examined)

Sliver of Gypsum

Gypsum, white, fine-grained, with 2 feet of anhydrite-like

layer in middle, massive, forming prominent mappable escarpment

in region, underlain by normal Blaine sequence, exposed 10.0

Section 4. Yellowstone Creek

Northern Woods County, Oklahoma

Beginning at top in Marlow Formation, section measured in SW $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 3, T. 28 N., R. 17 W., north of section-line road and east of creek, down to lower part of Dog Creek Shale. Section then extrapolated to NE $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 15, T. 29 N., R. 17 W. for lower portion of Dog Creek Shale to Shimer Gypsum, and then NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 26, T. 29 N., R. 17 W., in bluff east of road for Blaine and Flowerpot Formations, northern Woods County, Oklahoma.

MARLOW FORMATION (Top not exposed)

Sandstone*, moderate reddish-brown to moderate reddish-orange, fine-grained, weakly indurated, massive	5.0
Sandstone, greenish-gray, mottled moderate reddish-brown to moderate reddish-orange, fine-grained, weakly indurated, thinly laminated, as above	0.9

DOG CREEK SHALE (Total thickness, 48.1 feet)

Shale, red-brown, blocky	2.9
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Unit C (Dog Creek):

Dolomite*, greenish-gray, fine-grained, dense, well-indurated .	0.25
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Unnamed Unit (Dog Creek):

Shale, red-brown, blocky, with well-indurated dolomitic shale in upper 1 inch	2.0
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Southard Dolomite Member:

Dolomite*, light-gray, fine-grained, dense, well-indurated	0.1
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(Yellowstone Creek Section 4, continued)

Unit B (Dog Creek):

Shale*, purplish-brown, platy, thin-bedded, dolomitic in basal 1 inch	0.3
Shale, red-brown, blocky, with dolomitic shale in basal 1 inch	0.5
Shale, greenish-gray, mottled red-brown, weakly indurated, platy, thin-bedded	2.8
Siltstone*, greenish-gray, dolomitic, well-indurated, massive.	0.5

Unnamed Units (Dog Creek):

Shale, red-brown, blocky, with some greenish-gray siltstone layers	4.5
Sandstone*, greenish-gray and red-brown, silty, fine-grained, blocky	1.3
Shale, red-brown, blocky	3.0

Unit A (Dog Creek):

Siltstone, light-brown, argillaceous, gypsiferous, well- indurated, forming a ledge	5.0
Siltstone*, red-brown, calcareous, gypsiferous, quartzose, thin-bedded, cross-bedded, well-indurated, forming ledge ...	4.0

Unnamed Units (Dog Creek):

Siltstone, moderate reddish-brown to moderate reddish-orange, argillaceous, weakly indurated, blocky, massive	2.7
Siltstone, as above, well-indurated, massive	2.2

(Yellowstone Creek Section 4, continued)

Shale, red-brown, mottled greenish-gray, silty, thin-bedded, weakly indurated; section extrapolated to sec. 15, T. 29 N., R. 17 W.	2.8
Sandstone*, greenish-gray, silty, weakly-indurated	1.2
Shale, red-brown, blocky	2.0
Shale, greenish-gray, blocky	0.1
Shale, red-brown, blocky	2.2
Siltstone, greenish-gray, mottled red-brown, weakly indurated.	0.2
Shale, red-brown, silty, platy	2.0
<u>Watonga Dolomite Member:</u>	
Siltstone*, greenish-gray, dolomitic, arenaceous, thin-bedded, platy, with two sets of symmetrical ripple marks, the top set striking northeast and the bottom set striking northwest ...	0.5
<u>Unnamed Units (Dog Creek):</u>	
Shale, greenish-gray, mottled red-brown, silty, weakly indurated	0.25
Shale, red-brown, silty, blocky	4.75
BLAINE FORMATION (Total thickness, 63.9 feet)	
<u>Shiner Gypsum Member:</u>	
Gypsum, white, fine-grained, massive, weathering coarsely selenitic, forming mappable escarpment	15.75
<u>Altona Dolomite Member:</u>	
Dolomite*, light-brown, fine-grained, oolitic, thin-bedded, forming ledge	0.3

(Yellowstone Creek Section 4, continued)

Unnamed Units (Blaine):

Shale, greenish-gray, blocky; section extrapolated to sec. 26,
T. 29 N., R. 17 W. 0.1

Shale, red-brown, blocky, with some greenish-gray shale layers 7.5

Nescatunga Gypsum Member:

Gypsum, white, fine-grained, massive, weathering coarsely
selenitic, forming escarpment 10.5

Hagpie Dolomite Member:

Siltstone*, greenish-gray, arenaceous, dolomitic, weakly
indurated 0.2

Unnamed Units (Blaine):

Shale, greenish-gray, blocky 0.2

Shale, red-brown, blocky, with some greenish-gray layers 7.0

Medicine Lodge Gypsum Member:

Gypsum, white, fine-grained, massive, weathering coarsely
selenitic, forming a mappable escarpment 22.0

Cedar Springs Dolomite Member:

Dolomite*, light-gray to light-brown, fine-grained, dense to
oölitic, thin-bedded 0.3

FLOWERPOT SHALE (Exposed thickness, 21.4 feet)

Unit K (Flowerpot):

Shale, greenish-gray, blocky 0.5

Units I-J (Flowerpot):

Siltstone*, red-brown and greenish-gray, blocky, weakly
indurated 2.4

(Yellowstone Creek Section 4, continued)

Unit H (Flowerpot):

Shale, red-brown, blocky, with some greenish-gray streaks 3.1

Units E-G (Flowerpot):

Shale, greenish-gray, mottled red-brown, silty, weakly
indurated, thin-bedded, blocky 1.0

Unit D (Flowerpot):

Shale, red-brown, blocky 3.5

Unit C (Flowerpot):

Siltstone*, red-brown, mottled greenish-gray, arenaceous,
weakly-indurated, thin-bedded, blocky 2.75

Shale, greenish-gray, weakly indurated, blocky 0.1

Siltstone, red-brown and greenish-gray, as above 0.75

Shale, moderate brown, mottled greenish-gray, silty, platy ... 0.25

Siltstone, red-brown and greenish-gray, as above 1.5

Shale, moderate brown and greenish-gray, silty, platy 0.2

Siltstone, red-brown and greenish-gray, as above 1.2

Units A-B (Flowerpot):

Shale, red-brown, blocky 3.0

Siltstone, greenish-gray, argillaceous, weakly indurated,
blocky 0.1

Shale, red-brown, silty, blocky, exposed 1.0

Section 5. Greenwood Creek

Northern Woods County, Oklahoma

Beginning at top in Marlow Formation, section measured in NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 28, continued in Dog Creek Shale in NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 28 and SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 21 for lower part of Dog Creek Shale and entire Blaine Formation, ending in NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 13, T. 28 N., R. 16 W. for Flowerpot Shale, northern Woods County, Oklahoma.

MARLOW FORMATION (Top not exposed)

Dog Creek Sandstone Members:

Sandstone*, moderate reddish-brown to moderate reddish-orange, calcareous, medium- to coarse-grained, quartzose, well-indurated, thin-bedded, cross-bedded, with box-work weathered surfaces, forming prominent mappable escarpment 8.25

Unnamed Unit (Marlow):

Sandstone*, moderate reddish-brown to moderate reddish-orange, fine-grained, quartzose, weakly indurated, cross-bedded 56.0

DOG CREEK SHALE (Total thickness, 51.6 feet)

Shale, red-brown, mottled greenish-gray, blocky, conformable with beds above 4.2

Unit E (Dog Creek):

Dolomite*, red-brown, argillaceous, fine-grained, well-indurated, wavy bedded, massive 0.1

Unnamed Units (Dog Creek):

Siltstone, greenish-gray, mottled red-brown, argillaceous, platy, weakly indurated 0.4

(Greenwood Creek Section 5, continued)

Shale, red-brown, silty, blocky, with some greenish-gray beds. 5.0

Unit C (Dog Creek):

Dolomite*, light-brown to light-gray, fine-grained, dense,
massive, blocky 0.2

Unnamed Unit (Dog Creek):

Shale, red-brown, blocky 0.75

Southard Dolomite Member:

Dolomite*, mottled greenish-gray and pink, fine-grained, dense,
well-indurated, massive 0.1

Unit B (Dog Creek):

Shale, purplish-brown, platy 0.25

Shale, red-brown, blocky 1.0

Dolomite*, light-brown, fine-grained, dense, well-indurated,
massive 0.1

Shale, red-brown, blocky 1.0

Dolomite*, mottled greenish-gray and light-pink, fine-grained,
dense, well-indurated, massive 0.2

Unnamed Unit (Dog Creek):

Shale, red-brown, silty, blocky 8.25

Unit A (Dog Creek):

Siltstone*, moderate reddish-brown to moderate reddish-orange,
arenaceous, well-indurated, thin-bedded, forming prominent
ledge 6.0

(Greenwood Creek Section 5, continued)

Siltstone, greenish-gray, mottled red-brown, well-indurated ..	0.5
<u>Unnamed Units (Dog Creek):</u>	
Shale, red-brown, silty, blocky	3.0
Siltstone, red-brown, mottled greenish-gray, argillaceous, weakly indurated, thin-bedded	2.2
Siltstone, greenish-gray, mottled red-brown, moderately indurated, massive	0.5
Shale, red-brown, blocky, mottled greenish-gray at base	0.75
Siltstone, mottled red-brown and greenish-gray, moderately indurated, massive	0.8
Siltstone, greenish-gray, dolomitic, well-indurated, massive forming a ledge	0.1
Siltstone, greenish-gray, mottled moderate reddish-orange, weakly indurated, massive	0.6
Shale, red-brown, blocky	0.8
Siltstone, mottled greenish-gray and red-brown, weakly indurated, thin-bedded	1.0
Shale, red-brown, blocky, silty at top	1.5
Siltstone, greenish-gray, argillaceous, platy, indurated in places	0.1
Shale, red-brown, blocky	2.3
Siltstone, greenish-gray, argillaceous, gypsiferous, weakly indurated	0.1

(Greenwood Creek Section 5, continued)

Shale, red-brown, blocky	0.8
Siltstone, greenish-gray, argillaceous, well-indurated, platy, thin-bedded	0.05
Shale, red-brown, blocky	2.8
<u>Watonga Dolomite Member:</u>	
Siltstone, greenish-gray, mottled red-brown, argillaceous, dolomitic at top, platy, forming small ledge	0.8
<u>Unnamed Unit (Dog Creek):</u>	
Shale, red-brown, blocky, with some greenish-gray shale spots.	5.25
BLAINE FORMATION (Total thickness, 68.3 feet)	
<u>Shiner Gypsum Member:</u>	
Gypsum, white, fine-grained, massive, weathering coarsely selenitic, forming mappable escarpment	11.0
<u>Altona Dolomite Member:</u>	
Dolomite*, light-gray, fine-grained, oblitic, well-indurated, medium-bedded, weathering into box-works, forming escarpment	0.5
<u>Unnamed Units (Blaine):</u>	
Shale, greenish-gray, blocky	0.2
Shale and siltstone*, red-brown, blocky, with some greenish- gray layers	7.8
<u>Nescatunga Gypsum Member:</u>	
Gypsum, white, fine-grained, massive, weathering coarsely selenitic, forming an escarpment	10.0

(Greenwood Creek Section 5, continued)

Maggie Dolomite Member:

Siltstone*, light-brown to greenish-gray, gypsiferous, dolomitic,
weakly indurated, massive 0.25

Unnamed Units (Blaine):

Shale, greenish-gray, blocky 0.25

Shale*, red-brown, blocky, with some greenish-gray shale layers
and crinkly bedded selenite 7.5

Medicine Lodge Gypsum Member:

Gypsum, white, fine-grained, massive, weathering coarsely
selenitic, forming an escarpment 31.0

Cedar Springs Dolomite Member:

Dolomite*, light-brown to light-gray, fine-grained, oblitic,
well-indurated, thin-bedded, grading into gypsum above 0.25

FLOWERPOT SHALE (Exposed thickness, 148.7 feet, base not seen)

Unit K (Flowerpot):

Shale, greenish-gray, blocky 0.1

Units I-J (Flowerpot):

Shale, red-brown, selenitic, blocky; section extrapolated to
sec. 13, T. 26 N., R. 16 W., in isolated butte 0.9

Shale, greenish-gray, selenitic, blocky 0.1

Shale, red-brown, selenitic, blocky 0.75

Shale, greenish-gray, silty, selenitic, blocky 0.1

Shale, red-brown, selenitic, blocky 2.6

Shale, mottled greenish-gray and red-brown, selenitic,
well-indurated 0.1

(Greenwood Creek Section 5; continued)

Shale, red-brown, selenitic, blocky	1.5
Gypsum, white, mottled greenish-gray, nodular, well-indurated, forming a ledge	0.3
<u>Unit H (Flowerpot):</u>	
Shale, red-brown, selenitic, blocky	1.0
<u>Units F-G (Flowerpot):</u>	
Siltstone, mottled greenish-gray and red-brown, arenaceous, thin-bedded, blocky	0.5
<u>Unit D (Flowerpot):</u>	
Shale, red-brown, silty, blocky, with some gypsum nodules	0.75
<u>Unit C (Flowerpot):</u>	
Siltstone, red-brown, arenaceous, calcareous, weakly indurated, thin-bedded	3.0
Shale, mottled red-brown and greenish-gray, silty, thin-bedded	0.3
Siltstone, red-brown, argillaceous, weakly indurated, massive.	2.0
Siltstone, greenish-gray, arenaceous, weakly indurated, blocky	0.2
<u>Unit B (Flowerpot):</u>	
Shale, red-brown, blocky, with some gypsum nodules	2.6
<u>Unit A₃ (Flowerpot):</u>	
Siltstone, greenish-gray, mottled red-brown, argillaceous, blocky, indurated in places	0.2
Shale, red-brown, selenitic, blocky	0.3
Siltstone, mottled greenish-gray and red-brown, argillaceous, weakly indurated, thin-bedded	0.6

(Greenwood Creek Section 5, continued)

Shale, red-brown, selenitic, blocky	0.6
Shale, red-brown, mottled greenish-gray, selenitic, well- indurated, crinkly bedded, forming a ledge	0.25
Shale, red-brown, selenitic, blocky	0.75
Shale, red-brown, selenitic, well-indurated, thin-bedded, crinkly bedded, forming a ledge	0.3
Shale, red-brown, blocky, selenitic, with some thin greenish-gray shale layers	2.5
Shale, greenish-gray, blocky	0.2
Shale, red-brown, selenitic, blocky	2.2
Shale, greenish-gray, mottled red-brown, selenitic, well- indurated, crinkly bedded	0.25
Shale, red-brown, selenitic, blocky	0.75
Shale, red-brown, mottled greenish-gray, selenitic, well- indurated, thin-bedded, crinkly bedded	0.25
Shale, red-brown, blocky	0.25
Shale, greenish-gray, blocky	0.1
Shale, red-brown, blocky	1.0
Shale, greenish-gray, selenitic, silty, well-indurated, crinkly bedded	0.2
Shale, red-brown, selenitic, blocky	1.75
Shale, greenish-gray, mottled red-brown, selenitic, silty, well-indurated, thin-bedded, crinkly bedded	0.3

(Greenwood Creek Section 5, continued)

Shale, red-brown, selenitic, blocky	1.0
Shale, greenish-gray, selenitic, blocky	0.2
Shale, red-brown, selenitic, blocky	0.5
Shale, red-brown, selenitic, well-indurated, crinkly bedded ,.	0.2
Shale, red-brown, selenitic, blocky	0.8
Shale, greenish-gray, selenitic, blocky	0.25
Shale, red-brown, selenitic, blocky, with some greenish-gray shale spots	5.2
Shale, greenish-gray, selenitic, well-indurated, thin-bedded, crinkly bedded, forming a ledge	0.25
Shale, red-brown, blocky	0.2
Dolomite*, greenish-gray, silty, fine-grained, dense, well- indurated, thin-bedded	0.2
Shale, red-brown, blocky, with some gypsum nodules	0.8
Shale, red-brown, gypsiferous, silty, well-indurated, thin- bedded, crinkly bedded	0.4
Shale, red-brown, blocky	1.0
Siltstone*, red-brown, mottled greenish-gray, calcareous, thin-bedded, weakly-indurated, with many small white gypsum nodules	1.6
Shale, red-brown, silty, blocky, with some gypsum nodules	2.3
Shale, greenish-gray, selenitic, blocky, well-indurated, crinkly bedded	0.2
Shale, red-brown, selenitic, blocky	0.8

(Greenwood Creek Section 5, continued)

Shale, greenish-gray, selenitic, well-indurated, crinkly bedded	0.1
Shale, red-brown, selenitic, blocky	1.0
<u>Unit A₂</u> (Flowerpot):	
Siltstone*, greenish-gray, arenaceous, dolomitic, gypsiferous, well-indurated, massive, forming ledge, at base of extremely gypsiferous section	0.5
Siltstone, red-brown and greenish-gray, argillaceous, well- indurated, thin-bedded, platy	2.1
Siltstone, greenish-gray, argillaceous, blocky, well-indurated at top	0.2
<u>Unit A₁</u> (Flowerpot):	
Shale, red-brown, blocky	1.75
Shale, greenish-gray, silty, blocky	0.2
Shale, red-brown, blocky, with some selenite	1.0
Shale, greenish-gray and red-brown, selenitic, blocky	0.6
Shale, red-brown, blocky	0.75
Shale, greenish-gray and red-brown, selenitic, blocky	0.75
Shale, red-brown, selenitic, blocky, with some gypsum nodules and thin greenish-gray shale layers	5.5
Shale, greenish-gray, selenitic, blocky	0.2
Shale, red-brown, blocky, with some selenite	2.6
Shale, greenish-gray, selenitic, blocky	0.3

(Greenwood Creek Section 5, continued)

Shale, red-brown, blocky	1.7
Shale, greenish-gray, selenitic, well-indurated, crinkly bedded	0.1
Shale, red-brown, blocky	0.9
Shale, greenish-gray, selenitic, well-indurated, crinkly bedded	0.1
Shale, red-brown, blocky	0.8
Shale, greenish-gray, selenitic, blocky	0.1
Shale, red-brown, blocky	1.0
Shale, greenish-gray, mottled red-brown, selenitic, blocky ...	0.2
Shale, red-brown, selenitic, blocky	1.8
Shale, greenish-gray, blocky	0.2
Siltstone, mottled greenish-gray and red-brown, argillaceous, moderately indurated, thin-bedded	1.8
Shale, red-brown, silty, blocky	1.1
Siltstone, greenish-gray, argillaceous, blocky, massive	0.3
Shale, red-brown, blocky	0.8
Siltstone, greenish-gray, argillaceous, selenitic, well- indurated, crinkly bedded	0.1
Shale, red-brown, blocky, with some satin-spar layers	1.4
Siltstone, greenish-gray, argillaceous, blocky	0.1
Shale, red-brown, blocky	1.25
Shale, greenish-gray, blocky	0.1
Shale, moderate to dusky brown, blocky	0.6

(Greenwood Creek Section 5, continued)

Shale, red-brown, blocky, with much satin-spar	2.7
Shale, red-brown, blocky, with a 1 inch greenish-gray shale layer at top, one in middle, and one at base	1.0
Shale, red-brown, blocky	2.25
Shale, mottled greenish-gray and dusky brown, blocky	0.25
Shale, red-brown, blocky, with some gypsum nodules	2.2
Shale, greenish-gray, selenitic, blocky	0.2
Shale, red-brown, selenitic, blocky	2.8
Shale, red-brown, selenitic, blocky, with many thin greenish- gray shale stringers	0.75
Shale, red-brown, selenitic, blocky	3.75
Shale, greenish-gray, selenitic, well-indurated, crinkly bedded	0.1
Shale, red-brown, blocky	0.25
Shale*, dusky brown, mottled greenish-gray, blocky	3.0
Shale, red-brown, selenitic, blocky, with much satin-spar and some greenish-gray layers	3.5
Dolomite*, greenish-gray, mottled red-brown, silty, blocky,...	0.1
Siltstone, greenish-gray, mottled red-brown, argillaceous, dolomitic, well-indurated, blocky	0.9
Shale, red-brown, silty, blocky	1.5
Siltstone, greenish-gray, argillaceous, selenitic, well-indurated, crinkly bedded	0.7

(Greenwood Creek Section 5, continued)

Shale, red-brown, blocky	1.0
Siltstone, greenish-gray, mottled red-brown, selenitic, argillaceous, thin-bedded, crinkly bedded	0.5
Shale, red-brown, blocky, with much satin-spar	2.2
Siltstone, greenish-gray, mottled red-brown, thin-bedded, platy	0.25
Shale, red-brown, blocky, with thin satin-spar veins	2.1
Shale, greenish-gray, blocky	0.2
Shale, red-brown, blocky	4.2
Shale, red-brown, blocky, with much satin-spar	3.0
Siltstone, greenish-gray, selenitic, well-indurated, crinkly bedded	0.1
Shale, red-brown, blocky	4.5
Siltstone, greenish-gray, argillaceous, selenitic, well- indurated	0.2
Shale, red-brown, blocky, with much satin-spar	7.75
Siltstone, greenish-gray, argillaceous, selenitic, well- indurated	0.2
Shale, red-brown, blocky	1.0
Shale, mottled greenish-gray and red-brown, blocky	0.2
Shale, red-brown, blocky	1.0
Shale, mottled greenish-gray and red-brown, selenitic, well- indurated, blocky	0.5

(Greenwood Creek Section 5, continued)

Shale, red-brown, silty, blocky, with some satin-spar	6.25
Siltstone, mottled greenish-gray and red-brown, moderately indurated, thin-bedded, forming a ledge	3.0
Shale, red-brown, blocky	1.8
Siltstone, greenish-gray, argillaceous, blocky	0.25
Shale, red-brown, blocky, with some satin-spar	4.2
Siltstone, greenish-gray, with many gypsum nodules	0.2
Shale, red-brown, blocky	0.3
Siltstone, greenish-gray, argillaceous, with many gypsum nodules	0.2
Shale, red-brown, blocky	1.8
Siltstone, greenish-gray, argillaceous, weakly indurated at top	0.2
Shale, red-brown, blocky, exposed	3.0

Probably all the same section, being visible at base and top of section
 increasing at top section (lower part) with 1.75
 the same (red-brown, blocky) (red-brown)
 Shale, red-brown, blocky, with some satin-spar, 1.8
 Siltstone, greenish-gray, argillaceous, weakly indurated, 0.25
 Shale, red-brown, blocky, with some satin-spar, 4.2
 Siltstone, greenish-gray, with many gypsum nodules 0.2
 Shale, red-brown, blocky 0.3
 Siltstone, greenish-gray, argillaceous, with many gypsum nodules 0.2
 Shale, red-brown, blocky 1.8
 Siltstone, greenish-gray, argillaceous, weakly indurated at top 0.2
 Shale, red-brown, blocky, exposed 3.0

Section 6. Whitehorse Creek

Central Woods County, Oklahoma

Beginning at top in Marlow Formation, Doe Creek Sandstone Member, type section for the Whitehorse Group, in NE $\frac{1}{4}$, NE $\frac{1}{4}$, NW $\frac{1}{4}$ sec. 29, T. 27 N., R. 16 W., north of highway, and in S $\frac{1}{2}$, SW $\frac{1}{2}$ sec. 20 along Whitehorse Creek for the Elaine section, into the upper part of the Flowerpot Shale. The remainder of the Flowerpot was measured in SE $\frac{1}{4}$, SE $\frac{1}{4}$, NW $\frac{1}{4}$ sec. 6, T. 26 N., R. 16 W., just west of Whitehorse Creek.

MARLOW FORMATION (Only lower portion exposed)

Doe Creek Sandstone Member:

Dolomite*, moderate reddish-brown to moderate reddish-orange, algal, arenaceous, quartzose, with medium to coarse subrounded to well-rounded grains, well-cemented, with fossil clams and snails abundant in middle 3 inches, clastic material abundant near base, and algal material abundant near top. The algae are of two forms, probably of the same species, being oblitic at base and lamellar-incrusting at top; section thicker toward north 1.75

DOG CREEK SHALE (Total thickness, 62.3 feet)

Shale, moderate reddish-brown to moderate reddish-orange, silty, blocky 1.25

Siltstone*, moderate reddish-brown to moderate reddish-orange, arenaceous, well-indurated, massive, blocky, with some 1 inch white calcite nodules, forming ledge 0.3

Shale, greenish-gray, blocky 0.1

(Whitehorse Creek Section 6, continued)

Shale, red-brown, silty, blocky	4.5
<u>Unit F₂</u> (Dog Creek):	
Siltstone*, moderate reddish-brown to moderate reddish-orange, arenaceous, well-indurated, massive, forming ledge	0.5
<u>Unnamed Unit</u> (Dog Creek):	
Shale, red-brown, silty, blocky, with some greenish-gray layers at base	10.25
<u>Unit E</u> (Dog Creek):	
Dolomite*, very dusky red-purple, platy, silty, argillaceous, thin-bedded	0.2
<u>Unnamed Unit</u> (Dog Creek):	
Shale, red-brown, silty, blocky	4.0
<u>Unit C</u> (Dog Creek):	
Dolomite*, light-brown, fine-grained, dense, well-indurated, massive, forming a ledge	0.1
<u>Unnamed Unit</u> (Dog Creek):	
Shale, red-brown, silty, blocky	2.7
<u>Southard Dolomite Member:</u>	
Dolomite*, greenish-gray, silty, argillaceous, well-indurated, platy	0.1
<u>Unit B</u> (Dog Creek):	
Dolomite and siltstone*, very dusky red-purple, well-indurated, massive, blocky	0.9
Shale, dark red-brown, blocky	3.75

(Whitehorse Creek Section 6, continued)

Dolomite [#] , mottled greenish-gray and very dusky red-purple, silty, fine-grained, dense, well-indurated, massive	0.1
<u>Unnamed Unit₂</u> (Dog Creek):	
Siltstone, red-brown, argillaceous, well-indurated, wavy bedded, massive	0.8
Shale, red-brown, blocky	1.2
Siltstone, greenish-gray, mottled red-brown, argillaceous, weakly indurated	0.25
Shale, red-brown, silty, blocky, with some greenish-gray spots and layers	6.0
<u>Unit A</u> (Dog Creek):	
Sandstone [#] , red-brown, mottled greenish-gray, silty, fine- to medium-grained, thin-bedded, forming ledge	9.0
Siltstone [#] , greenish-gray, dolomitic, well-indurated, thin- bedded	0.1
<u>Unnamed Units</u> (Dog Creek):	
Shale, red-brown, blocky	0.75
Siltstone [#] , light-gray to greenish-gray, dolomitic, fine- grained, dense, well-indurated	0.1
Siltstone, red-brown, mottled greenish-gray, weakly indurated, thin-bedded	0.2
Shale, red-brown, blocky, grading into siltstone at base	3.0
Siltstone, greenish-gray, argillaceous, weakly indurated, platy, crinkly bedded	0.3

(Whitehorse Creek Section 6, continued)

Shale, red-brown, silty, platy	0.7
Siltstone, greenish-gray, mottled red-brown, platy	0.25
Shale, red-brown, blocky	2.75

Watonga Dolomite Member:

Siltstone, greenish-gray, mottled red-brown, dolomitic, well-indurated in places, thin-bedded	0.6
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Unnamed Units (Dog Creek):

Shale, red-brown, blocky	2.5
Siltstone, greenish-gray, mottled red-brown, argillaceous, weakly indurated, massive	1.0
Shale, red-brown, blocky, with some greenish-gray siltstone beds	3.0

BLAINE FORMATION (Total thickness, 56.1 feet)

Altona Dolomite Member:

Dolomite*, light-gray, fine-grained, oolitic, weathering into box-works, forming ledge	1.0
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Unnamed Unit (Blaine):

Shale, red-brown, mottled greenish-gray, blocky, covered in part	11.0
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Nescentunga Gypsum Member:

Gypsum, white, fine-grained, massive, weathering coarsely oolitic, silty at base, forming ledge	11.0
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Magnie Dolomite Member:

Siltstone*, light-gray, dolomitic, fine-grained, oolitic	0.75
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(Whitehorse Creek Section 6, continued)

<u>Unnamed Unit (Blaine):</u>	
Shale*, red-brown, blocky, mottled with greenish-gray shale spots	10.0
<u>Medicine Lodge Gypsum Member:</u>	
Gypsum, white, mottled light-gray, fine-grained, massive, weathering coarsely selenitic, forming prominent mappable escarpment	22.0
<u>Cedar Springs Dolomite Member:</u>	
Dolomite*, light-gray to light-brown, fine-grained, oolitic, medium-bedded, weathering massive	0.3
FLOWERPOT SHALE (Exposed thickness 112.9 feet, base not seen)	
<u>Unit K (Flowerpot):</u>	
Shale, greenish-gray, mottled red-brown, blocky	0.75
<u>Unit J (Flowerpot):</u>	
Shale, red-brown, selenitic, blocky	0.5
<u>Unit I (Flowerpot):</u>	
Shale, greenish-gray, selenitic, blocky	0.2
Shale, red-brown, selenitic, blocky	1.25
Shale, greenish-gray, blocky	0.25
Shale, red-brown, selenitic, blocky	0.9
Shale, greenish-gray, blocky	0.2
Shale, red-brown, selenitic, blocky	1.5
Siltstone, greenish-gray, gypsiferous, well-indurated, crinkly bedded	0.2

(Whitehorse Creek Section 6, continued)

<u>Unit H (Flowerpot):</u>	
Siltstone, red-brown, mottled greenish-gray, with many 1- to 3-inch selenite patches	1.5
<u>Units E-G (Flowerpot):</u>	
Siltstone*, greenish-gray, dolomitic, argillaceous, weakly indurated, thin-bedded	1.75
<u>Unit D (Flowerpot):</u>	
Shale, red-brown, silty, blocky	1.9
<u>Unit C (Flowerpot):</u>	
Siltstone, greenish-gray, mottled red-brown, argillaceous, moderately indurated, crinkly bedded	0.5
Siltstone, red-brown, argillaceous, thin-bedded, with many small gypsum nodules	3.5
Siltstone, greenish-gray, selenitic, argillaceous, weakly indurated	0.1
<u>Unit B (Flowerpot):</u>	
Siltstone, red-brown, argillaceous, as above, with many moderate reddish-orange gypsum nodules	2.9
<u>Unit A₃ (Flowerpot):</u>	
Shale, greenish-gray, blocky	0.2
Shale, red-brown, blocky, selenitic, mottled with greenish-gray spots, partly covered section extrapolated to NW $\frac{1}{4}$ sec. 6, T. 26 N., R. 16 W., in hill west of Whitehorse Creek	6.25

(Whitehorse Creek Section 6, continued)

Siltstone*, greenish-gray, fine-grained, well-indurated at top	0.2
Shale, red-brown, blocky, with much selenite	3.0
Siltstone, greenish-gray, argillaceous, weakly indurated, massive	0.2
Shale, red-brown, blocky, with much selenite	5.25
Shale, greenish-gray, weakly-indurated, blocky	0.2
Shale, red-brown, blocky	2.0
Shale, greenish-gray, blocky	0.1
Shale, red-brown, blocky	0.2
Siltstone, greenish-gray, argillaceous, gypsiferous, well-indurated	0.1
Shale, red-brown, blocky	0.4
Siltstone, greenish-gray, mottled red-brown, weakly indurated, thin-bedded	0.25
Shale, red-brown, blocky	4.2
Shale, red-brown, blocky, with many greenish-gray shale layers and much nodular and selenitic gypsum, forming ledge and base of extremely gypsiferous section	2.5
Shale, greenish-gray, blocky	0.25
Shale, red-brown, blocky	0.6
Shale, greenish-gray, selenitic, blocky, thin-bedded	0.1
Shale, red-brown, blocky, with many satin-spar veins	5.0
Siltstone*, greenish-gray, dolomitic, moderately indurated, crinkly bedded	0.3

(Whitehorse Creek Section 6, continued)

Shale, red-brown, blocky, with some selenite crystals	2.0
<u>Unit A₂</u> (Flowerpot):	
Siltstone*, greenish-gray, gypsiferous, dolomitic, arenaceous, well-indurated, crinkly bedded, thin-bedded, forming a ledge	0.8
<u>Unit A₁</u> (Flowerpot):	
Shale, red-brown, blocky, with some thin selenite veins	3.3
Siltstone, mottled greenish-gray and red-brown, gypsiferous, weakly indurated, thin-bedded	0.75
Shale, red-brown, platy, thin-bedded,	0.25
Shale*, greenish-gray, weakly indurated, blocky	0.3
Shale, red-brown, blocky, with some selenite	1.6
Shale, greenish-gray, mottled red-brown, gypsiferous, blocky, indurated in places	0.25
Shale, red-brown, blocky	2.0
Siltstone, greenish-gray, argillaceous, gypsiferous, well- indurated, forming a ledge	0.2
Shale, red-brown, blocky, with some gypsum nodules	2.0
Siltstone, greenish-gray, gypsiferous, argillaceous, well- indurated, crinkly bedded	0.1
Shale, red-brown, mottled greenish-gray, blocky	0.75
Siltstone*, greenish-gray, mottled reddish-brown, arenaceous, light-brown at base, thin-bedded, with alternating well- indurated and weakly indurated layers	1.5

(Whitchorse Creek Section 6, continued)

Shale, red-brown, blocky	2.25
Shale, greenish-gray, weakly indurated, platy	1.2
Shale, red-brown, blocky, with some greenish-gray layers and gypsum nodules	7.0
Shale, greenish-gray, gypsiferous, weakly indurated, blocky ..	0.25
Shale, red-brown, blocky	0.3
Siltstone, greenish-gray, argillaceous, gypsiferous, well- indurated in places	0.1
Shale, red-brown, selenitic, blocky	2.0
Shale, greenish-gray, selenitic, blocky	0.7
Shale, red-brown, selenitic, blocky	3.5
Shale, greenish-gray, selenitic, blocky	0.1
Shale, red-brown, blocky	1.0
Shale, greenish-gray, gypsiferous, silty, blocky	0.2
Shale, red-brown, blocky, with some greenish-gray layers	2.0
Shale, greenish-gray, selenitic, silty, blocky	0.7
Shale, red-brown, blocky, selenitic	5.25
Siltstone, greenish-gray, gypsiferous, dolomitic, weakly indurated massive, forming prominent light-colored band ...	1.75
Shale, red-brown, blocky	2.6
Shale, greenish-gray, selenitic, blocky	0.1
Shale, red-brown, blocky, with greenish-gray layers at base ..	4.0
Shale, greenish-gray, blocky	0.1
Shale, dusky brown mottled greenish-gray, weakly indurated, blocky	3.0
Shale, red-brown, blocky, exposed	10.0

Section 7. Redhorse Creek

Central Woods County, Oklahoma

Beginning at top in Marlow Formation, section measured in SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 10, T. 27 N., R. 17 W. along creek, to Shiner Gypsum, continuing through the Blaine Formation in SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 10, ending in the Flowerpot Shale and lower part of the Blaine Formation in SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 22, T. 27 N., R. 17 W., where Redhorse Creek crosses Highway 64, central Woods County, Oklahoma.

MARLOW FORMATION (Top not exposed)

Sandstone, moderate reddish-brown to moderate reddish-orange,
fine-grained, quartzose, weakly indurated 5.0

Doe Creek Sandstone Member:

Sandstone*, light-gray, coarse-grained, quartzose, moderately
indurated, friable 0.25

DOG CREEK SHALE (Total thickness, 54.2 feet)

Shale, red-brown, silty 0.3

Siltstone*, light-gray to greenish-gray, calcareous, moderately
indurated 0.2

Siltstone*, red-brown and greenish-gray, calcareous, moderately
indurated, blocky 1.2

Shale, red-brown, blocky 2.25

Siltstone, greenish-gray, moderately indurated, crinkly
bedded, thin-bedded 0.25

(Redhorse Creek Section 7, continued)

Shale, red-brown, mottled greenish-gray, weakly indurated, blocky	1.4
Siltstone*, greenish-gray, calcareous, platy, well-indurated at top	0.2
Shale, red-brown, weakly indurated, blocky	1.0
<u>Unit E (Dog Creek):</u>	
Siltstone*, greenish-gray, calcareous, well-indurated, platy .	0.1
Dolomite*, light-gray, fine-grained, dense, well-cemented, massive, weathering light brown	0.1
Shale, red-brown, well-indurated, blocky	0.1
Dolomite*, light-gray to greenish-gray, silty, argillaceous, weakly indurated, platy	0.3
<u>Unnamed Unit (Dog Creek):</u>	
Shale, red-brown, silty, blocky, thin-bedded	4.0
<u>Unit D (Dog Creek):</u>	
Dolomite*, light-brown, fine-grained, argillaceous, dense, blocky, massive, forming ledge	0.1
<u>Unnamed Unit (Dog Creek):</u>	
Shale, red-brown, blocky	0.8
<u>Unit C (Dog Creek):</u>	
Dolomite*, light-brown, silty, argillaceous, fine-grained, dense, massive, blocky	0.25

(Redhorse Creek Section 7, continued)

Unnamed Units (Dog Creek):

Shale, red-brown, blocky, silty at top	1.2
Shale, light-brown, mottled greenish-gray, weakly indurated, blocky	0.25
Shale, mottled greenish-gray and red-brown, weakly indurated, blocky	1.4

Southard Dolomite Member:

Dolomite*, greenish-gray, well-indurated, silty, crinkly bedded, thin-bedded, forming ledge	0.25
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Unit B (Dog Creek):

Siltstone*, greenish-gray, calcareous, argillaceous, weakly indurated, becoming dolomitic at base	0.8
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Unnamed Units (Dog Creek):

Shale, red-brown, silty, blocky	2.75
Siltstone*, greenish-gray, calcareous, moderately indurated, massive, forming ledge	0.5
Shale, red-brown, blocky	2.0
Shale, mottled greenish-gray and red-brown, silty, blocky	0.8
Shale, red-brown, silty, blocky	4.0

Unit A (Dog Creek):

Siltstone*, greenish-gray, arenaceous, quartzose, moderately indurated, friable, forming ledge	1.1
Siltstone*, moderate reddish-brown to moderate reddish-orange, calcareous, moderately indurated, thin-bedded, arenaceous at top, forming ledge	7.0

(Redhorse Creek Section 7, continued)

Siltstone, greenish-gray, argillaceous, thin-bedded, crinkly bedded	0.5
<u>Unnamed Units (Dog Creek):</u>	
Shale, red-brown, silty, weakly indurated, blocky	0.75
Siltstone, mottled red-brown and greenish-gray, well- indurated, thin-bedded, crinkly bedded	0.5
Shale, red-brown, silty, blocky	5.5
Siltstone, mottled red-brown and greenish-gray, argillaceous, massive	0.7
Shale, red-brown, blocky	4.75
Siltstone*, greenish-gray, arenaceous, weakly indurated	1.5
Shale, red-brown, blocky	2.0
<u>Watonga Dolomite Member:</u>	
Siltstone*, greenish-gray, arenaceous, dolomitic, well- indurated, platy, with symmetrical ripple marks that strike northwest	0.1
<u>Unnamed Unit (Dog Creek):</u>	
Shale, red-brown, mottled greenish-gray, blocky	3.25
BLAINE FORMATION (Total thickness, 56.4 feet)	
<u>Shimer Gypsum Member:</u>	
Gypsum, white, fine-grained, crystalline, well-indurated, massive, wavy bedded at top, forming escarpment	12.0
<u>Altona Dolomite Member:</u>	
Dolomite*, light-gray, fine-grained, oblitic, medium-bedded, massive, weathering into box-works	0.75

(Redhorse Creek Section 7, continued)

Unnamed Units (Blaine):

Shale, greenish-gray, blocky 0.2

Shale, red-brown, mottled greenish-gray, weakly indurated,
blocky 13.6Nescatunga Gypsum Member:Gypsum, white, fine-grained, massive, weathering coarsely
selenitic, forming escarpment 11.5Maggie Dolomite Member:Dolomite*, light-gray, gypsiferous, fine-grained, dense in part,
massive 0.25Unnamed Units (Blaine):

Shale, greenish-gray, blocky 0.1

Shale*, red-brown, silty, with 9 inch greenish-gray gypsiferous
zone 4 feet above base 11.5Medicine Lodge Gypsum Member:Gypsum, white, fine-grained, medium-bedded, weathering
coarsely selenitic, forming escarpment; section extrapolated to
SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 22, T. 27 N., R. 17 W., on Highway 64 26.0Cedar Springs Dolomite Member:Dolomite*, light-gray, fine-grained, oolitic, well-indurated,
massive 0.5

FLOWERPOT SHALE (Exposed thickness, 62.7 feet)

Unit K (Flowerpot):

Shale, greenish-gray, blocky 0.25

(Redhorse Creek Section 7, continued)

Units I-J (Flowerpot):

Shale, red-brown, blocky, selenitic, with many gypsum nodules and some thin greenish-gray shale layers	1.5
Shale, greenish-gray, silty, selenitic, with many gypsum nodules	0.25
Shale, red-brown, blocky, with some greenish-gray spots and layers	2.6
Siltstone*, greenish-gray, dolomitic, gypsiferous, well- indurated, crinkly bedded, massive, forming ledge	0.2

Unit H (Flowerpot):

Shale, red-brown, blocky, with some greenish-gray spots and layers	2.7
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Units K-G (Flowerpot):

Siltstone, greenish-gray, mottled red-brown, gypsiferous, well-indurated, massive, crinkly bedded, forming ledge	0.2
Shale, red-brown, silty, blocky	0.8
Siltstone, greenish-gray, argillaceous, gypsiferous, well- indurated, crinkly bedded	0.1

Unit D (Flowerpot):

Shale, red-brown, silty, blocky	1.0
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Unit C (Flowerpot):

Siltstone, mottled red-brown and greenish-gray, thinly laminated, well-indurated, with many gypsum nodules, forming ledge	5.2
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Keshora Creek Section 7, continued)

Unit B (Flowerpot):

Shale, greenish-gray, mottled red-brown, silty, weakly indurated, blocky	0.5
Shale, red-brown, blocky, with some small gypsum nodules	4.0

Unit A₂ (Flowerpot):

Shale, greenish-gray, weakly indurated, blocky	0.2
Shale, red-brown, blocky, with many gypsum nodules	1.8
Shale, mottled greenish-gray and red-brown, weakly indurated, blocky	0.75
Shale, red-brown, blocky	1.0
Siltstone*, greenish-gray, mottled red-brown, argillaceous, gypsiferous, moderately indurated, thin-bedded, with many small gypsum nodules, forming ledge	2.4
Shale, red-brown, blocky, with some greenish-gray spots and gypsum nodules	2.5
Siltstone*, greenish-gray, mottled light-brown, dolomitic, gypsiferous, argillaceous, selenitic, well-indurated, massive, crinkly bedded, forming ledge	0.2
Shale, red-brown, weakly indurated, platy	0.3
Shale, red-brown and greenish-gray, gypsiferous, alternating weakly to well-indurated layers, thin-bedded, crinkly bedded	0.6
Shale, red-brown, blocky, with some greenish-gray spots and thin sections of thin-bedded	5.5

(Redhorse Creek Section 7, continued)

Siltstone, greenish-gray, argillaceous, weakly indurated, platy	0.2
Shale, red-brown, blocky, with many thin greenish-gray shale layers and satin-spar seams, forming base of extremely gypsiferous section	4.2
Shale, red-brown, weakly indurated, blocky	2.6
Shale, greenish-gray, silty, selenitic, weakly indurated, blocky	0.25
Shale, red-brown, blocky, with some greenish-gray spots and thin satin-spar beds	1.8
Siltstone*, greenish-gray, dolomitic, selenitic, well- indurated, crinkly bedded, forming ledge	0.25
Shale, red-brown, blocky, with some greenish-gray spots and gypsum nodules	2.75
<u>Unit A₂ (Flowerpot):</u>	
Siltstone*, greenish-gray, mottled red-brown, dolomitic, gypsiferous, moderately indurated, thinly laminated	0.9
<u>Unit A₁ (Flowerpot):</u>	
Shale, red-brown, blocky, with some thin satin-spar seams and gypsum nodules	1.3
Siltstone, red-brown, mottled greenish-gray, argillaceous, gypsiferous, well-indurated	0.3
Shale, red-brown, blocky	0.2

(Redhors^e Cr^{ee}k Section 7, continued)

Shale, greenish-gray, blocky	0.3
Shale, red-brown, blocky, with some greenish-gray spots and thin satin-spar layers	1.6
Siltstone, greenish-gray, mottled red-brown, gypsiferous, argillaceous, massive, well-indurated, crinkly bedded, forming ledge	0.6
Shale, red-brown, weakly indurated, blocky	1.2
Shale, greenish-gray, weakly indurated, blocky	0.2
Shale, red-brown, blocky, with some thin satin-spar veins	0.75
Shale, greenish-gray, blocky, with some satin-spar layers	0.25
Shale, red-brown, silty, blocky, moderately indurated	0.9
Shale, red-brown, blocky	0.75
Shale, greenish-gray, blocky	0.1
Shale, red-brown, blocky, exposed to base	6.0

Siltstone, moderate red-brown to moderate reddish-orange, fine-grained, weakly indurated	0.8
Siltstone, greenish-gray, mottled red-brown to moderate reddish-orange, fine-grained, massive, with small irregular patches of red-brown shale	1.8

RED HORSE CREEK SHALES (Total thickness, 12.9 feet)

Shale, red-brown, weakly indurated, blocky	0.75
Siltstone, mottled greenish-gray and red-brown to moderate reddish-orange, argillaceous, blocky	2.1

Section 8. West Moccasin Creek

Western Woods County, Oklahoma

Beginning at top in Marlow Formation, section measured along West Moccasin Creek in SE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 36, T. 28 N., R. 19 W., proceeding downstream to base of Shiner Gypsum Member in SE $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 28 N., R. 18 W. Section then extrapolated to road cut on Highway 64, south of highway and east of West Moccasin Creek for Blaine section, ending in the Flowerpot Shale in bluff on the Cimarron River in SW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 28, T. 27 N., R. 18 W., western Woods County, Oklahoma.

MARLOW FORMATION (Top not exposed)

Sandstone, moderate red-brown to moderate reddish-orange, fine-grained, weakly indurated, exposed	5.0
Sandstone, light-brown, mottled greenish-gray, fine-grained, moderately indurated, thinly laminated, platy	0.6
Sandstone, moderate red-brown to moderate reddish-orange, fine-grained, weakly indurated	0.8
Sandstone*, greenish-gray, mottled red-brown to moderate reddish-orange, fine-grained, quartzose, with small irregular patches of red-brown shale	1.0
DOG CREEK SHALE (Total thickness, 49.9 feet)	
Shale, red-brown, weakly indurated, blocky	0.75
Siltstone*, mottled greenish-gray and red-brown to moderate reddish-orange, argillaceous, blocky	2.5

(West Moccasin Creek Section 8, continued)

Unit E (Dog Creek):

Siltstone*, greenish-gray, mottled red-brown to moderate reddish-orange, calcareous, argillaceous, well-indurated, massive, forming ledge 0.3

Unnamed Unit (Dog Creek):

Shale, red-brown, blocky 0.75

Unit D (Dog Creek):

Dolomite*, greenish-gray, silty, blocky, thin-bedded in middle, forming ledge 0.25

Shale, red-brown, blocky 0.4

Dolomite*, light-gray, mottled pink, silty, argillaceous, fine-grained, dense, well-indurated, nodular to massive, forming ledge 0.1

Unnamed Unit (Dog Creek):

Shale, red-brown, blocky 1.25

Unit C (Dog Creek):

Dolomite*, light-gray, silty, argillaceous, fine-grained, dense, nodular to massive, forming ledge 0.2

Unnamed Units (Dog Creek):

Shale, greenish-gray, dolomitic, weakly indurated, blocky 0.25

Shale, red-brown, weakly indurated, blocky 3.3

Southard Dolomite Member:

Dolomite*, light-gray, silty, argillaceous, fine-grained, dense, well-indurated, platy, with many salt casts, forming an escarpment 0.4

(West Kocasin Creek Section 8, continued)

Unit B (Dog Creek):

Siltstone⁺, greenish-gray, calcareous, argillaceous, weakly
 indurated, thinly laminated to blocky, with some well-
 indurated dolomitic shale layers near base 2.0

Unnamed Unit (Dog Creek):

Shale, red-brown, silty, blocky, with some greenish-gray medium-
 bedded siltstone layers 7.4

Unit A (Dog Creek):

Sandstone, light-brown, mottled red-brown to moderate reddish-
 orange, fine-grained, quartzose, well-indurated, massive,
 forming ledge 1.0

Sandstone and siltstone, red-brown to moderate reddish-orange,
 fine-grained, quartzose, moderately indurated, thin- to
 medium-bedded, weathering massive, forming ledge 3.6

Siltstone⁺, greenish-gray, mottled red-brown to moderate
 reddish-orange, calcareous, thinly laminated, weakly indurated
 at top, well-indurated at base 1.0

Unnamed Units (Dog Creek):

Shale, mottled red-brown and greenish-gray, silty, weakly
 indurated, thin-bedded, crinkly bedded 0.3

Siltstone, greenish-gray, argillaceous, well-indurated, thin-
 bedded, crinkly bedded, forming ledge 0.75

Shale, red-brown, silty, weakly indurated, blocky 1.5

(West Moccasin Creek Section 8, continued)

Watonga Dolomite Member:

Siltstone*, red-brown, mottled greenish-gray, dolomitic,
fine-grained, thin-bedded, well-indurated, forming ledge ... 0.6

Unnamed Units (Dog Creek):

Shale, red-brown, silty, blocky 3.4

Shale, greenish-gray and red-brown, silty, weakly indurated,
blocky, partly covered 6.25

Gypsum, greenish-gray, selenitic, silty, well-indurated,
wavy bedded 0.2

Shale, red-brown, mottled greenish-gray, silty, gypsiferous,
weakly indurated 0.6

Gypsum, greenish-gray, silty, well-indurated, wavy bedded,
massive 0.4

Shale, red-brown, mottled greenish-gray, weakly indurated,
blocky 0.7

Haakow Gypsum Member:

Gypsum and siltstone, interbedded, red-brown and greenish-gray,
well-indurated, thinly laminated, crinkly bedded, forming
ledge 1.3

Shale, red-brown, blocky, weakly indurated, with some thin
satin-spar layers 1.2

Gypsum, white, mottled red-brown and greenish-gray, fine-
grained, well-indurated, crinkly bedded, massive, forming
ledge 2.75

(West Moccasin Creek Section 8, continued)

Unnamed Unit (Dog Creek):

Shale, red-brown, mottled greenish-gray, blocky, with much
satin-spar 4.5

BLAINE FORMATION (Total thickness, 83.5 feet)

Shiner Gypsum Member:

Gypsum, white, fine-grained, well-indurated, massive, weathering
coarsely selenitic 19.0

Altona Dolomite Member:

Dolomite*, light-gray, fine-grained, oölitic, well-indurated,
grading upward into gypsum 0.3

Unnamed Units (Blaine):

Shale, greenish-gray, mottled red-brown, weakly indurated,
blocky 0.5

Shale, red-brown, blocky, mottled with greenish-gray spots,
with some selenite and satin-spar beds in lower 5 feet 14.5

Nescatunga Gypsum Member:

Gypsum, white, fine-grained, massive, weathering coarsely
selenitic, being red-brown and greenish-gray in upper 2 feet,
forming an escarpment 11.0

Maggie Dolomite Member:

Siltstone*, light-gray, fine-grained, dense to oölitic, well-
indurated, massive 0.2

(West Moccasin Creek Section 8, continued)

Unnamed Member (Blaine):

Shale, red-brown, blocky, with some satin-spar 9.0

Medicine Lodge Gypsum Member:

Gypsum, white, fine-grained, massive, weathering coarsely
selenitic, forming escarpment 28.25

Cedar Springs Dolomite Member:

Dolomite*, light-gray, fine-grained, dense to oolitic, well-
indurated 0.75

FLOWERPOT SHALE (Exposed thickness, 100.6 feet)

Unit K (Flowerpot):

Shale, greenish-gray, weakly indurated, blocky; section
extrapolated to SW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 28, T. 27 N., R. 18 W., in
bluff on Cimarron River 0.25

Unit J (Flowerpot):

Shale, red-brown, selenitic, blocky 0.75

Unit I (Flowerpot):

Siltstone*, greenish-gray, dolomitic, gypsiferous, thin-
bedded, crinkly bedded, well-indurated in places 0.5

Shale, red-brown, selenitic, blocky 1.1

Shale, greenish-gray, selenitic, blocky 0.1

Shale, red-brown, selenitic, blocky, with many thin satin-spar
layers 4.5

Shale, greenish-gray, mottled red-brown, blocky, with much
satin-spar 0.8

(West Moccasin Creek Section 8, continued)

Unit H (Flowerpot):

Shale, red-brown, blocky, with some gypsum nodules	0.75
Shale, greenish-gray, mottled red-brown, selenitic, thin-bedded, crinkly bedded, alternating well- to weakly indurated layers	0.5
Shale, red-brown, selenitic, blocky	1.7

Units E-G (Flowerpot):

Shale, greenish-gray, silty, weakly indurated, blocky	0.75
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Unit D (Flowerpot):

Shale, red-brown, silty, blocky, mottled with greenish-gray spots	1.6
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Unit C (Flowerpot):

Siltstone*, moderate red-brown, mottled greenish-gray, arenaceous, calcareous, well-indurated, with 1- to 3-inch gypsum nodules	1.25
Siltstone, light-brown to red-brown, mottled greenish-gray, argillaceous, massive, moderately indurated, with some gypsum nodules, forming ledge	3.1

Units A3-B (Flowerpot):

Shale, greenish-gray, mottled red-brown, silty, weakly indurated, thin-bedded, platy	0.2
Shale, red-brown, silty, weakly indurated, blocky, with some greenish-gray spots	7.1
Gypsum, white, mottled greenish-gray, well-indurated, fine-grained, crinkly bedded	0.2

(West Moccasin Creek Section 8, continued)

Shale, greenish-gray to dark-gray, weakly indurated, blocky ..	0.2
Shale, red-brown, siliceous, blocky	1.1
Shale, greenish-gray to dark-gray, weakly indurated, blocky ..	0.25
Shale, red-brown, blocky	3.9
Shale, greenish-gray and red-brown, gypsiferous, well-indurated, thin-bedded, crinkly bedded, forming ledge	0.8
Shale, red-brown, blocky, with much satin-spar	0.4
Shale, dark greenish-gray, weakly indurated, blocky, with satin-spar	0.1
Shale, red-brown, blocky, with much satin-spar	3.4
Shale, greenish-gray, blocky, with much satin-spar	0.6
Shale, red-brown, blocky, with much satin-spar	1.5
Shale, greenish-gray, blocky, with much satin-spar, forming base of extremely gypsiferous section	0.7
Shale, red-brown, blocky	1.2
Shale, greenish-gray, blocky	0.2
Shale, red-brown, blocky	3.8
Siltstone*, greenish-gray, dolomitic, argillaceous, well- indurated, crinkly bedded, massive, forming ledge	0.2
Shale, greenish-gray, mottled red-brown, weakly indurated, blocky	0.7
Shale, red-brown, blocky	1.3
Shale, greenish-gray, gypsiferous, well-indurated, crinkly bedded, platy	0.2

(Lost Moccasin Creek Section 8, continued)

Shale, red-brown, blocky	0.3
Shale, greenish-gray, blocky	0.1
Shale, red-brown, blocky	0.9
Shale, greenish-gray, mottled red-brown, gypsiferous, well-indurated, crinkly bedded, with much nodular gypsum and satin-spar	0.4
Shale, red-brown, blocky, with some satin-spar	2.5
<u>Unit A₂ (Flowerpot):</u>	
Siltstones, greenish-gray, mottled red-brown, argillaceous, gypsiferous, weakly indurated, with nodular gypsum	1.0
<u>Unit A₁ (Flowerpot):</u>	
Shale, red-brown, blocky	1.9
Shale, greenish-gray, blocky, with platy selenite	0.2
Shale, red-brown, blocky	0.8
Shale, greenish-gray, mottled red-brown, blocky, with nodular gypsum	0.8
Shale, red-brown, blocky	2.0
Shale, greenish-gray, blocky, with some satin-spar	0.4
Shale, red-brown, blocky	1.1
Shale, greenish-gray, blocky	0.1
Shale, red-brown, blocky	1.75
Shale, greenish-gray, mottled red-brown, blocky, with much satin-spar	0.2
Shale, red-brown, blocky, with some satin-spar	5.0

(West Moccasin Creek Section 8, continued)

Shale, greenish-gray, selenitic, well-indurated, crinkly bedded	0.2
Shale, red-brown, blocky, with some satin-spar	0.75
Shale, greenish-gray, blocky, with much satin-spar	0.2
Shale, red-brown, blocky, with some paper-thin selenite and satin-spar	0.8
Shale, greenish-gray, blocky, with some satin-spar	0.3
Shale, red-brown, blocky	0.9
Siltstone ² , greenish-gray, gypsiferous, well-indurated, massive, crinkly bedded	0.1
Shale, red-brown, blocky, with some paper-thin satin-spar layers	7.2
Shale, greenish-gray, weakly indurated, blocky	0.4
Shale, red-brown, blocky, with some greenish-gray spots	4.0
Shale, greenish-gray, gypsiferous, well-indurated, crinkly bedded	0.1
Shale, red-brown, blocky	2.0
Shale, greenish-gray, mottled red-brown, gypsiferous, well- indurated, thin-bedded, crinkly bedded	0.3
Shale, red-brown, blocky	0.9
Shale, greenish-gray, mottled red-brown, blocky	0.6
Shale, red-brown, blocky, with many vertical paper-thin selenite veins	4.2
Shale, greenish-gray, weakly indurated, blocky	1.2

(West Moccasin Creek Section 8, continued)

Shale, red-brown, blocky	2.0
Shale, greenish-gray, blocky, weakly indurated, with some paper-thin satin-spar	0.3
Shale, red-brown, moderately indurated, blocky	3.5
Shale, greenish-gray, mottled red-brown, weakly indurated, blocky	0.5
Shale, red-brown, weakly indurated, blocky, exposed	6.0

Section 9. Sleeping Bear Creek

Harper County, Oklahoma

Beginning at top in Marlow Formation, section measured in SW¹/₄ SE¹/₄ sec. 10, T. 25 N., R. 20 W., supplemented by section along Highway 34 between secs. 16 and 17, T. 25 N., R. 20 W., for section between Marlow Formation and Southard Dolomite, continuing to the Nescatunga Gypsum Member in NE¹/₄ NW¹/₄ sec. 15, T. 25 N., R. 20 W. and Magpie Dolomite Member in NE¹/₄ NE¹/₄ SW¹/₄ sec. 10, T. 25 N., R. 20 W. section then extrapolated to NW¹/₄ NW¹/₄ sec. 22, T. 26 N., R. 20 W. for remainder of Blaine Formation, ending in the Flowerpot Shale in the bluff on the Cimarron River in NE¹/₄ SE¹/₄ sec. 24, T. 27 N., R. 20 W., Harper County, Oklahoma.

MARLOW FORMATION (Top not examined)

Sandstone, moderate reddish-brown to moderate reddish-orange, fine-grained, gypsiferous, quartzose, weakly to well-indurated, forming gypsiferous ledge, grading into an impure arenaceous gypsum	2.0+
siltstone*, greenish-gray, arenaceous, gypsiferous, weakly indurated, thin-bedded, crinkly bedded	1.0
DOG CREEK SHALE (Total thickness, 49.2 feet)	
Shale, red-brown, silty, blocky	1.8
Shale, greenish-gray, mottled red-brown, silty, weakly indurated, blocky	0.1
Shale, red-brown, silty, blocky, with some greenish- & spots	3.0

(Sleeping Bear Creek Section 9, continued)

Shale, mottled greenish-gray and red-brown, silty, weakly indurated, blocky	0.5
Shale, red-brown, silty, blocky	2.0
<u>Unit F₂ (Dog Creek):</u>	
Siltstone*, mottled red-brown and greenish-gray, argillaceous, thin-bedded, weakly indurated, blocky, with basal 1 inch well-indurated and greenish-gray	2.7
<u>Unnamed Units (Dog Creek):</u>	
Shale, dark red-brown, blocky	1.1
Siltstone, greenish-gray, mottled red-brown, argillaceous, weakly indurated, blocky	0.2
Shale, dark red-brown, weakly indurated, blocky	2.5
Shale, greenish-gray, weakly indurated, blocky	0.2
Shale, dark red-brown, weakly indurated, blocky	2.25
<u>Unit E (Dog Creek):</u>	
Siltstone, greenish-gray, mottled red-brown, weakly indurated, thin-bedded, crinkly bedded	1.0
<u>Unnamed units (Dog Creek):</u>	
Shale, red-brown, blocky	1.4
Siltstone, greenish-gray, argillaceous, well-indurated, thin-bedded, crinkly bedded	0.2
Shale, red-brown, blocky	0.5

(Sleeping Bear Creek Section 9, continued)

Unit D (Dog Creek):

Siltstone, greenish-gray, argillaceous, well-indurated, thin-bedded 0.2

Unnamed Unit (Dog Creek):

Shale, dark red-brown, blocky 2.75

Unit C (Dog Creek):

Dolomite⁺, light-gray, fine-grained, dense, well-indurated, massive, blocky; section slumped 0.25

Unnamed Unit (Dog Creek):

Shale, dark red-brown, blocky 2.0

Unit B and Southard Dolomite Member:

Shale, greenish-gray, blocky, dolomitic, partly covered 3.0

Dolomite⁺, light-gray, argillaceous, thin-bedded, fine-grained, dense, well-indurated, with salt casts, section slumped 0.1

Unit A (Dog Creek):

Siltstone, red-brown, argillaceous, blocky, well-indurated, in places weakly indurated 5.0

Unnamed Units (Dog Creek):

Shale, red-brown, blocky, with some greenish-gray spots 2.75

Shale, red-brown and greenish-gray, gypsiferous, weakly to well-indurated alternating layers, crinkly bedded, thin-bedded, slumped and partly covered, probably containing the Watonga

Dolomite Member 6.0

(Sleeping Bear Creek Section 9, continued)

Haskew Gypsum Member:

Gypsum, white, mottled moderate reddish-orange and greenish-gray, coarsely selenitic, crinkly bedded 4.0

Unnamed Unit (Dog Creek):

Shale, red-brown, mottled greenish-gray, gypsiferous, blocky . 3.7

BLAINE FORMATION (Total thickness, 84.8 feet)

Shiner Gypsum Member:

Gypsum, white, fine-grained, massive, weathering coarsely selenitic, forming escarpment 13.0

Altona Dolomite Member:

Dolomite*, light-gray, fine-grained, oblitic, massive, well-cemented 1.5

Unnamed Units (Blaine)

Shale, greenish-gray, blocky 0.2

Shale*, red-brown, blocky, with much paper-thin selenite 15.6

Nescatunga Gypsum Member:

Gypsum, white, mottled light-gray, fine-grained, massive, weathering coarsely selenitic 13.0

Maggie Dolomite Member:

Dolomite*, light-gray, fine-grained, oblitic, well-indurated, massive 0.75

Unnamed Unit (Blaine):

Shale*, red-brown, mottled greenish-gray, blocky, weakly indurated 15.0

(Sleeping Bear Creek Section 9, continued)

Medicine Lodge Gypsum Member:

Gypsum, white, fine-grained, massive, weathering coarsely selenitic, forming ledge; section extrapolated to NW $\frac{1}{4}$ sec. 22, T. 26 N., R. 20 W.	25.0
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Cedar Springs Dolomite Member:

Dolomite [#] , light-gray, fine-grained, oblitic, massive	0.75
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FLOWERPOT SHALE (Exposed thickness, 72.6 feet)

Unit K (Flowerpot):

Shale, greenish-gray, blocky	0.25
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Unit J (Flowerpot):

Shale, red-brown, blocky	0.8
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Unit I (Flowerpot):

Shale, greenish-gray, blocky	0.1
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Shale, red-brown, blocky, with gypsum nodules	2.0
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Gypsum, white, mottled red-brown, nodular; section extrapolated to bluff on Cimarron River in SE $\frac{1}{4}$ sec. 24, T. 27 N., R. 20 W.	0.75
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Shale, red-brown, weakly indurated, blocky	1.6
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Gypsum, white, mottled red-brown, well-indurated, nodular	0.4
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Unit H (Flowerpot):

Shale, red-brown, mottled greenish-gray, weakly indurated, blocky	0.6
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Shale, greenish-gray, weakly indurated, blocky	0.25
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Shale, red-brown, weakly indurated, blocky	0.75
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(Sleeping Bear Creek Section 9, continued)

Units E-G (Flowerpot):

Shale, greenish-gray, weakly indurated, blocky 0.75

Unit D (Flowerpot):

Shale, red-brown, blocky, with many gypsum nodules 1.3

Shale, greenish-gray, well-indurated, blocky, with many gypsum
nodules 0.5

Shale, red-brown, blocky 0.6

Gypsum, white, mottled red-brown, nodular, well-indurated 0.6

Unit C (Flowerpot):

Siltstone, mottled red-brown to moderate reddish-orange,
weakly indurated, thin-bedded 1.7

Gypsum, white, nodular, well-indurated 0.2

Siltstone[†], red-brown to moderate reddish-orange, mottled
greenish-gray, weakly indurated, thin-bedded 0.8

Siltstone, greenish-gray, mottled red-brown, gypsiferous,
well-indurated in places 1.0

Siltstone[‡], red-brown, mottled greenish-gray, argillaceous,
weakly indurated, blocky 1.2

Unit B (Flowerpot):

Gypsum, white, mottled red-brown and light-gray, nodular 0.2

Shale, red-brown, blocky, with some small gypsum nodules 2.5

Unit A₃ (Flowerpot):

Shale, greenish-gray, weakly indurated, blocky, with some
sat in-spar 0.2

(Sleeping Bear Creek Section 9, continued)

Shale, red-brown, blocky with much satin-spar	2.0
Shale, greenish-gray, platy	0.2
Shale, red-brown, platy	0.3
Gypsum and shale, interbedded, greenish-gray, mottled red- brown, with much satin-spar, well-indurated, crinkly bedded, thin-bedded, forming ledge	1.0
Shale, red-brown, blocky, with many thin satin-spar layers ...	1.0
Shale, greenish-gray, weakly indurated, blocky, with much satin-spar	0.25
Shale, red-brown, blocky, with much satin-spar and some greenish-gray shale beds	3.5
Shale, greenish-gray, blocky, well-indurated, with satin-spar.	0.2
Shale, red-brown, blocky, weakly indurated, with satin-spar ..	0.25
Shale, greenish-gray, weakly indurated, blocky, with many crinkly satin-spar layers	0.75
Shale, red-brown, blocky, with many thin satin-spar beds	0.7
Shale, greenish-gray, weakly indurated, blocky	0.2
Shale, red-brown, blocky, with many thin satin-spar beds	1.75
Shale, mottled red-brown and greenish-gray, gypsiferous, well-indurated, crinkly bedded	1.0
Shale, greenish-gray, weakly indurated, blocky	0.2
Shale, red-brown, blocky, with many thin satin-spar beds	2.7

(Sleeping Bear Creek Section 9, continued)

Shale, greenish-gray, blocky	0.1
Shale, red-brown, blocky, with some satin-spar beds	0.75
Shale, greenish-gray, gypsiferous, blocky, well-indurated in upper 1 inch	0.7
Shale, red-brown, blocky, with much satin-spar	0.8
Siltstone*, greenish-gray, mottled red-brown, gypsiferous, argillaceous, thin-bedded, crinkly bedded, well-indurated in upper 1 inch	1.0
Shale, red-brown, blocky, with thin satin-spar layers	1.0
Shale, greenish-gray, gypsiferous, well-indurated, platy	0.2
Shale, red-brown, blocky, with many thin satin-spar layers ...	2.2
Siltstone, red-brown to moderate reddish-orange, mottled greenish-gray, argillaceous, weakly indurated, massive	0.75
Siltstone, greenish-gray, mottled moderate reddish-orange, gypsiferous, well-indurated, massive, forming ledge	0.6
<u>Unit A₂ (Flowerpot):</u>	
Siltstone*, mottled greenish-gray and red-brown, arenaceous, dolomitic, indurated in places	0.75
<u>Unit A₁ (Flowerpot):</u>	
Shale, red-brown, blocky, with some thin satin-spar beds	1.75
Shale, greenish-gray, gypsiferous, blocky	0.1
Shale, red-brown, blocky, with many thin satin-spar beds	1.0
Shale, mottled greenish-gray and red-brown, weakly indurated, blocky	0.6

(Sleeping Bear Creek Section 9, continued)

Shale, greenish-gray, mottled red-brown, selenitic, well-indurated, crinkly bedded	0.4
Shale, red-brown, blocky, with some thin satin-spar beds and greenish-gray spots	1.0
Shale, greenish-gray, mottled red-brown, selenitic	0.1
Shale, red-brown, blocky, with some greenish-gray spots and satin-spar	1.0
Shale, greenish-gray, mottled red-brown, selenitic, well-indurated, crinkly bedded	0.4
Shale, red-brown, blocky, with some greenish-gray spots and thin selenite and satin-spar beds	2.2
Shale, greenish-gray, selenitic, well-indurated, crinkly bedded	0.1
Shale, red-brown, blocky, with some greenish-gray layers and paper-thin selenite and satin-spar layers, exposed	20.0

Section 10. Haskew

Northwestern Woodward County, Oklahoma

Beginning at top in Marlow Formation, section measured in SW $\frac{1}{4}$ S $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 6, T. 25 N., R. 18 W. and NW $\frac{1}{4}$ NE $\frac{1}{4}$ E $\frac{1}{4}$ sec. 7, along creek and on Highway 50, down to Altona Dolomite, including the type section for the Haskew Gypsum Member of the Dog Creek Shale, ending in the Elaine Formation and Flowerpot Shale at Alabaster Caverns State Park, in SE $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 29, T. 26 N., R. 18 W. and NE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 28, T. 26 N., R. 18 W., northwestern Woodward County, Oklahoma.

MARLOW FORMATION (Top not exposed)

Sandstone, moderate reddish-brown to moderate reddish-orange, quartzose, silty, weakly indurated, exposed to top	5.0
Sandstone*, greenish-gray, mottled moderate reddish-orange, fine-grained, quartzose, weakly indurated	0.5
Gypsum, greenish-gray, mottled light-pink, arenaceous, well- cemented, finely laminated, crinkly bedded, weathering massive, forming ledge	1.7
Sandstone, red-brown to moderate reddish-orange, gypsiferous, well-indurated, forming massive ledge	1.0

DOG CREEK SHALE (Total thickness, 51.8 feet)

Siltstone, red-brown to moderate reddish-orange, mottled greenish-gray, gypsiferous, weakly indurated, massive	0.5
Shale, red-brown, blocky	0.2
<u>Unit H (Dog Creek):</u>	
Siltstone*, greenish-gray, gypsiferous, dolomitic, argillaceous, well-indurated, crinkly bedded, massive	0.1

(Haskew Section 10, continued)

Unnamed Units (Dog Creek):

Shale, red-brown, blocky	1.0
Siltstone, greenish-gray, as above	0.2
Shale, red-brown, blocky	0.2
Siltstone, greenish-gray, as above	0.25
Shale, red-brown, selenitic, blocky	1.0

Unit F2 (Dog Creek):

Siltstone, greenish-gray, as above	0.25
Shale, red-brown, selenitic, blocky	0.5
Siltstone, greenish-gray, as above	0.25
Shale, red-brown, blocky	0.3
Siltstone*, greenish-gray, gypsiferous, dolomitic, well- indurated, crinkly bedded	0.75

Unnamed Units (Dog Creek):

Shale, red-brown, blocky	1.0
Siltstone, greenish-gray, gypsiferous, argillaceous, well- indurated, crinkly bedded	0.2
Shale, red-brown, blocky, with paper-thin selenite	1.5

Unit F1 (Dog Creek):

Siltstone, greenish-gray, mottled red-brown, as above	1.0
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Unnamed Unit (Dog Creek):

Shale, red-brown, blocky, with interbedded greenish-gray gypsiferous siltstone beds 1- to 3-inches thick	6.0
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(Haskew Section 10, continued)

Unit D (Dog Creek):

Dolomite*, light-gray, fine-grained, dense, silty, thinly
laminated 0.2

Unnamed Unit (Dog Creek):

Shale, red-brown, blocky 3.5

Unit C (Dog Creek):

Dolomite, pink to greenish-gray, fine-grained, dense, with
many salt casts 0.1

Unnamed Unit (Dog Creek):

Shale, grayish red-purple, blocky 1.0

Southard Dolomite Member:

Dolomite*, light-gray, fine-grained, dense, thinly laminated . 0.2

Unit B (Dog Creek):

Siltstone*, greenish-gray, dolomitic, argillaceous, mottled
grayish red-purple, platy in upper 6 inches, with indurated 1
inch dolomitic siltstone at base 2.75

Unnamed Unit (Dog Creek):

Shale, red-brown, blocky, with some greenish-gray shale spots
and moderate reddish-orange gypsum nodules 1.6

Unit A (Dog Creek):

Siltstone, greenish-gray, as above, gypsiferous, crinkly bedded,
with interbedded red-brown shale 1.0

Shale, red-brown, as above, partly covered 3.4

(Haskew Section 10, continued)

Gypsum, mottled greenish-gray and light-brown, silty, well-indurated, crinkly bedded, forming ledge	0.3
Siltstone*, red-brown to moderate reddish-orange, argillaceous, gypsiferous, weakly indurated	2.0
Siltstone, greenish-gray, mottled red-brown, gypsiferous, thin-bedded, crinkly bedded, with many paper-thin selenite layers	0.5
<u>Unnamed Units</u> (Dog Creek):	
Shale, red-brown, mottled greenish-gray, blocky, thin-bedded, crinkly bedded, with many paper-thin selenite layers, probably containing the equivalent of the Watonga Dolomite Member, partly covered	4.75
Gypsum, white, mottled red-brown and greenish-gray to moderate reddish-orange, coarsely selenitic, wavy bedded, massive ...	0.4
Siltstone, moderate reddish-orange, mottled red-brown and greenish-gray, argillaceous, weakly indurated	1.6
Shale, red-brown, blocky	1.0
Gypsum, red-brown, argillaceous, thin-bedded, crinkly bedded .	0.25
Shale, red-brown, blocky, mottled greenish-gray at top	1.5
Gypsum, white to red-brown, coarsely selenitic, well-indurated, crinkly bedded	0.2
Siltstone, greenish-gray, mottled red-brown, gypsiferous, well-indurated, thin-bedded	1.0

(Haskew Section 10, continued)

Haskew Gypsum Member (Type section):

Gypsum, mottled moderate reddish-orange and greenish-gray to white, wavy bedded, well-indurated, massive, fine-grained, weathering coarsely selenitic	0.5
Siltstone, red-brown and greenish-gray, gypsiferous, well-indurated, thinly laminated	0.8
Shale, red-brown, mottled greenish-gray, blocky	0.75
Gypsum, white, fine-grained, well-indurated, alabaster-like, massive, forming resistant ledge	2.75

Unnamed Unit (Dog Creek):

Shale, red-brown, mottled greenish-gray, weakly indurated, blocky	4.5
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BLAINE FORMATION (Total thickness, 88.0 feet)

Shiner Gypsum Member:

Gypsum, white, mottled light-gray, fine-grained, massive, weathering coarsely selenitic, forming ledge	14.6
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Altona Dolomite Member:

Dolomite*, light-gray, fine-grained, oblitic, medium-bedded, weathering into massive box-works; section extrapolated to Alabaster Caverns State Park SE $\frac{1}{4}$ sec. 29, T. 26 N., R. 18 W.	1.25
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Unnamed Units (Blaine):

Shale, greenish-gray, weakly indurated, blocky	0.2
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(Haskew Section 10, continued)

Shale, red-brown, mottled greenish-gray, blocky, with some
red-brown selenitic beds in middle 15.75

Nescatunga Gypsum Member:

Gypsum, white, fine-grained, well-indurated, coarsely
selenitic, massive, forming ledge 15.0

Magnie Dolomite Member:

Dolomite*, light-gray, fine-grained, oblitic, weakly indurated 0.4

Unnamed Units (Blaine):

Shale, greenish-gray, selenitic, blocky 0.1

Shale, red-brown, mottled greenish-gray, selenitic, with 3
inch red-brown gypsiferous shale about 4 feet below top 9.5

Medicine Lodge Gypsum Member:

Gypsum, white, mottled light-gray, fine-grained, massive,
weathering coarsely selenitic, forming ledge 30.7

Cedar Springs Dolomite Member:

Dolomite*, light-gray, fine-grained, oblitic, well-cemented,
massive 0.5

FLOWERPOT SHALE (Exposed thickness, 64.3 feet)

Unit K (Flowerpot):

Shale, greenish-gray, blocky 0.2

Unit J (Flowerpot):

Shale, red-brown, weakly indurated, blocky, with some greenish-
gray layers 1.25

(Haskew Section 10, continued)

Unit I (Flowerpot):

Gypsum, white, mottled red-brown, fine-grained, nodular, forming ledge	0.75
Shale, greenish-gray, silty, blocky, weakly indurated	0.2
Shale, red-brown, blocky, with some greenish-gray spots	1.3
Gypsum, white, mottled red-brown, nodular, as above, forming ledge	1.0

Unit H (Flowerpot):

Shale, red-brown, blocky, weakly indurated	0.25
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Units E-G (Flowerpot):

Siltstone*, greenish-gray, dolomitic, weakly indurated, blocky	0.5
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Unit D (Flowerpot):

Shale, red-brown, blocky, with some greenish-gray spots	0.6
Shale, greenish-gray, mottled red-brown, gypsiferous, well-indurated	0.1
Shale, red-brown, blocky, with some greenish-gray spots	1.5

Unit C (Flowerpot):

Siltstone*, greenish-gray, mottled light-brown, arenaceous, dolomitic, weakly indurated, thin-bedded	0.5
Siltstone, light-brown, mottled red-brown, argillaceous, weakly indurated	0.75
Siltstone*, greenish-gray, mottled light-brown, gypsiferous, dolomitic, arenaceous, with many small to medium-size gypsum nodules, forming an escarpment	5.0

(Herkew Section 10, continued)

Siltstone, greenish-gray, gypsiferous, weakly indurated, massive	1.2
<u>Units A3-B (Flowerpot):</u>	
Shale, red-brown, blocky, with some thin satin-spar layers ...	5.3
Shale, greenish-gray, mottled red-brown, well-indurated, blocky, crinkly bedded, with many satin-spar layers	1.0
Shale, red-brown, mottled greenish-gray, blocky	1.1
Gypsum, white, mottled greenish-gray, well-indurated, massive.	0.5
Shale, red-brown, mottled greenish-gray, blocky	0.9
Shale, greenish-gray and red-brown, gypsiferous, thin-bedded, crinkly bedded, platy, forming ledge	0.8
Shale, red-brown, weakly indurated, blocky	0.8
Siltstone*, greenish-gray, dolomitic, argillaceous, well-indurated, massive	0.25
Shale, red-brown, blocky, with some thin selenite beds	3.75
Gypsum, greenish-gray, mottled red-brown, argillaceous, well-indurated, nodular	0.2
Shale, red-brown, as above, with much selenite, satin-spar, and nodular gypsum	4.5
Gypsum greenish-gray, selenitic, well-indurated, platy, with interbedded red-brown shale, crinkly bedded, forming prominent ledge and base of otherwise gypsiferous section	1.0
Shale, greenish-gray, blocky, with satin-spar at top	0.75

(Maskev Section 10, continued)

Shale, red-brown, blocky, with some satin-spar	0.75
Shale, greenish-gray, silty, with some satin-spar	0.5
Shale, red-brown, blocky, with some greenish-gray spots and satin-spar	3.1
Siltstone, greenish-gray, mottled red-brown, forming ledge ...	1.0
Shale, red-brown, silty, blocky	1.0
<u>Unit A₂ (Flowerpot):</u>	
Siltstone, greenish-gray, gypsiferous, argillaceous, moderately indurated, blocky	1.0
Siltstone ^r , red-brown, argillaceous, blocky	0.6
<u>Unit A₁ (Flowerpot):</u>	
Shale, greenish-gray, blocky, with some gypsum beds	0.3
Shale, red-brown, blocky	0.5
Shale, greenish-gray, blocky, as above	0.2
Shale, red-brown, blocky	0.9
Shale, greenish-gray, blocky, as above	0.7
Shale, red-brown, as above	2.5
Shale, greenish-gray, gypsiferous, blocky, as above	0.25
Shale, red-brown and greenish-gray, with much satin-spar, exposed to base of measured section	15.0

Section 11. Quinlan - Chimney Creek

Central Woodward County, Oklahoma

Beginning at top in Marlow Formation, section measured in road cut between NW $\frac{1}{4}$ sec. 17 and NE $\frac{1}{4}$ sec. 18, T. 23 N., R. 17 W., down to Southard Dolomite Member; then extrapolated to Copeland Ranch in SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 22, T. 24 N., R. 18 W., north side of branch of Chimney Creek to base of Dog Creek Shale. The Shiner was measured in SE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 2, T. 23 N., R. 18 W. and the remainder of the Blaine to the Medicine Lodge was measured in SW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 6, T. 24 N., R. 17 W. The Medicine Lodge and Flowerpot were measured in SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 1, T. 24 N., R. 18 W., central Woodward County, Oklahoma.

MARLOW FORMATION (Top not exposed)

Sandstone[†], red-brown to moderate reddish-orange, fine-grained, quartzose, weakly indurated, friable, thin-bedded, exposed . 20.0

DOG CREEK SHALE (Total thickness, 67.5 feet)

Siltstone[†], dark red-brown to very dark-red, arenaceous, dolomitic, platy, thin-bedded, crinkly bedded 1.2

Unit H (Dog Creek):

Siltstone[†], moderate reddish-orange, mottled red-brown, dolomitic, arenaceous, well-indurated, blocky, massive; greenish-gray and dolomitic in basal 1 inch 0.7

Unnamed Units (Dog Creek):

Shale, red-brown, silty, blocky 3.0

Siltstone, moderate reddish-orange, argillaceous, well-indurated, massive 0.25

(Quinlan-Chimney Creek Section 11, continued)

Shale, red-brown, blocky, mottled with some greenish-gray spots	2.4
<u>Unit F₂</u> (Dog Creek):	
Siltstone, moderate reddish-orange, argillaceous, thin-bedded, grading into fine-grained quartzose sandstone	8.0
<u>Unnamed Units</u> (Dog Creek):	
Shale, red-brown, silty, moderately indurated, blocky	4.0
Siltstone, red-brown, argillaceous, well-indurated, massive, forming ledge	0.2
Shale, red-brown, silty, blocky	3.75
<u>Unit F₁</u> (Dog Creek):	
Siltstone*, greenish-gray, mottled red-brown, dolomitic, argillaceous, moderately indurated, thin-bedded, forming prominent light-colored band in region	0.5
<u>Unnamed Units</u> (Dog Creek):	
Shale, red-brown, silty, blocky	3.6
Shale, mottled greenish-gray and red-brown, silty, blocky	0.75
Shale, red-brown, blocky	7.0
<u>Unit E</u> (Dog Creek):	
Siltstone*, greenish-gray, mottled moderate reddish-orange, thin-bedded, crinkly bedded	0.25
<u>Unnamed Units</u> (Dog Creek):	
Shale, red-brown, mottled greenish-gray, blocky	1.25

(Quinlan-Chimney Creek Section 11, continued)

Siltstone, moderate reddish-orange, mottled greenish-gray, weakly indurated, massive	1.0
Shale, red-brown, blocky, mottled with some greenish-gray spots	3.0
<u>Unit D (Dog Creek):</u>	
Shale, greenish-gray, dolomitic, blocky	0.1
<u>Unnamed Unit (Dog Creek):</u>	
Shale, dark red-brown, blocky	1.0
<u>Unit C (Dog Creek):</u>	
Dolomite, greenish-gray, silty, argillaceous, fine-grained, well-indurated, massive	0.1
<u>Unnamed Units (Dog Creek):</u>	
Shale, red-brown, blocky	0.25
Shale, greenish-gray, dolomitic, well-indurated, blocky	0.1
Shale, red-brown, blocky	0.5
<u>Southard Dolomite Member:</u>	
Dolomite, greenish-gray, argillaceous, silty, fine-grained, well-indurated, thin-bedded	0.1
<u>Unit B (Dog Creek):</u>	
Shale, greenish-gray, mottled red-brown, thinly laminated, platy, with some thin dolomite beds	5.0
Dolomite, light-gray, fine-grained, dense, crinkly bedded, massive, blocky	0.3

(Quinlan-Chimney Creek Section 11, continued)

Unnamed Units (Dog Creek):

Shale, red-brown, blocky, with some greenish-gray spots	1.0
Shale, greenish-gray, silty, weakly indurated, blocky	0.2
Shale, red-brown, blocky, with some greenish-gray streaks; section extrapolated to Copeland Ranch	7.5

Unit A (Dog Creek):

Siltstone, light-brown, gypsiferous, weakly indurated, massive	3.0
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Unnamed Units (Dog Creek):

Siltstone and gypsum, interbedded, red-brown, argillaceous, well-indurated, thin-bedded, crinkly bedded, probably contain- ing Watonga and Haskew equivalents	4.5
Siltstone*, greenish-gray, mottled red-brown, gypsiferous, dolomitic, well-indurated, thin-bedded, crinkly bedded	3.0

BLAINE FORMATION (Total thickness, 87.7 feet)

Shiner Gypsum Member:

Gypsum, white, coarsely selenitic, becoming wavy bedded and red-brown at top; section measured in NW $\frac{1}{4}$ sec. 2, T. 23 N., R. 18 W.	17.0
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Altona Dolomite Member:

Dolomite*, light-gray, fine-grained, oolitic, well-cemented, thin-bedded at base, massive at top, weathering into box- works; section extrapolated to NW $\frac{1}{4}$ sec. 6, T. 24 N., R. 17 W.	1.0
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(Quinlan-Chimney Creek Section 11, continued)

Unnamed Units (Blaine):

Shale, greenish-gray, weakly indurated, blocky	0.25
Shale, red-brown, mottled greenish-gray in spots, blocky	11.0

Nescatunga Gypsum Member:

Gypsum, white to light-gray, fine-grained, well-cemented, weathering coarsely selenitic, with dolomite stringers in basal 2 feet, forming mappable escarpment	23.0
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Maggie Dolomite Member:

Dolomite*, light-gray to greenish-gray, fine-grained, oolitic, well-cemented, medium-bedded	1.2
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Unnamed Units (Blaine):

Shale, greenish-gray, weakly indurated, blocky	0.25
Shale, red-brown, blocky, with some greenish-gray spots and layers, and selenite nodules	4.2

Kinafisher Creek Gypsum Member:

Gypsum and shale, interbedded, red-brown, well-indurated, thin-bedded, crinkly bedded, forming minor ledge	0.25
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Unnamed Unit (Blaine):

Shale, red-brown, blocky, with many selenite nodules	3.0
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Medicine Lodge Gypsum Member:

Gypsum, white, mottled red-brown at top, fine-grained, well- cemented, massive, forming ledge; section extrapolated to NE $\frac{1}{4}$ sec. 1, T. 24 N., R. 18 W.	15.75
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(Quinlan-Chimney Creek Section 11, continued)

Anhydrite, light-gray, fine-grained, well-indurated, massive, weathering light-white	3.5
Gypsum, white, fine-grained, well-indurated, forming ledge ...	5.25
<u>Cedar Springs Dolomite Member:</u>	
Dolomite*, light-gray, fine-grained, oolitic, weakly cemented, thin-bedded, weathering light-gray	2.0
FLOWERPOT SHALE (Exposed thickness, 46.6 feet)	
<u>Unit K (Flowerpot):</u>	
Shale, greenish-gray, blocky	1.0
<u>Units I-J (Flowerpot):</u>	
Shale, red-brown, mottled greenish-gray, crinkly bedded, blocky, with many satin-spar stringer	1.8
Gypsum, greenish-gray, mottled red-brown, argillaceous, well- indurated, crinkly-bedded, forming ledge	0.5
Shale, greenish-gray, blocky	0.2
<u>Unit H (Flowerpot):</u>	
Shale, red-brown, blocky, with many greenish-gray spots and small gypsum nodules	2.2
<u>Unit G (Flowerpot):</u>	
Dolomite*, light-gray, well-indurated, thin-bedded, forming ledge	0.75
<u>Units E-F (Flowerpot):</u>	
Siltstone*, greenish-gray, blocky, with some light greenish-gray bands	5.3

(Quinlan-Chimney Creek Section 11, continued)

Unit D (Flowerpot):

Shale, red-brown, mottled greenish-gray, with interbedded gypsum, thin-bedded, crinkly bedded, forming ledge	0.3
Shale, red-brown, blocky, with some satin-spar	2.75
Shale, greenish-gray, blocky, with much selenite	0.3
Siltstone, red-brown, weakly indurated, massive	0.2
Shale, red-brown, blocky, with much satin-spar	2.0
Shale, greenish-gray, blocky, with much selenite	0.2
Shale, red-brown, blocky, with much satin-spar	0.8
Shale, greenish-gray, gypsiferous, well-indurated, crinkly bedded	0.2

Unit C (Flowerpot):

Siltstone*, light-brown to red-brown, gypsiferous, thin-bedded, crinkly bedded, forming ledge	3.2
Siltstone, greenish-gray, mottled red-brown, weakly indurated, massive	0.8

Unit B (Flowerpot):

Shale, red-brown, blocky, with occasional greenish-gray spots.	1.1
Gypsum, white, fine-grained, nodular	0.2
Shale, greenish-gray, silty, gypsiferous, blocky	0.75
Shale, red-brown, blocky, with some selenite veins	2.0
Shale, greenish-gray, mottled red-brown, blocky, thin-bedded, crinkly bedded, platy, with gypsum nodules at top and base .	1.5

Section 12. Ewers Creek

Eastern Woodward County, Oklahoma

Beginning at top in Marlow Formation, section measured in SE $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 16, T. 22 N., R. 17 W. and NE $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 21, T. 22 N., R. 17 W., ending in Southard Dolomite. Section then continued from Southard Dolomite to Shimer Gypsum in SW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 15, T. 22 N., R. 17 W., from Altona Dolomite to Nescatunga Gypsum in SW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 11, T. 22 N., R. 17 W., from Nescatunga Gypsum to Medicine Lodge Gypsum in NE $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 10, T. 22 N., R. 17 W., Woodward County, and from Medicine Lodge Gypsum to 24 feet below Cedar Springs Dolomite in SE $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 33, T. 23 N., R. 16 W., ending in the Flowerpot Shale in SW $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 34, T. 23 N., R. 16 W., western Major County, Oklahoma.

MARLOW FORMATION (Top not exposed)

Siltstone*, moderate reddish-orange, coarse-grained, quartzose, weakly indurated, with red-brown clay shale stringers in lower part, exposed 2.0

DOG CREEK SHALE (Total thickness, 62.1 feet)

Shale, red-brown, silty, well-indurated, blocky 0.2

Shale, red-brown, silty, moderately indurated, blocky 3.8

Siltstone, moderate reddish-orange, argillaceous, blocky, moderately indurated, forming minor ledge 0.5

Shale, red-brown, silty, blocky 3.5

Unit G (Dog Creek):

Shale, dark red-brown to dark red, thinly laminated, platy ... 0.25

(Ewers Creek Section 12, continued)

Unnamed Unit (Dog Creek):

Shale, red-brown, silty, blocky 1.25

Unit F₂ (Dog Creek):

Siltstone, greenish-gray, mottled red-brown, well-indurated .. 0.4

Unnamed Unit (Dog Creek):

Shale, red-brown, silty, blocky, with many greenish-gray
spots 9.2

Unit F₁ (Dog Creek):

Siltstone, light greenish-gray, arenaceous, well-indurated,
waxy, massive, forming ledge 0.25

Siltstone*, greenish-gray, arenaceous, dolomitic, weakly
indurated, becoming red-brown in middle 0.75

Unnamed Units (Dog Creek):

Shale, red-brown, silty, blocky, with some greenish-gray shale
layers 3.75

Siltstone*, mottled red-brown and greenish-gray, arenaceous,
dolomitic, weakly indurated 0.75

Siltstone*, mottled moderate reddish-orange and greenish-gray,
arenaceous, dolomitic, well-indurated, forming ledge 0.2

Siltstone, mottled moderate reddish-orange and greenish-gray,
gypsiferous, argillaceous, thinly laminated, forming ledge . 1.75

Shale, red-brown, silty, platy, with many paper-thin calcite
layers 1.5

(Ewers Creek Section 12, continued)

Siltstone, moderate reddish-orange, mottled red-brown, argillaceous, moderately indurated, blocky, with some paper-thin selenite	1.2
<u>Unit E (Dog Creek):</u>	
Siltstone*, greenish-gray, argillaceous, weakly indurated	0.2
<u>Unnamed Units (Dog Creek):</u>	
Shale, red-brown, mottled greenish-gray, platy, with thin selenite in basal portion	1.6
Siltstone*, moderate reddish-orange, mottled greenish-gray, dolomitic, weakly indurated	0.4
Shale, red-brown, blocky, with some thin selenite layers	2.25
Siltstone*, greenish-gray, argillaceous, dolomitic, blocky, with many paper-thin selenite layers	0.2
Shale, red-brown, silty, blocky, mottled with some greenish- gray spots	1.0
<u>Unit D (Dog Creek):</u>	
Dolomite*, light-gray, fine-grained, dense, well-indurated, crinkly bedded, gypsiferous	0.1
Shale, dark-brown, weakly indurated, platy	0.8
Dolomite*, light-gray, mottled pink, fine-grained, dense, well-cemented, forming ledge	0.1
<u>Unnamed Units (Dog Creek):</u>	
Shale, dark-brown to dark red-brown, moderately indurated, blocky	2.6

(Ewers Creek Section 12, continued)

Siltstone*, greenish-gray, argillaceous, dolomitic, platy to blocky, with a thin dolomite seam at top (<u>Unit C</u>) and one 11 inches below top	2.7
<u>Southard Dolomite Member:</u>	
Dolomite*, light-gray, fine-grained, dense, well-cemented, weathering into a light-brown ledge	0.1
<u>Unit B (Dog Creek):</u>	
Shale, greenish-gray, dolomitic, blocky	1.75
Dolomite*, greenish-gray, silty, fine-grained, dense, well-indurated, thin-bedded, crinkly bedded, weathering into a ledge	0.2
Shale, red-brown, blocky	0.9
Dolomite*, light-gray to greenish-gray, silty, fine-grained, dense, thinly laminated, crinkly bedded	0.8
Shale, greenish-gray, moderately indurated, blocky	0.5
<u>Unnamed Units (Dog Creek):</u>	
Shale, dark red-brown, blocky, mottled with some greenish-gray spots	5.25
Siltstone*, light-brown, arenaceous, well-indurated, greenish-gray in upper 2 inches, forming ledge	1.2
Shale, red-brown, blocky, mottled with greenish-gray spots; section extrapolated to S½ sec. 15, T. 22 N., R. 17 W. ...	0.6
Siltstone*, greenish-gray, mottled red-brown, arenaceous, weakly indurated	0.3

(Ewers Creek Section 12, continued)

Shale and siltstone, red-brown to moderate reddish-orange,
mottled greenish-gray, moderately indurated, blocky 3.3

Unit A (Dog Creek):

Sandstone*, moderate reddish-orange, mottled greenish-gray,
well-indurated, thinly laminated, gypsiferous, crinkly
bedded, with many paper-thin satin-spar beds, forming ledge. 9.0

Unnamed Units (Dog Creek):

Shale, red-brown, mottled greenish-gray, blocky 2.3

Shale, greenish-gray, mottled red-brown, thin-bedded,
crinkly bedded 0.8

Shale, red-brown to dark-brown, blocky, as above 4.0

Watonga Dolomite Member:

Dolomite*, greenish-gray to light-gray, mottled red-brown,
fine-grained, dense, thin-bedded, slabby, well-cemented 0.2

Unnamed Units (Dog Creek):

Shale, red-brown, mottled greenish-gray, silty, platy 1.0

Siltstone*, greenish-gray, gypsiferous, crinkly bedded, thin-
bedded, with many paper-thin selenite layers, well-indurated
in basal 1 foot, forming ledge 1.5

Shale, dark-brown, silty, platy 1.0

Siltstone, red-brown, argillaceous, gypsiferous, well-indurated,
thin-bedded, crinkly bedded, with much selenite, forming
ledge 2.0

(Ewers Creek Section 12, continued)

Haskew Gypsum Member:

Gypsum, white, mottled red-brown, fine-grained, wavy bedded,
massive, forming ledge 0.5

Unnamed Unit (Dog Creek):

Shale, red-brown, silty, well-indurated, crinkly bedded, with
much gypsum 3.7

BLAINE FORMATION (Total thickness, 86.5 feet)

Shiner Gypsum Member:

Gypsum, white, fine-grained, well-cemented, laminated, with
crinkly upper surface 21.0

Altona Dolomite Member:

Dolomite*, light-gray, fine-grained, oblitic, medium-bedded,
weathering massive, in box-works; section extrapolated to NW $\frac{1}{4}$
sec. 11, T. 22 N., R. 17 W. 1.7

Unnamed Units (Blaine):

Shale, greenish-gray, weakly indurated, blocky 0.3
Shale, red-brown, blocky, mottled with greenish-gray spots ... 12.5

Nescatunga Gypsum Member:

Gypsum, white, fine-grained, massive, weathering coarsely
selenitic, forming escarpment 22.0

Maggie Dolomite Member:

Dolomite*, light-gray, oblitic, well-cemented, massive, grading
into gypsum at top, weathering into box-works 0.5

(Ewers Creek Section 12, continued)

Unnamed Units (Blaine):

Shale*, greenish-gray, dolomitic, blocky, weakly indurated, grading into argillaceous dolomite	2.0
Shale, red-brown, blocky	1.0

Kingfisher Creek Gypsum Member:

Gypsum, greenish-gray and red-brown, argillaceous, well- indurated, thin-bedded, crinkly bedded, forming ledge	1.2
---	-----

Unnamed Unit (Blaine):

Shale, red-brown, blocky, with much selenite	2.8
--	-----

Medicine Lodge Gypsum Member:

Gypsum, white, mottled light-gray, fine-grained, massive, weathering coarsely selenitic; section extrapolated to SW $\frac{1}{4}$ sec. 33, T. 23 N., R. 16 W., Major County	17.0
---	------

Cedar Springs Dolomite Member:

Dolomite*, light-gray to light-brown, fine-grained, oblitic, thin-bedded, grading upward into gypsum	4.5
---	-----

FLOWERPOT SHALE (Exposed thickness, 97.0 feet)

Unit K (Flowerpot):

Shale, greenish-gray, weakly indurated, blocky, grading upward into dolomite	0.6
---	-----

Units I-J (Flowerpot):

Siltstone, greenish-gray to light-brown, dolomitic, gypsiferous, well-indurated, crinkly bedded	0.4
--	-----

(Ewers Creek Section 12, continued)

Siltstone*, moderate yellow, dolomitic, gypsiferous, well-indurated, crinkly bedded	0.25
Shale, greenish-gray, mottled red-brown, weakly indurated, blocky, with some satin-spar layers	1.25
Shale, red-brown, mottled greenish-gray, with many satin-spar layers	5.25
Dolomite, greenish-gray, argillaceous, gypsiferous, well-indurated, crinkly bedded	0.1
<u>Unit H (Flowerpot)</u>	
Shale, red-brown, blocky, with some paper-thin selenite beds .	2.0
Shale, greenish-gray, weakly indurated, blocky	1.5
Shale, red-brown, blocky, with some satin-spar	3.75
<u>Unit G (Flowerpot):</u>	
Dolomite*, mottled red-brown and greenish-gray, silty, fine-grained, well-indurated, porous, thin-bedded, crinkly bedded	0.1
<u>Units E-F (Flowerpot):</u>	
Siltstone*, greenish-gray, blocky, with some red-brown shale streaks	5.5
<u>Unit D (Flowerpot):</u>	
Shale, red-brown, silty, blocky, weakly indurated, with some greenish-gray layers	3.25

ABSTRACT 3

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**THE RED EAGLE CYCLOTHEM
(Lower Permian)**

by

Alistair William McCrone
B.A., University of Saskatchewan, 1953
M.S., University of Nebraska, 1955

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December, 1960

Advisory Committee:

R. C. Moore
Chairman

H. A. Ireland

Walter M. Kollinger

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THE RED EAGLE CYCLOTHEM

by

A.W. McCrone

ABSTRACT

The Red Eagle Cyclothem, a Lower Permian marine sedimentary rock succession, includes rocks of the Johnson Shale, Red Eagle Limestone and Roca Shale formations.

Despite facies changes these stratigraphic units can be traced along their outcrop belt southward from Lincoln, Nebraska, across Kansas, to Burbank, Oklahoma.

Detailed stratigraphy, sedimentary petrography and paleontology of the Red Eagle Cyclothem provide the basis for interpretations of its paleosedimentation and the paleoecology of its plant and animal mega- and microfossils. Acetate peels and insoluble residues studies were used to advantage.

Postulates concerning the approximate physical and chemical characteristics of the Red Eagle Cyclothem waters are attempted. The assembled evidence supports Elias's (1937) proposal that the depositional environments of the various faunal-lithologic phases of the cyclothem were most directly controlled by marine water depths which ranged between approximately 10 and 180 feet.

Accumulation of red muds in shallow waters began the Red Eagle cyclothem succession in the middle part of Johnson time and concluded it near the middle of Roca time. Muddy depositional conditions which produced the upper part of the Johnson Shale were similar to those which later produced the lower part of the Roca Shale. In the meantime the Red Eagle limestones and their shaly equivalents accumulated in the deepest, lime-rich waters of the cyclothem.

Fossil spores present in the Red Eagle Cyclothem seem similar to later Permian floral assemblages from other parts of the world.

This investigation of the Red Eagle Cyclothem is the outgrowth of personal interest in the Red Eagle Limestone itself. Preliminary work showed that this formation could not be understood properly unless the Johnson Shale and overlying Roca Shale were studied also, because the Red Eagle Cyclothem extends from the Johnson Shale through the Red Eagle Limestone into the Roca Shale. The present objective is to interpret the geologic and paleogeographic setting that yielded lithofacies and biofacies recognizable as the Red Eagle Cyclothem in Kansas. This approach entails suggestions,

INTRODUCTION

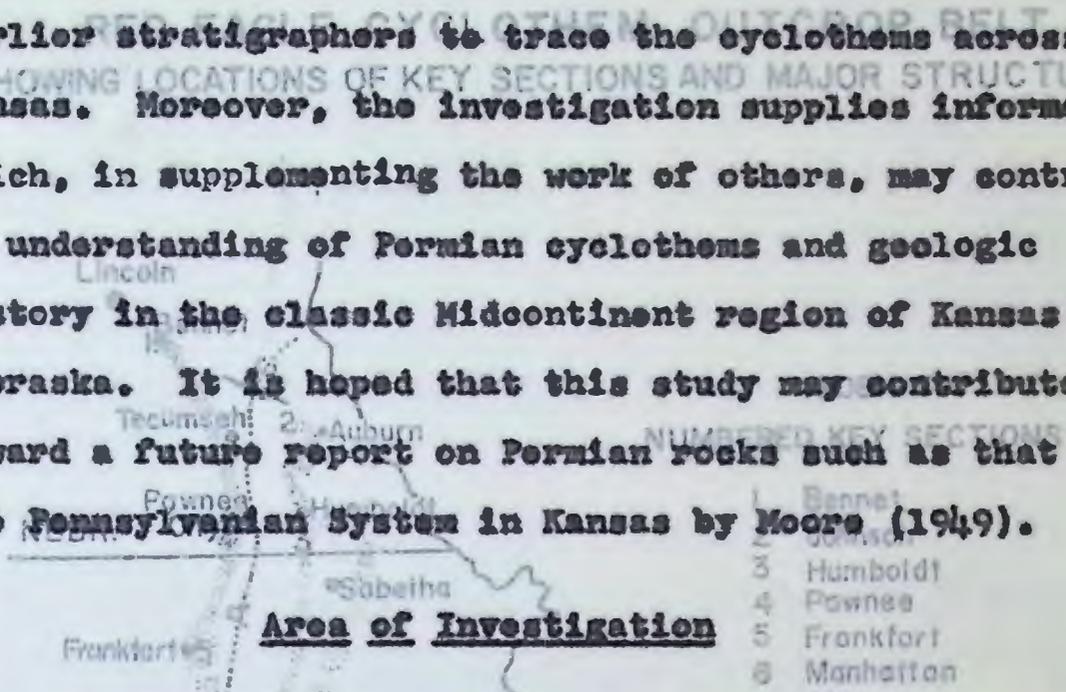
Purpose and Scope of Investigation

"Cyclothem," especially in Pennsylvanian rocks, have provoked much study and discussion. They present problems of correlation which can be resolved only by detailed studies that lead to paleoecological interpretations. Once their stratigraphy and paleoecology are understood, the problems of origin remain. The subject is still open, especially in the Lower Permian of Kansas, where many cyclothem remain to be studied in detail. Understanding of the broader aspects of the origin of cyclothem and of Permian cyclothem history cannot be expected until most or all of the Lower Permian cyclothem have been examined carefully.

This investigation of the Red Eagle Cyclothem is the outgrowth of personal interest in the Red Eagle Limestone itself. Preliminary work showed that this formation could not be understood properly unless the underlying Johnson Shale and overlying Roca Shale were studied also, because the Red Eagle Cyclothem extends from the Johnson Shale through the Red Eagle Limestone into the Roca Shale.

The present objective is to interpret the paleo-sedimentary and paleoecological setting that yielded lithofacies and biofacies recognizable as the Red Eagle Cyclothem in Kansas. This approach entails explanations

of certain facies patterns that hindered attempts by earlier stratigraphers to trace the cyclothem across Kansas. Moreover, the investigation supplies information which, in supplementing the work of others, may contribute to understanding of Permian cyclothem and geologic history in the classic Midcontinent region of Kansas and Nebraska. It is hoped that this study may contribute data toward a future report on Permian rocks such as that on the Pennsylvanian System in Kansas by Moore (1949).



Area of Investigation

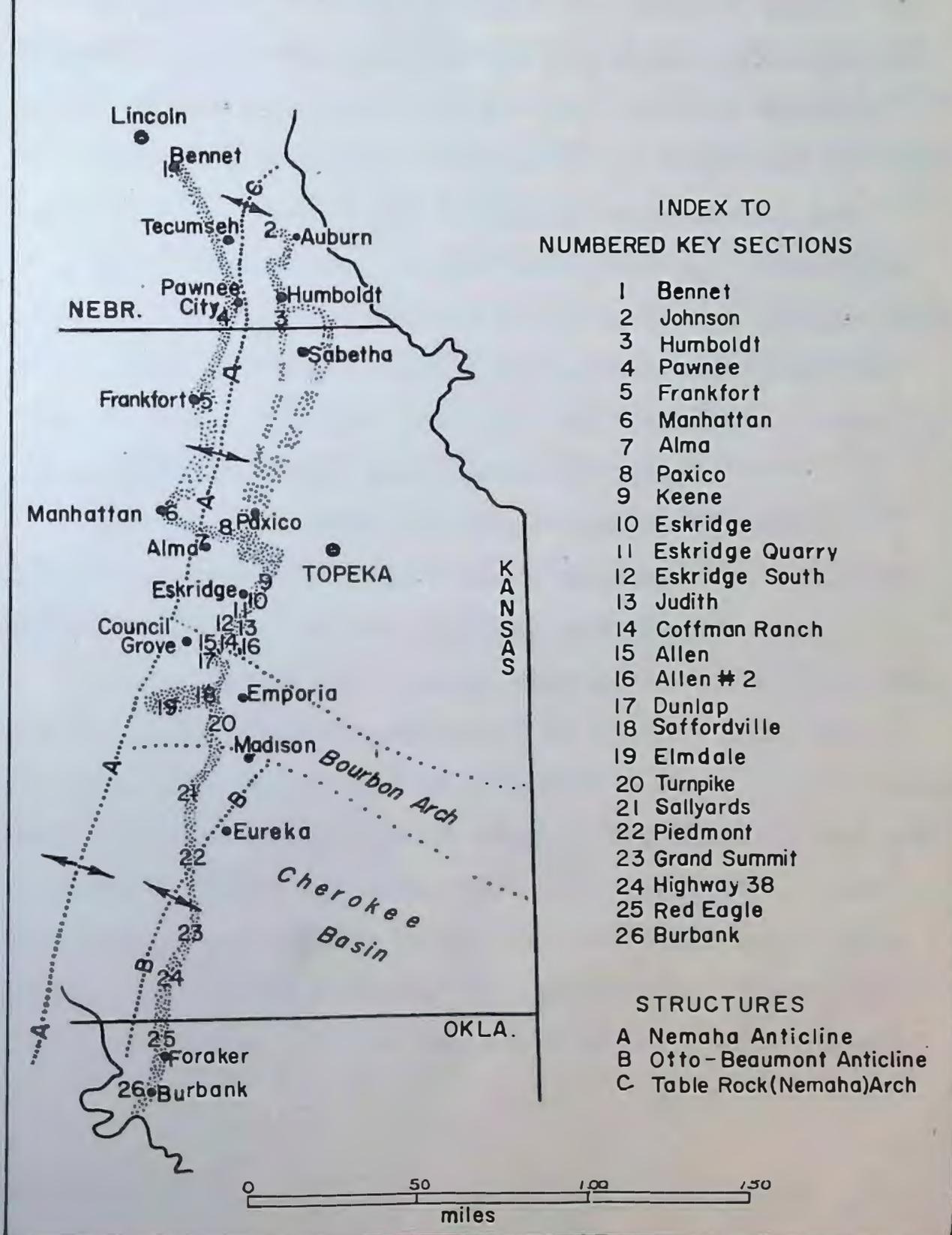
The Red Eagle Cyclothem crops out along a narrow belt extending roughly north-south from Lincoln, Nebraska, through Manhattan, Kansas, to the oilfield of Burbank, Oklahoma (Fig. 1).

Well-exposed sections are rare. Most limestone members form minor topographic benches, but shales commonly lie beneath shallow grassy slopes and are exposed in relatively few places. Fortunately, road cuts and quarries provide sections in areas where nature did not.

From Chase County, Kansas, northward to Lincoln, Nebraska, the more resistant (limestone) members of the Red Eagle assemblage are thin and, where exposed, form only minor benches on valley slopes below the major upland benches of the Neva and Cottonwood Limestones. In southern Kansas and northern Oklahoma, where the Red Eagle becomes

Figure 1

RED EAGLE CYCLOTHEM OUTCROP BELT SHOWING LOCATIONS OF KEY SECTIONS AND MAJOR STRUCTURES



INDEX TO NUMBERED KEY SECTIONS

- 1 Bennet
- 2 Johnson
- 3 Humboldt
- 4 Pawnee
- 5 Frankfort
- 6 Manhattan
- 7 Alma
- 8 Paxico
- 9 Keene
- 10 Eskridge
- 11 Eskridge Quarry
- 12 Eskridge South
- 13 Judith
- 14 Coffman Ranch
- 15 Allen
- 16 Allen # 2
- 17 Dunlap
- 18 Saffordville
- 19 Elmdale
- 20 Turnpike
- 21 Sallyyards
- 22 Piedmont
- 23 Grand Summit
- 24 Highway 38
- 25 Red Eagle
- 26 Burbank

STRUCTURES

- A Nemaha Anticline
- B Otto-Beaumont Anticline
- C Table Rock(Nemaha)Arch

a thick limestone, it forms benches more conspicuous than the Neva and Cottonwood.

In northern Kansas, between the Nebraska border and Manhattan, beds belonging to the Red Eagle Cyclothem are mostly hidden by glacial tills. This lack of exposure presented no correlation problem in the course of the Red Eagle studies because the sequences at Manhattan and Frankfort, Kansas, and Pawnee, Nebraska, are remarkably similar. In southern Kansas, however, facies changes occur where there are few outcrops, so that correlations are less obvious. The best Red Eagle exposures are in Nebraska and between Manhattan and Emporia in Kansas.

The entire belt of Red Eagle outcrop is readily accessible from state and federal highways and a closely spaced network of county highways and minor roads.

Topography of the outcrop belt is dominated by gently rolling hills, locally supported by flatter limestone benches. The relief rarely exceeds 200 feet. Major valleys such as those of the Nemaha, Kansas, Big Blue, Neosho and Cottonwood rivers are wide, with alluvial floors. The many lesser tributaries derive most of their water from normal runoff, but a number are spring-fed. Vegetation ranges from grass on the uplands to woods in the valleys.

Stratigraphic Position of the Red Eagle Cyclothem

The Lower Permian of Kansas contains many cyclic repetitions of lithologic sequence. Each cycle of rocks is called a cyclothem. Each cyclothem is named from its principal limestone formation. Thus, the Red Eagle Cyclothem is named from the Red Eagle Limestone.

The Red Eagle Cyclothem embraces the Johnson, Red Eagle and Roca formations (Table 1). These rocks occur in the Council Grove Group of the Lower Permian (Wolfcampian) about 150 feet stratigraphically above the base of the system (Moore and Moss, 1934). Red shales within the Roca and Johnson formations mark the upper and lower limits, respectively, of the Red Eagle Cyclothem (Elias, 1937).

TABLE 1. Stratigraphic Placement of Red Eagle Cyclothem Units (Marked by Asterisks) in Lower Permian Rock Succession of Kansas.

The area of this investigation, famous for its distinctive Wolfcampian Stage Permian rocks, for over 100 years has been the subject of study by geologists from all parts of the world and several foreign countries. Some of the early workers in this region of America listed these rocks in their papers as follows:

Wolfecampian Stage
 Chase Group
 Council Grove Group
 Speiser Shale
 Funston Limestone
 Blue Rapids Shale
 Crouse Limestone
 Easy Creek Shale
 Bader Limestone
 Stearns Shale
 Beattie Limestone
 Merrill Limestone
 Florence Shale
 Cottonwood Limestone
 Eskridge Shale
 Grenada Limestone
 Neva Limestone
 Salem Point Shale
 Burr Limestone
 Legion Shale
 Sallyards Limestone
 * Roca Shale
 * Red Eagle Limestone
 * Howe Limestone
 * Bennett Shale
 * Glenrock Limestone
 * Johnson Shale
 Foraker Limestone
 Long Creek Limestone
 Hughes Creek Shale
 Americus Limestone
 Adaire Group
 Virgilian Stage (Pennsylvanian System)

Some of the Red Eagle Cyclothem were included by Crosson (1932) in the "Almota Formation," which included rocks ranging upward from the top of the Americus Limestone member of the Foraker Limestone, to the base of the Neva Limestone member of the Grenada Limestone. Crosson (1932) did not cite this classification essentially due to

Previous Geologic Work

The area of this investigation, famous for its distinctive Pennsylvanian and Permian rocks, for over 100 years has been visited and studied by geologists from all parts of the United States and several foreign countries.

Some of the earliest scientific explorers of America noted these rocks, sampled their profuse fossil remains, measured and described sections. Swallow and Hawn (1858) published the earliest reference to Permian rocks in Kansas. Meek and Hayden (1860) added more, as did Swallow (1866) when he placed the lower boundary of the Permian at a horizon included in the Grenola Limestone of present classification. This position is stratigraphically above the Red Eagle Cyclothem.

In the 65 years following Swallow's (1866) publication, a series of renamings and reclassifications of Upper Pennsylvanian and Lower Permian rocks appeared in the literature. The newer positive correlations led to revision of the older classifications.

Rocks of the Red Eagle Cyclothem were included by Prosser (1902) in the "Elmida^o Formation," which embraced rocks ranging upward from the top of the Americus Limestone member of the Foraker Limestone, to the base of the Nova Limestone member of the Grenola Limestone. Bass (1929) did not alter this classification essentially when he

added the Neva Limestone to Prosser's "Elmdale Formation." By moving the Pennsylvanian-Permian boundary upward to the base of the Cottonwood Limestone member of the Beattie Limestone he left the Red Eagle rocks in the Upper Pennsylvanian.

Moore and Moss (1934) defined the Pennsylvanian-Permian boundary at the base of the Indian Cave Sandstone, which is the lowest unit of the Admire Group. Thus, the Johnson, Red Eagle and Roca formations were transferred to the Lower Permian.

The Johnson and Roca formations were named by Condra (1927) and have presented no serious correlation problems because they lie between widely persistent, readily recognizable units.

The Red Eagle Limestone was named by Heald (1916) from exposures in Osage County, Oklahoma. It was thought to be part of the "Elmdale Formation" of Prosser (1902).

Condra (1927) named the Glenrock, Bennett and Howe units from exposures in southeastern Nebraska. Subsequently, Condra traced them southward into Kansas, where he was able to recognize them near Manhattan and elsewhere.

O'Connor and Jewett (1953, p. 333) summarized the work of Bass (1936) in establishing the correlation of the Glenrock, Bennett, and Howe, of Nebraska, with the Red Eagle Limestone of Oklahoma as follows:

"Bass (1929, pp. 54-55) identified the Red Eagle limestone in Cowley County, Kansas, and expressed the belief that it is continuous into central Kansas in the Cottonwood River Valley. Later, Bass (1936, pp. 41-42) stated that he recognized as members of the Red Eagle limestone beds in Cottonwood River Valley bluffs east of Elmdale that Moore and Condra had identified as equivalents of the Glenrock limestones, Bennett shale, and Howe limestone of northern Kansas and southern Nebraska. Thus, correlation of the Red Eagle limestone, Bennett shale, and Howe limestone in southern Nebraska was indicated."

The work of O'Connor and Jewett (1952) verified the correlations indicated by Bass (1936), and added some detailed stratigraphic descriptions useful in tracing the Red Eagle formation across Kansas.

Jewett (1933) recognized the "cyclic" nature of certain Permian rocks of Kansas. This was greatly amplified by Elias (1937) when he described the faunas associated with the sequences of lithologic units making up the cycles of the Lower Permian ("Big Blue Series") of Kansas. Elias's principal postulate is that the repeated lithologies and especially the faunas of the cycles were controlled primarily by water depth during deposition.

Moore (1959) lucidly summarized the present understanding of cyclic sedimentation as manifested in Pennsylvanian and Permian rocks of Kansas. His conclusions emphasized the need for more study of cyclothem.

Several recent county reports published by the State Geological Survey of Kansas and the United States Geological Survey contain brief general descriptions and measurements

Limestones were sampled by removing, where possible, of rocks of the Red Eagle Cyclothem. References to these reports appear in the bibliography.

Methods of Investigation

Field Procedures

During preliminary field reconnaissance for this project in the fall of 1956, primary interest in the Red Eagle Limestone formation was extended to include the Johnson and Rosa formations. For purposes of comparison, other cyclothem rocks of the Council Grove Group were also studied. Detailed sampling and study of sections for this report was begun in the fall of 1958.

Most Red Eagle exposures are readily accessible by car, but some of the creek-bank outcrops must be reached on foot.

Approximately 50 exposures were examined. Of these, 22 were measured, sampled and described in detail.

Continuous shale samples were obtained by channelling through the section, extreme care being taken to avoid contamination. Intervals as thin as 0.05 feet were sampled, where field relations dictated. Between 1- and 5- (rarely 10-) pound samples were usually taken. Thick beds with uniform lithologies were sampled at intervals of not more than 0.5 feet to avoid overlooking details of microfacies not observed in the field. Thus, at least one sample was taken from every lithologic unit thicker than half an inch.

Limestones were sampled by removing, where possible, a fresh vertically-oriented slab or elongate fragment from fractured portions of the outcrop. This was best accomplished in road cuts where blasting had provided

freshly-fractured limestone in place. Each sample was marked to indicate the top of the bed. More than a ton of shale and limestone samples were taken in the manner described.

Shale samples were boiled in a dispersant solution to liberate mega- and microfossils. Dispersed silts and clays were usually deposited. Some dispersed clays were

Laboratory Procedures Every sample was examined under the binocular microscope to check and augment the field description.

Representative small limestone samples were broken to pea-size, using mortar and pestle. A weighed quantity of each broken sample was then digested in dilute (10 percent) hydrochloric acid, following procedures described by Ireland (1936, 1958). Insoluble residues from each digested sample were weighed, and later studied under the binocular microscope. Percentage (by weight) of insoluble material in each sample was computed and expressed in bar graphs beside a work sheet showing the graphic rock column (Appendix III). A few selected limestone samples were digested in acetic acid to check against the results obtained from the same material in hydrochloric acid. Differences between the two were insignificant, but conodonts were preserved in residues obtained with acetic acid and

I.) Later in the project the polished limestone surfaces were compared and studied alongside the magnified peel and evaluation of the special insoluble residues technique used in this study appears in Appendix I.

Microfossils were picked from the insoluble residues and identified as to genus.

Shale samples were boiled in a dispersant solution to liberate mega- and microfossils. Dispersed silts and clays were usually decanted. Some dispersed clays were allowed to settle on microscope slides for use in X-ray studies. The dried shale samples also yielded microfossils and megafossils which were subsequently identified generically. Detailed description of "washed-shale" technique is given in Appendix I.

Limestone specimens were cut perpendicular to the bedding planes and polished. The polished surfaces were etched for 5 or 10 seconds in dilute (1 percent) hydrochloric acid. When the imperceptibly etched surfaces were dried, acetate film was pressed against them to obtain on the film an impression of the rock texture. These films were then used in a photographic enlarger to make magnified photographic prints (peel-prints) of the textural details. The technique used to prepare the acetate peels for this study differs in several respects from common procedures. It was faster, but results were approximately the same. (Detailed explanation of this technique appears in Appendix

I.) Later in the project the polished limestone surfaces were compared and studied alongside the magnified peel photographs.

The laboratory procedures described above were supplemented by X-ray diffraction studies and differential thermal analyses of clays from selected samples. Fossil spore content of selected samples was also determined.

Acknowledgements

To the several members of the Kansas Geological Survey who have helped me in this work I offer my sincere appreciation. I wish to thank Profs. L.F. Dellwig, P.C. Foley, and H.A. Ireland for making special facilities available to me at critical times.

The help of Mr. H. Cousminer, who identified the fossil spores, is gratefully acknowledged. To Prof. Raymond C. Moore who supervised this work from its inception, I extend my greatest thanks.

In southeastern Greenwood County the trend of the Osage Seamount anticline swings northward toward Neosho. The Red Eagle outcrop belt continues northward, in a position between the Neosho anticline to the west and the Osage Seamount arch to the east.

Farther north, the head of outcrop lies almost the Neosho-Bourbon arch area of Chase County, and the Neosho-Alex

STRATIGRAPHY

Structural-Stratigraphic Setting

Jewett (1951) provided a concise summary of the major structural features of Kansas. Reed (1954) indicated the Nebraska names for extensions of the structures identified by Jewett. As examples: Table Rock arch is the Nebraska name for the famous Nemaha anticline of Kansas; Central Nebraska basin is the Nebraska name for the northern extension of the Salina basin of Kansas.

It should be interesting to observe the relations of the Red Eagle Cyclothem to these structures because if they existed or had been initiated in Red Eagle time they might have influenced the cyclothem sedimentary facies. Figure 1 shows significant structures.

In southern Kansas (Cowley and Elk counties) the Red Eagle Limestone crops out close to the axis of the Otto-Beaumont anticline. The outcrop belt is closely parallel to this structural trend.

In southwestern Greenwood County the trend of the Otto-Beaumont anticline swings northeastward toward Eureka. The Red Eagle outcrop belt continues northward, in a position between the Nemaha anticline to the west and the Otto-Beaumont arch on the east.

Farther north, the band of outcrop lies athwart the Nemaha-Bourbon arch area of Chase County, and the Nemaha-Alma

arch areas of Riley and Wabaunsee counties. Northward from Manhattan the band of outcrop divides, running parallel to the Nemaha anticline on either flank in Marshall and Nemaha counties, Kansas, and in Nebraska.

The close association of the outcropping rocks with these structurally positive areas raises a question as to whether the structures were tectonically active during deposition of the Red Eagle Cyclothem, and if so, whether they controlled the sedimentary facies. Evidence to support this possibility may be sought in facies changes in Red Eagle rocks as the belt of outcrop wanders away from, or toward, the aforementioned structural trends.

Moreover, the facies patterns may give evidence not only of activity along major structural trends (e.g., Nemaha anticline) during Red Eagle time, but they also may indicate short intervals of tectonic activity in isolated areas where the structural record has not been amplified by accumulated "extra-Red Eagle" movements.

Whereas rocks of the Red Eagle Cyclothem crop out along a belt trending roughly north-south from Lincoln, Nebraska, through Manhattan, Kansas, to Burbank, Oklahoma, their gentle regional dip is toward the west. They can be detected in wells drilled as far west as Barber and Rice counties, Kansas.

Figure 1 shows the outcrop belt and locations of key sections that were measured and sampled for this report. Detailed descriptions and illustrations of these sections appear in Appendix III. Plate 19 (Appendix III) is a simplified north-south cross section through localities shown on Figure 1, showing fundamental correlations of rock units within the Red Eagle Cyclethen.

General Statement

The Red Eagle Limestone is easily identified by its position above the gray shales and mudstones of the Johnson Shale and is easily recognizable below the lowest fusulinid-bearing limestone (Glenrock) of the Red Eagle Limestone, and above the upper (Long Creek) limestone member of the Foraker Limestone. Where best exposed, near Manhattan, Kansas, the Red Eagle Limestone is a sort of "sandwich" -- the gray Bennett Shale member lies between the Glenrock Limestone member, below, and the pelletoid Howe Limestone member, above.

The Glenrock member is a single, massive, light-brown limestone unit about 1 foot thick containing abundant fusulinid remains. Its uniformity of thickness and lithology through 150 miles of outcrop from Lincoln, Nebraska, to Allen, Kansas, is truly remarkable.

The Bennett member can be readily recognized by its basal "black" Orbiculoides-bearing shale that rests on the distinctive Glenrock Limestone. The gray shales and rare

limestones of the Bennett member may also be identified by their relations to the overlying (equally distinctive) Howe Limestone.

The Howe member is a massive limestone unit 2 or 3 feet thick. In a number of localities it is uniquely pelletoid (pseudo-oolitic). The pellets are coatings of calcium carbonate around tiny nuclei such as foraminifers or ostracodes.

The Roca Shale is easily identified by its position above the Howe Limestone. The top of the Roca is equally well defined at the base of the overlying Sallyards Limestone (lowest member of the Grenola Limestone). The Sallyards Limestone is a thin, light gray-brown unit crowded with well-preserved pelecypods (e.g., Pseudomonotis, Aviculopecten). Red shales are common in the midst of the principal gray and greenish-gray shales of the Roca Shale.

The three members of the Red Eagle "sandwich" merge to form the thick Red Eagle Limestone of southern Kansas and northern Oklahoma. In the same area, as farther north, Johnson and Roca Shales are readily recognizable by their relations to the distinctive Red Eagle Limestone and to other marker horizons above and below. Near Burbank, Oklahoma, the Roca Shale is mostly red.

Rocks of the Red Eagle Cyclothem can be detected and traced in wells as far west as central Kansas, where their general stratigraphic relations remain similar to those in

the outcrop belt. Well records of the Kansas Geological Survey yield little information about rocks in the Red Eagle part of the column. Marker beds above and below the Red Eagle Cyclothem are all that can be safely identified, and these are known chiefly from electric logs. Sample logs of rocks between the markers (especially the shales) are muddled because of cavings and the thinness and numerous alternations of the various lithic components. This precludes the reconstruction of accurate detailed sections from the few available cuttings samples. Hattin (1958, p. 107) reported similar difficulties.

The available electric logs and sample logs permit identification of the Red Eagle limestones, and provide a general impression of Johnson and Roca shales. A fundamental similarity of subsurface sections to outcropping sections is indicated. Lee (1949) has shown that the thicknesses and major lithic types of the Johnson, Red Eagle and Roca in southern and central Kansas are generally similar to those in the outcrop belt 100 miles to the east. These data indicate that, in the southeastern quadrant of Kansas, major facies patterns of the Red Eagle Cyclothem developed in roughly east-west belts. Well data reveal the presence of gray and red shales in the Roca Shale, and gray shales in the Johnson Shale. Traces of selenite seem to be present near the redbeds in the subsurface Roca. Only

slightly calcareous (50 percent), slightly silty shales of

the predominant limestone components of the Red Eagle formation are identifiable. The thin Bennett Shale is not recognized in the subsurface.

Johnson Shale

The Johnson Shale was named by Condra (1927, p. 86).

"From exposures 1 1/2 miles north of Johnson, Johnson County, Nebraska; formed of bluish argillaceous shale modified by thin, grayish, sandy layers, calcareous plates, and some gypsiferous material, and geodes; thickness 16 to 18 feet. There are very few fossils."

The Johnson Shale is still well exposed in a creek bank north of Johnson, Nebraska, approximately where Condra indicated (Johnson section, Appendix III). However, Johnson is in Nemaha (not Johnson) County, Nebraska. This location is east of the axis of the Table Rock (Nemaha) anticline (Fig. 1).

At the type locality the base of the Johnson Shale is difficult to ascertain. The Long Creek Limestone below is badly disintegrated and weathered to a rusty to greenish limonitic, chalky, soft residuum. In parts of Kansas the Long Creek Limestone is more resistant and clearly defined.

The Johnson Shale is approximately 17 feet thick at the type locality, where it is comprised mainly of medium- to light-gray mudstones. Greenish-gray shales occur just above the middle of the unit, and medium-gray shales comprise the upper 2 feet. The medium-gray, moderately laminated, highly calcareous (50 percent), slightly silty shales of

the upper 2 feet weather to a light-buff color. Some of the shales seem to be vaguely ripple-marked. Laboratory examination reveals the presence of fish teeth, ostracodes, and small gastropods.

A thin, light brownish-gray, argillaceous limestone underlies the upper, fossil-bearing shales. In the field this limestone appears aphanitic or microcrystalline, but actually it is a laminated argillaceous calcisiltite with a few angular calcareous mudstone fragments (Pl. 1A). It shows vague small-scale diastems and graded bedding. Fragments of carbonized woody-plant detritus are present in the light greenish-gray mudstones that immediately underlie the aforementioned limestone.

At the type locality the remainder of the Johnson Shale, down to its base, is mainly greenish-gray calcareous mudstones. In the lower half of the formation these mudstones are slightly less calcareous than those above. A thin plate of light brownish-gray, dense, argillaceous limestone occurs just below the middle of the formation, but below it the only "limestones" present are sparse calcium carbonate nodules within the greenish-gray calcareous mudstones.

At the northernmost exposure, near Bennet,¹ Nebraska,

1. The spelling "Bennet" is correct for the town but not for the rock unit named from this locality.

the Johnson Shale is similar to the type section, with only a few minor differences in general aspect. This location



Plate 1

- A. Enlarged (X3) peel-print of laminated argillaceous calcisiltite of upper Johnson Shale at Johnson section. Note the angular calcareous mudstone granules.
- B. Peel-print (X3) of upper Johnson "platestone" at Pawnee section.

is about 25 miles northwest of the axis of the Table Rock (Nebraska) anticline. The Johnson Shale is about 16 feet thick at the Bennet section (Appendix III). The upper 2 feet of medium-gray, well-laminated shale is equivalent to the upper 2 feet of moderately-laminated shale at the type section. This shale is barren of fossils, and much less calcareous (15 percent) than its equivalent at the type section. The rest of the formation consists almost entirely of moderately-laminated calcareous light-gray shales. The lower half of these is somewhat more calcareous than the upper, in contrast to the conditions at the type section.

A thin, brick-red shale which seems to have no red equivalent anywhere else appears in the middle of the Johnson Shale at the Bennet section. Shales with limestone lenses near the base of the Bennet section (Appendix III) seem equivalent to the mudstones with limestone nodules near the base of the type section. Traces of foraminifers, gastropods, and fish teeth occur about 5 feet from the base of the Bennet section.

To the south, in Pawnee County, Nebraska, 6 miles west of the Table Rock (Nebraska) anticline axis (Pawnee section, Appendix III), the Johnson Shale is composed of mudstones, also very similar to those at the type locality. Rare fragments of carbonaceous plant remains occur in thin, shaly, medium-gray mudstones in the top foot of the unit. These fine-silty mudstones contain traces of ostracodes, a few

clay-filled tubes suggesting worm burrows, and local mudstone-pebble breccia (some pebbles are oriented roughly parallel to bedding planes). The rest of the formation is virtually unfossiliferous.

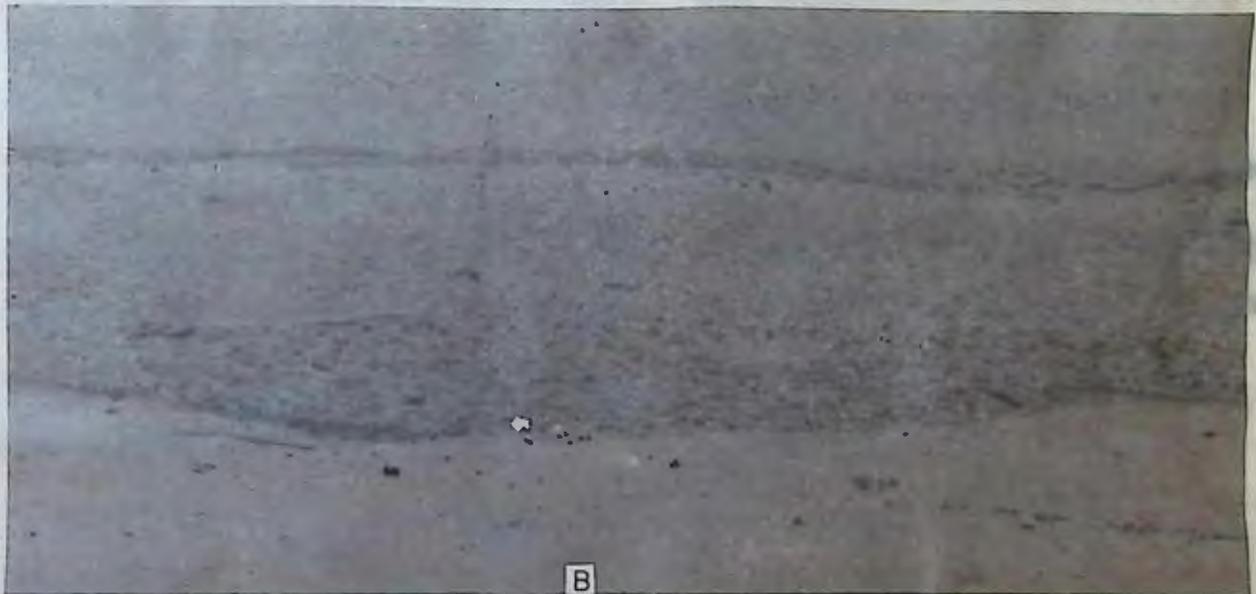
A compact laminated noncalcareous siltstone or mudstone unit (microbrecciated in places) appears near the top of the Johnson Shale at Pawnee. Textures vary microscopically from one lamina to another (Pl. 1B). This unit yields platy debris, and is called "platestone" for convenience in the following descriptions. Commonly this unit is calcareous. It can be traced southward at least as far as Eskridge, Kansas.

The remainder of the formation at the Pawnee section is mainly gray and greenish-gray mudstones and calcareous muddy siltstones. They rest on pitted, light-brown, sublithographic Long Creek Limestone. This uniform sequence is interrupted only by a massive foot of argillaceous limestone, vaguely nodular in some places, which occurs about 2 feet below the platestones. Megascopically this limestone appears uniformly microgranular to aphanitic. However, magnified peel-prints reveal that it contains minute wavy laminations associated with microscopic graded textures (Pl. 2A), suggesting faint diastems.

About 20 miles east of the Pawnee section, 0.5 miles east of the Humboldt fault, the upper portion of the Johnson Shale is exposed in a small road cut (Humboldt section,



A



B

Plate 2

- A. Peel-print (X3) of limestone in Johnson Shale at Pawnee section. Note wavy laminae and microscopic graded texture.
- B. Peel-print (X3) of upper Johnson platestone at Keena section. Note laminae and microscopic graded textures.

Appendix III). The upper Johnson sediments resemble those at the Pawnee section in general appearance, but they are more calcareous. In carbonate content they resemble the upper Johnson at the type section. At the Humboldt section a thin uppermost shale unit of the Johnson Shale correlates with shales in analogous position at the other Nebraska sections. The difference at Humboldt is that these upper shales are deeply weathered from their original gray color to a light yellowish buff.

The Frankfort section lies just west of the axis of the Nemaha anticline, about 30 miles south of the Pawnee section. Only the upper portion of the Johnson Shale is exposed at Frankfort -- sufficient to show the same clay shale at the top, and a thinner, more compact platestone unit than manifest farther north. Ostracodes occur in shales between these units. Here the platestone is a limestone, thinly laminated, yielding platy debris much more brittle than the argillaceous equivalents to the north. The bulk of the Johnson Shale at Frankfort consists of calcareous, light-gray and greenish-gray shales and mudstones typical of the Johnson Shale elsewhere.

At the Manhattan section the Johnson Shale is largely light-gray shales, with some light greenish-gray shales in the lower half. The section is as thick (16 feet) here as in Nebraska where other complete sections of Johnson Shale are exposed. The distinctive platestone horizon occurs

about 4 feet below the top of the formation, although nearby it is only 2 feet below the top. Above it are the usual ostracode-bearing light-gray shales, topped by a foot of well-laminated shales containing traces of crinoid, bryozoan, brachiopod, and ostracode remains. These uppermost shales correlate with beds similar in position and lithology farther south. Beneath the platestone unit, the medial few feet of the formation contain light-buff to gray argillaceous limestones and highly calcareous light-gray shales. Greenish-gray and gray, slightly calcareous shales comprise the lower third of the formation. The base rests on resistant Long Creek Limestone. The Manhattan section lies just west of the crest of the Nemaha anticline.

The Alma section (Appendix III) is 20 miles southeast of Manhattan and east of the Nemaha anticline. At this locality only a few feet of the Johnson Shale are sufficiently exposed to permit reliable sampling. The familiar platestones occur here, overlain by the equally familiar ostracode-bearing gray shales of the uppermost Johnson. Slumping confuses suprajacent beds, but the fossils certify that the sampled shales are nearly equivalent to the topmost Johnson Shale. However, the local absence of the Glenrock Limestone precludes definitive measurement to the top of the Johnson.

The upper portion of the Johnson Shale is well-exposed at the Paxico section (Appendix III). Three feet of the

typical gray, well-laminated, ostracode-bearing shales top the formation, and rest on 4 feet of calcareous mudstones. These in turn rest on the platestones. Thus, at the Paxico section, there is about twice the usual thickness of Johnson sediments above the platestone horizon. Moreover, the platestones themselves are comparatively even-textured and less argillaceous than at other sections. Light greenish-gray mudstones lie beneath the platestones.

At the Keene section (Appendix III), 10 miles southeast of Paxico, only the platestone part of the Johnson Shale is well exposed. Here the platestones are well laminated, with the usual microscopically graded textures (Plate 2B). Their low content of insoluble mud is similar to that of the platestones at Paxico. About 5 feet of upper Johnson shales above the platestones are not exposed.

The Eskridge section (Appendix III) is the southernmost exposure of the platestone facies in the Johnson Shale of Wabaunsee and Lyon counties. The platestone is faintly ripple-marked and shows channelling as deep as 2 mm. About 2.5 feet of ostracode-bearing shales lie above the platestone. Light-gray and greenish-gray calcareous mudstones and shales typical of the Johnson Shale lie below. These are similar to their equivalents in Nebraska and northern Kansas, except that rare traces of ostracodes and carbonaceous remains occur in the upper 2 or 3 feet. Charophytes are present near the base of the formation.

At the Eskridge South section (Appendix III), 4 miles south of the Eskridge locality, the upper half of the Johnson Shale is partially exposed in a farmyard. Dark-gray, calcareous, ostracode-bearing shales, some with plant remains, comprise the upper 5 feet of the unit. These rest on muddy limestones equivalent to the platestone but somewhat thicker than normal. The lower part of the exposure shows greenish-gray shales below a thin local argillaceous limestone that contains traces of ostracodes.

The few feet of upper Johnson sediments exposed at the Coffman section (Appendix III) are quite similar to those at Eskridge South. Ostracodes and carbonaceous plant remains are common in the upper calcareous shales. Traces of carbonaceous remains are visible in the underlying laminated muddy limestones.

At the Allen section (Appendix III) carbonaceous remains and ostracodes are common in the upper shale of the Johnson Shale. These rest on vaguely laminated muddy limestones and limy mudstones very similar to their stratigraphic equivalents at the nearby Coffman locality.

About 40 miles to the southwest of Allen, at the Elmdale section (Appendix III), the upper two-thirds of the Johnson Shale are well-exposed. Here too, plants and ostracodes are present in the uppermost shales. A laminated platy argillaceous limestone unit, faintly ripple-marked, is the apparent equivalent of the so-called platestones farther

north in Kansas. Some of the laminations are extremely smooth and even. Greenish-gray mudstones, increasingly calcareous towards the base, comprise the remainder of the formation.

At the Saffordville section, 12 miles east of Elmdale (Appendix III), only platy limestones (platestones) bearing ostracodes are exposed below the Red Eagle formation.

In southern Kansas, at the Grand Summit section (Appendix III), the upper half of the Johnson Shale is well exposed. The uppermost 5 feet are light brownish-gray, calcareous, well-laminated shales containing light-gray aphanitic limestone nodules and lenticles. The shales contain gastropods, ostracodes, brachiopods, and carbonized fragmental plant material. Among the brachiopods, Linoproductus, Chonetes, and Productella are common. Gastropod and brachiopod fragments occur in the limestones. Calcareous mudstones comprise the remainder of the formation at Grand Summit.

At the Highway 38 section (Fig. 1) in Cowley County, the upper half of the Johnson Shale is similar to that at the Grand Summit locality (Appendix III). Here, in the upper 5 feet, similar shales with nodular limestones contain the same assemblage of ostracodes, plant remains, and common productid brachiopods observable at Grand Summit. They lie above 3 feet of barren calcareous gray shales.

Because it is complete, the Highway 38 exposure permits observation of the light-gray mudstones which comprise most of the lower part of the Johnson Shale. A thin maroon mudstone occurs near the base of the section. This is interpreted to mark the base of the Red Eagle Cyclothem. No good exposures of Johnson shales are known south of this locality. Red Eagle Limestone was named by Beal (1916).

Summary. The Johnson Shale is a distinct unit composed mainly of light-gray shales and mudstones immediately below the distinctive Red Eagle Limestone. In Nebraska it is at least 15 feet thick, and it thickens to a maximum of 18 feet southwards through Kansas. Workable exposures are rare. In most places, especially southern Kansas and northern Oklahoma, it forms gentle grass-covered slopes between thin limestone benches. Maroon mudstones have been observed in the lower half of the formation only at the Oklahoma-Kansas border, in southern Kansas, and at Bennet, Nebraska. In southern Kansas the upper 5 feet of the Johnson Shale are fossiliferous shales, containing aphanitic limestone nodules and lenticles. From central Kansas to the Nebraska border the upper few feet of the Johnson Shale consist of laminated gray shales with ostracodes and carbonized plant remains. The plant remains are rare in Nebraska. In the same area these shales are underlain by a horizon characterized by laminated muddy limestones yielding platy debris. In some places the purer platy brittle limestones may be conveniently

called platestones. The platy horizon is identifiable from a few miles north of the Nebraska-Kansas border, southward to Eskridge, Kansas. The lower half of the formation is almost invariably unfossiliferous.

Red Eagle Limestone

The Red Eagle Limestone was named by Heald (1916, pp. 24-25) from "excellent" exposures near Red Eagle School, about 3 miles west of Foraker, Osage County, Oklahoma.

".... a number of distinct beds of limestone, between which are beds of shale in some localities." (Heald 1916, p. 25)

The Red Eagle School mentioned by Heald was destroyed many years ago, and the limestone exposures in that neighborhood (Plate 3A) represent only a part of the total thickness.

The best exposures of the Red Eagle Limestone are in the large quarry immediately north of U.S. Highway 60 just east of Burbank, Osage County, Oklahoma (Burbank section, Appendix III). This is the southernmost locality sampled for this investigation.

The Burbank section exposes approximately 22 feet of Red Eagle limestone beds. The base is not visible. In the lower 6 feet of the exposed interval, brownish-gray aphanitic to microcrystalline, medium- to thin-bedded limestones grade laterally to similar but shaly laminated limestones. Somewhat wavy, laminated, calcareous shaly interbeds are

characteristics of the Red Eagle limestone are...
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Plate 3

- A. Red Eagle Limestone at Red Eagle section.**
- B. Limestone of the Bennett Shale at Grand Summit section.**

The...
 surface...
 limestone...
 evidence...
 Red Eagle...

characteristic of this part of the sequence. These beds contain common productid brachiopod fragments, crinoid columnals, and rare ostracodes, all oriented roughly parallel to bedding planes. Three feet of hard, dense, massive, medium- to thick-bedded, light brownish-gray limestone rest on the aforementioned shaly limestones. Common crinoid columnals and rare brachiopod and ramose-bryozoan remains are present in a dense microcrystalline matrix. Stringers of shaly calcareous material and calcareous shale intergrade laterally with the limestones. Shaly interbeds up to 0.5 inches thick emphasize the thick resistant limestone beds. Seven feet of light to medium greenish-gray, argillaceous, medium-bedded limestones overlie the massive limestones. The greenish-gray color accompanies 15 to 20 percent more clay content than in the lower limestones. Crinoid discs and brachiopod fragments are rare to common in aphanitic to microcrystalline, and argillaceous matrices. Some beds are vaguely laminated and argillaceous enough to appear shaly when deeply weathered. Half a foot of calcareous shale containing gastropods and bryozoans occurs near the base of this part of the sequence.

The three assemblages of strata just described from the Burbank section total about 16 feet in thickness. Their lithologies, bedding, and faunal content indicate that they represent a facies equivalent of the Bennett member of the Red Eagle Limestone. The more massive, resistant parts of

the Bennett member form subdued benches which can be mapped from air photos in northern Oklahoma and southern Kansas.

At the Burbank section, 4 feet of irregularly-bedded limestones rest on the limestones of the Bennett member. Their character is distinctive -- thick to thin beds, pitted, rusty-weathering, and penetrated by brick-red clay and clayey limestone stringers and tubes. Traces of crinoids, brachiopod fragments, and arenaceous foraminifers are present. Nothing quite like these beds is known in Kansas. They are correlated as equivalents of the Howe member of the Red Eagle Limestone, largely because of their position below red Rock shales and above Bennett limestones. Their faunal content only vaguely resembles the Howe Limestone fauna at the Coffman section. No equivalents of the Glenrock member of the Red Eagle Limestone have been recognized in Oklahoma.

South of the Burbank area the Red Eagle Limestone is poorly and only partially exposed. The resistant portions of the Bennett member thin southward in Osage County, Oklahoma, and can be traced to the Arkansas River west of Fairfax, where Fisher (1956, p. 83) noted a thickness of 1.9 feet of Red Eagle Limestone amid a 125-foot covered interval. In the Foraker area, at the Red Eagle section (Appendix III), about 1.5 miles east-southeast of the old type locality, the massive limestones of the medial Bennett member form a small hillside bench. This can be traced northward into Kansas and southward beyond Burbank,

Oklahoma. Depending upon the proportions of less-resistant argillaceous limestones, the ledge-forming beds of the Bennett member range in thickness from 3 to 6 or more feet. The Red Eagle section reveals 5 feet of massive, thick-bedded light brownish-gray, somewhat vuggy, pure limestones (Pl. 3A). The assemblage of bryozoans, arenaceous foraminifers, crinoids, and brachiopod fragments indicate that these beds are equivalent to the medial, purer, resistant limestones of the Bennett member at the Burbank section. In the Foraker (Red Eagle section) area of northern Oklahoma the Howe member equivalent does not seem to survive weathering any better than the softest of the Bennett limestones. The Howe is detectable in the Foraker area only from rare slabs of limestone float (similar to Burbank "Howe") in covered intervals just above the resistant Bennett limestones.

In southern Kansas, at the Highway 38 section (Appendix III), the three members of the Red Eagle Limestone are all definitely recognizable. The Glenrock member disappears somewhere south of Highway 38, probably near the state line. Northward from Highway 38, the Glenrock, Bennett, and Howe members of the Red Eagle Limestone are traceable to and beyond their type localities in southeastern Nebraska.

Glenrock Limestone

The Glenrock Limestone member of the Red Eagle Limestone was named by Condra (1927, p. 86)

".... from exposures high in the valleyside just northwest of Glenrock, Nemaha County, Nebraska; dark gray, dense, weathering light gray or slightly buff; thickness 1 to 2 feet. This forms rectangular blocks. The leading fossils are Fusulina, bryozoa, brachiopods, and Pinna sp."

At its type locality near Glen Rock¹, Nebraska, the

-
1. The spelling Glenrock for the rock unit is retained for reasons discussed by Moore (1952).
-

Glenrock member forms an inconspicuous ledge cropping out in the midst of long gentle grassy slopes which hide shales above and below. Upper and lower contacts are not visible. The unit may be sampled best from rare blocks displaced by road-building or in ditch cuts. The type Glenrock member is a light brownish-gray fusulinid-bearing limestone, 1 foot thick. It weathers to a light gray color. Common fusulinids (Triticites sp.), brachiopods, and ostracode fragments repose in a microcrystalline to aphanitic calcareous matrix containing only 10 percent insoluble clays. The rock is hard and even-textured, and presents an "oatmeal" appearance on fresh surfaces. Fusulinids here are slightly smaller than in other parts of the Glenrock member.

O'Connor and Jewett (1952, p. 343) assert that "the Glenrock limestone can be divided into two faunal and lithologic parts: (1) fusulinid-bearing rock above, and (2) a nonfusulinid part at the base" and that "in a few places one

or the other is not present or is poorly developed." This is an accurate appraisal of what field reconnaissance reveals. Detailed studies show that the lower portion of the Glenrock member is not everywhere "nonfusulinid" although its fusulinid content is commonly sparse. Where this twofold character of the Glenrock Limestone is manifest, the fusulinid-bearing rock grades into "nonfusulinid" rock with no perceptible break.

At the Bennett section (Appendix III) the Glenrock Limestone is a massive ledge-forming unit 1.5 feet thick. The upper 0.5 feet of this rock contain numerous fusulinids, but the lower 1 foot contains few. Brachiopods, foraminifers, and ostracodes are common where fusulinids are scarce. Traces of linear algae occur in this lower portion. The calcareous microcrystalline matrix for fusulinids and other fossil detritus contains less than 10 percent insoluble clays. The upper foot of the unit has a few random patches of muddy limestone somewhat similar to the overlying shales of the Bennett member. Some of the fusulinids in this part of the Glenrock member show a tendency toward orientation parallel to the bedding. Vague, wavy, clay-limestone seams much thinner than the subtlest of diastems share the vague preferential orientation. The lower part of the member is virtually structureless and even-textured. The Glenrock Limestone weathers light gray. The lower contact of the Glenrock is gently undulatory. It rests on the shales of

the uppermost Johnson Shale paraconformably but with only slight evidence of erosion. The upper contact is also slightly undulatory beneath the dark-gray Orbiculoidea-bearing Bennett shales. These contacts are unusually clear and sharp.

At the Tecumseh section (Appendix III) the Glenrock Limestone is also 1.5 feet thick. The upper 1.3 feet contain abundant fusulinids and common brachiopods in an aphanitic to microcrystalline matrix. Blotches of organically barren limestone occur at random. Aphanitic, somewhat dolomitic, limestone with random stringers of calcarenaceous and calcisiltaceous material comprise the lower 0.2 feet. Here the base is undulatory, as it is at the Pawnee section.

At the Johnson section (Appendix III) the Glenrock Limestone is 1 foot thick and resembles its equivalent at the type section. The upper 0.9 feet contain abundant fusulinids and rare to common brachiopod detritus. The basal 0.1 feet of the unit consists of hard, dense to microcrystalline limestone lacking fusulinids. The upper and lower contacts are faintly undulatory and typically sharp.

The Pawnee section (Appendix III) exposes a distinctive development of Glenrock Limestone. The thickness ranges from 0.7 to 1.0 feet. Fusulinids abound in the upper half of the unit together with a profusion of brachiopod fragments and traces of gastropods. The lower half lacks fusulinids. Acetate peel-prints reveal that many of these fossil fragments

(except the fusulinids) are coated with secondary calcite, similar to algal Oeagia. The calcareous matrix of the detrital material is aphanitic and somewhat argillaceous, ranging to pure microcrystalline.

The base of the unit is gently undulatory (Pl. 4A) and locally rests on small lenses, an inch or two thick, of buff aphanitic limestone containing brachiopod fragments. The upper limit is even more distinctive than the gently undulatory base. It is undulatory on a small scale (1/2 inch) or "lumpy" and channelled. The pattern of lumps and channels suggests that the top of the limestone is traversed at random by depressions representing the trails of benthonic animals (Pl. 5C). The shales of the overlying Bennett member are impressed into these "trails" and, surprisingly, contain fusulinids. The top few inches of the limestone are randomly penetrated by tubes (worm burrows?) filled with black muddy material (Pl. 4B, 5A, 5B) continuous with the black shales of the basal Bennett member. Some of these black tubes also contain fusulinids.

The Glenrock Limestone at Pawnee South is similar to its equivalent at the Pawnee section.

In southwestern Richardson County, Nebraska, athwart the Nemaha anticline, the Glenrock Limestone is well-exposed at the Humboldt section (Appendix III). Here also, the base of the unit is undulatory, with relief of about 0.1 feet.



Plate 4

- A. Glenrock Limestone at Pawnee section: showing undulatory base.
- B. Glenrock Limestone at Pawnee section: closeup showing worm burrows (below face of hammer).

1. Top of ...
 2. ...
 3. ...
 4. ...



Plate 5

- A., B. Uppermost Glenrock Limestone at Pawnee section, showing black tubes interpreted as worm burrows.
- C. Top of Glenrock Limestone at Pawnee section, showing channels and trails.
- D. Lingula sp. in black basal Bennett Shale at Bennett section.

The upper contact is almost flat. As usual, fusulinids are abundant with many brachiopod fragments in an aphanitic to very finely granular calcareous matrix. Most of these fossils are oriented crudely parallel to the bedding. Some brachiopods are coated by calcareous deposits which suggest Osagia or other algae. There is also some evidence of "linear algae." Articulating brachiopod shells are present but scarce. They are filled with calcarenaceous bioclastic detritus in a microcrystalline clear calcitic matrix. Locally the rock is medium grayish-brown on fresh surfaces, but it weathers to a medium rusty-brown color rather than the light gray typical of most weathered Glenrock Limestone. It forms an indistinct ledge, 1 foot thick, in the grassy hillsides of the area.

The Glenrock member is thicker (2 feet) than average at the Frankfort section (Appendix III). Fusulinids are extremely rare in the lower 0.5 feet of the unit but gradually increase in number upwards. Where fusulinids are scarce, brachiopods are quite common. The upper 0.5 feet of the Glenrock Limestone contains abundant fusulinids and scarce brachiopods which include Composita sp. Not all the shell detritus is broken. Traces of articulating brachiopod shells are visible in polished rock sections. A few ^ctracodes and uncrushed gastropods accompany the brachiopod detritus. Some brachiopod fragments are coated by calcareous algal deposits similar to Osagia. The organic detritus in

the fusulinid-rich limestone is not visibly sorted. In the lower portion of the unit a patchy sorting is common where some textural patterns vaguely extend parallel to bedding and some brachiopod shell detritus is similarly aligned.

At the Manhattan section (Appendix III) the Glenrock member (1.3 feet thick) is superficially "normal", but close examination reveals a distinctive local lithology (Pl. 6). The Glenrock member is comprised of 1.3 feet of fine conglomeratic, calcirudaceous, medium to light brownish-gray limestone. Randomly oriented granules and small pebbles of aphanitic buff argillaceous limestone are bound by a calcarenaceous and microcrystalline limy matrix containing many brachiopod shell remains. Most of these shells are coated by calcareous deposits similar to Osgia, and some show crude preferential orientation parallel to bedding. Ostracodes and gastropods are also in the matrix. The rock lacks fusulinids. Upper and lower contacts are relatively even and clearly defined.

At the Paxico section (Appendix III) the lithology of the Glenrock Limestone is intermediate between the material at Manhattan and the widespread fusulinid-rich rock found elsewhere. Aphanitic buff limestone granules occur in the calcisiltaceous to microcrystalline light creamy-gray matrix of the lower half of the unit. Both fusulinids and the granules are extremely sparse in similar but medium brownish-gray matrices of the upper half of the limestone. A few



Plate 6

Peel-print (X3) from Glenrock Limestone at Manhattan section. Note three brachiopod shells, convex upward, coated by algal Osagia (in upper central part of picture) and oriented roughly parallel to bedding.

brachiopod fragments and spines, ostracodes, bryozoans, and small gastropods occur randomly throughout the unit. The upper and lower contacts are even and distinct.

The Glenrock member is absent from the Alma area (Alma section, Appendix III). Shales of the Bennett member of the Red Eagle Limestone rest paraconformably on upper Johnson shales. Moreover, poor exposures make it impossible to determine whether the Glenrock is the only part of the Red Eagle Limestone which is missing. Paleosedimentological studies indicate that such absence is the result of nondeposition.

O'Connor and Jewett (1952, p. 343) placed the base of the Red Eagle Limestone "at the contact between the black or dark-gray shale beds and the gray-green or gray lity beds of the Johnson." Actually, the dark-gray shales contain ostracodes and carbonaceous remains characteristic of uppermost Johnson elsewhere. Hence the contact must be slightly higher in the Alma section than noted by O'Connor and Jewett. Precisely how much higher cannot be ascertained because of unsatisfactory exposures.

About 13 miles southeast of Alma and Paico, at the Keene section (Appendix III), the Glenrock member is quite normal -- 1 foot of light brownish-gray calcareous fusulinid-bearing limestone. The base of the unit is even. The upper contact, partly obscured by weathering, is somewhat lumpy and resembles that at the Pawnee section. In some

parts of the outcrop the top inch of Glenrock Limestone, lacking fusulinids, is medium gray in color, as though heralding the complete change to Bennett black shales at the top contact.

At the Eskridge section (Appendix III) the Glenrock is the usual fusulinid-bearing light brownish-gray limestone about one foot thick. Traces of argillaceous material bearing Orbiculoidea fragments are present in the uppermost 1 inch, vaguely similar to the relations at the Pawnee section. Upper and lower contacts are mostly clear and sharp but weathering has obscured details of the upper contact in some places.

The Glenrock member at the Judith section (Appendix III) is almost identical to that at the Eskridge section, except that the upper contact has not been weathered. Fusulinids abound, with many brachiopods and a few ostracodes and smaller foraminifers, in the calcarenaceous to microcrystalline matrix. The top is gradational to the Bennett member above through 0.5 inches of shaly argillaceous limestone. This thin limestone contains numerous Orbiculoidea, traces of Lingula and traces of fish teeth. The lower contact is buried.

At Eskridge South (Appendix III) the Glenrock Limestone is almost the same as at the Judith section, except that the upper half inch contains patches of dark-gray argillaceous material. The top is gently lumpy and undulatory, (relief,

0.05 feet) and displays random patches of fusulinid coquina with traces of Orbiculoides and fragments of bryozoans.

The section at Coffman Ranch (Appendix III) displays the Glenrock member as a medium brownish-gray limestone, considerably thinner than normal. It resembles Glenrock lithofacies in southern Kansas, and yet shows other features characteristic of Nebraska and northern Kansas facies. Thickness ranges from about 0.2 to 0.4 feet within 500 yards of exposure. The base is gently undulatory through about 0.1 feet of section. Fusulinids are extremely abundant in the calcarenitic and calcaphanitic matrix, accompanied by many or few brachiopods and smaller foraminifers. Many of the brachiopod fragments have coatings of algal calcium carbonate but other fossils do not. Some parts of the rock are faintly conglomeratic, containing granules of aphanitic limestone similar to, but much less numerous than, those at the Manhattan and Paxico sections. The difference may be that some of these aphanitic limestone granules are pieces of the aforementioned algal type of material. A solitary 1-inch aphanitic limestone pebble was seen in the normal fusulinid-bearing rock (Pl. 7). For this anomalous occurrence no explanation is offered.

Locally, the upper part of the unit is penetrated by "tubes" of Orbiculoides-bearing medium to dark gray argillaceous material continuous with the Bennett shales above. These are much like the tubes at the Elmdale and Pawnee

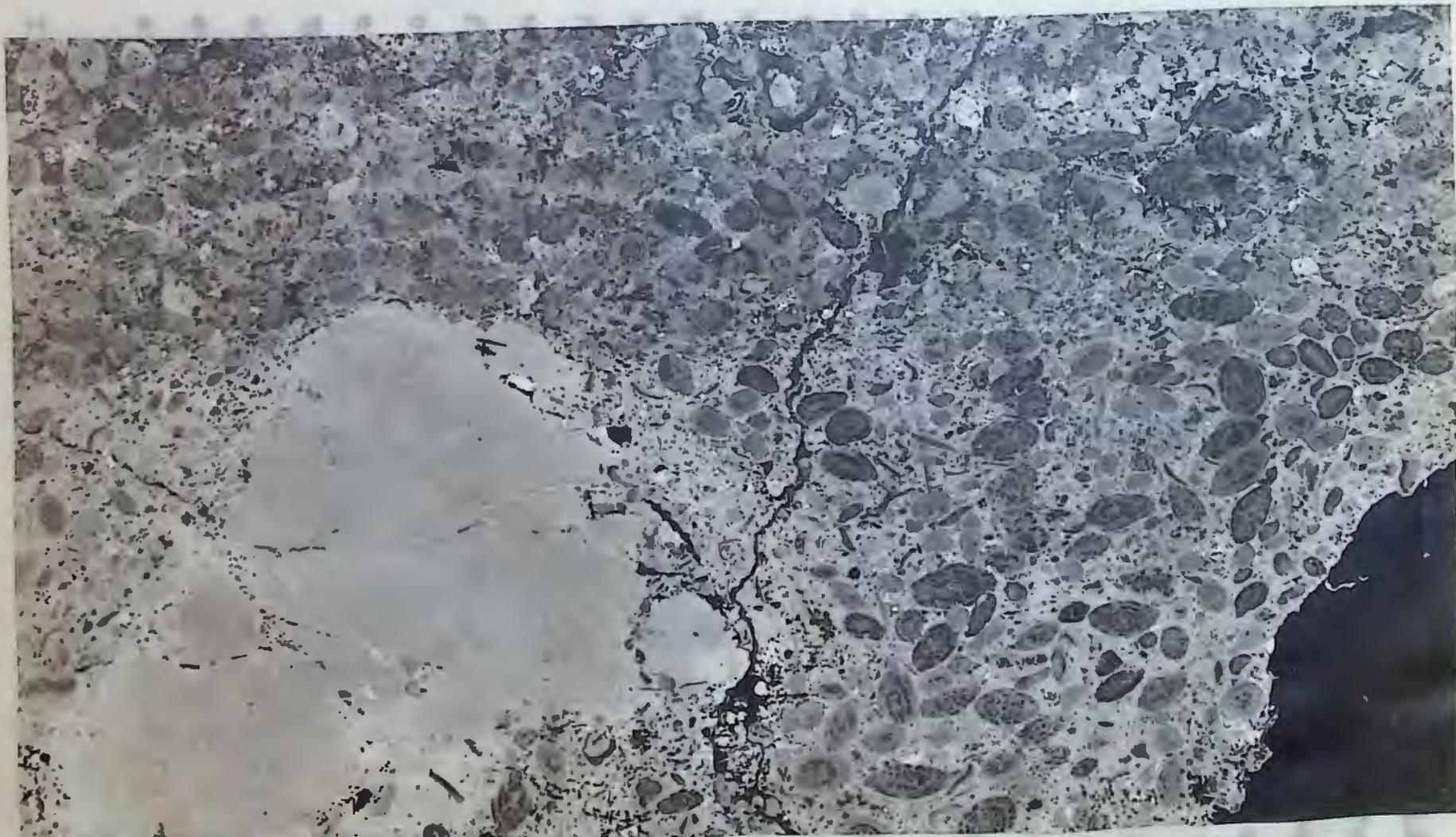


Plate 7

Peel-print (X30) of Glenrock Limestone at Coffman section. Note large aphanitic limestone pebble and faint preferential orientation of fusulinids parallel to bedding planes.

sections (Pl. 5, 9). At the top, the Glenrock Limestone grades upwards through 0.1 inch of rock from a fusulinid subcoquina to an Orbiculoidea subcoquina continuous with the overlying black Orbiculoidea-bearing shales of the Bennett member. That is, the top contact is typically sharp.

At the Allen section (Appendix III) the Glenrock member is a light brownish-gray ledge-forming limestone 1.3 feet thick. The upper half of the unit is crowded with fusulinids. Downwards their numbers decrease, so that the lower third of the limestone is almost barren of fusulinids. Common aphanitic limestone granules and small pebbles similar to those at Manhattan are present in the medial part of the unit where fusulinids are numerous (Pl. 8). Some of these (algal?) pebbles show shrinkage cracking. The pebbles are rarer and smaller in the lowest part of the unit. A variety of fragmental fossil remains, most of which are brachiopods, with a few tiny gastropods and ostracodes occur amid the fusulinids and lime granules. These fragments are more common where fusulinids are lacking. Many of the brachiopods are coated by deposits of calcium carbonate similar to Osagia. The matrix for the detritus is aphanitic to microcrystalline, slightly argillaceous, calcium carbonate. The top contact of the Glenrock member is gently undulatory but the lower contact is even (Pl. 10).

The Glenrock Limestone at Allen No. 2 section (Appendix III) is similar to the Allen No. 1 section. Fusulinids are

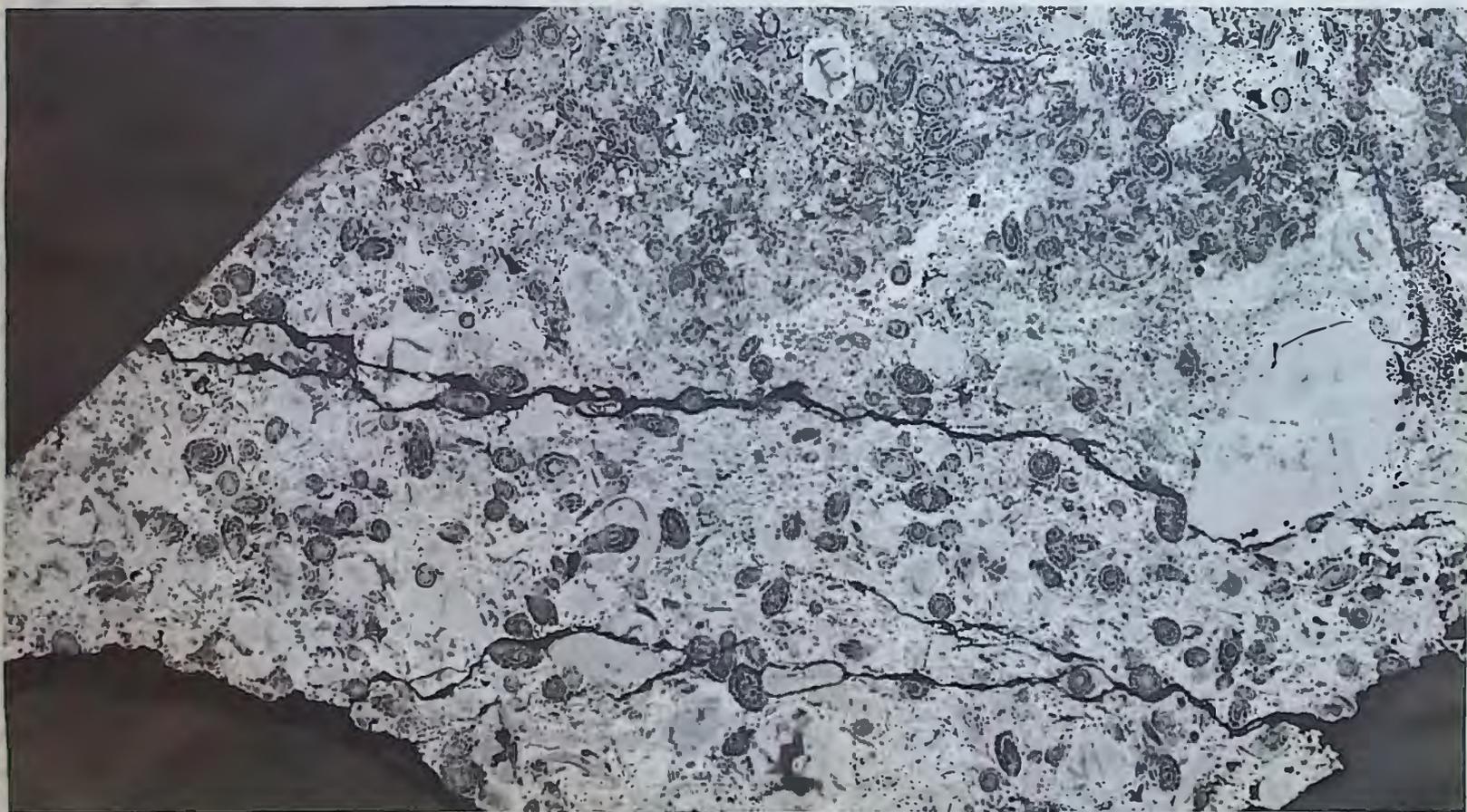


Plate 8

Peel print (X2.5) of Glenrock Limestone at Allen section. Note aphanitic limestone granules, and aphanitic (algal?) lime coatings on shells near bottom left of picture. Note shrinkage cracks in lime granules at bottom, left, and top center of picture. The long axes of many fusulinids are oriented crudely parallel to the bedding planes.



Plate 9

- A. Contact of Johnson Shale and Bennett member of Red Eagle Limestone at the Elmdale section. Hammer head is at contact.
- B. Sample of uppermost Johnson Shale at Elmdale section. Note dark Orbiculoidea-bearing tubes near top.

abundant, with many brachiopods and a few gastropods in the usual calcaphanitic to calcarenitic matrix. Granules of aphanitic limestone and algally coated brachiopods are uncommon. Irregular tubes of gray argillaceous material containing Orbiculoidea (similar to those at the Pawnee and Coffman localities) penetrate the upper 2 inches of limestone. The base of the unit is quite distinct and even, but the top is gently undulatory and sharply defined. A subequina, 0.15 inches thick, of Orbiculoidea and Lingula fragments in a black argillaceous matrix continuous with the overlying Bennett shale (similar to the one at the Coffman section), is plastered upon the top of the Glenrock Limestone.

The Glenrock Limestone is not developed at the Saffordville section (Appendix III) where lower Bennett shales rest paraconformably on upper (not uppermost) Johnson shales.

A peculiar lithofacies is visible at the Elmdale section (Appendix III) below Bennett black shale. It is represented by about 1 foot of argillaceous light-gray to brownish-gray vaguely laminated and faintly cross-laminated limestone. Tubes of dark clayey material containing Orbiculoidea and fish teeth penetrate the upper 0.1 feet of the unit from the black Bennett shale above (Pl. 9B). A coquina of Orbiculoidea lies at the base of the overlying shale. These lithologies and structures are similar to those in the uppermost Glenrock Limestone at the Pawnee, Coffman, and Allen section. Thus, this unit might be mistaken as an argillaceous facies of the

argillaceous spots (containing rare tiny Orbiculoidea fragments) suggesting cross-sections of worm burrows. The overlying Bennett shale contains abundant Orbiculoidea.

The Highway 38 section (Fig. 1) is the southernmost exposure of the fusulinid-bearing Glenrock Limestone. As at the Piedmont section, the Glenrock Member is thin (0.5 feet) and is identified as much by its relation to the overlying Orbiculoidea-bearing Bennett Shale as by its own distinctive lithology. At the Highway 38 locality the Glenrock Limestone is softer and more argillaceous than its equivalents to the north, but contains the same fusulinids. Some brachiopods and crinoid discs accompany the fusulinids. Wormy tubes of black clay penetrate the top of the limestone. Upper and lower contacts are gently undulatory.

Summary. The Glenrock member of the Red Eagle formation is fusulinid-bearing medium to light brownish-gray limestone. Over much of its outcrop belt (north of Allen, Kansas) it is a single unit about 1 foot thick and hard enough to support minor topographic benches. It is readily identifiable in the field by means of its persistent characteristics, and by its position beneath black Orbiculoidea-bearing shales of the lower Bennett member. In localities where the Bennett limestone facies is thick, the Glenrock member is normally less than 0.5 feet thick. Where the Glenrock member is absent, the position of the corresponding paraconformity can be closely approximated at the base of the Orbiculoidea-bearing

black or gray Bennett shales where they lie directly on ostracode- and plant-bearing gray shales of the upper Johnson formation. The Glenrock Limestone commonly contains brachiopod fragments and spines, traces of gastropods and ostracodes, with profuse fusulinids, set in a calcareous matrix. Much of the matrix is bioclastic calcium carbonate grading from calcarenaceous to calcilutaceous to microcrystalline.

Wormlike tubes and ribbons of Orbiculoidea-bearing gray clays that are continuous with the basal Bennett shales penetrate the top of the Glenrock limestone at some localities. Osagia-like calcium carbonate coatings on brachiopod fragments are rare to common in the Glenrock Limestone, especially in Nebraska and northern Kansas.

The outstanding characteristic of the Glenrock Limestone is its uniformity of thickness and lithology between Bennet, Nebraska, and Allen, Kansas. Between Allen and the Highway 38 locality the Glenrock Limestone is commonly less than 0.5 feet thick. No stratigraphic equivalent of the Glenrock member is known in Oklahoma and southern Kansas south of Highway 38.

The fusulinid-bearing Glenrock limestones, with the black Orbiculoidea-bearing Bennett shales resting directly upon them, are a reliable stratigraphic "marker", recognizable and useful from Bennet, Nebraska, to southern Kansas.

Bennett Shale

The Bennett Shale member of the Red Eagle Limestone was named by Condra (1927, p. 86)

".... from exposures along the Little Nemaha and its branches south of Bennett, Lancaster County, Nebraska; formed of bluish gray and nearly black argillaceous shale, with one carbonaceous streak resembling coal and a thin yellowish to brownish limestone; combined thickness 5 to 11 feet.

Fauna: *Orbiculoidea missouriensis*, *Lingula* sp., *Composita subtilita*, *Spirifer cameratus*, and a few other species."

At the type section (Bennett¹ section, Appendix III) the

-
1. Note that Condra misspelled the town name Bennet. The spelling Bennett is retained in stratigraphic nomenclature for reasons discussed by Moore (1952).
-

Bennett member is approximately 14 feet thick. The lowermost 4 feet are slightly calcareous gray shales and mudstones containing Orbiculoidea and an abundant microfauna. The basal shales are dark gray to black. Many emit a fetid odor when treated with hydrochloric acid. A few frail specimens of Lingula (Pl. 5D) are associated with common Orbiculoidea just above the contact with the distinctive Glenrock Limestone. Equivalents of this basal Orbiculoidea-bearing black shale are an excellent stratigraphic marker traceable to southern Kansas. About 5 feet from its base, the Bennett member includes a hard, light brownish-gray, slightly argillaceous, microgranular limestone 1 foot thick. Above this limestone is another 3 feet of buff-colored shaly limestone, which looks more like shale and mudstone in weathered exposures. These beds lack conodonts and orbiculoids, but

some contain fish teeth and ostracodes. Three feet of massive hard aphanitic light-gray Howe Limestone rest on the tooth-bearing beds. The type locality is satisfactory for observation of the lower Bennett shales and their relations to the Glenrock member, but the relations of upper Bennett to the overlying Howe Limestone are much better observable in central Kansas.

Only 5 feet of light- and medium-gray shales and mudstones containing Orbiculoidea and other brachiopod fragments are exposed at the Tecumseh section (Appendix III). These beds contain a characteristic Bennett microfauna of conodonts and fish teeth in the blacker, less calcareous, shales; with ostracodes and foraminifera in the calcareous shales and mudstones.

About 2 feet of lower Bennett black, well-laminated, Orbiculoidea-bearing shales with abundant microfossils are exposed at the Johnson section (Appendix III). The contact with the Glenrock Limestone is sharp and gently undulatory.

Excellent exposures of the Bennett member are available at the Pawnee section (Appendix III). The lower contact of the basal black shales is impressed into peculiar channels (Pl. 5) and fills the tubes of the uppermost Glenrock Limestone. Some of the black shale within the channels and against the top of the Glenrock contains small lumpy accumulations of crushed shells and carbonate rich in fusulinids. Individual free fusulinids are common on the upper surface of the

Glenrock Limestone, where they are surrounded and covered by black Bennett clays. Lingula accompanies Orbiculoidea in the lowermost 0.25 inches of shale resting on the Glenrock Limestone.

The lower 5 feet of the Bennett member, at Pawnee consists of gray, and very dark-gray, almost black, slightly calcareous shales. These contain a varied microfauna and few, but conspicuous, articulate brachiopod shells and spines oriented roughly parallel to bedding and fissility.

Orbiculoidea is typical of the entire assembly. The dark shale sequence grades upward through a foot of calcareous siltstones and mudstones into the soft, pitted Hows Limestone.

The Bennett member at the nearby Pawnee South section (Appendix III) is quite similar to its equivalent at Pawnee, but it differs in the lesser abundance of the fauna.

Only the basal 3 feet of the Bennett member are exposed at the Humboldt section (Appendix III). These are the same as the dark-gray well-laminated Orbiculoidea-bearing shales at the type section. The unit is estimated to be about 5 feet thick in this area. A 0.25-inch horizon of Orbiculoidea coquina occurs near the base of the black shales. At the very base, where many of the shells are only slightly flattened, rare Lingula accompany the orbiculoids.

Only the lower 2 feet of the Bennett shale is exposed at the Frankfort section (Appendix III). The beds are almost identical with the slightly calcareous black shales exposed

at the Humboldt section, with the exception that a few ostracodes occur with the abundant Orbiculoidea at the base.

At the Manhattan section (Appendix III) the Bennett member is 4 feet thick and well exposed. At the other exposures within the Manhattan metropolitan area, and at the Tuttle Creek dam a few miles north of Manhattan, the Bennett Shale is also 4 feet thick. In these exposures, and at the sampled section, the Bennett member is entirely shale.

Orbiculoidea is rare in these beds but bryozoans and brachiopods are common. The shales are well laminated, calcareous, and wafer-like.

The Bennett facies of the Paxico section (Appendix III) are different from those in Nebraska and northern Kansas. Two feet of the characteristic black fissile shale lies at the base, but the remaining 6 feet consist of brownish-gray vaguely-laminated argillaceous limestones. Despite the different lithofacies, traces of Orbiculoidea and fish teeth are present from base to top of the member. Orbiculoidea coquinas similar to the one at Humboldt are present along some laminae in the basal 0.5 feet of the black shales.

Exposures are so poor at the Alma section (Appendix III) that they yield little information about the local characteristics of the Bennett member. The thickness is about 14 feet. The uppermost Bennett beds, beneath the Howe Limestone, are argillaceous calcisiltites somewhat similar to those in similar stratigraphic position at Paxico.

At the Eskridge section (Appendix III) the Bennett member is not exposed and the Howe Limestone is absent so that only an extrapolated estimate (6.5 feet) of Bennett Shale thickness is possible. This local thinning of the Bennett member shales might be overlooked were it not for the thick Bennett limestone development exposed less than 3 miles away (Eskridge Quarry section, Appendix III). Thus, the most abrupt facies change in the Bennett member is indicated.

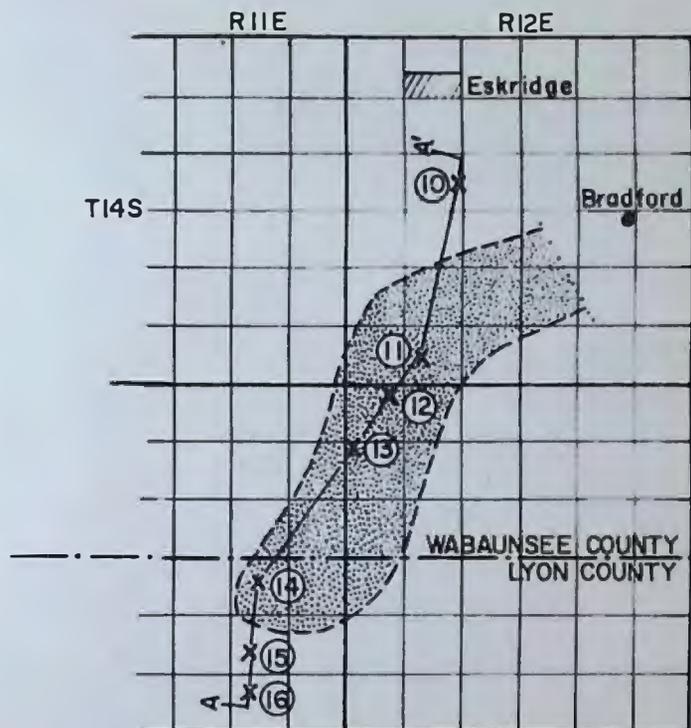
When quarrying is active, a complete section of Bennett member may be seen at the Eskridge Quarry. During suspension of quarry operations the excavations accumulate enough water to submerge the lower 7 feet of the Bennett member and so conceal the lower shales. At such times these lower beds may be sampled at the nearby Judith section (Appendix III) where the Bennett member is very similar to the Quarry Section.

At the Eskridge Quarry section and Judith section, the lower 3 feet of the Bennett member consist of typical black Orbiculoides-bearing shales. The lowermost of these also contain traces of Lingula and conodonts. Medium-bedded very light brownish-gray limestones 15 feet thick rest upon the shales. Orbiculoides and fusulinids are present in the lower foot or two of these Bennett limestones. Brachiopods, echinoid and brachiopod spines, crinoid discs, and foraminifera are rare to common in the aphanitic to microcrystalline calcareous matrix which comprises most of the rock.

Laboratory analyses reveal that few of these limestones contain more than one percent insoluble clay residue. The sudden thickening, and the purity of these limestones suggest that they might be a part of a Bennett reef facies. This thickened limestone facies extends from the Eskridge Quarry through the Judith and Coffman Ranch areas where it forms a conspicuous bench on the local grassy hillsides. Shallow sink holes in the Bennett Limestones are common topographic features of this Eskridge-Coffman area.

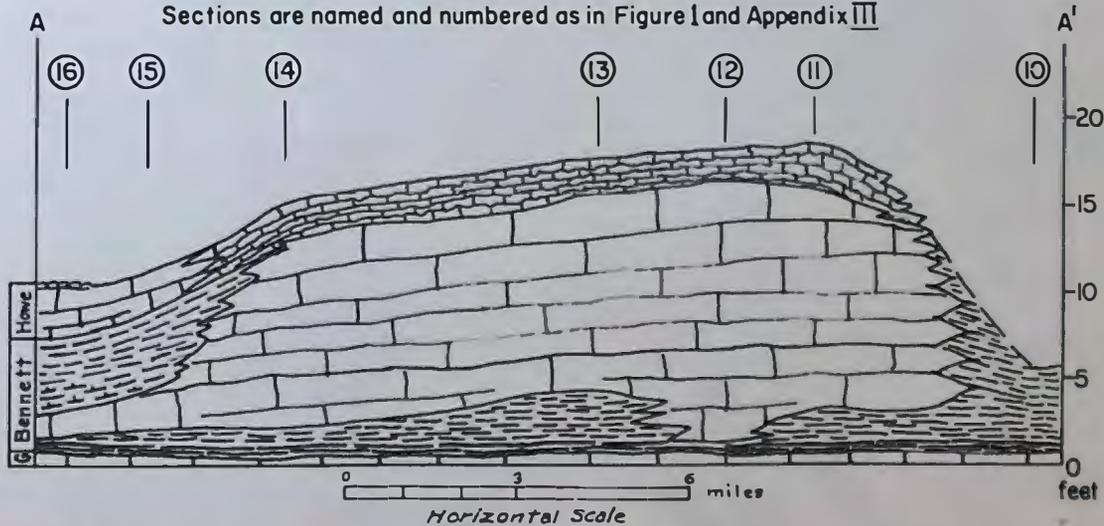
O'Connor and Jewett (1952) noted this Bennett lithofacies (Fig. 2) and called it a "bioherm". The original definition of "bioherm" by Cummings (1932, p. 333) applies it to "reeflike, moundlike, lenslike or otherwise circumscribed structures of strictly organic origin, embedded in rocks of different lithology." In broad outline the Bennett limestones of the Eskridge-Coffman area faintly resemble part of a bioherm. However, the internal characteristics of these limestones (e.g. bedding) certainly are not reeflike, nor can their "strictly" organic origin be verified, although much of their mass is obviously organic shell detritus. Moreover, the Bennett limestone lithofacies of southern Kansas and Oklahoma are extremely similar to those of the Eskridge-Coffman area, except that they are too broadly distributed and uniform in thickness to permit the slightest suggestion that they are biohermal or reeflike in form.

Figure 2



- KEY TO
NUMBERED
SECTIONS
- 10 Eskridge
 - 11 Eskridge Quarry
 - 12 Eskridge South
 - 13 Judith
 - 14 Coffman Ranch
 - 15 Allen
 - 16 Allen # 2

Sections are named and numbered as in Figure I and Appendix III



TOP: Approximate locations of sampled sections, showing area (stippled) of thick Bennett limestone facies in Eskridge-Coffman Ranch area.

BOTTOM: Composite cross section AA' through numbered sections showing thick Bennett limestones in Red Eagle formation.

It must also be noted (Fig. 2) that whereas the western and northern margin of the Eskridge-Coffman area of limestone is bounded by shale ("rocks of different lithology", Cummings, 1932) the southern edge of the thickened beds passes gradually into thinner beds of like composition visible within the Bennett member at the Allen, Elmdale, Saffordville, etc. sections.

The words of Moore (1957, p. 1240) seem to fit perfectly the observed Bennett stratigraphic conditions.

"It seems objectionable to class as reefs (bioherms) the locally thickened masses of bedded limestone that occur in some formations.....even though these masses are predominantly (or exclusively) made by organisms and originally formed prominences on the sea floor. The thickened beds pass very gradually, not abruptly, into thinner beds of like composition."

Paleoecological evidence hereinafter presented indicates that these Bennett limestones probably were deposited in water at least 90 feet deep. Their maximum thickness is not much more than 15 feet where they are surrounded by contemporaneous shales at least 5 feet thick. Their minimum horizontal dimension is about 2 miles. Hence, the Bennett limestones in the Eskridge-Coffman area could not have been much more than a slight, flat, prominence on the sea floor. Such a low feature on the floor of waters 90 feet or more deep certainly should not be regarded as a "reef" or bioherm.

Hudge and Burton (1959, p. 60 and Pl. 9) also noted this feature of Bennett stratigraphy, but called it a "biostrome." Cummings (1932, p. 334) proposed the term

biostrome for "purely bedded structures, such as shell beds, crinoid beds, coral beds, etcetera, consisting of and built mainly by sedentary organisms, and not swelling into round-like or lenslike form" and that, "Biostrome means literally an organic layer". As Weller (1958, p. 612) pointed out, "biostrome was intended as a structural term, in contrast to bioherm, for limestone deposits some of which have been called coral or other reefs but do not have biohermal form." The thickened Bennett limestones are bedded and are built in large degree by organisms. Perhaps this was the reason for Hodge and Burton to call them a biostrome. However, these limestones of the Eskridge-Coffman area certainly do "swell" somewhat, and cannot be certified as purely organic layers. That is, they do not fit the original definition of biostrome.

Apart from the fact the "biostrome" does not exactly fit the local Bennett stratigraphic relations described here, Moore (1957, p. 1789, 1790) and Weller (1958, p. 612, 613) have shown that there are good reasons why biostrome should be dismissed altogether from stratigraphic vocabulary.

Since "Bioherm" and "biostrome" being inappropriate, there is no concise substitute term which, by definition, would describe the stratigraphic relationships manifested by the limestones and associated shales of the Bennett member in the Eskridge-Coffman area. Perhaps Bennett limestone "lithosome" might be tried as a last resort because the

original definition of lithosome (Wheeler and Walby 1956, p. 2719) accommodates the interfingering of the aforementioned Bennett limestones and shales. Moore (1957, p. 1789) pointed out that "A lithosome has lower and upper boundaries as well as lateral ones. Commonly, these coincide with bedding planes...". This implication that lithosomes are bedded further suggests that the bedded Bennett limestones may comprise a limestone lithosome. However, Moore (1957) also stated "Lithosome as a term does not belong to formal nomenclature of stratigraphic units as substitute for commonly recognized terms such as facies." Hence, at Moore's suggestion lithosome is not used in this report. Nomenclatural difficulties are avoided by simply referring to thick or thin limestone or shale facies of the Bennett member or to the localities where such facies are best developed (e.g. the Eskridge-Coffman facies, or Grand Summit facies of the Bennett member), or to both facies and localities. The assumption is that shades of meaning will be quite clear from context. Moore (1957, p. 1782) and Weller (1958, p. 632) endorse the general practicality and clarity of this sort of facies nomenclature.

The thick (15 feet) limestone facies which comprise most of the Bennett member at the Eskridge Quarry continue through the Judith and Coffman Ranch sections. Southward, the limestones thin and give way to the thinner shaly facies visible at the Allen sections and beyond (Fig. 2).

The Bennett member is about 8 feet thick at the Allen section (Appendix III). Here, as elsewhere, the lowermost beds (1 foot thick) are dark-gray, Orbiculoidea-bearing shales. Only 2 feet of hard massive light-gray limestone similar to the Coffman Ranch limestones rest on these basal shales. The limestone contains silicified brachiopods, a few fusulinids, and light-gray chert nodules in an aphanitic calcitic matrix. The upper half has medium-gray chert nodules (Pl. 10). It grades upwards into shaly light-gray limestones that contain a typical Bennett mixed fauna of brachiopods, horn corals, crinoids, and Orbiculoidea.

At the Allen No. 2 section the lowest Bennett shales are only 0.6 feet thick. One foot of Orbiculoidea-bearing massive limestone rests on the shales. The upper few inches of this limestone contain milky chert and silicified fossils. It grades upward through 2 feet of shaly limestone into 3 feet of gray and greenish-gray calcareous shales bearing Orbiculoidea and the Bennett mixed fauna. The upper 1 foot of the unit is a light-gray waddy limestone which contains a sparse Bennett fauna and lacks Orbiculoidea.

The Bennett limestone facies is only 5 feet thick at the Saffordville section (Appendix III) where it rests on about 3 feet of typical Orbiculoidea-bearing lower Bennett gray shales. Algal deposits of calcium carbonate occur at random throughout the limestones (Pl. 11). Some of these (Anchicodium) are called "linnar algae," which appear in

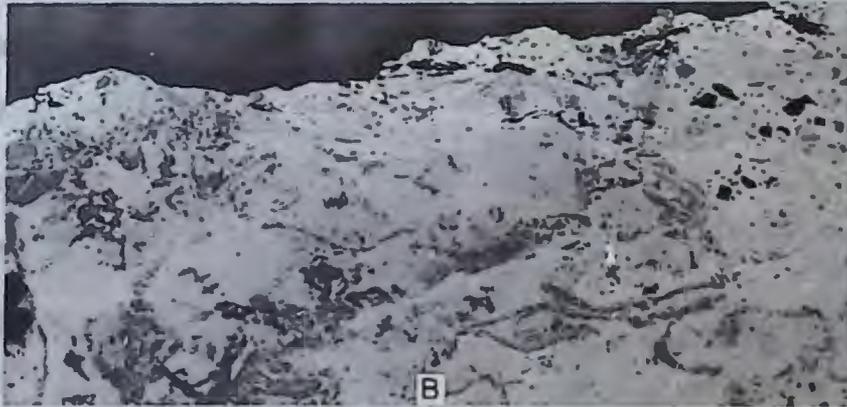


Plate 11

- A. Peel-print (X3) of algal limestone in medial Bennett limestones at Saffordville section. Extended wavy lines are thin sheet-like algal crusts.**
- B. Peel-print (X3) of uppermost Bennett algal limestone at Saffordville. Short wavy dark lines are fragments of crustose ribbon-like algae. Aphanitic matrix is believed to be consolidated algal calcium carbonate particles.**

vertical sections as thin wavy lines oriented roughly parallel to bedding. In three-dimensions they are really ribbon-like or sheetlike crusts, but the term "linear" is retained because it is commonly used in field descriptions and defines the gross appearance of vertical sections of the structures. Other calcareous algal particles comprise much of the apparently structureless aphanitic matrix of the Bennett limestones. The top of the limestone assembly consists of 0.4 feet of unique moundlike limestone structures which seem to contain both of the above types of algal calcium carbonate, as well as fossil detritus (Pl. 11B). Rusty iron staining seems to favor the sheetlike algal structures. Rubbly, wavy-bedded limestones comprise most of the upper 2 feet of Bennett limestone at the Saffordville section. The remainder (3.7 feet) is a massive light-gray resistant, pure limestone containing scattered linear algae some of which are broken (Pl. 11A). In general aspect this limestone resembles equivalent limestones at the Allen section. It grades downward into fusulinid- and Orbiculoidea-bearing calcareous shales of the lower Bennett. About 7 feet of upper Bennett sediments, probably shales, are covered at the Saffordville section.

At the Elmdale section (Appendix III) the lower Orbiculoidea-bearing black shales of the Bennett member are reduced in thickness to about 1 inch. They lie below 5 feet of predominantly pure, massive, and resistant limestones

(Pl. 9A) which contain a few fusulinids at the base. These limestones are equivalent in thickness, position, and fauna to the Bennett limestones exposed at Saffordville. Within the upper foot of this limestone sequence at the Eldred section are linear algal limestones (Pl. 12A). About 4 feet of medium-gray calcareous shales rest on the thick Bennett limestones. A typical Bennett fauna of common brachiopods (Neospirifer, Linoproductus, Crurithyris, Ambo-coelia, Wellerella), bryozoans (Fenestella, Rhombocera, etc.), foraminifers, ostracodes, and fish teeth is abundantly represented in these upper Bennett shales.

Two feet of massive limestone enclosed by shales at the Turnpike section (Appendix III) superficially resemble Glenrock limestone. However, this designation is refuted by the presence in the limestone of Orbiculoidea, Fenestrellina and linear algae typical of the Bennett member. Moreover, fusulinids are absent. This evidence indicated that the limestone may be a thin, tongue-like extension of the Bennett limestone farther north. The Bennett limestone bed rests paraconformably on shales of the upper Johnson Shale. Calcareous shales immediately above the limestone contain a common Bennett fauna. Equivalents of the lower Bennett Orbiculoidea-bearing black shales are absent from the Turnpike section.

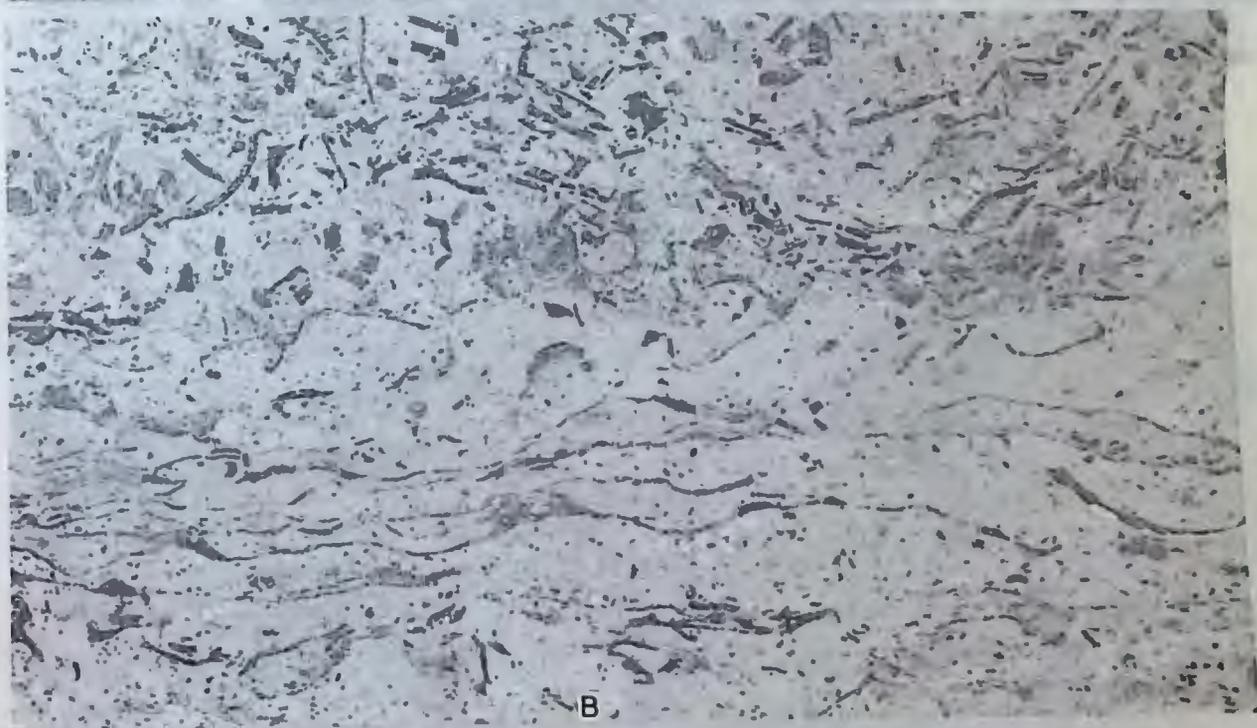


Plate 12

- A. Peel-print (X3) of upper Bennett limestone at Elmdale section. Wavy dark lines are sheetlike algal crusts (Anchicodium). Note crust fragments in lower and upper left of picture.
- B. Peel-print (X3.5) of Bennett limestone at Highway 38 section. Note wavy sheetlike algal crusts in the lower half of picture, and broken algal crusts with brachiopod fragments in upper half.

Fossils in the limestone and shale exposed at the Sallyards section (Appendix III) indicate that these beds are also correlative with Bennett sediments farther north.

At the Piedmont section (Appendix III) only limestones of the Bennett member are exposed. The base of the unit is covered. Shaly light-gray limestones containing common fusulinids make up the lower 2 feet of the exposure. Eleven feet of massive, resistant, light-gray, medium- to thick-bedded limestones comprise the remainder of the Bennett member at Piedmont. Orbiculoidea is present in the lowermost of these limestones. Fusulinids are rare to common throughout the section, together with a typical Bennett fauna of brachiopods, ostracodes, crinoid discs, etc. (Pl. 13). Some of the limestones are vuggy; others contain secondary chert nodules surrounding silicified fossils. South from the Piedmont section the light-gray limestones of the Bennett member comprise most of the Red Eagle Limestone.

The basal Bennett shales are only 0.1 feet thick at the Grand Summit section (Appendix III). This resembles the conditions at Elmdale. Orbiculoidea abounds in these shales, together with many fusulinids, ostracodes, conodonts, and brachiopod fragments. The rest of the Bennett is all hard, light-gray, aphanitic limestone. The lower 4 feet of these limestones weather out as thin wavy beds in which linear algae are common. Five feet of massive thick- to medium-bedded limestone comprise the medial portion of the member.



Plate 13

Peel-print (X2.5) of fusulinid-bearing Bennett limestone from the Piedmont section. Note random orientation of fusulinids, and the articulating productid brachiopod filled with calcilutite.

Thinner beds make up the upper 3 feet. Brachiopods, crinoid columnals, ostracodes, and small gastropods are rare to common in an aphanitic matrix.

At the Highway 38 section (Fig.1) (Appendix III) the massive, light-gray, medium-bedded limestones which constitute the entire Bennett member are similar in thickness, purity, and lithology to their equivalents at the Grand Summit section. This is the southernmost section where correlations of the Red Eagle Limestone of Oklahoma with its members to the north can be recognized. Farther south the Glenrock Limestone disappears, whereas the Bennett limestones thicken and become more argillaceous towards the Burbank area where they comprise the bulk of limestones defined as Red Eagle Limestone formation.

Limestones of the Bennett member at the Highway 38 section embody characteristics typical of all limestone lithofacies of the Bennett member. Fragments of brachiopods, bryozoans, and ostracodes are rare to common in an aphanitic calcareous matrix. Orbiculoidea and fusulinids are rare to common at the base of the unit, and rare throughout the remainder. Linear algae (Anchicodium?) (Pl. 12B) are present in limestones near the base of the Bennett member.

Summary. At the type area near Bennet, Nebraska, and southward to Manhattan, Kansas, the Bennett member is comprised mainly of calcareous (30 percent CaCO_3) medium-gray, moderately to well-laminated shales. Brachiopod

shells and spines are common, whereas bryozoans, conodonts, foraminifers, ostracodes, and crinoid discs are rare. The lower Bennett shales are fissile, dark gray or black, and characteristically contain numerous Orbiculoidea, a few conodonts and fish teeth, and even fewer fusulinids. They are easily identified in the field because they rest on the distinctive Glenrock Limestone. Sparse Orbiculoidea may occur throughout the Bennett member, regardless of lithology.

The Bennett member is about 7 feet thick at Bennet, Nebraska, and gradually thins southward to 4 feet at Manhattan, Kansas. Between Manhattan and Paxico the Bennett "shales" become thicker (8 feet) and more calcareous, until at the Paxico section only the lower, black fissile shales maintain the typical northern character (approximately 30 percent CaCO_3). In the same area the upper two-thirds of the Bennett member appear in the field to consist of light-gray, very calcareous mudstone and shales. Laboratory analyses reveal that these are laminated muddy limestones containing approximately 70 percent calcium carbonate.

This argillaceous-calcareous facies of the Bennett member continues southward to an area about 3 miles south of Eskridge where the Bennett facies change abruptly to the medium-bedded, very pure (95 to 98 percent CaCO_3) limestones, 15 feet thick, visible at the Eskridge Quarry. The thickest part of this limestone facies of the Bennett member trends in a band about 2 miles wide (Fig. 2) southwest from Bradford,

through the Eskridge Quarry to the Coffman Ranch section where it supports a conspicuous bench on local hillsides and creek banks. Sink holes are not uncommon in these limestones. Brachiopods, crinoid columnals, horn corals, bryozoans, and fusulinids are rare to common throughout the limestones. Between the Coffman Ranch section and the Allen section the entire Bennett member thins to about 9 feet. The pure limestone facies thin to about 2 feet, whereas the rest of the upper Bennett changes to muddy limestone facies like that at Paxico. In the short distance from the Allen to Allen No. 2 section the Bennett member thins to less than 8 feet, the pure limestone becomes slightly argillaceous, and the muddy limestones become shaly (45 percent CaCO_3). The black and dark-gray shales of the lowest Bennett member maintain a thickness of about 1 foot below the aforementioned facies changes of the medial and upper Bennett. Southwestward from Allen No. 2 to Elmdale, the Bennett member thickens slightly to 9 feet. The massive pure limestone facies of the Bennett member thicken to about 5 feet whereas the basal black shales thin to less than 0.1 feet at the Elmdale section. Some of the massive limestones contain wavy algae. Upper Bennett shales contain the same kind of mixed fauna visible in Nebraska. There are few sections of the Bennett member suitable for sampling between Saffordville and Piedmont. Where it is visible, the member lacks black shales, and is comprised

of fossiliferous gray shales enclosing massive (1 to 2 feet) pure limestone beds, similar to those at the Allen section.

In southern Kansas, between the Sallyards and Piedmont sections, the Bennett member thickens and changes to a thick limestone facies very similar to the lithofacies at the Eskridge Quarry. This limestone assemblage is relatively thick (10 to 15 feet) and continuous southward into Oklahoma, where it constitutes most of the Red Eagle Limestone. The basal Bennett black shales are scarcely an inch thick in southern Kansas but they are, nonetheless, readily recognizable at the base of the massive Bennett limestones. The black shales are absent in Oklahoma.

Orbiculoidea fragments, so abundant in the Bennett black shales all the way from southern Kansas into Nebraska, are rarely found in the lower and middle portions of the Bennett limestones. Their presence (with a few fusulinids) in the lower Bennett limestones facilitates correlation, especially where the Glenrock limestones and lowest Bennett black shales are absent or not exposed.

Bennett limestones are all quite pure (93 to 98 percent CaCO_3) in southern Kansas. In northern Oklahoma they are more argillaceous (60 to 80 percent CaCO_3). The limestones weather to shades of light gray with tints of rusty yellow and brown.

Wherever the Bennett member is shale it underlies grassy slopes between the minor hillside benches supported by Howe

and Glenrock Limestones. A few good shale outcrops have been found along creek banks. Fresh road cuts provide the best exposures. Bennett limestone facies of central and southern Kansas commonly form hillside benches which are more conspicuous than those supported by the thinner Glenrock and Howe Limestones.

Howe Limestone

This upper member of the Red Eagle Limestone was named by Condra (1937, p. 86)

".... from exposures south of Howe, Nebraska; stone in its unweathered condition, dark gray, massive, and dense, with considerable free calcite; weathers buff to yellowish, granular, vesicular or cavernous, and very irregular; thickness about 4 feet. This carries geodes at places. It has few fossils."

Only one small incomplete exposure of limestone is observable about half a mile south of Howe, Nemaha County, Nebraska. Condra's description seems to apply fairly well to this limestone, except that it understates the amount of solution pitting and decay.

The decayed limestone which Condra described is not satisfactory as a type section for reference in correlating Howe rocks of other localities. The limestone at the exposure designated by Condra is so badly pitted, decayed, and recrystallized as to preclude confident estimation of its original lithology. Moreover, no fossil-bearing Hoca or Bennett beds are exposed above or below it, which could aid in identification of the limestone as Howe on the basis of stratigraphic position.

In southeastern Nebraska the Howe Limestone is normally a light-gray aphanitic limestone that weathers to shades of rusty and yellowish light brown as a result of secondary iron oxide deposition within interstices of the rock. It is about 3 feet thick. The commonly pitted and irregularly cellular (vuggy) Howe limestones have been partially dissolved by ground water in many places.

Near the Pawnee section springs of potable water emerge from the Howe Limestone. Iron oxides and travertine are being deposited in larger solution cavities (vugs) at the springs. The underlying fossiliferous Bennett shales serve as an effective aquifuge or aquiclude preventing seepage of water downward from the Howe. Roca shales above are somewhat siltier and more porous than those of the Bennett.

The Howe Limestone is well exposed at the Bennett and Pawnee sections, either of which would be a good standard section for the Howe Limestone in Nebraska. The lower contact is commonly gradational through a few inches of section into the shales of the topmost Bennett. This northern facies of the Howe Limestone contains few fossils (small foraminifers, gastropods) so that the Howe may be identified in the field only by lithology and stratigraphic position. Nebraska characteristics of the Howe Limestone may be followed southward to the Manhattan area of Kansas. Throughout this distance the Howe forms indistinct light brownish-gray or rusty-gray limestone benches cropping out on grassy hill

slopes. Where it caps hilltops it is usually badly pitted, decayed, and iron-stained. The thinner fusulinid-bearing Glenrock bench is readily recognizable a few feet below the Howe.

A change of Howe facies occurs between the Manhattan and Paxico areas of Kansas. The northern aphanitic texture gives way to the pseudo-colitic or pelletoid texture visible in the vicinity of Paxico and Alma (Pl. 14B). This distinctive texture characterizes the Howe Limestone of central and south-central Kansas between Paxico and Grand Summit. The Eskridge-Coffman area (where limestone of the Bennett member is thick) is the only part of central Kansas where the Howe does not display the pseudo-colitic texture.

The pseudo-colites are comprised of calcareous nuclei such as small foraminifers, ostracodes, or shell detritus, surrounded by coatings of algal calcium carbonate (Osagia sp.). Aggregates of these, with microcrystalline interstitial cement, produce the pseudo-colitic texture ("osagite") characteristic of the Howe Limestone in central Kansas. The rock weathers to a light gray color, commonly stained by limonitic rusty yellow or brown iron oxides.

A very remarkable development of larger calcareous algal structures is present at the top of the Howe Limestone at the Allen No. 2 section. A thick pseudo-colitic limestone bed comprises the bulk of the unit, but the upper 2 or 3 inches is capped with bun-shaped or roughly hemispherical



Plate 14

- A. Algal "buns" at top of Howe Limestone at Allen No. 2 section.
- B. Pelletoid Howe Limestone (osagite) from Alma section, magnified (X50) from thin section. Pellets or pseudocolites are tiny fossil fragments (ostracodes, foraminifers, brachiopods) covered by layers of algal (Osagia) calcium carbonate.

masses of concentrically layered algal calcium carbonate (Pl. 14A,15). O'Connor and Jewett (1952, p. 352) called these structures "cryptoscon-like." One of these masses was underlain by a nautiloid cephalopod coated by half an inch of aphanitic laminated hard calcium carbonate (Pl. 16). The nautiloid rests in the top of the pseudo-oolitic limestone. Greenish shales of the overlying Hoca Shale are impressed into and around the tops of the algal "bumps."

A fossiliferous Howe facies is developed on the thick Bennett Limestone at Eskridge Quarry and Coffman Ranch. Bryozoans, ostracodes, brachiopods, holothurian sclerites, foraminifers, and algae are common, and crinoid columnals are abundant in these unevenly thin-bedded "bubbly" limestones. Laboratory analyses show that these rocks contain about 5 percent less calcium carbonate than the underlying massive Bennett Limestone.

The distinctive pseudo-oolitic or pelletoid (esagite) Howe facies persists, with minor modification, southward to the vicinity of the Kansas-Oklahoma border. At the Highway 38 section the pellets or pseudo-oolites are smaller, less abundant, and less distinct than in central Kansas. Also, the proportion of elongate or discoid pellets of calcium carbonate is greater and algal coatings of the individual pellets are thinner.

In Oklahoma, because the pseudo-oolitic facies is absent, it is difficult to identify the Howe Limestone or its

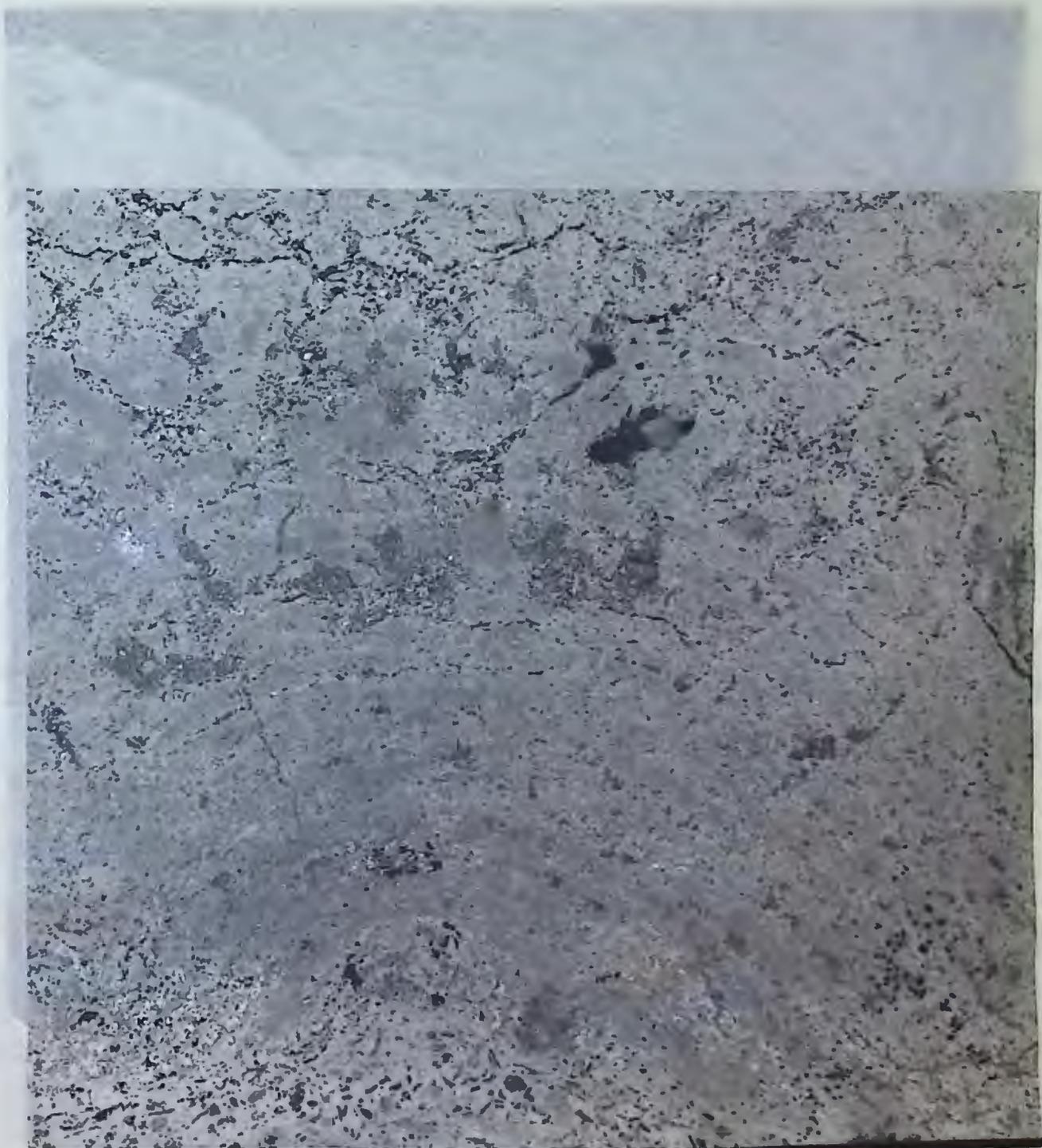


Plate 15

Peel-print (X3.8) of vertical section of algal "bun" from Allen No. 2 section. Note vague definition of concentric laminations. Puffy material at top is argillaceous algal limestone.



Plate 16

Feel-print (K30) of pelletoid Howe Limestone (pseudo-collitic or osagite) from Allen No. 2 section. Large fossil at left of picture is a coiled nautiloid cephalopod filled with clear calcite and coated by Osagia type of algal calcium carbonate. Note that pellets are fossil fragments (ostracodes, foraminifers, brachiopods) coated by Osagia. (See also Pl. 14B.)

equivalents. Largely because of their stratigraphic position atop Bennett Limestone, and beneath red Rock Shale, the irregularly thin-bedded, pitted, rusty, sparsely fossiliferous limestones at the top of the Burbank section are correlated with the Howe member of the Red Eagle Limestone. Additional support for this designation is provided by the sparse microfauna and observations that the thin wavy bedding resembles Howe bedding at the Eskridge Quarry, and the pitted, rusty condition is typical of Howe Limestone wherever it caps a section and is exposed to weathering and soil-forming processes.

Summary. The Howe member of the Red Eagle Limestone is a massive limestone recognizable in exposures along nearly 250 miles of an outcrop belt between Bennet, Nebraska, and Cloverdale, Kansas. Throughout this distance the rock generally is 2 or 3 feet thick and it exhibits only one major facies change. In Nebraska and northern Kansas the Howe member is an aphanitic to microcrystalline light-gray limestone in places pitted and decayed by weathering. In central and southern Kansas the Howe Limestone is a brown to gray-brown pelletoid limestone. The pellets (pseudo-oolites) are composed of fragments of organic shell detritus coated by algal (*Onagia*) calcium carbonate. Fossils are rare to absent, but a few ostracodes, brachiopods, and arenaceous foraminifers can be seen in some fresh exposures.

Roca Shale

The Roca Shale was named by Condra (1927, p. 86)

".... from Roca, Lancaster County, Nebraska; composed of bluish gray, olive green, and reddish argillaceous shale. There are thin fossiliferous limestone seams in the upper portion: thickness of division 18 to 20 feet in Nebraska and somewhat greater in Kansas. The limestone seams carry many pelecypods, as *Pleurophorus* sp., *Pseudomonotis* sp., and *Aviculopecten occidentalis*."

The pelecypod-bearing limestones ascribed by Condra to the upper portion of the Roca Shale are now known to be part of the Sallyards Limestone -- the lowest unit of the Grenola Limestone (Condra and Busby, 1933, p. 7-10).

As implied by Condra and Busby (1933, p. 7) and recognized by later workers (e.g., Lane, 1957, p. 127), the upper boundary of the Roca Shale is at the base of the Sallyards Limestone -- that is, the Sallyards is the first limestone above the red shales of the Roca Shale.

Thus, the Roca Shale is readily recognizable not only by its own red shale content, but by its position between the Howe Limestone below, and Pseudomonotis-bearing Sallyards Limestone above. It is characteristic of this portion of the Kansas rock column that correlation and identification of rock units is achievable only by recognizing unusual lithologies in their peculiar sequence. In this way the Roca Shale formation, in turn, may be used to affirm the stratigraphic position and boundaries of the Red Eagle Limestone below and the Grenola Limestone above.

The Roca Shale is not exposed at Roca, Nebraska. A few slopes in the town are reddish, after the fashion of weathered red shales of the Roca visible elsewhere, but they owe their color to red Pleistocene silts and loess.

At the nearby Bennet section (Appendix III) the lower 9 feet of the Roca Shale is well-exposed. The lowermost 3 feet consists of gray, and greenish-gray, slightly calcareous shale with traces of ostracodes and gastropods. One foot of hard, light-gray, aphanitic limestone separates the lower shale from overlying gray shale which includes approximately 1 foot of vivid brick-red shale. Gray shale below the red beds contains a few ostracodes and rare traces of fish teeth. Shales above the red beds are unfossiliferous. A thin, aphanitic, light-gray limestone caps the incomplete Roca exposure at the Bennet section. The complete Roca Shale thickness is estimated at 15 feet.

Exposures of Roca Shale satisfactory for detailed sampling without risk of contamination are extremely rare in southeastern Nebraska and in Kansas. Shaly beds of the Roca commonly underlie broad gentle grassy slopes between limestones of the overlying Grenola Limestone and underlying Red Eagle Limestone.

A partial exposure (lower 15 feet) of the Roca Shale occurs at the Pawnee section (Appendix III). The lowermost 9 feet consists of light greenish-gray calcareous mudstones barren of fossils. These are overlain by a foot of massive

light brownish-gray, hard, sublithographic limestone. The base of the limestone shows evidence of having covered and filled large cracks in the uppermost of the greenish-gray mudstones. This feature can be seen on the weathered base of the limestone where it is shown by overturned slump blocks (Pl. 17). The top of the limestone grades upwards through 0.2 feet of laminated, flaky, argillaceous limestone to calcareous shale with traces of tiny gastropods, brachiopod fragments, and arenaceous foraminifers. The brick-red mudstone next above is barren of fossils. Unfossiliferous light greenish-gray argillaceous limestone and shale comprise the uppermost beds. If unit thicknesses are disregarded, the sequence of green and red shales and limestones of the Pawnee section correlate satisfactorily with similar beds at the Bennet section despite the absence of fossils. Such correlation of subdivisions of the Roca Shale is not possible in Kansas, because of numerous local inconspicuous changes in facies, lack of fossils, and wide separation of exposures.

The Roca Shale is entirely exposed and accessible at the Manhattan section (Appendix III). Thickness of the unit here is 19 feet. Light greenish-gray, calcareous mudstone and shale are the principal rock types, but three levels of maroon and brick-red shales comprise nearly one-third of the sequence. Well-developed calcareous nodules occur in some of the calcareous red shales. Some of the maroon beds grade to light green color. A nodular microgranular limestone is



Plate 17

Base of limestone bed in the Roca Shale at Pawnee section. Raised angular wall-like structures fill cracks in top of underlying lower Roca Shale.

present just below the middle of the unit. Rare traces of brachiopods (Crurithyris?) are present in greenish-gray shales near the middle of the member.

At the Alma section (Appendix III) most of the Roca shale is medium to light gray and light greenish-gray, only slightly calcareous, and without fossils. The only red shale (noncalcareous) is near the top of the sequence and the only limestone is near the base.

The Roca contains several thin limestones at the Dunlap section (Appendix III). One of these, just below the middle of the unit, contains rare traces of ostracodes. As elsewhere, most of the Roca beds are light greenish-gray, slightly calcareous, and unfossiliferous. Only 2 feet of the greenish shale is not calcareous. One bed of noncalcareous brick-red shale occurs in the middle of the section.

The Roca Shale at the Elmdale section (Appendix III) is predominantly light greenish-gray or gray, and only faintly calcareous. A maroon shale near the top of the unit is noncalcareous.

The same general characteristics of the Roca Shale observable at Elmdale persist through southern Kansas into Oklahoma. Traces of carbonaceous remains, ostracodes, and gastropods are present close to the top of the unit. In the area of the Kansas-Oklahoma border, the Roca Shale consists of an upper 6-foot division of buff-weathering gray shales and a lower one of brick-red and maroon shales 11 feet thick (Taylor, 1953, p. 57).

At the Burbank section (Appendix III) the lower 7 feet of the Roca Shale is comprised of brick-red shales. Pinkish-gray shales 4 feet thick lie between the lower red shale and 6 feet of buff-weathering gray shales at the top of the unit. Traces of carbonaceous remains, ostracodes, and gastropods are present in the upper 2 feet of Roca beds at the Burbank section.

Summary. Good exposures of the Roca Shale are the rarest of any in the Red Eagle Cyclothem. Between Bennet, Nebraska, and Grand Summit, Kansas -- a distance of 250 miles -- the Roca Shale consists of light gray, slightly calcareous shales about 15 feet thick. Brick-red shales 1 or 2 feet thick are invariably present and conspicuous within the characteristic gray shale sequence. Except at the top, where traces of ostracodes and gastropods are sometimes found, the Roca Shale is almost entirely unfossiliferous.

In Oklahoma the lower third of the Roca Shale consists of brick-red shales, succeeded by an upper sequence of gray shales which weather light yellowish-gray or buff.

In almost all shales and in all limestones extracted, shell remains, some crinoid originally but now changed to calcite, comprise a large portion of the calcareous substrate in the Red Eagle limestones. A few calcareous corals are also significant. Traces of dolomite are present in some shales of the Red Eagle Cyclothem.

MINERALOGY

angular to subrounded quartz silt are widespread in all units

Study of insoluble residues obtained by acid treatment of the Red Eagle Cyclothem. The minor amounts of quartz of rocks belonging to the Red Eagle Cyclothem shows that silt in the Red Eagle Limestone was largely to have been clays are the most abundant minerals. Clays comprise the bulk of the Johnson and Roca shales, regardless of their color, and are an important constituent of the Red Eagle Limestone. Differential thermal analyses and X-ray diffraction patterns from selected samples show that illite is the

most common and abundant clay mineral. Chlorite is commonly present in small amounts. These green minerals account for the greenish tint in most of the gray Johnson and Roca Shales. Variable small amounts of illite occur in limestones

Traces of calcium montmorillonite and some unknown mixed-layer minerals are randomly rare in the Johnson and Roca Shales. Traces of calcium montmorillonite and some unknown mixed-layer minerals are randomly rare in the Johnson and Roca Shales.

It is significant that, as in the shales, the major constituent of the small amounts of clay in the Red Eagle limestones is illite, with traces of chlorite.

Next to clays, calcite is the most abundant mineral in the Red Eagle Cyclothem. Finely-divided calcite is present in almost all shales and in all limestone matrices. Shell remains, some aragonitic originally but now changed to calcite, comprise a large portion of the calcium carbonate in the Red Eagle Limestone. Algal calcium carbonate is also significant. Traces of dolomite are present in some shales of the Red Eagle Cyclothem.

Insoluble residues also show that traces of clear sub-angular to subrounded quartz silt are widespread in all units of the Red Eagle Cyclothem. The minor amounts of quartz silt in the Red Eagle Limestone seem largely to have been built into the shells of arenaceous foraminifera. In the Johnson and Roca Shales the quartz silts are sparsely dispersed. Extremely rare traces of muscovite accompany the quartz in some residues.

Glauconite is extremely rare in the Bennett Shale. At the Grand Summit section glauconite fills tiny gastropod shells in the lower part of the Bennett.

Variable small amounts of limonite occur in limestones of the Red Eagle Cyclothem in some places. The "osagite" facies of the Howe Limestone is characteristically limonitic where weathered. Limonitized fossils are rarely evident in the limestones of the Bennett member. Hematitic pyritchedral pseudomorphs are present in the limestones near the type locality of the Red Eagle Limestone in Oklahoma.

Siliceous materials such as beekite are rare in the Red Eagle Limestone of southern Kansas.

Rare manganese dioxide dendrites are present along shaly laminae in some of the weathered shales in the Red Eagle Cyclothem.

PALEONTOLOGY

survive much of the matrix of Bennett limestones are believed to be large Paleobotany origin (consolidated algal particles).

Fragmentary carbonized plant remains and impressions are commonly present in the uppermost gray shales of the Johnson formation. Much of this material is quite vitreous and "coalified" to the extent that details of original organic structure are rarely visible. Only one fragment could be identified definitely as remains of a gymnosperm. Rare traces of fragmentary carbonized materials are also present in some gray shales in the lower part of the Bennett member, and in the uppermost shales of the Roca formation.

Evidence of the vital activities of algae is present in the Red Eagle formation. The secondary laminar calcium carbonate deposits which coat small shell detritus, especially in the Howe Limestone and to a much lesser degree in the Glenrock member, are attributed to precipitation caused by algae, and have been given the "form" generic name Osaigia (Johnson 1946, p. 1104). The Howe member so abounds with these pellets of Osaigia that it and similar rocks in other parts of the column have been called "osaigites." Limestones of the Bennett member contain traces of so-called "linear algae" at some localities (Pl. 11). These are really ribbon-like and thin, crustose, calcium carbonate structures, some of which are related to Anchicodium. Harbaugh (1959) noted similar algal materials in Pennsylvanian rocks. Also, the masses of apparently structureless calcium carbonate which

comprise much of the matrix of Bennett limestones are believed to be largely algal in origin (consolidated algal particles).

Oogonia of charophytes ascribed to the genus Trochiliscus have been found in upper (and lower) parts of the Johnson Shale at two localities. Lane (1958, p. 129) was the first to note "charophytes" in uppermost shales of the Roca in southern Kansas.

Several genera of spores are present in the lower black shales of the Bennett member. These include Pityosporites sp., Lueckisporites sp., Florinites sp., Punctatisporites sp., Huskosporites sp., and Entylissa sp., and Cycadopites? sp.

This list records results from analyses of the few samples chosen to give a general indication of the spore content in the Red Eagle Cyclothem. Doubtless the list is incomplete. It is interesting to note that the genera seem to be similar to younger Permian assemblages from other parts of the world. Could this indicate that in Wolfcampian time middle North America was the cradle of development of a floral assemblage which did not flourish in other continents until later in the Permian?

Few works on fossil spores and pollen from the Pennsylvanian and Permian rocks of Kansas have been published up to now. It may be expected that much will be added to understanding of cyclothems and paleoclimatology when more spore and pollen data are assembled. The new information should,

and probably will be used to affirm or revise the presently recognized (Moore and Moss, 1944) position of the Pennsylvanian-Permian boundary in Kansas and adjoining states.

TABLE 2. Animal Remains Recognizable in the Red Eagle

Larger forms (fossiliferous)

Paleozoology

General Statement

The Johnson and Roca Shales are mostly either barren of fossils or only very sparsely fossiliferous. On the other hand, the Red Eagle Limestone is abundantly fossiliferous.

Gastropods and ostracodes are the only major groups of invertebrates that occur in all units of the Red Eagle Cyclethem. Other kinds of invertebrates are almost all confined

to the Glenrock and Bennett members of the Red Eagle Limestone. Table 2 lists all animal fossils found in the Red Eagle Cyclethem.

	Ammonoites	Glyptostrophia
	Ammonoidea	Hyperammina
	Ammonites	Ammonitiformis
	Corymbifera	Trochammina
	Unidentified horn corals (Leptocyathids)	
HYDROZOANS		
	Gastropoda	Strophomena
	Fenestrellina	Serfordobasis
	Fenestella	Serpens
	Magyarthopora	Syringodonta
	Milne	Thammaria
	Penninotopora	
TROCHOPORANS	Leptocyathus	
BRACHIOPODS		
Inarticulates	Lingula	
	Obolus	
Articulates	Unidentified fragments and spines	
	Antrochalis	Paraspirifer
	Chonetes	Chonetes
	Cosquilla	Marginalifera
	Graptolites	Yonahillya
	Derbyia	Strophomena
	Metrypa	Strophomena
	Rhynchonella	Wellerella
	Strophomena	

TABLE 2. Animal Remains Recognizable in the Red Eagle Cyclothem.

FORAMINIFERS

Larger forms (fusulinids)

Triticites

Schwagerina

Smaller forms (mostly arenaceous)

Amnobaeculites

Glyphostmella

Ammodiscella

Glomospira

Ammodiscina

Hyperammia

Ammodiscus

Nodosinella

Amnoverella

Nummulostigina

Bigenerina

Tetrataxis

Cornuspira

Polypamina

Globivalvulina

Trochammina

COELENTERATES

Unidentified horn corals (lophophyllids)

BRYOZOANS

Cryptostomes

Acanthocladia

Polypora

Bactropora

Rhabdomeson

Chainodictyon

Rhomporora

Fenestrellina

Saffordotaxis

Fenestella

Septopora

Megacanthopora

Syringoclema

Minilya

Thamnicous

Penniretopora

Trepostomes

Leioclema?

BRACHIOPODS

Inarticulates

Lingula

Orbiculoidea

Articulates

Unidentified fragments and spines

Amboceella

Juresania

Gonostes

Linoproductus

Composita

Marginifera

Crurithyris

Neespirifer

Derbyia

Rhipidomella

Dictyoelastus

Schuchertella?

Echinoconchus

Wallerella

Hustedia

TABLE 2 (continued)

MOLLUSKS

• Pelecypods	Avisculopinna	
	Allorisma	
• Gastropods	Anomatina?	
	Small unornamented forms	
• Cephalopods	Unidentified coiled nautiloid	

ECHINODERMS

• Crinoids	Columnal discs	
• Echinoids	Spines	
	Interambulacral plates	

ARTHROPODS

Trilobites	Unidentified pygidial or thoracic remains	
Ostracodes	Amphissites	Jonesina
	Aparchites	Kirkbya
	Bairdia	Kirkbyella
	Bythocypris	Knightina
	Cavellina	Macrocypris
	Cypridina	Paraparchites
	Cytherella	Roundyella
	Discoidella	Ulrichia
	Geffenina	Youngiella
	Hollinella	

HOLOTHUROIDS

	Small, wheel-shaped sclerites (Paleochir- idota?)	
	Not like sclerites (Eccaudina?)	
	Achistrum	

CONCORDANTS

	Cavusgnathus	Polygnathodella
	Rindeodella	Prioniodina
	Lonchodus	Streptognathodus
	Moreyella	Synprioniodina
	Ozarkodina	
• Tooth fragments	Cocleyella	Multidentodus
	Cooperella	Paleoniscus
	Distacodus	Scolopodus
	Idiacanthus	

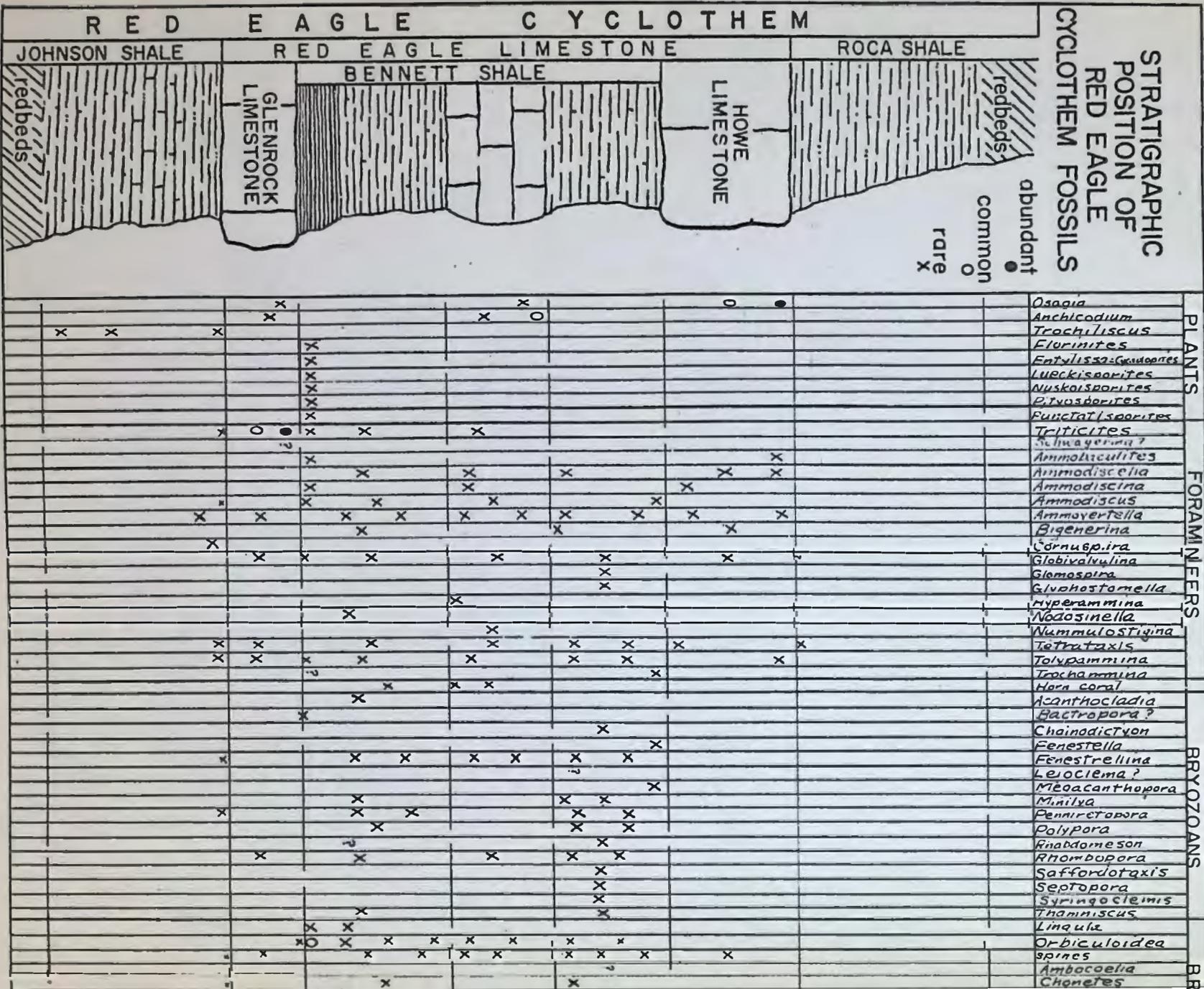
WORM BURROWS

Stratigraphical Paleontology

Plate 18 shows the stratigraphic position of all fossils recognized in the Red Eagle Cyclothem. To some extent recognition of these fossils depends upon the efficiency and refinement of extraction methods. Most genera named were collected from shales of the Bennett member of the Red Eagle Limestone.

The fusulinid foraminifer Triticites is the most abundant fossil in the entire Red Eagle Cyclothem (Pl. 18). It is mainly confined to the Glenrock Limestone, where at many places its large numbers constitute a major part of the rock. A few Triticites are present in lowermost shales and the limestone facies of the Bennett member and in uppermost beds of the Johnson Shale only at the Highway 38 section.

With five exceptions only, identified foraminifer genera are confined to the Red Eagle Limestone. Amodiscus, Ammovertella and Tolypammina are arenaceous foraminifers found in both the Johnson and Red Eagle formations. There are no publications on Permian arenaceous foraminifers but Ireland (1956) has found them in beds younger than Red Eagle and states that they are indistinguishable from Upper Pennsylvanian forms he has described. Tetrataxia ranges from uppermost beds of the Johnson Shale, through the Red Eagle Limestone, to the lowermost Roca Shale. Cornuspira is very rare in the upper part of the Johnson Shale.



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ACHIOPODS	OSTRACODES	CONODONTS	TEETH
<i>Compositia</i>			
<i>Crurithyris</i>			
<i>Derbyia</i>			
<i>Diphyoclostus</i>			
<i>Echinocoelostus</i>			
<i>Hustedia</i>			
<i>Muresonia</i>			
<i>Lino-productus</i>			
<i>Marginites</i>			
<i>Neospirifer</i>			
<i>Rhipidomella</i>			
<i>Schuchertella?</i>			
<i>Wellerella</i>			
<i>Allorisma</i>			
<i>Aviculopinna</i>			
<i>Anemalina?</i>			
<i>Undenites nautilus</i>			
<i>Crinoid columns</i>			
<i>Echinoid spines</i>			
<i>Echinoid plates</i>			
<i>Trilobite frags.</i>			
<i>Amphisites</i>			
<i>Aparchites</i>			
<i>Gardia</i>			
<i>Dythocypris</i>			
<i>Cavellina</i>			
<i>Cyprina</i>			
<i>Cythereia</i>			
<i>Discoidella</i>			
<i>Gardina</i>			
<i>Holmella</i>			
<i>Urbesina</i>			
<i>Kirkbya</i>			
<i>Kirkbyella</i>			
<i>Knightina</i>			
<i>Macrocyparis</i>			
<i>Paraparchites</i>			
<i>Koumaveitia</i>			
<i>Ulrichia</i>			
<i>Youngrepta</i>			
<i>Pleochiridota?</i>			
<i>Eosaidina?</i>			
<i>Achistram?</i>			
<i>Cavusgnathus</i>			
<i>Hindeoella</i>			
<i>Concorus</i>			
<i>Moreyella</i>			
<i>Ozarkoana</i>			
<i>Polygnathocella</i>			
<i>Prionotharia</i>			
<i>Streptopogonites</i>			
<i>Synpharacma</i>			
<i>Cooleyella</i>			
<i>Cooperella</i>			
<i>Styloceras</i>			
<i>Lalia canthus</i>			
<i>Mantelidontes</i>			
<i>Meleomiscus</i>			
<i>Scoropodus</i>			
<i>Warm burrows</i>			

Bryozoans (mostly cyclostomes) are largely confined to the Bennett and Glenrock members of the Red Eagle formation. Penniretopora, characteristic of the Bennett member, is also found at the top of the Johnson Shale and in the upper part of the Roca Shale. All bryozoan genera were washed from these shales. The fenestellate bryozoans in the Glenrock Limestone are not readily identifiable because they are difficult to extract. A few more genera are present in the upper Bennett shales than in the lower part of the Bennett Shale.

Brachiopod fragments generally occur profusely in the Glenrock and Bennett members and sparingly in the Howa member of the Red Eagle formation.

The inarticulate brachiopod Orbiculoidea is common in the black shales of the lower Bennett, and rare in gray shales and buff limestones higher in the Bennett member. Here and there Lingula accompanies Orbiculoidea at the base of the Bennett. Orbiculoidea is the stratigraphic indicator of the Bennett member.

Productid brachiopod fragments and spines are common in the Glenrock and Bennett members. In southern Kansas the upper parts of the Johnson Shale contain Linoproductus and Juresania.

Crurithyris and Chonetes are very rare in uppermost Johnson shales and rare to common in Bennett shales.

Crurithyris, the only brachiopod found in all three formations, is rare in the Roca Shale.

Although ostracodes are present in all units of the Red Eagle Cyclothem, they are most numerous in the Red Eagle Limestone. Only the uppermost shales of the Johnson formation contain many ostracodes, in company with carbonized plant remains. An association of Bairdia, Cavellina and Bythocypris characterizes the upper part of the Johnson. These genera also appear sporadically in the Red Eagle and Roca formations. A few Geffenina and Paraparchites are found in the uppermost part of the Johnson Shale but are unknown in the rest of the section. Cypridina, Discoidella, Kirkbya, Kirkbyella, and Knightina have been observed only in the Bennett member.

Ostracodes are rare in the Howe Limestone. Scarce Bairdia, Bythocypris, Cavellina, Cytherella and Macrocypris are the only ostracodes in the generally unfossiliferous Roca Shale.

All conodonts are confined to the Bennett member. They prevail in the black shales of the lower part of the Bennett. Streptognathodus is the most common genus. Minute fish teeth (?) (Idiacanthus, Distacodus, etc.) which usually accompany the Bennett conodonts are very scarce in the upper part of the Johnson Shale, and in the Roca Shale. The Howe Limestone lacks conodonts and tooth remains.

Tiny gastropods, resembling Ancmatina, are present in all units of the Red Eagle Cyclothem.

Allorisma and Aviculopinna are the only pelecypods found in the Red Eagle Cyclothem. Aviculopinna was observed in only two (Nebraska) localities. It occurs, with Allorisma,

Worm burrows are visible in limestone lenticles of the upper part of the Johnson Shale, and in the top of the Glenrock member of the Red Eagle Limestone.

Rock of the Red Eagle Cyclethos are believed to have been deposited in warm shallow marine waters, sometimes clear, sometimes turbid, sometimes teeming with organisms, sometimes almost lifeless. Marine animals are the only fossils in the Red Eagle Cyclethos.

Following the principle of uniformity ancient environments may be interpreted on the assumption that animals similar to living forms experienced analogous influences, preferences, and tolerances. Hence, certain fossils have come to be considered as reliable indicators of environment ("environmental index fossils"). They are admitted as evidence for reconstructing the environments under which the sediments were deposited. Conversely, the sediments may serve to indicate something of the conditions under which the fossils lived.

Danger lies in depending on fossils alone for paleoecological interpretation. The adjoining sediments may show that fossils were moved from their original positions and thus to rest in a different environment (Miller, 1960, p. 171). However, when fossils are absent, the paleoecology can be interpreted only from the physical characters of the rock. Interpretations may be hindered by the fact that diagenesis can obscure or destroy the paleoecological records.

THE FOLLOWING PALEORCOLOGY AND THE RESULTS OF PALEORCOLOGY
 RESEMBLE. THE FIRST SECTION SUMMARIZES THE PRESENTATION
 OF IMPORTANT GROUPS AND TYPES OF INVERTEBRATES AS GENERALLY

General Statement

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Danger lies in depending on fossils alone for paleo-
 ecological interpretation. The enclosing sediments may show
 that fossils were moved from their original positions and
 came to rest in a different environment (Weller, 1960, p. 204).
 However, when fossils are absent, the paleoecology can be
 interpreted only from the physical characters of the rocks.
 Interpretations may be hindered by the fact that diagenesis
 can obscure or destroy the paleoecological record.

The following chapters treat two aspects of paleoecology separately. The first section summarizes the paleoecology of important groups and genera of invertebrates as generally interpreted and as supported or amended by this study. This deals with environmental index fossils and their significance. The second section interprets the paleosedimentation (depositional environments) of the major lithologic units in the Red Eagle Cyclothem using information from the first section and other relevant data.

Detailed discussions of ecologic factors which control and limit the activities of organisms appear in both volumes of the *Treatise on Marine Ecology and Paleoecology* (Hedgpeth et al., 1957, Ladd et al., 1957). Weller (1957, 1960) gave concise appraisals of ecologic factors as they apply in paleoecology. The interpretations which follow are based on current knowledge of such ecologic factors.

Marine Plants

Calcareous Algae

All three members of the Red Eagle formation contain calcium carbonates of algal origin. They are recognizable as the Osagia (Johnson, 1946) coatings on shell fragments in the Glenrock and especially Howe Limestones. Another type appears as long, roughly horizontal, ribbon- or sheet-like crustose layers (Pl. 12), commonly called linear algae (Anchicodium?) in limestones of the Bennett member. Intact

specimens are presumably in situ. Some of the ribbon-like material is broken and randomly oriented (Pl. 12). It may have come from encrusted upright-growing algal forms (Harbaugh, 1959, pp. 303-306).

It is axiomatic that algae thrive only at depths where light penetration is sufficient to support photosynthesis. Turbidity and turbulence control light penetration in sea water. The purity of the Bennett limestones containing obvious algal deposits suggests that there was very little muddy material in the waters.

If it is assumed that the earth's crust of the Midcontinent region has not shifted appreciably since Permian time, present day observations (Hedgpeth 1957, p. 18) support the additional assumption that in clear waters, the base of the photic zone and the compensation depths, in Kansas latitudes at noon, on a cloudless calm June 21 during Wolfcampian time, would have been at least 200 feet below the surface. Elias (1936) postulated that limestones such as the Glenrock were deposited at depths less than 180 feet. The presence in the Glenrock Limestone of small amounts of algal material in situ indicates that Elias probably did not underestimate the depth of deposition of Glenrock-type limestones in the Kansas Lower Permian. Possibly he overestimated it, because, as Ellison (1951) noted, about "95 percent of light available for photosynthesis has been absorbed in waters 50 meters in depth." Certainly, algal growth involves more than mere

presence of light. Intensity and wave length of light are significant if algae are to flourish.

Elias (1937, p. 410) stated that calcareous algae favor depths between 75 and 110 feet. Illing (1954) pointed out that in the Bahama Banks, calcareous algae abound near the edge of the banks (depths of about 50 or 60 feet) where they contribute the major portion (40 percent) of calcium carbonate to accumulating sediments. Johnson (1954, p. 36) stated that the modern coralline algae grow best at depths less than 70 feet. Deeper than this (Johnson, 1954; Teichert, 1958) they diminish in size and abundance. Cloud and Barnes (1948) wrote that depths less than 15 fathoms (90 feet) are favorable to good development of algae. Williams and Barghoorn (1959) are convinced that control of calcium carbonate precipitation by plants is best at depths shallower than 60 feet. Algal biscuits in Florida Bay are found in waters 2 to 5 feet deep (Ginsberg and Lowenstam, 1958).

Accordingly, it seems justifiable to assume that the profuse algal (Osagia) carbonates in the Howe Limestone were probably deposited in waters less than 60 feet deep.

The few algally-coated shell fragments within the Glenrock Limestone show no signs of abrasion or other suggestion of damage due to transportation. This indicates that although they must have been turned over by gentle currents from time to time in the Glenrock lime cozes (for the algae to grow all around the nuclei) these materials are found essentially

in place, and demonstrate that light penetration was sufficient to support sparse benthonic algal life at the same depths where fusulinids lived. Hence, the question arises as to whether such light penetration was because of shallow waters in Glenrock time, or merely because of exceptionally clear, deeper waters, free of suspended detritus. The latter seems most likely.

A large part of the calcareous matrices of the Red Eagle Limestone is aphanitic and microcrystalline. Johnson (1946) suggested that such very fine-grained calcite is an accumulation of dust-like algal particles. In these matrices traces of the same sort of algal threads described by Johnson (1946, p. 1107) are rarely observable, possibly because of effacement by recrystallization. Thus, it seems reasonable to believe that a large proportion of the structureless, aphanitic calcium carbonate in the Red Eagle limestones (especially Bennett limestone facies) is of algal origin. Bacteria also may have precipitated some of the particulate calcium carbonate by removing carbon dioxide from sea water (Field, 1932). Where consolidated aphanitic algal accumulations are associated with crustose fragments of linear algae (Pl. 11) it can be suggested that if the algal ribbons grew in the upright position, they may have served as filter traps for the algal detritus. Moreover, as Harbaugh (1954, p. 306) suggested, mats of fallen algal ribbons may have been "sufficiently rigid to maintain open spaces" which also could have served as filter traps for fine sediment.

Marine and Brackish-Water Plants

Charophytes

Oogonia of charophytes are present only in the Johnson formation of the Red Eagle Cyclothem. Johnson (1946) has pointed out that although many living forms of charophytes live in fresh and brackish waters, Paleozoic forms seem to have lived in shallow marine waters. They appear to have thrived in clear, lime-rich waters.

The oogonia of charophytes in calcareous mudstones of the Johnson formation support the conclusion that these beds were deposited in shallow marine, limy waters of less than normal salinities. Perhaps this is why fossils are so rare in the Johnson formation. Tentative explanations for such abnormal conditions are given on page 114.

Spores

Spores are present in a number of the shales of the Red Eagle Cyclothem, especially the black Bennett shales. They are of no use in marine environmental interpretations because they must have blown or washed into the Red Eagle Cyclothem sediments from terrestrial sources. However, the assemblage seems to indicate a cool climate in the lands which surrounded the seas of earliest Bennett time.

Waxy plant residues are also present in the black Bennett shales. Presumably much of this unidentifiable material is of terrestrial origin similar to the spores.

Its presence merely demonstrates that the Bennett black-mud environment preserved plant material.

Carbonized Terrestrial-Plant Materials

The only significant black carbonaceous plant remains occur in the uppermost shales of the Johnson formation. Plant materials are randomly distributed through the mudstones and shales. They must have been buried quickly under accumulating Johnson clastics to avoid destruction by physical or organic agencies. Some are gymnospermous, but other fragments, which might be seaweed, look "grassy." The material is too badly altered for certain identification.

Marine Animals

Foraminifera

Larger foraminifera, of which the fusulinid Triticites is representative in the Red Eagle Cyclothem, are thought to have lived in warm, shallow seas (Cushman, 1937). Elias (1936, p. 418) suggested that fusulinids were benthonic organisms that lived in tropical waters shallower than 180 feet.

Triticites is abundant in the Glenrock Limestone member of the Red Eagle formation, and rare in the Bennett member.

In the Glenrock Limestone fusulinids are so abundant that they comprise a major proportion of the rock. They are associated with numerous brachiopod fragments and traces of ostracodes, bryozoans, and smaller foraminifera, in a nearly pure calcareous matrix. Unlike the broken associated

organisms, the fusulinids are little damaged. This is usual with fusulinids (Dunbar, 1957). Their shape, size, and cellular internal structure all tend to resist breakage, but their undamaged surfaces are nonetheless surprising, and suggest that they are found nearly in place. At some localities the long axes of the fusulinids show slight preference for orientation in the bedding plane direction but otherwise they are pointed randomly. This could be expected, because spindle-shaped objects would be in unstable equilibrium in any other position than "on their sides." Their random orientation in the Glenrock Limestone might be explained by a sea-floor covering of viscous calcareous ooze, which would tend to hold fallen fusulinids in random position somewhat in the way that gelatin can support fragments of fruit.

Another noteworthy character of the fusulinids in limestones of the Glenrock and Bennett members is that they do not have algal calcium-carbonate coatings (e.g., Ooagia) even in the company of brachiopod, and other, fragments which do have such coverings. This suggests that the fusulinids were moving about on a substrate where algae were depositing calcium carbonate on and around broken shell detritus of several kinds. Perhaps they were too active to permit algae to accumulate on them, in the way (literally) that "rolling stones gather no moss," or their physiologic habits repelled algae. Perhaps, even after death, the chemical makeup of their shells was distasteful to algae.

There is no doubt that Red Eagle fusulinids enjoyed clear water. They are numerous only in limestones containing less than 15 percent of insoluble clay and silt detritus. Moreover, the pure calcium-carbonate tests of fusulinids can comprise up to 60 percent (by volume) of the rock. Thus, if a limestone containing 50 percent (by volume) of fusulinid tests yields, say, 5 percent (by weight) of insoluble residue, the matrix would actually contain about 10 percent of insoluble residue. It is, of course, the matrix that reflects the degree of turbidity of the depositional waters. Glenrock matrices containing abundant fusulinids contain slightly less calcium carbonate than where they are sparse.

The association of fusulinids with algal carbonates also indicates warm, clear waters, shallow enough to permit light penetration sufficient for algal photosynthesis. This evidence suggests that Elias (1936) was approximately correct in estimating that fusulinids in Lower Permian rocks of Kansas (including the Red Eagle formation) lived in waters less than 180 feet deep.

Normally, temperature is a major control of the distribution of foraminifers (Glaessner, 1955; Myers and Cole, 1957) but it does not influence zonation in shallow waters (Myers and Cole, 1957, p. 1976). Hence, temperature being less important at such shallow depths, light (function of depth) should have been one of the principal controls of Red Eagle

foraminiferal distribution, probably because of its control over the microscopic plants necessary for the foraminifers' dist. under conditions close to the tolerance limits of Fusul. During Glenrock time clear, marine, fusulinid-rich waters, of uniform depth and faunal content, covered most of eastern Kansas. That is, deposition of the Glenrock Limestone was uniform over a broad area of the Midcontinent region, far from shore or sources of detrital silicates.

In brief, the sedimentary relations of fusulinids in the Glenrock Limestone indicate that, as Dunbar (1957, p. 753) phrased it, "they lived and accumulated on a quiet sea floor free from active agitation by waves and free from bottom currents capable of transporting and size grading the empty shells." Dunbar made it clear that the normal habitat of the benthonic fusulinids is believed to have been in shallow epeiric seas.

Fusulinids in the black tubes near the top of the Glenrock Limestone at the Pawnee section seem to have fallen into worm tubes or holes made by some other animals. The tube-makers must have burrowed downward from basal Bennett black muds into loosely consolidated Glenrock lime muds. The few loose fusulinids that lie atop the Glenrock Limestone (slightly impressed into it) and that are largely engulfed by black Bennett muds were probably killed by the first incursion of toxic Bennett muddy conditions.

If the sparse fusulinids which are present in some Bennett limestones are approximately in situ, they must have lived under conditions close to the tolerance limits of fusulinids. The implication of their small numbers, their faunal association, and their association with large volumes of algally-deposited limestones, would be that these fusulinids lived in quite shallow waters ($\leq 140-150$ feet). A corollary to this would be that the algae possibly used up a large portion of nutrients that would be necessary to support fusulinid life. Perhaps some critical nutrient was in short supply, so that only a sparse fusulinid population could develop. Moreover, the particulate algal calcium carbonate that was probably precipitating rapidly might have interfered with the food-intake mechanisms of the fusulinids, perhaps killing them before they could proliferate.

On the other hand, it is remotely possible that the fusulinids could have washed into the area of study from unknown sources, or they might have been reworked from now-absent Glenrock deposits in central Kansas. However, these possibilities seem unlikely, because the Bennett fusulinids show no damage or abrasion to suggest erosion or transportation.

The very rare fusulinids in the top part of the Johnson Shale at the Highway 38 section are broken and abraded, betokening damage during long transportation from an unknown source area.

The smaller foraminifers of the Red Eagle Cyclothem are almost all arenaceous forms. They are common in the Red Eagle Limestone, rare in the Johnson Shale, and extremely rare in the Roca Shale. They are not as restricted in their lithologic associations as Triticites. Such foraminifers, because of their small size and fragility, are difficult to extract from sedimentary rocks. Hence, their record and sedimentary associations in these and other sediments is incomplete, and any paleoecological interpretation based on them is tentative.

The tolerance of the smaller foraminifers for a variety of marine conditions is suggested by their occurrence in a variety of lithologies ranging from very pure limestone to moderately calcareous shales and mudstones. Although Tetrataxis and Ammodiscus are present in various Red Eagle Cyclothem lithologies, they occur most commonly in the rocks containing less than 40 percent of calcium carbonate. Glyphostomella is found in lithologies containing about 75 percent of insoluble clastic residue. On the other hand Ammevertella and Tolypamnina seem to favor the calcareous environments represented by lithologies containing less than 10 percent of insoluble residues. Thus, their preference for clear waters is indicated. Also, calcareous places of attachment were preferred by these genera.

Ammoverbella were found encrusted on fragments of Rhabdomeson? and Fenestrellina?. Tolypammina are rarely seen encrusted on corals.

Lane (1950) and Hatten (1957) noted that certain specimens of Osagia studied by them contained traces of the arenaceous foraminifer Ammoverbella, together with Nubecularia, which, as Johnson (1946, p. 1103) discovered, is the intimate associate of calcareous algal filaments in all Osagia. In this study, too, traces of Ammoverbella were found in Osagia of the Howe Limestone, and on some linear algae in the Bennett member as well. However, the Ammoverbella are so few that these coincidences of occurrence are not construable as indicating definite organic associations (e.g., commensal, symbiotic, etc.). That is, considering the variety of calcareous materials on which it encrusts, Ammoverbella in the Red Eagle Cyclothem simply seems to have preferred calcareous surroundings or places of fixation. If they had encrusted on a calcareous algal coating of Osagia, they would naturally have been covered by the next-deposited Osagia layer, giving the false impression that Ammoverbella were functional interrelatives of algae and active contributors to Osagia.

In glauconitic residues from limestone in all parts of the Red Eagle Cyclothem commonly contain traces of quartz silt which, where represented by Bennett limestones and shales,