DISTRIBUTION OF LITHOLOGIC COMPONENTS ON THE EASTERN SCOTIAN SHELF

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ABSTRACT

Major lithologic components, selected minor constituents and statistics on sand beds have been contour-mapped using data from the Canstrat east-coast file, for the area 42^{0}N - 46^{0}N, 57^{0}W - 63^{0}W. Vertical distributions of some of the minor constituents are shown as histograms which represent the data summed for all the available wells. The maps and histograms use seven regional formation levels, which in the case of the older levels are composites of two or three formations. Data and picks were available for approximately ninety wells.

INTRODUCTION

This report is one of several being undertaken to investigate the potential for using the Canstrat east coast well lithology file for regional mapping. The Canadian east coast offshore is a frontier area, but the eastern two-thirds of the Scotian Shelf is the area with the most dense well control. Many of the wells are concentrated in the vicinity of Sable Island and Venture Field, but the data coverage of an area roughly 500 km parallel to the coast by 200 km perpendicular is sufficiently uniform for regional mapping. The data in most cases is sufficiently coherent from well to well for contouring, and this criterion has been subjectively used in deciding generally whether a map should be included in this report.

Seven lithostratigraphic intervals (i.e. slices of the geologic column of regional extent) have been used, as follows:

1. Banquereau Formation
2. Wyandot Formation
3. Dawson Canyon Formation
4. Logan Canyon Formation
5. Missisauga + Verrill Canyon Formations
6. Mic Mac + Abenaki (+ Mohawk) Formations
7. Mohican + Iroquois Formations

Data for the Argo and Euridice Formations are too sparse for mapping. Picks for these formations have been taken in most cases from the Offshore

Schedule of Wells (1985) (Table 1). Isopach maps are included (Maps 2a, 3a,...7a). There is no isopach map for the Banquereau Formation, but depth to the bottom (Map 1a) and the thickness of the interval with lithologic data (Map 1b) are shown. Other than this there are no structural maps. All maps are identified in Table 2.

All wells drilled were considered to be vertical except for wells D091, D101, D112 and D118. These four wells were omitted from the isopach maps. In two wells, D207 and D227 the Verrill Canyon Formation was picked below the Mic Mac Formation. The Mic Mac Formation thus interfingers within the Missisauga Formation and Verrill Canyon Formation composite level. In these cases the Verrill Canyon should have been treated as composite with the Mic Mac, but this has not been done here. In these two wells the posted values were calculated by combining the Missisauga Formation interval with the Verrill Canyon interval. For this reason Table 1 shows the bottom of the Missisauga composite level below the Mic Mac composite level. The term "caprock" below the Mic Mac Formation has been included in the Mohican and Iroquois formations composite level whereas it is actually equivalent to earlier evaporites.

As well as lithostratigraphic intervals, time-slice maps were also investigated, using intervals picked for each geologic age. The major single source of age picks is Barss, Bujak and Williams (1979), but some more recent ones are taken from Open Files and internal reports. These maps proved to be of poor quality, which can be attributed to the fact that thicknesses deposited per age interval are not much greater than the depth uncertainty of age picks. Thicknesses per epoch are comparable to or greater than the formation intervals, and add little information. Comparisons of the formation tops with the nearest age horizon are shown in a series of maps (2b, 3b,...6b) in which the depth difference are posted. The top and bottom of the Wyandot Formation and the top of the Mic Mac, Abenaki and Mohawk Composite show a progression across the Shelf. The map for the top of the Missisauga Formation indicates progression with more localised geography, and the top of the Logan Canyon Formation shows largely random scatter. Subdividing the Banquereau Formation and the Missisauga Formation by time-slices was also examined, but no significant distinctions were found between levels within those units. A table of age ranges (Table 3) for the lithostratigraphic intervals is useful to indicate doubtful picks and also to indicate the age equivalence of the formations.

POSTING AND CONTOURING MAPS

Methods used to sum the data from the intervals picked for observations in the Canstrat file are described by Fricker (in preparation). Since the formation picks used for the maps were made independently, some sampling error for the lithology is inevitable. An interval picked in the Canstrat file and assigned a position at the limit of one formation may be included in the adjacent formation for this compilation, even though the lithology described corresponds to the first formation. The average thickness of data intervals is 6 or 7 metres, whereas the thickness of formations summed may be hundreds of metres.

Values are posted at the well locations. A value is shown whenever one can be obtained. The contours have been drawn to highlight the general field. They do not strictly observe every point, particularly when wells close together have very different values. No geological interpretation is made. Data in which less confidence is placed are indicated. This is a somewhat subjective judgement, but is usually based on very straightforward criteria such as the depth interval for the well being small and with only a few observations. All points plotted on the maps are values from single wells except for west Sable Island wells D039, D069, D081, D091, D101,D112, D118. In this case the procedure followed was to eliminate the highest and lowest calculated value for each map and take the average of the remaining values to post on the map.

HISTOGRAMS OF VERTICAL DISTRIBUTION

The histograms have vertical scales in units of level number. For example, a vertical coordinate of 3.0 means the top of the Dawson Canyon Formation. Depths within each level have been converted to a coordinate with a decimal fraction by interpolating between the top and bottom picked depths for the level. Each observation in the lithology file belongs to a depth interval, and is treated as if it were at its mid-depth. Observations have been divided into five smaller divisions within each level and summed to give five bars in the histogram for each level. Sea-level has been used to calculate the interpolated level of the Banquereau Formation where tops are not available (the majority of wells).

Only the lowest one-fifth of the Banquereau calculated is shown in the histograms.

Two types of summation have been used in the histograms. Where rock percentages are available, the fraction of the entire rock body has been calculated as described for major component mapping (next section). Where percentages are predominantly absent (5% or less) the fraction of the formation interval in which the constituent is detected has been calculated. In each type of summation the result is averaged over all the wells which penetrated that interval. Thus, a well with 100 metres of the interval has the same weight as one with 1,000 metres.

Owing to the averaging method just described, to the precision of the basic observations (discussed in the next section) and the uneven distribution of wells in the map area, the histograms should be taken as accurate to a few percent. Results below 1% should be regarded only as indications of where observations have been made.

MAJOR COMPONENTS

Major components are regarded as follows:

1. Sand
2. Shale
3. Silt

4. Carbonate

5. Evaporite

6. Other (igneous; coal; dolomitic tuff)

There are very few occurrences of igneous rock and virtually no evaporite reported in the formations which have been mapped. Siltstone has not been mapped. In addition to sandstone, shale and carbonate maps, the sandstone/shale ratio has been mapped. There is no sandstone in the Wyandot Formation.

The major component maps display that component as a fraction of the rock in the interval of the formation. The thickness for each observation is multiplied by the percentage observed for that component, and this is summed for the interval and divided by the total thickness observed. The original observations are made with percentages rounded to the nearest multiple of ten. Since the number of observations summed in a formation is of the order of one hundred, data posted on the maps can reasonably be taken as accurate to the order of a few percent.

The observations use thirty lithologic descriptors, of which percentages in each interval normally add to 100 percent. For major component mapping all of the rock volume is classed in one or other major category. Each of the original descriptors is put in one of these categories (Table 4).

MINOR CONSTITUENTS

Minor constituents were investigated as follows:

1. Coal (including stringers and "coaly")
2. Glauconite
3. Pyrite
4. Siderite (including nodules and stringers)
5. Pebbles and conglomerate

Observations of minor constituents generally have a reported percentage of zero or ten. The occurrences of coal and of siderite (Table 5) are bimodal with lesser peaks at 100% and 90% respectively. The small quantities reported do not usually show any statistically significant regional pattern. It is the simple existence of a constituent that has normally been examined and mapped. This is done by calculating the percentage of the formation interval of the intervals in which the constituent was reported. The histograms indicate that the formations can be characterised to some degree by the minor constituents.

Coal occurrences are almost entirely confined to levels 4, 5 and 6 (Logan Canyon to Mohawk). Traces of coal have a fairly even vertical distribution within that interval (Fig 1). Posted maps show essentially random scatter and have not been included. Bedded coal (where a percent volume is reported) shows a strong regional concentration (Map 9n), and the vertical distribution by volume (Fig 2) also suggests some concentration in the middle parts of the Logan Canyon and Missisauga formations. The totals of bedded coal are too small to be statistically significant regionally, but the presence of coal is real.

Both glauconite and pyrite are trace accessories, although they have been observed pervasively through the sections (Figs 3 and 4). Fairly coherent regional patterns of distribution can be traced, although the contours indicate that the values are only marginally significant. The patterns for the Banquereau, Wyandot and Dawson Canyon Formations (Maps 81 and 8m) were sufficiently similar, and the same for the Logan Canyon, Missisauga and Mohawk (Maps 91 and 9m) to justify combining them, and the resulting maps show far greater coherence.

Siderite is a bulk accessory (Figure 5), predominantly in the Dawson Canyon and Logan Canyon formations. Maps of occurrence are of poor quality, and the percentage observed has been mapped instead (Maps 3j, 4j and 5j). The amounts observed are numerically significant and some confidence can be placed in them. The occurrence of siderite is strongly related to the stratigraphic levels, rather than to depth.

SAND BEDS

An observed interval is treated as sandstone when sandstone is reported as 50% or more. When two or more such intervals are adjacent they are treated as one bed. This technique has resulted in quite high values of interbedding, e.g. beds typically every 10-20 metres, and the highest average in the case of Logan Canyon of about 8 metres.

The statistics mapped for each formation are the number of discrete beds, the (arithmetic) mean porosity and the (geometric) mean grainsize. It should be remembered that these porosities are observed and not from wireline logging. The mean vertical position of the beds within the formation was examined but in no case was any particular pattern observed. For the Banquereau Formation, where there is not data for the entire interval, the number of beds per 100 metres is shown. The same has been done for the Mic Mac, Abenaki and Mohawk formations, for which the isopach data is very irregular.

CONCLUSIONS

Apart from the supporting maps (well location, isopach, age-formation comparison) there are three kinds of information that have been investigated - major components, minor constituents and statistics on sandstone bedding.

Maps of major components are commonly compiled by assigning each observation a major lithology and summing the footages for each. Using a database has permitted the alternative of summing percentages of each constituent in the observed intervals. This is more sensitive for the purposes of displaying regional variation of the lithology of a formation and of interpreting the paleoenvironment of a give time.

The database has made examining minor constituents as clues in the history of the basin much simpler. The maps that have been included in this report are those that indicate a regional pattern and which require interpretation. The maps of sandstone porosity and grainsize should be interpreted similarly. Other parameters such as fossil occurrence and diagenesis have not been fully investigated at this time, but the consistency and detail of these observations mean that they offer less promise.

The technique for counting the numbers of sandstone beds should in future be applied to other constituents. Depth measurements are the data in the lithology file on which most confidence can be placed. Statistics from characteristic constituents may give information on the occurrences of depositional events. The numbers of sandstone beds calculated by this technique are higher than commonly reported and mapped for a formation. For the purposes of reservoir evaluation the intervening beds may not have great lateral extent and may be of minor importance, but for the physical history of the basin and particularly for fluid migration the shale interbedding and the higher numbers of beds will be significant.

Of the areas covered by the lithology file, the Scotian Shelf has greater data density, and has lithostratigraphic picks of generally greater regional consistency. The depth resolution into seven levels has produced satisfactory contour maps. Maps of individual formations are possible with good picks. The same can be said in principle for time-slice maps, but for the Scotian Shelf these have been found to add little.

Points have been ignored in some cases of contouring. Some cases are of an isolated well at the extreme of a formation. Others tend to occur in the vicinity of Sable Island, where the control is most dense. The differences in values for adjacent wells are sometimes greater than the expected error discussed earlier. For most parameters this might be attributed to structural effects, and indicates the limitations of the regional view taken here.

Computer programming for this project has been directed towards compilation and tabulation. The maps were done by hand. The results justify using commercial mapping software in future, and directing the compilation into the project database for this software.

REFERENCES

Canadian Oil and Gas Lands Administration, Ottawa. (1985) Offshore Schedule of Wells, 1966-1984.

Fricker, A. (in preparation). Using the Canadian Stratigraphic Service east coast lithology data base for mapping and statistical examination of lithostratigraphy.

Barss, M.S., Bujak, J.P. and Williams, G.L. (1979) Palynological Zonation and correlation of sixty seven wells, Eastern Canada. Geological Survey of Canada Paper 74-30, v.2.

TABLE 1. BOTTOMS of FORMATIONS and/or COMPOSITES IN METERS

WELL I.D.	WELL NAME & PICK	BANQUEREAU FM	WYANDOT FM	DAWSON CANYON FM	LOGAN CANYON FM	MISSISAUGA COMP	MIC MAC COMP	MOHICAN COMP
D001	SABLE ISLAND NO 1	1362.4	1423.4	1599.5	2868.4	*		
D002	ONONDAGA E-84	1349.6	1419.4	1556.0	2701.4	3959.6		
D003	ONEIDA O-25	1219.2	1238.4	1457.5	2468.2	2882.1	3864.8	*
D004	NASKAPI N-30	553.5	579.1	979.6	1446.5	1675.1	2010.4	2131.1
D006	CREE E-35	1217.3	1248.1	1478.0	2581.6	*		
D007	MIC MAC J-77	649.8	766.5	1037.8	1983.6	2962.0	*	
D008	MIC MAC H-86	712.0	834.5	1070.4	2000.1	3025.1	4539.0	*
D009	MISSISAUGA H-54	936.6	1067.4	1316.7	2414.0	3537.2	*	
D010	ABENAKI J-56	871.7	?	1083.2	2074.1	3041.9	4287.0	*
D011	HURON P-96	908.3	1085.0	1255.7	2188.4	2663.3		2995.8
D012	TRIUMPH P-50	1716.0	1826.9	1943.1	3505.2	*		
D013	ESPERANTO K-78	955.5	1205.1	1445.9	2273.8	2840.7	*	
D016	ABENAKI L-57	624.8	?	728.1	1491.9	1946.4	1996.4	2167.1
D017	ARGO F-38			*487.6	1050.0	1530.0	1949.2	2305.5
D018	WYANDOT E-53	338.3	415.7	682.7	1413.0	2075.6	2873.6	2962.6
D019	ERIE D-26			*554.7	1224.6	1626.4	2294.5	2371.3
D020	CROW F-52			*223.7	772.6	998.2	1302.1	1387.7
D022	ONANDAGA O-95	1316.7	1389.2	1535.5	2859.0	*		
D023	FOX I-22				*591.9	703.4	784.5	
D024	IROQUOIS J-17	494.9	513.2	700.4	1453.8	1804.4		2044.2
D027	DAUNTLESS D-35	1432.5	1829.4	2161.0	2935.2	3707.9	*	
D029	SAUK A-57	1405.1	1642.2	1717.2	3019.9	3760.6	*	
D030	CHIPPEWA L-75			*571.8	1094.2	2099.4	2125.0	
D033	ONONDAGA F-75	1338.0	1447.8	1591.0	2973.6	*		
D034	EURYDICE P-36					*521.8		795.5
D039	SABLE ISLAND E-48	1132.6	1216.1	1396.5	2520.7	2914.5		2985.8
D068	CHIPPEWA G-67	1050.9	1210.0	1378.0	2380.4	3223.8	3509.4	3593.6
D069	SABLE ISLAND O-47	1153.6	1238.7	1463.0	2539.5			3887.4
D070	MARMORA C-34	1433.4	1543.8	1687.0	3133.3	*		
D074	MOHICAN I-100	unconformity		1711.7	2358.5	2813.3	3623.4	4365.3
D075	PRIMROSE N-50	1356.3	1445.9	1497.7	1571.5			1707.4
D080	EAGLE D-21	1598.3	1799.5	1877.5	3517.3	*		
D081	SABLE ISLAND 1H-58	1193.2	1276.5	1501.7	2613.6	*		
D085	TETCO THEBAUD P-84	1236.8	1284.1	1504.1	2610.3	*		
D086	PRIMROSE A-41 C	1416.4	1617.5	1645.6	1690.1			*
D091	SABLE ISLAND 3H-58	1279.5	1361.2	1609.9	2705.4	*		
D094	BLUENOSE G-97	1449.3	1505.7	1630.9	2935.8	4413.5	*	
D095	PRIMROSE F-41	1470.6	1657.5	1696.5	1981.2			
D096	COHASSET D-42	1002.7	1066.1	1298.4	2247.9	2983.0	*	
D097	PRIMROSE 1A-41	1418.5	1661.4	1717.2	3558.8	*		
D098	MARMORA P-35	1387.4	1506.9	1639.8	3003.2	*		
D099	TUSCARORA D-61	875.3	1072.5	1309.4	2316.1	3348.5	*	
D101	SABLE ISLAND 4H-58	1211.8	1300.2	1541.6	2681.9	*		
D112	SABLE ISLAND 5H-58	1128.3	1214.0	1435.3	*			
D118	SABLE ISLAND 6H-58	1376.4	1464.2	1731.8	*			

TOPS PICKED BY C.O.G.L.A. SCHEDULE OF WELLS (1985)
EXCEPT THOSE INDICATED BY: C - CANSTRAT, H - HUSKY, J - JANSA, P - PETRO-CANADA, S - SHELL, M - MOBIL

* INDICATES INCOMPLETE PENETRATION OF FORMATION OR COMPOSITE

TABLE 1(Cont.) BOTTOMS OF FORMATIONS and/or COMPOSITES IN METERS

WELL I.D.	WELL NAME	& PICK	BANQUER-EAU FM	WYANDOT FM	DAWSON CANYON FM	LOGAN CANYON FM	MISSI-SAUGA COMP	MIC MAC COMP	MOHI-CAN COMP
D121	OJIBWA E-07		534.6	631.5	860.1	1486.8	1819.3	2017.7	2304.2
D123	CITNALTA I-59		1226.5	1324.6	1509.3	2670.6	3934.9	*	
D125	DEMASCOTA G-32		990.5	1119.0	1368.0	2397.5	3400.5	*	
D126	INTREPID L-80		1385.0	1509.3	1660.2	2935.2	*		
D129	SAMBRO I-29				*726.0	1103.3	1489.2		
D130	HERCULES G-15					*393.8	772.3	1054.6	
D131	JASON C-20				*641.3	1375.2	1615.4	2162.2	2449.3
D144	ADVENTURE F-80		396.8	519.9	849.1	992.4			1034.1
D146	SACHEM D-76		1380.7	1770.8	2062.2	2976.0	3819.1	*	
D158	ONONDAGA B-96		1308.8	1422.2	1596.2	2647.1	*		
D160	MIC MAC D-89		570.2	1660.1	905.8	1742.2	2654.8	*	
D164	WENONAH J-75		1575.8	1627.3	1771.8	2983.6			
D165	PENOBSCOT L-30		866.8	948.5	1182.9	2251.2	3191.2	4112.6	*
D168	MOHEIDA P-15		1102.7	1161.2	1360.9	2450.5	2903.5	3577.7	3851.1
D169	PENOBSCOT B-41		858.9	967.7	1202.1	2246.9	3174.4	*	
D170	MIGRANT N-20		1014.9	1147.2	1371.2	2447.5	4027.6	*	
D171	ACADIA A K-62	J	2358.0	2425.0	2779.0	unconformity		4618.0	*
D172	THEBAUD I-94		1256.9	1291.1	1512.7	2632.8	*		
D174	COHASSET P-42		1000.0	1062.5	1293.8	2258.8	*		
D177	COHASSET L-97		979.0	1034.4	1245.4	2219.8	3069.9	4767.9	*
D178	VENTURE D-23		1372.0	1495.0	1666.0	2952.0	4707.0	*	
D195	VENTURE B-13		1412.0	1516.0	1673.0	2966.3	*		
D202	VENTURE B-43		1366.0	1500.0	1677.0	2967.0	*		
D207	BANQUEREAU C-21		1672.0	1854.0	2056.0	3575.0	*	4115.0	
D213	OLYMPIA A-16		1312.0	1442.0	1624.0	2799.0	4612.0	*	
D214	N. BANQUEREAU I-13		1575.0	1727.0	1941.0	3460.0	4885.0	*	
D216	W. ESPERANTO B-78A		935.0	1156.0	1375.0	2324.0	3296.0	*	
D217	SOUTH VENTURE O-59		1399.0	1533.0	1693.0	3065.0	*		
D219	SHUBENACADIE H-100		3702.0	3767.0	*				
D223	BLUENOSE 2G-47		1434.5	1504.5	1624.5	2945.5	4032.5	*	
D224	SOUTH VENTURE B-52		1377.0	1501.0	1681.0	2970.0	4185.0C	*	
D225	ARCADIA J-16	M	1371.0	1464.0	1641.0	2896.0	5835.0	*	
D226	GLENELG J-48	C	1646.0	1774.5	1975.0	3469.0	*		
D227	SW BANQUEREAU F-34	C	1773.0	1927.0	2149.0	3918.0	*	4676.0	
D228	UNIACKE G-72	C	1125.0	1218.0	1410.0	2563.0	3819.0	*	
D231	GLOOSCAP C-63	C	954.0	1104.0	1317.0	2217.0	2594.0	3490.0	4100.0
D232	VENTURE H-22		1408.0	1523.0	1681.0	2932.0	?	*	
D239	ALMA F-67	S	1313.0	1325.0	1509.0	2847.0	*		
D242	CHEBUCTO K-90	H	1770.7	1911.2	2026.4	3425.0	*		
D248	DOVER A-43	P		*823.0	1030.0	1925.0	2842.0	4075.0	*
D256	GLENELG E-58	C	1581.0	1690.0	1829.0	3364.0	*		
D257	HESPER I-52	C	1246.3	1493.0	1766.0	2752.0	*		
D261	GLENELG H-38	C	1672.0	1769.0	1942.0	3213.0	*		
D267	ALMA K-85	S	1324.0	1336.0	1512.0	2843.0	*		

TOPS PICKED BY C.O.G.L.A. SCHEDULE OF WELLS(1985)
EXCEPT THOSE INDICATED BY: C - CANSTRAT P - PETRO-CANADA
H - HUSKY S - SHELL
J - JANSA M - MOBIL

* INDICATES INCOMPLETE PENETRATION OF FORMATION OR COMPOSITE

Table 2. Identification of the maps in this report

Banquereau	Wyandot	Dawson	Logan	Mississauga + Verrill	Mohawk + MicMac + Abenaki	Mohican + Iroquois
1. Well location and study area						
1a. Depth to bottom	2a. Isopach	3a. Isopach	4a. Isopach	5a. Isopach	6a. Isopach	7a. Isopach
1b. Data thickness	2b. Top of Campanian	3b. Top of Santon-ian	4b. Top of Cenom-anian	5b. Top of Barremian	6b. Top of Jurassic	7b.
1c. Sand/shale		3c. Sand/ shale	4c. Sand/ shale	5c. Sand/shale	6c. Sand/shale	7c. Sand/shale
1d. % Sand		3d. % Sand	4d. % Sand	5d. % Sand	6d. % Sand	7d. % Sand
1e. % Shale	2e. % Shale	3e. % Shale	4e. % Shale	5e. % Shale	6e. % Shale	7e. % Shale
1f. % Carbonate	2f. % Carbon-ate	3f. % Carbon ate	4f. % Carb-onate	5f. % Carbonate	6f. % Carbonate	7f. % Carbonate

Table 2 (Cont.) Identification of the maps in this report.

Banquereau	Wyandot	Dawson	Logan	Mississauga + Verrill	Mohawk + MicMac + Abenaki	Mohican + Iroquois
1g. Sand beds/ 100 meters		3g. # of sand beds	4g. # of sand beds	5g. # of sand beds	6g. # of sand beds	
1h. Sand porosity		3h. Sand porosity	4h. Sand porosity	5h. Sand porosity	6h. Sand porosity	
1i. Grain size		3i. Grain size	4i. Grain size	5i. Grain size	6i. Grain size	
		3j. Siderite	4j. Siderite	5j. Siderite		
1k. Pebbles + conglomerate				5k. Pebbles + conglomerate		
(——	81. Pyrite	——)	(——	91. Pyrite	——)	

Table 2 (Cont.) Identification of the maps in this report.

Banquereau	Wyandot	Dawson	Logan	Mississauga + Verrill	Mohawk + MicMac + Abenaki	Mohican + Iroquois
	8m.			9m.		
(———	Glauconite	———)	(———	Glauconite	———)	
				9n.		
			(———	Coal	———)	

TABLE 3. FORMATION TOPS FOR EACH WELL (COGLA NUMBER), TABULATED AGAINST AGE

AGE	FORMATIONS								
	WYANDOT FM	DAWSON CANYON	LOGAN CANYON	MISSISAUGA FM	VERRILL CANYON	MIC MAC	ABENAKI	MOHAWK	MOHICAN	IROQUOIS (CAPROCK)
PALEOCENE	27									
MAASTRICH-TIAN	13,24,29,75,86 96,126,178,202 226									
CAMPANIAN	1,2,3,4,6,7,8 9,12,18,39,94 121,144,164 172,195,213	2,4,6,7,18,24 121								
SANTONIAN	170	3,8,9,13,27,94 96,144,178								
CONIACIAN		12,29,86,95,126 164,170,172,195 202,216,226	121							
TURONIAN		75,213	164							
CENOMANIAN			1,3,4,6,7,8,9 12,13,17,18,24 27,29,74,75,85 86,94,95,96,97 126,144,170,172 178,195,202,213 216,226							
ALBIAN			2				171			
APTIAN				3,6,8,9,12,17,18 23,27,121,130 172,178,195,202	3					
BARREMIAN				1,2,4,7,13,24,29 74,85,94,96,97 126,213,216,226	2					34
HAUTERIVIAN					125,226					
VALANGINIAN-BERRIASIAN					1,6,12,85 126	4,9,10,29 94,121,178 228	3,27,125			
TITHONIAN						8,13,17,18 96,123,213 216	10,29,74 130,165 168,228			
KIMMERIDGIAN						7,130,170	4,17,96		121	
OXFORDIAN								17	4	
CALLOVIAN							18		10,18,165 168,171	171
BATHONIAN							8,216		74	
BAJORCIAN										17,74
AALENIAN TOARCIAN										
[illegible]										24,144

AGE PICKS FOR EACH WELL AS FOLLOWS	
ASCOLI,P.	8 10 123 125 126 165 168 170 172 195 202 213 216 226 228
BUJAK,J.P.	12 13 17 34 96 121 144 178
DAVIES,E.H.	2 85
GRADSTEIN,F.M.	39 75 95 164
WILLIAMS,G.L.	1 3 4 6 7 9 18 23 24 27 29 74 86 94 97 130 171

TABLE 4. ROLLUP NAME USED FOR EACH ACTUAL ROCK DESCRIPTION

ROLLUP NAME	ACTUAL ROCK DESCRIPTION	
SAND	CHERT	PEBBLE IGNEOUS
	CHERTY	PEBBLE LIMESTONE
	CONGLOMERATE	PEBBLE METAMORPHIC
	GLACIAL TILL	PEBBLE QUARTZ
	GLAUCONITE	PEBBLE VOLCANIC
	MINERAL QUARTZ XL	SANDSTONE
	PEBBLE CHERT	SANDSTONE STRINGER
	PEBBLE DOLOMITE	SANDY
	PEBBLE FELDSPAR	SILICEOUS
SHALE	ARGILLACEOUS	CLAYEY
	BENTONITE	KAOLIN
	BENTONITE STRINGERS	PEBBLE SHALE
	CLAY	SHALE
	CLAY STRINGERS	SHALE STRINGERS (SHALEY)
SILT	PEBBLE SILTSTONE	SILTSTONE STRINGERS
	SILTSTONE	SILTY
OTHER	CARBONACEOUS MATERIAL	COALY
	COAL	PEBBLE COAL
	COAL STRINGERS	PYRITE
	IGNEOUS - ACIDIC	VOLCANIC
	METAMORPHIC	VOLCANIC STRINGERS
	IGNEOUS - BASIC	
CARBONATE	BRECCIA (DOLOMITE)	MARL
	BRECCIA (LIMESTONE)	MARLSTONE
	CALCAREOUS (LIMEY)	NODULES DOLOMITE
	CALCITE CRYSTALS	NODULES IRONSTONE
	DOLOMITE	NODULES LIME
	DOLOMITE SLUMP BRECCIA	NODULES PHOSPHATE
	DOLOMITE STRINGERS	NODULES SIDERITE
	LIMESTONE	PHOSPHATE
	LIMESTONE STRINGERS	SIDERITE
	LIMEY (CALCAREOUS)	SIDERITE STRINGERS
EVAPORITE	ANHYDRITE	POTASH SALT
	GYPSUM	SALT
	GYPSUM STRINGERS	
	ANHYDRITE STRINGERS AND NODULES	
	SALT CAST AND SALT STRINGER	

Table 5. Frequency distribution of bulk accessory observed percentages.

Percentage	Coal Occurrences	Siderite Occurrences
100	62	62
90	27	89
80	3	60
70	9	47
60	1	32
50	0	25
40	2	11
30	19	347
20	33	983
10	999	6,760
0	4,126	415

FIGURE 1. VERTICAL DISTRIBUTION OF COAL TRACES - percent of lithology in which coal is mentioned

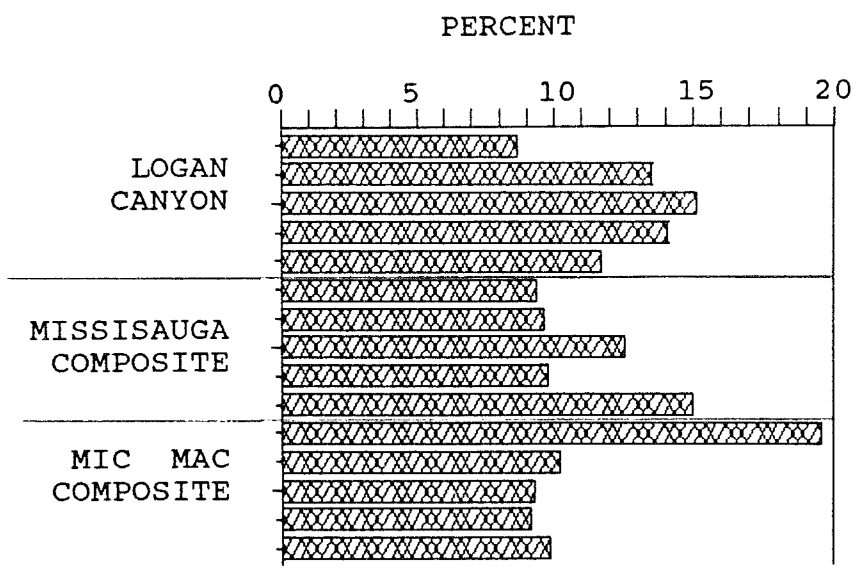

FIGURE 2. VERTICAL DISTRIBUTION OF COAL - percent by volume

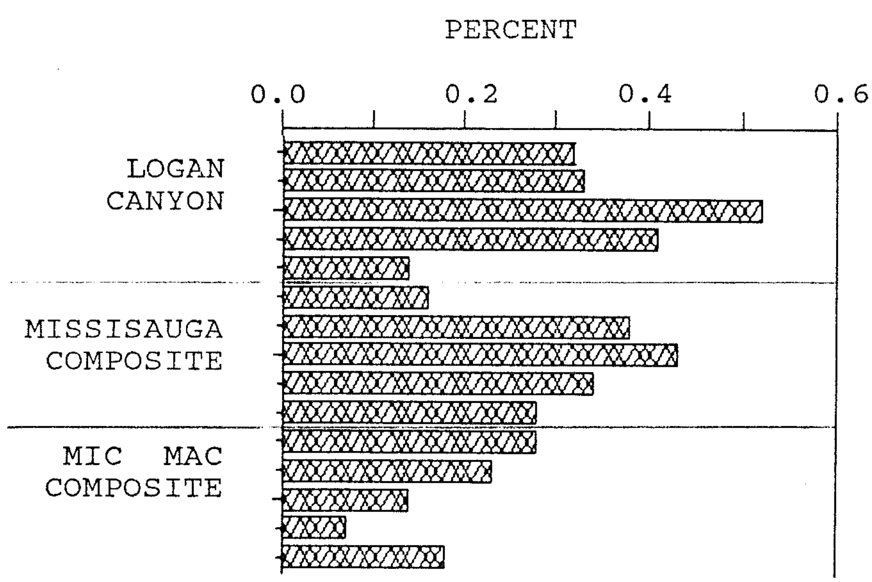

FIGURE 3. VERTICAL DISTRIBUTION OF GLAUCONITE TRACES - percent of lithology in which glauconite is mentioned

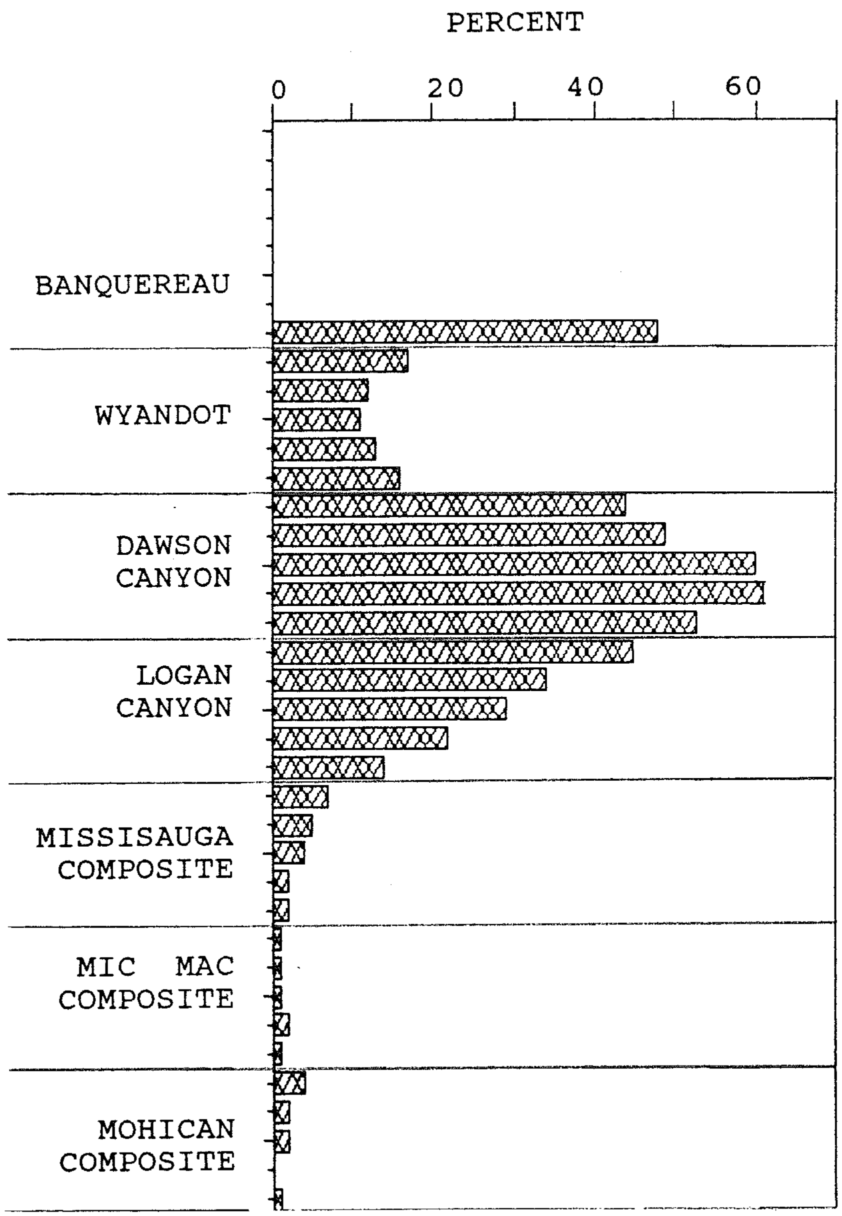

FIGURE 4. VERTICAL DISTRIBUTION OF PYRITE TRACES - percent of lithology with pyrite mentioned

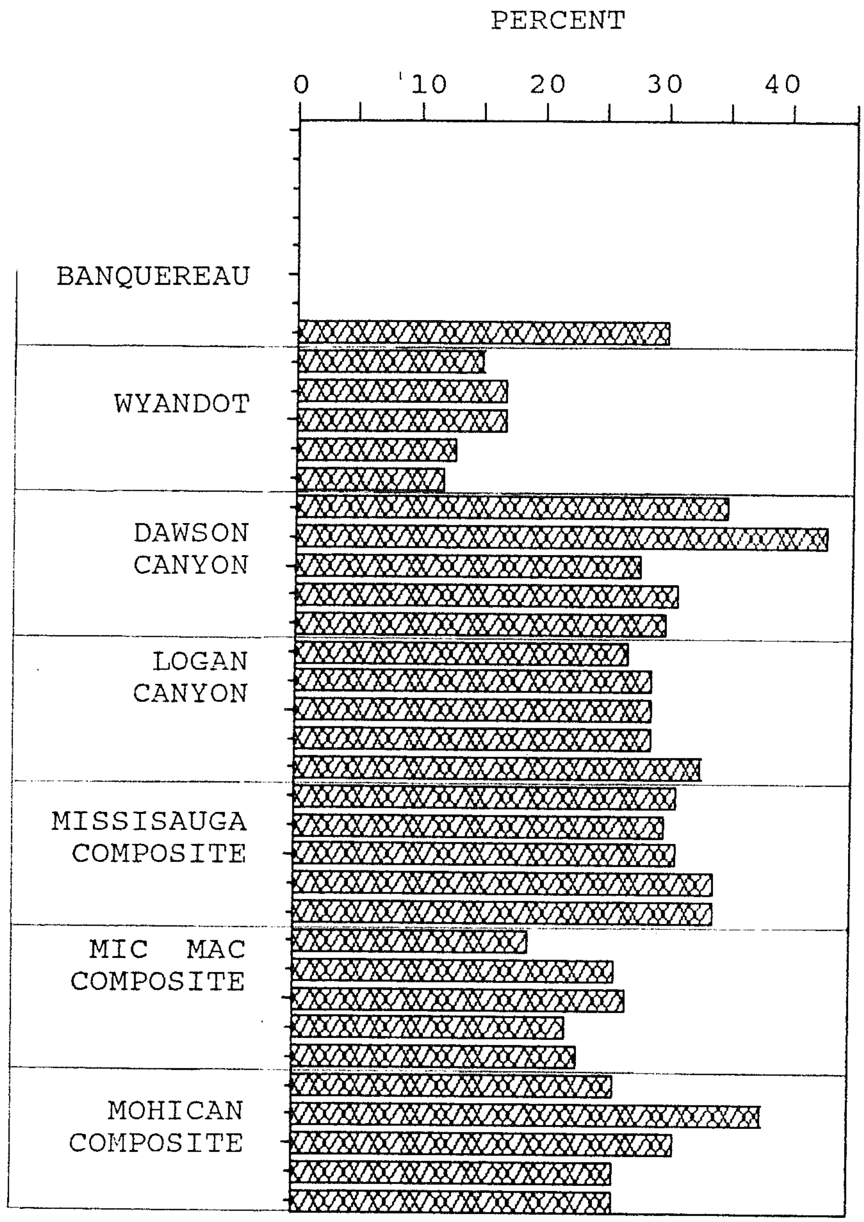

FIGURE 5. VERTICAL DISTRIBUTION OF SIDERITE - percent by volume