EVALUATION OF ANALYTICAL DATA
FROM TEST HOLES 76-135 AND 76-136
HAT CREEK NO.1 COAL DEPOSIT

by

Dr. A.J. Sinclair, P.Eng.

March, 1977

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SUMMARY AND CONCLUSIONS

A statistically-oriented evaluation of analytical data for diamond drill holes 76-135 and 76-136 1000 feet apart in the Hat Creek No. 1 coal deposit was undertaken by the writer. Data were grouped and analyzed by major stratigraphic zones (A, B, C and D zones - A is the youngest zone in a right-side-up sequence that is extensively faulted and characterized by marginal zones of extreme facies changes).

Emphasis in the writer's study was on dispersion (variability) of variables, evidence of trends and/or autocorrelation along the drill holes, comparison of data from one hole with data from the second hole, and the question of an appropriate sampling scheme for future drill core analyses. Very few guidelines were provided with regard to boundary conditions for a sampling program.

Proximate and Btu Data

Proximate variables and Btu/# are, in general, comparable from one hole to another within a single zone. However, large differences exist among the principal stratigraphic zones - A, B, C and D.

For most proximate variables A and C zones show general similarities as do B and D zones. A and C zones are low quality coals compared with B and D zones.

Probability plots of proximate variables (incl. Btu/#) commonly show a multi-modal form. In the case of A-zone this is consistent with other data (especially variograms) and leads to a useful conceptual model of cyclical variations of, for example, high ash and low ash coals. The cyclical character is important in sample design. Although the model differs slightly in detail in the two test holes, a simple view of the model is - a repetitive cycle in which one cycle consists of a 40 to 50-foot layer of high Btu/# coal followed by a 20 to 25-foot layer of lower Btu/# coal.

C-zone appears cyclical but the pattern is not as clear cut as for A-zone. A probable ideal model for C zone is - a 10 to 15-foot low Btu/# layer followed by a 30 to 50-foot thick higher Btu/# layer.

B and D zones also appear to contain multiple populations of proximate variables but these are interdispersed in random (rather than cyclical) fashion throughout the thickness of the respective zones. Of course, cyclical interbeds either of coal or waste would not be recognized over distances of a few feet because they would be smoothed out in the 10-foot sample lengths on which much of this study is based.

Most proximate variables have comparable variability in each of the two test holes. An analysis of variance on ash (% dry) illustrates the fact that local variations are greater than variations between the two test holes (which are separated by 1000 feet). This test has not been made rigorously for all proximate variables but by inspection shows that comparable results would be obtained for other variables. Consequently, an important generalization is that where zones A, B, C and D can be recognized unambiguously the local variability (10's of feet) across stratification is high relative to lateral variability (100's of feet). In fact, locally the "across stratification" variability is a good approximation of the total variability.

Autocorrelation studies show that proximate variables are largely random in nature; although note the presence of cyclical variations of some proximate variables in A and C zones. The main implication of this dominant random nature is that short range variability (over 10's of feet) is the same as the total variability occurring throughout a particular zone.

Sulphur and CO_2

Total sulphur, organic sulphur and pyritic sulphur were examined. All are random variables in all four zones and have lognormal density distributions. In most zones a few percent of S_{total} values are much higher than most, of the order of one percent or more. For zones A, B and C about two-thirds of S_{total} is organic sulphur - for D zone about 88 percent total sulphur is organic sulphur. Analytical data show that pyritic sulphur is the only other significant component of total sulphur. All zones show a slight increase in mean total sulphur content as Btu/# increases.

Sulphur contents and variability are comparable from one test hole to the other. The principal exceptions are total sulphur and organic sulphur in D zone. However, both variables are lower in D zone than any other zone and evidence of a slight trend laterally in sulphur values is not critical in D zone.

Carbon dioxide contents of zones A, B and D are comparable. Zone C has a much higher carbon dioxide content and variability than the other three zones. Virtually all CO_2 is derived from siderite layers that seem to be distributed randomly throughout each of the four main stratigraphic zones.

Mineral Ash

Most mineral ash variables show comparable means and dispersions in each of the test holes. TiO_2 and K_2O variability, however, differ from one hole to another in zones B and D. Similarly, P_2O_5 and CaO variability differ from one hole to another in zones A and C. Such differences would seem to imply that ash of zones B and D have features in common, which, in turn differ somewhat from ash in zones A and C.

There is a surprising statistical uniformity of mean values of mineral ash variables for the two test holes. The implication is that vertical variability (i.e. across stratification) is large and lateral variability is relatively slight. This generalization should be applied only where zones A, B, C and/or D can be identified unambiguously, and not where grossly different facies prevail.

Virtually all mineral ash variables are random in character. Hence, the total variability can be found locally.

Probability plots for mineral ash variables are, in general, more complex in make-up than are those of proximate variables. Their complexity (multi-modal character) arises through contributions to variability from fundamentally different types of ash (e.g. silt, kaolin, illite, montmorillonite), rather than simply different percentages of two end members. It is probable that different normal and/or lognormal mixed populations represent interlayered and fundamentally (mineralogically) different types of ash in the coal sequence.

Ultimate Variables

Ultimate variables show the greatest disparity in means and standard deviations from one test hole to the other. Nitrogen and chlorine trends are probably of little practical significance because of the low levels of abundances of these variables in all zones. Carbon, Hydrogen and oxygen values are multi-modal, probably because their variabilities derive from grossly different ash-coal populations and partly from different mineralogies. Oxygen by difference is consistently less than is oxygen by analysis. The differences for all zones are significant statistically and indicate a systematic error in one or the other of the oxygen estimation procedures. If the error lies with oxygen by difference then the basic error occurs in the estimation of some other variable(s). Surprisingly, D zone shows the most statistically significant differences for ultimate variables (nitrogen, chlorine, oxygen) between test holes. Despite their statistical significance the differences are small quantitatively and arise from a small local dispersion of values relative to other zones.

Comments on Populations

Analysis of probability graphs, particularly for proximate data, show that each zone is characterized by two populations, high ash - low Btu/# and low ash - high Btu/# respectively. These populations do not correspond in mean values or dispersions from one zone to another. Furthermore, these populations tell us little or nothing about the possibility of fundamentally different types of coal or ash.

Some mineral ash variables appear to have simple density distributions but many have complex (i.e. multi-modal) distributions that probably relate to fundamentally different types of ash (e.g. montmorillonite, kaolinite, silt). Variables that appear to have potential for classifying ash into fundamentally different groups are MgO, Na_2O, K_2O, CaO, Al_2O_3, Fe_3O_4, TiO_2 and possibly P_2O_5. Combinations of these variables might relate to various clay types, silt or fine sand. To show such relationships with certainty requires detailed mineralogical study of a variety of ash types. There are no data available to the writer at the present time that lead to recognition of two or more fundamental types of solid hydrocarbon in Hat Creek coal.

Variability

Variability of all variables decreases as the sample length increases. For samples from 10 to 40 feet long this decrease of dispersion closely approximates an exponential form. Empirical exponential relationships thus provide a means of interpolating dispersions for sample lengths other than 10-foot, 20-foot, etc. lengths if such are required.

Lateral variability (parallel to stratification) is substantially less than vertical (across strata) variability. Thus, local vertical samples taken contiguously (as along a drill hole) provide a good approximation of total local variability.

In general, the variability shown by A and C zones is substantially greater than that shown by B and D zones. Zone D, in particular, is relatively uniform in character. For a few variables different relations exist among zones.

Autocorrelation

Autocorrelation has been studied by examining semivariograms for 10-foot samples along the direction of the drill holes. For proximate variables, Btu/# and total sulphur there is no significant difference between the two test holes. The results indicate a cyclical autocorrelation function for zone A and, more ambiguously, zone C. This pattern can be ascribed to a regular interlayering of high ash and low ash layers.

Mineral ash and ultimate variables show essentially no autocorrelation - that is, they are random variables on the scale on which they have been studied (10-foot samples).

The important implication of the random aspect of nearly all variables is that local variability is essentially the same as variability throughout the drill intersection of an entire zone.

Optimal Sampling Plan

An optimal sampling plan to provide estimates of mean values and local variability (dispersion) requires continuous sampling with 15-foot sample lengths in A and C zones and 20-foot sample lengths in B and D zones. Twenty-foot sample lengths in all zones would be nearly as good but would not monitor local variability in A and C zones as well. The optimal sampling plan is recommended for proximate analyses, Btu/#, total sulphur, pyritic sulphur and CO_2.

In cases where local variability is not required for a variable, sample lengths of 40 feet (bench height) are adequate. Hence, in such cases two adjacent 20-foot samples can be combined to form a 40-foot composite to be analyzed for particular variables. Such a procedure will be more readily evaluated when all analytical results for the 1977 drilling program have been appraised - such an appraisal may even obviate the necessity of certain variables being determined.

The recommended sampling plan will be superceded by practical considerations relating to such features as faults, zone contacts, pronounced facies changes, etc.

INTRODUCTION

In the spring of 1976 the writer was approached by Dr. L.T. Jory of Dolmage Campbell and Associates Ltd. on behalf of British Columbia Hydro and Power Authority and requested to conduct an evaluation of analytical data to be obtained early in the summer of 1976 through a drilling program on the Hat Creek No. 1 coal deposit. Originally, the author's study was planned to precede analytical work on most of the cores, and, in fact, was to provide a basis for design of a sampling plan for such cores. Such a study involves estimation of density distributions of the variables in question.

Some indication of mean values and standard deviations for proximate variables could be obtained from the results of previous drilling campaigns. Available data were coded and reviewed, but were not entirely representative either of mineable coal or of the total coal-bearing section (i.e. coal plus interbedded waste). This was because of the manner in which samples had been grouped (mixed) for chemical analysis of relatively long composite samples. Thus, a set of control samples was required on which to base a sampling design. For this purpose two test holes (diamond drill holes 76-135 and 76-136) were chosen, separated by about 1,000 feet in plan. This sample separation was chosen to provide some detailed information on lateral variability in the coal-bearing sequence. Sampling plans were developed for each main stratigraphic zone (A, B, C and D zones) based on an evaluation of variability as indicated on geological and geophysical drill logs and by existing proximate data. These sampling plans are as follows:

A Zone:	Five 10-foot samples followed by two 5-foot samples
B Zone:	Two 10-foot samples followed by two 5-foot samples
C Zone:	10-foot samples
D Zone:	Two 10-foot samples followed by two 5-foot samples

These plans are unit plans that were repeated throughout the appropriate zones. Note the advantages of such a sampling procedure.

1. The continuous nature provides mean values and dispersions for the entire coal-bearing sequence;
2. Large interbeds of waste can be purposely ignored if such is appropriate;
3. Samples can be combined to study variations (statistical dispersions) of 10-foot, 20-foot, 30-foot, etc., sample lengths.

Consequently, with all samples completely analyzed an appropriate data base would be available for developing sampling plans for much of the deposit and for design purposes.

These sampling patterns were applied to both test holes and the resulting samples analyzed "chemically" for proximate, mineral ash and ultimate variables. Long delays in completing the analyses resulted in one purpose of the study being negated. It was essential to determine a basic sampling procedure for the remaining holes long before complete analyses were available for the two test holes. Thus, a subjective recommendation was made by the writer based on analysis of pre-existing data (mainly proximate) that a sample length of 20 feet be maintained except where other lengths were dictated for obvious reasons (e.g. end of a zone, a fault, a thick interbed of waste). Part of the rationale for this length was based on a proposed bench height of 40 feet for mining purposes.

The data base obtained by analyses of core from test holes 135 and 136 provided:

1. estimates of means and dispersions for all variables in all stratigraphic zones
2. a comparison of data between the two drill holes, separated by 1,000 feet
3. a means of examining auto-correlation of all variables in each zone, and
4. a base for evaluating density distributions and their implications.

However, such a statistical study is only as good as the data on which it is based. We recognized in advance that two drill holes cannot reflect entirely the variations to be expected in a deposit in which abundant facies changes are recognized. On the other hand, a great deal of the No. 1 deposit appears to be relatively uniform in gross stratigraphy (i.e. four stratigraphic zones are recognizable fairly unambiguously) and it appears likely that these two test holes are representative of parts of the No. 1 deposit in which these zones are recognizable.

GENERAL EVALUATION OF DENSITY DISTRIBUTIONS

All variables considered here were output as histograms and cumulative probability plots for both raw and log-transformed data. Purpose was to permit visual evaluation of density distributions, particularly in connection with recognizing the possible presence of two or more distinguishable sub-populations.

The general procedure followed was:

1. Comparison of statistics for each drill hole, and
2. Examination of histograms and probability plots of combined data for both test holes

Initial work with proximate variables indicated relatively little difference statistically between data sets for the two test holes and subsequent work emphasized the combined data. In general, the combined data are considered more useful for sample design because they are more representative of the deposit than are data for one hole.

Xerox reductions of histograms and probability plots are reproduced in Appendices I, II and III for proximate, mineral ash and ultimate data respectively.

Means and standard deviations are shown for all variables as a function of test hole and stratigraphic zone in Tables I to IV incl. In addition, these tables permit comparison of parameters for each hole with parameters for the combined data for both holes. In general, it is the combined data that are most representative of the No. 1 coal deposit.

Probability plots can be used to make a subjective interpretation as to the underlying nature of the various density distributions, particularly with regard to:

1. the possibility that the data represent one or more symmetric populations, and
2. the nature of the symmetric populations - approximately normal or lognormal.

These interpreted features of the data are summarized in Tables VI, VII and VIII for proximate, mineral ash and ultimate dry data.

DISPERSION OF VARIABLES

Dispersion or spread of values of a variable about its mean value can be evaluated in several ways. Here we will examine the implications of

1. dispersion as a function of sample length,
2. F-tests to evaluate whether dispersion of variables for individual holes could represent the same symmetric distribution, and

TABLE I

COMPARISON OF STATISTICAL PARAMETERS
FOR TEST HOLES 135 AND 136

ZONE A

Variable*	DDH 135 (n=55)		DDH 136 (n=54)		Combined (n=108)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Btu/#	6415	2068	6227	2176	6321	2115
Ash	42.92	14.00	45.68	16.41	44.32	15.27
F.C.	27.46	9.54	26.15	10.01	26.80	9.75
V.M.	29.63	5.08	29.41	5.78	29.52	5.42
S total	0.680	0.244	0.671	0.383	0.676	0.320
Sorg	0.498	0.174	0.438	0.210	0.468	0.194
CO_2	1.61	2.14	1.64	1.50	1.62	1.84

* Btu/# of dry coal, other variables % dry coal.

Variable*	DDH 135 (n=55)		DDH 136 (n=54)		Combined (n=109)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
P_2O_5	0.260	0.208	0.345	0.382	0.302	0.308
SiO_2	54.45	6.05	53.21	4.20	53.84	5.23
Fe_2O_3	7.03	2.71	7.95	4.38	7.48	3.65
Al_2O_3	28.45	4.29	29.66	3.64	29.05	4.01
TiO_2	0.888	0.317	0.820	0.383	0.854	0.351
CaO	3.08	5.73	2.29	1.25	2.69	4.16
MgO	1.53	0.603	1.51	0.448	1.52	0.530
SO_3	1.60	0.775	1.61	1.10	1.61	0.947
K_2O	0.773	0.189	0.886	0.373	0.829	0.299
Na_2O	0.775	0.256	0.885	0.256	0.830	0.261
Mn_3O_4	0.074	0.085	0.099	0.156	0.087	0.123
V_2O_5	0.056	0.016	0.051	0.015	0.054	0.016

• All variables are % dry ash.

Variable	DDH 135(n 55)		DDH 136(n 54)		Combined(n 109)	
	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
Nitrogen	0.968	0.382	0.719	0.260	0.845	0.194
Chlorine	0.075	0.136	0.048	0.029	0.057	0.090
O_2 (Diff.)	14.32	2.13	13.96	2.58	14.14	2.36
O_2 (Anal.)	15.00	2.41	15.30	2.50	15.15	2.48

All variables are % dry coal

See Table V for S_{py}, ultimate carbon and ultimate hydrogen

TABLE II

COMPARISON OF STATISTICAL PARAMETERS
FOR TEST HOLES 135 AND 136

ZONE B

Variable*	DDH 135 (n=24)		DDH 136 (n=26)		Combined (n=50)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Btu/#	7679	1229	7639	1645	7658	1446
Ash	34.84	8.35	40.34	17.72	37.90	14.48
F.C.	33.78	5.69	33.78	7.45	33.78	6.60
V.M.	31.37	3.24	31.48	3.88	31.43	3.55
S total	0.792	0.190	0.817	0.256	0.805	0.225
Sorg	0.524	0.082	0.557	0.160	0.541	0.128
CO_2	1.68	1.53	1.67	2.14	1.68	1.85

* Btu/# of dry coal, other variables % dry coal

Variable*	DDH 135 (n=25)		DDH 136 (n=26)		Combined (n=51)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
P_2O_5	0.178	0.260	0.227	0.317	0.203	0.289
SiO_2	51.51	5.87	52.77	4.01	52.15	5.00
Fe_2O_3	7.25	5.10	6.59	4.49	6.92	4.76
Al_2O_3	32.41	3.27	31.57	4.34	31.98	3.84
TiO_2	0.711	0.092	0.822	0.175	0.768	0.150
CaO	2.30	1.56	2.90	3.13	2.60	2.48
MgO	1.53	0.967	1.51	0.577	1.52	0.780
SO_3	1.42	1.51	1.22	0.904	1.32	1.23
K_2O	0.639	0.072	0.593	0.152	0.616	0.121
Na_2O	1.37	0.281	1.18	0.303	1.27	0.305
Mn_3O_4	0.056	0.151	0.061	0.091	0.059	0.123
V_2O_5	0.054	0.010	0.048	0.012	0.051	0.011

* All variables are <u>% dry ash</u>.

Variable*	DDH 135 (n=25)		DDH 136 (n=26)		Combined (n=51)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Nitrogen	1.09	0.180	0.933	0.156	1.012	0.185
Chlorine	0.191	0.237	0.095	0.150	0.142	0.201
O_2 (Diff.)	14.03	1.12	14.65	1.49	14.35	1.34
O_2 (Anal.)	15.73	1.42	16.01	1.69	15.87	1.55

* All variables are % dry coal.

See Table V for S_{py}, ultimate carbon and ultimate hydrogen

TABLE III

COMPARISON OF STATISTICAL PARAMETERS
FOR TEST HOLES 135 AND 136

ZONE C

Variable*	DDH 135 (n=22)		DDH 136 (n=15)		Combined (n=37)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Btu/#	4111	1567	4924	1731	4413	1653
Ash	58.42	10.46	51.83	10.48	55.75	10.83
F.C.	17.31	7.38	21.59	7.53	19.06	7.64
V.M.	24.27	4.49	26.58	3.58	25.21	4.25
S total	0.377	0.163	0.402	0.192	0.387	0.173
Sorg	0.234	0.113	0.301	0.142	0.261	0.128
CO_2	4.71	3.73	3.78	2.27	4.34	3.23

* Btu/# of dry coal; other variables % dry coal.

Variable*	DDH 135 (n=23)		DDH 136 (n=15)		Combined (n=38)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
P_2O_5	0.215	0.227	0.247	0.137	0.228	0.195
SiO_2	52.72	6.43	52.66	4.22	52.70	5.60
Fe_2O_3	8.90	6.25	8.09	3.44	8.58	5.28
Al_2O_3	29.00	4.78	30.72	1.88	29.68	3.95
TiO_2	0.759	0.174	0.828	0.157	0.786	0.169
CaO	2.96	3.00	2.43	1.34	2.75	2.47
MgO	1.78	1.11	1.81	0.540	1.79	0.9116
SO_3	0.919	0.434	0.789	0.600	0.867	0.502
K_2O	1.00	0.292	0.757	0.196	0.906	0.283
Na_2O	0.764	0.185	0.717	0.165	0.745	0.176
Mn_3O_4	0.153	0.231	0.137	0.096	0.147	0.188
V_2O_5	0.038	0.009	0.047	0.005	0.042	0.009

* All variables are <u>% dry ash</u>.

Variable*	DDH 135 (n=23)		DDH 136 (n=15)		Combined (n=38)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Nitrogen	0.729	0.269	0.743	0.127	0.734	0.222
Chlorine	0.252	0.244	0.343	0.231	0.288	0.240
O_2 (Diff.)	11.85	1.62	13.05	1.31	12.32	1.60
O_2 (Anal.)	14.31	2.63	14.43	1.69	14.36	2.28

* All variables are % dry coal.

See Table V for S_{py}, ultimate carbon and ultimate hydrogen

TABLE IV

COMPARISON OF STATISTICAL PARAMETERS
FOR TEST HOLES 135 AND 136

ZONE D

Variable*	DDH 135 (n=25)		DDH 136 (n=29)		Combined (n=54)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Btu/#	9211	1371	9665	1010	9455	1201
Ash	25.99	8.65	22.17	6.36	23.94	7.68
F.C.	41.10	6.86	42.44	5.06	41.82	5.94
V.M.	32.91	2.45	35.39	1.81	34.24	2.45
S total	0.231	0.067	0.296	0.061	0.266	0.071
Sorg	0.191	0.055	0.272	0.062	0.235	0.071
CO_2	1.36	1.63	1.18	1.18	1.26	1.40

* Btu/# of dry coal; other variables % dry coal.

Variable*	DDH 135 (n=25)		DDH 136 (n=29)		Combined (n=54)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
P_2O_5	0.163	0.148	0.197	0.187	0.181	0.169
SiO_2	51.10	6.10	51.76	5.77	51.46	5.88
Fe_2O_3	6.21	4.77	5.52	4.06	5.84	4.38
Al_2O_3	33.98	4.57	33.64	4.55	33.80	4.52
TiO_2	0.798	0.121	0.822	0.195	0.811	0.164
CaO	3.04	1.75	3.11	1.34	3.08	1.53
MgO	1.19	0.672	1.12	0.631	1.15	0.645
SO_3	1.08	0.742	1.13	0.761	1.11	0.745
K_2O	0.325	0.139	0.271	0.046	0.296	0.103
Na_2O	1.57	0.444	1.86	0.577	1.724	0.535
Mn_3O_4	0.166	0.195	0.154	0.234	0.159	0.215
V_2O_5	0.048	0.009	0.052	0.007	0.051	0.008

* All variables are % dry ash.

Variable*	DDH 135 (n=25)		DDH 136 (n=29)		Combined (n=54)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Nitrogen	0.932	0.152	0.991	0.099	0.964	0.128
Chlorine	0.267	0.248	0.097	0.165	0.176	0.222
O_2 (Diff.)	14.89	0.903	15.33	0.476	15.12	0.733
O_2 (Anal.)	16.35	1.16	16.77	0.679	16.58	0.946

* All variables are % dry coal.

See Table V for S_{py}, ultimate carbon and ultimate hydrogen

TABLE V

STATISTICAL PARAMETERS FOR
PYRITIC SULPHUR AND ULTIMATE C AND H_2

Zone		H_2 (ult.)	C (ult.)	Pyritic Sulphur
A	n	109	109	109
	$\bar{X}$	3.30	36.96	0.203
	s	0.725	11.91	0.206
B	n	51	51	51
	$\bar{X}$	3.71	45.24	0.257
	s	0.503	7.93	0.172
C	n	38	38	38
	$\bar{X}$	2.46	27.85	0.118
	s	0.678	9.40	0.093
D	n	54	54	54
	$\bar{X}$	4.27	55.41	0.027
	s	0.378	6.76	0.016

Means (X's) and standard deviations (s's) are percent dry coal

TABLE VI

INTERPRETED FORM OF DENSITY DISTRIBUTIONS
PROXIMATE VARIABLES - DRY COAL
COMBINED TEST HOLE DATA

Variable (dry coal)	ZONE A	B	C	D
Btu/#	N-2	N-2	N-2	N-2
Ash %	N-2	N-2	N-2	N-2
Fixed Carbon	N-2	N	N-2	N
Volatile Matter	N	N	N	N-2
CO_2	L-2	L-2	L-2	L-2
Total Sulphur	L	L	L	L-2
Pyritic Sulphur	L	L	L	L
Organic Sulphur	L-2	L	L-2	L-2

N normal distribution; L lognormal distribution

Number refers to no. of symmetric distributions interpreted. One symmetric distribution is implicit if only a letter is presented.

TABLE VII

INTERPRETED FORM OF DENSITY DISTRIBUTIONS
MINERAL ASH VARIABLES - DRY ASH
COMBINED TEST HOLE DATA

Variable	ZONE A	ZONE B	ZONE C	ZONE D
P_2O_5	L-2	L-2	L	L
SiO_2	N-2	N-2	N-2	N-3
Fe_2O_3	N-2	N-2	N-2 (?)	N-2 (?)
Al_2O_3	N-2	N-2	L-2 (?)	N-2
TiO_2	N-2 (?)	L-2	L-2	L
CaO	L-3 (?)	L-2	L-2	L
MgO	L	L	L	L
SO_3	N-2	L	L	N-2
K_2O	L-3	L	L	L-2
Na_2O	L-3	L	L	L
Mn_3O_4	L	L-2	L	L-2
V_2O_5	L	L	L	L

TABLE VIII

INTERPRETED FORM OF DENSITY DISTRIBUTIONS
ULTIMATE VARIABLES - DRY COAL
COMBINED TEST HOLE DATA

Variable	ZONE A	ZONE B	ZONE C	ZONE D
Nitrogen	L	L-2	L-2 (?)	L
Chlorine	L-2	L-2	L-2 (?)	L-2 (?)
O_2 (diff)	N-2	N-2	N	N
O_2 (Anal.)	N	N	N	N
C	N-3	N-2	N-2	N-2
H_2	N-2	N-2	N-2	N-2(?)

N = normal distribution L = lognormal distribution

Number refers to no. of symmetric distributions interpreted. One symmetric distribution is implicit if only a letter is present. A question mark indicates uncertainty in the interpretation.

3. analysis of variance to test whether within-hole variations are equivalent to between-hole variations.

Variability of a Variable as a Function of Sample Length

Whether dispersions calculated for individual test holes represent the same symmetric distribution or not, it is apparent that the combined data represent our best sample of the total population. Hence, standard deviations of all variables studied have been plotted as a function of sample length. The procedure used was simple to calculate the dispersion for a variable using all available samples of a given length from test hole analyses. For example, in the case of 10-foot samples all adjacent pairs of 5-foot samples were combined and included in the estimation. Similarly, for 20-foot samples, all adjacent pairs of 10-foot samples were combined, and so on. In each case the data base is the same (or nearly so), consequently, the relationship that emerges between dispersion and sample length is real. Necessary data are tabulated in Tables IX and X(A) to X(D) and shown graphically in Figure 1. Evaluation of these diagrams shows that over the range of sample lengths studied, dispersion decreases approximately exponentially as a function of sample length. Most variables are well described by this empirical relationship. Those that depart most from the relationship are:

C Zone   Btu/# (dry coal)
          Ash (% dry coal)
          Fixed Carbon (% dry coal)
          V_2O_5 (% dry ash)

D Zone   Nitrogen (% dry coal)

The forgoing variables do not depart seriously from the empirical relationship. Hence, one can conclude that the relationship forms a reasonable means of interpolating to estimate variability for sample lengths other than those available in the raw data or by combining adjacent raw data values.

Comparison of Dispersions Between Test-Holes 135 and 136

Variability of data for the two holes can be examined by a Snedecor F test which provides a statistical evaluation of the probability that two measurements of dispersions (variance) could come from the same population. This test is based on the assumption that data are normally distributed, a condition that does not apply to all variables. The test has been applied on raw data for all those variables that have at least a crude approach to a normal distribution as evaluated subjectively by examination of probability graphs (see Appendices I, II and III). In the remaining cases a log transform has been imposed on the data for purposes of the F test. An F value is calculated as follows:

$$F\ (n, ni) = \frac{S_1^{\,2}}{S_2^{\,2}}$$

TABLE IX

STATISTICAL PARAMETERS FOR DRY PROXIMATE DATA
FOR VARIOUS SAMPLE LENGTHS - HOLES 135-136 COMBINED

Zone	Var.	10-foot samples		20-foot samples		30-foot samples		40-foot samples	
		$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
A	Btu/#	6321	2115	6429	1601	6462	1374	6469	1162
	Ash	44.32	15.27	43.74	11.92	43.68	10.48	44.03	9.58
	F.C.	26.80	9.75	27.32	7.41	27.48	6.36	27.54	5.35
	V.M.	29.52	5.42	29.77	3.97	29.80	3.36	29.77	2.92
	S(tot.)	0.676	0.320	0.663	0.249	0.653	0.190	0.647	0.159
B	Btu/#	7658	1446	7771	931	7733	795	7699	762
	Ash	37.90	14.48	37.08	11.46	36.75	10.42	36.78	9.47
	F.C.	33.78	6.60	43.22	4.35	34.03	3.82	33.88	3.65
	V.M.	31.43	3.55	31.80	2.05	31.73	1.61	31.63	1.49
	S(tot.)	0.805	0.225	0.810	0.171	0.812	0.136	0.810	0.129
C	Btu/#	4413	1653	4520	1189	4479	891	4418	681
	Ash	55.75	10.83	55.17	8.10	55.34	6.24	55.77	4.95
	F.C.	19.06	7.64	19.59	5.29	19.56	3.96	19.36	3.01
	V.M.	25.21	4.25	25.24	3.25	25.10	2.66	24.88	2.20
	S(tot.)	0.387	0.173	0.370	0.152	0.361	0.130	0.352	0.115
D	Btu/#	9455	1201	9506	1061	9548	984	9533	961
	Ash	23.94	7.68	23.60	6.80	23.32	6.32	23.40	6.10
	F.C.	41.82	5.94	42.01	5.28	42.17	5.00	42.07	4.90
	V.M.	34.24	2.45	34.40	2.03	34.51	1.73	34.52	1.67
	S(tot.)	0.266	0.071	0.263	0.060	0.260	0.054	0.258	0.052

All values relate to dry coal.
All variables except Btu/# are percent.

TABLE X(a)

MEANS AND STANDARD DEVIATIONS FOR 10, 20 AND 30-FOOT SAMPLES, MINERAL ASH AND ULTIMATE VARIABLES
ZONE A

Variable	Sample length					
	10 foot n = 109		20 foot n = 103		30 foot n = 98	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
P_2O_5	.302	.308	0.308	0.245	0.314	0.228
SiO_2	53.84	5.23	53.73	4.07	53.75	3.28
Fe_2O_3	7.48	3.65	7.50	2.78	7.48	2.22
Al_2O_3	29.05	4.01	29.03	3.26	29.14	2.73
TiO_2	.854	.351	0.860	0.310	0.863	0.298
CaO	2.69	4.16	2.75	2.98	2.64	2.10
MgO	1.52	0.530	1.53	0.367	1.51	0.276
SO_3	1.61	0.947	1.64	0.745	1.65	0.620
K_2O	.829	.299	0.824	0.261	0.818	0.245
Na_2O	.830	.261	0.833	0.208	0.836	0.182
Mn_3O_4	.087	.125	0.084	0.082	0.085	0.065
V_2O_5	.054	.015	0.052	0.013	0.054	0.011
N_2	.845	.349	0.845	0.298	0.852	0.280
Cl_2	.062	.099	0.067	0.090	0.059	0.055
ODF	14.14	2.36	14.28	1.75	14.35	1.42
O_2	15.15	2.45	15.26	1.81	15.32	1.49
S_{org}	.468	0.194	0.467	0.151	0.467	0.121
CO_2	1.62	1.84	1.62	1.32	1.58	0.997

TABLE X(b)

MEANS AND STANDARD DEVIATIONS FOR 10, 20 AND 30-FOOT SAMPLES, MINERAL ASH AND ULTIMATE VARIABLES
ZONE B

Variable	Sample length					
	10-foot n = 51		20-foot n = 46		30-foot n = 58	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
P_2O_5	.203	.289	0.212	0.209	0.216	0.180
SiO_2	52.15	5.00	51.84	3.43	51.73	2.72
Fe_2O_3	6.92	4.76	7.08	3.38	7.17	2.76
Al_2O_3	31.98	3.84	31.99	2.90	32.00	2.47
TiO_2	0.768	0.150	0.762	0.133	0.757	0.117
CaO	2.60	2.48	2.67	1.78	2.63	1.31
MgO	1.52	0.784	1.57	0.53	1.57	0.404
SO_3	1.32	1.23	1.36	0.93	1.39	0.714
K_2O	0.616	0.121	0.603	0.089	0.599	0.073
Na_2O	1.27	0.305	1.26	0.221	1.26	0.184
Mn_3O_4	0.059	0.123	0.062	0.090	0.062	0.070
V_2O_5	0.051	0.011	0.050	0.009	0.051	0.008
N_2	1.01	0.185	1.03	0.160	1.03	0.149
Cl_2	0.142	0.201	0.089	0.162	0.050	0.107
ODF	14.35	1.34	14.45	0.866	14.40	0.760
O_2	15.87	1.55	16.04	0.916	16.05	0.682
S_{org}	0.541	0.128	0.546	0.097	0.546	0.086
CO_2	1.68	1.85	1.73	1.40	1.77	1.20

TABLE X(c)

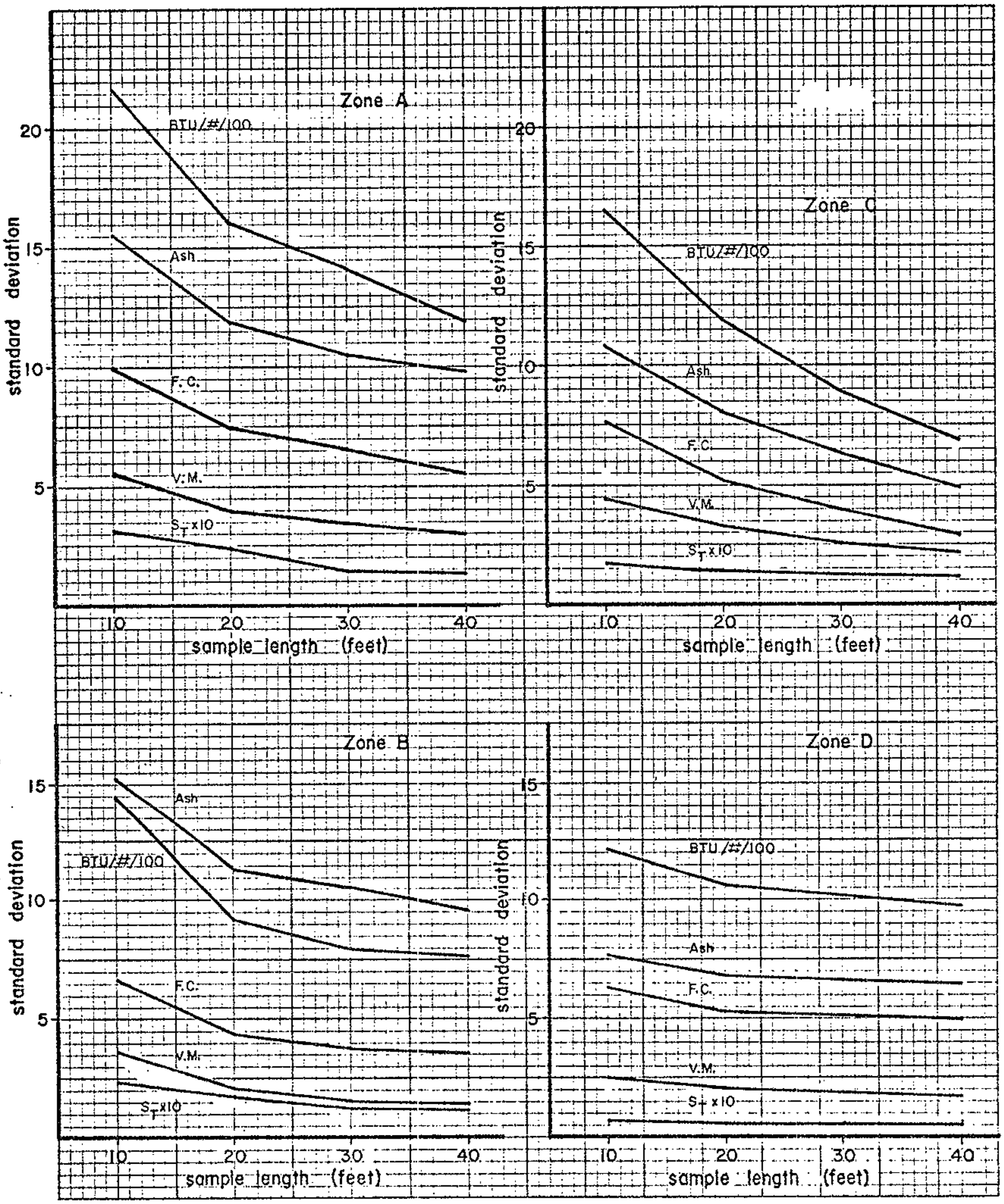
MEANS AND STANDARD DEVIATIONS FOR 10, 20 AND 30-FOOT SAMPLES, MINERAL ASH AND ULTIMATE VARIABLES
ZONE C

Variable	Sample length					
	10-foot n = 38		20-foot n = 32		30-foot n = 29	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
P_2O_5	0.228	0.195	0.241	0.141	0.248	0.125
SiO_2	52.70	5.60	52.64	3.75	52.74	3.34
Fe_2O_3	8.58	5.28	8.23	3.29	8.09	2.93
Al_2O_3	29.68	3.95	30.55	1.62	30.63	1.32
TiO_2	0.786	0.169	0.791	0.114	0.796	0.106
CaO	2.75	2.47	2.39	1.06	2.35	0.934
MgO	1.79	0.916	1.69	0.446	1.68	0.382
SO_3	0.867	0.502	0.822	0.384	0.814	0.330
K_2O	0.906	0.283	0.915	0.254	0.922	0.227
Na_2O	0.745	0.176	0.746	0.131	0.741	0.106
Mn_3O_4	0.147	0.188	0.134	0.109	0.129	0.092
V_2O_5	0.042	0.009	0.039	0.008	0.043	0.007
N_2	0.734	0.222	0.762	0.157	0.773	0.137
Cl_2	0.288	0.240	0.322	0.233	0.252	0.244
ODF	12.32	1.60	12.29	1.32	12.27	1.13
O_2	14.36	2.28	14.35	1.63	14.32	1.42
S_{org}	0.261	0.128	0.258	0.111	0.257	0.095
CO_2	4.34	3.23	3.94	1.51	3.90	1.32

TABLE X(d)

MEANS AND STANDARD DEVIATIONS FOR 10, 20 AND 30-FOOT SAMPLES, MINERAL ASH AND ULTIMATE VARIABLES
ZONE D

Variable	Sample length					
	10-foot n = 54		20-foot n = 53		30-foot n = 66	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
P_2O_5	0.181	0.109	0.171	0.129	0.171	0.114
SiO_2	51.46	5.88	51.54	4.95	51.20	4.23
Fe_2O_3	5.84	4.38	5.85	3.08	5.86	2.31
Al_2O_3	33.80	4.52	33.72	3.97	33.91	3.33
TiO_2	0.811	0.164	0.813	0.147	0.813	0.145
CaO	3.08	1.53	3.06	1.09	3.16	0.810
MgO	1.15	0.645	1.15	0.493	1.18	0.383
SO_3	1.11	0.745	1.09	0.519	1.11	0.419
K_2O	0.296	0.103	0.290	0.096	0.292	0.007
Na_2O	1.72	0.535	1.73	0.480	1.76	0.445
Mn_3O_4	0.159	0.215	0.165	0.150	0.163	0.118
V_2O_5	0.051	0.008	0.050	0.007	0.050	0.006
N_2	0.964	0.128	0.961	0.113	0.973	0.089
Cl_2	0.176	0.222	0.196	0.230	0.110	0.186
ODF	15.12	0.733	15.14	0.576	15.18	0.500
O_2	16.58	0.946	16.59	0.629	16.63	0.500
S_{org}	0.235	0.071	0.234	0.066	0.231	0.059
CO_2	1.26	1.40	1.24	0.970	1.26	0.777



Zone A
BTU/#/100
Ash
F.C.
V.M.
S_Tx10
standard deviation
sample length (feet)
Zone C
BTU/#/100
Ash
F.C.
V.M.
S_Tx10
standard deviation
sample length (feet)
Zone B
Ash
BTU/#/100
F.C.
V.M.
S_Tx10
standard deviation
sample length (feet)
Zone D
BTU/#/100
Ash
F.C.
V.M.
S_Tx10
standard deviation
sample length (feet)

Figure 1(a)

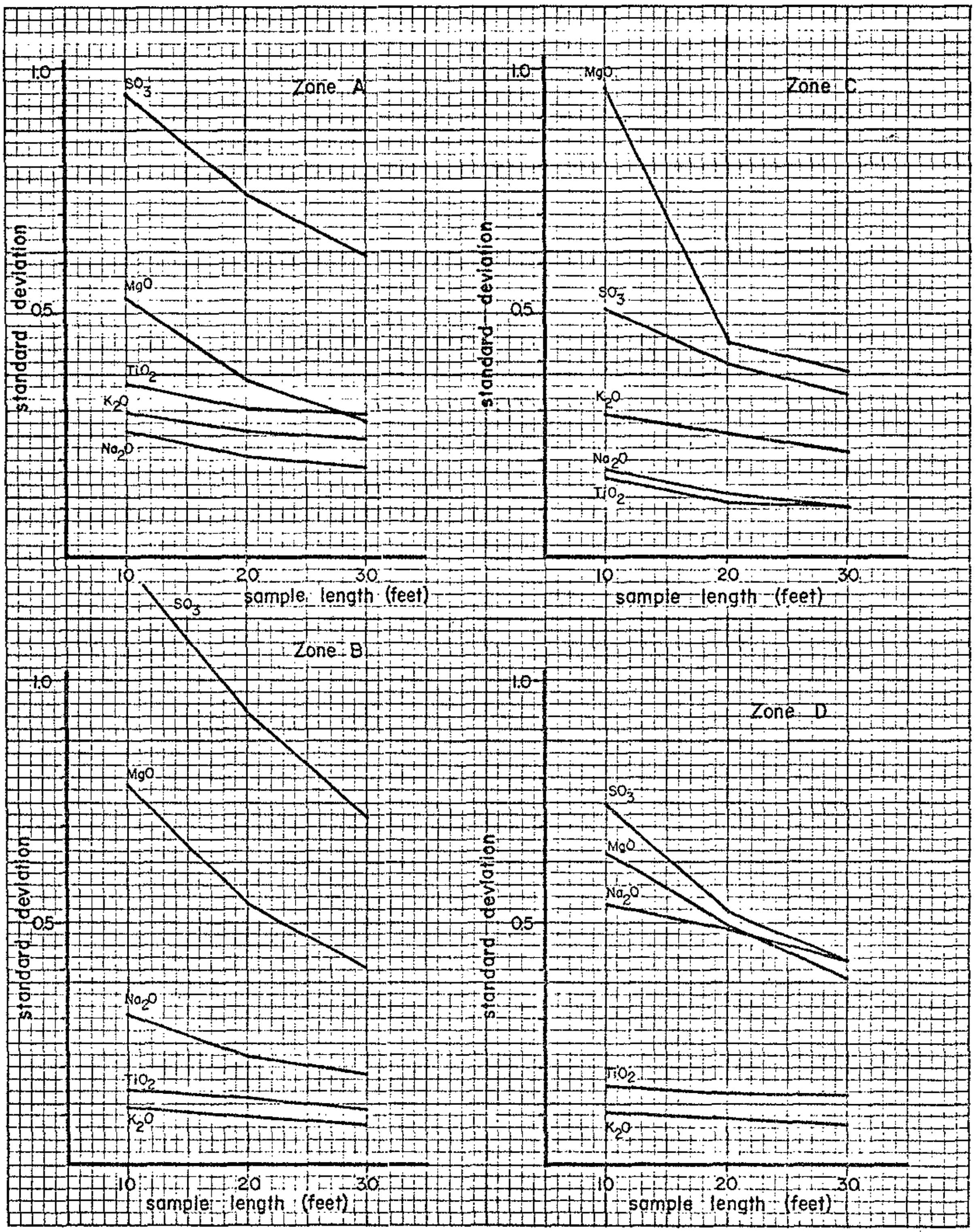

Zone A
1.0
0.5
standard deviation
SO3
MgO
TiO2
K2O
Na2O
10
20
30
sample length (feet)
Zone C
1.0
0.5
standard deviation
MgO
SO3
K2O
Na2O
TiO2
10
20
30
sample length (feet)
Zone B
1.0
0.5
standard deviation
SO3
MgO
Na2O
TiO2
K2O
10
20
30
sample length (feet)
Zone D
1.0
0.5
standard deviation
SO3
MgO
Na2O
TiO2
K2O
10
20
30
sample length (feet)

Figure 1(b)

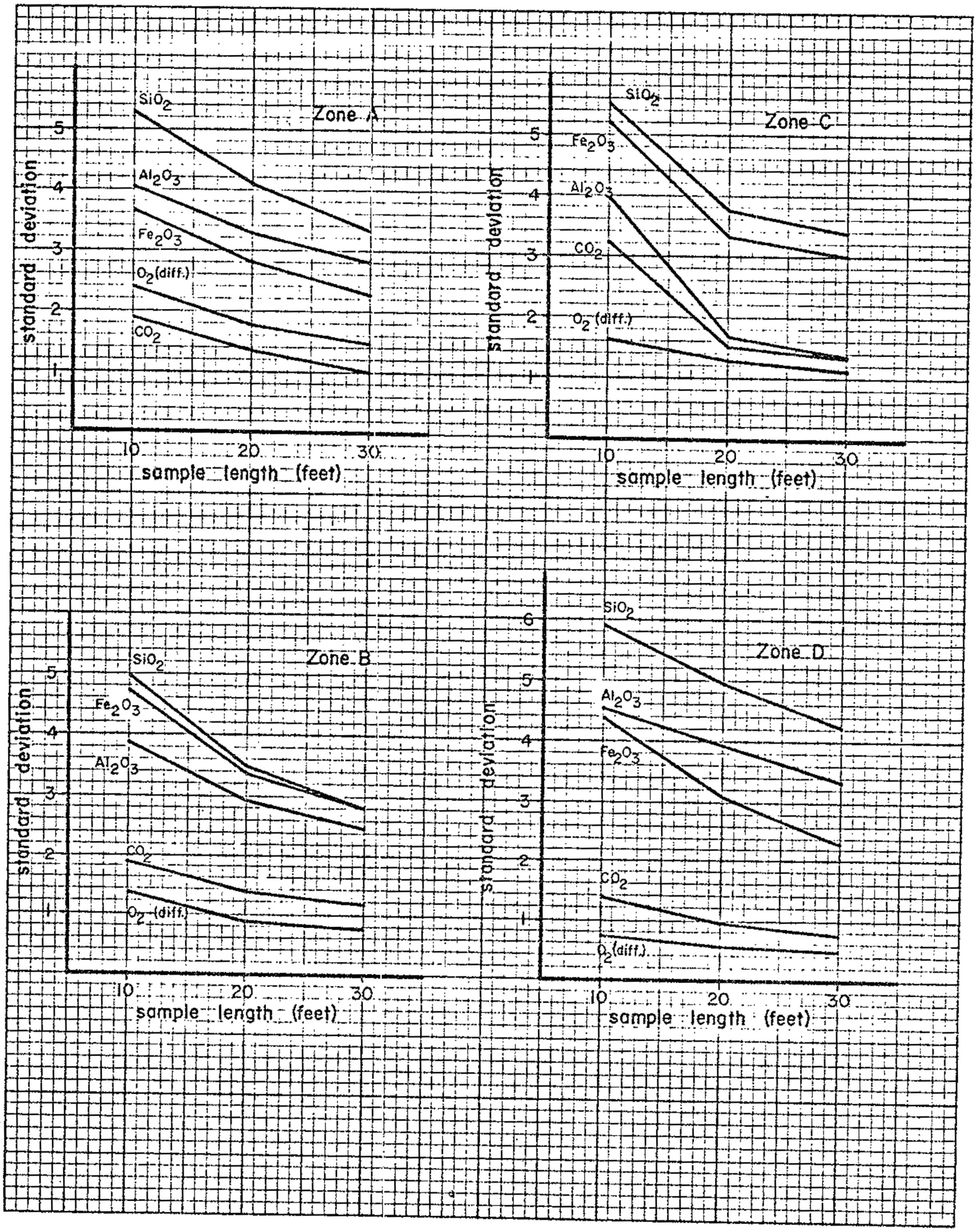

Zone A
standard deviation
sample length (feet)
SiO_2
Al_2O_3
Fe_2O_3
O_2 (diff.)
CO_2
Zone C
standard deviation
sample length (feet)
SiO_2
Fe_2O_3
Al_2O_3
CO_2
O_2 (diff.)
Zone B
standard deviation
sample length (feet)
SiO_2
Fe_2O_3
Al_2O_3
CO_2
O_2 (diff.)
Zone D
standard deviation
sample length (feet)
SiO_2
Al_2O_3
Fe_2O_3
CO_2
O_2 (diff.)

Figure 1(c)

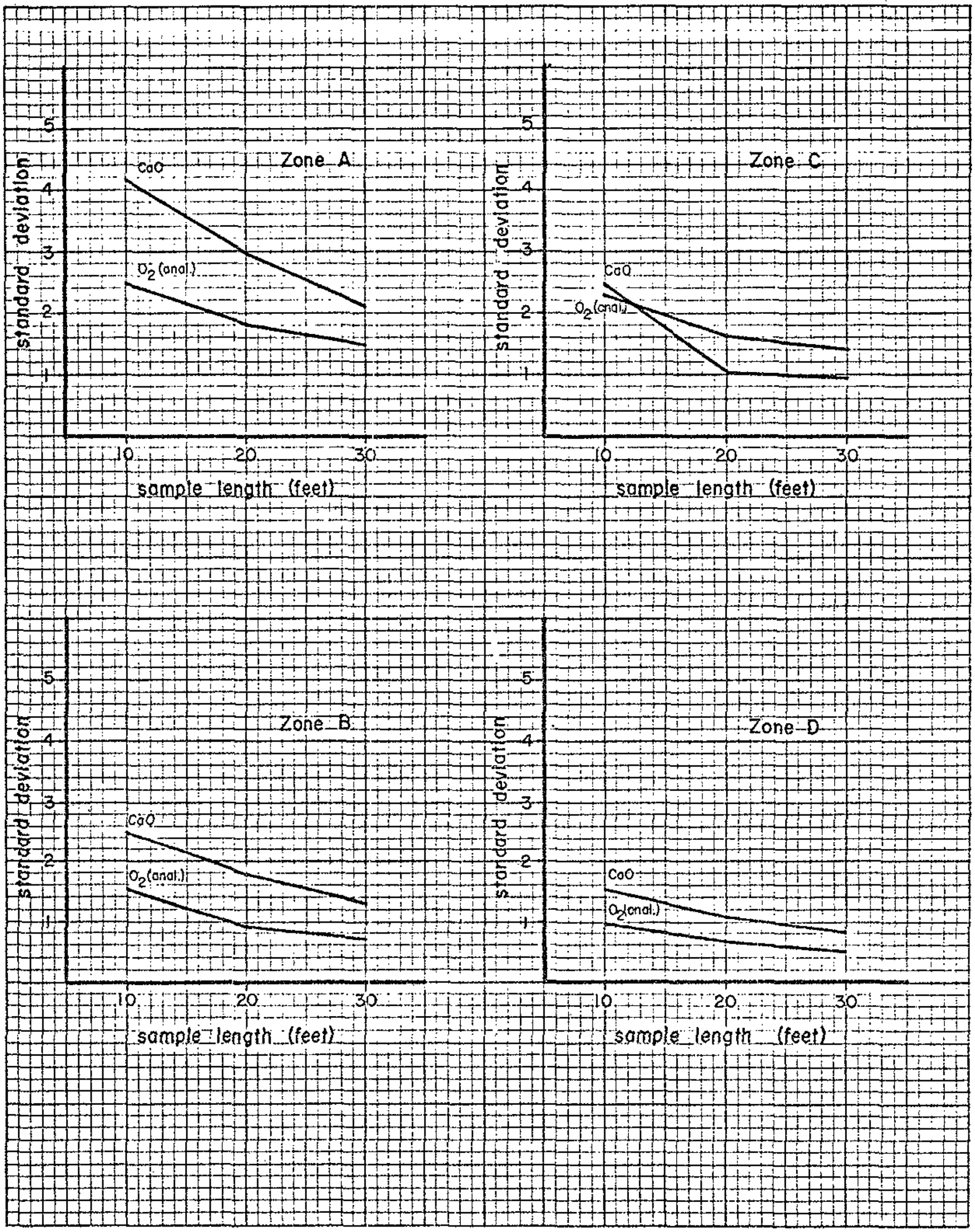

Zone A
CaO
O_2 (anal.)
standard deviation
sample length (feet)
Zone C
CaO
O_2 (anal.)
standard deviation
sample length (feet)
Zone B
CaO
O_2 (anal.)
standard deviation
sample length (feet)
Zone D
CaO
O_2 (anal.)
standard deviation
sample length (feet)

Figure 1(d)

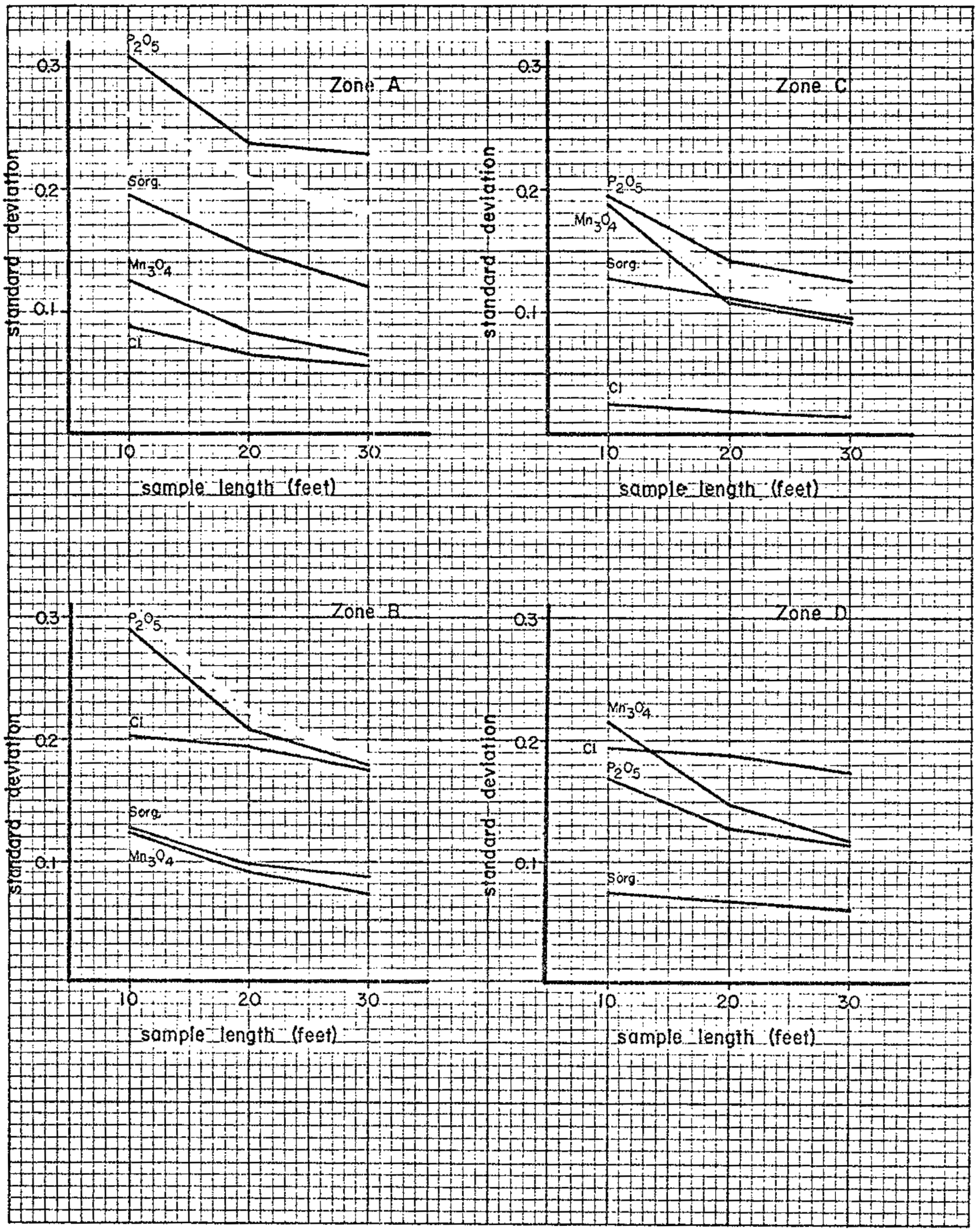

Zone A
Zone B
Zone C
Zone D
standard deviation
sample length (feet)
P_2O_5
Sorg.
Mn_3O_4
Cl
0.1
0.2
0.3
10
20
30

Figure 1(e)

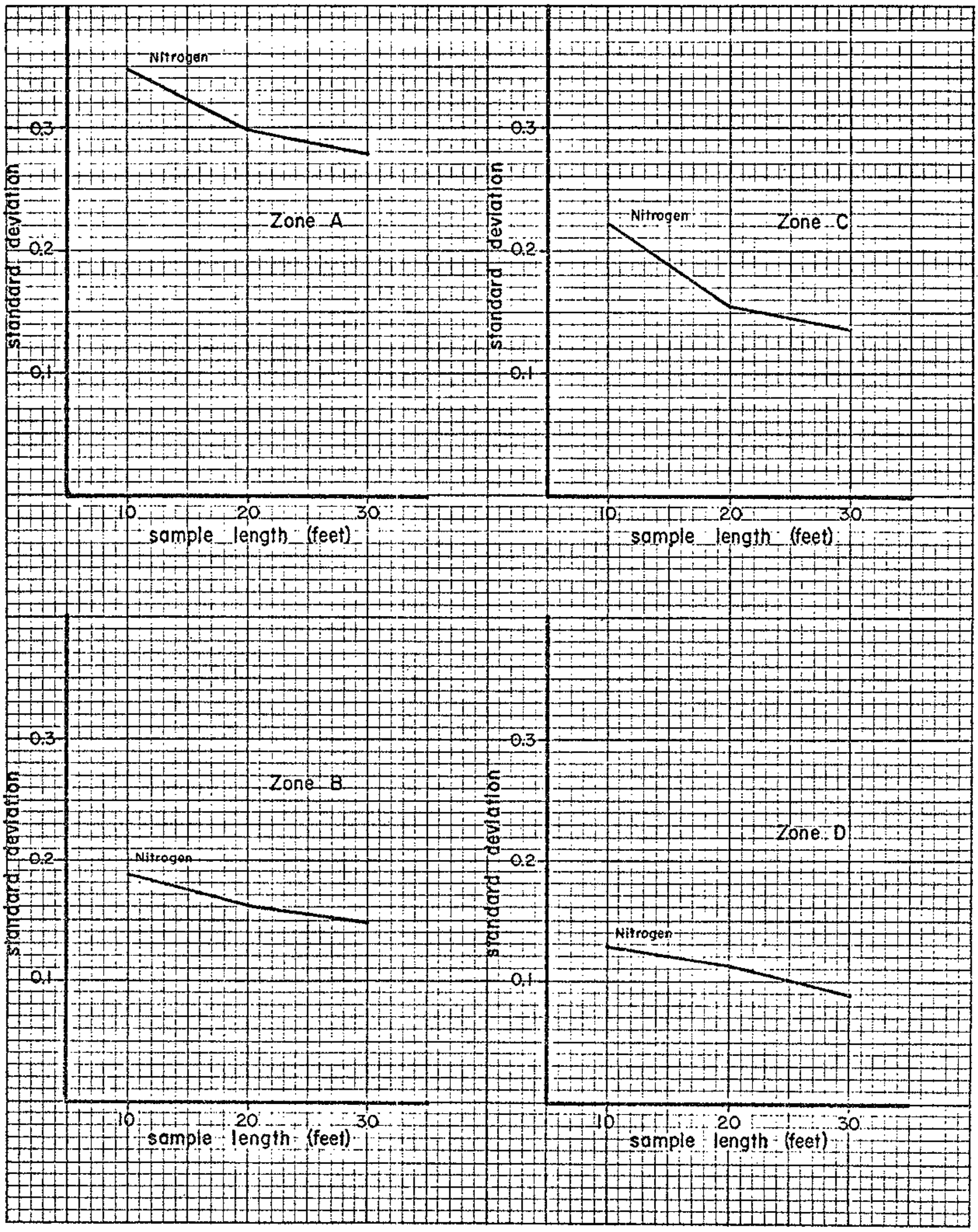
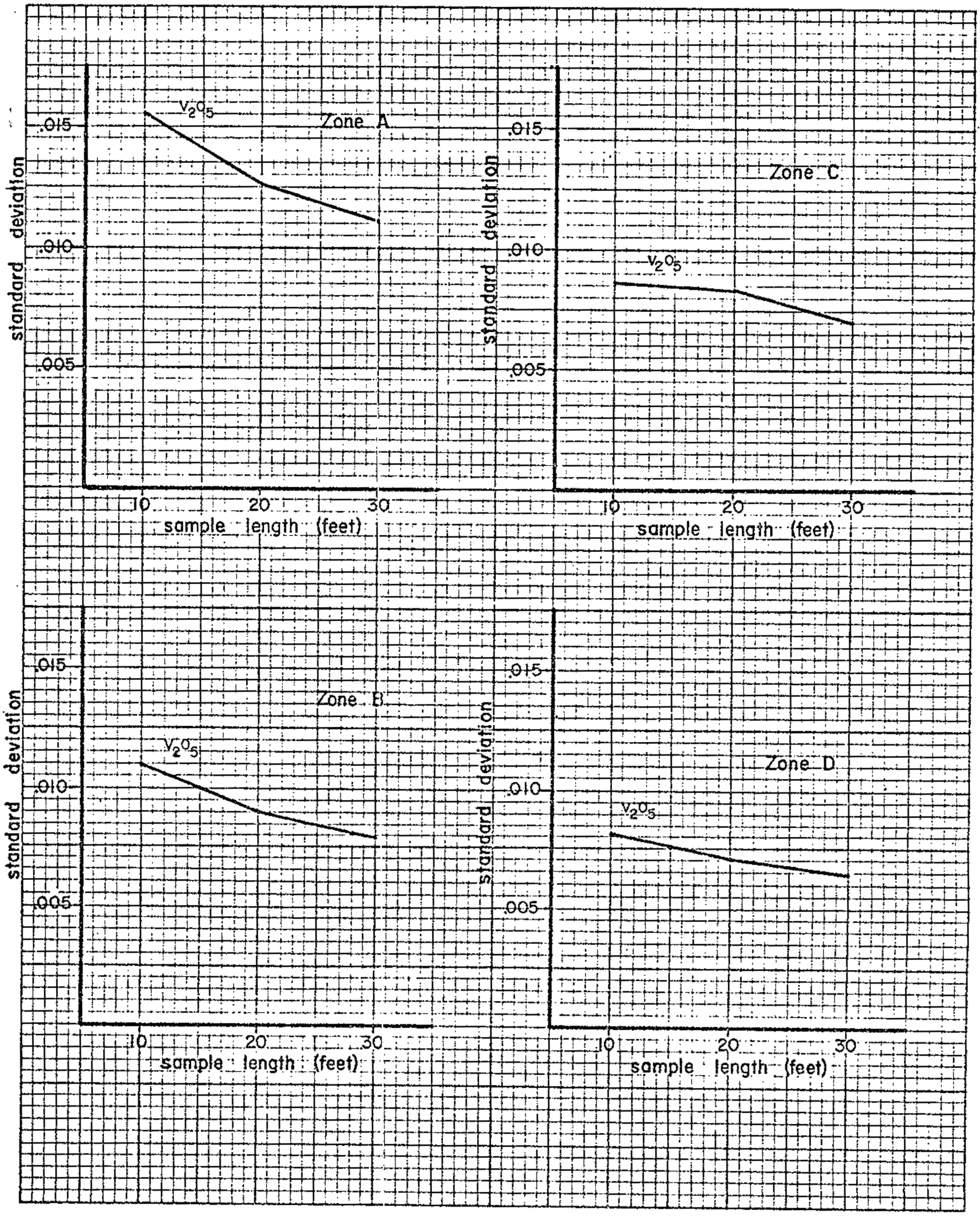

Nitrogen
Zone A
standard deviation
0.3
0.2
0.1
10
20
30
sample length (feet)
Nitrogen
Zone C
standard deviation
0.3
0.2
0.1
10
20
30
sample length (feet)
Zone B
Nitrogen
standard deviation
0.3
0.2
0.1
10
20
30
sample length (feet)
Zone D
Nitrogen
standard deviation
0.3
0.2
0.1
10
20
30
sample length (feet)

Figure 1(f)



Zone A
V_2O_5
standard deviation
.015
.010
.005
10
20
30
sample length (feet)
Zone C
V_2O_5
standard deviation
.015
.010
.005
10
20
30
sample length (feet)
Zone B
V_2O_5
standard deviation
.015
.010
.005
10
20
30
sample length (feet)
Zone D
V_2O_5
standard deviation
.015
.010
.005
10
20
30
sample length (feet)

Figure 1(g)

This ratio, F, has a known sampling distribution for normally distributed samples. In general, values from the same population can be expected intuitively to be near 1.0 and as values depart more and more either side of 1.0 the chance increases that the two samples do not represent the same normal population. Critical units to the ratios can be found in tables for various choices of α (type 1 error)* and various sample sizes (n1 and n2). Here, tests were run at $\alpha = 0.025$. Results would not differ appreciably for small changes in α. Results of the F tests are as follows:

1. All proximate variables (including Btu/#, sulphur and CO_2 values) except A zone total sulphur, B zone ash and B zone organic sulphur provide a positive F test, that is, data for both holes could be random samples of the same population. This hypothesis is rejected for the three above-mentioned variables whether the test is conducted on raw or log-transformed data and one must assume that real differences or trends exist in these variables even where homogenity apparently exists for other variables.

2. Mineral ash variables tested show considerable differences in dispersions from one test hole to the other for several variables from each zone. These are summarized in Table XI. Note the similarity of F-test results for B and D zones. A vague similarity exists also between A and C zones in that P_2O_5 and CaO are common to both lists of elements that show significantly different variability.

3. For ultimate analyses A zone samples are similar in both test holes. B zone data and C zone data show significant variability for chlorine and nitrogen respectively. D zone variability of ultimate data is significantly different between the two test holes, in all four variables considered.

4. The F-test does not deal with absolute variability but only with relative variability. That is, we have only tested whether or not both test holes <u>likely</u> are random samples from the same normal distribution. For most variables the dispersions are comparable in both test holes.

Analysis of Variance

This procedure provides a good example of a method that permits comparison of within-hole variations relative to between-hole variations. To illustrate the method twenty-four B zone ash values are selected from each of the two test holes (i.e. the total population has been selected excluding two high ash values from ddh 136). Raw data and analysis of variance parameters are given in Table XIII. The important result is

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* In an F-test α is the chance of being wrong when we say that a calculated F value greater than the critical F value indicates the two variances are not drawn from the same population.

TABLE XI

RAW DATA AND STATISTICS FOR B ZONE ASH (% DRY COAL). FOR ANALYSIS OF VARIANCE

B Zone	136	135	
	(n = 24)	(n = 24)	N = 48
	46.81	19.90	
	22.63	29.96	
	23.32	25.91	
	29.92	29.22	
	25.25	28.96	
	39.96	43.25	
	27.30	28.15	
	26.95	39.15	
	27.76	30.46	
	26.16	31.40	
	29.65	32.61	
	28.39	53.28	
	34.84	37.05	
	43.78	32.59	
	21.10	28.37	
	39.96	50.95	
	27.38	23.60	
	33.50	47.58	
	35.84	30.71	
	37.28	39.57	
	53.53	41.92	
	47.55	36.74	
	35.22	28.84	
	26.82	36.12	
$\bar{x}$ =	32.954	34.429	33.692
s =	8.6725	8.4177	8.4874
Σx =	790.9	826.29	1617.19
Σx^2 =	27793.3	30077.9	57871.2
$(n-i)s^2$ =	1729.87	1629.74	3385.70

Variation	SSQ	d.f.	mss	F
Within zone	3359.6	46	73.0	2.80
Between hole	26.1	1	26.1	
Total	3385.7.	47	72.04	

F_c (23, 23) = 2.3

that within-hole variation is significantly different (greater in this case) than between-hole variation. A comparable test could be run for all variables but in many cases it is apparent from inspection that a comparable result would be obtained, particularly for proximate variables. These tests emphasize the lateral homogenity of proximate data and the relative heterogeneity across stratification. Hence, a measure of across-strata variation represents a reasonable estimate of total variability, particularly if data for more than one hole are used for such an estimation. This conclusion applies in cases where A, B, C and D zones are recognizable unambiguously. Note that the between-hole variability has brought into account the different mean values of data from the two test holes.

COMPARISON OF MEAN VALUES FOR DRILL HOLES 135 AND 136

The simplest way to compare the mean values of two populations (ddh's 135 and 136 respectively) and thereby test for the presence of trends (e.g. facies changes) is to conduct a t-test. Samples from the same normal distribution need not be identical but are not expected to depart a great deal from each other. A value

$$t = \frac{\overline{X}_1 - \overline{X}_2}{S_p \; 1/n_1 + 1/n_2}$$

$\overline{X}_1$ = mean of sample 1

$\overline{X}_2$ = mean of sample 2

n_1 = no. of items in sample 1

n_2 = no. of items in sample 2

S_p = pooled std. dev.

can be calculated readily from data in Tables I, II, III and IV and has a known sampling distribution for the situation where $\overline{X}_1$ and $\overline{X}_2$ are samples drawn from the same normal population. In general t is low if the two samples come from the same population. High values are unlikely unless the samples represent different populations. For given numbers of items in the two populations and a particular level of significance (= 0.025 means that there is a 2.5% chance of making a wrong decision) a critical value of t is identified (from tables). Calculated values below the critical value indicate that the two samples (two drill hole data sets in this case) represent the same population. Calculated t values above the critical value are interpreted as indicating that significant differences exist between the mean values in the two sample sets.

t values were calculated for all variables listed in Tables I, II, III and IV separately for each zone. No significant differences were found for most variables when

when tested at the = 0.025 level. Those variables for which significant differences were identified for the two drill holes are as follows:

A zone: Na_2O, nitrogen

B zone: TiO_2, Na_2O, nitrogen

C zone: K_2O, V_2O_5, O_2 (diff.)

D zone: Volatile matter, S_{Tot}, S_{org}, chlorine, O_2 (diff.)

Of a total of 92 tests, 13 significant differences were identified whereas only two or three are to be expected by chance. Hence, the differences are largely real, although in many cases small. It is particularly interesting to note the five significant differences for D-zone data considering the general uniformity and narrow dispersion of D-zone variables. In fact, the overriding conclusion to be drawn from t-test results is the remarkable uniformity of analytical data for the two test holes.

AUTOCORRELATION - GENERAL EVALUATION OF SEMI-VARIOGRAMS

Semi-variograms show half the mean squared difference in values of a variable, for various sample spacings.* This half mean squared difference is termed "gamma h" (i.e. γ (h)) where gamma is the value calculated for a particular sample separation h. Several patterns of a variogram are indicative of particular features of a variable and can be illustrated with idealized diagrams (figure 2) in which the saw-tooth curves simulate real data and the smooth curves are ideal models that describe the general form of the real data.

Test-Hole Data

Semi-variograms were constructed for proximate variables for both test holes using 10-foot, 30-foot and 40-foot sample lengths. A general evaluation of these semi-variograms is tabulated in Table XII based principally on the 10-foot samples. Direct copies of the computer-plotted semi-variogram are included in Appendix IV.

For the remaining variables, semi-variograms were constructed only for test hole 135. A summary evaluation of these data is given in Table XII based on 10-foot samples.

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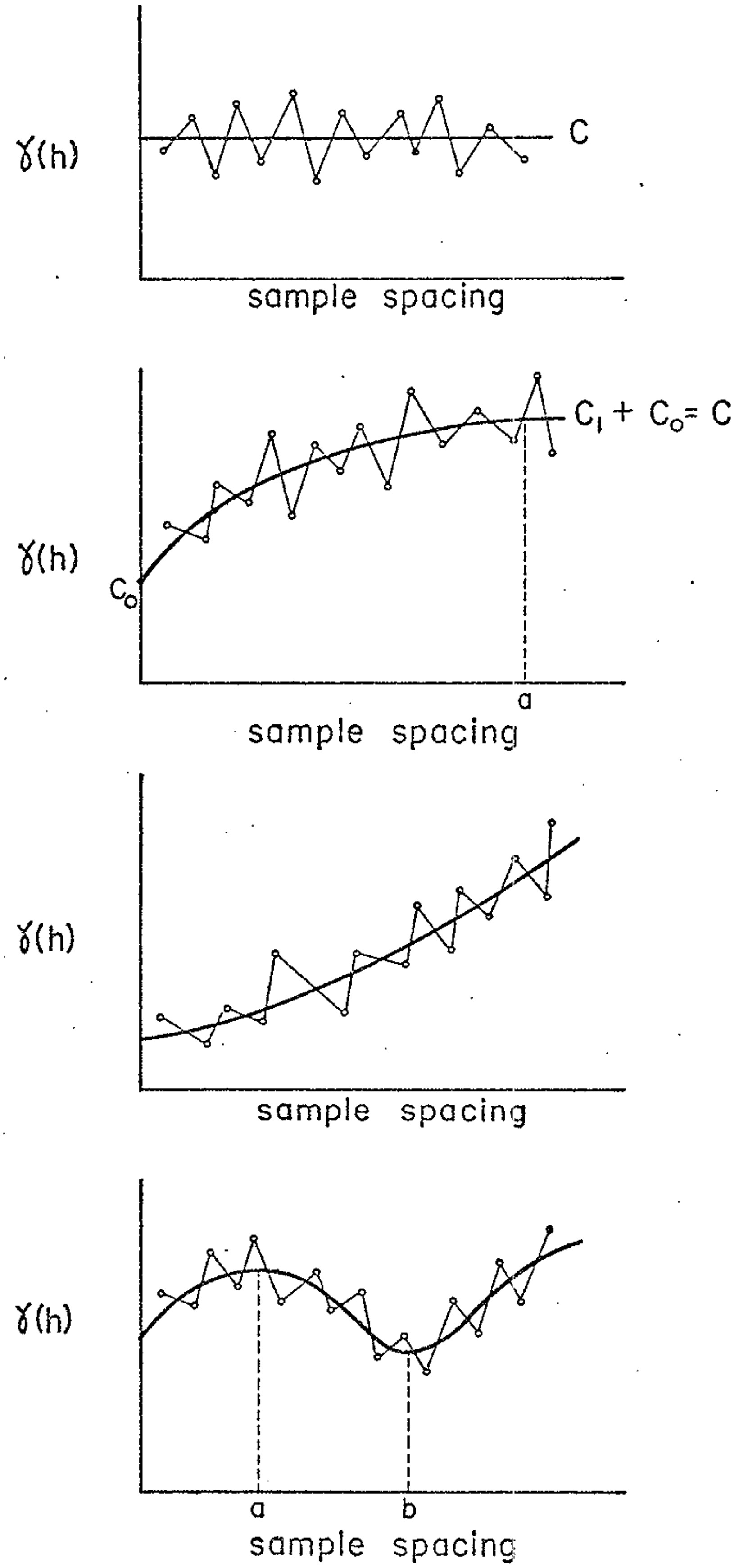
* $\gamma(h) = \frac{\sum (x_{ith} - x_i)^2}{2n}$



RANDOM VARIABLE
SILL=C

STRUCTURED VARIABLE WITH RANGE "a" AND SILL (C_0 & C_1)

PRESENCE OF A TREND IN DATA.

CYCLICAL VARIATIONS (MUST BE VERY REGULAR TO GIVE THIS PATTERN)

Figure 2

TABLE XII

SUMMARY OF INTERPRETATION OF SEMI-VARIOGRAMS

Variable	Zone	General Nature of Semi-Variogram
% P_2O_5	A	Random
	B	Random
	C	Random to 100' Beyond 100' trend apparent
	D	Random to 80' Slight trend evident at spacings greater than 80 feet
% SiO_2	A	Random
	B	Random
	C	Random
	D	Random
% Fe_2O_3	A	Random
	B	Random
	C	Random
	D	Random
% Al_2O_3	A	Appears to be correlation over 20 - 30 feet but random beyond that
	B	Random
	C	Locally random but with trend
	D	Apparently a structure over sample spacing of 20 - 40 feet, random beyond that
% TiO_2	A	Very strong trend beyond 30' sample spacing. May be a 20 - 40 foot structure present
	B	Random, perhaps with cyclic highs and lows separated by 20 - 30 feet
	C	Random
	D	Strong trend

TABLE XII(cont'd)

Variable	Zone	General Nature of Semi-Variogram
	D	Slight structure but variability is low so assume random
% Sorg	A	Rcndom (slight correlation over 20 to 40 feet
	B	Random
	C	Slight correlation over 20 - 30 feet assume random
	D	Random
% CO_2	A	Random
	B	Random
	C	Much fluctuation in variogram but both trend and structure are possibly present
	D	Random
% N_2	A	Correlation over distances less than 40 to 50 feet; then random for sample separations up to about 130 feet, beyond which a slight trend is indicated
	B	Slight trend apparent throughout
	C	Slight structure to 50 feet, beyond which variable is random
	D	Random
% Cl2	A	Assume random. May be cyclical trends over distance of 160 feet
	B	Random
	C	Random
	D	Random

TABLE XII(cont'd)

Variable	Zone	General Nature of Semi-Variogram
% CaO	A	Random
	B	Random
	C	Random for sample spacing less than 60 feet. Trend apparent beyond 60 foot spacing.
	D	Random
% MgO	A	Random
	B	Random
	C	Random
	D	Random
% SO_3	A	Random
	B	Random
	C	Random
	D	Random
Fixed Carbon	A	Structural cyclical, comparable to Btu/#
	B	No structure at spacings less than 100 feet
	C	Indication of structure comparable to A zone but less clearly defined
	D	Some indication of long range structure but the two holes are not consistent. Short range variability over distances of 80 feet or less are low and can be assumed random
Volatile Matter	A	Structured and cyclical, comparable to Btu/#
	B	Random
	C	Structured and cyclical, comparable to Btu/#

TABLE XII(cont'd)

Variable	Zone	General Nature of Semi-Variogram
	D	Random, very low variability
S Total	A	May be a short range structure of 20 - 30 feet but otherwise random
	B	Random
	C	Random (135 indicates cyclical variability)
	D	Random
% K_2O	A	Structured over 40 - 50 feet, beyond that random
	B	Random
	C	Structured with a range of approximately 30 feet. Also cyclical
	D	Trend apparent for samples separated by more than 20 feet
% Na_2O	A	Very weak correlation indicated over a range of 40 to 60 feet. Beyond this sample spacing variable is random
	B	Random
	C	Random
	D	Ill defined structure. May be cyclical with wave length of 50 feet
% Mn_3O_4	A	Random
	B	Random
	C	Random
	D	Random
% V_2O_5	A	Random
	B	Random

TABLE XII(cont'd)

Variable	Zone	General Nature of Semi-Variogram
	C	May be 10 to 20 foot structure, assume random
	D	Slight trend apparent, assume random
% ODF	A	Random
	B	Random
	C	Appears to be cyclical variation with cycle wavelength of about 80 feet
	D	Random
O_2%	A	Random
	B	Random
	C	Random. Could be construed as cyclical, akin to that pattern found in % ODF, but much more poorly defined here
	D	Random
Btu/#	A	Structured, cyclical with range of about 40 feet or a bit less. Cycles have a repeat pattern every 90 feet
	B	Random, at least for separations of 100 feet or less
	C	Random
	D	Low variability, assume random
Ash %	A	Structured, cyclical as in Btu/#
	B	Random. Strong trend shown by hole 136 results from waste bands
	C	Assume random although there is some indication of a cyclical structure comparable to but less developed than that in A zone

Discussion

Semi-variograms indicate that virtually all variables can be considered as random variables. In a few cases a short range correlation over distances of 20 to 50 feet is indicated but these are not well enough defined for the deposit as a whole to use them for estimation purposes.

Semi-variograms for comparable variables in the two drill holes commonly indicate the same features. In a few cases, significant differences in the internal structure of a particular zone are found that can be related to slight changes in facies. For example, some variables indicate a possible trend (parabolic form) for one test hole, whereas, such a trend is not apparent in the other test hole.

In several cases cyclical variations of a surprisingly regular nature are found. This is particularly well shown by proximate data for A zone, and combined with other information, leads to a realistic but simple conceptual model for stratification within the A zone, and in a less well defined way for the C zone (see figure 2 and the following section entitled "Summary of Single Variables). Semi-variograms for sample lengths greater than 10 feet add little to the generalizations noted above.

Despite some indications of structure (partial correlation of nearby values) to some of the variables, the dominant character of all variables is their random or nearly random nature. The important implication of this is that a few contiguous 10-foot samples can show the same variability as found throughout an entire zone.

GENERAL SUMMARY OF VARIABLES

<u>Btu/# (dry)</u> - Zone A

Histograms of data for both holes are indistinguishable statistically for 10-foot samples. Evaluation of probability plots shows that in both holes Btu/# can be considered a combination of two normal populations with about 65 percent of a higher valued population and 35 percent of a lower valued population. The best estimates of these populations can be obtained from the combined data for both test holes. It seems likely that these two populations represent two intercalated (interlayered) rock groups, one that comprises about 65% of the section and is a moderately high grade coal, and a second that is much lower grade. This interpretation is consistent with geological and geophysical logs of the two holes as well as the variogram data. Variograms constructed along each hole give an indication of the extent of autocorrelation up to distances of about 60 feet followed by periodic increases and decreases. These data are also consistent with a model of alternations of two dominant rock groups very roughly in the proportions of 2:1. Apart from these variations over short distances, no trend is apparent along either of the holes. This suggests that the simple model of two intercalated rock groups applies equally throughout the stratigraphic thickness of the zone. The model clearly applies to ddh 136 and somewhat less well to ddh 135.

Zone B

Btu/# data for holes 135 and 136 are very similar. Their combined probability plot indicates two overlapping normal populations, each having a fairly broad dispersion such that neither is well defined. There appears to be about 80 percent of an upper population and 20 percent of a lower. The variogram of B-zone shows no autocorrelation. Furthermore, a cyclical aspect is not present in the variogram as appears in the A-zone. In ddh 136 a slight trend is apparent for sample spacing of 100 feet or greater. No such trend is apparent in ddh 135. In general, Btu/# can be considered a random variable. Variance decreases as a function of increasing sample length.

Zone C

The Btu content estimated for ddh 136 appears appreciably higher than that for ddh 135 but statistically the two are indistinguishable. Combined data include the within-hole and between hole dispersions. Cumulative probability plots for both holes suggest the presence of two populations. These can be estimated from the combined probability plot as two normal populations: about 10-15% of a lower population and the remainder an upper population. Dispersion of data decreases significantly as sample length increases. The apparent differences between the two holes could represent a slight facies change but could also represent expected sampling fluctuations within a single population (tested at $\alpha = 0.05$ level). The variogram indicates cyclical variations at 40 to 50 feet on the average.

Zone D

Data for the two holes are almost identical and have a significantly higher mean and lower variability than the other three zones. The probability plot shows that the data can be interpreted as consisting of two overlapping populations, about 70 percent of an upper population and 30 percent of a lower. Both populations have comparable dispersions that are significantly less than the data as a whole. Analysis of geophysical and geological logs indicate that the two populations could represent fundamentally distinct rock types although both have high values and are not necessarily visible with ease megascopically as both are good coals. Dispersion decreases as sample length increases. The variograms show a slight structured character and possible faint cyclical variations at distances of about 30 feet that may represent intercalations of the two indicated populations.

Comment: Significant differences exist in mean Btu/# of zones A, B, C and D. Zones A and C have a cyclical nature with fairly regular intercalations of relatively low and relatively high Btu/# at 40 to 60-foot intervals. Interlayering indicated in zones B and D are more randomly distributed.

Ash (% dry) - Zone A

Histograms of dry ash % for both test holes are similar. The summary statistics are indistinguishable. Cumulative probability plots best viewed for the composite data show the converse of Btu/#, i.e., two normal populations with about 65 percent of a low ash population and 35 percent of a high ash population. These clearly correspond respectively to the high Btu/# and low Btu/# populations. Variograms for dry ash % show a similar cyclical pattern as do those for Btu/# and thus fit a comparable interstratified, two rock-group, model. The variograms show no indication of trends along the diamond drill holes, i.e. across the stratigraphic section. Hence, apart from the correlation arising from intercalation of two rock groups, dry ash % can be considered a random variable for 10-foot sample that cross the section. Dispersion of values decreases substantially with increase of sample length.

Zone B

B-zone ash has comparable means and standard deviations in the two test holes. Data differ on cumulative plots: ddh 135 containing a single normal population and ddh 136 data consisting of two populations. The lower population in ddh 136 is very comparable to the single population of ddh 135. This difference between holes can be interpreted as a facies change to particularly high ash material within a small percentage of zone B where cut by ddh 136. Dispersion decreases as sample length increases. The variograms indicate a possible trend in ddh 136 and no trend in ddh 135. In ddh 136 the trend is not apparent over sample spacing of 70 feet or less.

Zone C

Means and dispersions are similar in the two holes. The apparent difference in mean values (58.42 and 51.83) are not significantly different considering the dispersion (tested at the 0.05 level). The probability graph indicates two normal populations, about 20 percent of an upper population and 80 percent of a lower. These are somewhat more clearcut than the two populations recognized for Btu/# in zone C; however, the high ash and low Btu/# populations probably correspond, and vice versa. Dispersion decreases somewhat as a function of increasing sample length, but not as pronouncedly as in zones A and B. The variogram indicates an essentially random variable.

Zone D

Means and standard deviation for data from the two holes are comparable. The probability graph indicates two normal populations; about 30 percent of an upper population and 70 percent of a lower population. These correspond very closely with lower and upper populations respectively, for Btu/#, i.e., the high ash population corresponds with the low Btu/# populations, and vice versa. Dispersion decreases only slightly as sample length increases and there is no significant difference in variability for sample lengths of 30 feet or more. The variogram shows a character very like that for Btu/#, i.e., a structured variable with some indication of slight cyclical variations over distances of about 40 feet on the average.

Fixed Carbon (dry %) - Zone A

Fixed carbon (dry %) from the two test holes have distributions that are indistinguishable statistically assuming normality or lognormality. Probability plots for the two holes show a slight difference however. The plot for hole 135 is comparable to the Btu/# plot and indicates high carbon and low carbon populations in the approximate ratio of 2:1. The plot for ddh 135 shows a comparable upper population, and sufficient variability in the low values to indicate the possibility of two lower populations. These are not well defined, however, and the data are described adequately by the composite probability plot.

Fixed Carbon (dry %) has variograms that are comparable to those for dry ash % and Btu/# (dry) showing cyclical variations that reflect interstratification of the two compositional groups in a regular manner, i.e., 40-50 foot lengths of the high carbon population separated by 20-40 foot lengths of low carbon population. Both holes provide comparable results.

Variability of fixed carbon decreases appreciably as sample length increases

Zone B

Fixed carbon has essentially the same density distribution in both test holes. Data for both holes appear to each represent a normal population based on an evaluation of probability plots. A variogram study indicates no trend along ddh 135 but a slight but definite trend in ddh 136 beyond a sample spacing of about 100 feet. Variability decreases as sample length increases but sample lengths 30 feet and more have essentially similar variability.

Zone C

Fixed carbon data are comparable for test holes 135 and 136. The probability graph for the combined data show the presence of two normal populations, 80 percent of a high and 20 percent of a lower population. These correspond closely to the interpreted populations for Btu/# and ash. Variability decreases slightly as sample length increases. The variogram shows cyclical fluctuations, on the average every 40 to 50 feet as indicated by other proximate variables.

Zone D

Mean and standard deviations are almost identical in holes 135 and 136. The probability plot for combined data indicates a single normal population. Variability decreases slightly with increase in sample length. The variogram shows some structure possibly with a faint superposition of cyclical variations.

<u>Volatile Matter (dry %)</u> - Zone A

Data for both test holes are comparable. They are described best as a single normal population best estimated by the composite data. Nevertheless there is some suggestion in the probability graphs that more than one population exists although the patterns are insufficient to be certain. This departure of volatile matter from the definite pattern shown by Btu/# and ash might result from a combination of sources contributing to error in volatile matter estimation (e.g. organic sources, CO_2 and water of hydration and crystallization). The same argument would hold for fixed carbon which is determined by difference. Despite this difficulty of discerning individual populations the variograms show that the data fit an interstratified model well in ddh 136 and less well in ddh 135. Variability decreases as sample length increases.

Zone B

Data for both test holes are similar. A probability plot of combined data indicated two populations: about 90 percent of an upper population and 10 percent of a lower population - both are probably normal. Variograms along the two sections show no structure and no trend- the variable can be considered random. Dispersion decreases as a function of increasing sample length.

Zone C

Means and standard deviations are almost identical in the two test holes. The probability graph can be interpreted as indicating a single normal population. However, the variograms suggest a cyclical structure to the variable with relatively high and low values occurring every 30 to 40 feet.

Zone D

Statistical parameters are similar for the two test holes. A probability graph of combined data indicates two normal populations, about 82 percent of an upper population and 18 percent of a lower. These are somewhat different in proportion to the two population models for some other proximate variables, possibly because several sources contribute to the higher population, thus its proportion is increased over what might arise from volatile hydrocarbons alone. Dispersion shows almost no decrease with increasing sample length. The variogram indicates an essentially random variable.

Total Sulphur (% dry) - Zone A

Total sulphur data for the two test holes are very similar. They can be treated as two populations - about 5 percent of a population with values above 1.20 percent total sulphur and the remaining values forming a lognormal population (i.e. values less than 1 percent total sulphur). From available data it appears that there is no appreciable difference in total sulphur content of the two rock groups indicated by proximate variables. The variograms show indication of a slight trend in both drill holes but it does not become of any significance at sample spacings less than about 300 feet. Autocorrelation is not significant and the variable can be assumed random in nature across the stratification. Log_{10} (total S) shows a significant linear correlation with Btu/# (r = 0.514) but with considerable scatter of values. At 3000 Btu/# the mean total sulphur content is 0.45 percent whereas at 7500 Btu/# the mean total sulphur content is 0.69 percent. Dispersion of sulphur values decreases slightly with increasing sample length.

Zone B

Data for the two test holes are comparable. The composite data (50 values) indicate the possible presence of as many as four separate populations (perhaps in the ratio of 4:45:47:3). This is somewhat speculative and the total range of data can be described reasonably well with a single lognormal population. Variograms show that no trends exist in this variable along the length of the text holes and that they exhibit no structure or significant autocorrelation. That is, for sampling purposes they can be considered random variables. A slight decrease in variance is apparent with increase in sample length. A small but significant correlation exists between Log_{10} (total S) and Btu/# (r = 0.318). At 3000 Btu/# the mean total sulphur content is 0.59 percent and at 7500 Btu/# mean total sulphur is 0.78 percent.

Zone C

Means and standard deviations for the two test holes are comparable. The combined data can be interpreted as a mixture of two lognormal populations, 30 percent of a high and 70 percent of a low population. It is not possible to say how these populations correlate with the two populations indicated by some proximate variables. Dispersion decreases very slightly with increasing sample length. The variogram shows some indication of autocorrelation possibly over distances as much as 60 feet. The effect is slight however, and is of negligible significance. The variable can be treated as random. Log_{10} (total sulphur) correlates significantly with Btu/# (r = 0.465). At 3000 Btu/# the sulphur content is 0.28 percent and at 7500 Btu/# expected sulphur content is 0.48 percent.

Zone D

Means and standard deviations are comparable for the two test holes. The probability plot of combined data suggests the presence of two lognormal populations, about 7 percent of a high population (all values greater than 0.40

percent S_2) and 93 percent of a lower population.

Variance is essentially constant regardless of sample length.

The variogram indicates that total sulphur can be considered a random variable. Log_{10} (total sulphur) correlates significantly with Btu/# (r = 0.290). At 3000 Btu/# the corresponding sulphur content is 0.17 percent whereas at 7500 Btu/# the calculated total sulphur content is 0.23 percent.

S_{org} (dry %) - Zone A

Means and standard deviations are comparable for the two test holes. A probability graph indicates two lognormal populations, about 80 percent of an upper and 20 percent of a lower one. Variability decreases with increase in sample length. A variogram indicates that S_{org} is a random variable.

Zone B

Means are comparable but standard deviations differ for the two test holes. Data can be described well by a single lognormal population although it appears likely that the lowest five percent of values represent a distinct population. Variability decreases slightly with increase in sample length. A variogram indicates that S_{org} is a random variable.

Zone C

Means and standard deviations for the two test holes are comparable. A probability graph indicates the presence of three lognormal populations, about 25 percent of an upper, 55 percent of an intermediate and 20 percent of a lower population. Variability decreases slightly as sample length increases. A variogram shows that S_{org} is a random variable.

Zone D

Dispersions are similar but mean values differ somewhat for the two test holes. The data are described adequately by a single lognormal population. Variability decreases slightly with increase in sample length. A variogram indicates that S_{org} is a random variable.

Comment: Zones C and D contain about one-half the amount of organic sulphur that zones A and B contain.

Spyr (dry %) - Zone A

Data can be described by two lognormal populations, about 2 to 3 percent of an upper population (above0.7 percent pyritic sulphur) and the remainder a lower population. Variability is not great quantitatively but the standard deviation is essentially the same as the mean value indicating a skewed distribution. Pyritic sulphur is a random variable.

Zone B

Data can be described by a single lognormal population although there is a suggestion of two closely spaced overlapping populations. Variability is low relative to the mean but is only slightly less than variability in A zone. Pyritic sulphur is a random variable.

Zone C

Data can be described adequately by a single lognormal population. Variability as shown by the standard deviation is slightly less than the mean but the absolute value is substantially less than for A and B zones. Pyritic sulphur is a random variable.

Zone D

Data can be described by a single lognormal population. Variability as shown by the standard deviation is slightly more than half the mean and is much less than for A and B zones. Pyritic sulphur is a random variable.

Comment: Absolute variability of A and B zones is high relative to C and D zones which both have very low variability. Approximately 30 percent of total sulphur is present as pyritic sulphur in A, B and C zones (specific estimates are A - 30%, B - 32% and C - 30%). The corresponding estimate for D zone is 10%. Virtually all remaining total sulphur is present as organic sulphur.

CO_2 (dry %) - Zone A

Means and standard deviations are comparable for the two test holes. A probability plot indicates two lognormal populations, about 50 percent of each one. Variability decreases with increase in sample length. A variogram indicates that CO_2 is a random variable.

Zone B

Means and standard deviations are comparable. A probability graph indicates the presence of two lognormal populations, about 17 percent of an upper population and 83 percent of a lower one. The two are separated effectively by a value of 2.5% CO_2. Variability decreases with increasing sample length. A variogram indicates that CO_2 is a random variable.

Zone C

Means and standard deviations are comparable for the two test holes. A probability graph shows the presence of three lognormal populations, 25 percent of an upper one, 70 percent of an intermediate one and 5 percent of a lower one. Variability decreases with increase in sample length. A variogram shows CO_2 to be a random variable.

Zone D

Means and standard deviations are comparable for the two test holes. A probability graph shows the presence of two lognormal populations about 30 percent of an upper one and 70 percent of a lower one. Variability decreases with increase in sample length. A variogram shows that CO_2 is a random variable.

Comment: CO_2 contents are comparable for zones A, B and D. Zone C has a very much higher CO_2 content as well as a much wider dispersion. This would appear to result from thin carbonate-rich layers randomly disposed throughout zone C.

P_2O_5 (% dry ash) - Zone A

Measured standard deviations are comparable for the two test holes. The probability plot is suggestive of two lognormal populations butmore data are required to prove this. For the present P_2O_5 in A zone can be described adequately by a single lognormal population. The variogram indicates that P_2O_5 is a random variable. Variability decreases significantly as sample length increases.

Zone B

Means and standard deviations are comparable for the two test holes. The probability graph indicates that two approximately lognormal populations are present, about seven percent of an upper population (above 0.4% P_2O_5) and 93 percent of a lower population. The variogram indicates that P_2O_5 is a random variable. Variability decreases as sample length increases.

Zone C

Means and standard deviation are not significantly different (tested at the 0.025 level) for the two test holes. The probability graph indicates that the distribution is more highly peaked than is a normal distribution, and this may result from the presence of two populations. However, the data are described adequately by a single lognormal population. Variability of data decreases as sample length increases. Variograms show P_2O_5 to be essentially a random variable.

Zone D

Means and standard deviations are comparable for the two test holes. The probability graph indicates presence of a single lognormal population. Variability decreases significantly as a function of increasing sample length. The variogram indicates no significant autocorrelation.

Comment: Means and standard deviations appear comparable for zones A, B and C. Zone D appears to contain slightly less P_2O_5 than do the other three zones.

<u>SiO_2 (dry ash %)</u> - Zone A

Variability differs significantly from one hole to the other but means are similar. The probability graph can be described adequately by a single normal population but has the form of a bimodal curve formed by a narrow dispersion population (about 50 percent centered close to the same mean as a wide dispersion population. Variability decreases as a function of increasing sample length. Variograms show that SiO_2 is a random variable with no autocorrelation.

Zone B

Means and standard deviations for the two test holes are essentially identical. The probability graph can be described by a single normal population but in reality is somewhat peaked, and thus probably represents about 35 percent of a narrow dispersion population, within the range of a wider dispersion population. Variability decreases with increase in sample length. The variogram shows SiO_2 to be a random variable.

Zone C

Means and standard deviations for the two holes are not significantly different. The probability graph can be interpreted as two normal populations, about 93 percent of an upper population and seven percent of a lower. These probably represent rock types of fundamentally different character. Dispersion decreases as sample length increases. A variogram shows that SiO_2 can be considered a random variable.

Zone D

Means and standard deviations are virtually identical for the two test holes. The distribution is highly peaked suggesting the presence of a short dispersion population (about 60 percent) within the range of a wide dispersion population. These may represent two fundamentally distinct ash types. However, the overall distribution can be approximated closely by a single normal population.

Standard deviations decrease as sample length increases. A variogram indicates the possibility of autocorrelation with a short range, possibly about 20 feet. More data are required, however, and SiO_2 can be assumed to be a random variable.

<u>Fe_2O_3 (dry ash %) - Zone A</u>

Means and standard deviations are comparable for the two test holes. The probability graph can be closely approximated by two normal populations about 12 percent of an upper population and 88 percent of a lower one. The upper population might, in fact, be two separate populations. Variability decreases as sample length increases. A variogram shows that Fe_2O_3 is a random variable.

Zone B

Means and standard deviations for the two test holes are essentially the same. The probability graph can be interpreted as a mixture of two normal populations about 10 percent of an upper and 90 percent of a lower population. Means of these two populations differ by a factor of four or five. Variability decreases with increase in sample length. A variogram indicates that Fe_2O_3 is a random or unstructured variable (i.e., shows no autocorrelation).

Zone C

Means and standard deviations are statistically similar for the two test holes. A probability graph can be interpreted as a combination of two normal populations, eight percent of a high population and 92 percent of a lower population. Means of the two populations differ by a factor of four or five. Variability decreases as sample length increases. A variogram indicates that Fe_2O_3 is a random variable.

Zone D

Means and standard deviations for the two test holes are similar. The probability graph indicates the presence of two normal populations, 20 percent of a high, wide dispersion population, and 80 percent of a low, narrow dispersion population. Variability decreases as sample length increases. A variogram indicates that Fe_2O_3 is a random variable.

Al_2O_3 (dry ash %) - Zone A

Means and standard deviations are comparable for the two holes. A probability graph has the form of a bimodal (2 normal) distribution. The high population is about 80 percent of the total. These would appear to represent two fundamentally different ash types. The variability decreases as sample length increases. A variogram indicates that Al_2O_3 is a random variable.

Zone B

Means and standard deviations are comparable for the two holes. A probability graph clearly shows the presence of two normal populations with no significant overlap of values. The upper population is 86 percent of the data - the lower population 14 percent. A value of 27% Al_2O_3 is an efficient threshold separating the two groups. Variability decreases as sample length increases. A variogram indicates that the variable can be considered a random variable.

Zone C

Mean values are almost identical for the two holes but dispersions are significantly different. This difference in dispersion probably arises from the variable nature of facies changes. These two different dispersions are reflected in the probability graph which has the form of a highly peaked symmetric distribution that undoubtedly is a combination of the wide and narrow dispersion population referred to above. Variability decreases as sample length increases. The variogram indicates that Al_2O_3 is a random variable.

Zone D

Means and standard deviations are similar for the two test holes. A probability graph indicates the presence of two normal populations. An upper population is about 85 percent of the data and a lower population about 15 percent. The upper population may, in fact be two populations. These would appear to be fundamentally distinct ash types. Variability decreases as sample size increases. A variogram indicates that Al_2O_3 is a random variable.

TiO_2 (dry ash %) - Zone A

Means and standard deviations for the two test holes are comparable. A probability graph shows that the data very definitely fall into two groups probably best described by lognormal populations, about 75 percent of an upper population and 25 percent of a lower. Variability decreases slightly as a function of increasing sample length. A variogram indicates that TiO_2 is a random variable with a pronounced trend indicated.

Zone B

Both means and standard deviations are significantly different in the two test holes. The difference is slight, however, and may not be of practical consequence. A probability graph shows the presence of two well defined lognormal populations, about 20 percent of an upper population and 80 percent of a lower. Variability decreases slightly with increasing sample length. A variogram shows that TiO_2 is a purely random variable.

Zone C

Means and standard deviations are similar for the two test holes. The probability graph is somewhat ambiguous but probably represents at least two populations that could be resolved only very approximately. Variability decreases very slightly as a function of increasing sample length. A variogram indicates that TiO_2 is a purely random variable.

Zone D

Dispersion is distinctly different from one test hole to the other (high in 136, low in 135) but mean values are essentially identical in the two holes. A probability graph is ambiguous and could be interpreted equally well as a single lognormal population or as two lognormal populations. Variability decreases slightly as sample length increases. A variogram indicates that TiO_2 is a random variable.

Comment: The mean values are very close for all zones. Variability is similar in zones B, C and D but is greater in zone A

CaO (dry ash %) - Zone A

Means do not vary a great deal between the two test holes but variability (standard deviations) is distinctly different. The probability plot is complex, indicating the presence of at least two lognormal populations, and probably more, hence, its interpretation is ambiguous. This complexity probably arises principally from the variable distribution of limestone or limy clays, etc. as a result of facies changes. Variability decreases as a function of increasing sample length. A variogram indicates that CaO is a random variable with the presence of an identifiable trend for sample separation greater than 250 feet across stratification.

Zone B

Means are similar but standard deviations differ significantly between the two test holes. A probability graph can be interpreted as indicating two lognormal populations, about 15 percent of an upper population and 85 percent of a lower one. Variability decreases as sample length increases. A variogram indicates that CaO is a random variable.

Zone C

Means are comparable for the two test holes but standard deviations differ significantly. The probability graph for combined data indicates the presence of two predominant lognormal populations, about 29 percent of an upper population and 71 percent of a lower one. The two populations are separated approximately at 2.9% CaO. Variability decreases with increase in sample length. A variogram shows that CaO is a random variable.

Comment: Mean values of CaO are almost identical for zones A, B and C and are slightly less than for zone D. Conversely, the variability is lower for D than for the other zones, and is notably highest in zone A.

MgO (dry ash %) - Zone A

Means and standard deviations are comparable for the two test holes. A probability graph shows the presence of a single lognormal population. Variability decreases substantially with increase in sample length. A variogram shows that MgO is a random variable.

Zone B

Means are comparable for the two test holes but variances differ slightly. The probability graph for combined data can be approximated closely by a single lognormal population. Variability decreases markedly as sample length increases. A variogram shows that MgO is a random variable.

Zone C

Means are almost identical for the two test holes but variability is somewhat different for raw data. The probability graph closely approximates a single lognormal population. Variability decreases as sample length increases. A variogram shows that MgO is a random variable.

Zone D

Means and standard deviations are almost identical for the two holes. The probability graph can be closely approximated by a single lognormal distribution but could equally well be interpreted as a combination of three populations. Variability decreases with increasing sample length. A variogram shows that MgO is a random variable.

Comment: Mean values for zones A and B are almost identical, C is slightly higher and D is appreciably lower. Zone C is the most variable.

SO_3 (dry ash %) - Zone A

Means and standard deviations for the two test holes are similar. The probability graph indicates a single lognormal population. Variability decreases as sample length increases. SO_3 is a random variable.

Zone B

Means and standard deviations are comparable for the two test holes. A probability graph indicates the presence of one lognormal population. Variability decreases with increasing sample length. A variogram shows that SO_3 is a random variable.

Zone C

Means and standard deviations are comparable for the two test holes. A probability graph indicates the presence of one lognormal population, although a more complicated interpretation is possible. Variability decreases as sample length increases. A variogram shows that SO_3 is a random variable.

Zone D

Means and standard deviations are almost identical. A probability plot indicates that at least two lognormal populations are present but such a complex interpretation is difficult with limited available data. Variability decreases with increasing sample length. A variogram shows that SO_3 is a random variable.

Comment: Zones A and C have the highest mean SO_3 values and zones B and D have the highest variability.

K_2O (dry ash %) - Zone A

Means and standard deviations are comparable for the two test holes. A probability plot indicates the presence of at least three lognormal populations, about five percent of an upper population, 80 percent of an intermediate population and 15 percent of a lower populations. These may reflect fundamentally different types of ash. Variability is low and decreases very slightly with increasing sample length. A variogram indicates the K_2O is a structured variable with slight autocorrelation and a dominant random aspect. K_2O can be treated as a random variable but the indicated structure with a range of about 40 feet is consistent with the layered model suggested for the A zone on the basis of the analysis of proximate variables. If this structure exists it indicates fundamentally different ash in alternating layers of the model.

Zone B

Means are similar but dispersion differs for the two test holes. A probability graph indicates the presence of three lognormal populations, about four percent of an upper population (above 0.80% K_2O), 66 percent of an intermediate population and 30 percent of a lower one. Variability decreases very slightly with increasing sample length. A variogram shows that K_2O is a random variable.

Zone C

Means differ somewhat but variability is the same for the two test holes. A probability plot can be described by a single lognormal population but the interpretation could be more complex. Variability decreases very slightly with increase in sample length. A variogram shows that K_2O is a random variable.

Comment: K_2O is relatively uniform and low in value throughout all four zones. Content of zone D ash is about one-third the amount in the other three zones.

Na_2O (dry ash %) - Zone A

Means and standard deviations are essentially the same for both test holes. A probability plot can be described by a single lognormal population but could be more complicated than that in reality. Variability decreases slightly with increase in sample length. A variogram shows that Na_2O is a random variable.

Zone B

Means differ slightly but dispersion is similar for the two test holes. A probability graph is suggestive of three lognormal populations, about 10 percent of an upper, 80 percent of an intermediate and 10 percent of a lower population. Variability decreases slightly with increase in sample length. A variogram shows that Na_2O is a random variable.

Zone C

Means and standard deviations for the two test holes are similar. A probability graph can be approximated by a single lognormal population but probably represents three or more lognormal populations. Variability decreases slightly as sample length increases. A variogram shows Na_2O to be a random variable.

Zone D

Means and standard deviations for the two holes are similar. A probability graph can be approximated by a single lognormal population but could actually represent three identifiable populations. Variability decreases slightly with increase in sample length. A variogram shows that Na_2O is a random variable.

Comment: It is interesting to note that the inherent variability of Na_2O is twice as much for zone D as for each of the other three zones.

Mn_3O_4 (dry ash %) - Zone A

Means and standard deviations are comparable for the two test holes. A probability plot probably represents two (or more) lognormal populations, about 40 percent of an upper one and 60 percent of a lower one. Variability is low and decreases with increasing sample length. A variogram shows that Mn_3O_4 is a random variable.

Zone B

Means are comparable but dispersions differ slightly for the two test holes. A probability plot appears to represent two populations, about 20 percent of an upper lognormal population and 80 percent of a lower population. Variability decreases slightly with an increase in sample length. A variogram shows that Mn_3O_4 is a random variable.

Zone C

Means are comparable but standard deviations differ somewhat for the two test holes. A probability plot can be described by a single lognormal population but may be more complex. Variability decreases slightly with increase in sample length. A variogram shows that Mn_3O_4 is a random variable.

Zone D

Means and standard deviations are comparable for the two test holes. A probability plot can be interpreted as indicating at least two lognormal populations, about 35 percent of an upper one and 65 percent of a lower one. Variability decreases slightly with increase in sample length. A variogram shows that Mn_3O_4 is a random variable.

Comment: Zones A and B have less Mn_3O_4 and lower variability than found in zones C and D.

V_2O_5 (dry ash %) - Zone A

Means and standard deviations are comparable for the two test holes. The data can be interpreted either as a single normal or single lognormal population. Variability decreases slightly with increase in sample length. A variogram shows that V_2O_5 is a random variable.

Zone B

Means and standard deviations are comparable for the two test holes. A probability plot shows that the data closely fit a single lognormal distribution. Variability decreases slightly with increase in sample length. A variogram shows that V_2O_5 is a random variable.

Zone C

Means and standard deviations are comparable for the two test holes. Only four analytical values are recorded so a single lognormal distribution will be assumed. Variability decreases slightly with increase in sample length. A variogram shows that V_2O_5 is a random variable.

Zone D

Means and standard deviations are comparable for the two test holes. The data can be described by a single lognormal population. Variability is low and decreases slightly with increase in sample length. A variogram suggests a possible structure but in practice the variable can be assumed to be random.

Comment: Mean values are almost identical for all four zones. Variability is low but is appreciably higher in zone A than in the other three zones.

Carbon (% dry) Zone A: The distribution can be approximated closely by a single normal distribution. The probability plot, however, has a form suggestive of three normal populations, about 12% of an upper, 58% of an intermediate and 30% of a lower population. Ultimate carbon is a random variable.

Zone B: The distribution can be approximated by two normal populations about 60 percent of an upper one and 40% of a lower one. Ultimate carbon is a random variable.

Zone C: The data distribution is closely approximated by two lognormal populations, about 80 percent of an upper one and 20 percent of a lower one. Ultimate carbon is a random variable.

Carbon Zone D: The frequency distribution has a well developed bimodal form assuming normal distributions - about 65 percent of an upper population and 35 percent of a lower one. Ultimate carbon is a random variable.

Comment: All distributions are bimodal or trimodal in form and have a resemblance to the corresponding probability plots for ultimate H_2.

Hydrogen: (% dry) Zone A: Hydrogen is a random variable. Range of variability as measured by the standard deviation is small relative to mean value. The probability plot indicates two and possibly three normal populations. The bimodal interpretation is 70 percent of an upper population and 30 percent of a lower one. It is possible that the upper population actually consists of two such that the proportions of the three populations are 20:50:30.

Zone B: Variability is low relative to the mean. Hyrdogen is a random variable. The probability plot indicates at least two normal populations but interpretation of these is ambiguous.

Zone C: Variability is low, about the same as for A and B zones. The variable is random in nature. A probability plot indicates the presence of two normal populations, about 70 percent of an upper one and 30 percent of a lower one.

Zone D: Variability is lower, about two-thirds that of other zones, mean values is substantially higher than all other zones. The probability plot is slightly ambiguous but indicates the likelihood of two normal populations, 91 percent of an upper one and 9 percent of a lower one.

Nitrogen (dry %) - Zone A

Dispersions are comparable but means differ significantly for the two test holes. A probability graph indicates a single lognormal population. Variability decreases as a function of increasing sample length. A slight structured aspect may be present in nitrogen, i.e., some degree of autocorrelation exists for samples less than about 40 feet apart.

Zone B

Variability is comparable but means are somewhat different for the two test holes. This difference is reflected in the probability graph. Variability decreases with increasing sample length. A variogram shows that nitrogen is a random variable.

Zone C

Means are comparable but variabilities differ for the two test holes. This is reflected in the combined probability graph as two lognormal populations. Variability decreases as a function of increasing sample length. A variogram indicates the possibility of a structured aspect to the variable with some autocorrelation over sample spacings of about 50 feet or less.

Zone D

Means are comparable but dispersions differ slightly for the two holes. However, data are reasonably well defined by a single lognormal population. Variability decreases slightly with increasing sample length. A variogram indicates that nitrogen is a random variable.

Comment: Nitrogen can be interpreted as a random variable with lognormal distribution in each zone. Averages for the zones range from 0.7% to 1.0%. Zone A has a slightly higher dispersion than the other zones.

Chlorine (dry %) - Zone A

Means and standard deviations are comparable for $\log_{10}$ - transformed data butdiffer for arithmetic data. A probability graph indicates about 60 percent of an upper lognormal population and 40 percent of a lower one - these correspond approximately to the two test holes. Variability decreases slightly with increasing sample length. A variogram indicates that chlorine is a random variable.

Zone B

Means and standard deviations are somewhat different for the two test holes but both are low. The probability graph is poorly defined. Variability decreases slightly as sample length increases. A variogram shows that chlorine is a random variable.

Zone C

Means and standard deviations are comparable for the two test holes. The probability graph is poorly defined. Variability decreases slightly as sample length increases. A variogram shows chlorine to be a random variable.

Zone D

Standard deviations are comparable but means differ somewhat for the two test holes. The probability graph is poorly defined. Variability decreases slightly as sample length increases. A variogram shows chlorine is a random variable.

O_2 (diff) (dry %) - Zone A

Means and standard deviations are comparable for the two test holes. A probability graph indicates the presence of about 90 percent of an upper normal and 10 percent of a lower normal population. Variability decreases with increasing sample length. A variogram is suggestive of a cyclical aspect which would be in agreement with the simple interlayered model indicated by proximate variables.

Zone B

Means and standard deviations are comparable for the two test holes. The probability graph indicates two normal populations, about 83 percent of an upper and 17 percent of a lower one. Variability decreases with increasing sample length. A variogram shows that O_2 (diff) is a random variable.

Zone C

Standard deviations and means are comparable for the two test holes. A probability graph suggests about five percent of a low population and 95 percent of a high one, both are normal. Variability decreases only slightly with increase in sample length. A variogram indicates a definite cyclical aspect to the variable, with a range of about 40 feet that is consistent with that shown by some proximate variables.

Zone D

Both means and standard deviations differ for the two test holes, although the differences are not great and probably reflect slight facies changes in D zone. A probability plot indicates the likelihood of several normal populations but the data can be described by a single population. Variability decreases slightly with increasing sample length. A variogram indicates that O_2 (diff) is a random variable.

Comment: O_2 (diff) is consistently less in mean value than is O_2 (anal). Also O_2 (diff) invariably has a lower dispersion than O_2 (anal). A t-test shows in every case that a significant systematic variation exists between the two variables (at the 0.005 level).

<u>O_2 (anal) (dry %)</u> - Zone A

Means and standard deviations are comparable for the two test holes. A probability plot indicates that the data can be described by a single normal population, although an alternative interpretation could be that 75 percent of an upper and 25 percent of a normal population are present. Variability decreases with increase in sample length. A variagram indicates that O_2 (anal) is essentially a random variable.

Zone B

Means and standard deviations are comparable for the two test holes. Data are closely approximated by a single normal population. Variability decreases with increase in sample length. A variogram shows that O_2 (anal) is a random variable.

Zone C

Means are comparable but standard deviations differ somewhat for raw data for the two test holes. A probability plot indicates three probable normal populations, five percent of an upper, 80 percent of an intermediate and 15 percent of a lower population. Variability decreases with increasing sample length. A variogram shows that O_2 (anal) is a random variable.

Zone D

Means are comparable but standard deviations differ for the two test holes. A probability plot is ambiguous but shows that data can be described by a single normal population. Variability decreases with increasing sample length. A variogram shows that O_2 (anal) is a random variable.

Comment: O_2 (diff) and O_2 (anal) do not clearly show identical distributions and interpretations for the same zones. See also comment for O_2 (diff) regarding systematic differences between the two measures of O_2.

COMPARISON OF DRILL HOLE NOS. 135 AND 136 WITH REMAINDER OF NO. 1 COAL DEPOSIT

General pre-1976 analysis for proximate variables of known stratigraphic zone were examined previously by the writer. Sample lengths of 20 feet are most abundant for pre-1976 data and this length is used as a basis of comparison with data for drill holes 135 and 136 - as shown in Table
A comparison can be made only for proximate variables and total sulphur as these are the only pre-1976 data available to a comparable base.

In conducting this comparison the reader should bear in mind (1) that pre-1976 data were analyzed on the basis of a selection criterion, i.e. visual inspection and less than a particular ash content (75% dry), (2) the test hole data represents virtually a complete section with no selective extraction of high ash coals. Considering these limitations it is surprising that the two groups of variables are so similar.

Formal statistical tests were run at the 0.025 level to test more strictly for comparable dispersions and comparable meons of the two groups. It would seem particularly important that Btu/# for all zones are entirely comparable for the two sets of data.

Volatile matter is significantly different for both zones B and D. In both cases the test holes underestimate the value indicated by pre-1976 data. These differences could be more apparent than real because CO_2 is included in the reported values and is extremely variable.

Fixed carbon differences in means are also noted for zones B and D but because this variable is determined 'by difference', these discrepancies might arise purely for that reason

TABLE XIII

Btu/# (dry)

COMPARISON OF PRE-1976 DATA WITH DATA
FOR DRILL HOLES 135 AND 136
FOR 20-FOOT SAMPLES

Zone		Holes 135 and 136	Pre-1976 Data	F	t
A	n	102	83		
	$\bar{x}$	6429	6477		
	s	1601	1660	1.08	0.199
B	n	46	35		
	$\bar{x}$	7771	7439		
	s	931	1105	1.41	1.473
C	n	29	58		
	$\bar{x}$	4520	4653		
	s	1189	1389	1.36	0.453
D	n	52	74		
	$\bar{x}$	9506	9291		
	s	1061	1163	1.20	0.503

TABLE XIV

ASH (% dry)

COMPARISON OF PRE-1976 DATA WITH DATA
FOR DRILL HOLES 135 AND 136
FOR 20-FOOT SAMPLES

Zone		Holes 135 and 136	Pre-1976 Data	F	t
A	n	105	96		
	$\bar{x}$	43.74	49.9		
	s	11.92	22.7	3.63*	2.438*
B	n	51	35		
	$\bar{x}$	37.08	35.2		
	s	11.46	7.4	2.40*	0.856
C	n	31	59		
	$\bar{x}$	55.17	54.6		
	s	8.10	10.9	1.81	0.258
D	n	52	74		
	$\bar{x}$	23.60	23.8		
	s	6.80	7.4	1.18	0.155

* Significantly different at α = 0.025

TABLE XV

FIXED CARBON (dry %)

COMPARISON OF PRE-1976 DATA WITH DATA
FOR DRILL HOLES 135 AND 136
FOR 20-FOOT SAMPLES

Zone		Holes 135 and 136	Pre-1976 Data	F	t
A	n	102	83		
	$\bar{x}$	27.32	27.3		
	s	7.41	7.3	1.03	0.018
B	n	46	35		
	$\bar{x}$	34.22	31.4		
	s	4.35	5.0	1.32	2.719*
C	n	31	58		
	$\bar{x}$	19.59	20.0		
	s	5.29	5.8	1.20	0.329
D	n	52	74		
	$\bar{x}$	42.01	39.4		
	s	5.28	5.5	1.09	2.665*

* Significantly different at $\alpha = 0.025$

TABLE XVI

VOLATILE MATTER (dry %)

COMPARISON OF PRE-1976 DATA WITH DATA
FOR DRILL HOLES 135 AND 136
FOR 20-FOOT SAMPLES

Zone		Holes 135 and 136	Pre-1976 Data	F	t
A	n	102	83		
	$\bar{x}$	29.77	30.6		
	s	3.97	4.9	1.52	1.28
B	n	46	35		
	$\bar{x}$	31.80	33.4		
	s	2.05	3.4	2.75*	3.05*
C	n	31	58		
	$\bar{x}$	25.24	26.2		
	s	3.25	4.2	1.67	1.12
D	n	52	74		
	$\bar{x}$	34.40	36.8		
	s	2.03	2.9	2.04*	5.22*

* Significantly different at α = 0.025

TABLE XVII

S (Total) - dry %

COMPARISON OF PRE-1976 DATA WITH DATA
FOR DRILL HOLES 135 AND 136
FOR 20-FOOT SAMPLES

Zone		Holes 135 and 136	Pre-1976 Data	F	t
A	n	102	83		
	$\bar{x}$	0.663	0.692		
	s	0.249	0.232	1.15	0.813
B	n	46	35		
	$\bar{x}$	0.810	0.612		
	s	0.171	0.146	1.37	5.53*
C	n	31	58		
	$\bar{x}$	0.370	0.403		
	s	0.152	0.291	3.67*	0.612
D	n	52	74		
	$\bar{x}$	0.263	0.330		
	s	0.060	0.240	16.00*	2.23*

* Significantly different at α = 0.025

and thus relate back to the same cause of difference between volatile matter contents.

Mean ash contents differ significantly for the two groups only in zone A.

Sulphur content differs for the two data groups in B and D zones. In zone B the test holes provide the high estimate, whereas, in zone D the pre-1976 data have the higher mean.

RECOMMENDED SAMPLING PROCEDURE FOR ADDITIONAL DRILL HOLES

Here we will consider a somewhat idealized approach to sampling, drill core from the Hat Creek No. 1 coal deposit. It must be understood that the suggested sampling patterns are to be altered where required by specific purpose or accident of nature. For example, abrupt facies changes, faults, and so on will perhaps require that an ideal pattern be modified locally to suit circumstances.

Some of the principal aspects of a sampling program are:

1. Drill hole spacing
2. Sampling interval along drill holes
3. Length of sample
4. Bench height for mining
5. Ability to recognize waste visually
6. Stratigraphy within the sequence to be sampled.

This study has not dealt specifically with the problem of drill hole spacing. However, two principal results of this study bearing on such a problem are:

(a) The surprising similarity of proximate, mineral ash and ultimate data in the two test holes (1000 feet apart), and

(b) The general similarity of combined test hole data with comparable proximate data (20-foot samples) for the entire No.1 deposit.

Both of these results combine to indicate that where A, B, C and D zones are recognizable unambiguously (i.e. were highly variable lateral facies changes are not dominant) a lateral homogeneity is apparent for each zone. That is, the mean and dispersion of most variables are comparable at widely separated localities.

The stratigraphy within the sequence to be sampled has obvious importance. One of the important conclusions of this study is that very large differences exist among A, B, C and D zones. Consequently, it is important that these be recognized where ever possible, and used to advantage.

On a smaller scale the study indicates other important conclusions pertaining to sampling. Most important is the random or structured aspect of variables. Most variables have been found to be essentially randomly distributed. This means that a few contiguous samples can show the total variability exhibited by a particular section.

A few variables, especially proximate data, show that zone A and, to a lesser extent, zone C have a cyclical aspect on a scale that has important implications to sampling. Zone A has a range (vertically) of 40 to 60 feet whereas zone C appears to have a vertical range of about 40 feet or a bit less. The available data do not define the cycles more specifically. In order to sample these cycles thoroughly the sample length for continuous samples should be no more than one-half the range. Hence, this underlying regular interlayered aspect of A and C zones indicates that a maximum of a 20-foot sample length is required. Furthermore, the sampling should be continuous so that the alternating character (and hence the dispersion) of the coal will be retained.

Zones B and D have a random structure vertically. That is, recognized interlayering is not as regular as in A and C zones. In this case sample length is controlled by the proposed bench height for mining, and again a sample length of 20 feet is recommended with continuous sampling, as an optimal approach to determining mean value and maintaining a check on local variability. For determining mean value, of course, the sample length could coincide with the bench height (i.e. 40 feet). However this provides no check on local variability. A sample length of 20 feet permits estimation of local variability and extrapolation to longer or shorter lengths, based on empirical relationships established in a previous section.

The ranges (from semi variograms) observed for proximate variables in A and C zones represent averages. Thus some are less than the approximately 40-foot average. A value of 30 feet for example would stipulate a sample interval of 15 feet to guarantee that at least one sample was completely encompassed in the range. Consequently, although a 20-foot sample length would be adequate on average, a 15-foot sample would be optimal in guaranteeing that each part of a stratigraphic cycle be sampled thoroughly in order that mean values be well determined and variability be monitored.

In Summary:

Zone	I Preferred Sample Length	II Maximum Sample Length
A	15 feet	20 feet
B	20 "	20 "
C	15 "	20 "
D	20 "	20 "

Either of the foregoing sampling plans measures local mean and dispersion values. If discontinuous samples were taken an additional error would enter estimation of the mean value, and a cruder estimate of variability would be obtained. Continuous sampling is required because of the random aspect of many variables across strata, which means that substantial differences can exist in adjacent samples.

One of these patterns (I or II above) should be applied to obtaining proximate analyses including total sulphur, pyrite sulphur and CO_2 data. Once begun, a sampling program should be followed as closely as possible in order to provide a uniform data base for estimation purposes. However, as indicated previously, this optimum sampling plan will be altered locally for practical reasons such as the situation where a standard sample length includes part or all of a fault zone, an obvious waste band, or the contact between major stratigraphic zones. The general pattern will be overridden also by other criteria such as the need to obtain data for thin waste layers to some pre-determined minimum thickness for selection control in mining.

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