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SAMPLING LIMESTONE AND DOLOMITE DEPOSITS FOR TRACE AND MINOR ELEMENTS

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SAMPLING LIMESTONE AND DOLOMITE DEPOSITS FOR TRACE AND MINOR ELEMENTS

by

J. E. Lamar and K. B. Thomson*

ABSTRACT

Interest in the amount of trace and minor elements in limestones and dolomites, especially those used for agricultural limestone, has raised the question of how the deposits and quarry products may best be sampled. This investigation was made to evaluate tentatively a number of the problems involved.

Two limestone deposits and one dolomite deposit studied were found to vary considerably, both laterally and vertically, in trace and minor element content. Clay overburden and clay partings of deposits were richer in many trace elements than were the limestone or dolomite with which they were associated. Eighteen samples, taken on as many days from the commercial agricultural limestone of a quarry with a moderately high face, showed wide variations.

Careful sampling at two or more places in a quarry, involving sets of samples taken at about 1-foot intervals at each place, may give a reasonable idea of the trace and minor element content of those parts of deposits currently being quarried. A single sample of a commercial product, such as agricultural limestone, appears unlikely to give dependable data on the trace-element content of rock products produced over a considerable period, except possibly for some thin deposits. Equal amounts of commercial products, taken daily for about a month and combined into a composite sample, probably will afford fairly dependable information on the content of trace and minor elements in commercial products.

INTRODUCTION

Recent interest in the trace and minor element content of limestone and dolomite deposits, particularly in the trace element content of agricultural limestone, has resulted in the use of sampling procedures that have not been proved accurate or reproducible. This report presents the results of a preliminary investigation of this problem. All analytical data presented are spectrographic data.

Some of the variations in the quantities of different elements reported are very small in terms of actual percentage by weight. What commercial significance these variations have is not a primary concern of this paper and such significance no doubt varies for each trace element and with the various uses of the stone.

The assistance of Raymond S. Shrode, formerly of the Illinois State Geological Survey, in sampling and sample preparation, and of J. S. Machin of the Survey in checking spectrographic data is gratefully acknowledged.

* K. B. Thomson died in 1955.

PLAN OF STUDY

Stone was studied from three Illinois quarries, two of which were limestone quarries and one a dolomite quarry. Selected relatively thin beds were sampled at two places in each quarry to show lateral variation in individual beds. A ledge or portion of the face of each quarry was sampled at vertical intervals of 3 feet or less. At one of the limestone quarries, commercial products being made at that time also were sampled.

Samples. - Samples taken from the deposits were pieces of stone about 5 to 6 inches in diameter.

Analyses. - All spectrochemical data were obtained using a Bausch and Lomb large Littrow spectrograph. The excitation source was a National Spectrographic Laboratories Spec-Power. A Jarrel Ashe model 200 microphotometer was used for measurement of line densities.

For minor and trace elements, measurements were made relative to calcium using the A.C. arc. Major constituents other than calcium were measured relative to calcium using the spark to provide a correction for the calcium.

DEPOSITS SAMPLED

Limestone Deposit 1

At an active quarry an 18-foot thickness of limestone in 3- to 12-inch beds was sampled. The stone contained more than 90 percent carbonates. The samples were taken as described below within a period of three hours.

Samples Tr 1-18. Taken at vertical intervals of 1 foot from an 18-foot thickness of stone. Sample 1 represents the uppermost foot.

Samples Tr 21-38. Taken at vertical intervals of 1 foot from an 18-foot thickness of the same strata of stone mentioned above. Sample 21 represents the uppermost foot. The site at which samples Tr 21-38 were taken was 300 feet east of the site from which samples Tr 1-18 were obtained and the strata sampled were essentially equivalent stratigraphically.

Sample Tr 19 was taken from the upper 6 inches of a 12-inch bed and sample Tr 20 from the upper 6 inches of the same 12-inch bed but 50 feet to the east.

Sample Tr 40 was taken from a 4-inch bed and Tr 41 from the same bed 175 feet to the east.

Sample Tr 42 was taken from a 6-inch bed and Tr 43 from the same bed 175 feet to the east.

Sample Tr 46 is minus 1-inch stone from the primary crusher of the quarry. Sample Tr 48 is similar material taken 30 minutes later.

Sample Tr 47 is commercial agricultural limestone.

Limestone Deposit 2

Limestone deposit 2 is of different geologic age than deposit 1. An 11-foot thickness of limestone containing more than 90 percent carbonates was sampled.

Samples Tr 60 and 61 were taken from the same 10-inch bed but 100 feet apart. Samples Tr 62-66 were taken at approximately equal vertical intervals from the 11-foot ledge.

Dolomite Deposit 3

The dolomite deposit sampled was made up of beds 10 inches to 3 feet thick. A thickness of 21 feet was sampled. Noncarbonate impurities were not determined but are believed to be less than 10 percent. Samples were obtained, as described below, from the top of the stone downward.

Sample	Thickness represented, inches
Tr 77	30
76	36
75	23
74	19
73	12
72	14
71	12
70	10
69	31
68	28
67	36

Sample Tr 68A was taken from the same bed and position in the bed as Sample 68 but 300 feet to the west.

Sample Tr 69A was taken from the same bed and same position within the bed as Sample 69 but 300 feet to the west.

Sample Tr 76A was taken from the same bed and same position within the bed as Sample 76 but 300 feet to the west.

Samples Tr 78 and 79 are green and gray clay partings, respectively, along bedding planes.

Samples Tr 82-99 are commercial agricultural limestone taken, through the courtesy of the quarry company officials, usually on successive operating days during an elapsed time of 27 days. The agricultural limestone includes stone which was not accessible for sampling and, therefore, was not included in Samples 67 to 77.

PREPARATION OF SAMPLES

Field samples were broken by hammer in the laboratory, and about 100 grams of chips that had not been in contact with the hammer were taken from the inside of the stone block for spectrographic samples. These were crushed to about 60 mesh in a porcelain mortar and then reduced further in an agate mortar.

PRECISION OF SPECTROGRAPHIC ANALYSES

The precision of the A.C. arc data was about 10 percent. This figure increases markedly near the limit of detection for each element.

CHEMICAL SYMBOLS

For convenience a number of chemical symbols are used in the tables that follow. The meanings are as follows:

Ag - silver	Fe - iron	Pb - lead
Al - aluminum	K - potassium	Si - silicon
B - boron	Mn - manganese	Sr - strontium
Ba - barium	Mo - molybdenum	Ti - titanium
Co - cobalt	Na - sodium	V - vanadium
Cu - copper	Ni - nickel	Zn - zinc

VARIATION BETWEEN SAMPLES

The variations in weight percent of the elements in the samples involves data ranging from the first to the fifth decimal place. Therefore, in order that subsequent discussions of compositional differences may be on a comparable basis, it is the percentage variations between data on trace and minor elements that are considered rather than the weight percent differences. Thus 0.00002 and 0.00004 percent by weight nickel is considered to represent a 100 percent variation, as are weight percents of 0.20 and 0.40 iron.

Lateral variation. - Table 1 and table 2 give the data on lateral variation in trace and minor element content. Both samples of each pair came from the same bed but were taken some distance apart. However, each pair of samples came from a different bed as described under "Deposits sampled."

Samples 19 and 20, taken 50 feet apart, show reasonably good agreement. Sample 20 generally contains a somewhat greater percentage of trace and minor elements than sample 19 although sample 19 contains more boron and manganese than sample 20.

Samples 40 and 41 were 175 feet apart. Sample 40 contains a greater percentage of all elements (except strontium) than sample 41.

Samples 42 and 43 were 175 feet apart. The differences between samples are not large except in the case of silver and boron. In general, sample 43 contains somewhat larger percentages of trace and minor elements than sample 42.

Samples 60 and 61 were 100 feet apart. The percentages of all elements in sample 61 exceed those in sample 60, especially silver, copper, potassium, and sodium.

Each of the two samples in the pairs 68-68A, 69-69A, and 76-76A were 300 feet apart. Although there is variation in content of trace and minor elements in the two members of each pair, no member of any pair shows a greater amount of all the elements.

Of limestone samples 19 and 20 and 42 and 43, the higher numbered sample was the easternmost of each pair and was also generally the higher in trace and minor elements. This might be interpreted as indicating an eastward increase in trace and minor element content in the deposit sampled. However, samples 40 and 41 show the reverse of this trend. The data suggest that the lateral variations in the amounts of trace and minor elements are not necessarily consistent in direction in different beds. The similarity of the amount of strontium in all six samples is of interest.

TRACE AND MINOR ELEMENTS

7

Table 1. - Lateral Variation in Pairs of Samples,
Each Pair from the Same Bed

Sample No.	Weight percent										
	Ag	B	Ba	Cu	K	Mn	Na	Ni	Pb	Sr	Zn
LIMESTONE											
19	.00009	.00033	.00074	.00035	.042	.13	.021	.00087	.00024	.014	n.d.*
20	.00015	.00029	.00078	.00036	.050	.10	.027	.00110	.00030	.016	n.d.
40	.00022	.00066	.00140	.00083	.077	.19	.067	.00200	.00051	.015	n.d.
41	.00018	.00033	.00093	.00058	.060	.13	.045	.00130	.00037	.015	n.d.
42	.00016	.00048	.00100	.00074	.082	.12	.044	.00150	.00031	.020	n.d.
43	.00033	.00088	.00120	.00071	.089	.14	.054	.00130	.00038	.016	n.d.
60	.00008	n.d.	.0015	.00027	.78	.0037	.008	.0014	.00012	.036	.0047
61	.00019	n.d.	.0025	.00059	1.46	.0051	.049	.0023	.00021	.039	.0075
DOLOMITE											
68	-	.0006	-	.00034	.390	.05	.017	.0024	.00019	-	n.d.
68A	-	.0009	-	.00043	.282	.05	.012	.0022	.00006	-	n.d.
69	-	.0007	-	.00014	.482	.04	.016	.0024	.00007	-	n.d.
69A	-	.0009	-	.00020	.390	.04	.016	.0013	.00006	-	n.d.
76	-	.0016	-	.00007	1.046	.045	.006	.0020	.00015	-	n.d.
76A	-	.0011	-	.00017	.746	.044	.007	.0028	.00020	-	n.d.

* n.d. - not detected. Co, As, Mo not detected in any samples.

Table 2. - Percentage by Which the Larger of Any Pair of Values
in Table 1 Exceeds the Smaller of the Pair

Sample No.	Ag	B	Ba	Cu	K	Mn	Na	Ni	Pb	Sr	Zn
19	-	14	-	-	-	30	-	-	-	-	-
20	67	-	5	3	19	-	29	26	25	14	-
40	22	100	51	43	28	46	49	54	38	0	-
41	-	-	-	-	-	-	-	-	-	0	-
42	-	-	-	4	-	-	-	15	-	25	-
43	106	83	20	-	9	17	23	-	23	-	-
60	-	-	-	-	-	-	-	-	-	-	-
61	137	-	67	119	87	38	512	64	75	8	60
68	-	-	-	-	38	0	42	9	217	-	-
68A	-	50	-	26	-	0	-	-	-	-	-
69	-	-	-	-	24	0	0	85	17	-	-
69A	-	29	-	43	-	0	0	-	-	-	-
76	-	45	-	-	40	2	-	-	-	-	-
76A	-	-	-	143	-	-	17	40	33	-	-

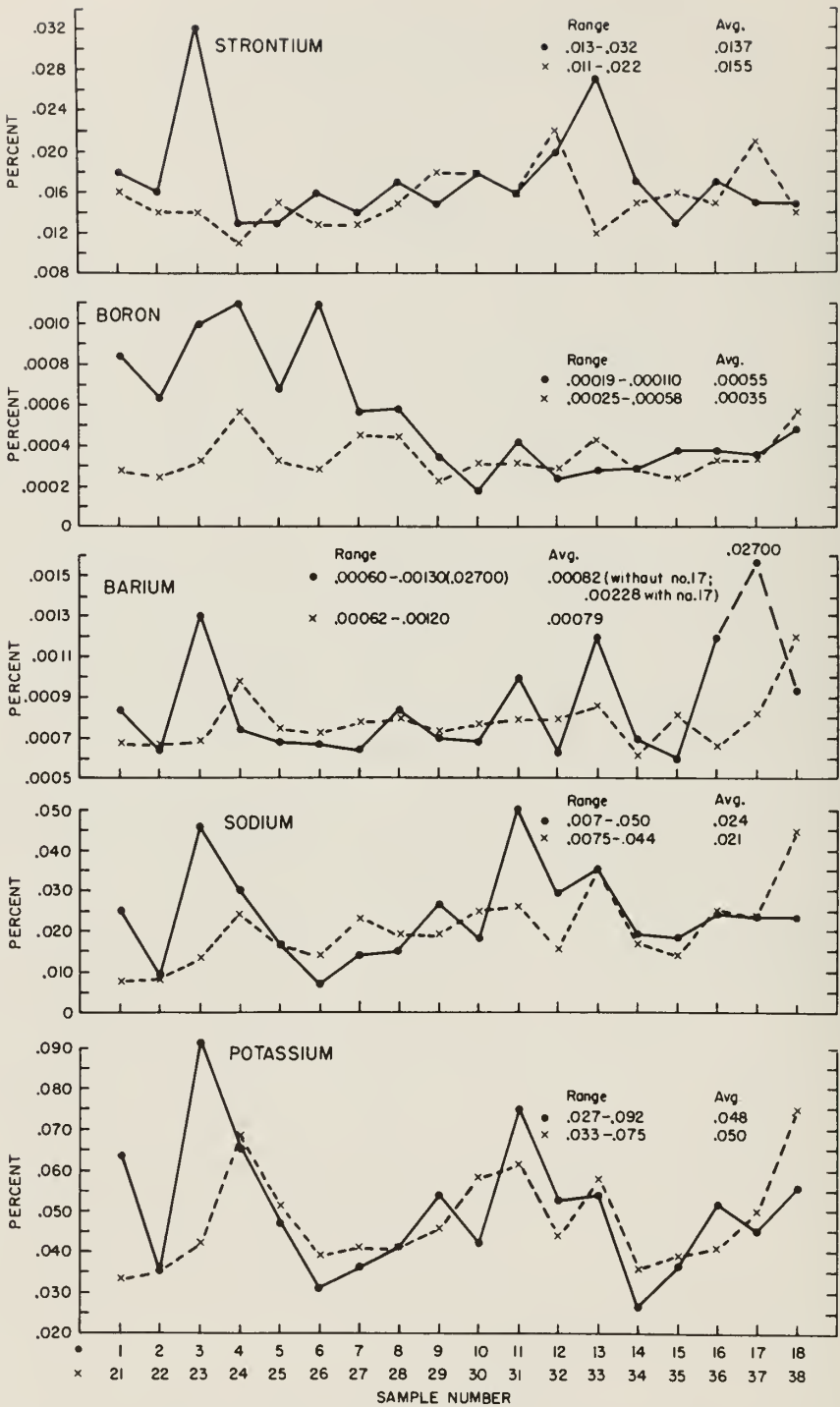


Fig. 1. - Vertical variation in composition of samples taken 300 feet apart horizontally and at 1-foot vertical intervals from 18 feet of thin bedded limestone, deposit 1. For samples from top to bottom, read from left to right.

TRACE AND MINOR ELEMENTS

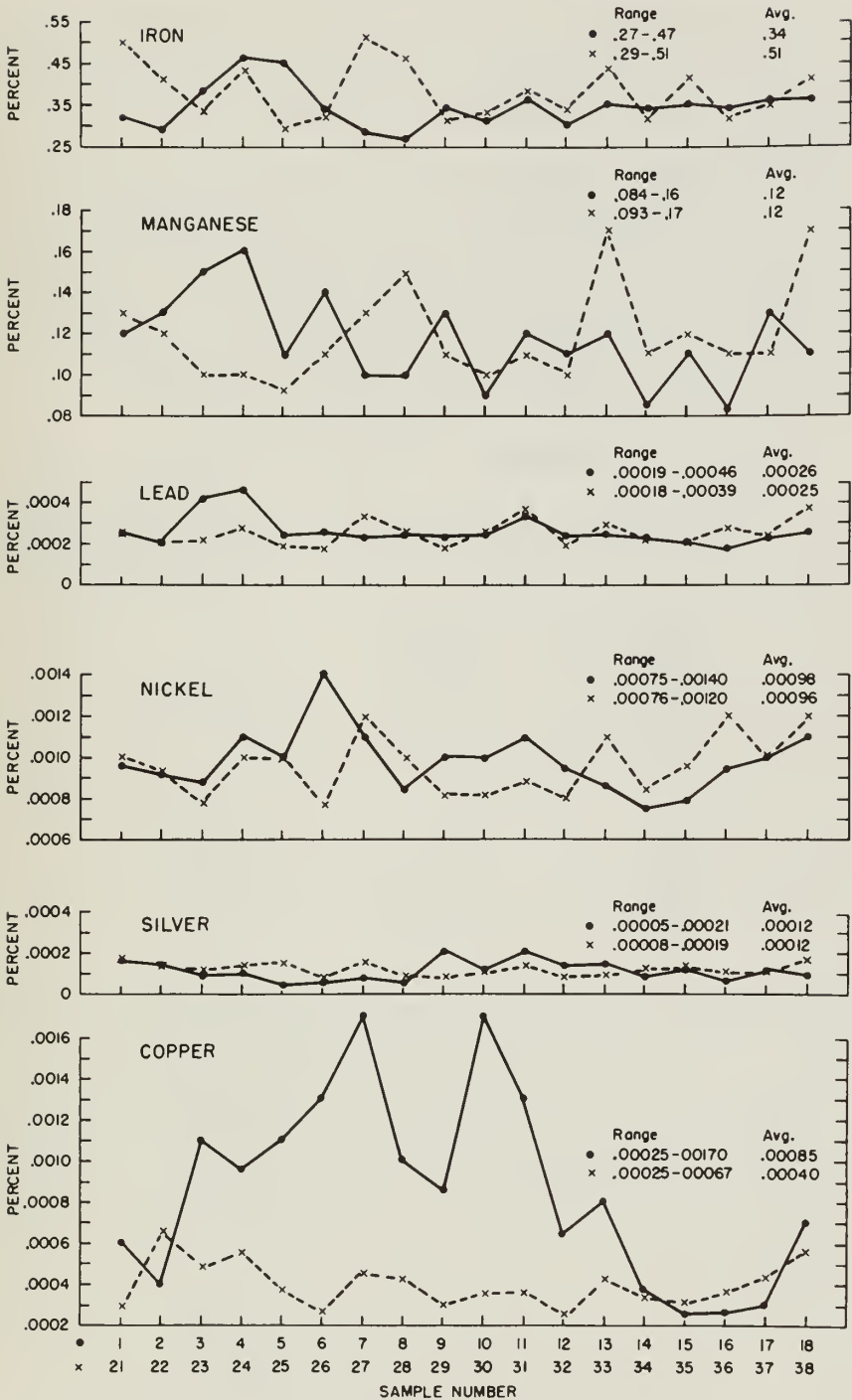


Fig. 2. - Vertical variation in composition of samples taken 300 feet apart horizontally and at 1-foot vertical intervals from 18 feet of thin bedded limestone, deposit 1. For samples from top to bottom, read from left to right.

No over-all directional changes are evident in the dolomite samples 68, 68A, 69, 69A, 76 and 76A, although copper content is higher in the westernmost sample of each pair and potassium content in the easternmost. The consistency of the manganese content in each of the pairs separately and in the pairs together is striking.

Additional light on lateral variation is shed by the data regarding samples 1-18 and 21-38 shown in figures 1 and 2. Inasmuch as the samples represented by the two curves are essentially stratigraphic equivalents, the lack of similarity between the curves indicates lateral variation in composition within a distance of 300 feet. The greatest lateral constancy of composition is shown by silver. Lead also is reasonably constant, and boron is reasonably so in the lower half of the strata sampled. The other curves show reasonable coincidence in places but differences, some of them considerable, at others.

Table 3. - Averages for Samples from Deposit 1

Element	Average, Samples 1 to 18	Average, Samples 21 to 38	Percentage by which larger weight % is greater than smaller weight % Samples	
			1-18	21-38
Ag	.00012	.00012	0	0
B	.00055	.00035	57	-
Ba	.00228	.00079	189	-
Cu	.00085	.00040	113	-
Fe	.34	.38	-	12
K	.50	.48	4	-
Mn	.12	.12	0	0
Na	.024	.021	14	-
Ni	.00098	.00096	2	-
Pb	.00026	.00025	4	-
Sr	.0173	.0155	12	-

Table 3 gives data on the average content of the two sets of samples from deposit 1. The close coincidence in the average amounts of a number of the elements in both sets of samples is noteworthy considering the vertical variations shown in figures 1 and 2. To what extent the situation is happenstance or truly characteristic of relatively pure limestone is not known. Nevertheless, other differences in the averages, such as those for boron, barium, and copper, indicate that lateral variation must be recognized as a distinct and significant factor in sampling limestone deposits for investigations of trace and minor element content.

Vertical variations. - Figures 1 and 2 depict the vertical variations in trace and minor element content of two sets of 18 samples taken at 1-foot intervals from top to bottom of an 18-foot thickness of flat-lying limestone, deposit 1. Sample 1 is nearly the exact stratigraphic equivalent of sample 21, 11 of 31, and so on. The two sets of samples were from locations 300 feet apart in the quarry.

All curves show considerable vertical variation in the amounts of the elements except the curves for silver and, to a lesser degree, lead. The copper

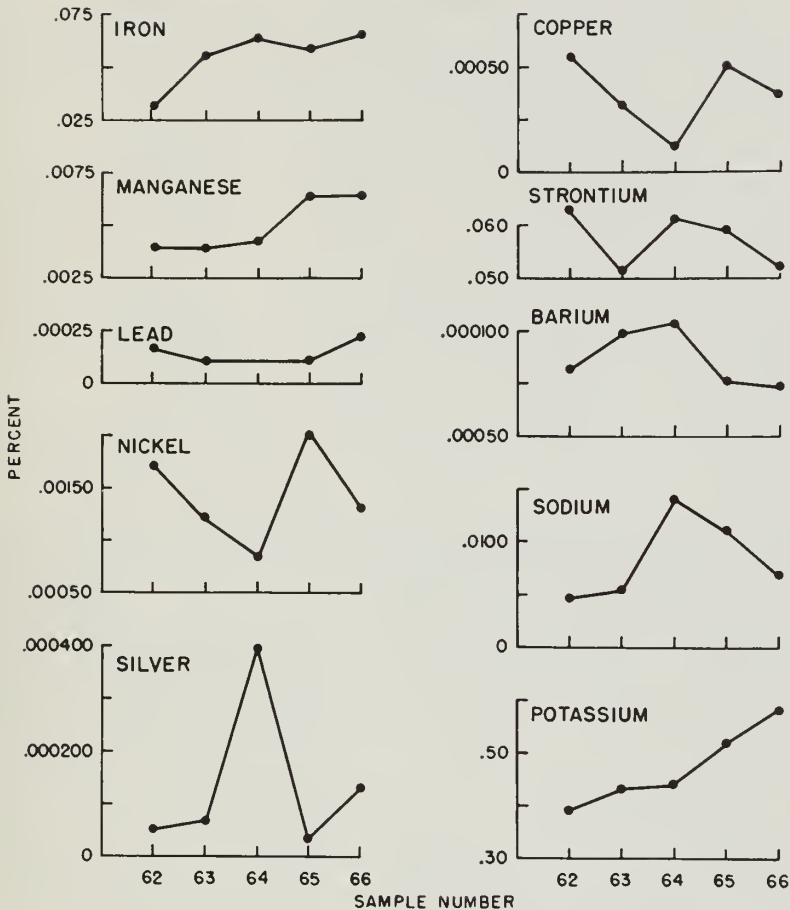


Fig. 3. - Trace and minor element content of five samples taken at 2-foot vertical intervals from an 11-foot limestone face. For samples from top to bottom, read from left to right.

curve of samples 1 to 18 indicates great vertical variation in copper content. Lesser but considerable are the variations in the curves for samples 1 to 18 of potassium, sodium, barium, boron, strontium, and manganese. The curves of samples 21 to 38 generally show less vertical variation than the other curves but marked variations occur in the potassium and manganese curves.

The vertical variations in the trace and minor element content of five samples, 62 to 66, taken from limestone deposit 2 are shown in figure 3. There is considerable variation in the amounts of all elements except lead and, to a lesser extent, iron and manganese.

Figure 4 shows the compositional variations of 11 samples taken from a 24-foot thickness of dolomite. Composition is not vertically constant, nor does there appear to be a consistent relationship between increases and decreases in the amounts of the various elements.

CONSISTENCY IN AMOUNTS OF ELEMENTS

Table 4 shows the difference in weight percent between the maximum and minimum amounts of various elements in the four sets of samples previously mentioned. Computation of the range of trace and minor element content shows that the maximum percentage of a given element generally is double or triple the minimum percentage.

Data for elements determined in all four sets of samples show that the maximum potassium percentage is 2 or 3 times the potassium minimum; the maximum for iron, manganese, nickel, and lead was 2 or 3 times the minimum in three sets, but greater than 3 times in one set; copper and sodium are more variable than the other elements.

Data for elements determined in three sets of samples show that the maximum for strontium is 2 or less times the minimum; the maximum for boron is 2 or 3 times the minimum in two sets, and greater than 3 times in one set; silver and barium are more variable.

EFFECT OF OVERBURDEN AND CLAY PARTINGS

Quarry-face samples have certain inherent differences from the commercial grades of stone produced from the same face. The face samples do not ordinarily, and perhaps cannot, properly represent thin shale or clay partings along bedding planes or an unknown amount of contamination from remnants of unremoved overburden or other impurities that sometimes are unavoidably introduced into commercial stone during quarrying. For example, in a number of Illinois quarries working 10- to 20-foot deposits, face samples comprised of pieces carefully taken at 1-foot

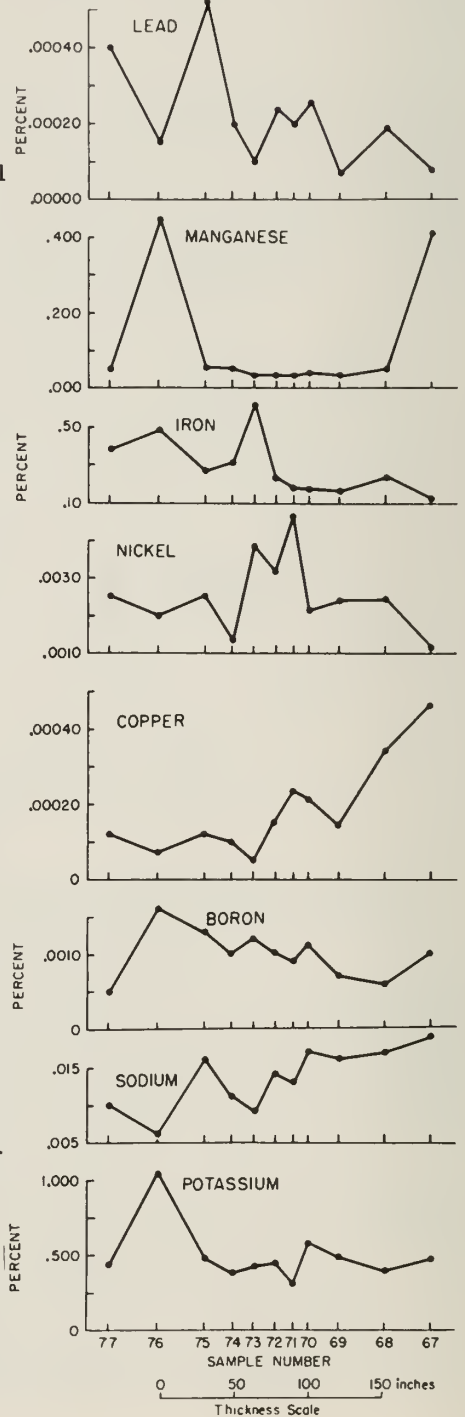


Fig. 4. - Vertical variation in the composition of 11 samples from 11 dolomite beds having a combined thickness of 24 feet. The spacing of the points on the curve is proportional to the thickness of the beds. For samples from top to bottom, read from left to right.

Table 4. - Difference between Maximum and Minimum Percentage of Elements

Element	Percent by weight			
	Samples 1-18	Samples 21-38	Samples 62-66	Samples 67-77
Ag	.00016	.00011	.00036	-
B	.00091	.00034	-	.00110
Ba	.02640	.00058	.00030	-
Cu	.00145	.00042	.00042	.00041
Fe	.20	.22	.033	.50
K	.065	.042	.16	.739
Mn	.076	.077	.0025	.416
Na	.043	.037	.0095	.010
Ni	.00065	.00044	.00117	.0035
Pb	.00027	.00021	.00012	.00046
Sr	.019	.011	.012	-

or less vertical intervals almost always gave carbonate content figures 2 to 4 percent higher than did the commercial agricultural limestone produced from the same deposits. This is interpreted to mean that stripping was incomplete, other contamination occurred in quarrying, or clay partings in the deposit were not adequately sampled, possibly all three. It indicates a possible introduction of 2 to 4 percent of materials which may be much higher in their trace element content than the quarry face samples, as is shown later.

Table 5 gives the analysis of a mixture of incompletely removed clay overburden (Tr 44) and dust resulting from drilling, which ultimately would have been mixed with some of the crushed products from deposit 1. For comparison, the average composition of the limestone deposit (samples 1-18 and 21-38) also is given. The overburden sample exceeds the average of the limestone samples in all the trace elements listed except manganese and strontium. The amount of boron, copper, iron, potassium, sodium, nickel, and lead in the overburden is five times or more greater than the amounts found in the limestone.

Table 5 also indicates the composition of green shale (Tr 78) and gray shale (Tr 79) partings between the dolomite beds of deposit 3, and the average for 11 face samples taken from the same deposit (Tr 67-77). The clay samples consistently exceed the average of the dolomite by three times or more in boron, sodium, copper, iron, and potassium. The dolomite exceeds the clays only in its content of manganese.

It is evident from the foregoing that overburden and clay partings may contribute to the trace element content of the output of a quarry and thus that they must be reckoned with in any sampling of a deposit for the purpose of determining its trace element content or the trace element content of the commercial products made from the deposit.

COMPARISON OF QUARRY SAMPLES AND COMMERCIAL PRODUCTS

Table 6 gives analytical data on the average of the two sets of face samples taken from deposit 1 and on a sample of agricultural limestone produced

Table 5. - Comparison of Clayey Materials and Limestone and Dolomite

Element	Weight percent				
	Deposit 1		Deposit 3		
	Glacial till & drilling dust Tr 44	Avg. Composition limestone Tr 1-18 & 21-38	Green clay from bedding planes Tr 78	Gray clay from bedding planes Tr 79	Avg. Composition limestone Tr 67-77
Ag	.00023	.00012	-	-	-
B	.052	.00045	.0140	.0075	.0010
Ba	.0021	.00154	-	-	-
Co	.001	n.d.*	.002	.00057	n.d.
Cu	.0038	.00063	.0032	.00065	.00018
Fe	1.85	.34	3.70	2.3	.28
K	1.73	.049	6.56	4.02	.494
Mn	.06	.12	.0093	.0047	.042
Mo	n.d.	n.d.	.00037	.00041	n.d.
Na	.780	.023	.24	.12	.013
Ni	.006	.00097	.0033	.0005	.0025
Pb	.0022	.00026	-	-	.00022
Sr	.0070	.0164	-	-	-
Ti	.1	n.d.	.23	.19	-
V	.005	n.d.	.016	.0041	-
Zn	.05	n.d.	n.d.	n.d.	n.d.

* n.d. - not detected.

Table 6. - Comparison of Face Samples and Commercial Products

Element	Avg. 2 sets of face samples (Tr 1-18 & 21-38)	Agricultural limestone (Tr 47)	Primary crusher product (Tr 46)	Primary crusher product $\frac{1}{2}$ hr. later than Tr 46 (Tr 48)
Ag	.00012	.00007	.00010	.00012
B	.00045	.00045	.00076	.00052
Ba	.00154	.00082	.0013	.0011
Cu	.00063	.00034	.00042	.00070
Fe	.36	.34	.35	.41
K	.049	.046	.083	.078
Mn	.12	.096	.11	.11
Na	.022	.017	.041	.037
Ni	.00097	.0010	.0013	.0014
Pb	.00026	.00022	.00028	.00031
Sr	.0164	.014	.016	.016

Co, Mo, Ti, V and Zn not detected.

TRACE AND MINOR ELEMENTS

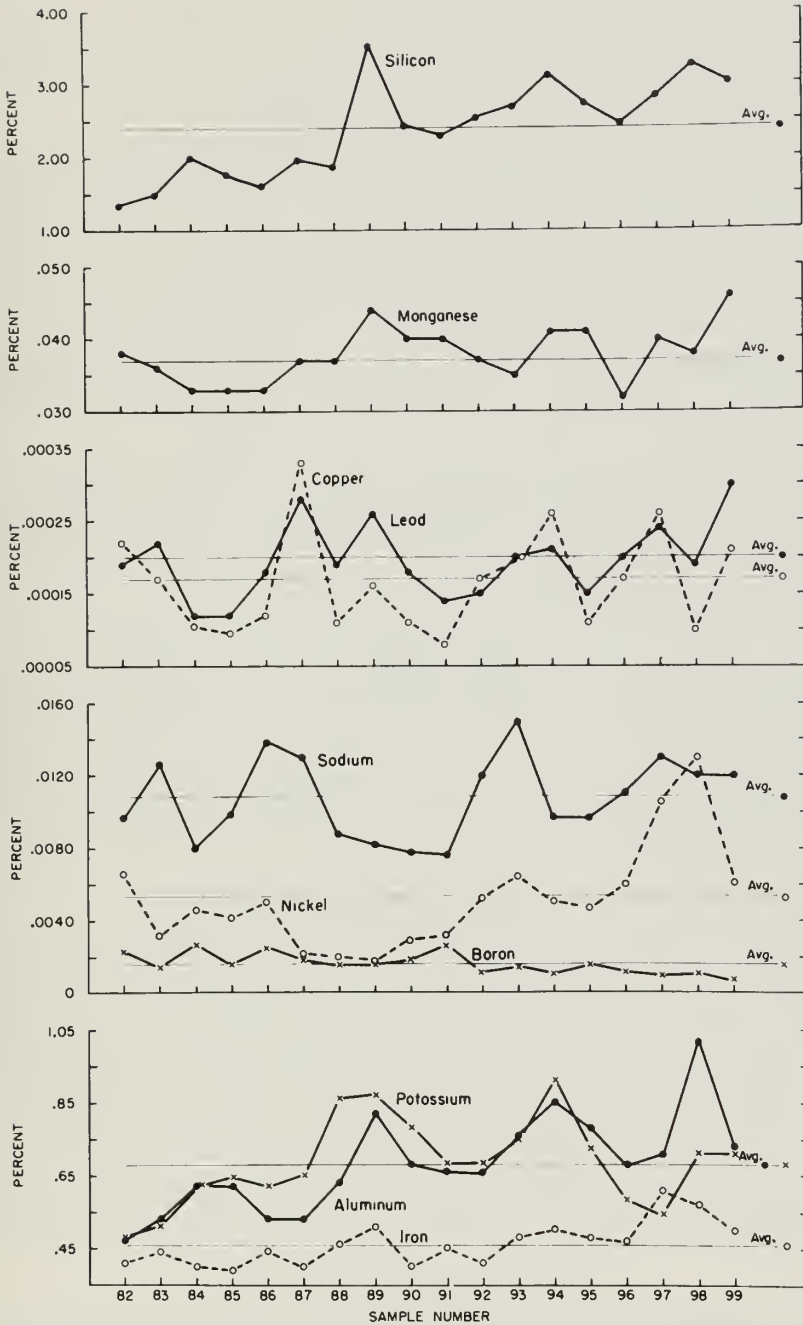


Fig. 5. - Variations in composition of 18 samples of commercial agricultural limestone taken from the output of a dolomite quarry on as many days during a period of three weeks.

from the same deposit. Also shown are data on two samples, taken one-half hour apart, of the stone from the primary crusher. All samples were taken within a period of three hours so that they represent stone from essentially the same portion of the limestone being worked.

The data for the agricultural limestone and the average of the two sets of face samples compare reasonably well from a practical standpoint. The amounts of some elements are almost the same in both analyses. The coincidence of the two analyses is rather remarkable in view of the variations between the two sets of face samples that were averaged to give the data in the first column.

In the two samples of the product of the primary crusher the amounts of most elements are in reasonable agreement, some of them surprisingly so. The same applies to a lesser extent to the crusher samples as compared to the face samples and the agricultural limestone.

The foregoing data suggest that by taking enough sets of face samples from a restricted thickness of limestone, in this case 18 feet, data may be obtained that give a reasonable idea of the probable trace and minor element composition of the quarry products made from the same part of the deposit providing that stripping is clean.

DAY-TO-DAY VARIATIONS IN COMPOSITION

To determine the trace and minor element variation that may be present from day to day in the agricultural limestone produced from a quarry operating a moderately high face, 18 samples of agricultural limestone were taken on separate days during a 27-day period. The deposit was dolomite. The results of analyses of these samples are given in figure 5, and include data on silica and alumina. All curves show considerable variation except boron, with iron and manganese the next least variable.

No attempt was made to determine compositional variations at different times during the day. Presumably these might vary according to the uniformity of the deposit and the number of shovels sending rock to the crusher. However, the data in figure 5 suggest that a sample of agricultural limestone taken from current production on a given day from a moderately high quarry face is a doubtful basis upon which to try to establish dependable information on trace element content that can be considered valid for any appreciable period of time. There is a general similarity between the potassium, aluminum, and silicon curves, probably reflecting the presence of clay minerals, or perhaps potash feldspar, in the dolomite. The copper and lead curves, and to a lesser degree the iron and manganese curves, commonly fluctuate together, though not with the same amplitude.

CONCLUSIONS

The foregoing data may be summarized and tentative conclusions drawn as indicated below. The applicability of the conclusions to limestone and dolomite deposits in general is not known. The conclusions suggest, however, that there are many problems involved in the adequate sampling of limestone and dolomite deposits for the purpose of determining their trace and minor element content, and in the sampling of commercial products of a quarry to the same

end. The conclusions below point out some of the pitfalls to be considered, and provide a preliminary basis for an evaluation of means to avoid them.

Variation in Deposits

1. The individual beds in limestone and dolomite deposits vary appreciably in their trace and minor element content in relatively short horizontal distances.

2. The trace and minor element content of the strata comprising limestone and dolomite deposits vary considerably from bed to bed vertically.

3. Clay or shale partings between the beds of a limestone or dolomite deposit, and clayey overburden or clayey quarry floor strata are likely to contain a greater percentage and possibly a greater variety of trace and minor elements than do the limestone or dolomite beds, unless the stone is impure.

Sampling Deposits

4. Careful sampling of a quarry face may be expected to give data that reasonably represent the composition of a limestone or dolomite deposit as it is exposed at the particular stage of development it is in when sampled. Sampling probably should include a series of samples taken at 1-foot or less intervals. It appears desirable to take several sets of such samples at different places in the quarry. The most informative and reliable data probably are to be expected from a sampling program in which the different lithographic units of a quarry face, or major units of different degrees of purity, are sampled individually.

5. Special care should be exercised to include shale, clay partings, clay beds, or other impure layers in the samples, or to sample them separately, because of their possible high content of trace and minor elements.

Variation in Commercial Products

6. There is apt to be considerable day-to-day variation in the percentage of various trace and minor elements in the agricultural limestone produced by a quarry unless the stone being worked has a greater vertical and lateral uniformity than the deposit investigated in this study. This may be less true for thin deposits than for thicker ones.

7. The possibility that the crushing and sizing of stones may cause a concentration of certain kinds of stones, for example softer, clayier stone, in certain commercial grades should be borne in mind in sampling commercial products and in attempts to relate information regarding the content of trace and minor elements in a deposit to their content in specific grades of stone.

Sampling Commercial Products

8. A single sample of commercial agstone or other products of a quarry is likely to be of questionable value as a basis for obtaining data regarding trace and minor element content that can be relied on to represent accurately the average output of the quarry, except possibly for a brief time. The trace and minor element content of samples taken at different times within the same day may vary, especially if the deposit being worked is not reasonably uniform lat-

erally and vertically. Probably this is especially so for large quarrying operations in medium or thick deposits.

9. It seems possible that reasonably good data regarding the content of trace and minor elements in agstone may be obtained by multiple sampling. Multiple sampling may be achieved by taking from the daily production, over a period of 30 days, two or more equally sized samples weighing 5 or more pounds, and combining them into a single large sample that should be thoroughly mixed and quartered down to a size suitable for the analytical laboratory.

10. Sampling coarser quarry products may well follow the procedure mentioned above but larger samples should be taken in order to include a greater number of pieces of stone in each sample.



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