

WHITEROCKIAN THROUGH GIVETIAN CHEMICAL STRATIGRAPHY IN THE ARROW CANYON RANGE, CLARK COUNTY, NEVADA

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ABSTRACT.—The presence and relative abundance of iron, magnesium, calcium, aluminum, silicon, manganese, copper, nickel, tin, titanium, vanadium, chromium, and silver was determined by emission spectroscopy in representative samples of each bed-level unit within the Op₆, Op₅, and Op₄ units of the Pogonip Group and within the Ely Springs Dolomite, Laketown Dolomite and Pitte Formation in the Arrow Canyon Range. Magnesium, calcium, aluminum, silicon, and manganese contents are generally uniform excepting Ca and Mg which occur in inverse proportion. Iron is ubiquitous, but decreases markedly in abundance from the base upwards within the Op₆, Op₅, and Op₄ units and within the Ely Springs Dolomite. The topmost bed-level unit of the Ely Springs Dolomite, however, has a large iron content, thus supporting the hypothesis that it is lithologically more closely related to the overlying Laketown Dolomite than to the remainder of the Ely Springs Dolomite. Sporadic occurrences of minor elements appear potentially useful in lithologic correlation within otherwise relatively uniform carbonate sequences.

The objectives of this study have been: 1) to investigate elemental content of rock units within a limited stratigraphic sequence in order to detect sequential changes in depositional environment; and 2), to test a rapid and economical method of qualitative estimate analyses for use in defining stratigraphic units.

In regard to the first objective,

differences in source material presumably will be reflected in the elemental composition of a sedimentary rock unit. Thus studies of minor elements in carbonate sediments and rocks, conducted by many investigators (Graf, 1960/ a./ b./ c./; LeRiche, 1959; Degens et al., 1958), have led to environmental interpretations regarding pH, Eh, temperature, pressure, biogenic factors, and diagenetic processes. Graf (1960e), however, has concluded that no one mechanism can be assumed responsible for the presence of a particular element in a carbonate rock and that time of introduction of an element in relation to post-depositional process cannot be adduced from the presence of the element. Thus, other data are required to approach these problems and it was felt that content analysis in relation to stratigraphic sequence might be profitable.

As for the second objective, an attempt to separate rock units on the basis of chemical variation was undertaken as part of a comprehensive investigation of the descriptive stratigraphy, structure and paleontology of the Arrow Canyon Range. Bed-level units comprising most of the

Paleozoic section in this area are relatively unfossiliferous, are repetitive in gross lithologic properties, and not all of them are laterally continuous. Thus tracing of specific subunits is difficult within some formations and addition of an analytically controlled parameter could prove useful for description and in both local and regional correlation. Chemical, spectrographic analysis coupled with the quantitative estimate method of Harvey (1950) was selected as a rapid, simple and economical method suitable for a predominately stratigraphic study. It is not considered, however, appropriate for refined geochemical investigation.

GEOLOGY AND STRATIGRAPHY

The Arrow Canyon Range is almost entirely within the bounds of the U. S. Geological Survey Arrow Canyon Quadrangle about 35 miles

northeast of Las Vegas, Nevada (Fig. 1). The range is a characteristic basin and range element comprised of Late Cambrian through Early Permian bedrock. Structure within the mountain block is relatively complex; moderate folding, thrust faulting, and much normal faulting antedates tilting and block faulting responsible for the present aspect of the range. General geology and stratigraphy in the region are treated respectively by Longwell et al. (1965) and by Langenheim et al. (1962).

The rocks under consideration include the topmost three informal units within the Pogonip Group, Op_a , Op_e , and Op_f , as recognized by Langenheim et al. (1962), the Late Ordovician Ely Springs Dolomite, the Silurian Laketown Dolomite and the Early and Middle Devonian Piute Formation. The Eureka Quartzite, which separates the Pogonip Group from the Ely Springs Dolomite was not sampled.

The Op_d Unit consists of relatively thin-bedded, readily eroded gray limestone which weathers gray streaked with rusty brown. This easily recognized, bench-forming unit is about 335 feet thick at the Monmouth Gulch Section (Fig. 2); and is regarded as equivalent to the Ranger Mountain Member of the Antelope Valley Limestone of the Pogonip Group as recognized by Byers et al. (1961) and Ross (1964). The lithologic character of bed-level units in this section are described in detail in Marks (1966, p. 29a-32).

The Op_e Unit is a very thick-bedded, massive gray limestone which weathers gray. This unit

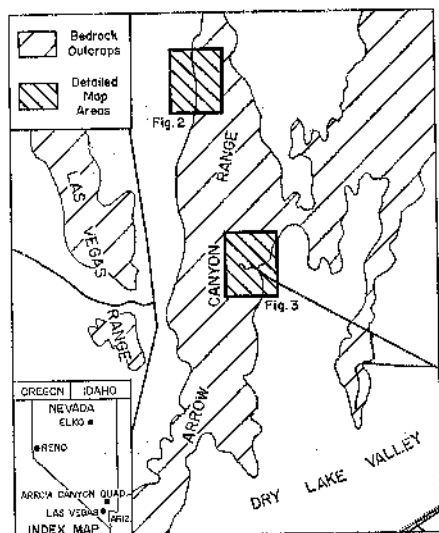


FIGURE 1.—Location map of the Arrow Canyon Quadrangle.

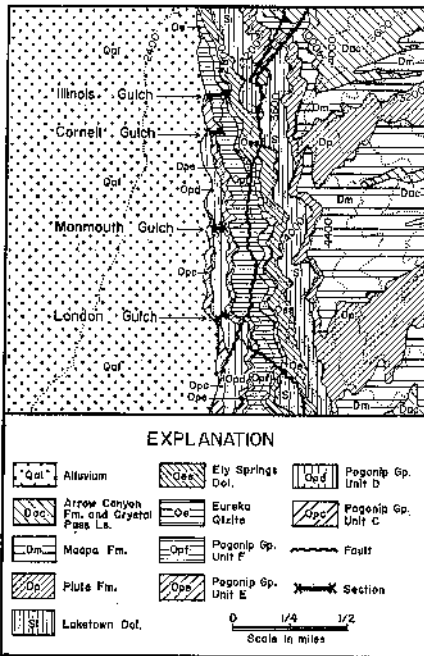


FIGURE 2.—Geologic map of a part of the northwest flank of the Arrow Canyon Range.

forms a prominent precipitous cliff and is about 460 feet thick at the Cornell Gulch Section (Fig. 2). These strata appear equivalent to the lower portion of the Aysees Member of the Antelope Valley Limestone of the Pogonip Group as recognized by Byers et al. (1961) and by Ross (1964). Only the uppermost 340 feet of this formation were sampled for this study. The lithologic character of the bed-level units of the rocks sampled in this section are described in detail in Marks (1966, p. 33-34). The Op₂ Unit is a heterogenous mixture of thick and thin beds of limestone with minor amounts of dolomite. Fresh rock is predominantly gray to dark gray, but weathered rock ranges

from gray through buff and brown to pink, and outcrops are strikingly banded. This bench forming unit is about 385 feet thick at the Illinois Gulch Section (Fig. 2), and appears equivalent to the upper portion of the Aysees Member of the Antelope Valley Limestone of the Pogonip Group as recognized by Byers et al. (1961) and by Ross (1964). The lithologic character of the bed-level units of this section are described in detail in Marks (1966, p. 35-41).

The Eureka Quartzite succeeds the Pogonip Group in the Arrow Canyon Range and consists of about 100 feet of quartzite at the Illinois Gulch Section (Langenheim et al., 1962).

The Ely Springs Dolomite consists of black, thick-bedded dolomite

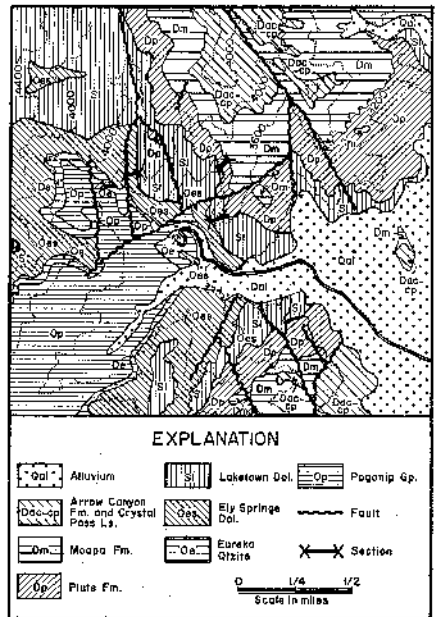


FIGURE 3.—Geologic map of the Silica Quarry area, central southeastern flank of the Arrow Canyon Range.

which weathers black capped by a relatively thin unit of thin-bedded, light gray, argillaceous dolomite. The formation forms a prominent black, cliffed slope in marked contrast to the pink-white Eureka Quartzite below, and is about 350 feet thick at the Silica Quarry Section (FIG. 3). The lithologic character of the bed-level units in this section are described in detail by Carss (1962). His descriptions and definitions have been used in this study with the exception that re-examination of the rocks in the field led to the following revision of his unit 4 (Carss, 1962):

Unit 4d	3'8"	Dolomite; gray, weathers brownish gray, slightly mottled; fine to medium-grained; abundant "spaghetti-like" structures.
4d	2'7"	Dolomite; black; very fine-grained; unfossiliferous.
4e	7'9"	Dolomite; very dark-gray to black, weathers brownish-gray; fine grained; scattered crinoid ossicles.
4b	7'10"	Dolomite; very dark-gray, weathers gray; abundant, impersistent chert layers.
4a	7'4"	Dolomite; buff, weathers cream-buff; coarse-grained; porous, structureless, massive bedding; sharp upper contact; few crinoid ossicles at base.

The Laketown Dolomite consists of a lower member of thick-bedded, coarse-grained, porous, gray dolomite and an upper member which is thinner-bedded, finer-grained, and more argillaceous. These rocks are gray to light gray and generally weather light gray, forming a lower cliffed portion and an upper slope of benches and risers. The forma-

tion is about 220 feet thick at the Silica Quarry Section (FIG. 3), where Kennerly (1959) has described the lithology of bed-level units in detail.

The Piute Formation is a heterogeneous mixture of dolomite and minor sandstone. At the Silica Quarry Section the lowermost member consists of 7 feet of rusty-weathering, fine to medium-grained sandstone and gray, sandy dolomite. (FIG. 3). This is succeeded by about 55 feet of light-gray weathering, fine-grained dolomite which is overlain by about 15 feet of strikingly alternating layers of light gray and black to dark gray dolomite. Above this about 90 feet of mottled, gray dolomite forms a slope between the banded cliff and about 60 feet of thick-bedded, coarsely crystalline, cliff-forming dolomite capped by the *Stringocephalus* biostrome, which is about 25 feet thick. Details of the lithology of bed-level units in this section are reported by Frost (1963, p. 114-121).

SAMPLING AND ANALYTICAL PROCEDURES

Rocks of the Opa-Op, Units of the Pogonip Group were sampled at the site of the measured section traverses in Monmouth Gulch, Cornell Gulch and Illinois Gulch on the west side of the north end of the Arrow Canyon Range (FIG. 2). Rocks of the Ely Springs Dolomite, Laketown Dolomite and Piute Formation were sampled in the vicinity of the Silica Quarry, about midway on the southeast side of the Arrow Canyon Range (FIG. 3). Exposures are essentially complete for the entire sequence, thus facilitating definition of bed-level units, and from each selection of characteristic samples. Rocks along all of the traverse lines had been painted and numbered to show limits of the bed-level units and there is no doubt, therefore, that the

materials under study here are the same as those described in the field and by conventional petrographic techniques by Pierce, Ely, Carss (1962), Kennerly (1959) and Frost (1963). Throughout the sequence, at least one hand-sized, "representative" sample was collected from each unit, but, in several cases, specimens were taken from the "top", "middle", and "base" of thick units, or, from the several distinctly different layers within lithologically heterogeneous bed-level units. Sampling bias toward collection of rock "fitting" the unit descriptions of prior investigators and favoring collection of better exposed or more readily accessible material within a unit has been accepted as not greatly influencing the overall aspect of the data within a formation-level sequence. It must be understood, however, that interpretations of specific samples refer to single points and should not be uncritically applied to an entire bed-level unit.

Ideally, samples should have been broken from each unit within stated lateral limits and spaced evenly or continuously throughout its thickness. In addition, study of lateral variation in elemental content within individual bed-level units would greatly enhance the significance of this study. Channel sampling and lateral variation studies, however, were considered beyond the scope of an investigation chiefly designed to test a technique and to produce a reconnaissance examination of 2,220 feet of rock.

Each sample was hammered to fragments. Thereafter selected unweathered fragments, excluding those having been in contact with the hammer, were crushed in a diamond mortar to an approximately 60-mesh powder. Fifty milligrams of randomly segregated rock powder were mixed with an equal amount (-0.001 g) of spectrographically pure graphite in a Spex Industries No. 3111 mixing vial using plexiglass balls.

Elemental constituents were determined with an Applied Research Laboratories Spectrographic Analyzer (1.5 meter, filterless, 20 micron slit width) using a 10 ampere D. C. arc. For analysis, approximately 10 mg. of graphite-rock powder mix were placed in a National Carbon Company, type SPK L3709 sample electrode opposed by a National Carbon Company, type SPK L3757 counter-electrode. Samples were exposed approximately 150 seconds or until totally consumed. A spectral region ranging

from 2450 to 4350 Å was recorded on Eastman SA #1 film which was developed in Eastman D-19 developer for 2 minutes and fixed according to standard procedure. Element concentration was determined by the method of Harvey (1950, p. 127-158). Visual estimate of line intensity on the film was made using an Applied Research Laboratory Model 2250 Densitometer in order to obtain a range of values for specific elements. Wave lengths and basic sensitivities of all elements noted in analysis are as follows:

Element	Wave length	Line sensitivity
Ag	3280.7 (A)	.0001
Al	2652.5 (B)	.01
Ca	4302.5 (B)	.01
Cr	2731.9 (B)	.1
Cu	3094.0 (B)	.1
Fe	3100.6 (B)	.1
Mg	2779.8 (B)	.01
Mn	2933.1 (B)	.01
Ni	3413.9 (B)	.1
Si	2881.6 (A)	.001
Sr	2840.0 (A)	.001
Ti	2942.0 (B)	.001
V	2952.1 (B)	.01

DATA

FIGURES 4 through 8 show the degree of spectrographic line blackening, expressed on a visually estimated scale of 0 to 10, plotted against a columnar section of the rocks under study. The line-blackening or abundance curve is based on 195 samples related to bed-level units throughout the sequence. Of these samples; 31 are from the Op₂ Unit, 21 from the Op₁ Unit, 65 from the Op₀ Unit, 22 from the Ely Springs Dolomite, 17 from the Laketown Dolomite, and 39 from the Piute Formation. Among all samples there are 112 of limestone and silty limestone, 81 of dolomite and sandy or silty dolomite, and 2 of siliceous sandstone.

The approximate range of elemental concentration was determined according to Harvey's (1950) method (TABLES 1-6). Thus, for a visually estimated intensity of 8 for magnesium, manipulation of the basic sensitivity for the analysis line, a multiplicative factor, the type of line, and a matrix factor would yield a percentage range of .3 to 3% (Harvey, 1950, p. 148-158). Intensity readings of 10, however, are considered to result from major constituents present in a range of from 10 to 100%; indicated by an "X" in the tables.

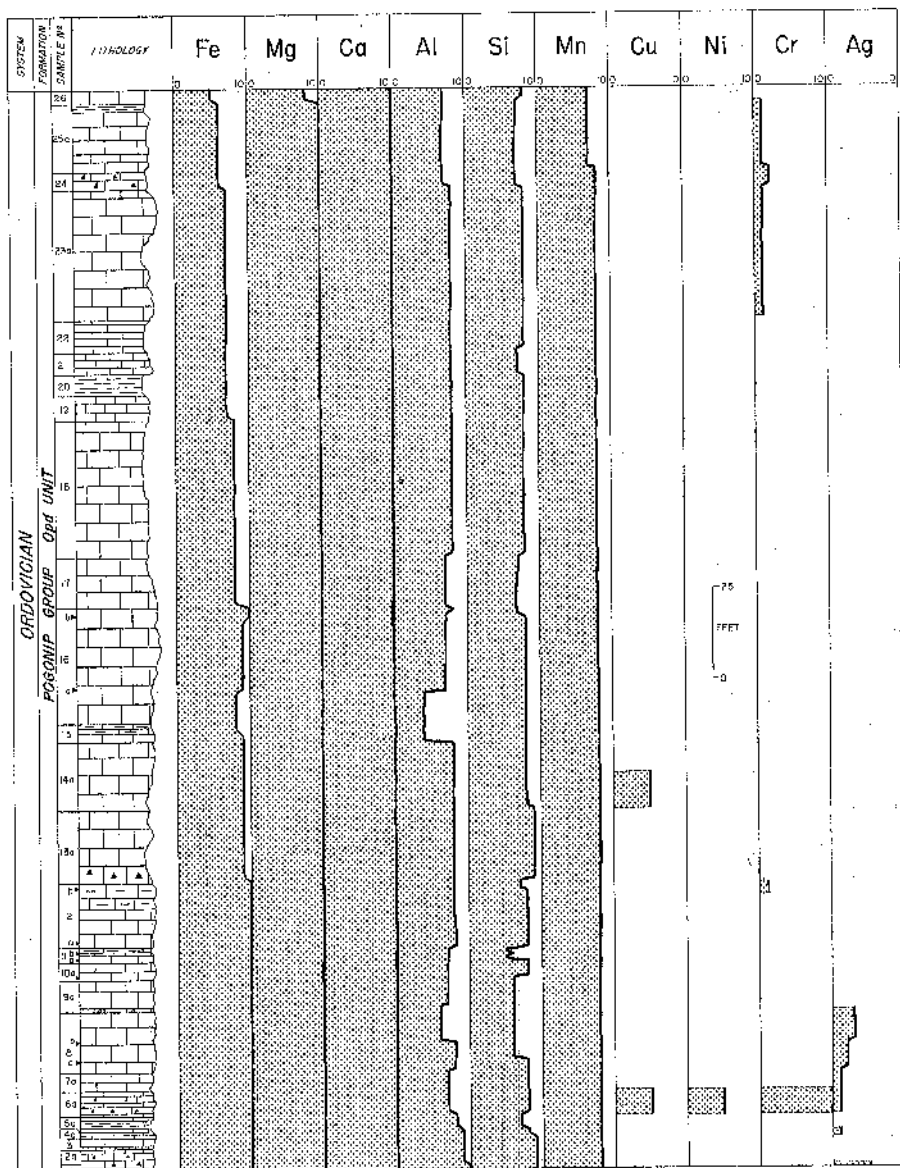


FIGURE 4.—Plot of spectrographic film blackening for elements in the Pogonip Group, lower Opf Unit. Film blackness is shown against an arbitrary intensity scale for each element.

Iron, magnesium, calcium, aluminum, and manganese are essentially ubiquitous in the sequence under study and are grouped as "major constituents". Copper,

nickel, chromium, silver, tin, titanium, and vanadium are restricted in range of occurrence and generally are in trace amounts or are minor constituents.

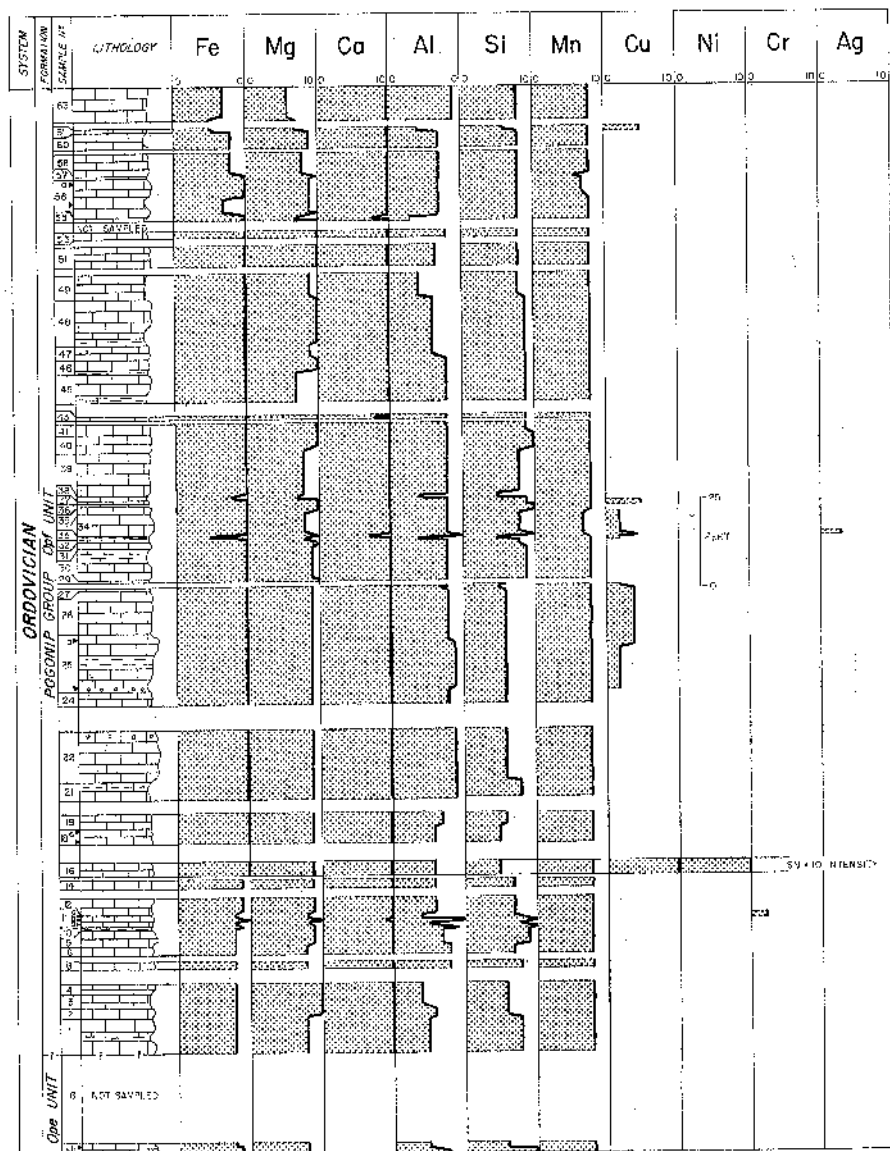


FIGURE 6.—Plot of spectrographic film blackening for elements in the Pogonip Group, uppermost Op₀ Unit and Op₁ Unit. Film blackness is shown against an arbitrary intensity scale for each element.

Springs Dolomite, the iron content markedly increases. In the Ely Springs Dolomite, however, the decreasing trend in iron content is ended by a large increase in beds 12 and 13.

Calcium and magnesium, of course, are major constituents and produced lines of strong intensity for all samples. There is an inverse relationship in the relative intensity of these elements in any given

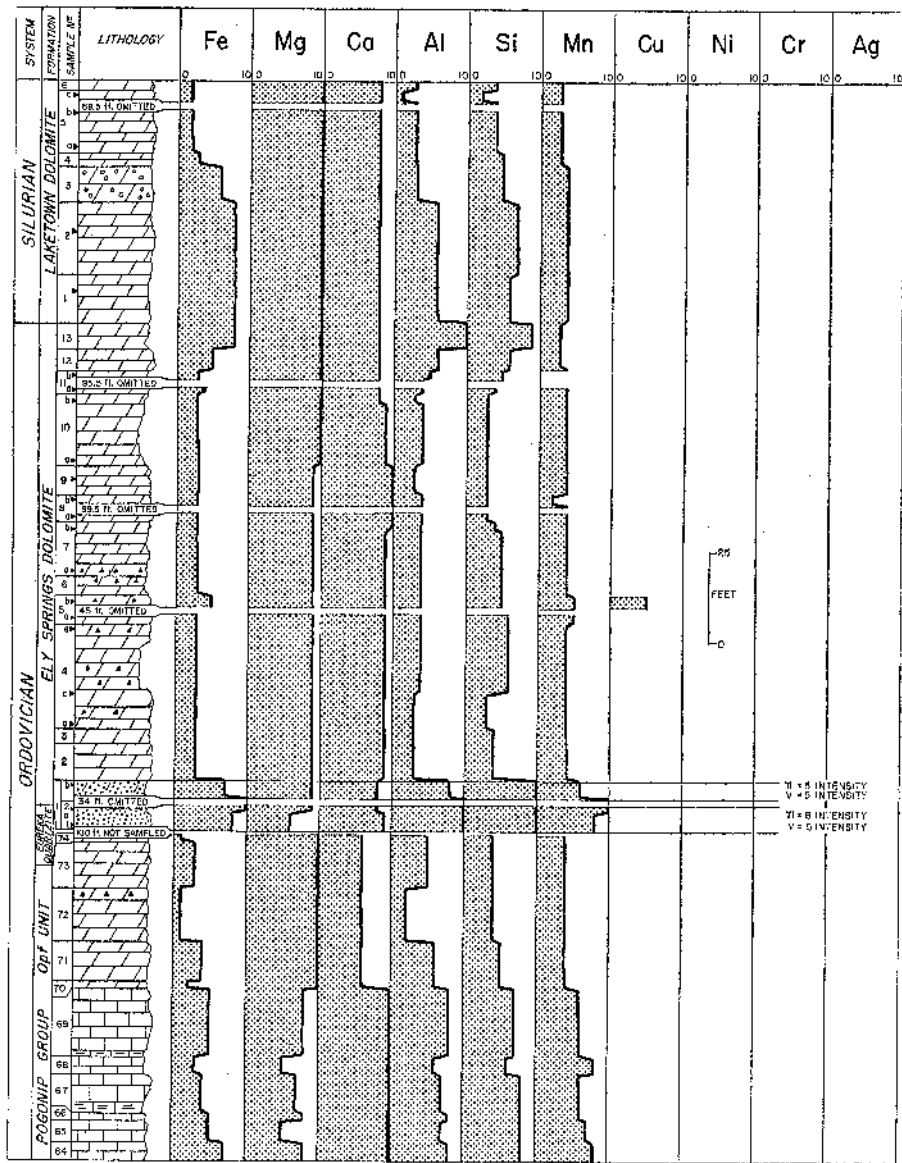


FIGURE 7.—Plot of spectographic film blackening for elements in the Pogonip Group, uppermost Op₂ Unit; Ely Springs Dolomite and lower Laketown Dolomite. Film blackness is shown against an arbitrary intensity scale for each element.

sample which is consistent with field identifications of the rocks as either limestone or dolomite.

Aluminum and silicon concentration patterns are approximately parallel. Deviations as in unit 72 of the Op₂ Unit,

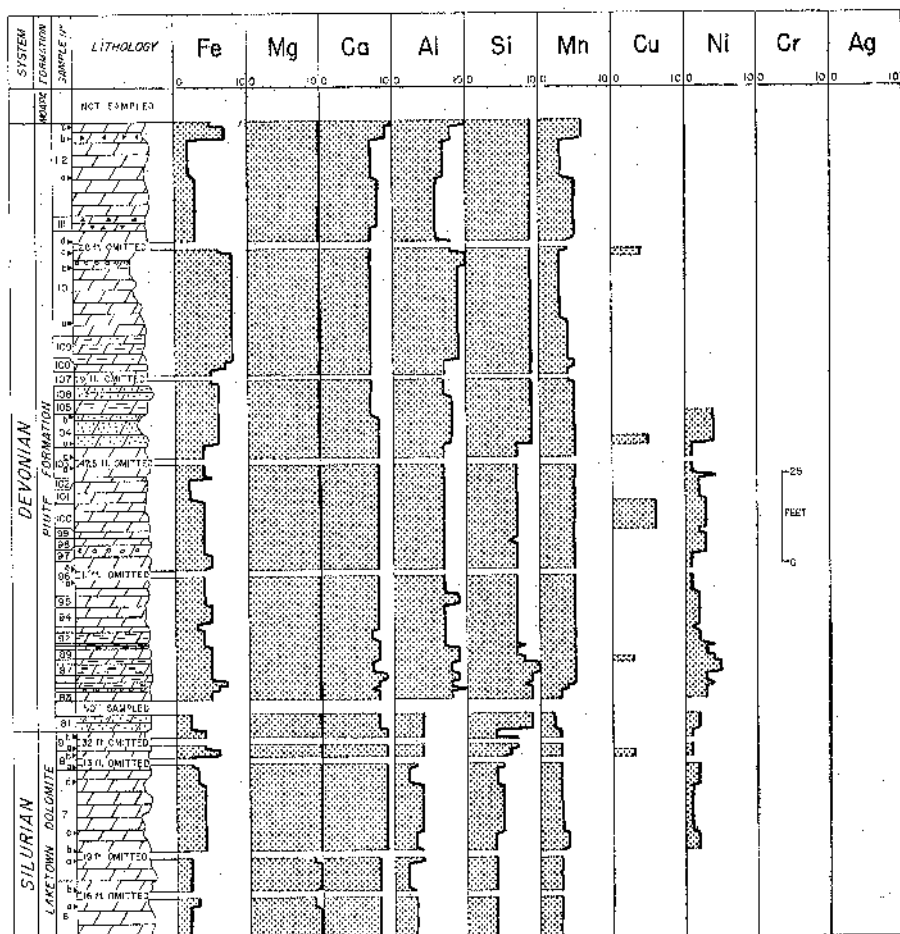


FIGURE 8.—Plot of spectrographic film blackening for elements in the uppermost Laketown Dolomite and Pinite Formation. Film blackness is shown against an arbitrary intensity scale for each element.

generally occur in the form of the silicon content not paralleling a decrease in aluminum.

Manganese intensity patterns roughly parallel those of iron.

The remaining elements, copper, nickel, chromium, silver, tin, titanium, and vanadium are not ubiquitous, but occur in isolated bed-level units or sequences of bed-level units. Copper occurs more less sporadically throughout the sequence, but is somewhat more widespread in the Op₁ Unit. Nickel is absent in the Pogonip Units and the Ely Springs Dolomite, with the exception of a rela-

tively high concentration in bed-level unit 16 of the Op₂ Unit. In marked contrast, nickel is almost continuously present between the middle portion of bed-level unit 7 of the Laketown Dolomite and bed-level unit 104 of the Pinite Formation. In this sequence it is accompanied by sporadically occurring copper. Chromium and silver are essentially confined to the Op₁ Unit where their occurrence is sporadic. Finally, tin, titanium and vanadium are of extremely limited occurrence. Tin was detected only in bed-level unit 16 of the Op₂ Unit where it is associated with relatively high con-

TABLE 1.—Concentration Ranges for Elements in the Pogonip Group Op. Unit. Numbers in Left-hand Column Refer to Specimens as Noted in Figs. 4-8. "X" Equals Concentrations in Excess of 10%.

	Fe	Mg	Ca	Al	Si	Mn	Cu	Ni	Cr	Ag
1.	X				.1-1%					.001-.01%
2a.	X	X	X	X	"	.1-1%				
3	X	X	X	"	"	"				
4a.	X	X	X	"	.03-.3%	"				.0001-.001%
5a.	X	X	X	"	"	"				
6a.	X	X	X	.1-1%	"	"	1-10%	1-10%	X	"
7a.	X	X	X	"	"	"				.0001-.001%
8a.	X	X	X	.3-3%	"	"				.0001-.001%
8b.				.1-1%	.01-1%	"				.0001-.001%
9a.	X	X	X	.1-1%	"	"				.0003-.003%
10a.	X	X	X	"	.03-.3%	"				
11a.	X	X	X	"	.01-1%	"				
11b.	X	X	X	"	"	"				
12a.	X	X	X	.3-3%	.03-.3%	"				
12b.	X	X	X	"	"	"			.03-.3%	
13a.	X	X	X	"	.1-1%	"	1-10%			
14.	X	X	X	"	.03-.3%	"				
15.	.3-3%	X	X	.03-.3%	"	"				
16a.	.3-3%	X	X	.1-1%	"	.1-1%				
16b.	.3-3%	X	X	.3-3%	"	"				
17.	1-10%	X	X	.1-1%	"	"				
18.	"	X	X	.3-3%	"	"				
19.	.3-3%	X	X	"	"	"				
20.	.3-3%	X	X	"	"	"				
21.	.3-3%	X	X	"	"	"				
22.	"	X	X	"	"	"				
23a.	"	X	X	"	"	"			.03-.3%	
24.	"	X	X	"	"	"			"	"
25a.	"	X	X	.1-1%	"	"			"	
26.	"	X	X	"	"	.03-.3%			"	
27a.	"	X	X	"	"	"			"	

TABLE 2.—Concentration Ranges for Elements in the Pogonip Group Op. Unit. Numbers in Left-hand Column Refer to Specimens as Noted in Figs. 4-8. "X" Equals Concentrations in Excess of 10%.

	Fe	Mg	Ca	Al	Si	Mn	Cu	Ni	Cr	Ag
1.	X	X	X	.1-1%	.1-1%	.1-1%				
2.	X	X	X	"	"	"				
3.	X	X	X	"	.03-.3%	"				
4.	X	X	X	"	.1-1%	"				
5.	X	X	X	.3-3%	"	"				
6.	X	X	X	.1-1%	.03-.3%	"				
7.	X	X	X	"	"	"				
8a.	X	X	X	"	"	"				
8b.	X	X	X	"	"	"				
9a.	X	X	X	"	"	"				
9b.	X	X	X	"	.01-.1%	"				
10.	X	X	X	"	X	"				
11a.	X	X	X	.03-.3%	.01-.1%	"			.1-1%	
11b.	X	X	X	"	"	"				
12.	X	X	X	"	"	"				
13a.	X	X	X	.1-1%	.03-.3%	"				
13b.	X	X	X	.3-3%	.01-.1%	"				
14a.	X	X	X	.1-1%	.03-.3%	"				
14b.	1-10%	.3-3%	X	"	"	"				
15a.	"	"	X	.3-3%	X	"				
15b.	"	"	X	.1-1%	.01-.1%	"				

TABLE 3.—Concentration Ranges for Elements in the Pogonip Group Ore, Unit. Numbers in Left-hand Column Refer to Specimens as Noted in Figs. 4-8. "X" Equals Concentrations in Excess of 10%.

	Fe	Mg	Ca	Al	Si	Mn	Cu	Ni	Cr	Ag
1.	.1-1%	.3-3%	X	.1-1%	.03-.3%	.1-1%				
2.	"	X	X	"	.01-1%	"				
3.	"	X	X	.03-.3%	"	"				
4.	"	X	X	"	"	"				
6.	"	.3-3%	X	.3-3%	.003-.03%	"				
8.	"	"	X	"	"	"				
9.	"	"	X	.1-1%	.1-1%	"				
10.	"	"	X	.3-3%	X	"				
11a.	"	"	X	.1-1%	.03-.3%	"				
11b.	X	X	3-3%	X	X	"			.1-1%	
11c.	1-10%	X	X	.03-3%	.03-3%	"				
12.	"	.3-3%	X	.1-1%	"	"				
14.	"	"	X	"	"	"				
16.	X	"	X	"	.01-1%	"	X	X		Sr=X
18a.	X	"	X	"	"	"				
18.	X	"	X	"	"	"				
19.	X	"	X	"	"	"				
21.	X	"	X	.3-3%	.03-.3%	"				
22.	X	"	X	"	.01-1%	"				
24.	X	"	X	"	"	"				
25.	X	"	X	.3-3%	.01-1%	"	.1-1%			
25a.	X	"	X	"	.03-3%	"	.3-3%			
26.	X	"	X	"	.01-1%	"	"			
27.	X	"	X	.1-1%	"	"	.1-1%			
28.	X	"	3-3%	.3-3%	X	.1-1%				
29.	X	.3-3%	X	.3-3%	"	"				
30.	X	X	X	"	.1-1%	.1-1%				
31.	X	.3-3%	X	"	.03-.3%	"				
32.	X	.3-3%	X	.03-.3%	.01-1%	"	.1-1%			
33.	.3-3%	X	.1-1%	X	X	.03-.3%	.3-3%			.0003-.003%
34.	X	.3-3%	X	.3-3%	"	"	.1-1%			
35.	X	X	X	"	X	.1-1%				
36.	X	X	X	"	.1-1%	"	1-10%			

TABLE 4.—Concentration Ranges for Elements in the Ely Springs Dolomite. Numbers in the Left-hand Column Refer to Specimens as Noted in Figs. 4-8. "X" Equals Concentrations in Excess of 10%.

	Fe	Mg	Ca	Al	Si	Mn	Cu	Ni	Cr	Ag
1a*	1-10%	.1-1%	.3-3%	X	X	.1-1%				
1a9**	X	.3-3%	"	X	X	X				
1b***	.3-3%	"	"	.3-3%	X	.03-.3%				
2	.1-1%	"	"	.03-.3%	.003-.03%	.01-.1%				
3	"	"	"	"	"	"				
4a	"	"	"	"	"	"				
4c	"	"	"	"	"	"				
4e	"	"	"	"	.01-.1%	"				
5a	"	"	"	"	"	.03-.3%				
5b	.3-3%	"	"	"	"	"				
6	.1-1%	"	"	"	"	.01-.1%	1-10%			
7a	"	"	"	"	"	"				
7b	"	"	X	"	"	"				
8a	"	"	X	"	"	"				
8b	"	"	X	"	"	"				
9	"	"	X	"	"	.003-.03%				
10a	"	X	.3-3%	"	"	.01-.1%				
10b	"	X	"	"	"	"				
11a	"	X	"	"	"	"				
11b	"	X	"	.1-1%	.01-.1%	"				
12	.3-3%	X	"	"	"	"				
13	1-10%	X	"	X	.1-1%	"				

*XI = .1-1% V = 1-1%
 **TI = .1-1% V = 1-1%
 ***TI = .01-.1% V = 1-1%

TABLE 5.—Concentration Ranges for Elements in the Laketown Dolomite. Numbers in the Left-hand Column Refer to Specimens as Noted in Figs. 4-8. "X" Equals Concentrations in Excess of 10%.

	Fe	Mg	Ca	Al	Si	Mn	Cu	Ni	Cr	Ag
1	1-10%	X	.3-3%	.1-1%	.01-1%	.01-1%				
2	"	X	"	"	.03-3%	"				
3	3-3%	X	"	.03-3%	.01-1%	"				
4	1-1%	X	"	"	"	"				
5a	.03-3%	X	"	"	.003-.03%	"				
5b	"	X	"	"	"	"				
5c	"	X	"	.01-1%	"	"				
6a	"	3-3%	"	.03-3%	"	"				
6b	1-1%	X	"	.01-1%	"	"				
7a	"	3-3%	"	.03-3%	"	"		1-1%		
7b	"	X	"	"	"	"		"		
7c	"	X	"	"	.01-1%	"		"		
7d	"	X	"	.01-1%	.003-.03%	"		"		
8a	.03-3%	X	"	.03-3%	"	"		"		
8b	3-3%	X	"	"	.03-3%	"	.3-3%	"		
9a	1-1%	X	"	"	.03-3%	"		"		
9b	"	X	"	"	.003-.03%	"		"		

TABLE 6.—Concentration Ranges for Elements in the Piate Formation. Numbers in Left-hand Column Refer to Specimens as Noted in Figs. 4-8. "X" Equals Concentrations in Excess of 10%.

	Fe	Mg	Ca	Al	Si	Mn	Cu	Ni	Cr	Ag
81.....	.03-.3%	X	.3-3%	.03-.3%	.1-1%	.003-.03%		.1-1%		
83.....	.3-3%	X	"	.3-3%	"	.01-.1%		.3-3%		
84.....	"	X	.1-1%	X	"	"		"		
85.....	"	X	.3-3%	.3-3%	.03-.3%	.03-.3%		"		
86.....	"	X	"	"	.1-1%	"		"		
87.....	"	X	.1-1%	"	X	"		1-10%		
88.....	"	X	.3-3%	"	.03-.3%	"	.3-3%	.3-3%		
89.....	"	X	"	"	"	"		"		
90.....	"	X	"	"	"	"		"		
91.....	.1-1%	X	"	.1-1%	"	"		.1-1%		
92.....	"	X	"	"	"	"		"		
93.....	"	X	.3-3%	"	"	"		"		
94.....	.3-3%	X	"	"	"	"		"		
95.....	.1-1%	X	"	.3-3%	"	"		"		
96a.....	.3-3%	X	"	.1-1%	"	"		"		
96b.....	.1-1%	X	"	"	"	"		"		
97.....	"	X	"	"	"	"		.3-3%		
98.....	"	X	"	"	.01-.1%	"		"		
99.....	"	X	"	"	.03-.3%	"		"		
100.....	"	X	"	"	"	"	1-10%	.3-3%		

	Fe	Mg	Ca	Al	Si	Mn	Cu	Ni	Cr	Ag
101.....	.03-.3%	X	"	"	"	"	"	.1-1%	"	"
102.....	.3-3%	X	"	"	"	"	"	.3-3%	"	"
103.....	.1-1%	X	"	"	"	"	"	.1-1%	"	"
103a.....	"	X	"	"	"	"	"	"	"	"
103c.....	.3-3%	X	.1-1%	.3-3%	.1-1%	"	1-10%	.3-3%	"	"
104a.....	"	X	.3-3%	"	"	"	"	"	"	"
104b.....	"	X	.1-1%	"	"	"	"	"	"	"
105.....	"	X	"	"	"	"	"	"	"	"
106.....	"	X	"	.1-1%	"	"	"	"	"	"
107.....	"	X	"	"	"	.01-1%	"	"	"	"
108.....	"	X	"	.3-3%	"	.03-3%	"	"	"	"
109.....	1-10%	X	"	"	"	.01-1%	"	"	"	"
110a.....	1-10%	X	"	"	"	"	"	"	"	"
110b.....	1-10%	X	"	X	"	"	"	"	"	"
110c.....	.3-3%	X	"	.3-3%	"	"	3-3%	"	"	"
110e.....	.1-1%	X	"	.1-1%	"	"	"	"	"	"
111.....	"	X	.3-3%	"	"	.03-3%	"	"	"	"
112a.....	.03-.3%	X	.1-1%	"	"	.01-1%	"	"	"	"
112b.....	.3-3%	X	.3-3%	.3-3%	"	.03-3%	"	"	"	"
112c.....	"	X	X	X	"	.03-3%	"	"	"	"

centrations of copper and nickel along with iron and manganese. Titanium and vanadium occur together only in unit 1 of the Ely Springs Dolomite in approximate concentrations of .1 to 1%.

DISCUSSION AND INTERPRETATION

The factors governing elemental composition of a sedimentary rock do not differ in any significant respect from those governing the composition of the rock expressed in mineralogic or biogenic terms. The agents responsible for the occurrence of minerals and biological materials are also responsible for the presence of the elements that make up these substances. Elemental spectrographic analysis, however, does present some advantages for stratigraphic and environmental interpretation. Among these are the following: (1) Attention is concentrated on the most simple compositional parameters. (2) Analytical methods may be reduced to simple, rapid and economic techniques permitting the routine processing of large amounts of material. (3) The data obtained are completely compatible, regardless of their rock source.

Stratigraphic analysis of elemental composition may proceed at the level of major constituent composition, may be based on occurrence of minor constituent composition, or may be based on the quantity of a minor constituent. In the first instance, lithologic units at all levels are characterized by the assemblage of major elemental constituents and their relative abundance. Thus, the limestone units of the Pogonip Group are distinguished from the dolomitic Ely Springs Dolomite, Laketown Dolomite and Piute For-

mation by dominance of calcium over magnesium. The distribution of iron, however, is of more interest, as the relatively high concentration of this element in unit 13 of the Ely Springs Dolomite tends to relate unit 13 more closely with the overlying Laketown Dolomite.

Paleontologic data and the distribution and gross lithologic character of the later Early Ordovician through Middle Devonian rocks of Nevada indicate the presence of regional unconformities at the base of the Eureka Quartzite, at the base of the Early Devonian and at the base of the Middle Devonian. At the Arrow Canyon Range the latter two unconformities are closely spaced within the lowermost portion of the Piute Formation and Early Devonian rocks are only sporadically present and are very thin. In the light of these data, iron distribution in the Arrow Canyon sequence appears to show a consistent relationship in which iron concentrations are greatest in the rocks directly above the surfaces of unconformity below the Ely Springs Dolomite and below the Piute Formation. The sequence above these positions shows a more or less steady decrease in iron content.

When this generalization is applied to the occurrence in unit 13 of the Ely Springs Dolomite, it suggests that there may be an unconformity below unit 13. A marked increase in insoluble residue content and an abrupt change in color and grain size also occur at this level tending to support such a conclusion. The fauna which occurs in Reso's (1963, p. 907, Pl. 2) upper

member of the Ely Springs Dolomite in the Pahranaagat Range, an apparent correlative of unit 13, however, is of Late Ordovician age. Thus, if unit 13 and the Laketown Formation are part of a continuously-deposited sequence, some of the lower portion of the Laketown Dolomite at this locality must be of Early Silurian age. Thus far, however, no Early Silurian fossils have been recovered from the Laketown Dolomite in any part of eastern and southern Nevada or western Utah. All of the fossils reported from the Laketown Dolomite in the area have been assigned a Middle Silurian or younger age. Our knowledge of the bio-stratigraphic data are not adequate to test the hypothesis that iron distribution within the Op_a and Op_f Units of the Pogonip Group indicates an unconformity.

In any event Krumbein and Garrels (1952) have concluded that iron compounds are most abundant in near-shore marine environments and that marine limestone deposited offshore should have little or no coprecipitation of siderite or hematite. Thus, theoretical geochemical considerations as well as stratigraphic distribution of iron in the Arrow Canyon Range sequence are consonant with deposition in shallow environments and, in otherwise ambiguous situations, a relatively high concentration might be taken as indicative of unconformity or shallowing in the depositional environment.

Concentrations of minor elements tend to characterize specific units and may be as unique as heavy mineral or insoluble residue characters in identification of such units for physical correlation. Occurrence of

nickel appears to characterize the uppermost Laketown Dolomite and the bulk of the Piute Formation and may be of value in correlation. The unique occurrence of tin in bed-level unit 16 of the Op_f Unit of the Pogonip Group and the joint occurrence of titanium and vanadium in bed-level unit 1 of the Ely Springs Dolomite are examples of such potentially identifiable key-beds.

Although many factors affect the transport and deposition of any given element, elemental occurrences may yield useful data for ecological interpretation. Copper is notably concentrated by some marine algae in modern environments and it should be noted that bed-level units six and fourteen of the Op_a Unit of the Pogonip Group are characterized by both fossil algal remains and relatively high copper content. Perhaps some of the other copper "highs" in the Pogonip Group, the Ely Springs Dolomite and the Piute Formation may be associated with as-yet unnoticed algal fossils or the concentrations may result from algae which left no other trace.

Occurrence of tin in bed-level unit 16 of the Op_f Unit of the Pogonip Group may possibly result from organic concentration. Bowen and Sutton (1951) report tin to be concentrated by a modern sponge species and sponge fossils are relatively widespread in the Op_f Unit and related rocks. Otherwise it is difficult to account for tin in a carbonate rock. Copper and nickel are also present and relatively abundant in this particular sample. Silver is also known to be concentrated by certain marine organisms, but there appears to be no suggested relationship be-

tween silver occurrence and that of any particular fossil group at Arrow Canyon.

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