MINOR CHEMICAL ELEMENTS IN FLUORITES FROM JAMESTOWN, COLORADO

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ABSTRACT

Four fluorites from Jamestown, Colorado, were analyzed spectrographically, and twenty minor elements were found to be present. Seventeen others were absent in all samples. Correlation between the minor elements present and the geologic environments of the fluorites was possible. No correlation was possible between minor elements present and radioactivity, fluorescence, or type of wallrock. The most abundant of the minor elements were Sr, Ba, Fe, Y, Cu, Mg, Al, and Si. These probably substitute for Ca in the ionic fluorite structure. The oldest fluorite was the most impure and the youngest was the purest.

INTRODUCTION

The spectrographic investigation upon which this paper is based was performed during 1940 in the Cabot Spectrographic Laboratory of the Geology Department at the Massachusetts Institute of Technology. The primary purpose of the work was to determine what minor chemical elements were present in the fluorites from four different mines in the Jamestown district, and to attempt to correlate the results with actual field relations, as well as with previous similar studies carried out by the writer (Bray, 1942 *a*; 1942 *b*) on the igneous rocks of the region.

The writer wishes to express his deep appreciation to Dr. E. N. Goddard, of the United States Geological Survey, for his invaluable assistance and interest in the problem, and for his suggestions in regard to securing samples. Professor W. H. Newhouse kindly permitted the use of the facilities of the Cabot Spectrographic Laboratory for the analytical work.

GENERAL GEOLOGY OF THE DISTRICT

The Jamestown district is located in Boulder County, Colorado, 10 miles northwest of Boulder, 35 miles northwest of Denver, at the northeast extremity of the Front Range mineral belt. The country rock is composed of pre-Cambrian gneisses and schists intruded by pre-Cambrian granites and a series of Tertiary stocks and dikes ranging from diabase to alaskite. The geology of the Front Range has been discussed by Ball (1908) and by Lovering (1929). Fenneman (1905) has considered the geology of the Boulder area. More recently Goddard (1935) has made detailed studies of the geology and ore deposits of the Jamestown region. Figure 1 is a sketch map (based on the work of Lovering and Goddard, 1938 and 1939) giving the areal geology of the section, together with the locations of the samples used.

The fluorite deposits are genetically related to a granite-quartz monzonite stock, one of the latest of the Tertiary intrusive porphyries. For a complete description the reader is referred to the paper by Goddard (op. cit.)

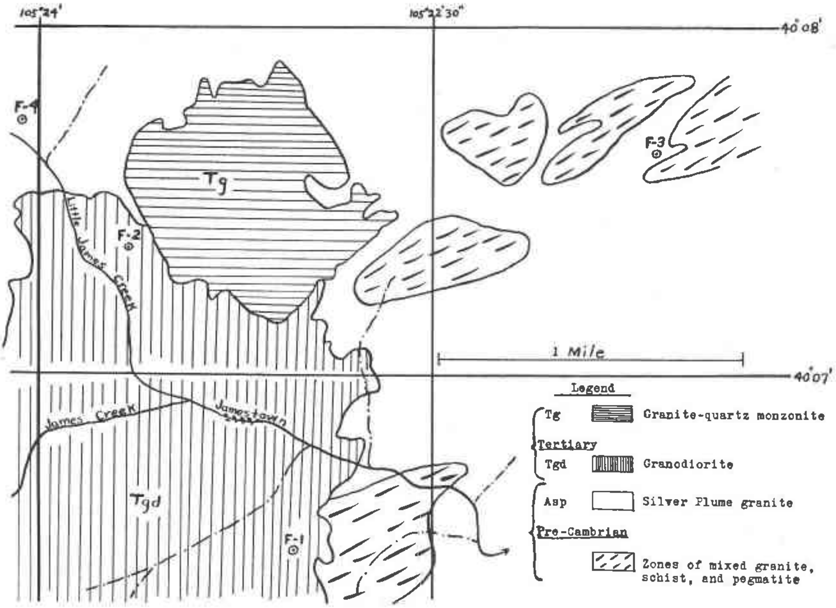

FIG. 1. Geological sketch map of the Jamestown area, showing locations of samples.

The writer (Bray, 1942 *a*; 1942 *b*) has discussed the distribution and relationships of the minor chemical elements in the igneous rocks of the Jamestown district.

THE FLUORITE DEPOSITS

Goddard (op. cit., p. 377) describes the deposits as breccia zones or veins containing a breccia matrix and filling of purple fluorite. Some pyrite, galena, chalcopyrite and coarse-grained quartz are also present. Many fluorite zones appear to be parts of larger barren breccia zones. Other mineral deposits in the district (all younger than the fluorite deposits) are lead-silver veins, pyritic-gold veins, and gold-telluride veins, in order of decreasing age. The oldest mineral deposits tend to be closest to the granite-quartz monzonite stock.

Specimens from the Argo, Brown Spar, Blue Jay and Caledonia mines (see Fig. 1 for locations) were analyzed. The Argo mine is in a fluorite-breccia zone near the parent stock. In this mine fragments of argentiferous galena and gray copper, sphalerite and pyrite are earlier than the fluorite, which is associated with small amounts of pyrite, galena, sphalerite and chalcopyrite. Goddard* reports a speck of pitchblende present in one of his fluorite specimens.

In the Brown Spar mine, which is also in a breccia zone, small quantities of galena, pyrite, and sphalerite are associated with the fluorspar. In the Blue Jay mine, a fluorite vein south of the parent stock and farther from it (and therefore younger?) than the Argo and Brown Spar breccia zones, minor galena, pyrite, and sphalerite are present with the fluorspar. Goddard reports occasional specks of pitchblende. The Caledonia mine is in a pyritic-gold vein, and therefore the mineralization is the youngest.

The relative ages can be tentatively summed up as follows: The Argo and Brown Spar breccia zones are nearest the parent stock and probably are oldest, the Blue Jay fluorite vein is probably intermediate, and the Caledonia pyritic-gold mineralization the youngest.

The Argo and Caledonia deposits are in a wallrock of pre-Cambrian Silver Plume granite, which is medium to coarse in texture, and contains numerous lath-like orthoclase phenocrysts in a groundmass of quartz, oligoclase, biotite and muscovite. The Blue Jay and Brown Spar deposits are in a wallrock of Tertiary granodiorite, which is medium in texture, and contains very abundant hornblende, andesine-labradorite, orthoclase, and less quartz, sphene and magnetite.

THE ANALYSES

Analytical Procedure

The analytical work was performed with a 21-foot, 30,000-line (per inch concave) grating spectrograph on a Wadsworth mounting. The particular method used was the cathode-layer carbon arc technique described by Strock (1936), with special modifications described by the writer (1942 *a*).

Results

Table 1 lists the four analyses and other pertinent data, including explanation of the symbols used. The quantities as expressed are spectrographic, and should be considered only as such. The symbols should be used only in comparing the quantities of a single element in the several samples. Comparisons between amounts of the several elements in a single sample should be made with extreme care, if at all, because the spectrographic sensitivities of the different elements vary greatly, and "large" for one might actually be less in percentage than a quantity designated as "medium" for an element spectrographically more sensitive.

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* Personal communication.

TABLE 1. SPECTROGRAPHIC ANALYSES OF THE FLUORITES

Sample	Na	K	Mg	Sr	Ba	Al	Sc	Y	La	Ce	Nd	V	Cr	Mn	Fe	Pb	Ag	Si	Cu	Be
F-4	M	S	M	VL	VL+	L−	T	M+	L	T	T	M−	T	S+	L	S+	A	VL	M	T
F-2	VT	A	M	VL	M	S	A	M−	A	?	?	A	A	S+	M−	S+	VT	VT	M−	A
F-1	T	A	S	VL	M+	S	A	M+	A	?	?	A	A	A	M−	A	A	T	M−	A
F-3	VT	A	S	VL−	S	S	A	M−	A	A	A	A	A	A	M−	A	A	T	M−	A

Not detected in any samples: As, Os, Co, Ge, Au, In, Ir, Mo, Ni, Pd, Ru, Ta, Sn, Ti, W, Zn, Zr.

F-4: Argo. mine. Fine grained. Blue. Wallrock, Silver Plume granite. Pitchblende present (minor). In zone.

F-2: Brown Spar mine. Massive. Purple. Wallrock, Tertiary granodiorite. In zone.

F-1: Blue Jay mine. Massive. Purple-black. Wallrock, Tertiary granodiorite. In vein. Minor pitchblende in vein.

F-3: Caledonia mine. Crystalline. Purple-black. Wallrock, Silver Plume granite. In pyritic-gold vein.

Explanation of symbols

Symbol	Spectrographic Quantity Present
A	Not detected
VT	Very small trace
T	Trace
S	Small
M	Medium
L	Large
VL	Very large

(Variations within one range expressed by plus and minus signs)

Twenty minor elements were detected in the samples, and seventeen were absent in all. Other elements were not determined. Correlations between the minor elements present and a number of other factors were attempted. For instance, do the minor elements have any relation to the color of the fluorites? The only possible relation, as seen from Table 1, is that the "purple-black" samples contain less Mg, Mn, and Pb than the lighter-colored samples. However, there is nothing to prove that the coloring is due to the presence or absence of the elements. In fact, a better explanation of the difference in content of Mn, Mg, and Pb probably lies in the geological environment of each fluorite. The light-colored fluorites were formed in the older zones whereas the darker ones were formed in the younger veins.

Correlation with the type of wallrock, grain size of sample, nearness to the parent stock, age, vein type (i.e., fluorite vein, pyritic-gold vein, etc.), metallic minerals present in the deposit, radioactivity, and fluorescence was also attempted. As for age and nearness to the parent stock, the same can be said as for geologic environment. That is, certain differences in content of minor elements (Mg, Mn, and Pb) appear to be associated either with age of the deposit, its areal position relative to the source rock, the structural environment, or to all of these factors. A noteworthy fact is that the vein fluorites do not contain larger quantities of any minor element than the zone fluorites. The latter however contain a greater number of minor constituents than the vein fluorites.

The fine-grained sample (also the oldest), F-4, is by far the most impure of any analyzed. This may be due to the fact that quick chilling may have caused minor impurities to be incorporated in the crystallizing mass either as ions in the individual crystals, or as foreign mineral fragments between the tiny fluorite grains. This fine-grained sample bears more Na, Ba, Al, Fe, and Si than all the others, and is the only one that contains K, Sc, La, Ce, Nd, V, Cr, and Be. The purest sample is F-3, youngest of the group.

No obvious correlation between the minor elements detected and the wallrock of the deposits is possible from the data of Table 1, although the wallrocks contain abundant Sr and Ba (Bray, 1942 *a*). The minor constituents show no relation to the occurrence of pitchblende. As for the the fluorescent properties, the writer tested the samples under the light of an iron arc, with negative results in all cases. The data do not permit exact correlations with vein type or nature of metallic minerals present. The two samples in which Pb was detected were from deposits containing minor galena, but one sample in which no Pb was detected also came from a deposit bearing galena.

The most general and abundant minor elements present are Sr, Ba, Fe, Y, Cu, Mg, Al, and Si. Sodium is not abundant and K was detected in only one sample. Does this fact indicate that the solutions depositing the fluorite were of an acid character (the usual belief)? In regard to the content of Sr and Ba, it has already been pointed out that these elements are abundant in the wallrocks. The rock with which the deposits are associated, the granite-quartz monzonite, is especially high in Sr and Ba (Bray, 1942 *a*).

TABLE 2. IONIC RADII OF THE ELEMENTS PRESENT*

Element	Group of Periodic System	Atomic Number	Atomic Weight	Valence	Ionic Radius (Å)
Na	I	11	22.99	1	0.98
Mg	II	12	24.32	2	0.76
Ca	II	20	40.08	2	1.06
Sr	II	38	87.63	2	1.27
Ba	II	56	137.36	2	1.43
Al	III	13	26.97	3	0.57
Y	III	39	88.92	3	1.06
Si	IV	14	28.06	4	0.39
Fe	Transition	26	55.84	2	0.83
Fe	Transition	26	55.84	3	0.67
Cu	I-B	29	63.57	1	0.96
Pb	IV-B	82	207.22	2	1.32

* Data obtained from Crystal Chemistry, by Stillwell, McGraw-Hill Book Co., **(1938)** (see appendix).

Table 2 lists the ionic radii of the elements of major importance to this discussion. It is notable that Y and Ca have identical radii, that Cu and Na have radii very near to that of Ca, and that only two of the elements listed have radii greater than that of Ca. These facts agree well with the conclusions drawn for silicate minerals of the Jamestown district (Bray, 1942 *a*; 1942 *b*), that most minor elements in ionic crystals probably occur as solid solution substitutes for major ions of like size in that structure. Some of the smaller ions, such as Si, may occur in interstitial solid solution. The strong affinity of Sr for Ca has been emphasized by several workers (Noll, 1934; Bray, 1942 *a* and 1942 *b*). Tröger (1935) has stated (with regard to the silicates) that rare-earth elements probably substitute for Ca because of similarity in their ionic radii. The same is probably true here. It is interesting to see Tröger's statement borne out here with regard to Y in all analyses, and with regard to a number of other rare earth elements in analysis F-4. The reason Na is not more abundant in the fluorites, despite its similarity to Ca in ionic radius, is that it probably was not abundant in the fluorite-forming solutions.

SUMMARY AND CONCLUSIONS

Conclusions based on spectrographic analyses of four fluorite samples from Jamestown, Colorado, can be stated as follows:

1. There apparently is some relation between the minor elements detected in the fluorites and their geologic environments. Age of the deposit, areal position in relation to the parent stock, and type of deposit (vein or zone) can be included under environment.
2. No correlation exists between the minor elements present in the fluorites and the wallrock of each deposit. The same is true for radioactivity. The samples do not fluoresce.
3. The most general and abundant minor elements detected were Sr, Ba, Fe, Y, Cu, Mg, Al, and Si. These elements probably substitute for Ca in the fluorite structure.
4. The scarcity of K and Na indicates that the solutions which deposited the fluorite were not alkaline.
5. The finest grained fluorite, also the oldest, was found to be most impure. The youngest fluorite, from a pyritic-gold vein, was the purest.

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