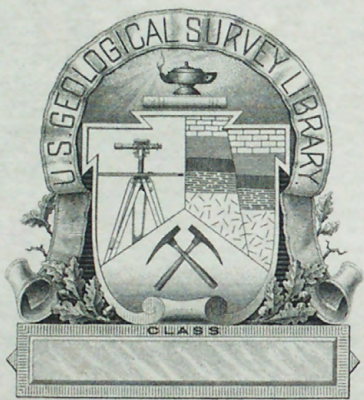


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UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

[Reports - Open file series]



PRELIMINARY RESULTS OF INDUCED

POLARIZATION-RESISTIVITY SURVEYS IN THE

NORTHGATE DISTRICT, COLORADO

By

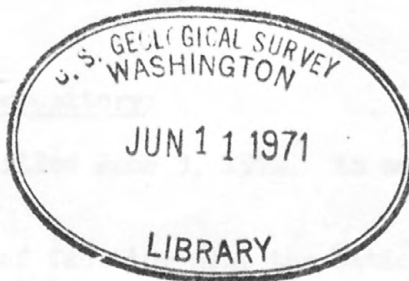
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1. Results of some airborne VLF surveys in northern Wisconsin, by Frank C. Frischknecht. 32 p. (including 7 text figs.), plus 55 plates. Wisconsin Geol. and Nat. History Survey, University of Wisconsin, 1815 University Ave., Madison, Wis. 53706.

2. Geologic map of the Negaunee Southwest quadrangle, Michigan, by Lorin D. Clark. Map, explanation, scale 1:24,000 (1 sheet). Dept. of Natural Resources, Geological Survey Div., Stevens T. Mason Bldg., Lansing, Mich. 48926. [Material from which copy can be made at private expense is available in the Lansing office.]

3. Preliminary results of induced polarization-resistivity surveys in the Northgate district, Colorado, by Gordon R. Johnson. 18 p., 7 figs. 1012 Federal Bldg., Denver, Colo. 80202; 8102 Federal Office Bldg., Salt Lake City, Utah 84111; Colorado Geol. Survey, 254 Columbine Bldg., 1845 Sherman St., Denver, Colo. 80203. [Material from which copy can be made at private expense is available at 1012 Federal Bldg., in Denver.]



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Preliminary results of induced polarization-resistivity surveys  
in the Northgate district, Colorado

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By Gordon R. Johnson

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Introduction

Induced polarization (I.P.) and resistivity surveys were made at selected locations in the Northgate district, Jackson County, Colorado. The objectives of the study were (1) to determine the feasibility of detecting and delineating pyrite-altered zones adjacent to fluorspar-mineralized veins, and (2) to locate buried or obscured extensions of these fluorspar veins.

The Northgate fluorspar deposits are among the largest in the western United States and have been commercially mined on a large scale since 1951. These deposits are being studied by Ronald G. Worl, U.S. Geological Survey, as part of an investigation of zoning in low-temperature barite, fluorite, and manganese oxide hydrothermal deposits. Of prime interest is the hypothesis that these deposits may form halos around adjacent base or precious metal deposits.

## Geologic setting

The Northgate district is located in the northeast corner of the North Park intermontane basin on the western flank of the Medicine Bow Mountains (fig. 1). The fluorspar deposits in the district have been studied by several investigators, notably Ladoo (1923, 1927), Burchard (1933), Cox (1945), and more recently, Steven (1953, 1954, 1956, 1957a and b, and 1960). The following geologic summary is based largely on U.S. Geological Survey Bull. No. 1082-F (Steven, 1960) and information supplied by Ronald G. Worl.

The rocks in the Northgate area are divided into two general categories: (1) Precambrian metamorphic and intrusive granitic rocks, and (2) younger sedimentary rocks filling old stream valleys (fig. 2). The oldest rock unit is a metamorphic complex consisting of hornblende gneiss of which large volumes have been converted into quartz monzonite gneiss by later metasomatism. A quartz monzonite stock and associated dikes are intruded into the gneiss complex in the vicinity of the fluorspar deposits. The texture of the stock varies widely but the main body of the stock is composed of medium- to coarse-grained, somewhat porphyritic rock. The dike rock is mostly fine to medium grained and aplitic. On fresh surfaces the rock appears mottled pink and gray.

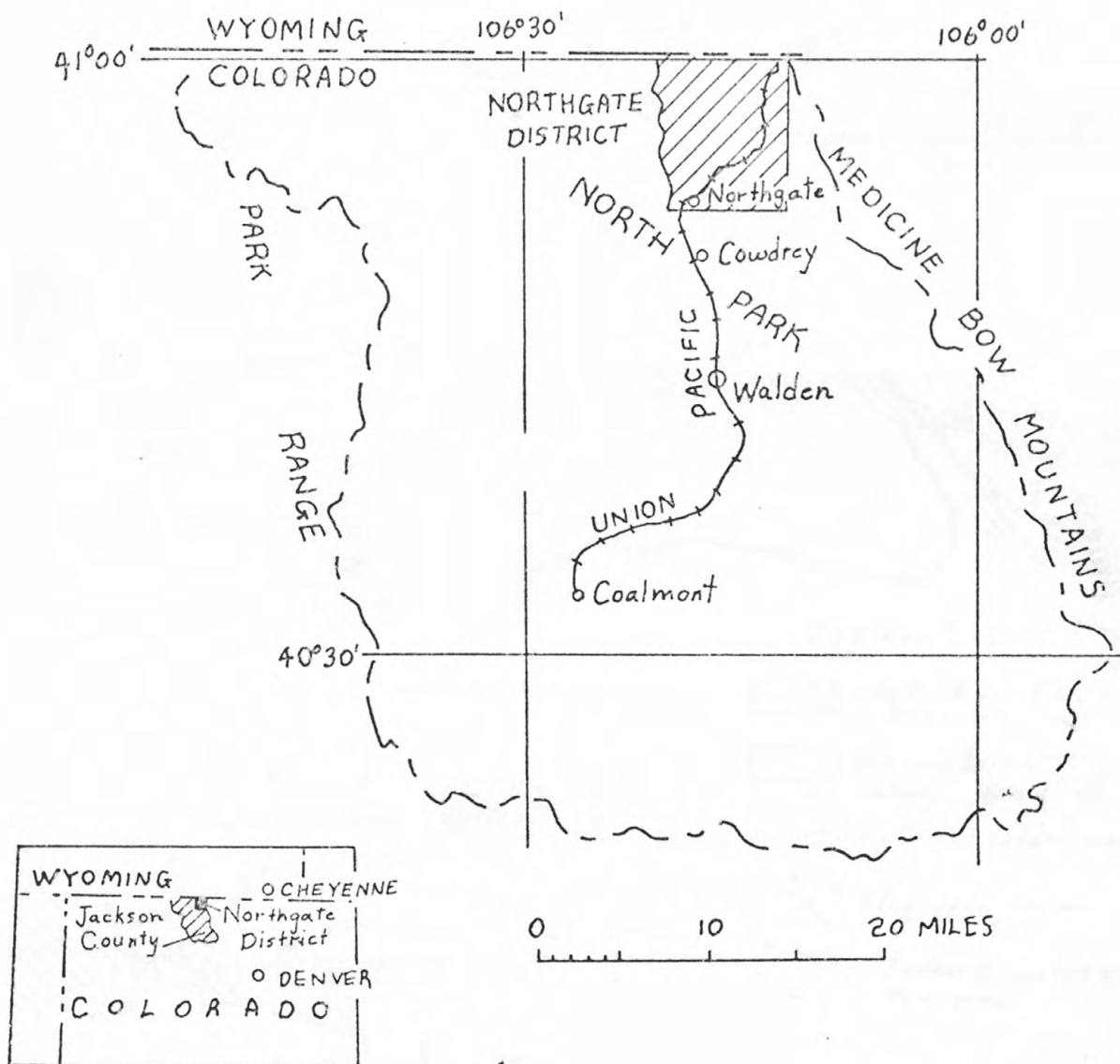


Figure 1.--Index map from Steven (1960) showing the location of the Northgate district, Colorado.

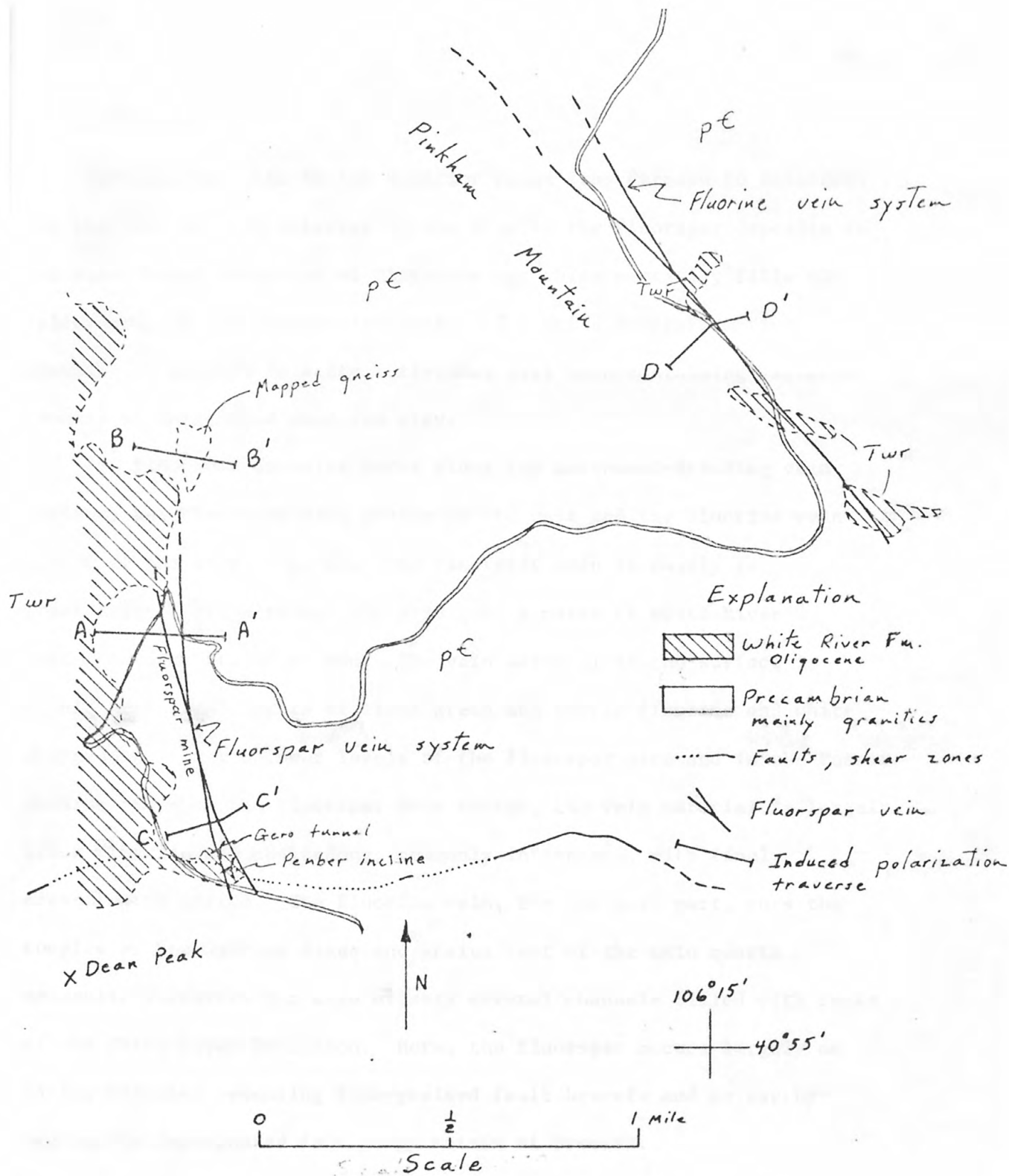


Figure 2.--Generalized geology of a portion of the Northgate district from Steven (1960) showing induced polarization traverses.

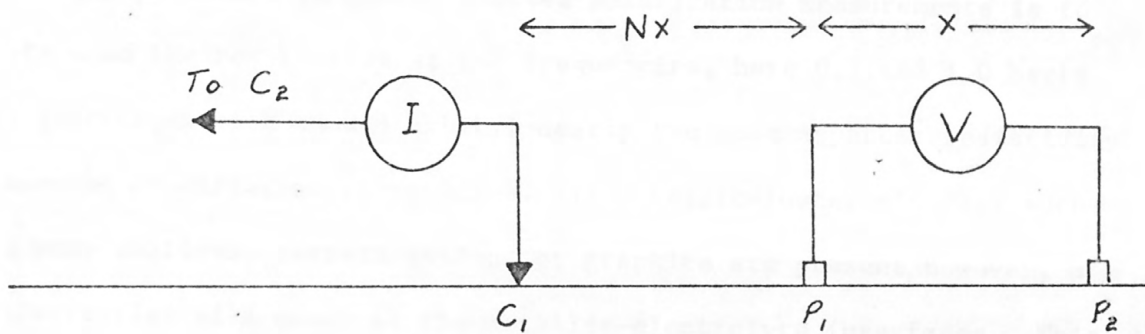
Sedimentary rocks in the district range from Permian to Holocene, but the only unit of interest in the area of the fluorspar deposits is the White River Formation of Oligocene age which partially fills old valleys cut in the Precambrian rocks. The White River Formation consists of grayish to white tuffaceous silt beds containing variable amounts of intermixed sand and clay.

The fluorspar deposits occur along two northwest-trending vein systems, the Fluorspar vein system to the west and the Fluorine vein system to the east (fig. 2). The Fluorspar vein is mainly in Precambrian rocks although the vein cuts a patch of White River Formation near its south end. The vein material at the surface is mainly botryoidal layers of clear green and purple fluorite and white chalcedony. In the lower levels of the Fluorspar mine and in the Pember incline, both on the Fluorspar vein system, the vein material is largely black fluorite and chalcedony, commonly intergrown, with finely disseminated pyrite. The Fluorine vein, for the most part, cuts the complex of Precambrian dikes and gneiss east of the main quartz monzonite intrusive but also offsets several channels filled with rocks of the White River Formation. Here, the fluorspar occurs largely as lacing veinlets cementing fine-grained fault breccia and as earthy aggregates impregnated in a gougy matrix of breccia.

Wall-rock alteration is apparent only along parts of the Fluorspar vein system, and is best seen in the lower levels of the Fluorspar mine. The most obvious alteration effect is a color change of the red quartz monzonite to a gray veined rock. In the altered gray rock the magnetite has changed to pyrite, some of the biotite has gone to chlorite, and much of the plagioclase has developed sericite cores. Pervasive, on all scales, through the gray altered rock are veinlets composed of some combination of black fluorite, gray chalcedony, pyrite, and sericite, which is the same material that makes up the bulk of the vein in the lower levels of the Fluorspar mine.

#### Induced polarization techniques

Induced polarization measurements were made using the dual-frequency method with a pole-dipole or "three electrode" configuration. With this arrangement two potential electrodes,  $P_1$  and  $P_2$ , forming the measuring array, and one electrode,  $C_1$ , of the current array are moved as a unit while the other stationary current electrode,  $C_2$ , is fixed at a distance of at least 10 times the maximum NX spacing (fig. 3) so that its influence is minimized when the geometric effect of the electrode arrangement is considered. The separation, X, of the measuring dipole used in this survey was 200 feet and the measurements were made at spacings, NX, of 200 and 400 feet.



I, current source

V, potentiometer

$x = 200$  feet

$N = 1, 2$

Frequencies used: 0.1 and 1.0 hertz

Figure 3.--Electrode configuration for induced polarization traverses.

The procedure in making induced polarization measurements is to determine the resistivity at two frequencies, here 0.1 and 1.0 hertz. In general, a rock should exhibit nearly the same apparent resistivity measured at different frequencies. If metallic-luster minerals such as many sulfides, certain oxides, or graphite are present, however, a polarization will occur at the metallic-electrolyte interfaces. This polarization will tend to impede the current flow, and, because the charging time is longer at the lower frequency than at the higher frequency, a higher apparent resistivity will be observed at the lower frequency. This property, called the frequency effect, is directly related to the inherent induced polarization of the metallic minerals.

The percent frequency effect is defined as 
$$PFE = \frac{(\rho_1 - \rho_2) \times 100}{(\rho_1 \rho_2)^{\frac{1}{2}}}$$
 where  $\rho_1$  and  $\rho_2$  are the lower and higher resistivities, respectively. To a lesser degree, clay minerals may also produce measureable induced polarization effects.

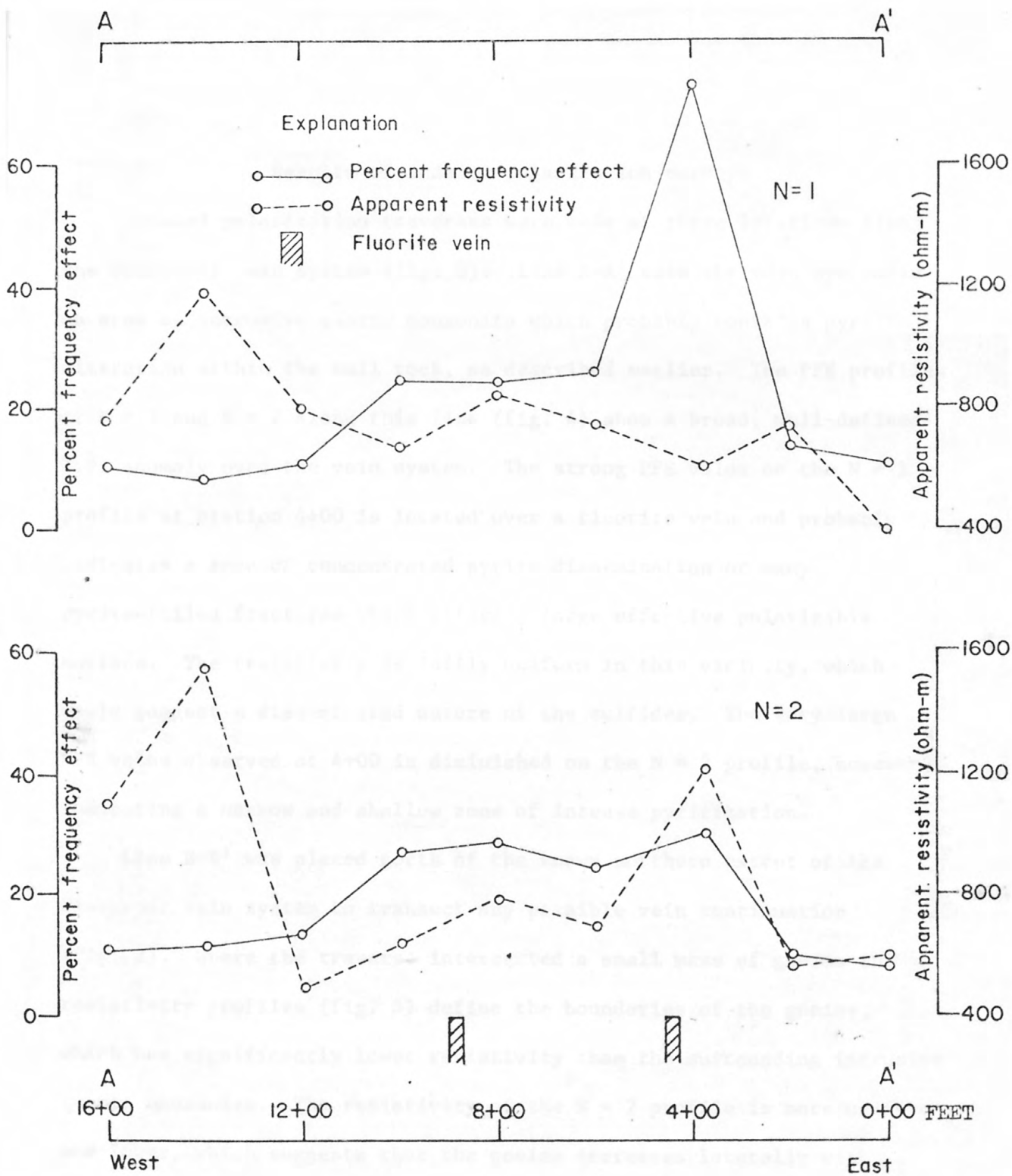


Figure 4.--Induced polarization and resistivity profiles along I.P. line A-A'.

## Results of induced polarization surveys

Induced polarization traverses were made at three locations along the Fluorspar vein system (fig. 2). Line A-A' cuts the vein system in an area of intrusive quartz monzonite which probably contains pyritic alteration within the wall rock, as described earlier. The PFE profiles at N = 1 and N = 2 along this line (fig. 4) show a broad, well-defined I.P. anomaly over the vein system. The strong PFE value on the N = 1 profile at station 4+00 is located over a fluorite vein and probably indicates a zone of concentrated pyrite dissemination or many pyrite-filled fractures which afford a large effective polarizable surface. The resistivity is fairly uniform in this vicinity, which would suggest a disseminated nature of the sulfides. The very large PFE value observed at 4+00 is diminished on the N = 2 profile, however, indicating a narrow and shallow zone of intense pyritization.

Line B-B' was placed north of the known northern extent of the Fluorspar vein system to transect any possible vein continuation (fig. 2). Where the traverse intersected a small mass of gneiss the resistivity profiles (fig. 5) define the boundaries of the gneiss, which has significantly lower resistivity than the surrounding intrusive quartz monzonite. The resistivity of the N = 2 profile is more uniform and lower, which suggests that the gneiss increases laterally with depth.

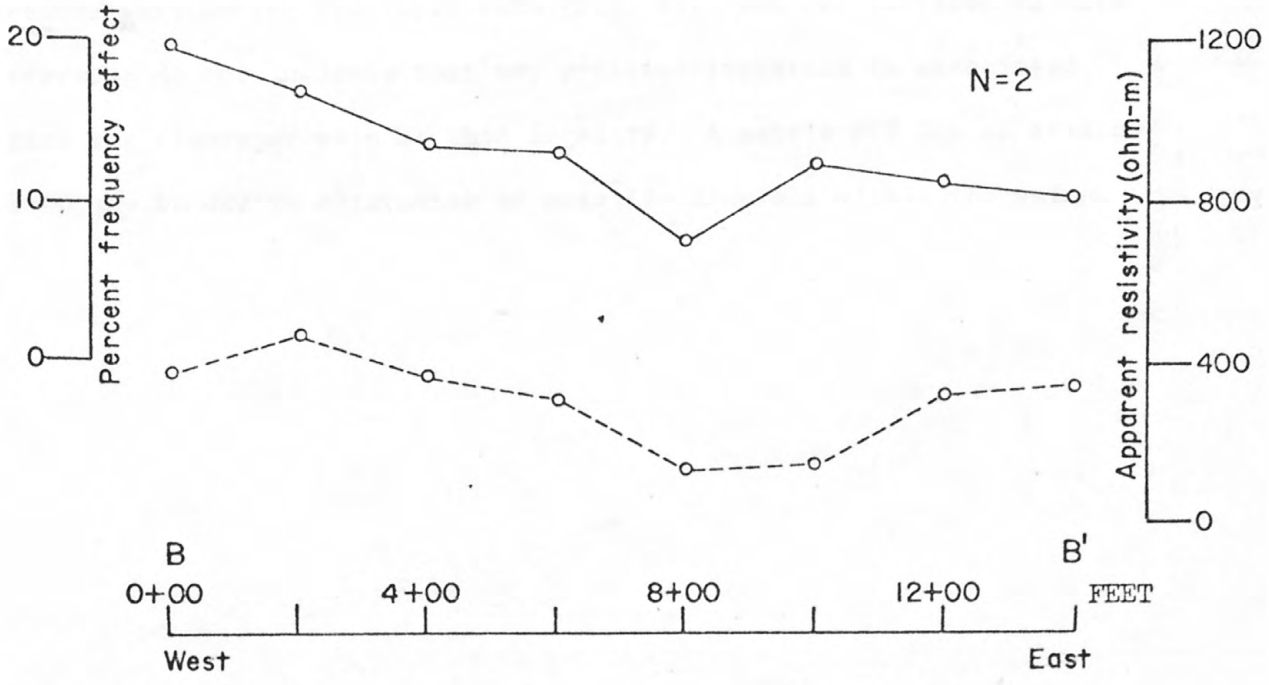
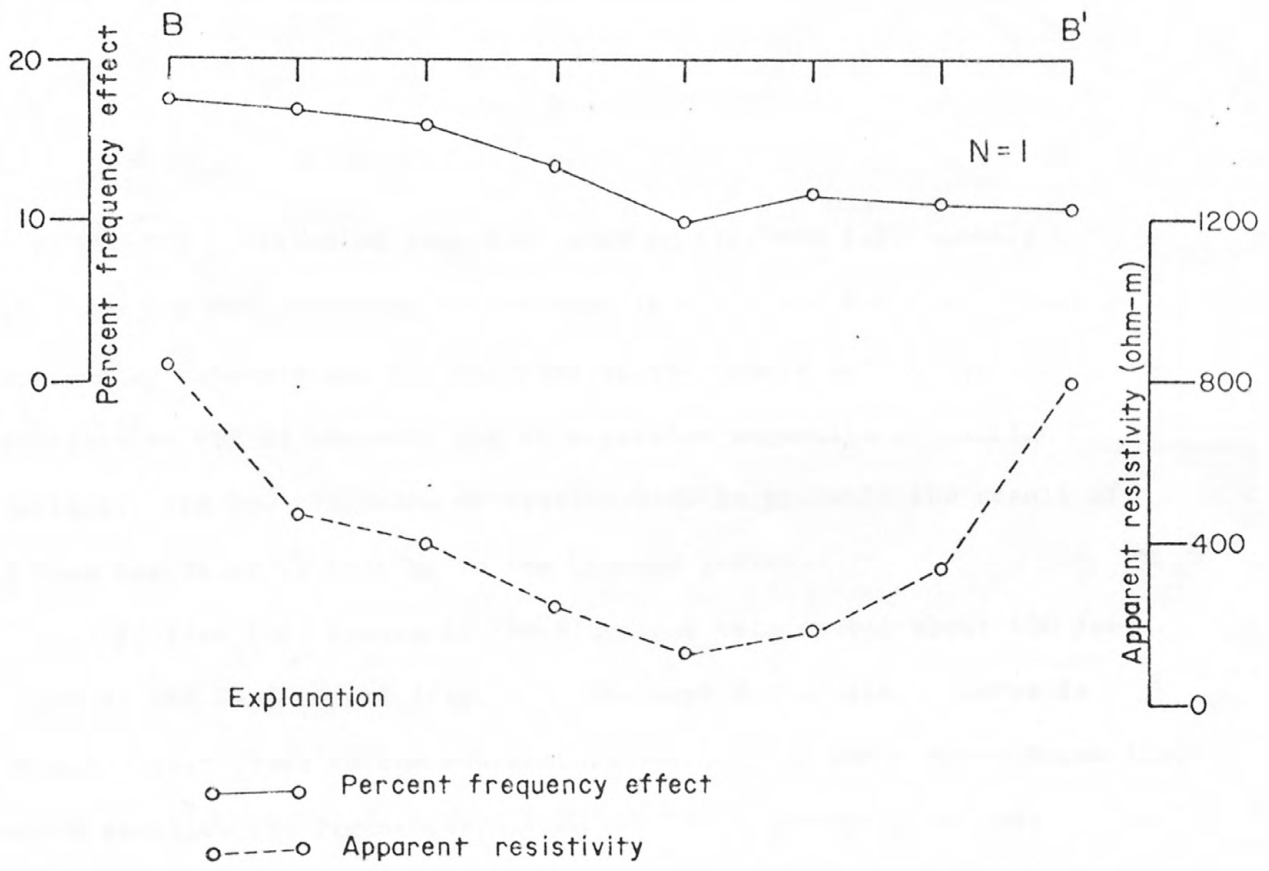


Figure 5.--Induced polarization and resistivity profiles along I.P. line B-B'.

The PFE profiles of line B-B' show no distinct I.P. anomaly although the PFE increases to the west in N = 1 and N = 2 profiles. Since clay minerals are not reported in the quartz monzonite, this increase in PFE is probably due to a greater magnetite or sulfide content. The low PFE value at station 8+00 is probably the result of a high degree of weathering in the exposed gneiss.

I.P. line C-C' transects the Fluorspar vein system about 400 feet north of the Gero tunnel (fig. 2). The west end of the traverse is probably very close to the sedimentary beds of the White River Formation, which overlies the Precambrian rocks, and this proximity of less resistive sedimentary rocks would account for the low resistivity values west of the Fluorspar vein (fig. 6). The PFE profiles of this traverse do not indicate that any pyritic alteration is associated with the Fluorspar vein at this locality. A subtle PFE low at station 2+00 may be due to alteration of metallic minerals within the veins.

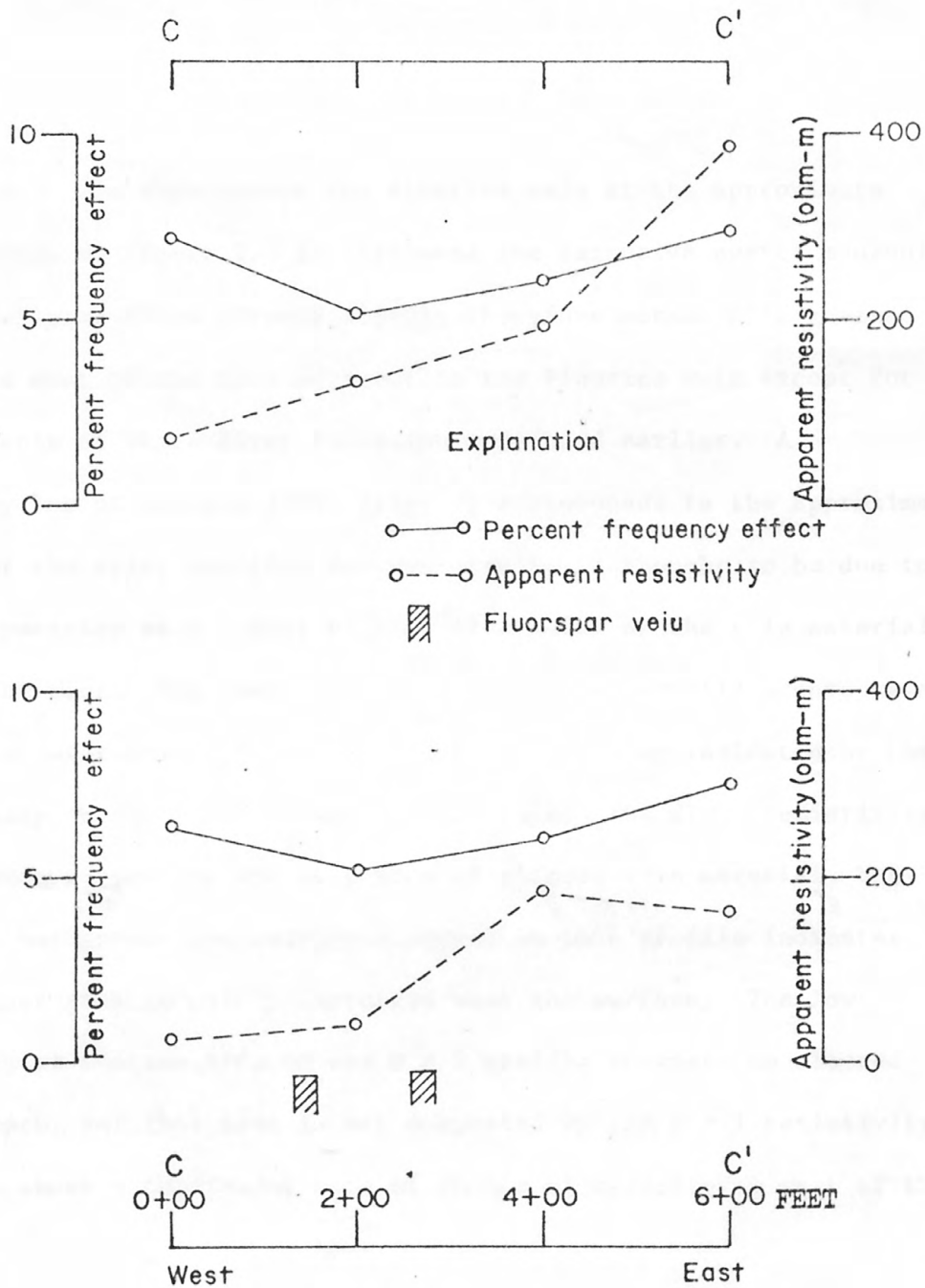


Figure 6.--Induced polarization and resistivity profiles along I.P. line C-C'.

Line D-D' was made across the Fluorine vein at the approximate location shown on figure 2. In this area the intrusive quartz monzonite occurs chiefly as dikes (Steven, 1960); therefore metamorphic gneiss constitutes most of the rock adjacent to the Fluorine vein except for small remnants of White River Formation mentioned earlier. A resistivity low at station 10+00 (fig. 7) corresponds to the approximate location of the vein, and this low resistivity is thought to be due to increased porosity as a result of clay alteration of the vein material and adjacent rock. The near-surface alteration apparently occurs as a wide band of weathering flanking the Fluorine vein as indicated by the broad anomaly on the N = 1 resistivity profile. The N = 2 resistivity profile lends support to the existence of altered vein material, but the higher background resistivity observed on this profile indicates that the host rock is mainly weathered near the surface. The low resistivity at station 4+00 on the N = 2 profile suggests an altered zone at depth, but this idea is not supported by the N = 1 resistivity data which shows a continuous rate of change of resistivity west of the vein.

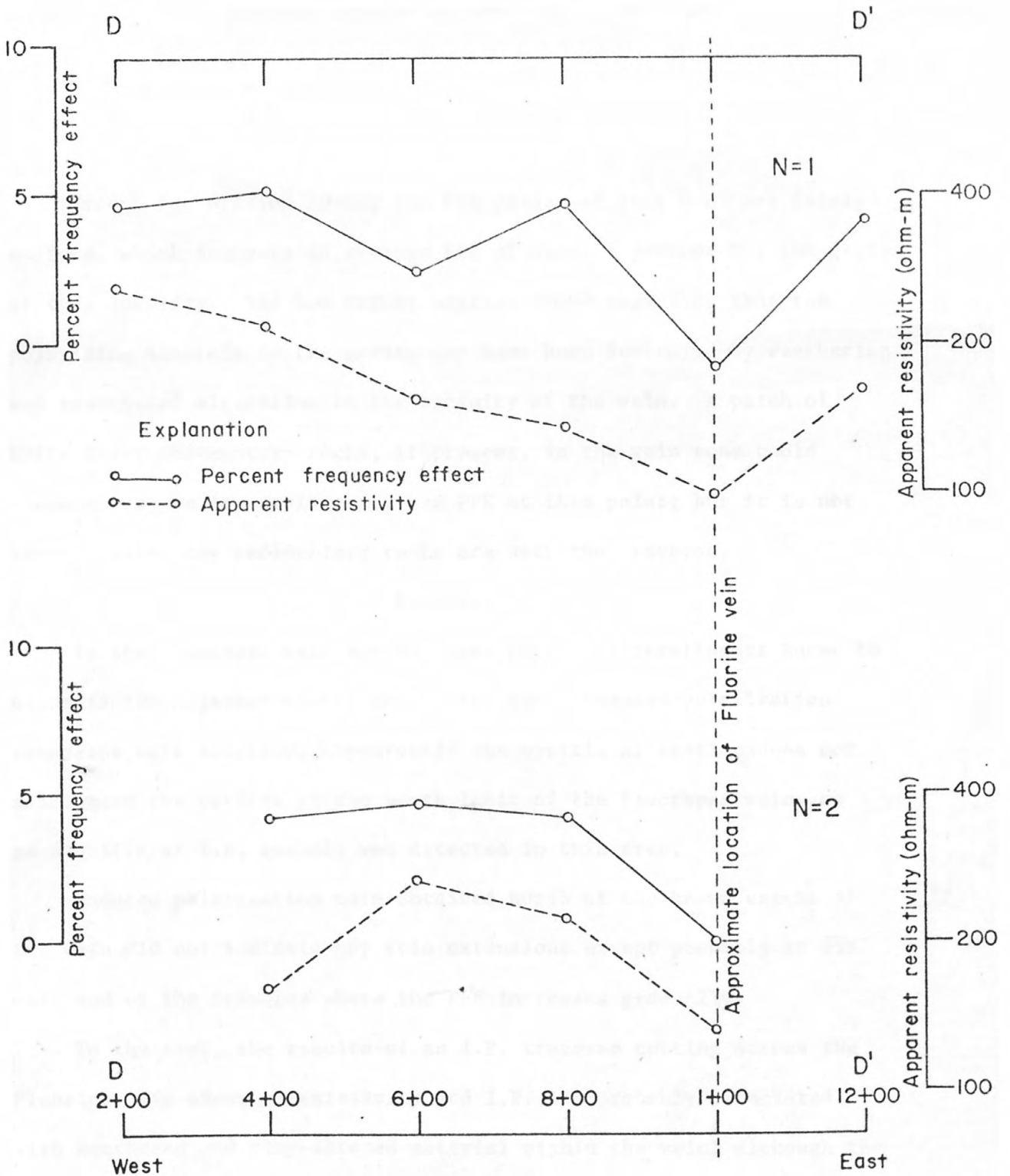


Figure 7.--Induced polarization and resistivity profiles along I.P. line D-D'.

Except for station 10+00, the PFE values of line D-D' are fairly uniform, which suggests an average PFE of about 5 percent for the gneiss at this locality. The low PFE at station 10+00 indicates that the polarizing minerals in the gneiss may have been destroyed by weathering and associated alteration in the vicinity of the vein. A patch of White River sedimentary rocks, if present, in the vein zone could account for the low resistivity and PFE at this point; but it is not known whether any sedimentary rocks are near the traverse.

#### Summary

In the Fluorspar vein system where pyritic alteration is known to exist in the adjacent quartz monzonite, large induced polarization anomalies were detected. Apparently the pyritic alteration does not exist near the surface at the south limit of the Fluorspar vein, as no significant I.P. anomaly was detected in this area.

Induced polarization data obtained north of the known extent of the vein did not indicate any vein extensions except possibly at the west end of the traverse where the PFE increases gradually.

To the east, the results of an I.P. traverse cutting across the Fluorine vein shows a resistivity and I.P. low probably associated with weathered and clay-altered material within the vein, although the near-zero I.P. values may be due to some sedimentary rocks of the White River Formation in close proximity to the traverse.

#### References cited

- Burchard, E. F., 1933, Fluorspar deposits in western United States:  
Am. Inst. Mining Metall. Eng. Tech. Pub. 500, 26 p.
- Cox, D. C., 1945, General features of Colorado fluorspar deposits:  
Colorado Sci. Soc. Proc., v. 14, no. 6, p. 263-285.
- Ladoo, R. B., 1923, Fluorspar mining in the western states; U.S. Bur.  
Mines Rept. Inv. 2480, 35 p.
- \_\_\_\_\_ 1927, Fluorspar, its mining, milling, and utilization; U.S. Bur.  
Mines Bull. 244, 185 p.
- Marshall, D. J., and Madden, T. R., 1959, Induced polarization, a study  
of the causes: Geophysics, v. 24, no. 4, p. 790-816.
- Steven, T. A., 1953, Geology of the Northgate fluorspar district, in  
Guidebook, 8th Ann. Field Conf., Laramie Basin, Wyoming and North  
Park, Colorado: Wyoming Geol. Assoc., and Wyoming Univ.,  
p. 106-110.
- \_\_\_\_\_ 1954, Geology of the Northgate fluorspar district, Colorado:  
U.S. Geol. Survey Mineral Inv. Field Studies Map MF-13.
- \_\_\_\_\_ 1956, Cenozoic geomorphic history of the Medicine Bow Mountains  
near the Northgate fluorspar district, Colorado: Colorado Sci.  
Soc. Proc., v. 17, no. 2, p. 35-55.
- \_\_\_\_\_ 1957a, Metamorphism and the origin of granitic rocks in the  
Northgate district, Colorado: U.S. Geol. Survey Prof. Paper 274-M,  
p. 335-375.

Steven, T. A., 1957b, Sentinel Mountain-Dean Peak faulted anticline, North Park, Colorado; in Guidebook to the geology of North and Middle Parks Basin, Colorado: Rocky Mountain Assoc. Geologists, p. 82-84.

\_\_\_\_\_ 1960, Geology and fluorspar deposits, Northgate district, Colorado: U.S. Geol. Survey Bull. 1082-f, 420 p. [1961].





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