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STRONTIUM ANOMALIES IN TILL OF THE POWELL-UNION CITY MORAINE, OHIO[1,2]

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ABSTRACT. The strontium concentration of till from the Powell-Union City Moraine varies with grain size and has maximum values in the −120+200 mesh (70−125 μm) fractions. It correlates positively with the carbonate content of till but depends also on the presence of feldspar, clay and other minerals. The strontium content of −120+200 mesh fractions of 19 till samples collected along the Powell-Union City Moraine increases from about 100 ppm in central Ohio up to 220 ppm at the Indiana border. The increase coincides with a change in the lithologic composition of the bedrock from sandstone and shale (Mississippian and Devonian) to carbonate rocks (Devonian and Silurian). Two positive strontium anomalies were found at Fulton and Piqua that might be attributed to the presence of celestite ($SrSO_4$) derived from the underlying bedrock. However, no celestite was found in the till samples. The excess strontium concentrations of samples in the Fulton anomaly correlate positively with their K-feldspar/plagioclase ratios and appear to be caused by a change in the mineralogical composition of feldspar rather than by an increase in the abundance of this mineral. The cause for the Piqua anomaly is unknown.

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INTRODUCTION

High Sr concentrations, ranging up to 30 ppm, in the ground and surface water of Champaign County in west-central Ohio were first reported by Feulner and Hubble (1960). Subsequent studies by Eastin and Faure (1970), Curtis and Stueber (1973), Steele and Pushkar (1973), and by Stueber et al. (1975) have confirmed this result for water in the drainage basin of the Scioto River. Feulner and Hubble (1960) attributed the high Sr concentrations to dissolution of celestite ($SrSO_4$) known to occur in the carbonate rocks of Silurian and Devonian age that form the bedrock of western Ohio.

The presence of celestite in Ohio was noted by Morrison (1935) and has been described by Stout (1941), Roedder (1969), Botoman and Faure (1976), Fisher (1977), Kessen et al. (1981), and Parr and Chang (1980). The mineral occurs in cavities and fractures in carbonate rocks of Middle Silurian to Middle Devonian age. It is associated with barite, fluorite, pyrite, marcasite, sphalerite, galena, and secondary calcite. Mychkovsky (1978) reported filling temperatures of fluid inclusions in celestite ranging from 80−180 C and concluded that the celestite was deposited by heated connate brines having salinities between 3.59 and 3.89 molar NaCl.

The common association of celestite with sphalerite in the carbonate bedrock of Ohio suggests that Sr may be a useful pathfinder element for Zn. For this reason we have measured Sr concentrations of 19 till samples from the Powell-Union City Moraine in Ohio (fig. 1) to determine whether anomalies are present that may become targets for additional study. The sample localities were described in a report by Taylor and Faure (1981) on the provenance of till based on Rb-Sr dates of feldspar.

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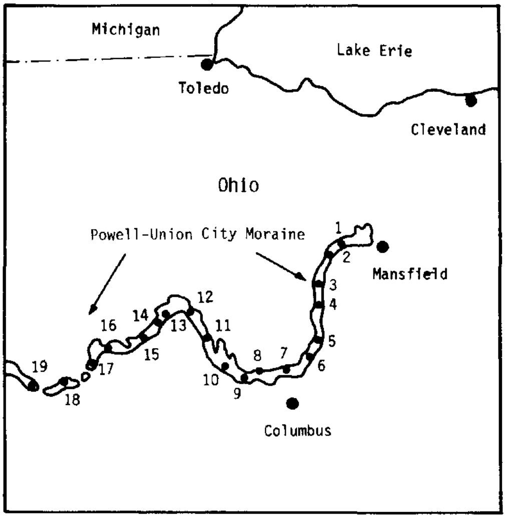

FIGURE 1. Location of samples collected from the Powell-Union City Moraine of Ohio. The samples are identified by number with reference to table 1.

METHODS AND MATERIALS

Sr concentrations of 7 grain-size fractions were determined for till collected at New California and Unionville, Ohio, in order to ascertain how this element is distributed among different grain size fractions. In addition, concentrations of calcite and dolomite were determined because they contribute significantly to the Sr content of till in Ohio. Sr concentrations were measured by x-ray fluorescence (Taylor and Faure 1979). Calcite and dolomite concentrations are based on x-ray diffraction combined with total carbonate contents obtained from the weight loss after leaching with 2N HCl. The results are presented in Figure 2.

RESULTS

The Sr concentrations of both till samples vary with grain size between about 110 ppm and 190 ppm. The highest abundance in each sample is in the 70–125 μm (−120+200 mesh) size fractions. This fraction was therefore chosen for analysis of the other 17 till samples from the Powell-Union City Moraine.

The concentration of calcite increases with grain size and peaks in the 500–2000 μm size range (fig. 2). The dolomite concentration increases with grain size beyond 2000 μm but has an additional abundance peak in the 70–125 μm fraction (−120+200 mesh). The bimodal distribution of the dolomite may indicate that this mineral originated both from local and more distant sources. Dolomite predominates over calcite in all grain sizes consistent with the prevalence of dolomite over limestone in the Silurian and Devonian carbonate rocks of northwestern Ohio (Stout 1941).

The Sr concentrations of the 70–125 μm (−120+200 mesh) fractions of till increase generally from east to west along the strike of the Powell-Union City Moraine. The regional trends of the concentrations of Sr, calcite, dolomite, and total carbonate are presented in fig. 3 as 2–point moving averages of the data for each locality compiled in table 1. The increases in the concentrations of Sr and of the carbonate minerals coincide approximately with the change in bedrock lithology from

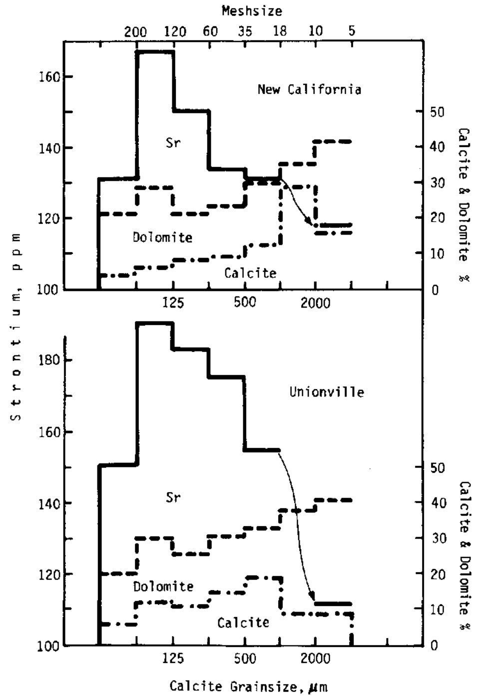

FIGURE 2. Effect of grain size on the Sr content and on the abundances of calcite and dolomite in 2 till samples from the Powell Moraine, Ohio. The Sr concentrations of the 1000–2000 μm fractions (−10 +18 mesh) were not determined because the quantity of material was insufficient.

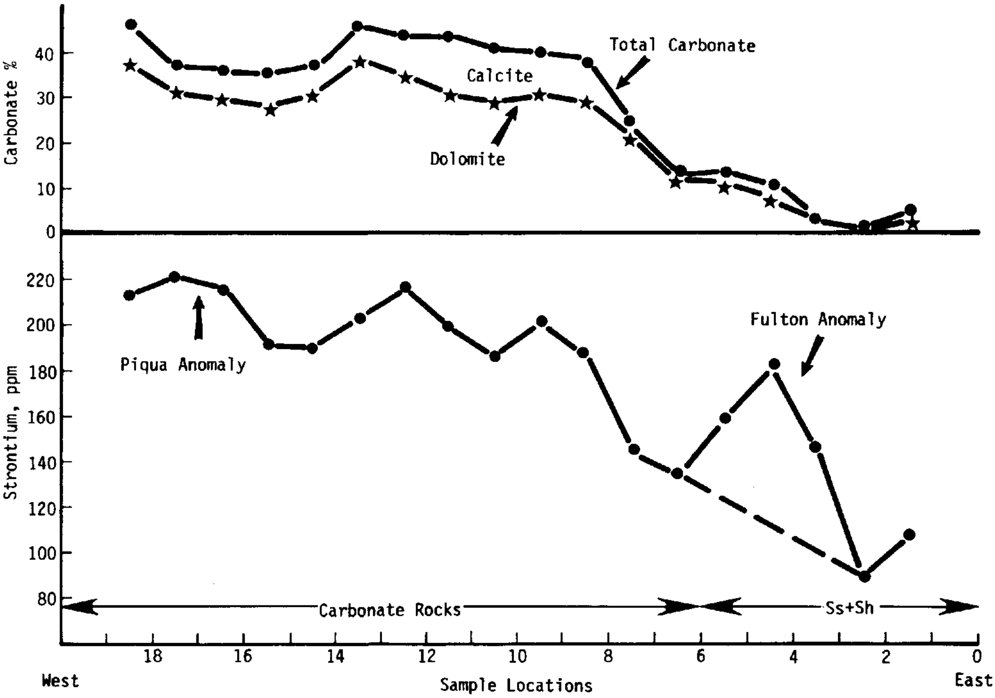

FIGURE 3. Two-point moving average of carbonate and strontium concentration in the −120 +200 mesh fraction of till along strike of the Powell-Union City Moraine, Ohio. The samples were plotted at regular intervals and are identified by number as in table 1.

TABLE 1

Analytical data for 70 to 125 μm (−120 + 200 mesh) fraction of till, Powell-Union City Moraine, Ohio.

Locality	Carbonate %	Calcite %	Dolomite %	Sr ppm
1. Crestline	8.5	1.9	6.6	132.0
2. Blooming Grove	0	0	0	81.5
3. Mt. Gilead	1.8	0	1.8	96.3
4. Fulton	4.5	0	4.5	191.4
5. Sunbury	17.0	4.9	12.1	171.5
6. Galena	10.2	0	10.2	146.8
7. Powell	14.5	0.7	13.8	121.4
8. New California	34.7	6.0	28.7	166.9
9. Unionville	41.3	11.4	29.9	190.7
10. Buck Run	37.1	6.5	30.6	208.0
11. East Liberty	43.7	15.0	28.7	166.9
12. Rushsylvania	44.1	11.1	32.9	231.0
13. Huntsville	43.5	7.3	36.2	201.2
14. Logansville	49.4	8.3	41.1	204.4
15. Port Jefferson	24.6	5.5	19.1	175.7
16. Sidney	45.5	8.6	36.9	205.5
17. Piqua	25.2	4.0	21.2	227.1
18. Gettysburg	48.0	8.6	39.4	215.1
19. Greenville	42.8	7.3	35.5	226.4

sandstones and shales (Mississippian and Devonian) in the east to carbonate rocks (Devonian and Silurian) in the west.

DISCUSSION

The Sr content of till results primarily from contributions by silicate minerals (feldspar and clay minerals) and by carbonate minerals (calcite and dolomite). Celestite may also be important as postulated by Feulner and Hubble (1960). The relationship between the carbonate content of till in the $-120+200$ mesh fraction and the Sr content is statistically significant. A least-squares regression of 16 samples yields the equation:

$$Sr(ppm) = 103.2 + 2.426 \text{ Carb } (\%)$$

and a correlation coefficient $r^2 = 0.9294$. Samples from Fulton, Piqua, and East Liberty deviate from this relationship and were excluded.

A significant positive Sr anomaly exists in till samples collected at Fulton (#4), Sunbury (#5), and Galena (#6) compared to the regional gradient shown in fig. 3. The Sr concentrations of these samples decrease in a southwesterly direction from 191.4 ppm (Fulton) to 146.8 ppm (Galena). The carbonate concentrations of these samples are low and range from 4.5% (Fulton) to 17.0% (Sunbury). Evidently, the carbonate concentrations are not sufficient to account for the high Sr content of these samples.

A second anomaly exists in the sample from Piqua (#17). Its carbonate concentration is only 25.2% , which is about half of the average in this region. However, the Sr content of the Piqua sample is 227.1 ppm, which is consistent with the regional average. In contrast, the low carbonate content (24.6%) of the sample from Port Jefferson (#15) is accompanied by a reduction of its Sr content (175.7 ppm). Therefore, the normal Sr content of the Piqua sample implies the presence of a Sr-rich mineral that compensates for the loss of Sr caused by the decrease of the carbonate content. The sample from East Liberty (#11) is anomalous only in the sense that its Sr content (166.9 ppm) is lower than expected from its carbonate concentration (43.7%) according to the above equation.

The high Sr concentrations of till from Fulton and Piqua may be caused by the presence of celestite whose density is 3.95. For this reason minerals having densities >3.3 and low magnetic susceptibilities were separated from $-60+200$ mesh fractions of till from Fulton and Piqua. However, no celestite was found in these fractions by x-ray diffraction analysis. Their Sr content was tested by x-ray fluorescence, but again no elevated concentrations were detected.

The failure to detect celestite in these samples is significant because the procedure used should have concentrated it sufficiently to assure its detection by x-ray diffraction. The Sr concentration of stoichiometric $SrSO_4$ is 47 705 ppm. Therefore, the concentration of this mineral required to raise the Sr content of the Piqua sample from 164 ppm (expected from the equation) to 227 ppm (observed) is 0.132%. The weight of the initial sample was 26.453 g and that of the final concentrate was 0.0556 g. Consequently, the celestite content of the final concentrate should have been 62.8% and should have been detected. The figures for Fulton are even more impressive. In order to increase its Sr content from 114 ppm to 191 ppm, its celestite content should have been 0.162%. Therefore, the celestite content of the final concentrate (0.0104 g remaining from an initial 12.808 g) should have increased to 199.5%. This means that the final concentrate should have weighed about twice as much as it actually did and should then have consisted entirely of celestite. The fact that celestite was not detected demonstrates convincingly that this mineral is not the cause for the Sr anomalies at Fulton and Piqua.

X-ray diffraction scans of samples from Fulton, Sunbury, and Galena indicate that their feldspar concentrations are nearly constant. However, the ratio of K-feldspar to plagioclase correlates positively with the

TABLE 2

Correlation between excess Sr in the −120 +200 mesh fractions of till from the Fulton Anomaly and the K-feldspar/plagioclase ratio of feldspar.

Sample	Sr obs. (1)	Sr carb. (2)	Sr ex. (3)	K-feldspar / Plagioclase (4)
Fulton	191	114	77	0.68 ± 0.08
Sunbury	172	144	28	0.55 ± 0.08
Galena	147	128	19	0.31 ± 0.11

(1) Measure Sr concentration in ppm.
(2) Calculated Sr concentration based on the carbonate concentration (table 1) and equation.
(3) Difference between (1) and (2).
(4) Based on replicate x-ray diffraction scans of peaks at $2\theta = 27.5°$ (K-feldspar) and $2\theta = 28.0°$ (Plagioclase).

excess Sr content of these samples. The relevant data are presented in table 2. These results suggest that the high Sr content of the till at Fulton, Sunbury, and Galena is caused by a change in the mineralogical composition of feldspar. However, further study of this phenomenon is needed. The cause for the Piqua anomaly is not known.

The results of this study emphasize that the Sr content of till in the Powell-Union City Moraine is controlled not only by the abundance of calcite and dolomite but also by the mineralogical composition of feldspar, especially the abundance of K-feldspar. Celestite ($SrSO_4$), which does occur in the carbonate rocks of western and northwestern Ohio, was not found.

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