

THE CHEMISTRY OF SOME NEW BRUNSWICK PYRITES

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ABSTRACT

A selection of pyrites from a range of sulphide occurrences in New Brunswick was analyzed for major and minor elements. The presence of copper, lead and zinc was shown to be the result of included sulphide impurities, the pyrite being associated with these sulphides in the majority of occurrences. Arsenic was also present in all analyses even though arsenopyrite was absent from some of the samples. The chemistry of the minor elements was essentially the same as that of analysed pyrites from other parts of the world. The analyses of these New Brunswick pyrites were corrected on the assumption that all of the copper, lead, zinc and arsenic was present as chalcopyrite, galena, sphalerite and arsenopyrite. The Fe:S ratios of the pyrites, which occur mainly in the range from 1:1.98-2.01, are included with the analyses in Table 3 and were calculated after these corrections had been made.

The cell dimensions of the pyrites were obtained by measurement from α -ray diffraction traces standardized against silicon. The results were statistically processed by a computer programme. The majority of the values fall within the range 5.4172-5.4178 Å. Two extreme values of 5.4158 ± 0.0001 Å and 5.4203 ± 0.0001 Å occur. The lowest value was obtained for a pyrite separated from a Pennsylvanian sandstone. No reason is apparent for the relatively small cell size of this pyrite. The largest value was obtained from the sample containing the high cobalt and nickel values.

INTRODUCTION

The New Brunswick Research and Productivity Council is at present engaged in a comprehensive research programme dealing with the sulphide occurrences of New Brunswick. Pyrite was chosen for the preliminary study as it is ubiquitous throughout the area. The results of such a study are of interest because of the development of an industrial complex at Belledune in the north of the province which may include the production of sulphur and iron matte from pyrite by the Outokumpu process. Sulphuric acid is already being produced in association with the Imperial Smelting Process plant from stack gas. As the metallurgical process will have to be adapted to cope with the impurities in pyrite, a knowledge of both the chemistry and the impurities is relevant to the problems of extraction.

The difficulty of obtaining a pure pyrite free from associated sulphides is illustrated by the present work. This study also includes precise cell size determinations on the pyrites to evaluate the influence, if any, of associated elements upon the structure of pyrite.

DESCRIPTION OF THE OCCURRENCES

Pyrite concentrates were prepared from eighteen different mineral localities (Fig. 1). The sulphide minerals associated with the pyrites are shown in Table 1. Eight of these pyrites are from the Bathurst-Newcastle area of northern New Brunswick where lead, zinc and copper mineralization occurs in massive pyritic and pyrrhotitic bodies (Stanton 1960 a, b) (Nos. 3-8, Fig. 1). The pyrites of the three producing mines, Brunswick No. 12 (Brunswick Mining and Smelting Corp. Ltd.), Heath Steele (Heath Steele Mines Ltd.) and Wedge (Consolidated Mining and Smelting Co. of Canada Ltd.) are included in the study. North of the Rocky Brook-Millstream break, vein deposits occur instead of the massive bodies found to the south. The main occurrences are the Nigadoo and Keymet (Elmtree River) veins (Nos. 1 and 2, Fig. 1).

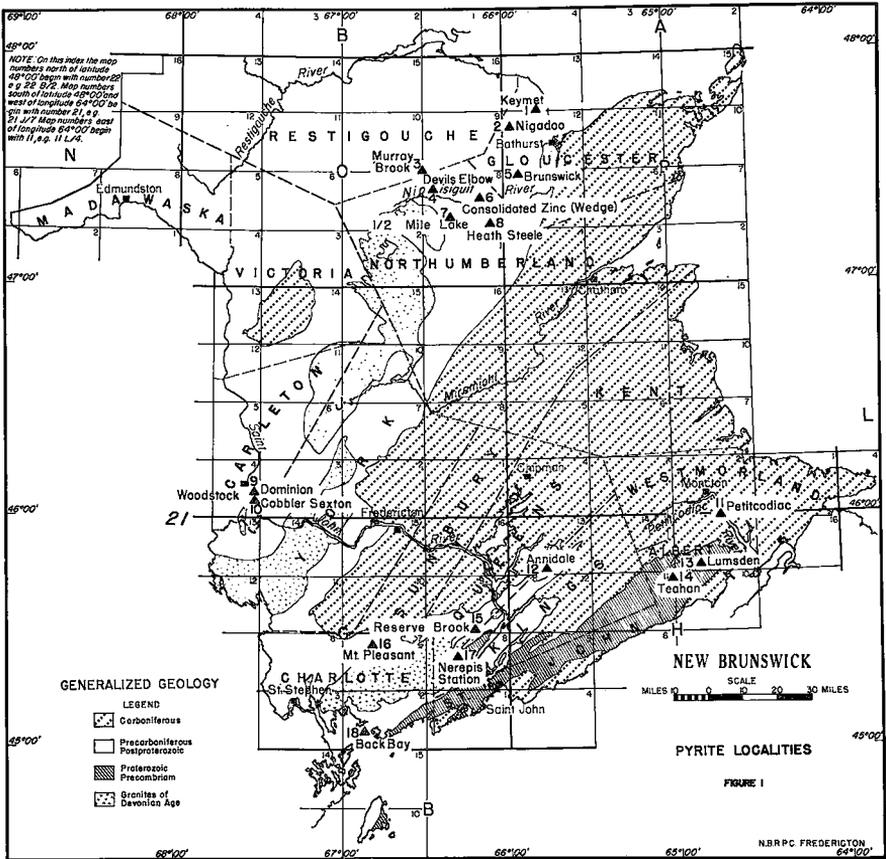


FIG. 1. Pyrite localities, New Brunswick.

TABLE 1. THE METALLIC MINERAL ASSOCIATION IN EACH OCCURRENCE

No.	Name	Type of Deposit	Mineralization									
			cp.	gn.	py.	po.	sp.	asp.	td.	ten.	mo.	mar.
1.	Keymet*	Vein	x	x	x	.	x	?	.	.	.	.
2.	Nigadoo*	Vein	x	x	x	x	x	x	.	.	.	.
3.	Murray Brook	Massive	x	x	x	.	x	x	.	.	.	.
4.	Devils Elbow	Massive	x	x	x	x	x	.	.	.	.	.
5.	Brunswick No. 12*	Massive	x	x	x	x	x	x	x	x	.	.
6.	Wedge*	Massive	x	x	x	.	x	?	.	.	.	.
7.	Half Mile Lake	Massive	x	x	x	x	x	?	.	.	.	.
8.	Heath Steele*	Massive	x	x	x	x	x	x	x	x	.	.
9.	Dominion	Vein	x	x	x	.	x	.	.	.	.	.
10.	Cobbler Sexton	Vein	x	x	x	.	x	.	.	.	.	.
11.	Petitcodiac	Sedimentary	.	.	x	.	.	.	.	.	.	x
12.	Annidale	Vein	x	x	x	.	x	.	.	.	.	.
13.	Lumsden	Shear zone	x	x	x	.	x	.	.	x	.	.
14.	Teahan	Vein	x	x	x	.	x	.	.	x	.	.
15.	Reserve Brook	Vein	x	x	x	.	x	x	x	.	.	x
16.	Mount Pleasant*	Veins	x	x	x	x	x	x	.	.	x	x
17.	Nerepis	Vein	x	x	x	x	x	.	.	.	.	.
18.	Back Bay	Vein	x	.	x	x	.	.	.	.	.	.

*Producing or developing mines.

cp.	chalcopyrite	sp.	sphalerite	ten.	tennantite
gn.	galena	asp.	arsenopyrite	mo.	molybdenite
py.	pyrite	td.	tetrahedrite	mar.	marcasite
po.	pyrrhotite				

The most important deposit in the province outside of the Bathurst-Newcastle area is at Mount Pleasant where tin mineralization occurs with associated sulphides as disseminations and veins in altered volcanic rocks (Petruk 1964). Numerous sulphide occurrences are located in the western and southern parts of the province (Nos. 9, 10, 12, 13, 14, 15, 17 and 18, Fig. 1). These are composed of iron, lead, zinc and copper sulphides which occupy fractures in pre-Carboniferous formations.

The Petitcodiac pyrite occurs replacing the calcite matrix of a conglomeratic sandstone of Pennsylvanian Age (No. 11, Fig. 1) (Fig. 4).

SEPARATIONS

The pyrite concentrates were obtained from crushed ore samples by heavy liquid, magnetic, froth flotation and micropanning techniques. The purity of the separations was judged from a microscopic examination and tested by *x*-ray diffraction. Powder mounts of the pyrites for reflection microscopy were made so that the amount of the final impurities could be estimated. The impurities present are mainly quartz, sphalerite, chalcopyrite, galena and arsenopyrite which occur as inclusions or as joined grains with the pyrite (Figs. 2, 5). Siderite inclusions are common in some of the samples (Fig. 3).

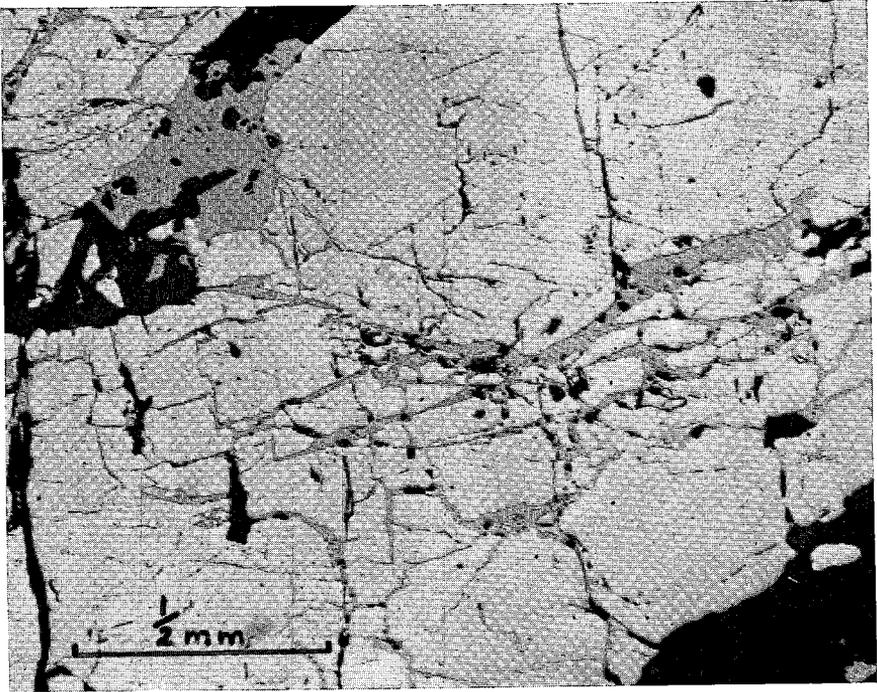


FIG. 2. Photomicrograph of the Annidale pyrite, showing cracks filled with chalcopyrite and also with inclusions of quartz (black).

Modal analyses on powder mounts of the pyrite samples were attempted in order to evaluate precisely the impurities present but the results were too variable to be reliable. A visual estimate, however, put the amount of inclusions at approximately one per cent in most of the pyrites.

In the massive sulphide bodies of the Bathurst-Newcastle area especially, mineral inclusions in pyrite may be less than 10 microns in size and in these examples it is practically impossible to obtain a pyrite entirely free of sulphide inclusions. The liberation of the sulphide impurities from the pyrites of these ore samples by repeated attempts at purification involves grinding the samples to successively finer grain sizes down to less than 200 mesh (74 microns). The final traces of impurity become increasingly difficult to remove and even in several fractions of the same pyrite sample, such impurities may be present in slightly different quantities sufficient to cause what appears to be a notable chemical difference between the various fractions. As an example of this, three separated pyrites from the Brunswick No. 12 mine and one from the Wedge mine were each analyzed twice (Table 2). The first analysis was

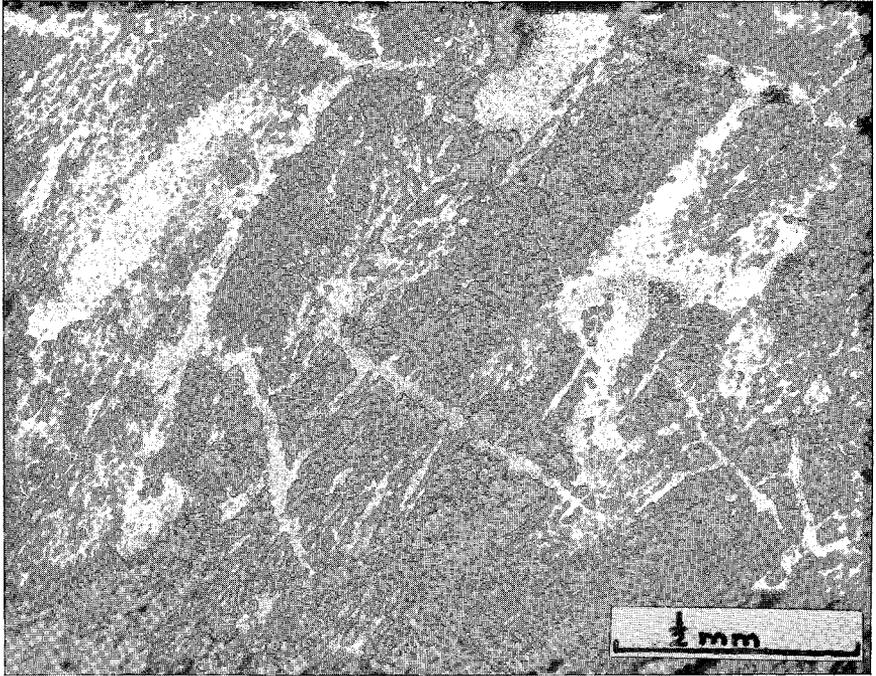


FIG. 3. Microfolds in the Reserve Brook pyrite. The fine black inclusions scattered throughout the pyrite and infilling the tension cracks across the fold are siderite.

TABLE 2. CHANGES IN THE COMPOSITION OF SOME OF THE PYRITE CONCENTRATES AFTER BENEFICIATION

Sample	Wt. Percentage						Total
	Pb	Zn	Cu	Fe	As	S	
Brunswick No. 12, A							
1st separation	0.39	0.28	0.24	46.21	1.52	50.26	98.90
2nd separation	0.08	0.08	0.18	45.86	0.60	51.84	98.64
Brunswick No. 12, B							
1st separation	0.29	0.56	0.27	46.21	0.16	50.28	97.77
2nd separation	0.09	0.29	0.19	45.53	0.02	52.72	98.84
Brunswick No. 12, D							
1st separation	1.11	1.41	0.47	44.60	0.50	49.50	97.59
2nd separation	0.98	1.10	0.23	44.95	0.25	51.20	98.71
Cominco, Wedge, C							
1st separation	0.34	0.66	1.54	45.81	0.27	50.15	98.77
2nd separation	0.13	0.47	1.52	44.63	0.15	53.19	100.09

made after initial beneficiation and the second after a repetition of the separation techniques on finer samples (less than 62 microns) but with the emphasis on froth flotation.

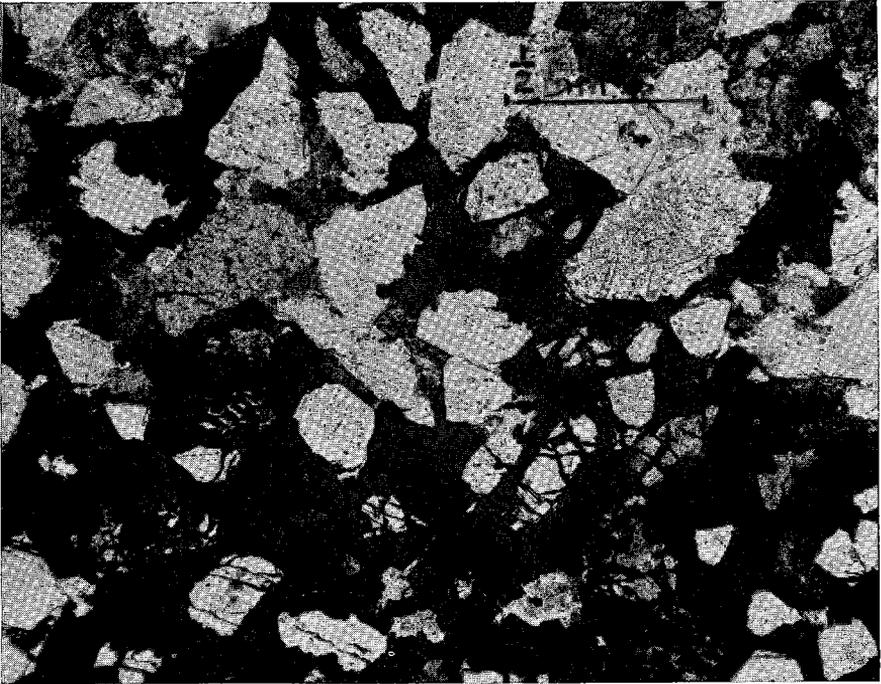


FIG. 4. A thin section of the Petitcodiac conglomeratic sandstone. The pyrite (black) replaces the calcite matrix and also appears to replace some of the quartz grains. (Plane polarised light).

After this second separation, it is obvious from the analyses that some additional removal of chalcopyrite, arsenopyrite, sphalerite and galena had been accomplished in each sample. The three fractions of the Brunswick pyrite, two of them from hand specimens of the ore (A and B) and the third from the mine concentrate (D) indicate the variations in chemistry which exist between apparently identical samples, as a result of the incomplete or preferential removal of certain impurities during purification. Two analyses of the Heath Steele pyrite (A, B) (Table 3) represent fractions of different magnetic susceptibility from the same sample. Fraction A is the more magnetic and contains more of the associated chalcopyrite and sphalerite.

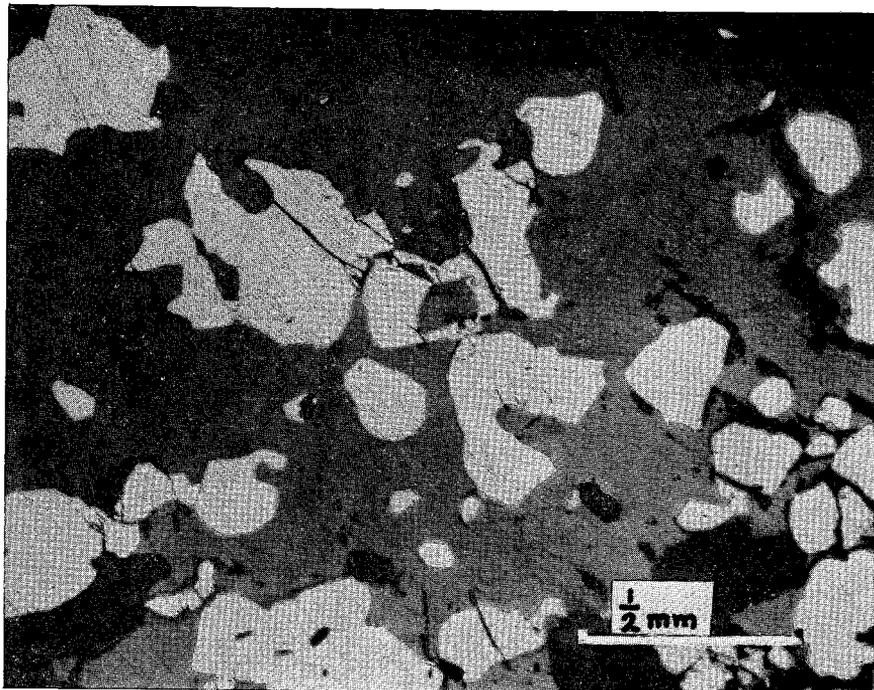


FIG. 5. The Teahan pyrite, replaced by sphalerite (dark grey). Small quartz inclusions (black) are present.

CHEMISTRY

The analyses of the pyrites were carried out by a commercial laboratory and are presented in Table 3. The elements arsenic, copper, iron, lead, sulphur, zinc and silica were determined quantitatively but the remaining elements semiquantitatively. Copper, lead, zinc and arsenic are present in all of the analyses in varying amounts. In many analyses of pyrite a similar variable range of these elements is encountered (Fleischer 1955). Although it is possible that small quantities might be in solid solution (Deer, Howie & Zussman 1962), the majority of impurities in pyrite, and certainly those from New Brunswick, represent inclusions of other sulphides.

Of the elements associated with impurities in the pyrite, the arsenic is the most inconsistent. It is practically absent from eight of the samples (Nos. 2, 4, 9, 10, 11, 12, 14 and 18), one of which (No. 2) occurs with arsenopyrite in the host sulphide body. The presence of arsenic in five

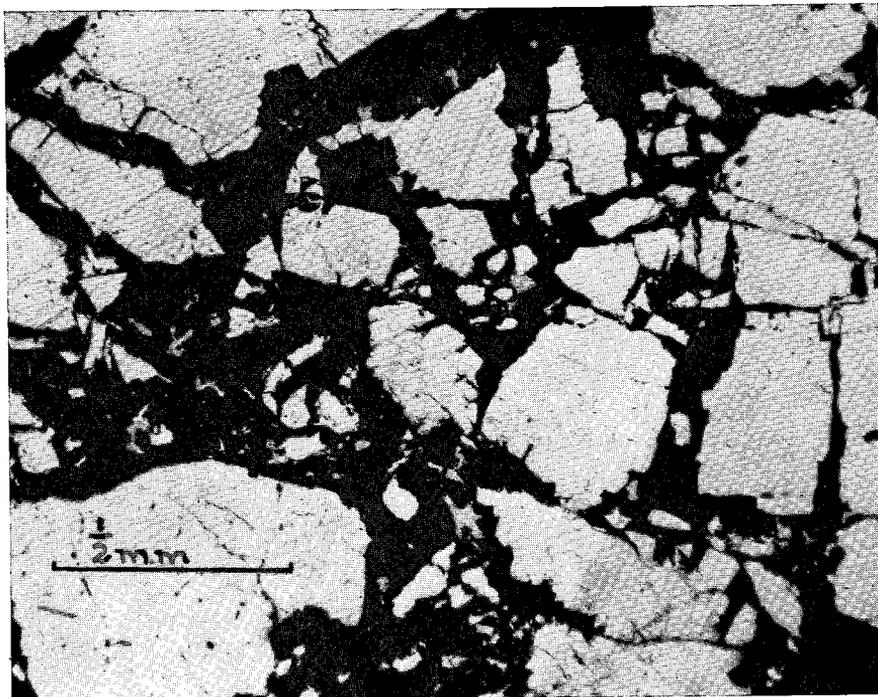


FIG. 6. The pyrite of the Lumsden mine associated with quartz (black). The large size range of the pyrite is well displayed.

other of the analyzed samples (Nos. 3, 5, 8, 15 and 16) is probably due in part to included arsenopyrite which is found with the pyrite. The remaining five samples (Nos. 1, 6, 7, 13 and 17) are not associated with arsenopyrite yet the analyses contain arsenic.

No experimental work has been done to determine the extent of solid solution of arsenopyrite in pyrite. Fleischer (1955) records analyses of pyrite with 5 per cent arsenic and some of this may be included in the lattice, since there is an increase in the cell parameter. In Table 3 a weak correlation is shown between the presence of arsenic in the New Brunswick samples, some of which may occur as arsenopyrite, and an increase in the cell size to values greater than 5.4173 \AA . This, together with the failure to detect a separate arsenic-bearing mineral in samples 1, 6, 7, 13 and 17, suggests that lattice incorporation of arsenic can take place.

Unlike arsenic, antimony is recorded in only three analyses (Nos. 3, 5 and 15) (0.05, 0.02 and 0.01 per cent); where it follows the content of arsenic fairly closely (4.52, 0.60 and 0.37 per cent).

Cobalt and nickel are found in all of the pyrites, but only in small amounts replacing iron. The cobalt-to-nickel ratio in pyrite is generally greater than one but is very variable even in those ore occurrences of similar origin.

The chemical analyses of the pyrites were adjusted by allocating the copper, lead, zinc and arsenic, with iron and sulphur, as chalcopyrite, galena, sphalerite and arsenopyrite and the resulting Fe + Co + Ni:S ratio calculated (Table 3). Theoretically the percentage of iron and sulphur in pure pyrite is 46.6 and 53.4 respectively, giving an atomic ratio Fe:S, of 1:2. The calculated ratios, after removal of the sulphide impurity from the analyses, are close to the ideal FeS₂ as the majority of these values occur within the range 1:1.98–2.01. Two extreme results at 1:1.85 (the Reserve Brook pyrite No. 15) and 1:2.07 (the Wedge pyrite No. 6) are encountered. The smaller ratio (1:1.85) is due to the occurrence

TABLE 3. PYRITE ANALYSES

	1 Keymet	2 Nigadoo	3 Murray Brook	4 Devils Elbow	5 Brunswick 12A	5 Brunswick 12B	5 Brunswick 12D
Fe	45.78	47.01	43.59	45.91	45.86	45.53	44.95
Co	0.05	0.02	0.05	0.1–0.2	0.10	0.05	0.05
Ni	0.01	0.01	0.008	0.006	0.005	0.005	0.005
S	53.18	46.86	47.06	52.39	51.84	52.72	51.20
Se	nd	0.0005	0.0005	0.003	0.0005	nd	0.0005
As	0.11	0.01	4.52	0.01	0.60	0.02	0.25
Cu	0.02	0.02	0.38	0.22	0.18	0.19	0.23
Pb	0.65	0.60	1.21	0.04	0.08	0.09	0.98
Zn	0.53	0.08	1.78	0.07	0.08	0.29	1.10
Sb	—	—	0.05	—	0.02	—	—
Ba	—	—	—	—	—	—	0.01
Bi	0.002	—	0.008	0.005	0.01	0.01	0.01
Cd	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Cr	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Ga	0.001	0.001	0.001	0.001	0.001	0.001	0.001
In	0.001	0.007	0.01	0.001	0.001	0.002	0.003
Mn	0.01	0.03	0.05	0.01	0.01	0.01	0.02
Mo	0.002	0.005	0.005	0.01	0.003	0.002	0.005
Si	0.17	0.12	0.18	0.08	0.05	0.09	0.28
Ag	0.015	0.003	0.003	0.001	0.001	0.002	0.006
Sn	0.003	0.004	0.02	0.003	0.02	0.05	0.05
Ti	0.01	0.02	0.03	0.03	0.02	0.01	0.02
V	0.005	0.01	0.005	0.005	0.005	0.005	0.005
Zr	0.02	0.02	0.02	0.02	0.01	0.01	0.02
Total	100.60	100.46†	99.01	98.95	98.93	99.12	99.23
Fe:S*	1:2.01	1:2.04	1:1.91	1:1.98	1:1.97	1:2.01	1:1.96
a ₀ †	5:4174	5.4163	5.4176	5.4173	5.4175	5.4174	5.4176

TABLE 3—*Continued*

	6 Wedge	7 Half Mile Lake	8 Heath Steele A	8 Heath Steele B	9 Dominion	10 Cobbler Sexton	11 Petitcodiac
Fe	44.63	45.53	43.98	45.53	45.02	46.16	45.14
Co	0.05	0.04	0.1-0.2	0.04	0.02	0.05	0.01
Ni	0.007	0.003	0.001	0.001	0.008	0.005	0.01
S	53.19	51.99	50.85	52.47	51.94	52.78	51.65
Se	nd	0.0005	nd	0.0005	nd	nd	0.0005
As	0.15	0.21	0.15	0.15	0.01	0.01	0.01
Cu	1.52	0.06	0.86	0.14	0.04	0.04	0.01
Pb	0.13	0.37	0.90	0.56	1.24	0.06	0.04
Zn	0.47	0.32	1.00	0.58	0.62	0.03	0.01
Sb	—	—	—	—	—	—	—
Ba	0.01	—	0.02	0.01	—	—	—
Bi	0.01	0.01	0.02	0.01	0.002	0.002	—
Cd	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Cr	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Ga	0.001	0.001	0.001	0.001	0.001	0.001	0.001
In	0.002	0.001	0.01	0.001	0.001	0.001	0.002
Mn	0.01	0.01	0.10	0.01	0.01	0.01	0.01
Mo	0.003	0.002	0.002	0.002	0.005	0.003	0.01
Si	0.18	0.15	0.53	0.14	0.10	0.05	1.19
Ag	0.001	0.006	0.006	0.001	0.001	0.001	0.001
Sn	0.01	0.01	0.02	0.005	0.005	0.005	0.003
Ti	0.02	0.05	0.03	0.01	0.02	0.01	0.05
V	0.01	0.005	0.005	0.005	0.005	0.005	0.01
Zr	0.01	0.02	0.02	0.01	0.02	0.02	0.02
Total	100.45	98.82	98.64	99.71	99.10	99.28	98.21
Fe:S*	1:2.07	1:1.99	1:1.99	1:2.00	1:1.99	1:1.99	1:2.00
ac‡	5.4178	5.4174		5.4173	5.4173	5.4173	5.4158

of finely included siderite in the pyrite (Fig. 3) which contributes an excess of iron to the analysis over that required for pyrite, the excess of iron appearing in the calculated ratio as a sulphur deficiency because the iron is fixed at unity. No reason other than possible analytical error is apparent for the high ratio for the Wedge Mine pyrite.

Of the remaining minor and trace elements detected in these pyrites, only zirconium has not previously been recorded in pyrite analyses.

CELL DIMENSIONS

The pyrite lattice parameters were determined by iron filtered cobalt radiation ($K\alpha_1 = 1.788952 \text{ \AA}$) and were standardized against silicon. The three reflections of both the silicon and pyrite (which were used in this study) the 422, 511 and 440, occur at about 108° , 118° , and $137^\circ 2\theta$.

TABLE 3—*Concluded*

	12	13	14	15	16	17	18
	Annidale	Lumsden	Teahan	Reserve Brook	Mount Pleasant	Nerepis	Back Bay
Fe	45.02	46.16	45.78	46.94	43.60	45.27	44.51
Co	0.30	0.03	0.02	0.05	0.01	0.02	1.0
Ni	0.01	0.005	0.005	0.02	nd	0.01	0.2
S	52.58	52.94	53.36	49.97	45.51	51.47	51.90
Se	nd	nd	nd	nd	nd	nd	nd
As	0.01	0.05	0.01	0.37	8.50	0.22	0.01
Cu	1.16	0.04	0.29	0.04	0.88	0.09	0.48
Pb	0.08	0.02	0.05	0.75	0.08	0.89	0.06
Zn	0.09	0.01	0.30	0.15	0.88	0.27	0.05
Sb	—	—	—	0.01	nd	—	—
Ba	—	—	0.01	—	nd	—	—
Bi	0.01	0.005	—	—	nd	—	0.002
Cd	0.005	0.005	0.005	0.005	nd	0.005	0.005
Cr	0.03	0.03	0.03	0.03	0.005	0.03	0.03
Ga	0.001	0.001	0.001	0.001	nd	0.001	0.001
In	0.002	0.001	0.001	0.005	0.01	0.005	0.001
Mn	0.01	0.01	0.01	0.02	0.005	0.03	0.01
Mo	0.005	0.005	0.01	0.01	0.01	0.005	0.005
Si	0.10	0.19	0.15	0.23	—	0.32	0.08
Ag	0.003	0.001	0.001	0.006	0.003	0.003	0.001
Sn	0.005	0.005	0.002	0.002	nd	0.005	0.003
Ti	0.02	0.01	0.03	0.005	0.10	0.02	0.04
V	0.005	0.005	0.005	0.005	0.01	0.005	0.005
Zr	0.02	0.02	0.02	0.02	nd	0.03	0.02
Total	99.47	99.54	100.09	98.64	99.60	98.70	98.41
Fe:S*	1:2.02	1:2.00	1:1.99	1:1.85	1:1.94	1:1.98	1:1.98
a ₀ †	5.4173	5.4172	5.4172	5.4177	5.4173	5.4175	5.4203

*This ratio includes Co and Ni with the iron and is obtained after the removal of some iron and sulphur into arsenopyrite, chalcopyrite, galena and sphalerite.

†Includes 5.60 per cent CO₂ present mainly as siderite but with some calcite. All of the CO₂ however was allocated to siderite. The Fe of this siderite was deducted from the total iron present, resulting in a higher Fe:S ratio than would actually occur.

‡All cell size determinations $\pm 0.0001 \text{ \AA}$.

These 20 measurements of the pyrites and of the silicon external standards were statistically processed by an IBM 1620 computer programme utilizing the value for the cell size of silicon of $5.430736 \pm 0.000014 \text{ \AA}$ at 15° C, quoted by Beu, Musil & Witney (1962).

An indication of the probable accuracy of the results is given by the sample of the Nigadoo pyrite. The initial value from the diffractometer measurements, $5.4163 \pm 0.0001 \text{ \AA}$, was thought to be erroneous and so the measurement was repeated using a large diameter powder camera (114.83 mm diam.). The result of $5.4165 \pm 0.0002 \text{ \AA}$ for the film method compares favourably with the previous value.

The precision of the determinations ($\pm 0.0001 \text{ \AA}$)* can be judged by the reproducibility of the three results obtained from three different pyrite samples from the Brunswick No. 12 Mine (Table 3) and which are 5.4174, 5.4175, 5.4176, all $\pm 0.0001 \text{ \AA}$. A further measure of the precision was obtained by making three separate determinations using the last one of the three samples and comparing it with three separate mounts of the one silicon external standard; the results were 5.4176, 5.4176 and 5.4176, all $\pm 0.0001 \text{ \AA}$.

The results of the lattice parameter determinations are given with the analyses in Table 3.

TABLE 4. CELL DIMENSIONS OF PYRITE

Cell Size (\AA)	Remarks	Authors
5.4160 \pm .0003	Pyrite, Rio Marina, Elba* $\text{FeS}_{1.98 \pm .01}$	Peacock & Smith (1941)
5.4176 \pm .0003	Pyrite, Leadville, Colorado $\text{FeS}_{2.00 \pm .01}$	Peacock & Smith (1941)
5.4177 \pm .0001	Pyrite, Leadville, Colorado	Kerr, Holmes & Knox (1945)
5.4179 \pm .0003	" " "	Gordon, (1951)
5.4176 \pm .0003	Synthetic pyrite	Lepp (1956)
5.4165 \pm .0007	Synthetic pyrite, "sulphur deficient"	" "
5.4163 \pm .0007	" " "	" "
5.417	Pyrite, average value	Deer, Howie & Zussman (1962)

*It has been established that the Elba pyrite contains hematite inclusions, and that after removal of the hematite, the ratio is Fe:S, 1:2.00.

The measurements show comparatively little variation in magnitude, but three deviate significantly from the main groupings of 5.4172–5.4176 \AA . These results are of the pyrites from Nigadoo (5.4163 \pm 0.0001 \AA , No. 2), Petitcodiac (5.4158 \pm 0.0001 \AA , No. 11) and Back Bay (5.4203 \pm 0.0001 \AA , No. 18). The value for the cell size of the Nigadoo pyrite is similar to that of the pyrite from Rio Marina, Elba, determined by Peacock & Smith (1941) (Table 4). These authors and later Lepp (1956) believed that low lattice parameters could be a result of a sulphur deficiency in the pyrite lattice, but this feature is now established as being caused by analytical discrepancies and some other reason for low cell size results must be sought. The contention expressed by Yoder & Kullerud (1959) that pyrite is stoichiometric is supported by the present results.

The Petitcodiac pyrite contains few sulphide impurities though some marcasite is present. The peaks measured are consistently broad which can probably be attributed to lattice distortion, though this feature

*Standard error of the mean of 3 reflections at 95% confidence.

cannot account for the low value of 5.4158 Å for the cell parameter. The quartz grains of the sandstone containing this pyrite are strained and there may be a relationship between the straining of the quartz and that postulated for the pyrite.

The Back Bay pyrite, which contains the highest percentages of cobalt and nickel, has a measured cell parameter of 5.4203 ± 0.0001 Å. The presence of cobalt and nickel increase the cell size, and this effect, which is almost linear (Bannister 1940) can be calculated by taking into account the cell parameters of vaesite (NiS_2) (5.6783 Å) and cattierite (CoS_2) (5.5347 Å). The calculated value of 5.4208 Å, assuming that pure pyrite has a cell of 5.4173 Å, is close to the measured value. In general, the results with a larger cell size than 5.4174 Å show arsenic in the analysis (Fleischer 1955). The true effect of this arsenic upon cell size cannot be determined, as some or all of this may be present as arsenopyrite.

SUMMARY

The chemical analyses of the pyrites show generally little variation. The occurrence of galena, sphalerite, chalcopyrite and arsenopyrite as fine inclusions and joined with pyrite, as seen in some of the polished sections, accounts for the presence of most of the corresponding elements in the analyses. The extent to which substitution into the pyrite lattice by these elements can occur is unknown, though it is expected to be negligible.

The cell parameters of all but three of the pyrites compare well with determinations made on synthetic pyrites by different authors, minor fluctuations being interpreted as resulting, in some examples, from the presence of arsenic. The influence of chemistry, notably the substitution of iron by cobalt and nickel in the pyrite lattice, accounts for some variation, but little is known of the effect of anionic substitution of sulphur on the cell parameter of pyrite.

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