A PRELIMINARY ASSESSMENT OF
THE CHEMICAL COMPOSITION OF IRON FORMATIONS IN CANADA

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ABSTRACT

Analytical data on 26 common elements, in over 600 specimens, are stored in a computerized file, which facilitates comparison of the composition of iron formations from different depositional environments and lithological facies. Significant differences are noted: (1) between Lake Superior (average of 201 samples) and Algoma types (447 analyses), (2) between iron formations (all facies) of the Lake Superior type from six depositional basins, and (3) between oxide, silicate and carbonate facies of the Lake Superior type (148, 22 and 31 analyses, respectively) and the mean Algoma type. In the latter the mean content of K_2O, Al_2O_3, Na_2O, P_2O_5, S, B, Cu, Ni, Sr, Ti, V and Zn is more than twice the average for Lake Superior type (all facies); CO_2, Mn and Sc are higher in the Lake Superior type. Correlation coefficients between elements in each of the three main facies for both types may be useful in recognizing genetic processes. For the Algoma type, consistently positive coefficients are found for Co, Ni, Cr and Mg in the carbonate facies, Cr and Ni in the sulfide facies, and Cu, Co, Ni and Cr in the oxide facies; positive correlations of Al, K and Ti were found for all facies of the Lake Superior type.

Keywords: iron formation, Algoma type, Lake Superior type, chemical composition, major elements, minor element content, oxide facies, silicate facies, carbonate facies, sulfide facies, correlation coefficients, Labrador geosyncline, depositional basins.

SOMMAIRE

Un fichier de données sur ordinateur, portant sur 26 éléments courants et plus de 600 échantillons, permet une comparaison des formations de fer de différents environnements de dépôts et facies lithologiques. On note les différences importantes suivantes: (1) entre le type "lac Supérieur" (moyenne de 201 échantillons) et le type Algoma (447 analyses), (2) entre six exemples distincts de formation de fer du type "lac Supérieur", et (3) entre les facies à oxydes, à silicates et à carbonates du type "lac Supérieur" (148, 22 et 31 analyses, respectivement) et la composition moyenne du type Algoma. Celui-ci contient plus de deux fois la te-
neur en K_2O, Al_2O_3, Na_2O, P_2O_5, S, B, Cu, Ni, Sr, Ti, V et Zn de la moyenne de tous les facies du type "lac Supérieur"; CO_2, Mn et Sc sont plus élevés dans ce dernier. Les coefficients de corrélation inter-éléments pour chacun des trois facies principaux des deux types peuvent servir à cerner les processus pétrogénétiques. Pour le type Algoma, les coefficients sont systématiquement positifs pour Co, Ni, Cr et Mg dans le facies à carbonates, Cr et Ni dans le facies à sulfures et Cu, Co, Ni et Cr dans le facies à oxydes; ils le sont pour Al, K et Ti dans tous les facies du type "lac Supérieur".

(Traduit par la Rédaction)

Mots-clés: formation de fer, type Algoma, type Lac Supérieur, composition chimique, éléments majeurs, concentration d'éléments en traces, facies à oxydes, facies à silicates, facies à carbonates, facies à sulfures, coefficients de corrélation, fosse du Labrador, bassin sédimentaire.

INTRODUCTION

Study of the geochemistry of iron formations has been in progress for some years in the Geological Survey of Canada project on the geology of iron deposits. Our aim is to determine variations and similarities in the composition of different iron-formation types and facies and to relate these to depositional environments.

A computer-based file has been developed to store and manipulate the analytical data and coded descriptions of the samples. Descriptive data for samples include: identification, location, associated rocks, geological age, type of iron formation (Algoma, Lake Superior, or other), classification according to five prominent facies (oxide, silicate, carbonate, sulfide or clastic) and information on grain size, texture and mineralogy of samples. Types of iron formation are classified according to systems previously outlined (Gross 1965, 1970, 1980). Some samples were selected to represent specific lithofacies; their iron content falls below 15 wt. %, the minimum considered in the definition of iron formation (James 1954). About 18% of the 650 samples in the file contain less than 15% Fe, and 3% of the samples contain more

TABLE 1. NUMBER OF SAMPLES IN CHEMISTRY-OF-IRON-FORMATION FILE

DOMINANT FACIES

Type of Iron-formation	Oxide	Silicate	Carbonate	Sulfide	Total
Lake Superior	148	22	31	0	201
Algoma	352	8	37	50	447 / 648

SECONDARY FACIES

	Oxide	Silicate	Carbonate	Sulfide	Clastic
Lake Superior	7	14	36	2	4
Algoma	19	33	38	47	11

than 50% Fe. Samples with low or high iron content are included in this study to better determine variability in composition and relationships between elements in the whole suite of siliceous ferruginous sediments.

Distribution of samples within the file by type and facies is far from uniform, as shown in Table 1; this reflects internal project priorities, availability of sample material and the convenience of analyzing batches of samples from selected geographical areas or geological environments.

Of the Algoma-type samples used in the present study, about 40% were collected from the Temagami and Kirkland Lake areas, 10% from the Red Lake–Bruce Lake area, 10% from the Kenora–Dryden area, and about 5% from each of the following areas: Melville Peninsula, N.W.T., Great Whale River, Qué., Michipicoten, Geraldton, Lake St. Joseph, Ont., Bathurst, N.B. and the remainder from other parts of the Superior geological province. Sample distribution for the Lake Superior type of iron formation is shown in Table 2.

For statistical study of the analytical results the data have been categorized according to the dominant lithological facies present in the samples. About one third of the samples were recorded as mixed facies and listed in descending order of dominant to subordinate facies based on mineralogical and petrological data, with some adjustment based on analytical results (Table 1). No further breakdown of the mixed facies samples has been undertaken at this stage of the study.

Descriptive and analytical data were incorporated in a computer-based file using the management system *Statistical Package for the Social Sciences* (Nie *et al.* 1975). The file has been set up for convenient manipulation of data pertaining to any combination of type and facies of iron formation. The system provides the option of inclusion or exclusion of "missing values" in carrying out statistical procedures. Further treatment of data is anticipated in the future, to take advantage of other procedures within this system. For the interpretation of data presented in this paper, only simple statistical measures have been used: maximum, minimum, mean, standard deviation and Pearson correlation coefficients.

ANALYTICAL METHODS

Samples were analyzed by the Analytical Chemistry Section of the Geological Survey of Canada. Fused discs of ground samples were analyzed for Si, Al, Fe, Mg, Ca, Na, K, Ti, P, S and Mn using a Philips PW1450 automatic sequential X-ray-fluorescence spectrometer; ferrous iron, carbon dioxide, water and high concentrations of sulfur were determined chemical-

TABLE 2. MEAN ELEMENT CONTENT OF ALL FACIES OF LAKE–SUPERIOR-TYPE IRON FORMATION IN SIX MAJOR BASINS

BASIN	NO.	CaO	K_2O	SiO_2	Al_2O_3	MgO	FeO	Fe_2O_3	Total* Fe_2O_3	Na_2O	P_2O_5	CO_2	Total H_2O	S
Northern Labrador Geosyncline	6	3.17	.06	39.9	1.22	1.98	11.0	37.2	49.5	.17	.05	3.8	1.5	.02
Central Labrador Geosyncline	31	.64	.03	52.7	.81	1.02	6.3	35.9	42.9	.12	.05	.6	1.9	.02
Southern Labrador Geosyncline	77	2.14	.02	43.5	.74	2.08	10.9	33.4	45.5	.07	.03	6.2	.4	.02
Lac Mistassini – Albanel	41	2.26	.06	46.5	1.02	1.86	15.3	22.2	39.2	.23	.11	8.5	1.5	.05
Belcher Islands	25	1.46	.70	47.6	3.82	2.08	8.8	25.9	35.7	.04	.08	5.2	2.9	.02
Gunflint	22	4.80	.78	56.7	3.16	2.35	11.4	5.9	19.7	.26	.25	9.1	2.6	1.63

	B	Ba	Co	Cr	Cu	Mn	Ni	Sc	Sr	Ti	V	Y	Yb	Zn	Zr
Northern Labrador Geosyncline	–	.001	–	.0092	.0015	.46	–	–	.0033	.027	.0039	–	.0004	–	–
Central Labrador Geosyncline	–	.002	.0022	.0191	.0006	.17	–	–	.0011	.006	.0021	–	.0005	–	–
Southern Labrador Geosyncline	.025	.037	.0030	.0085	.0010	.41	.0027	–	.0030	.007	.0030	.0054	.0006	.004	.0061
Mistassini – Albanel	–	.004	–	.0112	.0008	.42	–	–	.0022	.019	.0052	.0053	.0005	–	–
Belcher Islands	–	.015	–	.0091	.0015	1.34	.0023	.0007	.0059	.038	.0028	.0028	–	–	–
Gunflint	.017	.013	.0023	.0084	.0031	.25	.0053	.0020	.0032	.147	.0112	.0043	.0005	–	.0174

* Total Fe_2O_3 means total Fe calculated as Fe_2O_3
Mean values in lower table (B to Zr) are means only for samples with measurable values.

ly. High sulfur content prevented the determination of ferrous iron in some samples; Fe^{2+} was not analyzed in about 10% of the samples partly because of the high sulfur content. Consequently the total iron content in Tables 2 and 3 cannot be calculated from the mean contents reported for ferrous and ferric iron. Other reported elements were obtained by optical-emission-spectroscopy methods, including one developed specifically for samples containing more than 30% iron. Optical emission results were used for some elements, particularly Ca, Mg, Al, Ti and Mn, where concentrations as determined by X-ray fluorescence were low. Detection limits for As and Zn are relatively high using optical emission spectroscopy, and several elements, e.g., B, Co, Ni, Sc, V, Y, Yb and Zr, either were not found or are present in quantities below the detection limits in more than half the samples.

For the purposes of statistical manipulation in this preliminary study, only reported (i.e., measured) values were used for elements determined by emission spectrography. No attempt was made to assign arbitrary values where element contents fell below the measurable limits of the spectrographic methods.

For major and minor elements determined by X-ray fluorescence, zero values have been treated as such and included in statistical procedures used to determine mean values and in deriving correlation coefficients. In interpreting results, it is thus important to be aware of the proportion of samples that contain measurable quantities of the elements being considered. These proportions are graphically portrayed in Figure 1.

ANALYTICAL RESULTS

The percentages of samples with measurable quantities of spectrographically determined elements are shown in the upper lines of the graph in Figure 1 for the Algoma and Lake Superior types of iron formation and for six Lake Superior basins. The mean quantities of minor elements measured in these samples are shown in the lower lines of the graph. Note that the elements Ba, Cr, Cu, Mn, Ti, V and Sr are present in measurable amounts in a large proportion of the samples from all areas and in all the main facies of iron formation.

COMPARISON OF LAKE SUPERIOR AND ALGOMA TYPES OF IRON FORMATION

The mean contents of 26 elements in Algoma and Lake Superior types of iron formations (all facies) and in the three dominant facies of these two types are shown in Table 3. This table facilitates direct comparisons of mean compositions; differences greater than a factor of two are further emphasized in Table 4.

In silicate facies, K_2O, Na_2O and V are higher in Lake-Superior-type specimens but in other facies, these constituents are higher in Algoma-type specimens. The reverse is true for Fe_2O_3 and Mn; Zr is higher in silicate than in other facies of either type. Algoma-type carbonates are notably high in Cr, but Lake-Superior-type oxide and silicate facies have a higher Cr content. Barium is anomalously low in Lake-Superior-type carbonate, but high in Algoma carbonates. As expected, CaO, MgO and CO_2 are higher and Fe_2O_3 is lower in
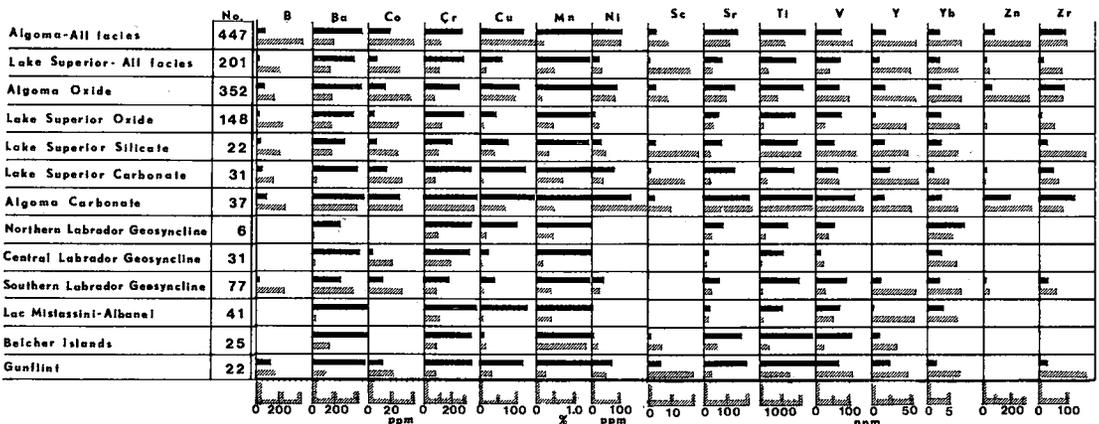
FIG. 1. Percentage of samples with measurable amounts of a trace element (solid line) and mean element content (hatched line).

TABLE 3. MEAN ELEMENT CONTENT OF ALGOMA- AND LAKE-SUPERIOR-TYPE IRON FORMATION BY DOMINANT FACIES

TYPE - DOMINANT FACIES	NO.	CaO	K_2O	SiO_2	Al_2O_3	MgO	FeO	Fe_2O_3	Total** Fe_2O_3	Na_2O	P_2O_5	CO_2	Total H_2O	S
Algoma - All Facies	447	1.87	.62	48.9	3.70	2.00	13.3	24.9	37.7	.43	.23	2.5	1.4	1.57
Lake Superior - All Facies	201	2.24	.20	47.1	1.50	1.93	10.9	28.2	40.1	.13	.08	6.0	1.4	.20
Algoma Oxide	352	1.51	.58	50.5	3.00	1.53	13.0	26.9	41.1	.31	.21	1.1	1.1	.29
Lake Superior Oxide	148	1.58	.14	47.2	1.39	1.24	8.2	35.4	44.5	.12	.06	3.0	1.3	.02
Algoma Silicate	8	.83	.41	46.2	7.56	3.89	18.1	15.8	36.1	.05	.42	1.5	3.5	1.85
Lake Superior Silicate	22	2.40	.63	59.0	2.41	2.73	16.3	8.7	26.7	.20	.10	4.6	2.5	.08
Algoma Carbonate	37	4.78	.86	43.6	6.07	5.54	15.0	4.1	20.0	1.07	.44	15.4	1.5	1.22
Lake Superior Carbonate	31	5.12	.15	38.1	1.40	4.54	21.2	5.1	28.5	.15	.15	21.2	1.5	1.13
Algoma Sulfide	50	2.27	.73	42.5	6.23	2.42	14.6	15.1	27.7	.91	.17	2.5	3.0	10.73

	B	Ba	Co	Cr	Cu	Mn	Ni	Sc	Sr	Ti	V	Y	Yb	Zn	Zr
Algoma - All Facies	.041	.019	.0041	.0118	.0149	.19	.0103	.0008	.0116	.124	.0109	.0054	.0006	.033	.0098
Lake Superior - All Facies	.021	.016	.0028	.0112	.0014	.49	.0037	.0018	.0037	.039	.0042	.0047	.0005	.004	.0081
Algoma Oxide	.016	.017	.0038	.0078	.0096	.14	.0083	.0008	.0098	.086	.0097	.0054	.0006	.033	.0084
Lake Superior Oxide	.024	.018	.0027	.0122	.0010	.46	.0032	-	.0042	.016	.0030	.0041	.0005	.002	.0056
Algoma Silicate	-	.007	.0036	.0038	.0099	.73	.0151	.0011	.0023	.191	.0054	.0084	.0007	.034	.0267
Lake Superior Silicate	.021	.017	.0027	.0102	.0037	.34	.0046	.0022	.0030	.190	.0124	.0043	.0005	-	.0165
Algoma Carbonate	.026	.040	.0031	.0357	.0079	.49	.0205	.0010	.0219	.257	.0140	.0047	.0005	.035	.0085
Lake Superior Carbonate	.015	.004	.0030	.0079	.0012	.72	.0039	.0016	.0029	.033	.0068	.0056	.0003	.010	.0068
Algoma Sulfide	.18	.014	.0057	.0135	.0466	.20	.0115	.0010	.0140	.238	.0153	.0054	.005	.029	.0151

** Total Fe_2O_3 means total Fe calculated as Fe_2O_3
Mean values in lower table (B to Zr) are means only for samples with measurable values.

TABLE 4. COMPARISON OF MEAN ELEMENT CONTENT IN ALGOMA- AND LAKE-SUPERIOR-TYPE IRON FORMATION

	Algoma at least X2 >Lake Superior type	Lake Superior at least X2 > Algoma type
All facies	K_2O,Al_2O_3,Na_2O,P_2O_5, S,B,Cu,Ni,Sr,Ti,V,Zn	CO_2, Mn, Sc*
Oxide facies	K_2O,Al_2O_3,Na_2O,P_2O_5, S,Cu,Ni,Sr,Ti,V,Zn	CO_2, Mn
Silicate facies	Al_2O_3,P_2O_5,S,Cu,Mn, Ni,Y	CaO,Na_2O,CO_2, Ba*,Cr*,Sc*,V*
Carbonate facies	K_2O,Al_2O_3,Na_2O,P_2O_5, Ba,Cr,Cu,Ni,Sr,Ti,V,Zn	

* But found in small percentage of samples.

carbonate than in other facies. Similarly, the Algoma-type sulfide facies have the highest contents of S, Co, Cu, B and V. This facies is not shown in Figure 1, but has a higher percentage of samples containing measurable amounts of Ba, Co, Cu, Ni, Sc, Y and Zr than do other facies.

Detection limits for As with emission spectrography are relatively high (0.1 or 0.2% depending on the method used); As content and distribution have not been shown in the figures and tables. In Lake-Superior-type iron formation, As has been found only in the Lac Mistassini–Albanel basin, where it was reported in measurable quantities in 11 of 41 samples (mean 0.29% in 11 samples). Eight of the samples were oxide and three were carbonate facies.

In Algoma-type iron formation, measurable quantities of As were found in only 9 of 447 samples from the Kirkland Lake–Noranda and Michipicoten areas. Of these samples, four are sulfide, four carbonate, and one is oxide facies.

Samples of Algoma-type iron formation of Early Paleozoic age from the Bathurst area, New Brunswick (Gross 1967) have greatly affected the mean values for some elements. The mean contents of Ba, Mn and P_2O_5 for 19 samples from this area are, respectively, 0.092, 1.83 and 1.82%; in the "Algoma-All Facies" group in Table 3, the mean values for these elements are 0.019, 0.19 and 0.23%, respectively (0.015, 0.11 and 0.16% if the Bathurst group is excluded).

COMPARISON OF LAKE-SUPERIOR-TYPE IRON FORMATION FROM SIX BASINS

The mean concentrations of 26 elements in all facies of each of six basins of Lake-Superior-type iron formation are shown in Table 2. The Na, P and S contents of six specimens from the North Labrador geosyncline are similar to those found in the Central basin of the Labrador geosyncline. B, Ni, V, Zn and Zr were not detected in the North- and Central-basin iron formations; their contents vary in the other basins. In the North basin, Ti, B, Co, Ni, Sc and Y fall below the mean for all Lake-Superior-type iron formations (Table 3). Mn is higher in the North basin than the mean for all specimens of the Lake Superior type.

In the Central basin, Ti, Ba, Cr and V contents fall below the mean for all examples of Lake Superior type (Table 3), and Ti is extremely low. The lower CO_2, MgO, CaO and Mn contents of the rocks of the Central basin are apparently related to the lower carbonate content of the iron formations. Surface weathering, especially in the Central basin, has affected the FeO/Fe_2O_3 ratio and probably further reduced the concentration of elements related to carbonates.

The South basin of the Labrador geosyncline (Wabush Lake area) has the most complete sample coverage available; it is characterized by the lowest contents of K_2O, Al_2O_3, P_2O_5 and S but the highest Ba content for all of the Lake-Superior-type basins studied. The anomalous Ba content is attributable to two samples containing 0.91 and 0.44%, in which barite was identified by X-ray diffraction. Deletion of these samples lowers the mean Ba content of the Southern basin to 0.002%, which is comparable to that in other parts of the Labrador geosyncline.

The iron formation in the Mistassini–Albanel basin is the only Lake-Superior-type example in which measurable quantities of As are reported, in 25% of the samples. A higher percentage of specimens in this basin contain measurable Cr and Cu than in other basins.

The Belcher Islands iron formation is notable for its high Mn content, about three times that in other Lake Superior basins. Along with the Gunflint basin, the Belcher Islands iron formation is high in K_2O, Al_2O_3, H_2O but low in Na_2O.

The lower iron content in the Gunflint samples is compensated to a large extent by the higher silica and carbonate contents and a number of minor elements: CaO, K_2O, MgO, Na_2O, P_2O_5, CO_2, S, Ti, Cu, Ni, Sc, V and Zr are the highest measured for all Lake-Superior-type basins. A higher percentage of specimens from the Gunflint basin contain measurable amounts of Ti, B, Ni, Sc, Sr, Y and Zr than from other basins of this type.

DISCUSSION OF CHEMICAL RELATIONSHIPS

Pearson correlation coefficients have been obtained from these data for most combinations of elements analyzed and have been examined for the common facies in each iron-formation type. The correlation data are being used to test models of chemical environment of deposition for the various facies of iron formation. Their interpretation is complicated by

TABLE 5A. POSITIVE CORRELATION COEFFICIENTS ≥ .70

	Oxide		Silicate	Carbonate		Sulfide
	Lake Superior	Algoma	Lake Superior	Lake Superior	Algoma	Algoma
Fe^{+3}	$T-Fe^{+3}$	$T-Fe^{+3}$			P	$T-Fe^{+3}$
Fe^{+2}			$T-Fe^{+3}$, Mg	$T-Fe^{+3}$ CO_2	$T-Fe^{+3}$	Cu
$T-Fe^{+3}$	Fe^{+3}	Fe^{+3}	Fe^{+2}	Fe^{+2}	Fe^{+2}	Fe^{+3}
Mn			CO_2		P	CO_2
Ti	K		Al,K	Cu,Al, Ba,K	V,Al	Al
V	Co				Ti,	
Co	V,Ni	Ni			Ni,Cr, Mg	
Ni	Co,S	Co,Cr			Co,Cr, Mg	
Cr		Ni			Co,Ni, Mg	
Cu			Al,K	Ti,Al K		Fe^{+2}
Al			Ti,Cu, Ba,K	Ti,Cu, K	Ti	Ti
Mg			Fe^{+2}	CO_2	Co,Ni, Cr	
P			S		Fe^{+3}, Mn	
Ba			Al,K	Ti		
K	Ti		Ti,Cu, Al,Ba	Ti,Cu, Al		
CO_2			Mn	Fe^{+2}, Mg		Mn
S	Ni		P			

the fact that about one third of the samples analyzed represent mixed facies. Combinations of elements of major interest with positive correlation coefficients equal to or greater than 0.4 and 0.7 and negative correlation coefficients equal to −0.4 or less are listed in Tables 5A and 5B, where pairs of elements have been reported in 10 or more samples of a particular facies. (Note that for sample populations of 10, correlation coefficients of 0.44 and 0.72 indicate probabilities of 90 and 99%, respectively, of a correlation different from zero.) These tables and comments refer to elements rather than to oxides as reported in Tables 2 to 4.

The correlation of ferric and ferrous iron with total iron in the various iron-formation facies is according to expectations. The correlation of ferric iron with total iron in the sulfide facies reflects the ferric iron content in magnetite in this facies. The consistently positive correlation-coefficients for Co, Ni, Cr and Mg in the Algoma carbonate facies, the Cr/Ni correlation in the sulfide facies, and Cu/Co/Ni/Cr

TABLE 5B. POSITIVE CORRELATION COEFFICIENTS ≥ .40

	Oxide		Silicate	Carbonate		Sulfide
	Lake Superior	Algoma	Lake Superior	Lake Superior	Algoma	Algoma
Fe^{+3}	T-Fe^{+3},Co	T-Fe^{+3},	T-Fe^{+3}, Cr	Cr	T-Fe^{+3}, Mn,P	T-Fe^{+3},Mn Co,Ni,S
Fe^{+2}	Mg, CO_2	T-Fe^{+3}	T-Fe^{+3}, Mn,Mg	T-Fe^{+3} Mn,V,Mg CO_2	T-Fe^{+3} Ba	Cu
T-Fe^{+3}	Fe^{+3},Co	Fe^{+3}, Fe^{+2},	Fe^{+3},Fe^{+2} Cr	Fe^{+2},V,Co Ni	Fe^{+3}, Fe^{+2},P Ba	Fe^{+3},S
Mn	K,CO_2	P	Fe^{+2},Mg, CO_2	Fe^{+2},Co Mg,CO_2	Fe^{+3},P	Fe^{+3},CO_2
Ti	Al,K	Al,Mg	Al,P,K	Cu,Al,Ba, K	V,Al	Cr,Al,Mg, K
V	Co			Fe^{+2} T-Fe^{+3}, Cr,Al	Ti,Al	
Co	Fe^{+3} T-Fe^{+3} V,Ni,P,K	Ni,Cr, Cu		T-Fe^{+3}, Mn,CO_2	Ni,Cr, Mg,CO_2	Fe^{+3}
Ni	Co,S	Co,Cr,		T-Fe^{+3},P	Co,Cr,	Fe^{+3},Cr,P
Cr		Co,Ni, Mg	Fe^{+3} T-Fe^{+3}	Fe^{+3},V	Co,Ni, Mg,CO_2	Ti,Ni,K
Cu		Co,Ni	Al,P,K	Ti,Al,Ba, K		Fe^{+2}
Al	Ti,K	Ti,K	Ti,Cu,P, Ba,K	Ti,V,Cu, Ba,K	Ti,V,K	Ti,Mg,K
Mg	Fe^{+2},CO_2	Ti,Ni, Cr	Fe^{+2},Mn	Fe^{+2},Mn CO_2	Co,Ni, Cr,CO_2	Ti,Al
P	Co	Mn	Ti,Cu,Al K,S	Ni	Fe^{+3} T-Fe^{+3}, Mn,Ba	Ni
Ba	S		Al,K	Ti,Cu, Al,K	Fe^{+2} T-Fe^{+3},P, K	K
K	Mn,Ti, Co,Al	Al	Ti,Cu, Al,P,Ba	Ti,Cu,Al, Ba	Al,Ba	Ti,Cr, Al,Ba
CO_2	Fe^{+2},Mn, Mg		Mn	Fe^{+2},Mn, Co,Mg	Co,Ni, Cr,Mg	Mn
S	Ba,Ni		P			Fe^{+3} T-Fe^{+3}

NEGATIVE CORRELATION COEFFICIENTS ≤ − .40

	Oxide		Silicate	Carbonate		Sulfide	
	L.S.	Algoma	L.S.	L.S.	Algoma	Algoma	
	CO_2		Fe^{+2} Mg,CO_2		V,Ni,Cr, Mg,CO_2	Ti Al Ba,K	Fe^{+3}
			Fe^{+3}		Ti,V,Ni	Cr,V	Fe^{+2}
					Ti,V,Ni, Mg,	Ti,Al K	T-Fe^{+3}
							Mn
				Cr	Fe^{+2} T-Fe^{+3}	Fe^{+3} T-Fe^{+3}. S	Ti
					Fe^{+3} Fe^{+2} T-Fe^{+3}	Fe^{+2}	V
			S	Cu,Al K			Co
				Fe^{+3} T-Fe^{+3}			
	Al P,S		Ti Mg	Fe^{+3}		Fe^{+2}	Cr
				Co			Cu
				Cr	Co,CO_2 Fe^{+3} T-Fe^{+3} S		Al
				Fe^{+3} Cr	Fe^{+3} T-Fe^{+3}		Mg
	Cr						P
						Fe^{+3}	Ba
				Co	Fe^{+3} T-Fe^{+3}		K
				Fe^{+3} Al	Fe^{+3}		CO_2
	Cr,Co					Ti,Al	S

correlation in Algoma oxide facies may reflect the derivation and hydrothermal transport of these elements from mafic or ultramafic rock sources.

Correlation of Cu with Al and K in Lake-Superior-type silicate and carbonate facies and with ferrous iron in Algoma sulfide facies is notable. Positive correlation coefficients for Al/K/Ti in all facies indicate that this is a significant factor to be considered in genetic modeling of any of the iron formations. Correlation coefficients for Ba with K of 0.4 to 0.5 are found in the silicate, carbonate and sulfide facies analyzed.

Moderate positive correlations involving P are encountered throughout the facies; they occur with Co in Lake Superior and with Mn in Algoma oxide facies, with Ti, Cu, Al and K in silicate facies, and with Ba and elements of the ferride group in carbonate and sulfide facies.

Sulfur is present in a large proportion of the samples in all facies; however, correlation coefficients considered significant are found for only a few elements and for a relatively small number of sample pairs. As the genesis of sulfur in the iron formation may have been influenced greatly by biogenic and metamorphic processes, it is not

surprising that correlations of sulfur with other constituents appear to be erratic where the data refer to a variety of facies and environments of deposition of iron formation. Study of sulfur distribution in well-defined depositional environments would probably reveal more significant correlation data that are compatible with specific genetic models for the iron-formation facies present.

The above comments provide a preliminary and general summary of the minor element data and some of the trends in composition that they may portray. Further study is in progress for the comparison and interpretation of these data with respect to the characteristics of basin environments (Gross 1973) and the origin of iron-rich sediments. Most of the chemical data on iron formations in the literature pertain to only 12 to 16 of the major or most common constituents (James 1966, Gross 1968, Lepp 1975, Kimberley 1979); furthermore, not all of the samples have been classified clearly with respect to the type, lithology or facies of the iron formation. More effective use can be made of the data from the literature for comparative studies of different depositional environments of iron formation by incorporating them in a system that is compatible with the Geological Survey of Canada file.

Preliminary examination of the correlation-coefficient data reveals no apparent inconsistencies with the models of volcanogenic and hydrothermal processes being tested for the various depositional environments as interpreted from field study of the iron formations. Comparison of iron formations with recent metalliferous sediments associated with rift systems and ocean basins (James 1969, Calvert 1978, Scott et al. 1978, Bonatti et al. 1979) suggests important similarities in composition that are being studied in greater detail.

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