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Chemical analyses of meteorites: A compilation of stony and iron meteorite analyses

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Abstract—A compilation of the chemical analyses of 241 stony and 36 iron meteorites is presented; 196 analyses were published previously, 81 are new. This compilation includes analyses of new falls, new finds, previously analyzed meteorites, previously analyzed meteorites with suspect values, analyses of separates and inclusions, and analyses of 53 stony and 29 iron meteorites from Antarctica, including one of the "lunar" type. Mean compositions of chondrite falls, finds, and Antarctic chondrites are compared. References are listed for earlier published analyses and an appendix provides an outline of the sampling procedures, sample preparation, and the analytical methods.

INTRODUCTION

MOST OF THE CHEMICAL ANALYSES in this compilation are from earlier studies, which covered a broad range of descriptive and interpretative research on the origin of meteorites. This paper presents 196 analyses published in 74 papers, and new analyses of 61 stony and 20 iron meteorites. Several of the new analyses are part of ongoing or incomplete studies, others were performed to ascertain whether or not there was anything unique about particular meteorites.

Chemical analysis of meteorites is complex, especially of those that contain metal and sulfides. The complexities are threefold. First, powdering the sample is difficult, especially for metal-rich chondrites and mesosiderites. Second, obtaining a representative sample is often a problem because of the limited amount of available material. Third, metal and sulfides interfere with silicate analysis and require modification of standard analytical procedures. These difficulties were recognized by early students of meteorites, and even with the advent of new techniques, they remain.

Although several new analytical methods are available for analysis of meteorites and silicates, classical methods of silicate analysis were used for most elemental determinations. These versatile methods can be readily modified for the analysis of any type of meteorite. They allow determination of many key phases including the mass fractions of metal, sulfide, sulfate, native sulfur, carbon, carbonate, water, and iron in different oxidation states (Jarosewich, 1966) (see Appendix). Although classical methods sometimes require a larger sample than other techniques, a comprehensive analysis results and the larger sample size gives greater assurance that each sample is representative. It is the opinion of the author that since many meteorites are analyzed only once, a reliable result is worth the modest increase in sample size. A large sample, prepared properly, also provides a representative and homogeneous powder for other studies.

Although classical methods are generally accepted as standard, other methods such as x-ray fluorescence (XRF) and atomic absorption have been used successfully for the analyses of meteorites. For example, Von Michaelis *et al.* (1969) presented XRF data for achondrites and chondrites, and Fulton and Rhodes (1984) for Antarctic meteorites. Atomic absorption has been successfully used for bulk analyses of meteorites (Shima, 1974). Neutron activation analysis gives reliable data for many major, minor and trace elements (*e.g.,* Kallemeyn and Wasson, 1981). Thus, the selection of methods clearly depends on the goals of the study and availability of instrumentation.

For modern geochemical studies, the quality of analytical data is of increasing importance. This was recognized by earlier scientists, and Fairbairn's (1951) compilation of G-1 and W-1 data contributed greatly to improving silicate analyses. These two samples became reference materials for monitoring the quality of analyses within individual laboratories, cross checking results between laboratories, and calibrating various types of analytical instruments. The general acceptance of G-1 and W-1 gave rise to other reference materials (Fleischer, 1969; Flanagan, 1982; Govindaraju, 1989). For meteorite studies, a reference sample was prepared from the Allende meteorite and analyzed by several chemists for 76 elements; 46 were determined by more than one method (Jarosewich *et al.,* 1987).

HISTORICAL OVERVIEW

For centuries, meteorites have been objects of great scientific interest. While some scientists considered meteorites to be extraterrestrial objects and studied them as such, others treated their extraterrestrial origin with a degree of skepticism. However, after the fall of the L'Aigle meteorite in 1803 the extraterrestrial origin of meteorites was accepted and more careful and systematic studies were conducted. The report by Biot on L'Aigle included chemical analyses by the noted chemists Howard, Vauquelin, Fourcroy, and Klaproth.

During the early studies of meteorites, emphasis was placed on their chemical composition. Chemists and mineralogists compared meteorite compositions with those of terrestrial rocks. Since there were clear differences, scientists such as Proust, Hutton, Shaw, Pearson, Higgins, Backwell, and Berzelius "all give the chemical work as the reason for the general acceptance by the scientific community of the fall and extraterrestrial nature of meteorites" (Sears, 1975). Early studies of meteorites were conducted by a small group of researchers, among them Tschermak (1885), Brezina (1904) and Prior (1920), who laid the foundation for our present meteorite classification.

The study of meteorites increased after World War II, and considerably more in the 1960s as space exploration became scientific and national goals. A significant step was Urey and Craig's (1953) evaluation of analytical data on 350 meteorites from early publications. Urey and Craig selected 94 analyses

Table 1. List of analyzed stony and iron meteorites

Meteorite	Class
Stony meteorites	
Abbott	H6
Air	L6
ALHA76004,10	LL3
ALHA76005	EUC
ALHA76008	H6
ALHA77003,20	CO3
ALHA77005,30	SHE
ALHA77005,89, dark	SHE
ALHA77005,90, light	SHE
ALHA77011,11	L3
ALHA77015,17	L3
ALHA77155,12	L6
ALHA77167,19	L3
ALHA77214,18	L3
ALHA77216,7,10,26,32	L3
ALHA77219,27	MES
ALHA77231,25	L6
ALHA77249,16	L3
ALHA77256,33	DIO
ALHA77257,57	URE
ALHA77260,17	L3
ALHA77270,18	L6
ALHA77271,21	H6
ALHA77278,23	LL3
ALHA77284,12	L6
ALHA77294,25	H5
ALHA77295,32	EH4
ALHA77296,12	L6
ALHA77297,23	L6
ALHA77299,17	H3
ALHA77304,24	L4
ALHA77307,55	CO3
ALHA78078,9	L6
ALHA78106,23	L6
ALH82101,16	CO3
ALH83100,74	CM2
ALH83102,45	CM2
ALH84136,23	URE
Allegan	H5
Allende	CV3
Allende, "A"	CV3
Allende, "C"	CV3
Allende, single aggregate	CV3
Allende, chondrules	CV3
Allende, dark inclusion	CV3
Allende, matrix	CV3
Andura	H6
Ankober	H4
Apt	L6
Arapahoe	L5
Ashmore	H5
Atarra	L4
Aumale	L6
Ausson	L5
Avanhandava	H4
Bald Mountain	L4
Bali	CV3
Bandong	LL6
Banten	CM2
Barea	MES
Belgica7904	C3
Bencubbin I	ANOM
Bencubbin II	ANOM
Bholghati	HOW
Bialystok	HOW
Bishunpur	LL3
Bonita Springs	H5
Brachina	ANOM
Bruderheim	L6
Bununu	HOW
Burdett	H5
Butsura	H6
Camel Donga	EUC
Canon City	H6
Casilda	H5
Chantonnay	L6
Chela	H5
Cherokee Springs	LL6
Chiang Khan	H6
Clovis (no.1)	H3
Colony	CO3
Conquista	H4
Coolidge	C4
Cranganore	L6
Crumlin	L5
Cumberland Falls, incl.	ANOM
Denver	L6
Dhajala	H3
Dingo Pup Donga	URE
Dwaleni	H4-6
Dyarrl Island	MES
Eagle	EL6
EETA79001,23,24,35,A	SHE
EETA79001,37,46,B	SHE
EET83213,38	LL3
EET87503,10	HOW
EET87526,11	C4
EET87860,5	C5
Efremovka	CV3
Ehole	H5
El Taco 1, incl.	IAB
El Taco 2, incl.	IAB
El Taco 3, incl.	IAB
Elenovka	L5
Emery	MES
Ensisheim	LL6
Etter	L5
Farmville	H4
Faucett	H4
Forest Vale	H4
Girgenti	L6
Goodland	L4
Grady (1937)	H3
Greenwell Springs	LL4
Guareña	H6
Guibga	L5
Hallingeberg	L3
Hammond Downs	H4
Happy Canyon	EL6
Haraiya	EUC
Hedjaz	L3-6
Holbrook	L6
Homestead	L5
Honolulu	L5
Ibitira	EUC
Inman	L3
Ioka	L3
Ipiranga	H5
Isna	CO3
Itapicuru-Mirim	H5
Jhung	L5
Johnstown	DIO
Kabo	H4
Karatu	LL6
Karkh	L6
Khohar	L3
Kiffa	H4
Knyahinya	L5
Krymka	LL3
Kunashak	L6
Kuttippuram	L6
Kyle	L6
Kyushu	L6
La Criolla	L6
Leedey	L6
LEW87009,4	C6
Lost City	H5
Louisville, dark	L6
Louisville, light	L6
Lowicz	MES
L'Aigle	L6
Mabwe-Khoywa	L5
MAC88105,41	LUN
Macau	H5
Malakal	L5
Manych	LL3
Marilia	H4
Marion (Iowa)	L6
Maryville	L6
Messina	L5
Mezö-Madaras	L3
Millen 5822	H4
Millen 5823	H4
Mills	H6
Minas Gerais	L6
Mirzapur	L5
Modoc (1905)	L6
Moorabie	L3
Murchison	CM2
Murchison, matrix 1	CM2
Murchison, matrix 2	CM2
Nashville, stone	L6
Nejo	L6
Netschaëvo, incl.	IIE
New Concord	L6
North Haig	URE
Nullarbor	H5
Olivenza	LL5
Orgueil	CI1
Oro Grande	H5
Oubari	LL6
Paranaiba	L6
Patrimonio	L6
Patwar	MES
PCA82506,6	URE
PCA82507,5	LL6
Peetz	L6
Petersburg	HOW
Pillistfer	EL6
Plainview (1917)	H5
Pribram	H5
Pulsora	H5
Putinga	L6
Ragland	LL3-4
Ramsdorf	L6
Rio Negro	L4
RKPA80256,7	L3
Rupota	L4
Saint-Séverin	LL6
São José do Rio Preto	H4
Saratov	L4
Schenectady	H4
Segowlie	L6
Semarkona	LL3
Serra de Magé	EUC
Sharps	H3
Shelburne	L5
Sitathali	H5
Study Butte	H3
St.Mary's Co.	LL3
St.Mesmin, dark	LL6
St.Mesmin, D-3	LL6
St.Mesmin, D-5	LL6
St.Mesmin, L-1	LL6
St.Mesmin, L-2	LL6
Sultanpur	L6
Suwahib (Buwah)	H3
Tafoya B	H4-5
Tathlith	L6
Tierra Blanca	ANOM
TIL82402,5	LL6
Tourinnes-la- Grosse	L6
Tuan Tuc	L6
Uberaba	H5
Ucera	H5
Vaca Muerta	MES
Valdinizza	L6
Via Natamoros	L3
Vouillé	L6
Weatherford	ANOM
Weekeroo Station, incl.	IIE
Wethersfield 71	L6
Wethersfield 82	L6
Wickenburg, stone	L6
Willaroy	H3
Winona	ANOM
Woodbine	ANOM
Y-791192	EUC
Y-791195	EUC
Y-791824	CM2
Y-793321	CM2
Iron meteorites	
Alvord	IVA
Filomena	IIA
Lazarev	UNGR (Om)
Navajo 5601	IIB
Nordheim	UNGR
Neptune Mountains	IAB
Sombrerete	UNGR
Waverly USNM 6268	IAB-an
ALHA76002,2	IA
ALHA77250,8	IA
ALHA77255,3	IVA
ALHA77263,3	IA
ALHA77283,7	IA
ALHA77289,7	IA
ALHA77290,6	IA
ALHA78100,4	IIA
ALHA78252,3	IVA
ALHA80104,3	UNGR (D)
ALHA81013,2	IIA
ALHA81014,3	UNGR
ALH84165,3	IIIAB
DRPA78002,3	IIB
DRPA78004,2	IIB
DRPA78005,3	IIB
DRPA78006,3	IIB
DRPA78008,3	IIB
DRPA78009,3	IIB
EET83230,3	UNGR (D)
EET83245,3	IIAB-an
EET83333,4	IAB
EET84300,4	IAB
GRO85201,1	IIIAB
ILD83500,3	UNGR (D)
PGPA77006,5	IA
RKPA79015,13	MES-an
RKPA80226,3	IA

which they considered to be "superior," and rejected 192 analyses as too inaccurate for interpretative studies. Although analytical chemistry was in an early developmental stage at that time, some of the results from these old analyses are in good agreement with more recent ones, and one must acknowledge the ingenuity with which these analyses were performed.

Chemical data have remained essential to the classification of meteorites ever since. Urey and Craig subdivided chondrites

Table 2. Chemical analyses of stony meteorites; concentrations are in wt.%; ND indicates not determined. Remarks(*) at the end of table list results totaled in "Other" column and give additional comments regarding the samples. Column heading abbreviation: FF, falls (FA) finds (FI); Ref, references

Meteorite	Class	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	H2O+	H2O-	Fe(m)	Ni	Co	FeS	C	Other	Total	Fe(t)	FF	Ref
Carbonaceous chondrites																									
Orgueil	* CI1	22.69	0.07	1.70	0.32	13.55	4.63	0.21	15.87	1.36	0.76	0.06	0.22	10.80	6.10				9.08	2.80	8.64	98.86	18.85	FA	68
ALH83100	* CM2	27.81	0.11	3.00	0.43	10.08	11.47	0.21	18.92	1.89	0.47	0.05	0.18	12.05	1.33	<0.1	1.17	0.05	6.77	1.46	2.64	100.09	21.17	FI	
ALH83102	* CM2	27.59	0.12	2.27	0.41	11.01	10.70	0.26	18.92	1.74	0.54	0.04	0.21	11.01	1.93	<0.1	1.14	0.06	7.05	1.39	3.18	99.57	20.50	FI	
Banten	* CM2	28.86	0.12	2.19	0.37		21.88	0.29	19.82	1.89	0.61	0.07	0.24	8.51	2.19	0.14			6.28	1.78	4.56	99.80	21.14	FA	
Murchison	* CM2	29.07	0.13	2.15	0.48		22.39	0.20	19.94	1.89	0.24	0.04	0.23	8.95	1.14	0.13			7.24	1.85	3.73	99.80	22.13	FA	14
Murchison, ma1	* CM2	25.49	0.11	2.52	0.39		28.01	0.22	14.91	1.76	0.36	0.03	0.23	10.08	2.37	ND			5.82	2.03	6.52	100.85	25.48	FA	
Murchison, ma2	* CM2	26.64	0.12	2.29	0.41		27.29	0.20	15.58	1.15	0.14	0.07	0.26	11.61	2.61	ND			4.61	2.69	3.41	99.08	24.14	FA	
Y-791824	* CM2	29.94	0.12	2.18	0.45		21.47	0.21	19.18	1.66	0.62	0.04	0.23	10.28	2.22	ND			6.38	1.22	4.44	100.64	20.75	FI	
Y-793321	* CM2	28.96	0.13	2.38	0.45		20.89	0.22	20.33	2.00	0.60	0.05	0.27	6.54	2.69	ND			8.71	1.35	3.81	99.38	21.77	FI	
Belgica7904	* C3	32.16	0.13	2.54	0.50		22.19	0.24	22.63	1.89	0.60	0.05	0.30	1.27	1.05	<0.1			10.69	1.05	3.42	100.71	24.05	FI	
ALHA77003	CO3	34.19	0.14	2.89	0.49		21.78	0.31	23.53	2.22	0.56	0.06	0.23	1.01	0.88	4.50	1.37	0.07	4.85	0.28		99.36	24.51	FI	60
ALHA77307	* CO3	31.37	0.11	2.50	0.48		24.34	0.20	21.38	1.80	0.15	0.03	0.22	4.54	2.26	0.29	1.72	0.06	6.22	0.80	0.92	99.39	23.16	FI	
ALH82101	CO3	34.51	0.13	3.23	0.46		19.26	0.21	24.00	2.16	0.73	0.07	0.21	<0.1	0.37	4.28	1.47	0.07	8.83	0.06		100.05	24.86	FI	
Colony	* CO3	32.11	0.13	2.73	0.50	22.68	10.21	0.21	19.94	1.39	0.09	0.05	0.24	4.33	1.37	<0.1			1.67	0.55	1.33	99.53	24.86	FI	62
Isna	* CO3	33.62	0.13	2.72	0.47		25.32	0.23	23.54	2.14	0.74	0.06	0.20	1.35	0.26	2.28	1.51	0.07	4.52	0.19		99.35	24.83	FI	29
Allende	* CV3	34.23	0.15	3.27	0.52		27.15	0.18	24.62	2.61	0.45	0.03	0.23	<0.1	0.00	0.17	0.36	0.01	4.03	0.29	1.68	99.98	23.85	FA	11
Allende, "A"	* CV3	29.79	0.99	31.61	0.06		0.37	0.02	10.82	26.76	0.11	0.00	0.00	ND	0.00	ND	0.03	ND	0.00	0.06		100.62	0.29	FA	11
Allende, "C"	* CV3	40.19	0.12	17.78	0.19		8.77	0.10	15.17	5.28	10.60	0.55	ND	ND	ND	ND	0.05	ND	ND	0.02	2.00	100.37	6.82	FA	11
Allende, agr.	* CV3	33.70	1.30	26.60	0.10		2.30	0.00	13.10	21.60	1.10	0.05	ND	ND	0.00	ND	0.06	ND	ND	ND		99.91	1.76	FA	11
Allende, chon.	* CV3	41.87	0.26	5.57	0.47		9.44	0.14	34.34	4.06	0.82	0.06	0.11	ND	0.00	ND	ND	ND	1.78	ND	0.90	99.82	8.47	FA	11
Allende, dark	* CV3	33.42	0.13	2.56	0.56		31.48	0.26	23.91	3.00	0.34	<0.01	0.31	ND	0.00	ND	ND	ND	1.95	0.37	2.32	100.61	25.71	FA	11
Allende, matr.	* CV3	33.11	0.13	3.07	0.55		29.68	0.22	21.42	2.67	0.44	0.03	0.25	ND	0.00	0.40	0.85	0.02	5.49	0.36	1.14	99.83	26.56	FA	11
Bali	* CV3	33.77	0.16	3.16	0.47		26.51	0.19	24.54	2.62	0.52	0.06	0.26	0.30	0.19	0.15	0.22	0.01	4.06	0.57	1.92	99.68	23.34	FA	
Efremovka	CV3	34.31	0.17	3.37	0.55		17.20	0.19	24.71	2.66	0.25	0.03	0.31	1.98	0.31	5.51	1.37	0.06	5.68	0.76		99.42	22.49	FI	9
Coolidge	C4	34.42	0.17	3.31	0.52	11.10	7.26	0.24	24.99	2.66	0.27	0.03	0.38	1.70	0.29	8.28	1.35	0.08	3.13	0.19		100.37	23.68	FI	1
EET87526	* C4	34.47	0.14	2.85	0.51		27.71	0.17	25.17	2.45	0.50	0.03	0.23	0.50	0.42	<0.2	0.97	0.05	2.93	0.03		99.13	23.40	FI	
EET87860	* C5	34.09	0.14	2.91	0.50		27.88	0.19	24.90	2.46	0.44	0.03	0.23	0.30	0.36	<0.3	1.38	0.06	3.33	0.03		99.23	23.79	FI	
LEW87009	* C6	34.51	0.19	3.28	0.51		28.94	0.17	25.11	2.67	0.40	0.04	0.24	<0.1	0.30	<0.3	0.95	0.06	2.22	0.04		99.63	23.91	FI	
H chondrites																									
ALHA77299	H3	35.94	0.11	2.27	0.41		13.15	0.30	22.50	1.81	1.08	0.12	0.22	1.15	0.56	12.26	1.67	0.08	5.23	0.38		99.24	25.80	FI	60
Clovis (no.1)	H3	35.40	0.10	2.06	0.46	10.29	9.02	0.31	22.28	1.64	0.64	0.07	0.33	2.53	0.97	5.09	1.56	0.08	6.36	0.22		99.41	23.33	FI	1
Grady (1937)	* H3	35.90	0.11	1.95	0.52	7.93	7.09	0.31	22.81	1.77	0.69	0.08	0.28	1.01	0.29	11.66	1.61	0.08	5.53	0.11		99.73	26.23	FI	3
Sharps	* H3	35.39	0.12	1.90	0.45		13.64	0.30	22.24	1.71	0.82	0.07	0.29	2.03	0.33	12.02	1.70	0.09	5.77	0.95		99.82	26.26	FA	8
Study Butte	* H3	34.33	0.13	2.06	0.50	14.57	10.93	0.28	21.39	1.81	0.72	0.07	0.24	2.98	0.33	3.75	1.38	0.07	3.98	0.20	0.63	100.35	24.97	FI	
Suwahib (Buwah)	* H3	39.38	0.11	2.35	0.50		9.56	0.35	24.80	1.88	0.88	0.09	0.22	0.21	0.25	11.49	1.25	0.06	5.76	0.07		99.21	22.58	FI	
Willaroy	H3	33.85	0.13	2.13	0.48	22.50	6.70	0.27	21.02	1.61	0.61	0.12	0.19	2.70	0.65	1.35	1.37	0.07	4.63	0.17		100.55	25.30	FI	43
Dhajala	H3	36.87	0.12	2.14	0.56		10.18	0.32	23.66	1.74	0.84	0.10	0.29	0.15	0.05	15.98	1.58	0.04	5.13	0.04		99.79	27.16	FA	
Ankober	* H4	35.35	0.12	2.32	0.55		13.05	0.32	22.86	1.72	0.84	0.12	0.33	0.45	0.46	13.96	1.71	0.10	5.29	0.10		99.65	27.47	FA	27
Avanhandava	H4	36.65	0.12	2.10	0.48		9.95	0.33	23.21	1.68	0.78	0.09	0.26	0.38	0.09	15.96	1.99	0.08	5.43	0.04		9.62	27.15	FA	32
Conquista	* H4	35.99	0.11	2.07	0.47	6.00	8.04	0.31	22.52	1.73	0.81	0.09	0.30	2.15	0.35	11.57	1.64	0.04	4.44	0.27		98.90	24.83	FA	50
Farmville	H4	37.05	0.11	2.09	0.50		10.11	0.33	23.29	1.66	0.82	0.09	0.26	0.22	0.14	16.53	1.82	0.09	4.99	0.12		100.22	27.56	FA	
Faucett	H4	36.12	0.11	2.21	0.53	3.68	9.24	0.29	22.75	1.54	0.70	0.08	0.25	0.86	0.46	13.36	1.70	0.07	5.46	0.15		99.56	26.59	FI	34
Forest Vale	H4	37.46	0.13	1.98	0.46		5.84	0.31	23.23	1.69	0.85	0.11	0.31	0.72	0.06	19.39	1.76	0.09	5.54	0.18		100.11	27.45	FA	3
Hammond Downs	H4	34.17	0.13	2.09	0.49	11.40	9.50	0.32	22.02	1.64	0.79	0.09	0.34	3.40	0.33	5.33	1.59	0.09	4.91	0.14		98.77	23.80	FI	23
Kabo	H4	36.54	0.12	2.15	0.53		9.60	0.33	23.24	1.72	0.82	0.08	0.28	<0.1	0.03	17.56	1.80	0.09	4.82	0.01		99.72	28.09	FA	27
Kiffa	H4	36.14	0.12	2.14	0.52		9.15	0.31	23.26	1.77	0.82	0.10	0.22	<0.1	0.10	17.65	1.77	0.09	5.62	0.01		99.79	28.33	FA	27
Marilia	H4	37.09	0.11	2.06	0.49		9.82	0.32	23.26	1.66	0.84	0.09	0.27	0.30	0.14	16.88	1.71	0.04	5.10	0.15		100.33	27.75	FA	53
Millen 5822	* H4	35.65	0.11	2.06	0.53	7.69	7.49	0.30	22.75	1.54	0.33	0.04	0.26	3.15	0.09	10.68	1.64	0.07	4.80	0.03	0.54	99.72	24.92	FI	
Millen 5823	* H4	34.71	0.09	2.00	0.48	17.38	7.57	0.30	22.20	1.46	0.37	0.04	0.26	2.37	0.61	2.22	1.62	0.05	4.88	0.03	0.64	99.25	23.36	FI	
São José do Rio	* H4	36.70	0.11	2.49	0.54		10.02	0.31	23.08	1.83	0.86	0.09	0.25	0.92	0.34	15.89	1.69	0.06	4.88			100.06	26.78	FA	46
Schenectady	* H4	36.20	0.12	2.25	0.55		11.77	0.32	23.00	1.77	0.83	0.10	0.29	0.69	0.23	15.01	1.72	0.09	5.29	0.12		100.35	27.52	FA	27
Tafoya B	H4-5	35.43	0.10	2.07	0.51		14.53	0.29	22.58	1.70	0.64	0.07	0.23	0.23	1.13	13.26	1.76	0.07	4.99	0.09		99.68	27.73	FI	
Dwaleni	H4-6	36.49	0.12	2.30	0.51		9.52	0.27	23.16	1.72	0.88	0.09	0.22	0.18	0.03	17.23	1.75	0.09	5.21	0.04		99.81	28.41	FA	27
ALHA77294	H5	37.75	0.14	2.31	0.57		8.76	0.33	23.66	1.83	0.72	0.07	0.25	<0.1	0.23	16.00	1.84	0.06	5.62	0.02		100.16	26.38	FI	60
Allegan	H5	36.69	0.10	1.95	0.54		9.16	0.30	23.04	1.65	0.85	0.09	0.27	<0.1	0.16	17.95	1.76	0.10	5.54	0.05		100.20	28.54	FA	9
Ashmore	H5	36.43	0.11	2.00	0.55	1.70	10.20	0.29	22.88	1.60	0.81	0.10	0.20	0.44	0.09	14.36	1.70	0.08	5.92	0.02		99.48	27.24	FI	28
Bonita Springs	H5	36.04	0.11	1.96	0.47		10.79	0.33	23.01	1.62	0.61	0.06	0.38	1.53	0.25	15.04	1.64	0.09	5.70	0.10		99.73	27.06	FI	1
Burdett	H5	35.60	0.12	2.07	0.53	7.14	8.80	0.30	21.82	1.48	0.49	0.06	0.23	1.94	0.55	11.15	1.68	0.09	5.40	0.08		99.53	26.42	FI	12
Casilda	* H5	37.13	0.12	2.08	0.52		12.52	0.30	23.32	1.60	0.66	0.08	0.24	1.12	0.25	11.80	1.64	0.08	5.81	0.13		99.40	25.22	FI	22
Chela	H5	37.34	0.12	2.23	0.48		9.67	0.30	23.96	1.76	0.83	0.09	0.25	0.61	0.21	15.72	1.73	0.08	4.96	0.06		100.40	26.39	FA	
Ehole	H5	36.84	0.14	2.02	0.49		10.37	0.29	23.66	1.76	0.85	0.10	0.25	<0.1	0.03	16.00	1.62	0.08	5.18	0.09		99.77	27.35	FA	1
Ipiranga	H5	37.10	0.12	2.17	0.52		9.90	0.27	23.55	1.77	0.90	0.11	0.26	0.51	0.15	14.96	1.68	0.09	5.68	0.11		99.85	26.27	FA	47
Itapicuru-Mirim	* H5	35.61	0.11	2.05	0.53		9.44	0.32	22.31	1.63	0.79	0.09	0.24	0.90	0.11	19.09	1.93	0.05	4.96	0.34		100.50	29.58	FA	39
Lost City	H5	36.49	0.12	2.08	0.53		9.42	0.29	23.67	1.72	0.89	0.10	0.33	<0.1	0.00	16.75	1.65	0.09	5.62	0.01		99.76	27.64	FA	17
Macau	H5	36.26	0.11	2.02	0.52	6.19	8.83	0.32	22.74	1.65	0.84	0.09	0.26	1.42	0.10	12.07	1.68	0.06	4.74	0.12		100.02	26.27	FA	40
Nullarbor	H5	38.36	0.12	2.12	0.52		11.28	0.35	24.22	1.75	1.03	0.13	0.22	<0.1	0.04	14.66	1.47	0.05	3.53	0.04		99.89	25.65	FI	
Oro Grande	H5	34.18	0.14	1.83	0.55	21.25	9.13	0.31	21.52	1.72	0.70	0.08	0.25	2.14	0.40	0.84	1.46	0.07	3.62	0.22		100.41	25.10	FI	20
Plainview (1917)	H5	35.86	0.12	2.26	0.55		12.90	0.32	23.04	1.77	0.69	0.10	0.26	0.98	0.28	13.03	1.64	0.08	5.90	0.11		99.89	26.81	FI	31
Príbram	H5	37.22	0.11	2.10	0.50		9.34	0.30	23.72	1.79	0.87	0.09	0.29	0.27	0.03	14.78	1.68	0.08	6.47	0.07		99.71	26.15	FA	17
Pulsora	H5	35.97	0.12	2.26	0.52		10.58	0.29	22.77	1.59	0.84	0.10	0.26	<0.1	0.10	17.23	1.78	0.10	4.99	0.14		99.64	28.62	FA	26
Sitathali	H5	36.65	0.14	2.37	0.43		9.96	0.31	23.45	1.71	0.87	0.10	0.30	0.10	0.06	16.08	1.79	0.09	5.76	0.05		100.22	27.48	FA	26
Uberaba	H5	37.50	0.12	2.30	0.55		11.52	0.32	23.43	1.78	0.90	0.09	0.25	0.57	0.05	13.50	1.73	0.05	5.70	0.09		100.45	26.08	FA	38
Ucera	H5	37.28	0.11	2.10	0.52		10.20	0.31	23.78	1.74	0.88	0.09	0.26	<0.1	0.00	14.70	1.67	0.08	5.98	<0.01		99.70	26.43	FA	17
Abbott	H6	36.15	0.12	2.25	0.45	7.23	8.04	0.31	22.96	1.77	0.59	0.07	0.23	1.32	0.48	10.89	1.52	0.08	4.96	0.10		99.52	25.35	FI	33
ALHA76008	H6	35.40	0.10	2.14	0.45	12.63	7.76	0.30	22.21	1.68	0.84	0.10	0.30	2.20	0.47	6.70	1.71	0.08	4.14	0.20		99.41	24.20	FI	51
ALHA77271	H6	36.88	0.11	1.97	0.50		13.43	0.28	23.36	1.60	0.83	0.10	0.22	0.91	0.34	12.90	1.69	0.09	4.42	0.04		99.67	26.15	FI	60
Andura	* H6	36.85	0.16	1.85	0.53		12.23	0.39	23.42	1.97	0.91	0.12	0.29	0.19	0.10	13.72	1.62	0.08	5.57	0.05		100.05	26.74	FA	26
Butsura	H6	36.27	0.12	1.98	0.56		9.65	0.31	23.21	2.00	0.85	0.08	0.31	0.53	0.13	16.61	1.75	0.07	5.89	0.06		100.38	27.85	FA	26
Canon City	H6	36.70	0.14	2.10	0.54		9.31	0.34	23.41	1.80	0.94	0.08	0.30	<0.1	0.12	16.95	1.82	0.09	5.62	0.06		100.32	27.76	FA	
Chiang Khan	H6	37.23	0.13	2.30	0.50		9.64	0.32	23.64	1.73	0.92	0.08	0.24	0.26	0.02	16.17	1.66	0.09	5.21	0.02		100.16	26.98	FA	
Guareña	H6	36.74	0.12	2.04	0.55		10.24	0.32	23.44	1.60	0.90	0.09	0.27	<0.1	0.15	16.30	1.74	0.09	5.48	0.02		100.09	27.74	FA	9
Mills	H6	35.27	0.12	2.45	0.47	16.19	7.91	0.28	22.13	1.68	0.77	0.11	0.23	1.83	0.57	4.05	1.63	0.07	4.28	0.09		100.13	24.24	FI	25
L chondrites																									
ALHA77011	* L3	38.21	0.14	2.29	0.57		20.07	0.27	23.89	1.78	0.92	0.12	0.25	2.12	0.63	1.94	1.02	0.06	4.47	0.97		99.72	20.38	FI	60
ALHA77015	* L3	38.23	0.14	2.29	0.57		19.63	0.26	23.97	1.71	0.74	0.10	0.25	2.09	0.46	2.30	1.12	0.06	4.69	0.98		99.59	20.54	FI	60
ALHA77167	* L3	37.94	0.13	2.18	0.58		19.64	0.26	23.85	1.64	0.91	0.11	0.24	2.11	0.63	2.44	1.13	0.06	4.55	0.99		99.39	20.60	FI	60
ALHA77214	* L3	37.73	0.11	2.30	0.49		19.63	0.33	22.69	1.70	0.82	0.07	0.21	2.34	0.95	2.02	1.18	0.06	5.73	1.08		99.44	20.77	FI	60
ALHA77216	L3	39.43	0.10	2.25	0.49		15.85	0.32	24.57	1.67	0.90	0.12	0.20	0.34	0.41	6.40	1.13	0.06	5.75	0.04		100.03	22.37	FI	60
ALHA77249	* L3	36.96	0.12	2.21	0.53		21.28	0.26	22.91	1.60	0.86	0.11	0.24	2.61	0.73	2.25	1.17	0.07	4.41	1.08		99.40	21.59	FI	60
ALHA77260	* L3	37.53	0.13	2.15	0.56		21.45	0.24	23.82	1.75	0.83	0.11	0.27	2.31	0.68	1.53	1.11	0.06	3.43	1.07		99.03	20.39	FI	60
Hallingeberg	L3	39.20	0.11	2.24	0.53		14.01	0.34	23.97	2.26	0.91	0.12	0.16	0.95	0.36	6.86	1.29	0.06	6.64	0.26		100.27	21.97	FA	1
Inman	L3	39.92	0.12	2.26	0.55	7.05	10.13	0.33	24.58	1.98	0.51	0.10	0.20	1.64	0.81	1.56	0.97	0.04	6.33	0.35		99.43	18.38	FI	48
Ioka	L3	38.99	0.15	2.11	0.43	5.49	11.56	0.33	24.13	1.83	0.88	0.11	0.21	1.47	0.35	3.75	1.24	0.05	6.61	0.12		99.81	20.77	FI	1
Khohar	L3	39.40	0.11	2.28	0.52		14.20	0.35	24.72	1.78	0.89	0.10	0.27	1.16	0.09	6.61	1.25	0.05	6.14	0.32		100.24	21.55	FA	1
Mezö-Madaras	L3	39.58	0.13	1.94	0.52		14.46	0.36	24.61	2.01	0.99	0.11	0.27	0.79	0.13	6.54	1.24	0.06	6.01	0.46		100.21	21.60	FA	3
Moorabie	L3	39.60	0.13	2.21	0.54		11.26	0.33	24.93	1.99	0.91	0.09	0.26	0.55	0.11	10.19	1.24	0.06	5.35	0.13		99.88	22.34	FI	
RKPA80256	L3	37.84	0.13	2.14	0.54		13.71	0.32	23.52	1.88	0.92	0.10	0.20	0.38	0.12	8.09	1.20	0.06	8.56	0.06		99.77	24.19	FI	
Via Natamoros	L3	39.30	0.15	2.37	0.42		16.06	0.32	24.53	1.86	0.87	0.10	0.19	0.67	0.25	5.30	1.19	0.06	5.81	0.21		99.66	21.47	FI	69
Hedjaz	L3-6	39.93	0.16	1.61	0.49		11.77	0.33	24.73	1.95	0.97	0.11	0.26	0.78	0.00	9.03	1.29	0.06	6.17	0.27		99.91	22.10	FA	67
ALHA77304	L4	40.49	0.14	2.35	0.57		16.36	0.28	25.10	1.81	1.01	0.13	0.22	0.76	0.23	4.36	1.16	0.07	4.80	0.01		99.85	20.13	FI	60
Atarra	* L4	39.58	0.14	1.76	0.54		14.07	0.34	24.87	2.07	1.04	0.12	0.23	1.12	0.10	7.12	1.41	0.06	5.37	0.64		100.58	21.44	FA	35
Bald Mountain	L4	38.53	0.13	2.22	0.58		12.78	0.33	23.95	1.83	0.83	0.12	0.20	0.63	0.10	8.44	1.26	0.07	8.09	0.29		100.38	23.52	FA	61

Table 2. Continued.

Meteorite	Class	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	H2O+	H2O-	Fe(m)	Ni	Co	FeS	C	Other	Total	Fe(t)	FF	Ref
Goodland	L4	39.67	0.15	2.27	0.52		14.61	0.33	24.67	1.86	0.77	0.08	0.24	0.53	0.26	5.91	1.25	0.05	6.64	0.04		99.85	21.49	FI	3
Rio Negro	* L4	39.32	0.12	2.18	0.56		14.54	0.34	24.26	1.77	0.90	0.10	0.26	2.56	0.04	6.67	1.17	0.07	5.24			100.10	21.40	FA	53
Rupota	L4	39.53	0.12	2.14	0.51		14.17	0.32	24.43	1.88	0.94	0.08	0.28	0.47	0.22	6.71	1.24	0.05	6.56	0.13		99.78	21.89	FA	9
Saratov	L4	40.48	0.13	2.27	0.57		12.42	0.34	25.27	1.99	0.85	0.10	0.22	0.32	0.04	8.34	1.16	0.04	5.77	0.10		100.41	21.73	FA	61
Arapahoe	L5	39.88	0.12	2.28	0.57		13.86	0.35	24.81	1.83	0.93	0.08	0.21	<0.1	0.08	7.14	1.30	0.07	6.29	0.03		99.83	22.09	FI	61
Ausson	L5	38.79	0.09	2.32	0.45		14.96	0.30	24.28	1.83	0.96	0.10	0.29	0.22	0.07	8.50	1.33	0.08	5.73	0.09		100.39	23.77	FA	61
Crumlin	L5	39.92	0.12	2.25	0.57		14.24	0.37	24.93	1.75	0.92	0.11	0.17	0.54	0.04	7.49	1.09	0.07	4.72	0.20		99.50	21.56	FA	61
Elenovka	L5	39.56	0.12	2.25	0.54		14.04	0.34	24.35	1.86	0.99	0.10	0.23	<0.1	0.08	8.14	1.24	0.06	6.28	0.05		100.23	23.04	FA	61
Etter	L5	39.71	0.12	2.29	0.55		16.56	0.30	24.98	1.90	0.81	0.07	0.24	0.76	0.24	4.10	1.15	0.06	5.76	0.04		99.64	20.63	FI	59
Guibga	L5	39.53	0.11	2.35	0.50		14.54	0.31	24.37	1.84	0.90	0.11	0.20	<0.1	0.08	7.88	1.44	0.07	6.01	0.04		100.28	23.00	FA	
Homestead	L5	39.79	0.13	2.27	0.56		13.56	0.35	24.86	1.78	0.95	0.13	0.27	0.36	0.10	8.05	1.31	0.07	5.84	0.16		100.54	22.20	FA	61
Honolulu	L5	39.35	0.12	2.26	0.58		14.42	0.28	24.72	1.76	1.08	0.14	0.16	0.18	0.03	7.17	1.28	0.08	6.39	0.12		100.12	22.44	FA	61
Jhung	L5	39.86	0.13	2.36	0.56		14.22	0.34	24.62	1.85	0.95	0.10	0.29	0.30	0.03	7.60	1.28	0.07	5.10	0.19		99.85	22.00	FA	61
Knyahinya	L5	41.01	0.12	2.36	0.52		14.93	0.37	25.34	2.01	0.96	0.10	0.27	0.24	0.02	4.31	1.05	0.05	6.00	0.21		99.87	19.72	FA	
Mabwe-Khoywa	L5	39.47	0.12	2.40	0.55		14.36	0.31	24.48	1.83	0.93	0.10	0.21	0.80	0.09	6.43	1.23	0.06	6.58	0.19		100.14	21.77	FA	35
Malakal	L5	40.38	0.14	2.14	0.50		15.32	0.28	24.88	1.85	0.95	0.10	0.17	<0.1	0.03	7.56	1.18	0.05	4.30	0.03		99.86	22.30	FA	27
Messina	L5	40.10	0.11	2.29	0.49		14.92	0.37	24.90	1.80	0.92	0.11	0.23	0.40	0.01	6.68	1.06	0.06	5.12	0.06		99.63	21.53	FA	63
Mirzapur	L5	40.51	0.11	2.34	0.46		14.42	0.34	25.26	1.72	1.02	0.10	0.21	<0.1	0.14	6.88	1.41	0.07	4.55	0.16		99.70	20.98	FA	35
Shelburne	L5	40.44	0.13	2.32	0.53		13.26	0.35	25.06	1.81	0.92	0.10	0.23	0.84	0.15	7.71	1.41	0.07	4.47	0.44		100.24	20.83	FA	61
Air	L6	39.51	0.12	2.54	0.54		13.88	0.34	24.94	1.88	0.98	0.10	0.27	0.19	0.07	6.88	1.41	0.06	6.36	0.07		100.14	21.78	FA	54
ALHA77155	L6	39.99	0.13	2.21	0.54		16.33	0.32	24.70	1.79	0.95	0.11	0.20	0.23	0.26	6.09	1.34	0.06	4.32	0.04		99.61	21.53	FI	60
ALHA77231	L6	39.43	0.11	2.18	0.49		16.07	0.31	24.47	1.75	0.91	0.12	0.23	0.45	0.30	6.37	1.20	0.06	4.88	0.03		99.36	21.96	FI	60
ALHA77270	L6	40.15	0.12	2.49	0.53		15.46	0.32	24.92	1.79	0.96	0.11	0.26	0.08	0.23	5.99	1.12	0.07	5.34	0.01		99.95	21.40	FI	60
ALHA77284	L6	40.43	0.12	2.30	0.48		14.50	0.32	25.17	1.78	0.91	0.10	0.18	0.58	0.21	5.90	1.20	0.06	5.16	0.01		99.41	20.45	FI	60
ALHA77296	L6	40.21	0.14	2.36	0.57		15.53	0.35	25.00	1.96	0.80	0.09	0.22	<0.1	0.20	6.00	1.26	0.06	4.80	0.01		99.56	21.12	FI	60
ALHA77297	L6	40.13	0.14	2.41	0.52		15.43	0.36	25.02	1.93	0.80	0.08	0.24	<0.1	0.14	6.39	1.11	0.07	5.24	0.01		100.02	21.72	FI	60
ALHA78078	L6	38.64	0.13	2.34	0.58		15.57	0.35	24.49	1.86	0.74	0.07	0.25	0.44	0.27	6.48	1.32	0.07	6.03	0.02		99.65	22.41	FI	60
ALHA78106	L6	39.70	0.13	2.36	0.51		14.31	0.36	25.13	1.96	0.75	0.07	0.22	<0.1	0.11	6.78	1.29	0.07	5.87	0.01		99.63	21.64	FI	60
Apt	L6	39.21	0.13	2.27	0.56		15.96	0.37	24.72	1.82	0.97	0.11	0.22	0.81	0.08	6.26	1.34	0.07	4.63	0.15		99.68	21.58	FA	54
Aumale	L6	39.94	0.12	2.31	0.50		13.51	0.30	24.92	1.87	0.98	0.11	0.26	0.20	0.05	7.46	1.26	0.07	5.81	0.09		99.76	21.65	FA	56
Bruderheim	L6	39.26	0.12	2.36	0.50		14.24	0.35	24.73	1.80	0.94	0.11	0.21	<0.1	0.03	7.46	1.16	0.06	6.20	0.15		99.68	22.47	FA	
Chantonnay	L6	39.63	0.12	2.45	0.55		17.61	0.34	24.96	1.82	0.90	0.11	0.25	0.43	0.09	4.08	1.17	0.06	5.29	0.06		99.92	21.13	FA	56
Cranganore	L6	39.56	0.14	2.32	0.54		14.06	0.31	24.68	1.75	1.00	0.11	0.26	1.21	0.17	7.37	1.29	0.06	5.02	0.90		100.75	21.49	FA	35
Denver	L6	40.57	0.14	2.48	0.47		14.16	0.33	25.30	1.83	1.01	0.12	0.23	<0.1	0.05	6.46	1.17	0.06	5.71	0.04		100.13	21.10	FA	6
Girgenti	L6	39.15	0.12	2.22	0.49		16.21	0.35	23.86	1.82	0.90	0.10	0.24	0.14	0.12	6.80	1.17	0.07	6.47	0.03		100.26	23.51	FA	19
Holbrook	* L6	38.84	0.12	2.30	0.52		20.10	0.35	24.15	1.84	1.02	0.13	0.24	1.49	0.35	1.42	1.07	0.05	5.43	0.32		99.74	20.49	FA	
Karkh	L6	38.70	0.12	2.26	0.52		14.32	0.31	25.01	1.60	0.92	0.10	0.23	0.27	0.11	6.87	1.63	0.06	6.91	0.02		99.96	22.39	FA	35
Kunashak	L6	39.96	0.12	2.42	0.53		15.28	0.35	25.00	1.83	0.93	0.12	0.26	0.10	0.05	6.40	1.20	0.07	5.48	0.12		100.22	21.76	FA	61
Kuttippuram	* L6	38.75	0.14	2.11	0.50		15.45	0.31	23.62	1.89	1.04	0.14	0.12	0.27	0.06	6.42	1.41	0.06	7.40	0.04		99.73	23.10	FA	35
Kyle	L6	38.41	0.11	2.13	0.55	8.02	14.83	0.31	23.10	1.60	0.74	0.08	0.19	1.73	0.37	0.38	1.22	0.05	5.98	0.03		99.83	21.31	FI	15
Kyushu	L6	39.64	0.12	2.34	0.53		14.46	0.34	24.72	1.82	0.92	0.09	0.17	0.14	0.24	6.99	1.12	0.06	5.81	0.24		99.75	21.92	FA	
La Criolla	L6	39.60	0.13	2.23	0.53		15.76	0.32	24.98	2.00	0.96	0.09	0.21	<0.1	0.24	6.31	1.23	0.05	5.35	<0.02		99.99	21.96	FA	
Leedey	L6	40.32	0.12	2.19	0.52		12.43	0.34	24.94	1.82	1.00	0.11	0.18	<0.1	0.05	8.37	1.21	0.06	6.42	0.08		100.16	22.11	FA	3
Louisville, d.	* L6	39.28	0.13	2.23	0.55		14.87	0.35	24.42	1.80	0.91	0.11	0.18	ND	0.03	7.44	1.31	0.08	6.01	0.06		99.76	22.82	FA	
Louisville, l.	* L6	40.73	0.13	2.22	0.55		15.09	0.36	25.45	1.80	0.96	0.11	0.19	0.12	0.03	5.85	1.23	0.06	4.83	0.04		99.75	20.65	FA	45
L'Aigle	L6	39.20	0.12	2.19	0.48		13.46	0.30	24.31	1.82	0.96	0.12	0.28	0.45	0.11	8.15	1.29	0.07	6.58	0.12		100.01	22.79	FA	56
Marion (Iowa)	L6	39.53	0.11	2.35	0.49		15.32	0.36	24.27	1.94	1.02	0.11	0.20	1.42	0.16	5.43	1.09	0.06	6.03	0.38		100.27	21.17	FI	
Maryville	L6	39.92	0.12	2.26	0.49		14.12	0.34	24.90	1.78	0.98	0.08	0.23	<0.1	0.04	7.39	1.24	0.06	5.43	0.09		99.47	21.47	FA	64
Minas Gerais	L6	39.32	0.12	2.41	0.60		15.27	0.35	24.83	2.00	0.96	0.11	0.29	0.37	0.25	7.08	1.34	0.05	5.29	0.23		100.84	22.31	FI	53
Modoc (1905)	L6	39.84	0.11	2.34	0.53		14.69	0.36	25.00	1.86	0.94	0.10	0.22	0.22	0.09	6.34	1.22	0.06	5.73	0.38		100.03	21.40	FA	
Nashville, stone	L6	39.30	0.13	2.28	0.52		16.34	0.34	24.53	1.76	0.74	0.07	0.33	1.10	0.48	4.21	1.19	0.05	6.44	0.05		99.88	21.00	FI	
Nejo	L6	39.98	0.12	2.27	0.56		14.22	0.32	24.83	1.82	0.92	0.10	0.24	<0.1	0.03	7.10	1.27	0.06	6.47	0.01		100.32	22.26	FA	21
New Concord	L6	39.30	0.13	2.24	0.52		14.68	0.33	24.65	1.68	1.04	0.11	0.18	<0.1	0.18	7.04	1.19	0.06	5.84	0.39		99.56	22.16	FA	
Paranaiba	L6	40.22	0.14	2.17	0.45		13.37	0.37	24.96	1.92	0.96	0.11	0.23	0.49	0.06	6.57	1.30	0.05	6.17	0.04		99.58	20.86	FA	
Patrimonio	* L6	39.84	0.11	2.06	0.47		16.11	0.33	24.38	1.84	0.91	0.10	0.21	0.80	0.21	5.07	1.14	0.04	6.17	0.28		100.07	21.51	FA	44
Peetz	L6	38.99	0.11	2.33	0.41		17.76	0.34	24.16	1.71	0.94	0.11	0.20	0.52	0.08	4.86	1.23	0.07	5.84	0.08		99.74	22.39	FI	61
Putinga	L6	38.95	0.13	2.35	0.52		17.03	0.34	24.32	1.80	0.95	0.11	0.27	0.81	0.06	6.03	1.15	0.07	4.96	0.20		100.05	22.42	FA	49
Ramsdorf	L6	39.03	0.13	2.40	0.52		15.42	0.33	24.60	1.86	0.91	0.11	0.18	ND	0.12	9.12	1.25	0.07	3.87	0.24		100.16	23.57	FA	
Segowlie	L6	39.05	0.16	2.30	0.51	3.03	14.36	0.33	24.34	1.67	0.96	0.13	0.20	0.35	0.24	4.16	1.22	0.04	6.31	0.06		99.42	21.45	FA	35
Sultanpur	L6	39.90	0.16	2.07	0.51		16.25	0.35	24.21	1.75	0.90	0.10	0.18	0.18	0.19	6.39	1.20	0.06	5.38	0.04		99.82	22.44	FA	35
Tathlith	L6	39.44	0.14	2.40	0.52		13.84	0.33	24.35	1.88	0.99	0.11	0.21	<0.1	0.11	7.61	1.14	0.06	6.58	0.03		99.74	22.55	FA	27
Tourinnes-la.	L6	39.78	0.12	2.24	0.55		14.78	0.34	24.65	1.87	0.94	0.12	0.26	0.22	0.06	7.31	1.16	0.07	5.00	0.09		99.56	21.98	FA	54
Tuan Tuc	L6	40.37	0.13	2.38	0.60		13.93	0.35	25.27	1.87	0.92	0.11	0.27	0.20	0.04	7.12	1.18	0.07	4.83	0.04		99.68	21.02	FA	56
Valdinizza	L6	40.73	0.12	2.31	0.56		14.16	0.33	25.57	1.93	1.02	0.11	0.21	<0.1	0.03	6.60	1.21	0.05	5.07	0.04		100.05	20.83	FA	13
Vouillé	L6	40.17	0.11	2.07	0.49		13.15	0.36	24.95	1.83	0.92	0.11	0.24	0.26	0.02	6.91	1.12	0.04	6.91	0.06		99.72	21.52	FA	56
Wethersfield 71	L6	39.42	0.12	2.26	0.50		15.48	0.34	24.64	1.82	1.05	0.11	0.18	<0.1	0.10	7.00	1.25	0.06	5.46	0.01		99.80	22.50	FA	27
Wethersfield 82	L6	40.50	0.13	2.29	0.61		13.82	0.36	25.40	1.94	0.81	0.09	0.20	<0.1	0.00	6.63	1.17	0.06	5.75	0.01		99.77	21.03	FA	
Wickenburg, stone	L6	40.38	0.12	2.29	0.47		14.94	0.36	25.29	1.86	0.96	0.13	0.25	<0.1	0.04	5.98	1.09	0.05	5.10	0.02		99.33	20.83	FI	61
LL chondrites																									
ALHA76004	LL3	40.46	0.13	2.30	0.56		15.99	0.36	24.92	2.07	0.92	0.10	0.18	0.43	0.20	3.63	0.97	0.06	5.95	0.02		99.25	19.84	FI	
ALHA77278	LL3	41.03	0.12	2.26	0.50		16.79	0.34	24.08	1.90	0.82	0.10	0.20	1.20	0.38	2.23	1.03	0.05	6.17	0.16		99.36	19.20	FI	60
EET83213	* LL3	41.59	0.14	2.30	0.54		15.37	0.29	25.61	1.98	0.92	0.09	0.17	0.40	0.32	3.95	0.98	0.05	4.99	0.02		99.71	19.07	FI	
Bishunpur	LL3	40.54	0.15	2.23	0.51		11.89	0.32	25.06	1.83	0.95	0.10	0.30	1.10	0.27	6.62	1.05	0.06	6.47	0.53		99.98	19.97	FA	1
Krymka	LL3	40.15	0.14	2.20	0.56		18.91	0.33	24.71	1.87	0.81	0.09	0.22	1.77	0.47	0.34	0.97	0.05	5.98	0.29		99.86	18.84	FA	55
Manych	LL3	39.69	0.12	2.34	0.57		14.55	0.33	24.61	1.90	0.83	0.12	0.20	0.64	0.20	4.11	0.99	0.06	8.39	0.28		99.93	20.75	FA	55
Ragland	LL3-4	39.60	0.11	2.38	0.55	11.82	12.98	0.33	23.00	1.85	0.36	0.06	0.20	2.45	0.63	0.64	0.68	0.03	0.77	0.61		99.05	19.58	FI	65
Semarkona	LL3	40.16	0.10	2.23	0.49		17.57	0.35	24.86	2.04	0.96	0.10	0.24	1.22	0.40	2.05	1.16	0.05	5.32	0.57		99.87	19.09	FA	1
St.Mary's Co.	LL3	40.45	0.14	2.08	0.55		17.28	0.33	24.71	1.86	0.97	0.10	0.16	ND	0.27	2.75	1.14	0.04	6.53	0.57		99.93	20.33	FA	36
Greenwell Spr.	LL4	40.88	0.11	2.19	0.53		17.57	0.36	25.29	1.95	0.95	0.11	0.21	<0.1	0.20	3.12	1.08	0.05	4.72	0.04		99.36	19.78	FA	
Olivenza	LL5	41.27	0.12	2.32	0.57		18.19	0.36	25.64	1.90	0.95	0.10	0.25	0.14	0.07	1.54	1.36	0.05	5.07	0.07		99.97	18.90	FA	61
Bandong	LL6	40.14	0.11	2.29	0.56		18.83	0.36	25.51	1.90	0.98	0.10	0.28	0.40	0.08	1.18	1.16	0.05	5.95	0.10		99.98	19.60	FA	61
Cherokee Spr.	LL6	40.81	0.17	2.12	0.51		18.51	0.40	25.32	1.85	0.97	0.11	0.18	0.12	0.03	2.28	0.97	0.05	5.84	0.03		100.27	20.38	FA	9
Ensisheim	LL6	40.65	0.14	2.25	0.53		17.26	0.35	25.54	2.24	0.98	0.05	0.27	0.34	0.05	2.40	1.05	0.03	5.35	0.09		99.57	19.22	FA	61
Karatu	LL6	41.80	0.15	2.20	0.50		19.71	0.35	26.14	1.79	1.04	0.14	0.15	0.33	0.07	0.68	0.83	0.04	4.03	0.10		100.05	18.56	FA	1
Oubari	LL6	39.99	0.13	1.96	0.50		18.61	0.33	24.83	1.97	0.87	0.09	0.24	0.88	0.17	1.74	1.09	0.04	6.36	0.06		99.86	20.25	FI	
PCA82507	LL6	42.15	0.14	2.51	0.56		19.22	0.34	26.07	2.09	1.02	0.09	0.21	0.49	0.10	1.17	0.46	0.04	2.96	<0.02		99.62	17.94	FI	
Saint-Séverin	LL6	40.62	0.11	2.37	0.58		18.43	0.32	25.24	1.92	1.00	0.11	0.22	<0.1	0.25	2.15	1.05	0.04	5.81	0.02		100.24	20.17	FA	9
St.Mesmin, dark	* LL6	36.52	0.14	2.15	0.48		11.06	0.35	23.60	1.67	0.82	0.09	0.25	ND	0.10	15.82	1.77	0.10	5.18	0.14		100.24	27.71	FA	
St.Mesmin, D-3	* LL6	44.78	0.27	2.79	0.56		19.32	0.41	27.78	2.77	1.04	0.11	0.15	ND	0.00	0.05	0.03	ND	1.56	ND		101.62	16.06	FA	30
St.Mesmin, D-5	* LL6	45.00	0.19	3.24	0.39		17.03	0.39	27.58	2.47	1.05	0.12	0.25	ND	<0.1	0.51	0.29	ND	1.92	ND		100.43	14.98	FA	30
St.Mesmin, L-3	* LL6	42.65	0.17	2.41	0.30		19.04	0.39	25.50	2.00	1.04	0.11	0.30	ND	<0.1	ND	0.64	ND	6.27	ND		100.82	18.78	FA	
St.Mesmin, L-3	* LL6	39.50	0.25	7.05	0.17		17.96	0.33	24.70	2.80	0.94	0.10	0.22	ND	<0.1	ND	1.03	ND	6.25	ND		101.30	17.93	FA	
TIL82402	LL6	41.07	0.12	2.38	0.52		18.76	0.34	25.25	2.03	0.97	0.10	0.37	<0.1	0.23	1.82	0.38	0.04	5.07	<0.02		99.45	19.65	FI	
Enstatite chondrites																									
Eagle	EL6	43.18	0.10	2.11	0.32		ND	0.28	23.92	0.75	0.83	0.09	0.23	0.43	0.16	18.36	1.38	0.07	8.11	0.32		100.64	23.19	FI	
ALHA77295	EH4	35.70	0.11	1.79	0.40			0.27	18.34	1.26	0.78	0.07	0.44	0.82	0.77	22.03	1.83	0.09	13.49	0.42		98.61	30.60	FI	
Happy Canyon	* EL6	38.58	0.10	2.24	0.24	26.64	0.50	0.07	20.69	1.01	0.66	0.05	0.13	4.60	0.19	1.13	0.10	0.01	1.31	0.46	2.19	100.90	20.99	FI	42
Pillistfer	* EL6	39.83		2.17	0.21			<0.02	20.94	0.62	0.80	0.09		<0.1	0.12	22.05	1.68	0.08	9.02	0.18	1.86	99.65	27.78	FA	9
Anomalous meteorites																									
Bencubbin I	ANOM	38.59	0.14	2.21	0.44		17.88	0.30	24.30	1.81	0.60	0.07	0.28	1.25	0.25	4.03	1.28	0.07	6.12	0.20		99.82	21.82	FI	5
Bencubbin II	ANOM	36.70	0.15	1.47	0.40		1.34	0.26	19.43	1.19	0.61	0.08	0.38	0.72	0.11	22.12	2.22	0.08	12.61	0.54		100.41	31.17	FI	5
Brachina	* ANOM	38.04	0.12	2.12	0.58		23.69	0.34	27.27	2.10	0.63	0.08	0.27	ND	0.26	ND			3.59	0.07	0.61	99.77	20.70	FI	41

Table 2. Continued.

Meteorite	Class	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	H2O+	H2O-	Fe(m)	Ni	Co	FeS	C	Other	Total	Fe(t)	FF	Ref
Cumberland,incl	* ANOM	41.77	0.20	2.13	0.53		4.01	0.66	26.08	2.21	1.31	0.14	0.24	0.86	0.26	10.95	0.96	0.06	7.76	0.11		100.24	19.00	FA	3
Tierra Blanca	* ANOM	37.86	0.11	1.34	0.26	21.88	3.70	0.21	24.16	1.06	0.36	0.04	0.28	3.02	0.54	0.54				0.18	6.08	101.62	18.74	FI	57
Winona	* ANOM	41.13	0.14	2.34	0.29	11.73	3.21	0.25	26.73	1.30	0.94	0.07	0.20	2.38	0.30	2.95	1.20	0.04	4.11	0.46		99.77	16.25	FI	2
Woodbine	* ANOM	8.55	0.02	0.53	0.03		0.49	0.03	5.19	0.34	0.29	0.02		ND	ND	73.06	9.08	0.15	1.65	0.21	0.47	100.11	74.49	FI	3
Weatherford	* ANOM	47.43	0.19	3.64	0.64	3.13	1.80	0.27	34.00	2.83	0.59	0.07	<0.05	1.69	0.59	1.34	0.10	ND	1.62	0.11		100.04	5.96	FI	7
Achondrites																									
ALHA77256	DIO	52.15	0.16	1.56	1.06		16.07	0.47	26.48	1.50	0.04	0.01	0.01	ND	0.02	ND	0.01	<0.01	0.15	0.03		99.72	12.49	FI	60
Johnstown	DIO	53.48	0.12	1.43	0.83		15.63	0.54	25.87	1.40	0.04	0.00	0.00	<0.1	0.05	ND	<0.05	<0.01	1.18	ND		100.57	12.90	FA	16
ALHA76005	EUC	48.92	0.73	12.22	0.39		17.56	0.56	6.74	9.63	0.43	0.06	0.06	1.49	0.37	<0.05	<0.01	<0.01	0.27	0.34		99.77	14.05	FI	51
Camel Donga	EUC	49.53	0.74	12.49	0.33		16.07	0.56	6.31	10.41	0.49	0.04	<0.01	<0.1	0.07	2.07	<0.01	<0.01	0.19	0.03		99.33	14.68	FI	66
Haraiya	EUC	48.30	0.57	11.92	0.33		19.95	0.43	6.96	9.67	0.37	0.03	<0.05	0.60	0.11	0.25	<0.01	ND	0.27	ND		99.76	15.93	FA	52
Ibitira	EUC	48.81	0.90	12.97	0.38		18.19	0.47	7.28	10.99	0.21	0.03	0.10	ND	0.04	ND	0.01	<0.01	<0.1	<0.02		100.38	14.14	FA	53
Serra de Magé	EUC	46.69	0.11	20.89	0.33		9.97	0.36	7.52	13.09	0.30	0.00	0.05	0.10	0.03	ND	0.11	0.01	0.00	0.05		99.61	7.77	FA	53
Y-791192	EUC	49.57	0.38	9.67	0.72		17.51	0.56	13.81	7.32	0.26	0.02	0.00	ND	0.06	ND	0.00	0.00	0.43	<0.01		100.31	13.88	FI	
Y-791195	EUC	49.72	0.26	12.96	0.32		17.17	0.56	7.60	10.24	0.37	0.04	0.03	ND	0.06	ND	0.00	0.00	0.54	<0.01		99.87	13.70	FI	
Bholghati	HOW	49.35	0.41	8.30	0.71		16.27	0.53	15.56	6.14	0.27	0.03	<0.05	0.50	0.14	0.55	0.04	<0.01	0.77	0.34		99.91	13.69	FA	52
Bialystok	HOW	48.97	0.56	12.63	0.72		17.83	0.58	7.88	9.72	0.32	0.03	0.09	ND	0.22	ND	0.01	<0.01	0.55	0.09		100.20	14.21	FA	52
Bununu	* HOW	48.67	0.51	8.87	0.56		16.04	0.53	14.20	6.77	0.34	0.04	<0.04	1.53	0.12	1.01	0.06	ND	0.96	ND		100.21	14.09	FA	3
EET87503	HOW	49.69	0.53	9.34	0.58		17.35	0.53	12.95	7.58	0.27	0.03	0.06	<0.1	0.24	0.42	0.01	0.00	0.35	0.01		99.94	14.13	FI	
Petersburg	HOW	49.18	0.57	10.82	0.56		17.00	0.52	11.24	8.49	0.35	0.03	0.08	ND	0.07	0.35	0.07	<0.01	0.74	0.10		100.17	14.04	FA	52
MAC88105	LUN	44.58	0.25	29.32	<0.1		4.31	0.07	3.89	16.86	0.33	0.03	0.00	<0.1	0.32	ND	0.03	0.00	0.00	0.03		100.03	3.35	FI	
ALHA77005	* SHE	42.40	0.46	3.14	1.05		19.85	0.46	28.16	3.39	0.48	0.04	0.41	ND	0.02	ND	0.01	<0.01	<0.1	0.02		99.89	15.43	FI	60
ALHA77005, dark	* SHE	41.41	0.52	3.41	0.89		20.84	0.45	27.84	3.36	0.60	0.04	0.45	ND	0.09	ND	0.03	<0.01	<0.1	0.01		99.94	16.20	FI	
ALHA77005, light	* SHE	45.80	0.31	1.99	1.08		18.51	0.45	28.16	3.37	0.27	0.02	0.19	ND	0.13	ND	0.03	<0.01	<0.1	0.02		100.33	14.39	FI	
EETA79001, A	SHE	48.52	0.70	5.68	0.58	0.70	17.94	0.52	16.59	7.10	0.84	0.05	0.65	<0.1	0.09	ND	0.03	<0.01	0.49	0.02		100.50	14.75	FI	58
EETA79001, B	SHE	49.03	1.23	9.93	0.14	0.22	16.87	0.47	7.32	11.00	1.68	0.09	1.25	<0.1	0.09	ND	<0.01	<0.01	0.60	0.01		99.93	13.65	FI	58
ALHA77257	URE	41.12	0.04	<0.1	0.70		13.57	0.38	39.66	1.07	0.03	0.01	0.06	ND	0.18	ND	0.08	<0.01	<0.1	3.34		100.24	10.55	FI	60
ALH84136	URE	45.15	0.10	0.29	0.57		6.62	0.43	40.03	2.34	0.05	0.00	0.09	0.47	0.35	0.45	0.12	0.00	0.66	2.46		100.17	6.03	FI	
Dingo Pup Donga	URE	38.26	0.08	0.34	0.74	11.52	8.51	0.33	30.36	1.41	0.06	0.03	0.19	3.16	0.53	0.36	0.23	ND	0.93	3.10		100.14	15.62	FI	4
North Haig	URE	36.87	0.08	0.18	0.67	9.25	8.07	0.40	34.68	1.26	0.08	0.03	0.21	2.76	0.36	0.34	0.11	ND	0.99	4.10		100.44	13.71	FI	4
PCA82506	URE	40.37	0.04	<0.1	0.79		16.34	0.39	34.87	0.96	0.03	<0.01	0.04	1.13	0.13	1.50	0.08	<0.01	<0.02	3.16		99.83	14.20	FI	
Mesosiderites and inclusions from iron meteorites																									
ALHA77219	MES	32.27	0.16	3.93	0.63	8.87	7.86	0.41	12.56	3.14	0.15	0.03	0.30	1.02	0.61	23.63	2.86	0.10	1.10	0.15		99.78	36.64	FI	60
Barea	MES	21.71	0.11	4.01	0.37		5.61	0.24	6.62	2.54	0.12	0.01	0.52	ND	0.01	50.24	6.19	0.12	1.62	0.04		100.08	55.63	FA	24
Dyarrl Island	MES	40.10	0.77	6.45	0.54		14.61	0.48	10.88	5.39	0.22	0.01	0.26	ND	<0.01	15.76	1.65	0.08	2.32	0.14		99.66	28.59	FA	24
Emery	MES	22.38	0.15	4.55	0.34		4.88	0.24	5.85	3.09	0.16	0.01	0.72	ND	<0.01	45.12	4.92	0.11	7.34	0.03		99.89	53.58	FI	24
Lowicz	* MES	50.33	0.36	10.60	0.71		12.39	0.51	14.08	8.12	0.31	<0.02	1.30	0.56	0.06	ND		ND	0.63	0.14	0.43	100.53	10.03	FA	
Patwar	* MES	25.76	0.16	5.86	0.26		6.86	0.31	6.88	3.63	0.19	<0.01	0.14	ND	ND	33.70	4.20	0.13	11.89	0.10	0.02	100.09	46.58	FA	9
Vaca Muerta	* MES	37.70	0.21	7.20	0.87	9.01	8.98	0.34	10.21	5.82	0.23	<0.02	1.39	2.61	0.18	ND		ND	15.30	0.05	0.72	100.82	23.00	FI	
El Taco1, incl.	* IAB	37.82	0.13	1.36	0.10		3.95	0.35	28.63	1.09	0.52	0.04	0.39	1.13	0.07	1.75	0.18	0.02	0.33	23.00		100.86	5.03	FI	37
El Taco2, incl.	* IAB	45.86	0.12	3.41	0.33		4.94	0.32	28.27	1.09	1.23	0.11	0.26	0.85	0.17	0.80	0.27	0.02	7.29	5.35		100.69	9.27	FI	37
El Taco3, incl.	* IAB	40.52	0.13	1.64	0.30		3.33	0.31	31.94	2.48	0.47	0.06	0.03	0.76	0.12	0.25	0.10	<0.01	1.32	16.41		100.17	3.68	FI	37
Netschaëvo,incl.	IIE	32.26	0.10	1.71	0.48	4.96	8.71	0.24	19.54	1.53	0.65	0.08	0.43	<0.1	0.66	21.30	2.50	0.10	3.70	0.21		99.16	33.89	FI	18
Weekeroo, incl.	IIE	54.54	0.29	5.22	2.76	0.93	10.67	0.59	16.24	5.16	1.80	0.20	0.10	ND	0.12	ND	0.05	ND	<0.1	0.98		99.65	8.64	FI	10

Remarks to Table 2:

SO4= is reported in all analyses as SO3.

ALHA77011	L3	77011, 77015, 77167, 77214, 77249, and 77260 are paired.
ALHA77296	L6	77296 and 77297 are paired.
ALHA77307	CO3	0.92% SO3; all Ni and Co is reported as metal although only a small amount of metal is present in the sample.
ALH83100	CM2	1.80% SO3; 0.84% CO2; paired with AHA83102.
ALH83102	CM2	1.53% SO3; 1.65% CO2; paired with ALH83100.
Allende	CV3	Ni(m) and Co(m) calculated from probe data for metal (68% Ni; 31% Fe; 1.6% Co); remainder is reported as sulfide: 1.60% NiS; 0.08% CoS.
Allende, "A"		chondrule "A".
Allende, "C"		chondrule "C"; 2.0% Cl; total 100.99% is corrected for chlorine, Cl=O 0.45%.
Allende, aggregate		single aggregate.
Allende, chondrules		0.87% NiS; 0.03% CoS.
Allende, dark incl.		2.26% NiS; 0.06% CoS.
Allende, matrix		1.05% NiS; 0.09% CoS.
Andura	H6	Joseph A. Nelen, analyst.
Ankober	H4	slightly weathered; all oxidized metal is reported as FeO.
Atarra	L4	Joseph A. Nelen, analyst.
Bali	CV3	Ni(m) and Co(m) is calculated from microprobe data for metal (58% Ni; 2% Co); remainder is reported as sulfide: 1.84% NiS; 0.08% CoS.
Banten	CM2	1.66% NiO; 0.08% CoO; 2.27% SO3; 0.55% CO2.
Belgica7904	C3	1.72% NiO; 0.10% CoO; 1.60% SO3; this sample was provided by K. Yanai of the National Institute for Polar Research, Japan.
Bununu	HOW	0.51% TiO2, revised value.
Casilda	H5	slightly weathered; all oxidized metal is reported as FeO.
Colony	CO3	heavily weathered; all Ni and Co is reported as oxide: 1.25% NiO; 0.08% CoO.
Conquista	H4	1.75% C, contamination; two "clean" fragments contained 0.36% and 0.27% C respectively.
Cumberland F.	ANOM	black chondritic inclusion; bracciated chondrite with fragments of white aubrite and dark chondrite.
EET83213	LL3	analysis indicates LL rather than L group as previously classified.
EET87526	C4	all Ni and Co is reported as metal; Kallemeyn et al. (1990) classify this meteorite as CK5.
EET87860	C5	all Ni and Co is reported as metal; Kallemeyn et al. (1990) classify this meteorite as CK5.
El Taco, incl.	IAB	three different silicate inclusions removed from a large slice of the Campo del Cielo meteorite.
Grady (1937)	H3	heavily weathered; all oxidized Ni and Co is reported as metal.
Happy Canyon	EL6	heavily weathered; FeO is an estimated value for enstatites; Ni and Co are proportioned to Fe(m), remainder is reported as 2.10% NiO and 0.09% CoO; Fe2O3 is reported as difference between Fe(t) and FeO and FeS; this meteorite is also classified as CHUNGR.
Holbrook	L6	weathered; this specimen was collected later than other specimens reported by Mason and Wiik (1961).
Isna	CO3	weathered; all oxidized metal is reported as FeO.
Itapicuru-Mirim	H5	metallic fraction contained a large metal grain (0.5 g in 12 g sample) resulting in high Fe(m) and Fe(t); 0.34% C.
Kuttipuram	L6	Joseph A. Nelen, analyst.
LEW87009	CO3	all Ni and Co is reported as metal; Kallemeyn et al. (1990) classify this meteorite as CK5.
Louisville, d.	L6	very large dark fragment in a light matrix (Louisville Light); D 3.58.
Louisville, l.	L6	bulk of meteorite consists of a light matrix; D 3.48.
Lowicz	MES	a non-magnetic fraction; 0.43% NiO; H2O was determined as loss on ignition.
Millen 5522	H4	heavily weathered; 0.42% SO3; 0.12% Cl; the total 99.75% is corrected for Cl=O 0.03%; this meteorite was found in the bank of the creek above the water level.
Millen 5523	H4	heavily weathered; 0.50% SO3; 0.14% Cl; the total 99.28% is corrected for Cl=O 0.03%; this meteorite was found in the bank of the creek at the water level.
Murchison	CM2	all Ni and Co is reported as oxide although some is present in metal and sulfide; 1.75% NiO; 0.08% CoO; 1.00% CO2; 0.90% SO3.
Murchison, matrix1		fine grained matrix (200 mesh); 2.04% NiO: 0.09% CoO; 1.80% CO2; 2.50% SO3; D 2.58-2.90.
Murchison, matrix2		fine grained matrix (200 mesh); 1.80% NiO, 0.10% CoO; 1.47% SO3.
Orgueil	CI1	5.63% SO3; 0.10% S; 1.50% CO2; 1.33% NiO; 0.08% CoO.
Paranaiba	L6	J. A. Nelen, analyst.
Patrimônio	L6	0.28% C; contamination.
Patwar	MES	0.02% P.
Pillisfer	EL6	0.18% Si (calculated from probe data, 0.83% Si in metal); 0.14% TiS; 0.29% Cr2S3; 0.26% MnS; 0.90% CaS; 0.09% P.
Rio Negro	L4	1.22% C; contamination.
Sao José	H4	0.48% C; contamination.
Schenectady	H4	slightly weathered; all oxidized metal is reported as FeO.
Sharps	H3	all Ni is reported as metal instead as NiO given in original analysis.
Study Bute	H3	0.63% SO3.
St.Mesmin, dark	LL6	dark inclusion; this inclusion was described by Pelas (1973).
St.Mesmin, D-3	LL6	Fe(m) calculated, assuming Fe/Ni in metal = 1.77 (Mason and Wiik 1964).
St.Mesmin, D-5	LL6	Fe(m) calculated, assuming Fe/Ni in metal = 1.77 (Mason and Wiik 1964).
St.Mesmin, L-1	LL6	non-magnetic fraction; this inclusion was described by Dodd (1973).
St.Mesmin, L-2	LL6	non-magnetic fraction; this inclusion was described by Dodd (1973).
Vaca Muerta	MES	non-magnetic fraction; 0.72% NiO; H2O was determined as loss on ignition; FeO was calculated on basis MgO/FeO in Lowicz; remaining Fe is reported as FeO3.
Weatherford	ANOM	Joseph A. Nelen, analyst.
Willaroy	H3	this meteorite is also classified as CHUNGR.
Winona	ANOM	all Ni and Co is reported as metal although some is present as oxide.
Y-791824	CM2	1.45% NiO; 0.09% CoO; 2.43% SO3; 0.48% CO2; this sample was provided by K. Yanai of the National Institute of Polar Research, Japan.
Y-793321	CM2	1.55% NiO; 0.09% CoO; 0.85% SO3; 1.32% CO2; this sample was provided by K. Yanai of the National Institute of Polar Research, Japan.

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Table 2. Continued.

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into high iron (H) and low iron (L) groups; these correspond broadly to Prior's bronzite and hypersthene chondrites. Newer chemical analyses allowed for a further refinement. Wiik (1956) distinguished three groups of carbonaceous chondrites on the basis of chemical composition. Keil and Fredriksson (1964) and Fredriksson *et al.* (1968) identified an LL group of chondrites, based on total iron and mineralogy. Van Schmus and Wood (1967) subdivided the chemical groups on the basis of petrologic criteria to establish the now widely-used chemical-petrologic classification. Similarly, Wasson (1967; Wasson *et al.*, 1989) classified the iron meteorites into chemically distinct groups on basis of Ni, Ga, Ge and Ir content and structural information.

Sears (1975) gives an excellent historical summary of the early studies of meteorites, particularly the evolution of chemical analysis and mineralogical investigations (also Sears and Sears, 1977). Mason (1962), Dodd (1981), Wasson (1985) and McSween (1987) also present enlightening discussions of these early stages of meteorite studies.

Because Urey and Craig's compilation underscored the value of reliable chemical data, a group of interested scientists met on 6 September 1962 at the British Museum (Natural History) to discuss and review methods of analysis, as well as techniques of sample preparation (Dyakonova, 1964). This exchange of views contributed to significant improvements in the quality of analytical data. This paper attempts to bring the subject up to date.

DISCUSSION OF DATA

General

Most of the chemical analyses presented in this paper have been published previously in collaborative studies with others, or independently by the author. Published and unpublished analyses are compiled in Table 2, other analytical data are presented in 7 tables and 3 graphs for discussion.

Table 1 alphabetically lists the full name of each meteorite and its classification as given in Graham *et al.* (1985). However, classification for several meteorites has been revised according to newer studies. These are: Bencubin, ANOM (Ref. 5); Dwaleni, H4-6, and Schenectady, H4 (Ref. 27); Ragland, LL3-4 (Ref. 65); Weatherford, ANOM (Ref. 7); ALHA77005, SHE (Ref. 74); and EET83213, LL3 rather than L3 as originally classified (B. Mason, pers. comm.).

Table 2 presents the complete chemical data, classification, references and remarks. The meteorites are listed by chemical groups, and within the chondrite groups, by petrologic type. The chemical data include Fe_2O_3 and SO_3 for several weathered chondrites, and CO_2, SO_3, and Fe_2O_3 for CI and CM carbonaceous chondrites. These components are grouped together in the "Other" column of Table 2 and are annotated in "Remarks." Other pertinent information about the condition of each meteorite is also included in "Remarks." A special column is reserved for Fe_2O_3 because it was determined in numerous weathered and some carbonaceous meteorites.

Analyses of iron meteorites are listed in Table 3.

Weathering

Table 4 gives the average compositions of several meteorite groups. Sample standard deviations are listed for means based on four or more analyses. In calculating average compositions, only observed falls were selected; observed falls are less altered than finds and less likely to be contaminated (sometimes falls are also altered or contaminated). While various studies of the weathering and contamination processes have emphasized different features, in the context of this paper the weathering of meteorites is indicated by one or more of the following: (1) presence of oxidized iron in the form of goethite, (2) high total water content and (3) water soluble sulfur ($SO_4^=$ listed as SO_3). Contamination is primarily reflected in higher total carbon and in some cases the presence of CO_2. These components were not always determined; their determination depended on the type of study and on the availability of sample.

The data in Table 2 confirm that metal is the component most susceptible to weathering. It appears that a larger fraction of the metal is weathered in H chondrites than in L and LL chondrites because of the lower Ni content of H chondrite metal. Buchwald and Clarke (1989) discuss the progressive weathering of metal.

The degree of weathering of silicate phases is not ascertained from the present data, but appears to be minimal. Gooding (1986) gives a detailed discussion of the presence of clay-mineraloid weathering products in Antarctic meteorites. A detailed determination of how weathering affects the composition of finds through leaching, contamination or other phenomena remains an important question that requires further study.

Antarctic and Non-Antarctic Meteorites

Even though falls are preferred for various studies because they are fresh, many valuable investigations have been conducted on weathered finds. Some of these are rare classes that provide information about meteorite diversity. The question of the effects of weathering on composition has been raised many times. To examine this question, the chemical composition of major and minor elements is compared for H, L and LL finds, falls and Antarctic meteorites for which a statistically meaningful comparison can be made (Table 5).

The one weathering effect that is well known is the oxidation of Fe(m) to Fe_2O_3. Therefore, all Fe_2O_3 in individual weathered meteorites was converted to Fe(m) and normalized to 100% before the mean composition was calculated. The data in Table 5 show good agreement among major and minor elements and few differences significant at the 99% confidence level between finds, falls and Antarctic chondrites. The difference between H-finds and H-falls and Antarctic chondrites in the abundance of Fe(t) can be ascribed to weathering. There is also a minor difference between L-falls and L-finds and Antarctic meteorites; the latter have lower Fe(m) and higher FeO. Chemically bound water (H_2O^+), the other component that varies considerably, is substantially higher in weathered meteorites. In the three groups of chondrites, H_2O^+ shows the same trend: lowest in falls, intermediate in Antarctic chondrites, and highest in other finds.

Pairing

Pairing, which can significantly bias the statistical data, is another important factor in the study of Antarctic meteorites. To illustrate the bias that may be introduced when paired meteorites are treated as separate entities, data for five groups of paired meteorites are presented in Table 6. Six fragments from the ALHA77011 L3, two from ALHA77296 L6, and two from ALH83100 CM2 were analyzed before they were identified as paired. Considering that these were different stones, the agreement between these analyses is remarkably good. For example, note that even though 70% of Fe(m) has been converted to oxide in ALHA77011, there is little variation in the amount of remaining Fe(m) among the six specimens. Five analyses of paired ALHA76002 and six of DRP78002 iron meteorites were performed to verify the original pairings. Pairing is always problematic, but the uniformity of these analyses supports the pairing which was originally based on metallographic structure.

Table 3. Iron meteorites

Meteorite		Class	Ni	Co	P	Ref
Alvord		IVA	8.64	0.39	0.06	
Filomena		IIA	5.73	0.50	0.35	
Lazarev		UNGR (Om)	9.69	0.63	0.19	
Navajo 5601		IIB	5.66	0.50	0.27	
Nordheim		UNGR	11.50	0.58	0.03	
Neptune Mountains		IAB	7.26	0.53	0.20	
Sombrerete	*	UNGR	10.26	0.59	0.27	
Waverly USNM 6268		IAB-an	8.64	0.53	0.23	
ALHA76002,2	#	IA	6.84	0.50	0.22	70
ALHA77250,8	#	IA	6.84	0.49	0.20	70
ALHA77255,3		IVA	12.23	0.64	<0.01	
ALHA77263,3	#	IA	6.84	0.49	0.22	70
ALHA77283,7		IA	7.33	0.50	0.22	70
ALHA77289,7	#	IA	6.84	0.49	0.21	70
ALHA77290,6	#	IA	6.84	0.49	0.23	70
ALHA78100,4		IIA	5.53	0.48	0.27	
ALHA78252,3		IVA	9.33	0.43	0.17	70
ALHA80104,3		UNGR (D)	15.87	0.71	0.22	72
ALHA81013,2		IIA	5.52	0.50	0.24	
ALHA81014,3		UNGR	11.03	0.57	0.26	
ALH84165,3		IIIAB	7.76	0.54	0.14	
DRPA78002,3	+	IIB	6.62	0.50	0.43	
DRPA78004,2	+	IIB	6.47	0.50	0.44	
DRPA78005,3	+	IIB	6.62	0.51	0.42	
DRPA78006,3	+	IIB	5.99	0.53	0.36	
DRPA78008,3	+	IIB	6.64	0.51	0.35	71
DRPA78009,3	+	IIB	6.59	0.46	0.34	71
EET83230,3		UNGR (D)	16.12	0.45	0.23	73
EET83245,3		IIAB-an	6.16	0.47	0.28	73
EET83333,4	*	IAB	8.18	0.52	0.41	
EET84300,4	*	IAB	9.71	0.54	0.53	
GRO85201,1		IIIAB	8.59	0.57	0.23	
ILD83500,3		UNGR (D)	18.90	0.87	0.28	73
PGPA77006,5		IA	7.27	0.51	0.20	70
RKPA79015,13	*	MES-an	9.87	0.52	0.15	72
RKPA80226,3		IA	8.52	0.49	0.17	72

Remarks:
* EET83333,4 3.26% residue, mostly silicates.
* EET84300,4 5.96% residue, mostly silicates.
* RKPA79015,13 2.14% FeS.
* Sombrerete 1.47% FeS; 3.7% silicates.
* results for these meteorites are given on residue-free basis.
# ALHA76002, 77250, 77263, 77289, and 77290 are paired.
+ DRPA78002, 78004, 78005, 78006, 78008, and 78009 are paired.

Classification

One of the genetic relationships of different chondrite and achondrite groups is facilitated by inter-element ratios, such as those discussed by Ahrens and Von Michaelis (1969). Several of these ratios and their standard deviations are listed in Table 7. In ordinary chondrites Mg/Si and Al/Si ratios are the same within experimental uncertainties, whereas ratios of Fe(t)/Si, Fe(m)/Ni and Fe(m)/Fe(t) decrease through the H, L, LL se-

Table 4. Average composition of falls, wt%.

	CM2	CV3	H		L		LL		EUC	HOW	
No. analyses	2	2	26	s.d.	54	s.d.	12	s.d.	2	4	s.d.
SiO2	28.97	34.00	36.60	0.55	39.72	0.55	40.60	0.54	48.56	49.04	0.25
TiO2	0.13	0.16	0.12	0.01	0.12	0.01	0.13	0.02	0.74	0.51	0.06
Al2O3	2.17	3.22	2.14	0.15	2.25	0.15	2.24	0.08	12.45	10.16	1.71
Cr2O3	0.43	0.50	0.52	0.03	0.53	0.04	0.54	0.03	0.36	0.64	0.08
FeO	22.14	26.83	10.30	1.16	14.46	1.07	17.39	2.06	19.07	16.79	0.70
MnO	0.25	0.19	0.31	0.02	0.34	0.02	0.35	0.02	0.45	0.54	0.02
MgO	19.88	24.58	23.26	0.38	24.73	0.41	25.22	0.44	7.12	12.22	2.95
CaO	1.89	2.62	1.74	0.09	1.85	0.10	1.92	0.11	10.33	7.78	1.41
Na2O	0.43	0.49	0.86	0.04	0.95	0.05	0.95	0.06	0.29	0.32	0.03
K2O	0.06	0.05	0.09	0.01	0.11	0.01	0.10	0.02	0.03	0.03	0.00
P2O5	0.24	0.25	0.27	0.03	0.22	0.04	0.22	0.04	0.05	0.04	0.04
H2O+	8.73	0.15	0.32	0.44	0.37	0.45	0.51	0.55	0.30	0.51	0.62
H2O-	1.67	0.10	0.12	0.11	0.09	0.07	0.20	0.14	0.08	0.14	0.05
Fe(m)	0.14	0.16	15.98	1.53	7.03	0.95	2.44	1.61	0.13	0.48	0.37
Ni	0.00	0.29	1.74	0.09	1.24	0.10	1.07	0.13	0.01	0.05	0.02
Co	0.00	0.01	0.08	0.02	0.06	0.01	0.05	0.01	0.00	0.00	0.00
FeS	6.76	4.05	5.43	0.38	5.76	0.80	5.79	1.04	0.14	0.76	0.15
C	1.82	0.43	0.11	0.18	0.12	0.10	0.22	0.21	0.00	0.13	0.13
NiO	1.71										
CoO	0.08										
NiS		1.72									
CoS		0.08									
SO3	1.59										
CO2	0.78										
Total	99.82	99.84	99.99	0.30	99.99	0.29	99.92	0.24	100.07	100.12	0.12
Fe(t)	21.64	23.60	27.45	0.84	21.93	0.80	19.63	0.68	15.04	14.01	0.19

Remarks:

CM2	Banten, Murchison.
CV3	Allende, Bali.
H	not included in average: Conquista and Macau (Fe2O3); Forest Vale (low Fe(m) and high FeO); Sao Jose do Rio Prato, 0.48% C.
L	not included in average: Segowlie and Holbrook (weathered); Attara, 0.64% C; Cranganore, 0.90% C; Modoc, 0.38% C; New Concord, 0.44% C; Shelburne, 0.44% C.
EUC	Haraiya, Ibitira.
HOW	Bholghati, Bialystok, Bununu, Petersburg.

quence; this is an indication of the decrease in siderophile abundances and the progressively higher oxidation state for these different chondrite groups. The standard deviations help in the assessment of possible relationships. For example, L chondrites can be distinguished from LL chondrites in terms of their Fe(t)/Si and Fe(m)/Fe(t) ratios, whereas the Fe(t)/Ni and Fe(m)/Ni ratios do not resolve these two groups (*e.g.*, Jarosewich and Dodd, 1981).

Another useful parameter based on chemical analyses is the definition of the three groups of ordinary chondrites by plotting SiO_2 *vs.* MgO, which is rather uniform in each group (Mason, 1979). In Fig. 1, MgO *vs.* SiO_2 for all the H, L and LL falls are

Table 5. Average composition of H, L, and LL chodrites; falls, finds and Antarctic meteorites, wt%.

	H chondrites						L chondrites						LL chondrites				
	falls		finds		Antarctic		falls		finds		Antarctic		falls		finds	Antarctic	
No. anal.	26	s.d.	19	s.d.	4	s.d.	54	s.d.	12	s.d.	11	s.d.	12	s.d.	2	4	s.d.
SiO2	36.60	0.55	36.96	0.81	36.90	0.64	39.72	0.55	39.68	0.53	39.64	1.15	40.60	0.54	40.73	41.18	0.61
TiO2	0.12	0.01	0.12	0.01	0.12	0.01	0.12	0.01	0.13	0.01	0.13	0.01	0.13	0.02	0.12	0.13	0.01
Al2O3	2.14	0.15	2.18	0.15	2.20	0.13	2.25	0.15	2.29	0.07	2.29	0.10	2.24	0.08	2.23	2.36	0.10
CrO3	0.52	0.03	0.52	0.03	0.49	0.06	0.53	0.04	0.51	0.06	0.54	0.03	0.54	0.03	0.54	0.54	0.03
FeO	10.30	1.16	9.93	1.95	10.86	2.44	14.46	1.07	14.40	2.11	15.88	1.94	17.39	2.06	16.10	17.69	1.34
MnO	0.31	0.02	0.32	0.02	0.31	0.02	0.34	0.02	0.34	0.01	0.31	0.03	0.35	0.02	0.34	0.35	0.01
MgO	23.26	0.38	23.34	0.53	23.19	0.43	24.73	0.41	24.63	0.43	24.72	0.59	25.22	0.44	24.46	25.08	0.71
CaO	1.74	0.09	1.72	0.11	1.75	0.09	1.85	0.10	1.86	0.11	1.85	0.08	1.92	0.11	1.95	2.02	0.07
Na2O	0.86	0.04	0.69	0.16	0.88	0.13	0.95	0.05	0.86	0.13	0.88	0.08	0.95	0.06	0.62	0.93	0.07
K2O	0.09	0.01	0.08	0.02	0.10	0.02	0.11	0.01	0.10	0.02	0.10	0.02	0.10	0.02	0.08	0.10	0.00
P2O5	0.27	0.03	0.26	0.05	0.25	0.04	0.22	0.04	0.23	0.04	0.22	0.03	0.22	0.04	0.22	0.24	0.08
H2O+	0.32	0.44	1.57	0.13	1.09	0.82	0.37	0.45	0.84	0.60	0.51	0.61	0.51	0.55	1.72	0.53	0.43
H2O-	0.12	0.11	0.07	0.01	0.41	0.13	0.09	0.07	0.27	0.21	0.27	0.14	0.20	0.14	0.41	0.23	0.10
Fe(m)	15.98	1.53	15.08	1.93	14.35	1.79	7.03	0.95	6.39	1.50	5.59	1.66	2.44	1.61	5.53	2.21	0.90
Ni	1.74	0.09	1.62	0.13	1.75	0.07	1.24	0.10	1.20	0.09	1.20	0.10	1.07	0.13	0.90	0.71	0.29
Co	0.08	0.02	0.08	0.01	0.08	0.01	0.06	0.01	0.06	0.01	0.06	0.01	0.05	0.01	0.04	0.05	0.01
FeS	5.43	0.38	5.35	0.76	4.90	0.54	5.76	0.80	6.01	0.52	5.29	1.23	5.79	1.04	3.58	5.04	1.27
C	0.11	0.18	0.12	0.08	0.16	0.15	0.12	0.10	0.14	0.12	0.12	0.30	0.22	0.21	0.35	0.05	0.07
Total	99.99	0.30	100.00	0.00	99.77	0.35	99.99	0.29	99.94	0.35	99.59	0.24	99.92	0.24	99.93	99.42	0.14
Fe(t)	27.45	0.84	26.19	1.25	25.63	0.85	21.93	0.80	21.42	0.93	21.30	1.28	19.63	0.68	20.38	19.16	0.74

Remarks:

H-falls	not included in average: Conquista and Macau (Fe2O3); Forest Vale, low Fe(m) and high FeO; Sao Jose do, 0.48% C.
H-finds	Fe2O3 was converted to Fe(m) and normalized to 100%.
H-Antarctic	Fe2O3 was converted to Fe(m) and normalized to 100%.
L-finds	Fe2O3 in Inman, Ioka and Kyle was converted to Fe(m) and normalized to 100%.
LL-finds	Fe2O3 in Ragland was converted to Fe(m) and normalized to 100%.

Table 6. Chemical compositions of paired meteorites; wt%.

Chondrites

	ALHA77011 L3								ALHA77296 L6		ALHA83100 CM2	
	77011	77015	77167	77214	77249	77260	Avg	s.d.	77296	77297	83100	83102
SiO2	38.21	38.23	37.94	37.73	36.96	37.53	37.77	0.44	40.21	40.13	27.81	27.59
TiO2	0.14	0.14	0.13	0.11	0.12	0.13	0.13	0.01	0.14	0.14	0.11	0.12
Al2O3	2.29	2.29	2.18	2.30	2.21	2.15	2.24	0.06	2.36	2.41	3.00	2.27
Cr2O3	0.57	0.57	0.58	0.49	0.53	0.56	0.55	0.03	0.57	0.52	0.43	0.41
Fe2O3											10.08	11.01
FeO	20.07	19.63	19.64	19.63	21.28	21.45	20.28	0.78	15.53	15.43	11.47	10.70
MnO	0.27	0.26	0.26	0.33	0.26	0.24	0.27	0.03	0.35	0.36	0.21	0.26
MgO	23.89	23.97	23.85	22.69	22.91	23.82	23.52	0.52	25.00	25.02	18.92	18.92
CaO	1.78	1.71	1.64	1.70	1.60	1.75	1.70	0.06	1.96	1.93	1.89	1.74
Na2O	0.92	0.74	0.91	0.82	0.86	0.83	0.85	0.06	0.80	0.80	0.47	0.54
K2O	0.12	0.10	0.11	0.07	0.11	0.11	0.10	0.02	0.09	0.08	0.05	0.04
P2O5	0.25	0.25	0.24	0.21	0.24	0.27	0.24	0.02	0.22	0.24	0.18	0.21
H2O+	2.12	2.09	2.11	2.34	2.61	2.31	2.26	0.18	<0.1	<0.1	12.05	11.01
H2O-	0.63	0.46	0.63	0.95	0.73	0.68	0.68	0.15	0.20	0.14	1.33	1.93
Fe(m)	1.94	2.30	2.44	2.02	2.25	1.53	2.08	0.30	6.00	6.39	<0.1	<0.1
Ni	1.02	1.12	1.13	1.18	1.17	1.11	1.12	0.05	1.26	1.11	1.17	1.14
Co	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.00	0.06	0.07	0.05	0.06
FeS	4.47	4.69	4.55	5.73	4.41	3.43	4.55	0.67	4.80	5.24	6.77	7.05
C	0.97	0.98	0.99	1.08	1.08	1.07	1.03	0.05	0.01	0.01	1.46	1.39
CO2											0.84	1.65
SO3											1.80	1.53
Total	99.72	99.59	99.39	99.44	99.40	99.03	99.43	0.21	99.56	100.02	100.09	99.57
Fe(t)	20.38	20.54	20.60	20.77	21.59	20.39	20.71	0.41	21.12	21.72	21.17	20.50

Iron meteorites

	ALHA76002 IA					DRPA78002 IIB					
	76002	77250	77263	77289	77290	78002	78004	78005	78006	78008	78009
Ni	6.84	6.84	6.84	6.84	6.84	6.62	6.47	6.62	5.99	6.64	6.59
Co	0.50	0.49	0.49	0.49	0.49	0.50	0.50	0.51	0.53	0.51	0.46
P	0.22	0.20	0.22	0.21	0.23	0.43	0.44	0.42	0.36	0.35	0.34

plotted. The H chondrites are clearly separated from the L and LL chondrites, but the L chondrites are not completely resolved from the LLs and there is considerable overlap. The L and LL chondrites differ in terms of their average compositions (dark symbols, Fig. 1).

Although the average composition and standard deviation of H and L chondrites indicate that these chondrites present compositionally coherent groups, the distribution of individual components show considerable scatter. The histograms of SiO_2 and MgO (Figs. 2, 3) show a reasonable Gausian distribution; however, the histograms of Fe(t), Ni and, particularly, Fe(m) and FeS show wide scatter. It appears that the silicate fraction within each group is more or less constant whereas metal and sulfide are variable. The scatter in the metal and sulfide distributions may indicate either heterogeneity of individual chondrites, sampling, or perhaps some discrete variation within the groups which may have broader implications for the history of the meteoritic material. These variations should be taken into account in any critical study of meteorites.

This discussion was focused on some of the more important and frequently used correlations; other trends based on these data will be considered in future studies.

Table 7. Summary of elemental ratios for different classes of meteorites

	CI	CM2	CV3	H	L	LL	EUC	HOW
Ca/Al	1.08	1.18	1.10	1.11	1.12	1.16	1.12	1.03
s.d.				0.10	0.13	0.07		
Mg/Si	0.90	0.89	0.93	0.82	0.80	0.80	0.19	0.32
s.d.				0.01	0.01	0.01		
Al/Si	0.085	0.085	0.107	0.066	0.064	0.062	0.290	0.234
s.d.				0.005	0.004	0.003		
Ca/Si	0.092	0.100	0.118	0.073	0.071	0.072	0.325	0.243
s.d.				0.003	0.004	0.005		
Ti/Si	0.004	0.006	0.006	0.004	0.004	0.004	0.019	0.013
s.d.				0.000	0.000	0.001		
Fe(t)/Si	1.78	1.60	1.48	1.60	1.18	1.03	0.66	0.61
s.d.				0.06	0.06	0.04		
Fe(t)/Ni	18.12	16.15	16.85	15.84	17.73	18.64		
s.d.				0.67	1.37	2.18		
Fe(m)/Ni				9.21	5.67	2.29		8.00
s.d.				0.79	0.79	1.56		
Fe(m)/Fe(t)				0.58	0.32	0.12		0.03
s.d.				0.04	0.04	0.08		

CONCLUSION

The basic purpose of this compilation is to summarize in one paper data for all the meteorites analyzed by the author. The analyses constitute a single data source (Table 2) obtained with the same methods, and thereby eliminate interlaboratory biases. Although this compilation presents the most comprehensive set of bulk meteorite analyses currently available, other extensive data sets (*e.g.*, Wiik, 1969; Haramura *et al.*, 1983; Mason *et al.*, 1979) also provide a broad chemical base for the study of meteorites.

The availability of meteoritic material for different studies depends primarily on the quantity of recovered material. For some meteorite groups for which falls are infrequent and few analyses are available, additional analyses of these rare meteorites would be desirable. For example, only 85 falls were recorded in the past 25 years. Twenty-two of these were analyzed by the author and are included in this paper. Most of these falls were ordinary chondrites, the group that is well-represented and well-studied. Few recent falls were of rare types; however, some of these few, such as Murchison and Allende, provided a wealth of material for many interesting studies. At this time, the large set of Antarctic meteorites provides new and moderately well-

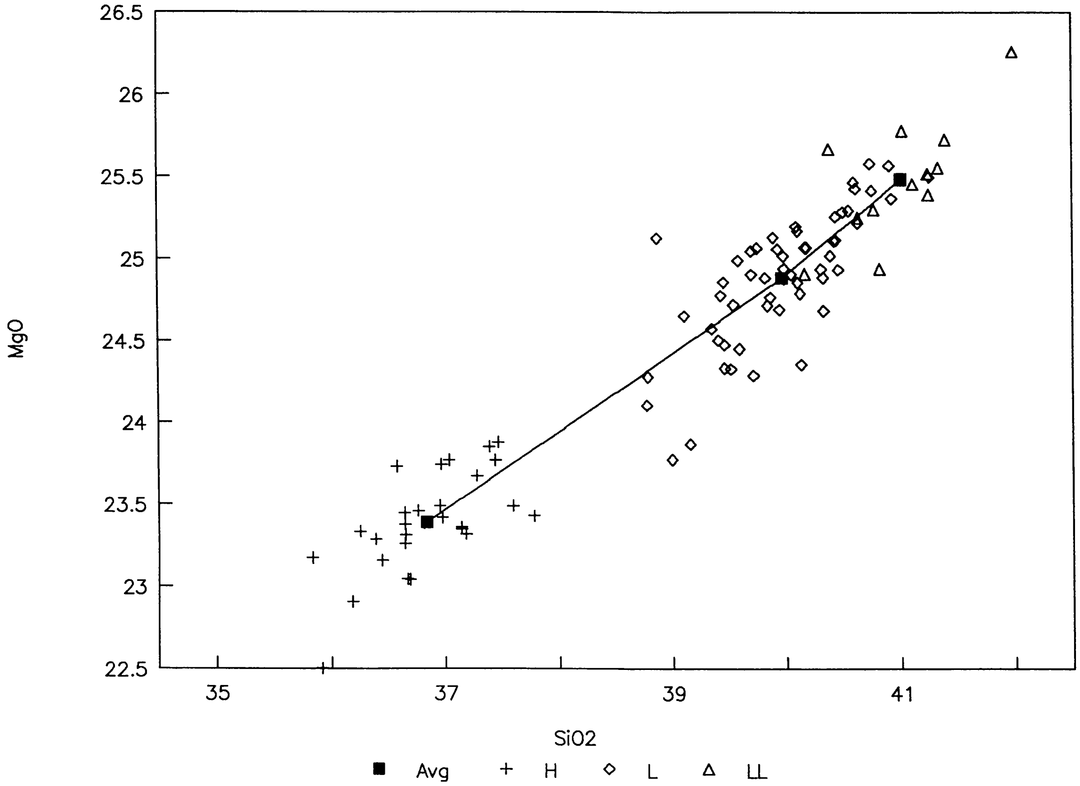

FIG. 1. MgO/SiO$_2$ plot of individual analyses and averages of H, L and LL chondrites. Individual analyses of L and LL chondrites show considerable scatter; the averages (dark symbols) clearly separate the three groups.

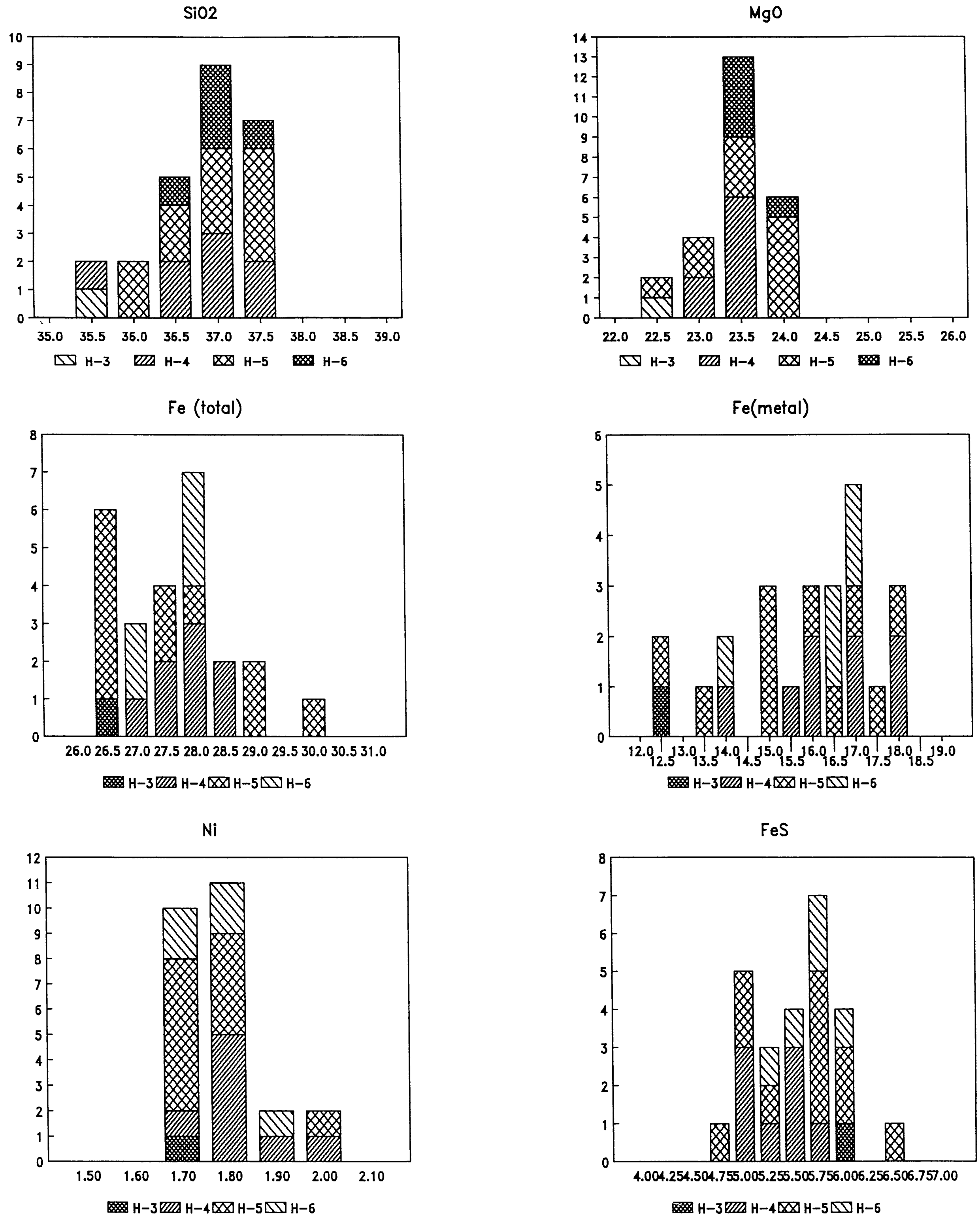

FIG. 2. Distribution of SiO_2, MgO, Fe(t), Fe(m), Ni and FeS in H chondrites. SiO_2 and MgO are closely clustered; Fe(t), Fe(m), FeS and Ni are randomly distributed showing greater variation.

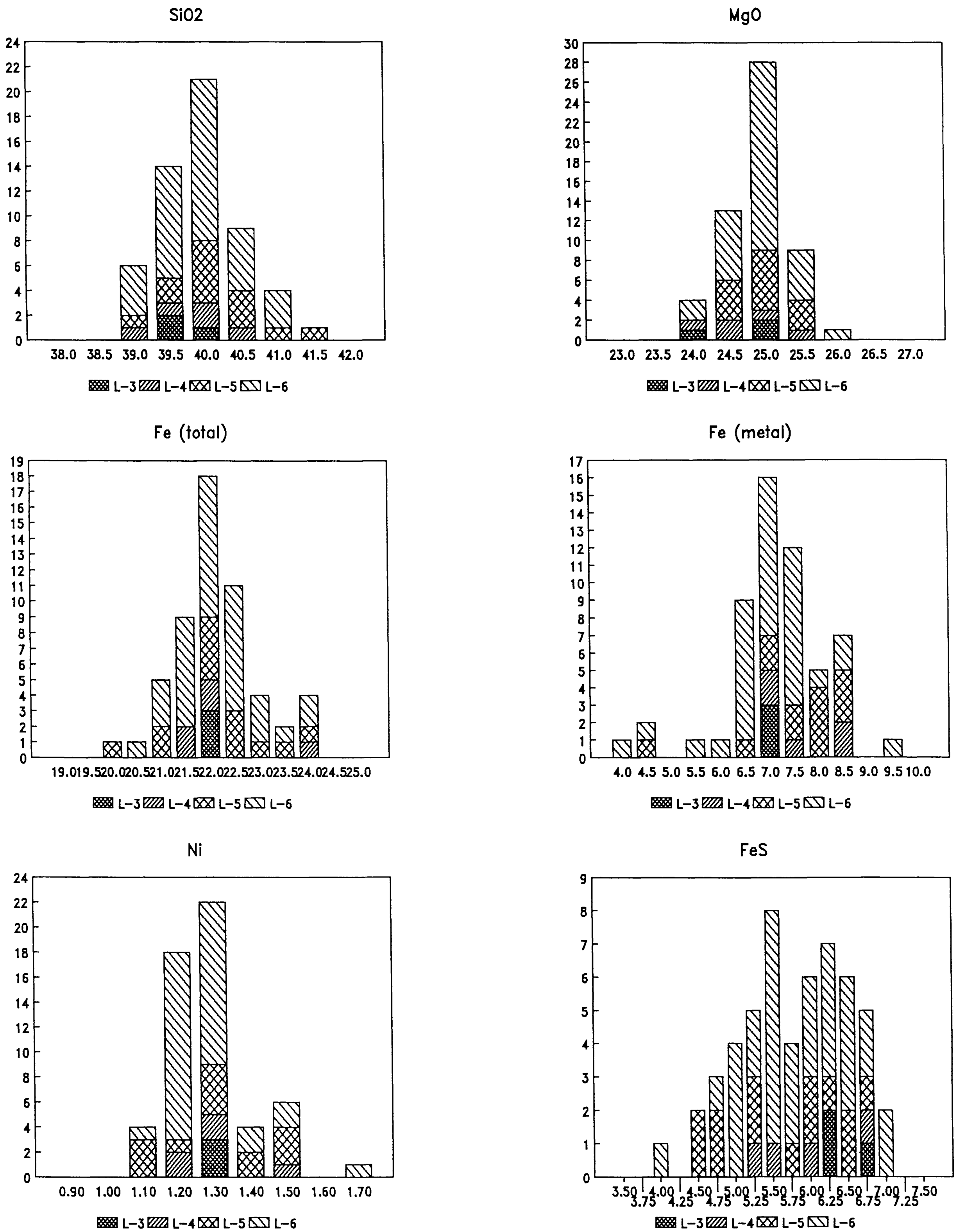

FIG. 3. Distribution of SiO_2, MgO, Fe(t), Fe(m), Ni and FeS in L chondrites. SiO_2 and MgO are closely clustered; Fe(t), Fe(m), FeS and Ni are randomly distributed showing greater variation.

preserved material which holds great promise for future studies of rare meteorite types. Although pairing, weathering and contamination are of concern, reliable data can generally be obtained through judicious selection of material.

Although some scientists thought that studies of lunar samples would result in diminished interest in meteorites, the opposite has been the case. Studies of lunar samples ultimately increased the effort devoted to meteorite research, which continues to be a rich source of information about our solar system.

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APPENDIX

Sampling

Sampling is a critical aspect of meteorite analysis because the amount of material is usually limited. Moreover, some meteorites are inhomogeneous and sampling requires special care. From petrographic observations, Keil (1962) estimated that a ten-gram sample is sufficient to provide representative sampling of an ordinary chondrite. In the author's experience, this is a reasonable estimate. However, brecciated meteorites, chondrites with coarse metal, and irons with silicate inclusions require much larger sample sizes. For instance, it was necessary to dissolve approximately 15 g of meteorite for each analysis of the Barea and Emery mesosiderites in order to assure a representative sample (Mason and Jarosewich, 1973). Wahl (1950), Wiik (1956) and Heide and Brückner (1968) describe some of the difficulties encountered in sampling meteorites.

Various models proposed for the sampling of rocks (*e.g.,* Wilson, 1964) involve preparation of material on a hand specimen scale; because of the scarcity of meteoritic material, these procedures simply are not applicable. As in other disciplines, experience, intuition and caution are important in sampling.

Table 8. Differences between analyses due to inadequate sampling, wt%.

	Saratov		Krymka	
	10.4 g	2.4 g	E.J.	Dyak.
SiO2	40.48	37.29	40.15	40.10
TiO2	0.13	0.12	0.14	0.14
Al2O3	2.27	2.11	2.20	2.93
Cr2O3	0.57	0.50	0.56	0.52
FeO	12.42	11.93	18.91	14.29
MnO	0.34	0.30	24.71	25.01
MgO	25.27	23.45	0.33	0.34
CaO	1.99	1.73	1.87	1.88
Na2O	0.85	0.97	0.81	0.84
K2O	0.10	0.10	0.09	0.07
P2O5	0.22	0.29	0.22	0.20
H2O+	0.32	0.28	1.77	
H2O-	0.04	0.19	0.47	
Fe(m)	8.34	10.44	0.34	4.71
Ni	1.16	1.53	0.97	1.15
Co	0.04	0.05	0.05	
FeS	5.77	6.66	5.98	6.05
C	0.10		0.27	0.27
Total	100.41	97.94	99.84	98.50
Fe(t)	21.73	23.95	18.84	19.67

An illustration of what appears to be inadequate sampling is the discrepancy between the analyses of Krymka by Dyakonova and Kharitonova (1960) and the one by the author (Jarosewich and Dodd, 1981; Table 8). Either Krymka is inhomogeneous or there is some other sampling problem that causes a marked discrepancy in metallic iron (D. and K., Fe(m) 4.71%; E. J., Fe(m) 0.34%). This difference is too large to ascribe to analytical error. Another example of inadequate sampling is two analyses of the Saratov L-chondrite by the author. The first was performed on a 2.4 g sample, which contained a large metal grain, the second, a more homogeneous 10.4 g sample. The first analysis could be interpreted as an inferior analysis of an H-chondrite, whereas the second analysis falls within the L-chondrite range (Jarosewich and Dodd 1985; Table 8).

In some instances, it is preferable to sample and analyze fragments or inclusions separately. Such analyses were performed on the Weekeroo Station IIE iron (Olsen and Jarosewich, 1970); CV-chondrite Allende inclusions (Clarke *et al.,* 1970); Netschaevo IIE iron (Olsen and Jarosewich, 1971); LL-chondrite St. Mesmin inclusions (Pellas, 1973; Dodd, 1974; Dodd and Jarosewich, 1976); IAB El Taco silicate inclusions (Wlotzka and Jarosewich, 1977) and EETA9001 dark and light fragments (McSween and Jarosewich, 1983).

Whenever possible, a large amount, usually between 8 and 20 g, was used to obtain a representative sample and to provide material for future work, although only 1–2.5 g is required for the analysis itself. For the study of Antarctic meteorites, whenever possible, 20 g of meteorite is routinely allocated in order to assure homogeneous and representative powders (Jarosewich, 1986).

Sample Preparation

Preparation of a meteorite for chemical analyses requires planning and attention to detail. The sample must be powdered so that it can be easily fused or dissolved in acid. For meteorites with no metal (achondrites, carbonaceous chondrites), preparation is relatively simple: the sample is ground and sieved through 100-mesh. Unfortunately, this technique is not suitable for metal-bearing chondrites, mesosiderites, and irons with silicate inclusions.

Grinding the sample in liquid nitrogen (Berry and Rudowsky, 1965) appeared promising. The author tried this method without success; the metal is malleable and does not pulverize. In fact, prolonged grinding contaminates the sample.

Grinding the sample, with subsequent separation into magnetic and non-magnetic fractions, is a technique that has been used in early (Prior, 1916) and recent works. A description of this technique is given by Dyakonova and Kharitonova (1966). Easton (1983) described a new and efficient separation technique for chondrites and minerals which uses a rotating magnetic field.

The method of meteorite preparation used in the present work was outlined by the author (Jarosewich, 1966) and is similar to the one described by König (1964). Basically, the preparation consists of grinding, sieving and separating the sample into two fractions, one coarse (mostly metal) and one fine (mostly silicates). The sample is ground (Fritsch vibrating micropulverizer), and then passed through a 100-mesh nylon sieve. In this manner, two portions are obtained: one, finer than 100-mesh, that consists primarily of silicates and some finely divided metal and sulfides, and a second, coarser than 100-mesh, that consists primarily of metal. Each portion is weighed accurately to determine the relative proportions. Then, a representative amount of each portion is weighed for analysis. The advantage of this method over conventional methods of quartering or splitting the powder is that the metal can be apportioned accurately.

Recovery of the sample with this technique is almost quantitative. With careful preparation, depending on the condition of the meteorite, <0.1 g of a 5–20 g sample is lost; the loss is slightly larger for weathered meteorites.

Iron meteorites do not require special preparation except for cleaning the surfaces. Although no special preparation is needed, care must be exercised when sampling iron meteorites because of the presence of inclusions such as schreibersite, silicates, sulfides, carbides and chromite, which cannot readily be seen (*e.g.,* a large grain of chromite was found in the Lazarev meteorite; Clarke, 1983). In most cases, the entire fragment is dissolved in acid and the solution is inspected for residues.

Analytical Procedure

The analytical procedure originally described by the author (Jarosewich, 1966) has been simplified; the earlier procedure involved dissolving the sample in HCl and analyzing acid soluble and acid insoluble portions. At present the whole sample is analyzed for major and minor elements.

The chief gain from analyzing acid soluble and acid insoluble portions is in the estimation of Fe_2O_3 in weathered meteorites. Since Fe_2O_3 can be calculated readily from olivine and pyroxene probe data and bulk chemistry, separate analyses of acid soluble and insoluble portions are applied only to weathered H3, L3 and LL3 chondrites with variable olivine composition. Separate analyses of acid soluble and insoluble portions are also used for mesosiderites and iron meteorites with silicate inclusions.

For brevity, only a general outline of the methods is presented. Detailed descriptions of elemental determination procedures are given in Hillebrand *et al.* (1953), Sandell (1959), Peck (1964) and Maxwell (1968).

Six different aliquots of the homogenized powder are taken for analysis:

1. Si, Al, Fe, Mg, Ca, Ti, Cr, and H_2O^- (moisture)	0.5–1 g
2. Ni, S, Mn, P, and Co	0.5–1 g
3. Metallic iron	0.3–0.5 g
4. H_2O^+ (bound water)	0.5 g
5. Na and K	50–100 mg
6. Carbon	50–150 mg

Major Elements

One of the necessary modifications of the conventional method of silicate analysis is the treatment of the meteorite powder with HCl to dissolve metal and FeS before fusion. This step is necessary to avoid the reaction of the metal with the platinum crucible. The dissolved sample is filtered, the residue (mostly pyroxene, feldspar, and chromite) is ignited and fused with Na_2CO_3, after which the fusion cake is dissolved in dilute HCl and combined with the filtrate. The rest of the analysis is continued as outlined below.

Si: separated as SiO_2 from HCl solution.
Fe: titrated with $K_2Cr_2O_7$.
Al: precipitated with 8-hydroxyquinoline.
Ti: determined colorimetrically with Tirone.
Ca: precipitated with ammonium oxalate.
Cr: determined colorimetrically with 1,5-diphenylcarbohydrazide.
Mg: precipitated with di-basic ammonium phosphate.
FeO: calculated by subtracting Fe(m) and Fe(S) from Fe(t). FeO can be determined directly in meteorites with no metal. Since direct chemical determination of FeO is always suspect because of interferences, the calculated value is preferred. For C1 and C2 chondrites, FeO is chemically determined in order to calculate Fe_2O_3.
Fe_2O_3: in conventional silicate analyses Fe_2O_3 is determined by difference, subtracting chemically determined FeO from Fe(t). Since FeO cannot be determined directly in chondrites and many other meteorites, it is calculated first from probe analysis of olivine and pyroxene (SiO_2, MgO, and FeO) and from SiO_2, MgO, and FeO in bulk sample. Thus calculated FeO, together with Fe(m) and Fe(S) is subtracted from Fe(t) and the remainder is reported as Fe_2O_3. Such Fe_2O_3 values are relatively uncertain because of additive errors of probe and chemical results.

Minor Elements

A sample for minor elements is dissolved in HF-HNO_3-Br-water and filtered into a 100 ml flask. Aliquots are taken for Ni, S, Mn, P, and Co.

Ni: precipitated with dimethylglyoxime.
S: precipitated with $BaCl_2$.
P: determined colorimetrically with molybdovanadate.
Mn: determined colorimetrically as permanganate.
Co: determined colorimetrically with 2-nitroso salt.

Other Constituents

Fe(m): sample is dissolved in $HgCl_2$ solution, filtered, and titrated with $K_2Cr_2O_7$ (Riot, 1941).
H_2O^+: determined with Penfield method (Peck, 1964).
H_2O^-: weight loss at 110 °C.
C: sample is ignited in a high-frequency furnace and CO_2 is measured by thermal conductivity using a LECO carbon analyzer.
Na, K: sample is dissolved in HF-H_2SO_4 and elements are determined by flame emission.

Iron Meteorites

The sample of iron meteorite is dissolved in aqua regia; the solution is filtered into a flask and is diluted to volume. Aliquots are taken for Ni, Co, and P determinations.

Ni, Co: determined as described under "minor elements."
P: determined colorimetrically with molybdenum blue.

There are two ways to present analytical results. They can be presented either in a conventional manner as oxides or as elements with oxygen reported separately (Wiik, 1969). The author prefers to report results as oxides and other phases such as sulfides, SO_3, CO_2, elemental sulfur, H_2O, Fe(m) and Fe_2O_3. Such presentation enables a better interpretation of the results in terms of mineralogy and gives a clearer picture of the condition of the meteorite.

Since the chemical data are used for various calculations, it is often instructive to know the precision of the methods. In the author's experience, the precision for meteorite analyses is similar to those for rock silicates, with the exceptions of FeO and Fe(m). Unlike instrumental analyses, where precision is expressed in terms of standard deviations based on counting statistics, precision for classical silicate analyses is expressed as a simple deviation (+/−) from the average result (Groves, 1951), or as an agreement between two or more analyses in absolute percentages (Peck, 1964). The following errors are expressed in terms of the latter: SiO_2, 0.20%; TiO_2, 0.01%; Al_2O_3, 0.05%; FeO, 0.25%; Cr_2O_3, 0.02%; MnO, 0.005%; MgO, 0.10%; CaO, 0.03%; Na_2O, 0.02%; K_2O, 0.005%; H_2O^+, 0.1%; H_2O^-, 0.02%; Fe(m), 0.2%; S, 0.05%; Fe(t), 0.15%; Ni, 0.03%; Co, 0.005%; C, 0.005%. The data for major and trace elements in The Allende Reference Material (Jarosewich *et al.,* 1987) can be used also as a guide to the precision for different methods.

Finally, summation is an approximate indicator of the quality of analyses for the major elements. Mason (1965) describes the criteria for acceptable analyses based on chemistry and mineralogy. Thus, it is generally accepted that one of the tests of a good analysis is a sum between 99.5% and 100.5%. However, good summation is not necessarily indicative of a good analysis; the best assurance of the quality of data is a comparison of the results with mineralogy. Some variation in summations can be expected in weathered meteorites.