



Date: 2026-06-29

**Written Submission from
Orano Canada Inc.**

**Mémoire d'
Orano Canada Inc.**

In the matter of

À l'égard d'

Orano Canada Inc.

Application to renew the McClean Lake
Operating Licence for 2-year term

Orano Canada Inc.

Demande pour le renouvellement du
permis d'exploitation de McClean Lake
pour une période de deux ans

**Hearing in writing based on written
submissions**

**Audience par écrit fondée sur des
mémoires**

September 2026

Septembre 2026

Hole		TMF23-01 Pore Water																				
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09A	SA09B	SA10	SA11	SA12	SA13	SA14A	SA14B	SA15	SA16	SA17	SA18	SA19
Sample Elevation (mASL)		434.16	432.49	429.49	426.49	423.49	420.47	417.50	414.68	411.68	411.05	408.43	405.56	402.48	399.46	398.85	398.24	395.47	391.87	388.77	386.66	383.59
Depth Interval		433-436	430-433	427-430	424-427	421-424	418-421	415-418	412-415	409-412	409-412	406-409	403-406	400-403	397-400	397-400	397-400	394-397	391-394	388-391	385-388	382-385
Source Deposit		Cigar Lake					JEB/Sue															
Analyte	Units																					
pH (Field)	pH units	7.67	6.94	7.43	7.67	7.76	7.47	6.95	7.30	7.19	6.30	6.94	7.94	7.23	7.28	7.33	7.77	7.51	7.81	7.44	7.60	7.70
Temp (Field)	°C	17.2		19.8	16.5		15.9		15.5	17.4				17.4	16.2	14.8	17.3	16.2	18.7	21	15	14.5
Eh (Field)	mV	196.6	277.2	105.5	158.1	204	224.3	296.8	137.5	345.3	282	343	301.5	100	210.9	138.5	230	342.6	303.3	340	364.4	215.2
Spec. Cond. (Field)	µS/cm	5600	6570	8150	7550	5910	4320	4390	5960	6470	8250	4400	3900	4790	6660	4460	4600	5460	4640	5590	4830	4520
D.O. (Field)	mg/L	6.56	5.7	6.42	6.75	6.2	7.52	7.57	7.54	8.28	8.53	8.05	8.2	7.42	9.71	8.18	8.59	10.72	9.18	9.24	11.19	9.25
pH (Lab)	pH units	7.93	8.18	7.74	7.86	7.85	7.72	7.8	7.67	7.58		7.73	7.95	7.59	7.76	7.63	7.61		7.87			
Spec. Cond. (Lab)	µS/cm	4940	5000	5800	5470	4400	3360	3490	3530	4730		4260	3000	3510	4550	3430	3610		3520			
Ca ²⁺	mg/L	508	501	482	489	532	540	540	518	501		524	571	566	502	550	619		563			
Mg ²⁺	mg/L	281	321	530	609	331	92	75	146	174		120	67	106	156	97	115		95			
Na ⁺	mg/L	410	393	386	211	199	190	245	383	471		392	120	135	402	142	148		192			
K ⁺	mg/L	38	33	38	28	30	28	36	33	32		26	27	35	46	43	38		43			
HCO ₃ ⁻	mg/L	129	79	126	161	76	61	76	101	98		73	51	202	129	117	360		189			
CO ₃ ²⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	<1		<1			
Cl ⁻	mg/L	134	148	138	135	48	43	40	36	104		90	63	52	83	52	57		82			
OH ⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	<1		<1			
SO ₄ ²⁻	mg/L	2960	3000	3700	3600	2800	2020	2060	2530	2740		2480	1830	2040	2590	1980	2000		1950			
Total Hardness	mg/L	2420	2570	3380	3720	2690	1720	1660	1890	1960		1800	1700	1850	1890	1770	2020		1790			
Sum of Ions	mg/L	4470	4480	5410	5240	4030	2990	3090	3760	4130		3730	2740	3200	3940	3010	3360		3130			
Total Alkalinity	mg/L	106	65	103	132	62	50	62	83	80		60	42	166	106	96	295		155			
P. Alkalinity	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	<1		<1			
NO ₃ ⁻	mg/L	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.7		4.7	<0.4	<0.4	<0.4	<0.4	<0.4		<0.4			
NH ₃	mg/L	9.1	5.3	6.8	6.6	14	14	13	8.7	6.2		15	12	49	24	26	17		9.8			
DOC	mg/L	3	5	3.4	7.1	8.9	2.6	6	6.7		5.7		4	4.1			8.4					4.3
TDS	mg/L	4670	4590	5670	5430	4160	2970	3060	3660	4180		3750	2810	3020	3860	3010	3160		3090			
Al	mg/L	0.0056	<0.005	<0.005	0.009	0.0062	<0.005	<0.005	<0.005	<0.005		0.009	0.005	<0.005	0.0052	0.0054	0.014		0.01	0.41	0.76	0.071
Sb	mg/L	0.001	0.013	0.006	0.004	0.004	<0.002	<0.002	<0.002	0.007		0.008	0.01	<0.002	0.0071	0.0038	0.005		0.015	0.012	0.02	0.006
As (Dissolved)	µg/L	966	1140	1670	870	266	950	870	1660	1780		1120	870	6350	3220	5050	5390		7420	4990	9860	13900
As (Total)	ASL		1535	2127	1233	262	1188	880	1960		962	1057	951	8610								
	Orano Lab			1810	974	277				1860					2750	5280			8040		11100	
As (III)	ASL	844	825	1900	1090	101	730	420	1680	1090	732	426	115	7990								
	Orano Lab			1980	887	122				1260					2560	5210			1900		1230	
As (V)	ASL	106	710	227	143	161	458	460	280		230	631	836	620								
	Orano Lab			117	36	123				659					473	119			4080		8350	
DMA (as As)	ASL	111	189	132	242	154	8.8	7.94	63.7		23.3	11.7	4	253								
	Orano Lab			43	40	38																
MMA (as As)	ASL	11	29.8	10.2	8	11.8	4	4	8.98		4	5.44	4.5	30								
	Orano Lab			12	4	4																
Ba	mg/L	0.011	0.015	0.01	0.008	0.01	0.014	0.014	0.012	0.008		0.016	0.02	0.018	0.0081	0.019	0.023		0.023	0.026	0.042	0.021
Be	mg/L	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001		<0.001	<0.0001	<0.001	<0.001
B	mg/L	2	2.7	2.9	3.4	1.6	0.1	0.2	0.2	0.5		0.4	0.2	0.5	0.84	0.55	0.5		0.6	0.71	0.6	0.7
Cd	mg/L	0.00061	0.0014	0.0005	0.0001	0.00017	0.002	0.0017	0.0021	0.0016		0.0014	0.0018	0.0007	0.00014	0.00011	0.0001		0.0002	0.00007	0.0003	0.0003
Cr	mg/L	<0.0005	<0.005	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.0005	<0.0005	<0.005					

Hole		TMF23-02 Pore Water																			
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA011	SA12	SA13	SA014	SA15	SA16	SA17	SA18	SA19A	SA19B
Sample Elevation (mASL)		432.44	429.98	427.58	424.58	421.58	418.58	415.61	412.28	409.42	406.45	403.80	400.58	397.71	393.70	392.14	389.40	386.71	381.79	379.70	379.10
Depth Interval		430-433	427-430	427-430	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391	385-388	379-382	379-382	379-382
Source Deposit		Cigar Lake										JEB/Sue									
Analyte	Units																				
pH (Field)	pH units	7.95	6.96	6.94	6.94	6.95	6.95	6.93	6.95	6.94	6.95	6.93	6.93	6.95	6.94	6.93	6.95	6.92	6.93	6.93	6.94
Temp (Field)	°C	18.1																			
Eh (Field)	mV	259.9	126.8	138	141.5	226	110	175.1	310.8	281.5	294.5	342	325.4	168.6	252.6	253.4	183	139	123.4	142.9	288.6
Spec. Cond. (Field)	µS/cm	5870	7330	6040	7330	5810	4110	4030	4880	4710	5580	5070	5010	6570	4170	4500	5160	4560	4550	4810	7470
D.O. (Field)	mg/L	6.11	5.49	6.2	6.22	6.27	5.03	8.8	9.05	8.85	8.43	9.22	8.62	8.01	8.48	8.05	8.3	7.06	7.33	6.3	7.96
pH (Lab)	pH units	8.03	7.50	7.57	7.75	8.27	7.46	7.64	7.76	7.72	7.58	7.76	7.80	7.46	7.82	8.01	7.79	7.85	7.84		
Spec. Cond. (Lab)	µS/cm	5200	5640	4760	5170	4540	3320	3290	3540	3820	3710	3630	3870	3560	3280	3460	3820	3680	3520		
Ca ²⁺	mg/L	493	487	508	490	502	569	537	530	487	548	546	517	524	583	602	550	550	572		
Mg ²⁺	mg/L	394	530	442	503	319	156	91	71	78	62	82	136	121	102	118	140	125	120		
Na ⁺	mg/L	370	368	210	262	288	103	197	282	377	334	282	299	205	121	137	252	227	176		
K ⁺	mg/L	34	39	22	34	33	18	18	22	26	20	23	26	34	34	38	40	36	36		
HCO ₃ ⁻	mg/L	104	112	171	150	98	228	122	88	84	52	88	115	76	295	374	139	171	223		
CO ₃ ⁻²	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Cl ⁻	mg/L	127	130	137	120	91	28	31	44	59	59	63	57	46	40	50	56	60	54		
OH ⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
SO ₄ ⁻²	mg/L	3200	3700	3070	3300	2910	2020	1970	2070	2180	2180	2150	2310	2140	1870	1930	2280	2140	2030		
Total Hardness	mg/L	2850	3390	3080	3290	2560	2060	1710	1610	1540	1620	1700	1850	1800	1870	1990	1950	1880	1920		
Sum of Ions	mg/L	4740	5370	4560	4870	4260	3130	2980	3130	3300	3270	3250	3480	3170	3070	3270	3470	3320	3220		
Total Alkalinity	mg/L	85	92	140	123	80	187	100	72	69	43	72	94	62	242	307	114	140	183		
P Alkalinity	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
NO ₃ ⁻	mg/L	<0.4	<0.4	<0.4	<0.4	<0.4	1.7	<0.4	1.4	2.1	3.1	2.2	2.4	1.1	<0.4	<0.4	0.8	0.8	<0.4		
NH ₃	mg/L	13	5.1	0.65	9.4	11	7.2	8	14	10	7.9	9.5	15	17	17	16	10	9.2	8.5		
DOC	mg/L	10	5.2	5.8	6.8	6.8															
TDS	mg/L	4910	5680	4630	4960	4260	3070	2910	3060	3250	3240	3140	3440	3310	3000	3190	3440	3310	3170		
Al	mg/L	<0.005	0.055	0.0036	0.53	0.0085	0.001	1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		0.31
Sb	mg/L	0.004	0.002	0.0013	<0.002	0.0029	0.0013	0.005	0.004	<0.002	0.005	0.008	0.002	<0.002	<0.002	0.004	0.006	0.002	0.003		0.0076
As (Dissolved)	µg/L	540	900	1650	3910	137	563	910	850	1040	570	1020	500	4220	6210	6740	14800	14100	21700		785
As (Total)	ASL	335.8	1007	2776	3681	94.2														10550	651
	Orano Lab	1140	1600	805	212	1410	1160	965	1300	850	1260	758	3440	7290	5330	16900	16000	28400			
As (III)	ASL	243	730	2600	3400	42.6														10300	531
	Orano Lab	835	1640	779	32	1340	922	545	522	278	657	352	3640	7600	4720	15800	16300	23900			
As (V)	ASL	92.8	277	176	281	51.6														250	120
	Orano Lab	230	81	24	56	95	212	382	676	318	408	333	101	165	574	441	543	338		200	4.64
DMA (as As)	ASL	215	17.7	47.3	44.6	65.1															
	Orano Lab	11	82																	200	4
MMA (as As)	ASL	12.8	10	20	40	4.17															
	Orano Lab	12				3															
Ba	mg/L	0.011	0.012	0.012	0.015	0.015	0.01	0.019	0.017	0.02	0.022	0.019	0.014	0.021	0.018	0.027	0.032	0.038	0.025		0.028
Be	mg/L	0.001	0.001	0.0001	0.001	0.0001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		<0.0001
B	mg/L	1.5	4	2.7	3.1	1.4	0.42	0.1	0.2	0.3	0.4	0.4	0.4	0.5	0.6	0.7	0.9	0.8	0.8		1
Cd	mg/L	0.0008	0.0004	0.00011	0.0005	0.00019	0.00022	0.0013	0.0019	0.0016	0.0024	0.003	0.0019	0.0013	0.0004	0.0007	0.0013	0.0009	0.0009		0.00022
Cr	mg/L	0.005	0.005	0.0005	0.005	0.0005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		0.0016
Co	mg/L	0.012	0.25	0.72	0.037	0.0043	0.04	0.051	0.01	0.004	0.003	0.016	0.027	0.023	0.018	0.01	0.02	0.011	0.022		0.038
Cu	mg/L	0.005	0.002	0.0005	0.002	0.0016	0.0002	0.002	0.002	0.002	0.002	0.006	0.002	0.002	0.002	0.002	0.002	0.002	0.002		0.004
Fe	mg/L	0.01	0.019	0.43	0.011	0.0014	0.69	0.005	0.005	0.005	0.005	0.012	0.005	0.16	0.2	0.005	0.005	0.005	0.005		0.31
Pb	mg/L	0.001	0.001	0.0001	0.001	0.0001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.0016
Mn	mg/L	0.48	2.4	3.48	1.7	0.32	2.9	1.8	0.61	0.31	0.5	1.8	1.7	6.1	4.9	4.1	3.7	2	5.8		4.36
Mo	mg/L	9.98	3.99	0.896	3.99	2.41	2.9	14.7	20.8	19.7	24.7	30.5	19.5	15	4.25	5.14	12.8	9.98	9.91		2.03
Ni	mg/L	0.087	0.63	0.696	0.14	0.036	0.446	2.59	0.69	0.58	0.62	2.48	1.1	0.39	0.42	0.25	0.59	0.33	0.45		1.28
Se	mg/L	0.003	0.005	0.0012	0.002	0.0018	0.0011	0.019	0.017	0.019	0.023	0.035	0.011	0.005	0.005	0.006	0.011	0.009	0.002		0.027
Ag	mg/L	0.0005	0.0005	0.00005	0.0005	0.00005	0.00005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		<0.00005
Sr	mg/L	0.32	0.34	0.3	0.34	0.39	0.28	0.43	0.62	0.73	0.66	0.73	0.56	0.58	0.77	1.1	0.98	0.97	0.96		1.69
Ti	mg/L	0.002	0.002	0.0002	0.002	0.0002	0.0002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002		0.0002
Sn	mg/L	0.001	0.001	0.0001	0.001	0.0001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.0001
Tl	mg/L	0.012	0.005	0.0009	0.008	0.0025	0.0034	0.018	0.03	0.019	0.026	0.033	0.02	0.014	0.005	0.005	0.011	0.01	0.016		0.019
V	mg/L	0.003	0.001	0.0002	0.001	0.0025	0.0001	0.001	0.002	0.004	0.004	0.008	0.006	0.002	0.017	0.033	0.042	0.026	0.01		0.011
Zn	mg/L	0.005	0.015																		

Hole		TMF23-03 Pore Water																				
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA11	SA12	SA13	SA14	SA15	SA16	SA17	SA18	SA19	SA20	SA21
Sample Elevation (mASL)		435.68	432.97	430.58	427.58	424.58	421.58	419.38	416.89	414.37	412.57	411.35	409.77	406.78	403.81	401.37	398.37	392.20	388.46	386.08	382.67	381.17
Depth Interval		433-436	433-436	430-433	427-430	424-427	421-424	418-421	415-418	412-415	412-415	409-412	409-412	406-409	403-406	400-403	397-400	391-394	388-391	385-388	382-385	379-382
Source Deposit		Cigar Lake										JEB/Sue										
Analyte	Units																					
pH (Field)	pH units	8.11	8.11	8.49	7.76	7.81	7.74	7.70	7.58	7.25	7.24	7.46	8.13	7.75	7.68	7.80	7.70	7.54	7.93	7.89	7.75	7.81
Temp (Field)	°C	17.9	17.9	20.3	19.9	17.7	18.4	19	17.8	17.2	19.7	18.8	18.4	18.5	19.6	20.2	20.1	18.5	17.2	18.1	18.7	18.9
Eh (Field)	mV	463.2	255.7	307	192.1	224.1	169.1	158.4	204.5	201.8	157.1	276.6	276.7	281.7	185.7	183.2	107.7	156.1	285.5	146.7	256.7	277
Spec. Cond. (Field)	µS/cm	5570	7340	6970	7840	7980	7480	5260	5430	5230	5310	6600	4280	4360	4260	5080	4850	5210	4600	4700	5020	4660
D.O. (Field)	mg/L	7.28	5.41	4.89	5.39	5.86	6.75	6.02	6.13	7.15	5.97	7.89	7.85	6.56	6.93	6.08	6	8.34	8.77	7.12	8.09	8.42
pH (Lab)	pH units	8.06	7.89	7.89	8.05	7.97	7.95	8.04	7.88	7.70	7.88	8.08	7.71	6.85	8.21	8.14	8.15	8.18	7.81	8.25	7.95	6.96
Spec. Cond. (Lab)	µS/cm	4920	5520	5160	5690	5760	5570	3920	4130	3970	3980	4210	3310	3340	3380	3750	3650	3570	3570	3660	3790	3600
Ca ²⁺	mg/L	490	486	491	484	480	485	531	521	516	515	515	558	564	585	591	603	580	572	626	590	590
Mg ²⁺	mg/L	271	395	329	462	543	618	196	219	165	151	163	89	110	146	177	186	110	117	135	205	200
K ⁺	mg/L	430	400	401	406	335	197	213	245	274	303	335	135	142	61	106	84	160	166	113	97	91
Na ⁺	mg/L	34	40	37	36	38	30	23	18	22	20	29	36	31	31	53	45	45	42	43	37	43
HCO ₃ ⁻	mg/L	107	77	134	118	102	139	126	74	87	161	85	149	206	290	373	354	206	412	389	360	360
CO ₃ ⁻²	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<10	<1	<1	<1	<1	<1	<1	<10	<10
Cl ⁻	mg/L	129	129	124	135	125	134	54	45	40	30	48	34	38	72	69	63	50	62	58	53	55
OH ⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<10	<1	<1	<1	<1	<1	<1	<1	<10
SO ₄ ⁻²	mg/L	2980	3300	3110	3500	3700	3600	2330	2510	2420	2400	2440	1920	1980	1900	2070	2030	1900	2020	1960	2160	2100
Total Hardness	mg/L	2340	2840	2580	3110	3430	3750	2130	2200	1960	1900	1950	1760	1860	2060	2200	2270	1900	1910	2120	2410	2290
Sum of Ions	mg/L	4400	4880	4580	5160	5350	5180	3490	3690	3520	3510	3700	2880	3010	3000	3380	3400	3200	3200	3370	3580	3440
Total Alkalinity	mg/L	54	88	63	110	97	84	114	103	61	71	132	70	122	169	238	306	290	169	338	319	295
P. Alkalinity	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<10	<1	<1	<1	<1	<1	<1	<1	<10
NO ₃ ⁻	mg/L	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
NH ₃	mg/L	14	7.2	4.2	6.5	7.5	4.9	2.5	4.6	4.6	9.3	15		2.5	15	11		13	14	11		
DOC	mg/L	6.2	13	2	2.2	5.7	5.2	2.8	2.7	2.2	2.5	2.9	2.5			6.2	10		15	6.7	9.6	
TDS	mg/L	4340	5130	4680	5300	5490	5480	3560	3740	3600	3540	3780	2840		2980	3350	3380		3150	3250	3520	
Al	mg/L	0.015	0.006	0.005	0.005	0.005	0.014	0.0056	0.0058	0.0043	0.0042	0.005	0.005	0.005	0.005	0.013	0.009	0.62	0.029	0.022	0.032	0.05
Sb	mg/L	0.014	0.005	0.022	0.003	0.016	0.003	0.0043	0.006	0.017	0.0034	0.003	0.005	0.008	0.007	0.003	0.002	0.009	0.007	0.007	0.004	0.004
As (Dissolved)	µg/L	650	620	1020	1390	430	320	4060	2070	870	860	1540	830	5900	7220	17200	5460	2960	11900	9010	2280	2290
As (Total)	ASL	µg/L	595	756	1784	290.8	226.6	4754	2448	1454	1498	842	960		7004	8043	18373	6263	3270	16300	10271	2299
	Orano Lab	µg/L	55000		1910							2120			1680					11600		2010
As (III)	ASL	µg/L		375	266	1550	98.8	179	4520	2220	1200	1280	632	167		6740	7550	17800	5930	2200	15200	9650
	Orano Lab	µg/L	43		1720								1570		1320				12900		1430	1830
As (V)	ASL	µg/L		220	490	234	192	47.6	234	228	254	218	210	793		264	493	573	333	1070	1100	621
	Orano Lab	µg/L	12		180								441		356				670		337	469
DMA (as As)	ASL	µg/L		146	282	41.1	158	93.6	40	13	11	8	8	7.73		60	74	250	153	27	471	124
	Orano Lab	µg/L	38		42																17.2	
MMA (as As)	ASL	µg/L		10.1	20.5	14.6	16.6	5.99	20	10	8	8	8	16.4		30	30	80	40	10	100	40
	Orano Lab	µg/L	4		13																4	
Ba	mg/L	0.014	0.009	0.01	0.011	0.012	0.011	0.018	0.015	0.013	0.011	0.01	0.012		0.012	0.014	0.017	0.027	0.023	0.026	0.023	0.022
Be	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	mg/L	1.7	2.1	2.3	2.7	4.4	4.1	0.26	0.15	0.28	0.19	0.3	0.2		0.2	0.3	0.4	0.7	0.7	0.9	0.9	0.8
Cd	mg/L	0.0001	0.0001	<0.0001	<0.0001	0.0001	<0.0001	0.00003	0.0002	0.00004	0.00009	<0.0001	0.0002		<0.0001	0.0001	0.0002	<0.0001	0.0001	0.0002	0.0001	0.0001
Cr	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Co	mg/L	0.022	0.047	0.014	0.11	0.068	0.054	0.073	0.14	0.19	0.26	0.05	0.003		0.68	0.08	0.01	0.019	0.007	0.008	0.016	0.016
Cu	mg/L	0.018	0.004	<0.002	0.004	0.005	<0.002	0.0006	0.0024	0.0009	0.0004	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Fe	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.0006	0.0018	0.0012	0.0013	<0.005	<0.005		<0.005	<0.005	<0.005	0.46	0.013	<0.005	0.08	
Pb	mg/L	0.007	0.003	0.004	0.001	0.004	0.01	0.0002	0.0002	0.0002	0.0001	<0.001	<0.001		<0.001	<0.001	<0.001	0.029	0.009	<0.001	0.003	
Mn	mg/L	0.34	0.72	0.17	1.7	1.3	2	3.15	2.83	1.96	2.33	1.6	0.35		5	2.9	3.4	4.6	1	3.8	5.1	5.1
Mo	mg/L	0.54	4.7	14.1	13.5	1.9	0.5	9.67	9.89	4.88	5.28	19.3	33.3		23	49.3	29.3	3.72	8.94	18.9	3.32	3.15
Ni	mg/L	0.13	0.26	0.095	0.48	0.26	0.18	0.901	3.16	9.88	8.21	3.01	0.3		0.95	0.34	0.25	0.39	0.21	0.32	0.64	0.62
Se	mg/L	0.055	0.004	0.002	0.002	0.007	0.004	0.001	0.0069	0.029	0.0009	0.014	0.012		0.002	0.004	0.002	0.005	0.055	0.005	0.005	0.008
Ag	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.00005	0.00005	<0.00005	<0.00005	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005	<0.000				

Hole		TMF23-04 Pore Water																				
Sample Number		SA01	SA02A	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA11	SA12	SA13	SA14	SA15	SA16	SA17	SA18	SA19	SA20	SA21
Sample Elevation (mASL)		431.70	432.70	429.70	426.09	424.69	421.04	418.65	415.70	412.55	409.50	406.42	403.61	400.71	397.69	393.40	390.30	387.02	383.92	380.52	377.80	373.61
Depth Interval		430-433	430-433	427-430	424-427	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	391-394	388-391	385-388	382-385	379-382	376-379	373-376
Source Deposit		Cigar Lake										JEB/Sue										
Analyte	Units																					
pH (Field)	pH	7.85	8.04	8.30	7.41	7.35	7.42	7.12	7.44	8.17	7.20	7.91	7.69	7.22	7.59	7.32	7.88	7.88	7.70	7.62	7.90	8.00
Temp (Field)	°C	16.8	15.5	15.7	16.9	17.9	15.7	16.9	16.2	16.8	17.8	15.6	14.2	18	19.8	15.1	14.9	17.5	18.7	19.8	17.5	16.7
Eh (Field)	mV	355	303.3	254.5	155.1	162.7	98	151.6	109.5	277.4	276.3	296.8	305.8	341.7	298.5	201.6	290	284.6	241.8	250.9	284.7	257.5
Spec. Cond. (Field)	µS/cm	7940	7380	7040	5110	4840	5040	6260	5700	5570	6640	5940	4560	4310	4560	4920	4720	4910	4760	5040	5430	5220
D.O. (Field)	mg/L	6.16		5.87	7.41	6.17	5.14	7.25	6.74	7.13	7.64	7.32	6.82	8.51	7.75	7.85	8.25	6.66	7.11	7.21	7.51	7.79
pH (Lab)	pH units	7.68	7.47	7.90	7.81	8.01	8.14	7.97	8.01	7.85	7.97	7.72	7.94	7.60	8.08	7.90	8.15	8.30	8.20	8.14	8.22	8.06
Spec. Cond. (Lab)	µS/cm	5670	5340	5170	3940	3870	3830	4350	4250	4170	5200	4500	3580	3410	3460	3780	3690	3830	3680	3800	4090	4110
Ca ²⁺	mg/L	462	478	494	519	523	511	489	499	512	478	506	525	552	564	541	602	642	587	596	604	587
Mg ²⁺	mg/L	482	424	406	137	126	107	102	82	76	137	62	160	136	157	237	147	150	183	184	186	237
Na ⁺	mg/L	359	305	312	287	286	314	459	453	424	655	481	148	102	86	89	145	145	90	117	189	147
K ⁺	mg/L	39	37	34	19	24	24	27	26	32	34	39	31	44	28	34	42	41	38	37	40	35
HCO ₃ ⁻	mg/L	58	44	90	92	105	159	104	118	88	108	92	98	41	146	98	327	478	332	188	311	201
CO ₃ ⁻²	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Cl ⁻	mg/L	125	124	110	43	54	51	49	48	43	53	56	37	34	28	63	51	58	49	50	42	99
OH ⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
SO ₄ ⁻²	mg/L	3500	3300	3200	2300	2240	2170	2500	2380	2340	3020	2480	2130	2090	2080	2350	2100	2100	2060	2260	2340	2540
Total Hardness	mg/L	3130	2940	2900	1860	1820	1710	1640	1580	1590	1760	1520	1970	1940	2050	2320	2100	2220	2220	2240	2270	2440
Sum of Ions	mg/L	5040	4750	4660	3400	3360	3340	3730	3620	3530	4490	3760	3140	3010	3120	3420	3430	3630	3350	3440	3730	3870
Total Alkalinity	mg/L	48	36	74	75	86	130	85	97	72	89	75	80	34	120	81	268	392	272	154	255	165
P. Alkalinity	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
NO ₃ ⁻	mg/L	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	
NH ₃	mg/L	13	27	13	5.2	3.7	1.8	1.8	6.3	11	2.5	37	12	11	21	9.2	15	13	11	7.6	12	18
DOC	mg/L	5.9	8.7	8.3		2.8	2.3	1.7		3.5	10	3			3.1		7.4	7.9	7.3	7.5	6.3	11
TDS	mg/L	5230	4800	4850	3310	3300	3260	3610	3530	3550	4320	3530	3090	2940	3050	3390	3350	3500	3310	3420	3750	3740
Al	mg/L	<0.005	0.007	0.011	0.01	0.01	0.0052	0.0044	<0.005	0.006	<0.005	0.006	<0.005	<0.005	0.009	<0.005	0.014	0.017	0.021	0.015	0.033	0.017
Sb	mg/L	0.002	0.006	0.006	0.0032	0.0061	0.0042	0.0048	<0.002	0.003	<0.002	0.003	<0.002	<0.002	0.002	0.003	0.007	0.006	0.004	0.0042	0.006	0.0062
As (Dissolved)	µg/L	490	590	910	4770	2680	3870	3020	2630	1110	460	3420	690	510	740	820	2140	5060	9440	1900	1330	
As (Total)	ASL	414	286	543.2	4691	3452	5242	3179	5325	860	709	2789.5	922	808	781	1099	2390	3980	5593	1933	2250	1273
	Orano Lab			1220																2050	1860	1540
As (III)	ASL	235	156	467	4370	3080	4960	2900	5010	430	359	69.5	590	154	565	817	1720	2950	5270	1580	910	485
	Orano Lab			401																2406	1180	1220
As (V)	ASL	179	130	76.2	321	372	282	279	315	430	350	2720	332	654	216	282	670	1030	323	353	1340	788
	Orano Lab			425																117	860	16
DMA (as As)	ASL	39.7	328	344	62	109	29	74.5	38	4	4	139	4	9.69	18.7	24	30	64	140	67.6	72.4	77.6
	Orano Lab			261																	24	8
MMA (as As)	ASL	5.32	10	17.5	20	20	20	20	20	20	4	147	4	4.64	4	5	10	33.5	20	28.1	81.7	60.2
	Orano Lab			59																7	61	
Ba	mg/L	0.009	0.011	0.012	0.01	0.015	0.015	0.013	0.011	0.011	0.01	0.012	0.012	0.009	0.015	0.009	0.022	0.023	0.025	0.022	0.037	0.028
Be	mg/L	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.0001
B	mg/L	2.2	1.2	1.4	0.14	0.27	0.16	0.11	0.1	0.1	0.2	<0.1	0.2	0.3	0.2	0.4	0.7	0.9	0.61	1	0.84	
Cd	mg/L	<0.0001	<0.0001	0.0001	0.0001	0.00019	0.00002	0.00012	0.0001	<0.0001	0.0002	<0.0001	0.0001	<0.0001	0.0004	0.0012	0.0003	0.0006	0.0001	0.00026	0.0006	0.00035
Cr	mg/L	<0.005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0005	<0.005	<0.0005
Co	mg/L	0.075	0.022	0.019	0.07	0.15	0.096	0.21	0.09	0.004	0.19	0.007	0.027	0.053	0.016	0.59	0.009	0.011	0.018	0.019	0.009	0.0057
Cu	mg/L	<0.002	0.005	<0.002	0.0007	0.0015	0.0004	<0.0002	<0.002	0.003	<0.002	0.004	<0.002	0.005	<0.002	0.002	<0.002	<0.002	0.002	0.0015	<0.002	0.0007
Fe	mg/L	<0.005	<0.005	<0.005	0.0006	0.0024	0.016	0.45	0.031	<0.005	0.032	0.022	<0.005	0.011	<0.005	<0.005	<0.005	<0.005	<0.005	0.0018	<0.005	0.0028
Pb	mg/L	0.003	0.003	0.002	0.0002	0.0002	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	0.0001	<0.001	0.0002
Mn	mg/L	1.2	0.44	0.34	4.89	6	3.18	2.4	2.8	0.29	1.5	0.19	1.3	1.2	2.3	2.9	2.8	4.5	6.3	5	2.8	2.18
Mo	mg/L	2.68	4.33	8.92	7.57	5.75	4.49	5.95	23.6	38	6.75	57.5	16.1	15.9	22.2	17.4	3.33	6	1.69	2.89	5.28	4.17
Ni	mg/L	0.43	0.16	0.1	1.7	4.89	4.96	9.04	2.34	0.14	8.47	0.35	1.62	5.14	1.94	3.29	0.32	0.38	0.62	0.918	0.35	0.279
Se	mg/L	0.002	0.002	0.002	0.0007	0.002	0.0011	0.0044	0.003	0.003	0.014	0.014	0.017	0.14	0.018	0.067	0.013	0.009	0.007	0.014	0.015	0.02
Ag	mg/L	<0.0005	<0.0005	<0.0005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.0005	<0.00											

Hole		TMF23-05 Pore Water																
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA11	SA12	SA13	SA14	SA15	SA16	SA17
Sample Elevation (mASL)		434.99	433.1	430.71	427.71	424.71	421.71	418.71	415.69	412.69	409.69	406.701	403.701	400.681	397.701	394.681	391.711	388.711
Depth Interval		433-436	433-436	430-433	427-430	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391
Source Deposit		Cigar Lake							JEB/Sue									
Analyte	Units																	
pH (Field)	pH units	8.49	8.98	8.19	7.84	7.73	7.76	7.86	7.05	7.09	7.10	7.10	7.48	7.18	7.24	7.69	7.56	7.44
Temp (Field)	°C																	
Eh (Field)	mV	223.9	219.6	247	211.9	245	218.6	275.5	201	216	216.7	182.2	167	194.4	161.6	279.6	267	162.2
Spec. Cond. (Field)	µS/cm	7770	5830	5790	6590	7050	7570	6810	4440	4870	4586	4130	3970	3750	4680	4900	4590	4500
D.O. (Field)	mg/L	5.25	5.58	6.49	7.51	7.5	6.99	8.5	9.14	7.47	7.12	9.6	9.31	9.35	8.19	7.27	7.31	7.08
pH (Lab)	pH units	7.49	7.75	7.81	7.94	7.75	7.88	7.84	7.74	7.76	7.82	7.66	8.07	7.95	8.02	8.02	8.06	7.88
Spec. Cond. (Lab)	µS/cm	5300	5030	5220	5850	6040	6640	5520	3720	4040	3630	3210	3280	3090	3860	3850	3610	3510
Ca ²⁺	mg/L	486	494	496	488	473	462	484	513	508	536	538	572	559	565	631	617	605
Mg ²⁺	mg/L	358	282	380	524	609	691	567	166	166	154	128	148	130	243	199	152	141
Na ⁺	mg/L	428	419	339	406	375	459	261	237	317	184	102	80	68	84	114	124	116
K ⁺	mg/L	38	41	36	37	40	48	40	20	18	33	33	21	21	40	51	38	46
HCO ₃ ⁻	mg/L	62	74	74	108	90	104	70	55	61	106	60	209	142	339	562	554	336
CO ₃ ²⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cl ⁻	mg/L	137	132	121	132	128	143	84	29	29	32	27	24	21	64	78	54	48
OH ⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
SO ₄ ²⁻	mg/L	3200	3010	3100	3600	3900	4300	3600	2310	2500	2210	1980	1950	1880	2260	2130	1960	2040
Total Hardness	mg/L	2680	2390	2800	3370	3680	3990	3540	1960	1950	1970	1870	2030	1930	2410	2390	2160	2090
Sum of Ions	mg/L	4710	4450	4550	5300	5620	6210	5110	3330	3600	3260	2870	3000	2820	3600	3790	3520	3350
Total Alkalinity	mg/L	51	61	61	89	74	85	57	45	50	87	49	171	116	278	461	454	275
P. Alkalinity	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
NO ₃ ⁻	mg/L	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.4	<0.4	<0.4
NH ₃	mg/L															22	15	17
DOC	mg/L	4.4	6.7	5.5	4.7	6.8	7	12	2.7	3.3	3.4	2.6	4.2	2.8	5.9	12	7.9	6.6
TDS	mg/L	5150	4640	4820	5680	5870	6620	5290	3550	3730	3340	2890	2980	2920	3560	3770	3550	3320
Al	mg/L	<0.005	0.068	0.049	0.006	<0.005	<0.005	<0.005	0.0014	0.0014	<0.005	<0.005	<0.005	<0.005	<0.005	0.65	0.7	0.7
Sb	mg/L	0.013	0.024	0.011	0.005	0.012	0.008	0.007	0.0066	0.0057	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	0.002	<0.002
As (Dissolved)	µg/L	450	860	600	990	520	500	290	573	853	570	400	2410	440	1560	15200	3170	9590
As (Total)	ASL	189.1	667	619	482	364	433	124.9	730	744	871	929	2323	1121	2316			
	Orano Lab	399	1050	747	614	530	659	279	886	773	691	887	1740	1210	939	9090	3010	14300
As (III)	ASL	51.1	350	420	253	199	240	66.7	564	538	579	755	2080	861	1760			
	Orano Lab	156	326	397	261	216	233	55	710	564	537	688	1320	830	763	7400	2270	12800
As (V)	ASL	138	317	199	229	165	193	58.2	166	206	292	174	243	260	556			
	Orano Lab	1	195	55	95	86	175	34	180	165	111	147	219	294	182	1360	667	391
DMA (as As)	ASL	233	250	117	125	215	107	129	12.8	12.2	36.2	26.2	111	24.3	36.4			
	Orano Lab	1	212	48	86	173	101	106	5	2		4	47	3		84	58	39
MMA (as As)	ASL	16.9	11	11.9	8.47	14.2	4.83	5.09	4	4	4	4	10	4	10			
	Orano Lab		16	10	11	14	4	5		1		4	5			59	29	16
Ba	mg/L	0.012	0.011	0.013	0.01	0.012	0.011	0.012	0.013	0.013	0.016	0.014	0.011	0.006	0.01	0.026	0.025	0.02
Be	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	mg/L	1.3	1.4	1.5	2.1	3.1	3.6	2.5	0.15	0.13	0.2	0.2	<0.1	<0.1	0.4	0.7	0.6	0.8
Cd	mg/L	0.0001	0.0007	0.0009	0.001	0.0002	0.0002	<0.0001	0.00068	0.00055	0.0009	0.0009	0.0036	0.0012	0.002	0.001	0.0001	0.0002
Cr	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Co	mg/L	0.01	0.018	0.016	0.074	0.07	0.13	0.033	0.24	0.23	0.12	0.092	0.034	0.33	0.75	0.013	0.016	0.032
Cu	mg/L	0.011	<0.002	<0.002	<0.002	0.006	0.004	0.017	<0.0002	0.0003	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	0.005	<0.002
Fe	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.0018	0.001	0.17	0.16	<0.005	0.005	<0.005	0.052	0.035	0.047
Pb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	mg/L	0.21	0.36	0.46	0.74	1.2	1.4	0.88	2.32	1.76	1.4	1.1	2.6	2	4.1	4.7	5.8	10.2
Mo	mg/L	1.25	9.23	8.17	12.6	1.65	1.82	0.54	7.25	6.18	11.5	11.2	42.7	13.6	24.7	10.1	1.25	2.02
Ni	mg/L	0.073	0.12	0.1	0.35	0.25	0.52	0.08	5.53	6.75	4.67	7.99	0.82	3.44	3.07	0.28	0.36	0.49
Se	mg/L	0.012	0.006	0.003	0.003	0.011	0.009	0.012	0.0012	0.0016	0.002	0.004	0.001	0.001	0.002	0.002	0.006	0.004
Ag	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.00005	<0.00005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sr	mg/L	0.29	0.38	0.35	0.4	0.36	0.29	0.23	0.33	0.23	0.29	0.27	0.29	0.22	0.34	0.76	1.3	0.93
Tl	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0002	<0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sn	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ti	mg/L	0.003	0.013	0.008	0.011	0.002	<0.002	<0.002	0.0076	0.0062	0.011	0.012	0.045	0.018	0.022	0.009	0.002	0.004
V	mg/L	0.002	0.003	0.002	0.004	0.003	0.003	0.002	0.0013	0.0016	<0.001	0.003	0.002	0.001	0.003	0.04	0.053	0.031
Zn	mg/L	0.006	<0.005	<0.005	0.005	0.012	0.01	0.008	0.017	0.014	0.06	0.024	0.019	0.01	0.012	0.023	0.043	0.016
F ⁻	mg/L	5.3	4.9	5.4	5.4	5.6	5.5	6.7	1.9	1.5	2	1.1	2.2	1.4	2.1	6.1	4.7	3.7
P	mg/L															0.3	0.2	0.1
²¹⁰ Pb	Bq/L	2	2	2	2	3	2	2	2	2	2	2	3	2	2	1	2	2
²¹⁰ Po	Bq/L	0.5	0.5	0.5	0.5	0.5	0.5											

Hole		TMF23-06 Pore Water																
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA010	SA011	SA012	SA013	SA14A	SA15	SA16	SA17
Sample Elevation (mASL)		431.38	428.71	425.71	422.71	419.71	416.71	413.68	410.69	407.69	405	401.69	397.48	395.7	392.7	389.8	386.71	383.67
Depth Interval		430-433	427-430	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391	385-388	382-385
Source Deposit		Cigar Lake						JEB/Sue										
Analyte	Units																	
pH (Field)	pH units	7.73	8.09	7.82	7.97	7.97	7.80	7.15	7.06	7.17	7.22	7.60	7.22	7.30	7.35	6.95	6.94	6.94
Temp (Field)	°C		16.4	16.2	17.6	17.9	16.7	17.6	17	17.8	18	17.8	18.5	20.5	18.8			
Eh (Field)	mV	272.5	257.1	191	230.4	278.5	242.2	173.5	184	135.9	147.7	220	184.6	128.8	136.6	190.5	203.8	163.5
Spec. Cond. (Field)	µS/cm	5500	5690	5440	7770	5320	6300	5240	5600	4930	4960	4140	5020	5300	5780	4460	4200	3800
D.O. (Field)	mg/L	5.07	7.08	6.78	6.66	6.61	7.2	6.59	7.17	6.24	6.33	7.13	6.61	6.65	7.3	3.98	7.19	6.85
pH (Lab)	pH units	7.88	8.10	7.96	7.88	8.00	7.88	7.66	7.74	7.80	7.69	7.81	7.77	7.56	7.90	7.92	7.92	7.75
Spec. Cond. (Lab)	µS/cm	4780	4870	4720	6680	4580	4350	3710	3950	3550	3520	3070	3370	3690	3680	3620	3400	3370
Ca ²⁺	mg/L	515	500	490	464	495	492	531	510	542	541	570	565	570	607	607	620	587
Mg ²⁺	mg/L	339	338	416	956	325	422	155	119	139	148	105	180	204	143	146	150	155
Na ⁺	mg/L	325	350	222	222	286	129	242	347	185	164	70	71	98	164	147	85	95
K ⁺	mg/L	36	28	27	39	30	28	18	27	29	32	20	23	41	39	43	38	32
HCO ₃ ⁻	mg/L	117	107	85	150	96	73	116	154	151	122	112	148	212	329	327	377	206
CO ₃ ²⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cl ⁻	mg/L	113	130	133	145	92	41	28	30	32	30	22	46	41	47	51	44	48
OH ⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
SO ₄ ²⁻	mg/L	3000	3050	3060	4800	2920	3040	2260	2340	2110	2160	1850	2080	2230	2130	2120	1960	2050
Total Hardness	mg/L	2680	2640	2930	5090	2570	2960	1960	1760	1920	1960	1850	2150	2260	2100	2110	2160	2100
Sum of Ions	mg/L	4440	4510	4440	6790	4260	4240	3360	3530	3200	3200	2780	3130	3400	3480	3460	3280	3180
Total Alkalinity	mg/L	96	88	70	123	79	60	95	126	124	100	92	121	174	270	268	309	169
P. Alkalinity	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
NO ₃ ⁻	mg/L	<0.04	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	1.2	0.6	<0.4
NH ₃	mg/L		8.2	7.3	14	9.1	7.7	6.7	3.1	13	3.8	23	14	6	16	14.00	7.00	6.50
DOC	mg/L	6.1	7.6	6.4	13	5.4	17	2.7	2.9		3.1	2.8	3.1	5.4				
TDS	mg/L	4460	4480	4600	7130	4440	4360	3460	3500	3220	3210	2780	3140	3420	3430	3370	3160	3120
Al	mg/L	0.0068	0.018	0.0069	<0.005	0.0084	0.013	0.0011	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.91	0.93	0.0096
Sb	mg/L	0.0017	0.02	0.0034	0.002	0.0037	0.008	0.0017	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	0.002	0.0017
As (Dissolved)		µg/L	758	569	770	260	207	87	1850	740	980	870	540	470	1190	5070	3830	5650
As (Total)	ASL	µg/L	701	186.2	739	241.8	101.1	36.6	2456	1551	1826	2144	813	961	3065	2587		
	Orano Lab	µg/L	908								1620				4620	3780	18000	4780
As (III)	ASL	µg/L	586	91.4	612	185	51.8	6	2050	1170	1500	1810	426	597	2590	2040		
	Orano Lab	µg/L	577								1370				3770	2310	14700	4450
As (V)	ASL	µg/L	115	94.8	127	56.8	49.3	30.6	406	381	326	334	387	364	475	547		
	Orano Lab	µg/L	50								115				316	822	433	296
DMA (as As)	ASL	µg/L	114	318	159	56.2	125	51.6	31.8	16.7	22.4	38	16	9.06	99	65.3		
	Orano Lab	µg/L	116															59
MMA (as As)	ASL	µg/L	7.9	22.2	17.3	9.46	3.71	4.55	10	10	10	10	10	4	20	25.7		
	Orano Lab	µg/L	8															29
Ba	mg/L	0.013	0.014	0.0097	0.012	0.01	0.011	0.015	0.014	0.018	0.013	0.011	0.009	0.011	0.019	0.024	0.028	0.025
Be	mg/L	<0.0001	<0.0001	<0.0001	<0.001	<0.0001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001
B	mg/L	2	1.6	2.8	3.7	1.8	1.8	0.27	0.2	0.2	0.3	0.1	0.2	0.6	0.8	0.7	0.8	0.84
Cd	mg/L	0.00028	0.00017	0.00014	0.0001	0.00008	0.00008	0.00073	0.0009	0.0011	0.0013	0.0013	0.0009	0.0013	0.0001	0.0003	0.0005	0.00015
Cr	mg/L	<0.0005	<0.0005	<0.0005	<0.005	<0.0005	<0.0005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0005
Co	mg/L	0.039	0.015	0.011	0.075	0.017	0.012	0.22	0.14	0.059	0.14	0.009	0.044	3.2	0.027	0.014	0.02	0.029
Cu	mg/L	0.0009	0.002	0.0005	<0.002	0.0057	0.0042	<0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	<0.0002
Fe	mg/L	0.0042	<0.0005	<0.0005	0.007	<0.0005	<0.0005	0.19	0.07	0.007	0.13	<0.005	<0.005	1.3	<0.005	<0.005	0.006	0.0026
Pb	mg/L	<0.0001	<0.0001	0.0002	<0.001	0.0001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001
Mn	mg/L	0.86	0.36	0.72	2.8	0.62	0.77	4.9	1.9	1.6	1.9	2.2	0.98	9.5	5.6	4.9	5.7	7.4
Mo	mg/L	3.73	2.12	1.69	0.92	0.793	0.724	7.86	13.4	18.6	15.7	18.2	13.2	20.8	1.53	2.28	4.87	1.82
Ni	mg/L	0.203	0.061	0.073	0.11	0.06	0.05	4.09	4.72	2.15	2.54	1.05	3.28	2.19	0.5	0.24	0.38	0.466
Se	mg/L	0.0019	0.031	0.0026	0.005	0.0042	0.01	0.0009	0.002	0.001	0.006	0.004	0.002	0.002	0.003	0.002	0.001	0.0022
Ag	mg/L	<0.00005	<0.00005	<0.00005	<0.0005	<0.00005	<0.00005	<0.00005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.00005
Sr	mg/L	0.3	0.44	0.34	0.33	0.29	0.32	0.27	0.26	0.32	0.23	0.32	0.21	0.3	0.84	0.98	0.93	0.84
Tl	mg/L	0.0002	0.0002	<0.0002	<0.002	0.0004	0.0003	<0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.0005
Sn	mg/L	0.0002	<0.0001	<0.0001	<0.001	<0.0001	<0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001
Ti	mg/L	0.0037	0.0022	0.0011	<0.002	0.0006	0.0008	0.01	0.014	0.02	0.015	0.017	0.012	0.018	0.002	0.004	0.01	0.0025
V	mg/L	0.0014	0.0025	0.0051	<0.001	0.0021	0.0017	0.0001	<0.001	<0.001	<0.001	0.003	0.002	<0.001	0.023	0.065	0.061	0.03
Zn	mg/L	0.0034	0.0039	0.0028	0.016	0.0056	0.0052	0.018	0.013	0.015	0.01	0.008	0.011	0.024	0.018	0.024	0.013	0.022
F ⁻	mg/L	4.6	9.2	5.8	6.4	7.5	6.2	2.1	2.3	2.6	1.9	2.5	1.5	2.4	4.7	4.9	5.1	4.5
P	mg/L		0.16	0.09	<0.1	0.11	0.08	0.04	<0.1	<0.1	<0							

Hole		TMF23-07 Pore Water												
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA11	SA12	SA13
Sample Elevation (mASL)		434.112	433.2	430.81	427.2	424.81	421.81	418.79	415.82	412.79	409.8	406.8	403.8	400.81
Depth Interval (mASL)		433-436	433-436	430-433	427-430	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403
Source Deposit		Cigar Lake						JEB/Sue						
Analyte	Units													
pH (Field)	pH units	7.90	8.04	8.11	9.30	8.09	6.92	7.26	7.30	7.21	7.45	7.09	7.35	7.10
Temp (Field)	°C	19	20.4	21.5	22.2	15.7	16.2	17.1	17.9	18.6	19.3	20.1	18.9	19.2
Eh (Field)	mV	442.1	270.5	226	182.7	238	109.5	129.6	167.3	214.1	238.8	203.1	196.7	190.2
Spec. Cond. (Field)	µS/cm	4880	5970	5230	4700	6020	5730	3950	5740	4640	3960	4160	4170	3540
D.O. (Field)	mg/L	5.51	7.12	5.7	6.35	6.64	6.12	3.95	8.28	5.8	7.01	7.02	7.06	4.93
pH (Lab)	pH units	7.89	7.75	7.89	9.42	8.04	7.65	7.86	7.94	7.79	7.73	7.71	7.79	7.72
Spec. Cond. (Lab)	µS/cm	4250	5040	4480	3710	5250	5140	3580	5160	4290	3430	3670	3530	3240
Ca ²⁺	mg/L	523	503	522	561	493	505	524	480	504	550	538	549	571
Mg ²⁺	mg/L	134	290	157	46	417	476	108	161	114	59	181	171	119
Na ⁺	mg/L	376	411	397	328	382	231	261	656	464	225	173	134	88
K ⁺	mg/L	38	38	35	40	33	36	25	28	29	33	33	30	31
HCO ₃ ⁻	mg/L	57	84	73	2	113	218	117	202	92	117	128	139	118
CO ₃ ²⁻	mg/L	<1	<1	<1	31	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cl ⁻	mg/L	138	136	120	115	97	61	33	57	36	33	34	32	25
OH ⁻	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
SO ₄ ²⁻	mg/L	2430	3000	2600	2060	3300	3200	2110	2900	2550	1960	2270	2180	1990
Total Hardness	mg/L	1860	2450	1950	1590	2940	3220	1750	1860	1720	1610	2080	2070	1910
Sum of Ions	mg/L	3700	4510	3950	3200	4850	4760	3180	4490	3800	3000	3370	3250	2970
Total Alkalinity	mg/L	47	69	60	54	93	179	96	166	75	96	105	114	97
P. Alkalinity	mg/L	<1	<1	<1	26	<1	<1	<1	<1	<1	<1	<1	<1	<1
NO ₃ ⁻	mg/L	<0.04	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
NH ₃	mg/L		36	35	9.5	12	28	2.6	4.4	5	21	6.8	9.1	21
DOC	mg/L	12	19	18	9.9	11	13	2.3	3.2	2.7	3.4	4	3.5	
TDS	mg/L	3710	4660	3810	3060	5080	4860	3140	4440	3810	3010	3400	3280	2980
Al	mg/L	0.007	1.4	0.0093	1.5	1.2	1.3	1.3	1.2	1.1	0.2	0.75	<0.005	<0.005
Sb	mg/L	0.008	0.018	0.011	0.025	<0.002	<0.002	0.002	0.003	0.003	<0.002	<0.002	<0.002	<0.002
As (Dissolved)		µg/L	1080	1330	1220	1280	930	32	1930	2030	540	730	620	430
As (Total)	ASL	µg/L	633	807	779	1035.9	877	19.14	2598		765	889		576
	Orano Lab	µg/L	1410	0	0	0	0	0	2850	0	0	841	1940	0
As (III)	ASL	µg/L	466	636	614	95.9	470	7.34	2430		337	549		306
	Orano Lab	µg/L	546						1980			607	1600	
As (V)	ASL	µg/L	167	171	165	940	407	11.8	168		428	340		270
	Orano Lab	µg/L	196						109			66	127	
DMA (as As)	ASL	µg/L	544	563	528	411	226	13	59		9.92	24.3		
	Orano Lab	µg/L	492											
MMA (as As)	ASL	µg/L	12.4	28.3	14.6	68.1	21.9	0.745	20		4.64	5.85		
	Orano Lab	µg/L	18											
Ba	mg/L	0.014	0.014	0.014	0.024	0.012	0.012	0.018	0.018	0.014	0.019	0.016	0.011	0.013
Be	mg/L	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	mg/L	1	1.9	1.4	0.5	1.5	1.4	0.3	0.3	0.2	0.2	0.3	0.3	0.2
Cd	mg/L	0.001	0.0004	0.00062	0.0011	0.0008	<0.0001	0.0012	0.0015	0.0009	0.0023	0.0011	0.0011	0.0015
Cr	mg/L	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Co	mg/L	0.014	0.013	0.018	<0.001	0.028	0.025	0.094	0.088	0.063	0.068	0.11	0.12	0.032
Cu	mg/L	<0.002	0.003	0.0023	0.002	0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Fe	mg/L	<0.005	<0.005	0.0014	<0.005	<0.005	0.58	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	mg/L	<0.001	0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	mg/L	0.3	0.64	0.27	<0.005	0.5	1.4	4.9	2.4	1.2	1.4	1.6	2.4	1.6
Mo	mg/L	13.6	6.35	9.41	16	9.84	0.32	14.7	20.2	14.5	34.4	15.3	15	21.3
Ni	mg/L	0.14	0.091	0.078	0.018	0.13	0.15	1.84	2.38	2.98	2.47	5	2.01	3.57
Se	mg/L	0.003	0.005	0.0036	0.008	0.003	0.004	0.002	0.003	0.002	0.002	0.004	0.003	0.003
Ag	mg/L	<0.0005	<0.0005	<0.00005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sr	mg/L	0.49	0.39	0.4	0.81	0.26	0.24	0.55	0.59	0.27	0.29	0.31	0.26	0.25
Tl	mg/L	<0.002	<0.002	0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sn	mg/L	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ti	mg/L	0.011	0.009	0.011	0.021	0.015	0.002	0.018	0.024	0.018	0.043	0.023	0.017	0.017
V	mg/L	0.002	0.003	0.0026	0.04	0.004	<0.001	<0.001	<0.001	0.003	0.003	0.002	<0.001	0.004
Zn	mg/L	0.033	0.006	0.0008	<0.005	<0.005	0.01	0.008	0.012	0.007	0.009	0.016	0.013	0.015
F ⁻	mg/L	5.1	7.3	6.7	2.6	5.4	6	3	3.2	2.8	2.2	1.9	1.9	1.4
P	mg/L		0.1	0.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
²¹⁰ Pb	Bq/L	6	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
²¹⁰ Po	Bq/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
²²⁶ Ra	Bq/L	7	5	5	21	4	2	2	4	4	3	1	1	2
²³⁰ Th	Bq/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
U	µg/L	1900	4050	522	110	6910	5340	1150	4040	320	1430	2850	720	790

Hole		TMF23-08 Pore Water						
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07
Sample Elevation (mASL)		436.29	435.36	432.36	429.36	426.36	423.28	420.36
Depth Interval (mASL)		436-439	433-436	430-433	427-430	424-427	421-424	418-421
Source Deposit		Cigar Lake						JEB/Sue
Analyte	Units							
pH (Field)	pH units	7.54	7.91	8.30	7.04	8.10	8.10	7.46
Temp (Field)	°C			18.9	21.1	23.5	24.9	20.4
Eh (Field)	mV	268.1	214.7	171.1	112.1	239	237	181.5
Spec. Cond. (Field)	µS/cm	6090	6360	5370	5970	5960	6250	4430
D.O. (Field)	mg/L	5.85	6.47	5.74	6.3	6.25	6.21	6.76
pH (Lab)	pH units	7.76	8.08	7.57	7.68	7.96	7.91	7.95
Spec. Cond. (Lab)	µS/cm	5080	4570	5180	5050	5030	5080	3760
Ca ²⁺	mg/L	512	529	497	505	500	497	533
Mg ²⁺	mg/L	240	126	369	326	379	464	166
Na ⁺	mg/L	501	489	418	420	341	251	238
K ⁺	mg/L	39	27	32	28	39	44	18
HCO ₃ ⁻	mg/L	78	65	71	143	99	94	144
CO ₃ ²⁻	mg/L	<1	<1	<1	<1	<1	<1	<1
Cl ⁻	mg/L	142	151	137	133	123	47	34
OH ⁻	mg/L	<1	<1	<1	<1	<1	<1	<1
SO ₄ ²⁻	mg/L	2900	2600	3200	3000	3100	3300	2290
Total Hardness	mg/L	2260	1840	2760	2600	2800	3150	2010
Sum of Ions	mg/L	4430	4000	4730	4560	4590	4720	3430
Total Alkalinity	mg/L	64	53	58	117	81	77	118
P. Alkalinity	mg/L	<1	<1	<1	<1	<1	<1	<1
NO ₃ ⁻	mg/L	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
NH ₃	mg/L	11	8.8	3.7	2.4	8.2	21	3.7
DOC	mg/L	18	14	5	1.6	8.1	18	3.7
TDS	mg/L	4560	3900	4910	4760	4680	4790	3560
Al	mg/L	1.2	1.1	1.1	0.99	0.98	0.8	0.75
Sb	mg/L	0.006	0.023	0.024	0.005	0.019	0.01	0.004
As (Dissolved)	µg/L	430	3620	4570	1240	1010	770	3560
As (Total)	ASL	336	307.2	9761	3331	986	325.1	
	Orano Lab	538	681	7680	1360	4100	398	4410
As (III)	ASL	202	251	8810	3060	716	249	
	Orano Lab	227	256	6820	874	3820	201	3670
As (V)	ASL	134	56.2	951	271	270	76.1	
	Orano Lab	54	61	596	152	376	4	130
DMA (as As)	ASL	164	102	300	65.1	236	134	
	Orano Lab	72	85	11	136		2	
MMA (as As)	ASL	7.21	4.59	100	20	23.8	7.55	
	Orano Lab	5	4	78	17			
Ba	mg/L	0.012	0.015	0.017	0.012	0.016	0.012	0.019
Be	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	mg/L	2.9	1.8	2.4	2.6	4.1	3.8	0.2
Cd	mg/L	0.0001	0.0012	0.0011	0.0008	0.0009	0.0002	0.0008
Cr	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Co	mg/L	0.049	0.008	0.022	0.036	0.011	0.027	0.075
Cu	mg/L	0.004	<0.002	<0.002	<0.002	<0.002	0.021	<0.002
Fe	mg/L	<0.005	<0.005	0.006	0.088	<0.005	<0.005	<0.005
Pb	mg/L	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Mn	mg/L	0.92	0.16	1.6	2.8	0.29	0.67	3
Mo	mg/L	0.74	19.4	15	9.24	10.1	3.09	11.6
Ni	mg/L	0.29	0.11	0.21	0.2	0.076	0.11	1.38
Se	mg/L	0.005	0.008	0.002	0.002	0.005	0.008	0.001
Ag	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sr	mg/L	0.31	0.38	0.56	0.7	0.49	0.31	0.36
Tl	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sn	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ti	mg/L	<0.002	0.022	0.022	0.013	0.016	0.005	0.013
V	mg/L	0.001	0.009	0.004	<0.001	0.009	0.01	0.003
Zn	mg/L	0.011	<0.005	0.016	0.015	<0.005	0.008	0.01
F ⁻	mg/L	3.4	5	6.7	7.6	6.2	7.8	3.4
P	mg/L	0.1	0.2	0.5	0.3	0.3	0.3	0.2
²¹⁰ Pb	Bq/L	3	2	<2	3	<2	<2	<2

²¹⁰ Po	Bq/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
²²⁶ Ra	Bq/L	2	4	10	4	7	4	3
²³⁰ Th	Bq/L	<1	<1	<1	<1	<1	<1	<1
U	µg/L	440	1670	750	4640	3680	2250	360

Interval		Pore Water by Weighted Average 3m Interval 2023																				Count	Min	Max	Average	Weighted Average	Standard Deviation		
Number of Observations		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19									
Average Sample Elevation (mASL)		373.61	377.80	380.46	383.46	386.64	389.24	392.53	395.28	398.19	401.19	404.18	407.04	410.33	413.20	416.27	419.33	422.15	425.34	428.59	431.72							434.58	
Analyte	Units																												
pH (Field)	pH Units			7.25	7.52	7.45	7.43	7.42	7.36	7.38	7.30	7.47	7.27	7.20	7.29	7.29	7.29	7.47	7.58	7.66	7.74	7.80	8.06	148	6.3	9.30	7.42	7.52	0.15
Temp (Field)	°C			17.30	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	17.35	148	16.00	24.90	17.89	17.49	0.58
EH (Field)	mV			216.56	219.30	227.70	241.87	219.67	250.90	187.55	222.13	235.20	248.17	264.21	211.03	199.49	188.68	186.58	194.94	175.63	319.31	338.40	148	98.00	496.40	217.03	236.54	25.72	
Spec. Cond. (Field)	µS/cm			4893.33	4212.50	3590.00	3870.00	3642.00	3657.50	3601.43	3932.86	3420.00	3417.14	3693.75	4118.75	3892.86	4243.75	4048.75	5083.33	6594.44	6156.00	5813.08	148	3540.00	8250.00	4107.20	4521.41	793.47	
D.O. (Field)	mg/L			7.44	7.83	7.84	7.80	8.01	8.28	7.88	7.43	7.70	7.60	7.82	7.39	7.69	7.96	8.46	8.29	8.62	8.29	5.46	3.95	147	3.95	11.19	7.40	7.00	0.62
pH (Lab)	pH Units	8.06	8.22	7.65	7.97	8.08	7.91	7.99	7.8	7.81	7.8	7.92	7.58	7.79	7.76	7.84	7.86	7.94	7.90	7.99	7.76	7.88	141	6.85	9.42	7.89	7.85	0.15	
Spec. Cond. (Lab)	µS/cm	4110.00	4090.00	3640.00	3613.33	3642.50	3642.00	3603.33	3606.67	3686.25	3420.00	3417.14	3748.57	4035.00	3903.75	4055.71	4048.75	5235.00	5027.76	5171.11	5158.67	4851.54	141	3000.00	6680.00	3984.05	4240.00	561.21	
Ca ⁺⁺	mg/L	587.00	604.00	586.00	600.67	609.50	587.20	585.00	594.67	561.50	560.86	555.57	537.14	516.88	516.75	511.71	520.63	494.75	495.22	501.00	493.40	506.15	141	448.00	642.00	554.00	533.08	40.43	
Mg ⁺⁺	mg/L	237.00	186.00	168.00	181.00	140.00	138.20	142.50	166.33	156.86	129.86	131.71	114.57	121.63	130.50	173.71	214.00	495.25	415.44	400.44	387.20	264.08	141	46.00	956.00	202.37	233.26	110.29	
Na ⁺	mg/L	147.00	185.00	128.00	84.00	142.50	165.20	144.33	111.00	152.75	124.00	141.29	258.43	341.13	336.13	308.86	251.38	270.13	300.11	354.00	379.93	406.00	141	61.00	656.00	208.38	261.10	88.20	
K ⁺	mg/L	35.00	40.00	38.67	35.67	39.75	42.60	39.50	42.00	37.13	32.86	27.86	30.14	31.25	24.25	24.86	26.13	35.50	31.33	33.56	37.53	37.69	141	18.00	53.00	34.11	33.85	5.70	
HCO ₃ ⁻	mg/L	201.00	311.00	257.00	309.00	359.50	267.00	316.50	356.33	211.00	145.71	130.43	100.71	114.13	88.38	110.29	119.88	125.13	112.56	110.33	68.53	72.00	140	2.00	562.00	197.15	151.77	96.78	
CO ₃ ²⁻	mg/L	1	1	4	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	141	1	31	1	1	1	1	
Cl ⁻	mg/L	99.00	42.00	53.00	50.00	55.00	53.60	57.67	53.00	54.88	40.00	45.86	48.00	49.13	35.75	41.57	52.13	90.00	106.44	128.89	126.13	140.77	141	21	164	61	76	26.78	
OH ⁻	mg/L	1	1	4	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	141	1	10	1	1	1	1	
SO ₄ ²⁻	mg/L	2540.00	2340.00	2130.00	2090.00	2040.00	2112.00	2036.67	2076.67	2145.00	2032.86	2042.86	2211.43	2351.25	2383.75	2452.86	2473.75	3385.00	3166.67	3208.89	3207.33	2910.77	141	1830.00	4800.00	2379.88	2559.86	422.94	
Total Hardness	mg/L	2440.00	2270.00	2150.00	2243.33	2095.00	2032.00	2043.33	2173.33	2045.00	1932.86	1927.14	1810.00	1788.75	1822.50	1990.00	2177.50	3270.00	2941.11	2895.56	2741.33	2347.69	141	1520.00	5090.00	2213.02	2287.95	407.18	
Sum of Ions	mg/L	3870.00	3730.00	3366.67	3370.00	3400.00	3382.00	3336.67	3420.00	3341.25	3091.43	3082.86	3315.71	3536.25	3526.25	3634.29	3665.00	4911.25	4635.56	4747.76	4688.00	4343.85	141	2740.00	6790.00	3650.68	3860.63	534.14	
Total Alkalinity	mg/L	165.00	255.00	210.67	253.33	294.75	218.80	259.50	292.33	173.00	119.57	106.86	82.57	93.63	72.38	90.43	98.25	102.50	92.33	96.33	56.33	59.31	141	34.00	461.00	161.96	124.84	79.09	
P. Alkalinity	mg/L	1	1	4	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	141	1	26	1	1	1	1	
NO ₃ ⁻	mg/L	0.40	0.40	0.40	0.40	0.55	0.64	0.40	0.40	0.40	0.49	0.69	0.66	1.57	0.65	0.53	0.40	0.56	0.40	0.40	0.40	0.26	0.29	138	0.04	4.70	0.54	0.51	0.27
NH ₄ ⁺	mg/L	18.00	12.00	8.05	9.50	10.80	13.80	13.20	15.00	18.57	22.33	8.15	15.94	9.59	7.80	6.98	6.19	13.90	7.36	6.23	14.89	16.23	110	0.65	49.00	11.76	12.02	4.67	
DOC	mg/L	11.00	6.30	7.50	7.07	7.30	9.67	5.50	8.70	6.85	3.96	3.96	3.56	5.53	3.47	3.35	5.55	4.44	9.34	7.41	5.41	6.75	9.49	110	1.60	19.00	6.42	6.36	2.22
TDS	mg/L	3740.00	3750.00	3295.00	3316.67	3305.00	3326.00	3330.00	3396.67	3308.75	3061.43	3070.00	3338.33	3527.50	3551.25	3655.71	3705.00	5070.00	4746.67	4901.11	4799.33	4395.38	138	2780.00	7130.00	3652.37	3892.79	594.15	
Al	mg/L	0.017	0.033	0.095	0.033	0.347	0.345	0.224	0.220	0.007	0.006	0.005	0.130	0.029	0.141	0.319	0.260	0.288	0.082	0.097	0.082	0.297	144	0.001	1.500	0.162	0.179	0.131	
As	mg/L	0.0062	0.0060	0.0047	0.0047	0.0074	0.0067	0.0047	0.0023	0.0034	0.0027	0.0049	0.0037	0.0033	0.0049	0.0047	0.0036	0.0045	0.0075	0.0081	0.0083	0.0141	144	0.0010	0.0460	0.0049	0.0060	0.0017	
As (Dissolved)	µg/L	1330.00	1900.00	6666.25	9500.00	11684.00	6385.00	4780.00	7333.33	4731.25	2284.29	1871.43	1185.00	961.25	1074.13	1310.00	1822.50	769.38	1765.56	1177.67	930.73	981.31	144	32.00	21700.00	3585.84	2754.94	3194.65	
Ba	mg/L	0.0280	0.0370	0.0243	0.0235	0.0314	0.0245	0.0217	0.0183	0.0153	0.0121	0.0140	0.0163	0.0136	0.0133	0.0144	0.0143	0.0123	0.0122	0.0130	0.0129	0.0136	144	0.0060	0.0420	0.0189	0.0167	0.0073	
Be	mg/L	0.0001	0.0010	0.0006	0.0008	0.0010	0.0009	0.0010	0.0010	0.0008	0.0010	0.0010	0.0010	0.0010	0.0010	0.0006	0.0006	0.0007	0.0007	0.0008	0.0008	0.0009	144	0.0001	0.0010	0.0008	0.0008	0.0002	
B	mg/L	0.004	1.00	0.80	0.79	0.76	0.75	0.63	0.63	0.45	0.27	0.24	0.27	0.26	0.20	0.40	0.71	2.47	2.53	2.28	2.02	1.77	144	0.10	4.40	0.86	1.10	0.74	
Ca	mg/L	0.00035	0.00060	0.00037	0.00016	0.00050	0.00036	0.00040	0.00060	0.00064	0.00097	0.00157	0.00117	0.00080	0.00080	0.00079	0.00057	0.00034	0.00046	0.00046	0.00046	0.00048	144	0.00022	0.00360	0.00064	0.00063	0.00036	
Cr	mg/L	0.0005	0.0050	0.0030	0.0039	0.0050	0.0043	0.0050	0.0039	0.0050	0.0039	0.0050	0.0050	0.0050	0.0050	0.0028	0.0031	0.0028	0.0033	0.0035	0.0040	0.0038	144	0.0005	0.0050	0.0039	0.0040	0.0012	
Co	mg/L	0.0057	0.0090	0.0038	0.0183	0.0144	0.0177	0.1117	0.1167	0.1196	0.0819	0.1479	0.0473	0.0833	0.1266	0.0900	0.0696	0.0530	0.0578	0.1407	0.0502	0.0235	144	0.0010	3.2000	0.1206	0.0995	0.2361	
Cu	mg/L	0.0007	0.0020	0.0024	0.0016	0.0026	0.0023	0.0025	0.0020	0.0016	0.0024	0.0026	0.0023	0.0020	0.0014	0.0021	0.0037	0.0045	0.0026	0.0021	0.0022	0.0072	144	0.0002	0.0050	0.0023	0.0028	0.0008	
Fe	mg/L	0.0028	0.0050	0.0062	0.0159	0.0082	0.0325	0.0656	0.5173	0.0507	0.0070	0.0239	0.0340	0.0371	0.0267	0.0072	0.1451	0.0777	0.0344	0.0642	0.0076	0.0043	144	0.0005	1.3000	0.0670	0.0521	0.1155	
Pb	mg/L	0.0002	0.0010	0.0037	0.0050	0.0130	0.0133	0.0057	0.0010	0.0008	0.0019	0.0010	0.0010	0.0010	0.0006	0.0006	0.0006	0.0018	0.0011	0.0009	0.0013	0.0022	144	0.0001	0.0810	0.0032	0.0027	0.0049	
Mn	mg/L	2.18	2.80	4.92	5.18	3.74	4.32	4.00	6.37	4.46	2.94	2.19	0.91	1.18	1.82	1.95	2.34	1.55	2.07	1.47	0.88	0.52	144	0.01	10.20	2.97	2.34	1.54	
Mg	mg/L	4.17	5.28	4.50	4.51	11.01	6.14																						

Hole		TMF23-01 Solids																				
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09A	SA09B	SA10	SA11	SA12	SA13	SA14A	SA14B	SA15	SA16	SA17	SA18	SA19
Sample Elevation (mASL)		434.16	432.49	429.49	426.49	423.49	420.47	417.5	414.68	411.68	411.05	408.43	405.56	402.48	399.46	398.85	398.24	395.47	391.87	388.77	386.66	383.59
Depth Interval		433-436	430-433	427-430	424-427	421-424	418-421	415-418	412-415	409-412	409-412	406-409	403-406	400-403	397-400	397-400	397-400	394-397	391-394	388-391	385-388	382-385
Source Deposit		Cigar Lake					JEB/Sue															
Analyte	Units																					
Al	ug/g	44700	22300	31200	52800	39200	65100	67100	73300	48600	40700	50100	53300	61500	46600	63100	72900	45300	61000	52600	56500	70800
Sc	ug/g	30	21	20	26	18	11	3.5	5	2.6	4.4	1.8	4.4	1.2	1.7	2	2.7	0.9	1.2	1.6	1.3	2.1
As	ug/g	7200	10200	3700	3720	2070	5300	2840	4100	493	601	308	1350	187	292	285	451	128	194	273	232	447
Ba	ug/g	2690	1120	1370	8100	2900	370	340	720	2080	17000	1590	170	270	1120	280	870	150	170	2050	77	380
Be	ug/g	13	5.2	9.1	16	10	2.8	2.8	3.1	2	1.6	1.8	2.3	3.1	2.8	3.9	3.4	2.3	3.8	2.9	3.3	4.4
B	ug/g	380	180	290	490	340	340	310	370	220	170	200	230	290	220	320	320	220	280	230	250	320
Cd	ug/g	0.6	0.5	0.3	0.6	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cr	ug/g	39	27	45	69	56	62	60	67	50	39	40	59	64	49	76	74	50	63	57	62	76
Co	ug/g	820	1400	670	700	340	35	16	26	17	32	9.1	96	7.2	9.9	11	14	4.7	7.2	15	8.7	16
Cu	ug/g	5000	4280	6000	5700	5900	66	20	33	21	100	9.2	20	14	25	22	32	7.9	13	66	21	34
Fe	ug/g	70600	40700	34000	48500	62000	19200	17500	18100	9700	11900	7200	8200	7600	8400	10100	10400	6100	9700	9000	9600	11700
Pb	ug/g	10000	4300	6300	11700	10700	390	450	450	130	260	68	210	410	460	720	1400	230	260	320	270	580
Mn	ug/g	350	130	160	330	320	130	120	150	75	180	49	77	67	68	95	120	50	83	74	74	140
Mo	ug/g	868	398	434	526	770	149	86	172	40	42	19	70	105	125	204	279	59	75	76	79	117
Ni	ug/g	4940	6500	2530	2640	1410	3610	2060	2950	400	422	271	1480	160	207	244	324	99	149	230	198	385
Se	ug/g	52	33	32	51	33	3.8	5.1	5.1	0.8	1.2	0.5	1.4	4.5	5.1	9.7	10	4	4.5	5.8	4.9	9.8
Ag	ug/g	9.3	5.9	6.5	6.7	5.8	1.2	0.7	0.9	0.2	0.4	0.2	0.6	0.7	1	1.8	1.5	0.5	0.5	0.7	1.3	1.4
Sr	ug/g	300	140	180	380	190	300	240	320	160	250	190	130	130	120	150	210	110	120	130	110	140
Tl	ug/g	3.8	2.8	3	3	2.5	0.5	0.5	0.4	0.3	0.5	0.3	0.4	0.4	0.5	0.6	0.5	0.3	0.4	0.4	0.4	0.6
Sn	ug/g	4.1	2.1	2.6	5.9	2.8	2	2.2	2.4	0.9	1	1.1	1	1.2	1.1	1.3	1.5	1	1.1	1.2	1.4	2
Ti	ug/g	440	390	570	710	650	190	200	210	140	140	160	150	190	180	250	210	150	180	180	200	240
U	ug/g	1570	441	455	1120	422	232	81	205	90	85	48	62	300	662	241	142	486	607	297	288	229
V	ug/g	640	270	410	640	740	610	500	700	340	230	300	530	560	580	990	880	440	700	520	620	930
Zn	ug/g	150	160	140	160	100	13	12	14	17	44	15	21	15	15	18	25	8.8	13	18	13	18
F2 (C10-C16)	mg/kg	2200	45	33	4900	1100	170	6.1	98	4.5	8.8	3.9	69	4.6	3.9	12	33	3.9	5.4	3.9	3.9	9
F3 (C16-C34)	mg/kg	62	12	14	140	62	11	7.9	12	8.6	62	9.5	20	12	13	22	23	13	210	9.1	13	11
F4 (C34-C50)	mg/kg	53	7.4	<5	19	26	<5	<5	<5	<5	26	6.3	<5	7	<5	<5	<5	<5	<5	<5	<5	<5

Hole		TMF23-02 Solids																			
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA11	SA12	SA13	SA14	SA15	SA16	SA17	SA18	SA19A	SA19B
Sample Elevation (mASL)		432.44	429.98	427.58	424.58	421.58	418.58	415.61	412.28	409.42	406.45	403.8	400.58	397.71	393.7	392.14	389.4	386.71	381.79	379.7	379.1
Depth Interval		430-433	427-430	427-430	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391	385-388	379-382	379-382	379-382
Source Deposit		Cigar Lake					JEB/Sue														
Analyte	Units																				
Al	ug/g	45400	52000	60700	44900	24400	39400	48300	46300	55800	49400	52600	49500	58800	68300	75500	50500	65100	72100	52800	34400
Sc	ug/g	20	32	43	31	16	22	15	3.8	1.2	2.7	4.8	4.3	0.8	1.5	2.1	1.4	1.4	2.4	3.8	2.7
As	ug/g	3010	5400	6200	5500	770	1780	2440	615	272	604	968	738	116	183	256	286	300	528	718	508
Ba	ug/g	2160	2860	4240	1130	2290	1900	<0.5	<0.5	<0.5	71	91	75	83	170	460	64	87	260	500	140
Be	ug/g	10	17	18	12	6.9	4.7	2.3	2	2.1	2.2	2.7	2.3	2.6	3.1	3.6	2.6	3.6	4.2	3.3	1.8
B	ug/g	380	500	500	400	240	230	240	230	260	240	240	240	250	320	360	240	270	330	240	150
Cd	ug/g	0.3	0.4	0.8	0.5	0.2	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cr	ug/g	800	70	80	67	32	47	50	51	49	57	53	60	66	77	83	76	70	80	220	38
Co	ug/g	310	800	1800	1200	130	50	31	11	4.1	6.2	13	24	5.8	7.8	10	9.5	10	16	21	12
Cu	ug/g	4280	7000	5300	4800	2190	160	26	14	3.9	10	15	15	11	16	22	31	39	35	53	33
Fe	ug/g	63600	60300	49000	36800	44300	57800	12700	9300	7000	8600	10200	6800	6200	7300	8600	9900	10400	14800	16300	9000
Pb	ug/g	6800	12000	12600	6600	6600	970	417	100	64	150	180	120	200	510	790	290	340	730	1600	340
Mn	ug/g	400	350	290	160	230	210	88	63	49	67	110	76	49	70	99	62	74	110	140	71
Mo	ug/g	746	772	381	417	198	70	77	28	17	39	72	59	47	115	178	77	84	135	182	53
Ni	ug/g	2600	3720	3180	3740	598	1240	2070	470	275	507	903	910	103	176	230	258	265	405	491	374
Se	ug/g	33	54	80	58	26	9.8	4.1	1	0.8	0.9	1.4	1.1	2.5	5.9	7.6	5.7	7.2	13	18	3.9
Ag	ug/g	5	8.1	10	9.6	2.5	1	0.7	0.2	0.1	0.4	0.7	0.8	0.3	0.7	1	0.7	0.9	1.4	1.7	0.5
Sr	ug/g	230	330	370	180	170	360	180	190	140	120	130	110	130	140	180	100	120	150	140	94
Tl	ug/g	1.9	3.7	3.1	3.4	0.9	0.4	0.4	0.3	0.3	0.4	0.5	0.4	0.3	0.4	0.5	0.3	0.4	0.6	0.5	0.3
Sn	ug/g	3.2	5.2	5.8	4.3	1.9	4.5	1.3	0.9	1	1	1.1	0.9	1.1	1.3	1.5	1.3	1.8	2.3	1.7	0.9
Ti	ug/g	420	860	820	600	500	420	150	140	140	140	160	170	150	210	220	190	190	240	170	140
U	ug/g	683	966	1140	696	294	358	163	93	68	166	409	109	199	158	147	343	258	248	310	187
V	ug/g	450	680	630	480	360	450	379	330	360	450	520	530	470	680	750	460	570	730	460	250
Zn	ug/g	70	98	290	210	28	28	18	15	10	20	24	21	13	18	18	14	16	20	20	24
F2 (C10-C16)	mg/kg	110	45	110	130	50	260	3.9	3.9	3.9	3.9	3.9	3.9	4.4	16	48	3.9	3.9	18	110	7.4
F3 (C16-C34)	mg/kg	24	21	42	23	10	59	<5	22	20	<5	10	43	170	15	36	19	16	9.5	24	11
F4 (C34-C50)	mg/kg	22	9.6	27	13	13	21	7.5	7.6	9.4	<5	6.9	8.1	15	5.8	63	20	12	7	6	7.2

Hole		TMF23-03																				
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA11	SA12	SA13	SA14	SA15	SA16	SA17	SA18	SA19	SA20	SA21
Sample Elevation (mASL)		435.675	432.97	430.58	427.58	424.58	421.58	419.38	416.89	414.37	412.57	411.35	409.77	406.78	403.81	401.37	398.37	392.2	388.46	386.08	382.67	381.17
Depth Interval		433-436	433-436	430-433	427-430	424-427	421-424	418-421	415-418	412-415	412-415	409-412	409-412	406-409	403-406	400-403	397-400	391-394	388-391	385-388	382-385	379-382
Source Deposit		Cigar Lake							JEB/Sue													
Analyte	Units																					
Al	ug/g	32700	39600	21400	28400	49700	31400	23500	33700	65500	69300	66100	69200	49200	46500	60500	55900	51800	61300	72800	83700	102000
Sc	ug/g	27	33	16	25	35	17	25	54	110	69	11	4.4	3.8	6.2	2.8	0.7	0.8	1.3	3.2	5.7	6
As	ug/g	7300	7300	7500	5000	5100	1610	3490	8600	12200	15600	5000	3960	1600	1640	593	212	118	204	604	1580	1780
Ba	ug/g	2710	3410	550	1820	3780	2030	280	690	1420	830	670	430	200	140	160	180	70	120	640	1470	1870
Be	ug/g	10	15	5.3	10	20	10	1.6	2.8	4.1	4.5	3.7	3.5	2.2	2.1	2.6	2.5	2.6	3.5	5.4	5.2	5.6
B	ug/g	260	340	180	280	480	280	120	160	290	300	310	340	210	180	230	220	220	280	380	340	390
Cd	ug/g	1	0.7	0.3	0.2	0.3	0.3	0.3	0.6	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Cr	ug/g	36	61	26	43	69	47	26	37	59	65	63	68	43	49	63	59	59	73	91	90	130
Co	ug/g	630	660	1000	580	660	260	95	170	130	180	53	23	57	430	120	6.4	4.7	8.7	22	45	39
Cu	ug/g	5700	4900	3170	3920	6000	3010	69	200	130	170	51	23	41	25	12	8.4	9.3	16	54	100	92
Fe	ug/g	47400	76300	38400	38900	60100	31000	14200	27300	37900	45100	22600	21000	13600	7400	6700	5700	5700	7400	11500	24600	21300
Pb	ug/g	12100	12600	2400	5900	13900	8600	150	560	1000	990	410	420	140	140	110	160	190	370	1100	2500	3200
Mn	ug/g	280	370	110	190	360	220	120	240	320	340	160	140	100	71	54	53	45	66	180	240	240
Mo	ug/g	373	1020	237	576	891	238	68	168	319	306	182	174	72	48	42	40	51	92	317	330	452
Ni	ug/g	5200	4700	5000	3740	3680	1070	2910	6300	8400	11200	3740	3010	1220	859	332	162	101	185	501	1230	1120
Se	ug/g	58	56	23	42	62	43	1.4	5.4	11	12	4.3	4.8	1.2	1.5	1.3	1.8	2.8	5.2	12	21	25
Ag	ug/g	8.8	9.1	4.3	7.1	10	3.8	0.9	2.3	2.7	3.9	1.2	1	0.4	0.4	0.3	0.3	0.4	0.9	2.5	2.7	3.2
Sr	ug/g	190	300	120	210	310	220	120	210	370	370	320	310	210	110	140	140	110	130	180	270	350
Tl	ug/g	3.1	3.8	2.1	2.8	4	1.6	0.4	0.6	0.8	1	0.5	0.5	0.3	0.4	0.4	0.3	0.3	0.4	0.9	0.9	1
Sn	ug/g	2.8	4.2	1.5	2.9	4.5	2.7	1.2	1.5	2.9	3	2.5	2.7	1	1.3	1.2	1	1	1.2	1.6	2.5	2.7
Ti	ug/g	440	780	370	620	930	580	120	180	200	240	210	220	170	160	170	170	170	230	330	300	330
U	ug/g	486	1060	293	479	1270	549	85	182	315	337	237	164	54	110	210	172	166	175	221	368	339
V	ug/g	460	710	240	400	790	442	360	640	880	930	670	760	320	430	480	450	450	660	1200	870	1300
Zn	ug/g	290	200	120	82	86	94	29	59	50	43	17	14	16	39	21	15	10	14	21	39	33
F2 (C10-C16)	mg/kg	250	870	16	280	200	160	81	190	78	190	35	37	19	49	12	32	3.9	3.9	150	950	150
F3 (C16-C34)	mg/kg	38	100	19	36	50	64	25	37	43	290	60	22	31	22	20	17	17	16	39	46	54
F4 (C34-C50)	mg/kg	34	38	5.8	13	20	12	<5	<5	<5	16	27	<5	<5	<5	<5	<5	<5	<5	<5	5.1	8.2

Hole		TMF23-04 Solids																				
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA11	SA12	SA13	SA14	SA15	SA16	SA17	SA18	SA19	SA20	SA21
Sample Elevation (mASL)		431.7	432.7	429.7	426.09	424.69	421.04	418.65	415.7	412.55	409.5	406.42	403.61	400.71	397.69	393.4	390.3	387.02	383.92	380.52	377.8	373.61
Depth Interval		430-433	430-433	427-430	424-427	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	391-394	388-391	385-388	382-385	379-382	376-379	373-376
Source Deposit		Cigar Lake				JEB/Sue																
Analyte	Units																					
Al	ug/g	44800	36700	42900	18400	20900	39400	47400	54300	48300	60200	77700	44100	76700	86600	75100	93800	87900	84500	91300	91400	26000
Sc	ug/g	29	35	33	17	22	28	9.5	11	4.2	19	6.5	4.1	8.8	4.4	20	3.6	4	5.7	6	5.4	36
As	ug/g	9200	8800	6500	3480	4380	4480	2240	3240	1620	9420	6370	3870	10700	4660	12000	663	688	1670	2380	1010	20300
Ba	ug/g	3670	2940	3020	180	270	120	110	260	190	620	760	330	820	1190	1460	800	1370	1980	2770	1990	1400
Be	ug/g	14	13	15	1.2	1.5	2	2.3	2.7	2.2	3.1	3.6	2.1	4	3.2	3.8	4.4	4.1	4.3	5.6	5.7	5.9
B	ug/g	350	330	360	84	87	170	200	240	220	270	370	230	400	390	340	400	370	320	410	520	190
Cd	ug/g	0.8	0.5	0.5	0.2	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.2	0.1	0.1	0.2	0.2	0.1	1.9
Cr	ug/g	66	55	66	18	21	37	43	46	45	52	67	41	76	69	73	98	86	99	140	51	
Co	ug/g	800	650	740	44	64	44	24	43	24	88	63	34	62	32	680	21	22	42	58	34	2800
Cu	ug/g	5400	7600	5900	74	190	46	22	34	19	64	43	26	52	25	69	46	50	130	120	78	3040
Fe	ug/g	90400	78400	83100	11200	14300	13700	12800	16200	17300	31400	28600	19700	36200	19300	37500	14000	12400	24100	26600	15700	63200
Pb	ug/g	10700	11400	11700	280	470	290	280	400	240	980	430	460	530	240	690	1900	2600	3400	2100	3600	10400
Mn	ug/g	370	320	380	74	100	80	68	95	88	210	170	140	250	240	320	160	180	230	300	250	290
Mo	ug/g	779	728	1060	53	71	64	85	140	76	284	195	137	371	148	316	319	422	429	385	395	554
Ni	ug/g	5700	6100	3840	2740	3420	3680	1480	2460	1140	5800	3880	2640	6600	3260	7700	478	499	1210	2010	694	12200
Se	ug/g	44	57	48	2.5	3.2	3	3.4	4.6	2.1	9.6	5	4.4	6.1	3.1	5.5	14	17	26	19	29	55
Ag	ug/g	11	10	9.2	0.8	1.2	1	0.6	0.8	0.5	2.1	1.2	0.8	1.7	0.8	2.6	1.8	2.4	3.1	3.7	3.4	11
Sr	ug/g	350	210	280	100	130	170	210	260	200	260	380	270	410	310	270	260	280	300	320	280	130
Tl	ug/g	4	4.2	4.2	0.2	0.4	0.4	0.3	0.4	0.3	0.6	0.6	0.4	0.8	0.5	0.9	0.7	0.8	1	1.1	1.1	4.7
Sn	ug/g	4.2	3.4	3.9	0.7	0.9	1	1	2.2	1.4	2.7	3.2	1.8	3.5	2	3.8	1.8	1.8	2.7	3	4.5	3.1
Ti	ug/g	680	780	880	110	130	120	120	140	140	160	190	170	220	200	180	230	220	270	290	380	620
U	ug/g	1040	1340	1200	111	108	166	134	78	47	330	254	130	277	142	350	376	321	267	245	259	936
V	ug/g	720	590	690	220	260	360	380	440	400	580	730	420	1100	800	1200	1100	1100	1000	1400	1400	390
Zn	ug/g	240	140	150	13	18	32	17	16	12	24	19	11	26	21	68	27	25	36	38	26	450
F2 (C10-C16)	mg/kg	710	120	520	57	26	44	6.8	29	20	130	32	12	46	330	67	49	68	1100	540	77	1600
F3 (C16-C34)	mg/kg	34	42	37	14	22	90	12	17	18	32	40	17	22	37	37	26	26	41	54	54	65
F4 (C34-C50)	mg/kg	18	19	14	<5	<5	12	<5	<5	6.4	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Hole		TMF23-05 Solids																
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA010	SA011	SA012	SA013	SA014	SA015	SA016	SA017
Sample Elevation (mASL)		434.99	433.1	430.71	427.71	424.71	421.71	418.71	415.69	412.69	409.69	406.701	403.701	400.681	397.701	394.681	391.711	388.711
Depth Interval		433-436	433-436	430-433	427-430	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391
Source Deposit		Cigar Lake							JEB/Sue									
Analyte	Units																	
Al	ug/g	19800	29200	34600	36200	65900	53000	57700	39900	78000	83000	95700	88500	86800	63800	77700	123000	128000
Sc	ug/g	12	22	27	32	39	42	29	49	100	7.8	6.1	7.2	20	15	1.8	4.4	5.2
As	ug/g	5400	9400	7200	8900	4880	8700	2580	9200	21500	10700	7200	5600	13500	7500	316	896	1320
Ba	ug/g	2690	1730	1720	2190	3530	3640	4340	530	1740	1310	960	660	1260	1160	520	1060	1790
Be	ug/g	6.1	8.3	10	10	22	16	15	2.7	4.4	3.6	4.2	3.6	4.1	3.1	3.2	5.1	8
B	ug/g	160	240	280	300	570	460	430	210	330	410	500	380	380	310	340	500	640
Cd	ug/g	0.4	0.4	0.8	0.3	0.7	0.4	0.4	0.5	0.6	0.1	0.1	0.2	0.3	0.1	0.1	0.1	0.1
Cr	ug/g	32	29	41	36	57	76	76	42	67	200	77	72	88	660	210	140	160
Co	ug/g	370	660	750	830	730	950	670	180	400	82	50	67	240	120	11	25	43
Cu	ug/g	2770	5600	3860	4340	7900	6800	7500	200	220	59	36	42	62	55	23	58	90
Fe	ug/g	37900	46100	57600	66100	65800	85600	84900	28300	54800	34100	25900	20100	39100	25400	8200	14500	17400
Pb	ug/g	4300	6000	6600	8600	17700	17600	18600	690	790	880	460	380	560	410	1000	2600	2300
Mn	ug/g	200	200	270	240	370	420	480	260	470	280	240	200	320	320	120	190	330
Mo	ug/g	206	571	505	685	1070	780	582	188	421	389	244	178	394	357	170	461	564
Ni	ug/g	4250	6800	4900	5800	3230	5700	1390	6600	15500	6000	4790	4460	8600	5700	252	629	911
Se	ug/g	29	38	36	40	68	54	45	6.5	12	9.4	6.1	3.6	5.2	4.3	8	17	20
Ag	ug/g	4.6	6.9	7.7	7.9	9.6	8.6	7.1	2.3	5.4	2	1.4	1.3	2.6	2.1	1.1	2.3	3.8
Sr	ug/g	200	170	180	220	370	320	300	220	470	460	440	360	290	180	170	320	340
Tl	ug/g	1.6	3.2	3.3	3.9	4.8	4.2	2.8	0.6	1.5	0.7	0.6	0.7	1.2	0.6	0.4	0.8	1.2
Sn	ug/g	1.9	2.4	2.6	3.7	5.5	8.2	4.4	1.7	3.8	3.4	3	2.1	2.8	3.4	1.3	2	2.2
Ti	ug/g	350	380	410	520	730	850	840	160	210	200	220	200	210	180	180	240	420
U	ug/g	442	1280	594	672	1270	1200	855	213	276	234	247	155	224	224	239	406	460
V	ug/g	290	320	530	480	880	850	900	620	1100	760	860	770	1100	890	630	1200	1700
Zn	ug/g	110	110	280	81	160	110	120	42	76	19	16	37	46	41	18	28	28
F2 (C10-C16)	mg/kg	28	180	520	230	260	63	380	60	160	44	68	140	56	100	64	550	190
F3 (C16-C34)	mg/kg	18	36	51	170	350	28	84	22	45	28	15	39	47	32	28	99	67
F4 (C34-C50)	mg/kg	14	31	30	35	37	16	34	7.7	11	8.6	7.8	6.4	11	5.9	6	11	10

Hole		TMF23-06 Solids																
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA11	SA12	SA13	SA014	SA015	SA016	SA017
Sample Elevation (mASL)		431.38	428.71	425.71	422.71	419.71	416.71	413.68	410.69	407.69	405	401.69	397.48	395.7	392.7	389.8	386.71	383.67
Depth Interval		430-433	427-430	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391	385-388	382-385
Source Deposit		Cigar Lake							JEB/Sue									
Analyte	Units																	
Al	ug/g	54500	59900	50700	37600	23900	45400	71400	72700	53200	92500	71500	72100	100000	114000	49700	90100	51100
Sc	ug/g	34	19	20	18	15	24	69	25	12	11	9.1	18	13	3.8	20	3.8	21
As	ug/g	7400	2020	3810	1630	592	600	16600	9400	6800	11900	7100	11000	5600	712	5600	1040	5400
Ba	ug/g	6600	1430	1960	1850	1610	2880	1350	800	390	1140	740	760	960	1180	880	1080	970
Be	ug/g	15	15	12	10	6.9	13	5.1	3.2	2.5	4.2	3	3.5	4	5	12	4.5	13
B	ug/g	440	510	420	340	220	400	330	320	280	440	340	330	410	470	360	370	380
Cd	ug/g	0.7	0.4	0.5	0.4	0.2	0.3	1.4	0.2	0.2	0.1	0.2	0.2	0.3	0.1	0.8	0.1	0.7
Cr	ug/g	50	70	66	55	32	60	65	60	53	72	60	72	89	150	50	170	51
Co	ug/g	740	430	440	570	110	160	300	120	51	97	36	96	1100	21	630	28	630
Cu	ug/g	5600	8000	3760	4780	1910	3600	510	74	90	55	33	62	60	51	5100	67	5400
Fe	ug/g	89000	65100	44700	40100	37500	71000	58900	34100	24900	39600	21800	34800	22200	13600	70200	17000	72700
Pb	ug/g	12400	9700	8500	8600	7400	13300	1400	760	460	810	240	500	530	2300	3400	1600	3600
Mn	ug/g	400	240	260	240	200	320	600	270	180	300	320	230	290	160	160	190	170
Mo	ug/g	973	568	339	372	169	440	350	277	151	370	197	326	234	425	610	226	611
Ni	ug/g	4560	1220	2900	796	461	459	11900	6900	4900	6800	5200	7600	2630	550	3720	754	3620
Se	ug/g	52	63	51	40	24	44	11	8.3	4.7	9.4	2.5	4.6	4.7	14	45	15	47
Ag	ug/g	9.2	6.6	4.9	5.5	2.5	4.4	5.1	2.2	1.7	2.2	1.4	2.5	1.4	2	7.1	2.2	7.2
Sr	ug/g	330	400	240	210	150	240	440	320	290	440	230	250	270	310	260	260	260
Tl	ug/g	4	2.7	2.1	2.2	1	1.9	1.1	0.6	0.5	0.8	0.8	1.2	0.7	0.7	3.9	0.8	4.1
Sn	ug/g	4.4	3.4	3.6	3.4	1.6	4.6	4.4	3.4	2.6	4.1	2.3	2.2	2.5	1.8	2.5	6.2	2.6
Ti	ug/g	590	710	660	570	520	780	260	190	200	200	170	190	200	230	410	280	420
U	ug/g	1120	1000	576	718	302	1030	424	509	147	330	668	187	292	374	739	194	768
V	ug/g	750	500	580	440	350	730	1100	670	580	950	680	1000	1000	1200	550	970	580
Zn	ug/g	160	84	120	120	33	36	67	29	14	23	28	43	84	28	240	27	220
F2 (C10-C16)	mg/kg	1600	89	250	770	170	670	310	64	33	310	270	44	330	66	340	110	1700
F3 (C16-C34)	mg/kg	56	33	20	81	35	41	54	24	16	30	30	47	32	45	54	46	290
F4 (C34-C50)	mg/kg	40	22	7.8	37	16	12	6.6	<5	<5	<5	5.2	<5	<5	7.1	<5	6.8	63

Hole		TMF3-07 Solids												
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA10	SA11	SA12	SA13
Sample Elevation (mASL)		434.112	433.2	430.81	427.2	424.81	421.81	418.79	415.82	412.79	409.8	406.8	403.8	400.81
Depth Interval		433-436	433-436	430-433	427-430	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403
Source Deposit		Cigar Lake						JEB/Sue						
Analyte	Units													
Al	ug/g	31300	41100	33400	31400	46000	49000	26900	53100	65000	78400	89300	83100	90000
Sc	ug/g	34	19	26	18	28	29	20	26	16	8.2	9	8.6	14
As	ug/g	10600	7800	7200	8200	6600	2580	3660	3960	7030	6600	11200	8800	11900
Ba	ug/g	1870	3150	1580	520	2230	3350	190	200	620	820	1280	890	1030
Be	ug/g	11	8.5	8.7	7	12	13	1.7	2.4	3	3.3	3.9	4	4
B	ug/g	300	350	290	260	380	420	120	240	280	360	430	420	440
Cd	ug/g	0.3	0.3	0.8	1	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.2
Cr	ug/g	39	160	60	95	62	81	30	51	54	71	75	76	79
Co	ug/g	760	620	910	910	690	390	64	46	72	73	76	98	49
Cu	ug/g	8200	6000	4180	4100	5300	4570	130	44	55	48	71	50	49
Fe	ug/g	62500	45100	58300	40000	79500	118000	13400	15400	24700	26300	37400	31100	34900
Pb	ug/g	10200	4600	6700	4000	10000	15400	380	350	750	480	700	520	410
Mn	ug/g	300	220	230	170	320	480	140	120	190	220	260	300	320
Mo	ug/g	812	500	635	342	821	661	84	122	186	373	391	244	442
Ni	ug/g	7600	6000	4800	5400	4430	2050	3610	3200	4970	4470	6400	5200	8200
Se	ug/g	54	38	51	34	39	47	5.9	4.2	8.1	5.2	8	6.5	5.1
Ag	ug/g	11	6.7	7.3	8	9.1	6.1	1.2	0.8	1.6	1.4	2	1.6	2.6
Sr	ug/g	180	160	160	150	210	340	150	220	250	380	520	400	320
Tl	ug/g	4.6	3.3	3.9	2.8	3.6	2.4	0.3	0.4	0.5	0.6	0.8	0.7	1.2
Sn	ug/g	2.9	2.2	2.3	1.9	3.5	8.4	1	1.4	2.5	2.7	3.6	2.8	3
Ti	ug/g	460	490	550	410	650	770	150	170	170	190	210	210	190
U	ug/g	1640	963	530	638	1210	1300	114	138	196	333	604	220	522
V	ug/g	460	470	480	340	720	850	280	450	530	650	870	870	1100
Zn	ug/g	140	180	230	280	86	58	21	21	21	18	21	22	33
F2 (C10-C16)	mg/kg	240	83	780	11	88	530	24	32	100	460	110	250	280
F3 (C16-C34)	mg/kg	33	30	42	14	43	67	16	17	56	37	34	57	38
F4 (C34-C50)	mg/kg	38	20	24	7	30	36	7	5.9	7.7	<5	8.3	6	<5

Hole		TMF23-08 Solids						
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07
Sample Elevation (mASL)		436.29	435.36	432.36	429.36	426.36	423.28	420.36
Depth Interval		436-439	433-436	430-433	427-430	424-427	421-424	418-421
Source Deposit		Cigar Lake						JEB/Sue
Analyte	Units							
Al	ug/g	46700	23100	48300	73600	28200	35100	31400
Sc	ug/g	31	16	24	18	14	27	23
As	ug/g	9000	5600	14900	6200	3550	5900	4850
Ba	ug/g	2590	640	380	430	690	2360	270
Be	ug/g	14	4.7	8.1	12	6.5	9.6	1.7
B	ug/g	350	180	350	470	230	280	150
Cd	ug/g	0.6	0.4	1.1	0.2	0.1	0.4	0.3
Cr	ug/g	190	68	170	180	28	52	36
Co	ug/g	850	670	1200	500	430	650	110
Cu	ug/g	7700	2660	7100	4920	5400	3890	82
Fe	ug/g	68700	51400	34700	36800	26900	48800	17900
Pb	ug/g	14100	3100	3600	3100	4000	10300	290
Mn	ug/g	390	190	110	110	110	250	170
Mo	ug/g	705	235	345	344	313	376	96
Ni	ug/g	6000	3910	10800	4660	2740	4070	3820
Se	ug/g	47	29	47	37	25	43	3.1
Ag	ug/g	11	4.2	7.8	6.2	5.2	6.6	1.2
Sr	ug/g	300	180	110	160	150	170	150
Tl	ug/g	3.4	2	3.7	3.7	2.7	2.6	0.4
Sn	ug/g	4.2	2.8	2	2.6	2	3.5	1.4
Ti	ug/g	700	370	420	410	340	590	140
U	ug/g	952	819	284	333	394	982	110
V	ug/g	720	270	330	630	250	580	450
Zn	ug/g	180	92	320	180	85	120	28
F2 (C10-C16)	mg/kg	300	6000	7.9	5.4	53	440	89
F3 (C16-C34)	mg/kg	36	110	14	11	18	35	23
F4 (C34-C50)	mg/kg	26	22	7.5	<5	12	24	<5

Appendix D

Section B: Geochemical Results Table – 2001-2018

Hole		TMF18-01 Pore Water																							
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA09	SA10	SA11	SA12	SA13	SA15	SA16	SA17	SA18	SA20	SA21	SA22	SA23	SA24	SA25	SA26	
Sample Elevation (mASL)		426.49	423.49	421.69	419.71	417.02	414.68	411.68	409.58	404.80	402.48	399.46	398.85	395.47	391.87	388.01	386.66	383.59	379.68	377.49	374.47	371.37	367.46	365.27	
Depth Interval		424-427	421-424	421-424	418-421	415-418	412-415	409-412	409-412	403-406	400-403	397-400	397-400	394-397	391-394	388-391	385-388	382-385	379-382	376-379	373-376	370-373	365-370	365-370	
Analyte	Units	Pore Water																							
pH (field)	pH units	7.104	7.68	7.493	7.1	7.1	6.472	6.957	7.048	7.437	7.476	7.212	7.186	7.425	7.587	7.164	7.54	7.537	7.646	7.168	7.502	7.453	7.282	7.367	
Temp (field)	°C	24.8	24	19	19.4	25.4	21.5	21.2	19.3	16.8	17	19.1	19	14.2	15.6	18.4	17.3	19.3	18.8	14.8	16.9	15.7	16.6	16.8	
Eh (field)	mV	359	131.5	305.4	269.5	355.6	402	220.3	204.7	253.6	409.6	161.9	152.9	180.8	220.8	161.4	171.7	210.4	191.7	146.5	152.1	165.5	122.1	289.4	
Spec. Cond. (field)	µS/cm	4710	3860	2970	3390	4460	4920	2880	2650	3370	3360	3750	3420	3290	3070	3060	3120	3080	3200	3110	4000	3610	3010	3470	
D.O. (Field)	mg/L	3.37	4.5	7.86	5.48	7.32	5.82	6.44	8.21	6.925	6.83	5.99	7.11	6.19	3.35	6.66	7.21	7.92	4.4	6.09	4.86	6.7	6.12	4.23	
pH (lab)	pH units	7.7	7.64	7.09	7.28	7.49	7.88	7.39	7.39	7.12	7.72	7.42	7.34	7.76	7.82	7.53	7.3	7.54	7.51	8.03	8.28	8.2	7.78	7.74	
Spec. Cond. (lab)	µS/cm	4800	3980	2900	3580	2390	4070	1530	1600	3440	2270	3160	2460	3400	2440	3590	2690	3290	3320	2690	3890	3670	3260	3510	
Ca ²⁺	mg/L	500	436	521	503	523	462	565	601	491	527	519	552	588	529	550	262	565	536	477	544	529	526	509	
Mg ²⁺	mg/L	226	235	68	101	76	392	42	38	121	136	146	106	123	56	144	98	95	113	118	228	211	110	228	
Na ⁺	mg/L	412	230	116	215	121	303	70	78	271	123	135	136	121	139	234	109	97	98	90	270	140	145	76	
K ⁺	mg/L	40	30	32	43	39	27	34	25	36	26	49	50	38	32	43	40	58	38	26	29	29	23	23	
HCO ₃ ⁻	mg/L	83	76	87	56	107	80	60	66	63	159	245	246	374	211	256	207	307	251	179	365	342	177	100	
CO ₃ ²⁻	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Cl ⁻	mg/L	151	22	36	71	78	132	34	44	97	54	55	56	47	64	83	22	74	63	53	85	75	80	62	
OH ⁻	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
SO ₄ ²⁻	mg/L	2760	2380	1770	2070	1830	3000	1680	1680	2120	1930	2140	1980	1940	1630	2180	990	1650	1780	1680	2410	2120	1870	2230	
Total Hardness	mg/L	2180	2050	1580	1670	1620	2760	1580	1660	1720	1870	1890	1810	1970	1550	1960	1060	1800	1800	1670	2290	2190	1760	2210	
Sum of Ions	mg/L	4180	3420	2640	3080	2790	4400	2490	2540	3200	2970	3370	3170	3250	2670	3500	1740	2860	2900	2640	3940	3460	2940	3240	
Total Alkalinity	mg/L	68	62	71	46	88	66	49	54	52	130	201	202	307	173	210	170	252	206	147	299	280	145	82	
P.Alkalinity	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
NO ₃ ⁻	mg/L	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	
NH ₃	mg/L	7.1	9.8	6.7	20	10	7.2	5	9	4.7	12	60	34	14	9.8	8.7	9.2	9.4	19	12	9.5	13	9.7	12	
DOC	mg/L	15	8.8	3.9	3.8	4.6	9.7	4.9	3.8	4.2	3.9	5.5	5.5	5.8	3.6	5.2	3.5	4.7	3.9	4.3	5.8	4.9	3.7	7.2	
COD	mg/L	64	35	18	18	45	45	30	19	29	19	27	32	24	17	24	21	25	21	17	24	20	12	29	
Al	mg/L	0.095	0.037	0.01	0.022	0.027	0.019	0.015	0.01	0.023	0.016	0.02	0.026	0.022	0.027	0.022	0.012	0.016	0.016	0.027	0.012	0.015	0.014	0.013	
Sb	mg/L	0.0084	0.005	0.008	0.003	0.008	0.019	0.004	0.004	0.006	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.006	0.002	0.003	0.0014	0.002	0.0013	0.007	
As	µg/L	673	170	520	1380	3800	401	1320	1550	570	800	12900	14500	4520	5710	16600	20900	17200	16200	10700	6060	10600	2300	780	
Ba	mg/L	0.023	0.017	0.026	0.03	0.024	0.017	0.052	0.034	0.024	0.018	0.021	0.016	0.026	0.018	0.021	0.041	0.038	0.024	0.04	0.023	0.029	0.018	0.02	
Be	mg/L	0.0001	0.001	0.001	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001	0.001	0.0001	0.0001	
B	mg/L	2.1	1.7	0.1	0.3	0.4	2.5	0.1	0.1	0.5	0.3	0.5	0.4	0.6	0.4	0.8	0.7	0.7	0.8	0.7	0.53	0.5	0.38	0.44	
Cd	mg/L	0.00003	0.0001	0.0001	0.0002	0.0002	0.00005	0.0003	0.0005	0.0002	0.0001	0.0001	0.0002	0.0001	0.0004	0.0002	0.0002	0.0001	0.0003	0.0001	0.00006	0.0001	0.00004	0.00001	
Cr	mg/L	0.0005	0.005	0.005	0.005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005	0.005	0.0005	0.0005	
Co	mg/L	0.0086	0.009	0.046	0.046	0.035	0.011	0.16	0.057	0.014	0.046	0.053	0.058	0.016	0.004	0.028	0.01	0.008	0.011	0.012	0.015	0.032	0.013	0.033	
Cu	mg/L	0.053	0.002	0.002	0.002	0.004	0.0002	0.002	0.002	0.002	0.002	0.002	0.002	0.002											

Hole		TMF18-03 Pore Water																					
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA08	SA09	SA11	SA12	SA13	SA14	SA16	SA17	SA18	SA19	SA20	SA21	SA23	SA24	
Sample Elevation (mASL)		424.60	421.60	419.40	416.90	415.90	414.40	412.60	411.40	409.80	406.80	403.80	401.40	398.40	392.20	388.50	386.10	382.70	381.20	379.40	373.60	371.10	
Depth Interval		424-427	421-424	418-421	415-418	415-418	412-415	412-415	409-412	409-412	406-409	403-406	400-403	397-400	391-394	388-391	385-388	382-385	379-382	379-382	373-376	370-373	
Analyte	Units	Pore Water																					
pH (field)	pH units	8.232	8.278	7.296	7.042	6.929	7.437	7.843	8.246	7.54	6.734	7.42	7.74	8.08	7.59	7.58	8.04	7.7	7.61	7.64	7.93	8.89	
Temp (field)	°C	15.2	15.7	19.7	18.9	17.9	15.4	16.7	18.5	19	21.7	19	24	23	14.7	19	16.6	19	19	21.7	21	19	
Eh (field)	mV	291.2	241.8	154.7	184.2	200.2	156.8	239.2	361.3	153.1	288.6	134.7	182.5	155.2	128.5	145.6	179.9	170	375.8	175.9	341	170	
Spec. Cond. (field)	µS/cm	4820	5370	5480	4400	3610	3600	3540	3010	3240	2700	3010	3410	3380	4090	4280	3270	3630	3390	3190	3660	3700	
D.O. (Field)	mg/L	4.63	4.29	4.23	4.81	4.22	4.71	7.22	5.23	5.64	5.83	4.92	5.91	5.45	5.02	6.53	6.48	6.11	5.25	4.45	6.13	5.2	
pH (lab)	pH units	7.67	8.09	7.35	7.95	7.22	7.55	7.77	8.09	7.75	7.62	7.70	7.77	7.56	7.98	7.77	7.78	8.02	8.07	7.81	7.88		
Spec. Cond. (lab)	µS/cm	4800	4840	3520	3660	3350	3390	3390	3190	3290	1860	2790	3390	2730	3980	4440	3330	3500	3410	3170	3710		
Ca ²⁺	mg/L	456	456	476	492	338	494	483	518	397	260	541	564	547	570	466	533	570	577	556	558		
Mg ²⁺	mg/L	435	476	212	149	119	120	105	78	79	42	110	160	155	172	174	135	166	172	146	208		
Na ⁺	mg/L	281	207	240	258	235	292	222	184	103	57	76	150	213	210	453	160	112	72	63	118		
K ⁺	mg/L	45	34	18	22	16	27	27	34	25	21	31	52	41	36	38	41	33	36	28	30		
HCO ₃ ⁻	mg/L	77	54	139	63	48	287	148	79	108	77	159	252	289	650	123	265	468	378	306	302		
CO ₃ ²⁻	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Cl ⁻	mg/L	153	107	37	29	13	31	35	32	25	26	57	70	74	59	109	60	46	42	42	43		
OH ⁻	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
SO ₄ ²⁻	mg/L	3400	3400	2480	2300	1750	2160	2020	1930	1500	930	1780	2100	2170	2110	2640	2020	1960	1940	1880	2240		
Total Hardness	mg/L	2960	3090	2060	1840	1330	1720	1640	1610	1310	821	1800	2060	2000	2130	1880	1880	2100	2150	1990	2250		
Sum of Ions	mg/L	5180	4750	3610	3320	2530	3420	3050	2870	2260	1430	2760	3360	3500	3830	4010	3230	3370	3230	3030	3520		
Total Alkalinity	mg/L	63	44	114	52	39	235	121	65	89	63	130	207	237	533	101	217	384	310	251	248		
P.Alkalinity	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
NO3 ⁻	mg/L	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.54	0.4	0.04	0.19	0.04	0.04	0.4	0.04	0.04	0.04	0.04	0.15	0.04		
NH3	mg/L	8.4	9.6	6.6	3.1	8.1	7	10	12	14	13	5.9	9.3	12	21	8.9	13	11	8.7	6.5	18		
DOC	mg/L	12	19	2.6	2.3	2.6	3.5	4.3	3.2	4.8	5	4.8	4.8	10	13	7.6	9.8	8.5	5.9	6.6	9.1		
COD	mg/L	37	108	12	10	15	15	20	15	12	15	15	15	30	34	23	29	26	16	19	32		
Al	mg/L	0.02	0.025	0.0038	0.0041	0.0029	0.009	0.009	0.012	0.028	0.026	0.023	0.027	0.032	0.031	0.011	0.03	0.034	0.036	0.038	0.035	0.05	
Sb	mg/L	0.0058	0.013	0.0072	0.015	0.0027	0.002	0.002	0.003	0.002	0.002	0.003	0.003	0.002	0.002	0.0021	0.003	0.002	0.002	0.002	0.002		
As	µg/L	209	409	1160	752	1450	1440	667	1120	760	520	11700	7600	15700	13400	1230	3430	12300	4720	10200	3940	3860	
Ba	mg/L	0.012	0.019	0.018	0.018	0.034	0.018	0.02	0.015	0.021	0.01	0.016	0.021	0.025	0.018	0.029	0.024	0.026	0.035	0.033	0.033	0.027	
Be	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001		
B	mg/L	1.9	1.5	0.18	0.25	0.19	0.1	0.5	0.2	0.2	0.1	0.2	0.3	0.4	0.7	0.91	0.7	0.7	0.7	0.8	1	0.8	
Cd	mg/L	0.00005	0.00004	0.00017	0.00014	0.0001	0.0003	0.0004	0.0003	0.0001	0.0001	0.0003	0.0003	0.0003	0.0001	0.00001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
Cr	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	
Co	mg/L	0.031	0.0073	0.25	0.12	0.24	0.055	0.023	0.002	0.025	0.001	0.37	0.11	0.005	0.025	0.01	0.006	0.024	0.028	0.033	0.008	0.022	
Cu	mg/L	0.092	0.0017	0.0002	0.0004	0.0002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.012	0.002	0.002	0.002	
Fe	mg/L	0.008	0.014	2.49	1.76	6.6	2.2	0.034	0.009	0.81	0.016	1.8	0.26	0.15	1.9	1.21	0.58	2.7	0.42	0.84	0.013	0.36	
Pb	mg/L	0.0049	0.0032	0.0003	0.0008	0.0001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.0008	0.001	0.003	0.001	0.002	0.003	0.004	
Mn	mg/L	0.73	0.36	2.8	2.14	2.94	1.9	0.86	0.25	1.4	0.24	4.2	2.6	2.1	8.8	1.84	2.3	7	5.6	7.1	2.9	13.9	
Mo	mg/L	0.389	2.06	8.6	5.3	5.57	18.3	20.2	30	22.7	19.9	30.1	44.7	29.9	2.5	2.58	7.25	2.03	1.92	1.37	5.03	2.15	
Ni	mg/L	0.086	0.048	4.44	6.74	5.73	1.89	0.57	0.12	1.41	0.065	0.48	0.35	0.15	0.44	0.147	0.12	0.35	0.42	0.5	0.19	0.44	
Se	mg/L	0.024	0.01	0.0006	0.0013	0.0003	0.003	0.003	0.005	0.008	0.003	0.001	0.002	0.001	0.002	0.011	0.006	0.001	0.001	0.001	0.003	0.007	
Ag	mg/L	0.0003	0.0015	0.00005	0.00013	0.00005	0.0005	0.0005	0.0016	0.0005	0.0005	0.0005	0.0										

[illegible]

Hole		TMF18-05 Pore Water												
Sample Number		SA01	SA02	SA03	SA05	SA07	SA08	SA09	SA11	SA13	SA14	SA15	SA16	SA17
Sample Elevation (mASL)		424.70	421.70	418.70	415.70	412.70	409.70	406.70	403.70	400.70	397.70	394.70	391.70	388.70
Depth Interval		424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391
Analyte	Units	Pore Water												
pH (field)	pH units	8.142	7.964	7.434	7.102	7.197	7.72	7.44	7.424	8.001	7.495	6.493	7.544	7.526
Temp (field)	°C	19	16.3	15.7	16.1	16.4	18.3	17.3	15.9	17.6	17.5	15.4	17.4	16.4
Eh (field)	mV	378.7	373.8	256.3	291.7	268	309.9	284.9	226.3	238.3	97.4	102.2	145.6	124.9
Spec. Cond. (field)	µS/cm	5280	5020	4830	3610	4130	4100	3490	4380	3460	4910	4640	3640	4030
D.O. (Field)	mg/L			5.13	5.86	3.63	4.53	6.13	4.85	4.14	5.2	4.48	6.8	7.03
pH (lab)	pH units	6.86	7.44	6.99	7.26	7.26	7.67	7.44	7.57	7.64	7.379	7.81	7.81	7.73
Spec. Cond. (lab)	µS/cm	4930	4590	3560	3440	2570	2920	3000	2950	2650	3680	3280	2590	3260
Ca ²⁺	mg/L	457	463	474	474	494	524	511	512	516	601	538	531	563
Mg ²⁺	mg/L	378	484	177	131	132	105	146	112	113	175	179	120	133
Na ⁺	mg/L	342	233	244	257	237	121	86	74	50	61	144	124	118
K ⁺	mg/L	42	36	18	22	26	33	21	23	17	46	44	35	42
HCO ₃ ⁻	mg/L	88	96	99	92	333	145	163	172	102	786	508	346	429
CO ₃ ²⁻	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1
Cl ⁻	mg/L	146	129	35	32	33	27	24	23	20	77	66	51	45
OH ⁻	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1
SO ₄ ²⁻	mg/L	3100	3400	2250	2100	2030	1830	1960	1850	1800	1930	2000	1820	2010
Total Hardness	mg/L	2690	3140	1910	1720	1770	1740	1870	1740	1750	2220	2080	1820	1950
Sum of Ions	mg/L	4560	4850	3300	3110	3300	2800	2930	2790	2630	3750	3500	3040	3350
Total Alkalinity	mg/L	72	79	81	75	273	119	134	141	84	644	416	284	352
P.Alkalinity	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1
NO3 ⁻	mg/L	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	2.8	0.04	0.04
NH3	mg/L	7.20	7.70	4.60	4.90	10.00	13.00	12.00	20.00	8.60	61.00	18.00	12.00	11.00
DOC	mg/L	14.0	15.0	4.0	2.8	3.0	2.6	3.5	3.2	2.8	9.5	10.0	9.2	10.0
COD	mg/L	41	48	14	12	14	14	10	12	12	38	32	26	30
Al	mg/L	0.17	0.022	0.085	0.0057	0.006	0.023	0.012	0.008	0.012	0.029	0.012	0.02	0.039
Sb	mg/L	0.011	0.0068	0.0044	0.012	0.002	0.002	0.002	0.002	0.004	0.002	0.002	0.0014	0.002
As	µg/L	437	211	1120	488	610	571	722	918	438	35400	11600	5410	9090
Ba	mg/L	0.05	0.011	0.034	0.024	0.016	0.03	0.024	0.018	0.012	0.026	0.02	0.036	0.042
Be	mg/L	0.0001	0.0001	0.0001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001	0.001
B	mg/L	1.4	2.4	0.12	0.22	0.2	0.1	0.2	0.1	0.1	0.7	0.6	0.39	0.6
Cd	mg/L	0.00003	0.00003	0.00014	0.00015	0.0004	0.0004	0.0003	0.0003	0.0002	0.0002	0.0001	0.00004	0.0001
Cr	mg/L	0.0006	0.0005	0.0005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005	0.005
Co	mg/L	0.043	0.037	0.13	0.16	0.22	0.01	0.062	0.017	0.012	0.17	0.009	0.012	0.047
Cu	mg/L	0.078	0.0078	0.01	0.0004	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.0003	0.002
Fe	mg/L	0.73	0.015	1.51	1.47	6.1	0.085	0.67	0.72	0.024	2	2.1	0.52	3.5
Pb	mg/L	0.14	0.0084	0.021	0.0003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0011	0.005
Mn	mg/L	0.28	1.38	2.53	2.19	1.7	0.61	2.8	2.2	0.42	7	5.6	5	12.5
Mo	mg/L	1.41	0.28	9.5	7.96	12.8	25.4	15.6	32.1	16.2	18.8	19.3	2.2	3.19
Ni	mg/L	0.179	0.096	2.74	6.62	6.55	0.75	1.42	1.06	0.48	0.68	0.2	0.226	0.6
Se	mg/L	0.038	0.0076	0.0004	0.0008	0.001	0.001	0.001	0.005	0.001	0.001	0.001	0.0013	0.001
Ag	mg/L	0.0088	0.0012	0.0013	0.00005	0.0005	0.0013	0.0033	0.0005	0.0005	0.0005	0.0005	0.00005	0.0005
Sr	mg/L	0.24	0.32	0.28	0.25	0.23	0.25	0.26	0.22	0.32	0.53	0.37	0.8	0.63
Tl	mg/L	0.0024	0.0002	0.0002	0.0002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.0003	0.002
Sn	mg/L	0.0003	0.0002	0.0006	0.0001	0.001	0.001	0.001	0.001	0.001	0.002	0.003	0.0001	0.001
Ti	mg/L	0.012	0.0015	0.031	0.022	0.036	0.071	0.042	0.082	0.042	0.051	0.095	0.011	0.01
V	mg/L	0.0052	0.0014	0.006	0.0017	0.001	0.003	0.002	0.003	0.004	0.032	0.017	0.036	0.041
Zn	mg/L	0.044	0.029	0.055	0.027	0.032	0.031	0.031	0.072	0.023	0.17	0.032	0.037	0.065
F ⁻	mg/L	0.7	0.57	0.26	0.23	0.25	0.29	0.23	0.2	0.25	0.59	6	4.6	0.45
210 Pb	Bq/L	30.00	43.00	5.00	5.00	9.00	8.00	4.00	0.80	2.00	5.00	16.00	26.00	19.00
210 Po	Bq/L	2.70	3.80	0.60	0.40	0.70	0.60	0.40	0.40	0.20	0.50	1.50	2.00	1.80
226 Ra	Bq/L	3.20	4.90	2.20	2.10	2.10	2.10	1.70	1.30	0.80	4.80	8.40	6.60	7.70
230 Th	Bq/L	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
U	µg/L	694	1150	63	121	2360	1330	690	1850	420	46500	36000	39800	31300
As(III)	mg/L	69.1	26.1											
As(V)	mg/L	63.7	10.8											

Hole		TMF18-06 Pore Water																TMF18-07 Pore Water							
Sample Number		SA01A	SA01B	SA02	SA03	SA04	SA06	SA07	SA09	SA10	SA12	SA14	SA15	SA16	SA17	SA18	SA19	SA01	SA03	SA04	SA06	SA07	SA09	SA10	SA12
Sample Elevation (mASL)		428.61	425.71	422.71	419.71	416.71	413.68	410.69	407.69	405.00	401.69	398.70	395.70	392.70	389.70	386.70	383.70	421.81	418.79	415.82	412.79	409.80	406.80	403.80	400.81
Depth Interval		427+	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391	385-388	382-385	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403
Analyte	Units	Pore Water																Pore Water							
pH (field)	pH units	7.649	7.583	7.833	7.769	7.189	6.972	7.316	8.095	6.858	7.396	6.777	6.95	7.215	7.409	7.515	7.278	7.756	7.336	7.525	7.272	7.532	7.334	7.4	7.588
Temp (field)	°C	21	20.7	16.4	18.5	19.9	18.8	19.5	18.1	18.9	20.8	21.9	19.3	24	19.1	20.6	22.8	17.4	20.6	18.4	23.2	12.6	13.3	16.1	16.4
Eh (field)	mV	423	350.7	258.2	316.6	143.7	209.9	156.4	348.4	143.2	169.2	189.4	132.3	105.6	127.2	176.5	100.7	367.2	193.7	255	216.8	177.4	292.6	234.5	320.5
Spec. Cond. (field)	µS/cm	4920	4250	3980	2920	3160	3210	2950	3880	2830	2640	2760	3030	3290	2850	2840	2600	3160	3260	4340	3980	2530	2350	2560	2480
D.O. (Field)	mg/L	6.04	6.17	6.85	4.33	3.73	6.27	3.97	4.94	5.5	5.9	7.37	3	4.14	4.33	5.13	4.7	7.02	7.03	5.94	4.53	2.34	4.32	4.32	4.77
pH (lab)	pH units	8.16	7.73	7.7	7.94	8.1	7.77	7.86	7.82	7.62	7.86	7.68	7.69	8.03	8.06	8.23	8.03	7.56	7.69	7.49	7.71	7.84	7.75	7.83	7.66
Spec. Cond. (lab)	µS/cm	2670	3540	3260	4940	3620	2560	1260	1920	1360	2370	2140	3520	1250	2570	3340	2510	3660	3700	4440	4050	2760	3080	2700	1840
Ca ²⁺	mg/L	362	445	135	454	503	255	190	258	215	281	227	536	243	433	603	351	342	346	132	492	298	514	390	192
Mg ²⁺	mg/L	161	87	169	406	266	100	44	52	49	74	82	193	54	122	140	138	91	101	61	107	125	132	134	60
Na ⁺	mg/L	135	461	153	341	111	212	119	79	53	59	39	102	64	124	86	60	311	418	491	415	177	96	87	32
K ⁺	mg/L	18	40	27	31	24	20	13	13	12	19	14	36	22	36	38	55	92	43	37	32	33	35	29	12
HCO ₃ ⁻	mg/L	63	76	46	85	120	37	58	44	46	50	46	185	90	206	377	178	156	77	199	135	98	66	132	40
CO ₃ ²⁻	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cl ⁻	mg/L	66	36	47	143	35	21	8	8	8	7	11	45	11	34	46	60	82	25	32	44	9	32	10	15
OH ⁻	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SO ₄ ²⁻	mg/L	1710	2240	1250	3400	2410	1380	830	950	810	1070	920	2190	860	1650	1940	1400	1770	2050	1510	2370	1490	1930	1540	740
Total Hardness	mg/L	1560	1470	1030	2800	2350	1050	655	857	738	1000	903	2130	828	1580	2080	1440	1230	1280	580	1670	1260	1820	1520	726
Sum of Ions	mg/L	2520	3400	1830	4870	3470	2030	1270	1410	1200	1590	1340	3290	1360	2620	3240	2250	2850	3060	2480	3600	2250	2820	2340	1110
Total Alkalinity	mg/L	52	62	38	70	98	30	48	36	38	41	38	152	74	169	309	146	128	63	163	111	80	54	108	33
P.Alkalinity	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NO ₃ ⁻	mg/L	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
NH3	mg/L	5.20	13.00	6.10	5.70	3.30	4.20	3.90	8.40	6.90	22.00	3.60	1.40	17.00	13.00	7.90	7.00	5.60	2.80	13.00	3.60	15.00	15.00	14.00	13.00
DOC	mg/L	4.8	5.5	4.0	20.0	9.8	2.4	1.1	2.8	3.2	4.0	3.6	5.0	6.0	7.6	7.6	5.3	3.6	3.1	4.2	3.7	3.2	2.6	4.6	2.7
COD	mg/L	23	27	16	104	34	11	10	11	16	14	18	19	19	25	29	21	10	13	15	13	11	10	15	10
Al	mg/L	0.051	0.009	0.013	0.018	0.026	0.0053	0.01	0.01	0.0048	0.008	0.01	0.007	0.019	0.033	0.025	0.024	0.017	0.0054	0.007	0.01	0.005	0.008	0.01	0.014
Sb	mg/L	0.0071	0.002	0.0037	0.013	0.0008	0.0044	0.003	0.002	0.0008	0.002	0.002	0.002	0.002	0.002	0.002	0.0012	0.006	0.015	0.007	0.004	0.002	0.002	0.002	0.004
As	µg/L	388	260	444	244	120	3880	940	2250	1700	450	1240	2300	6780	3820	11200	5890	1310	1060	2020	650	900	410	650	390
Ba	mg/L	0.014	0.006	0.011	0.012	0.015	0.02	0.022	0.017	0.01	0.015	0.02	0.018	0.028	0.026	0.03	0.035	0.018	0.017	0.018	0.019	0.013	0.012	0.014	0.016
Be	mg/L	0.0001	0.001	0.0001	0.0001	0.0001	0.0001	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001	0.001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001
B	mg/L	3	0.1	1.8	1.9	0.9	0.26	0.2	0.2	0.21	0.1	0.2	0.6	0.7	0.6	0.7	0.64	0.1	0.19	0.2	0.3	0.1	0.1	0.1	0.1
Cd	mg/L	0.00002	0.0001	0.00002	0.00002	0.00002	0.00008	0.0001	0.0003	0.00011	0.0009	0.0001	0.0002	0.0001	0.0001	0.0001	0.00002	0.0003	0.00011	0.0002	0.0001	0.0001	0.0004	0.0003	0.0001
Cr	mg/L	0.0005	0.005	0.0005	0.0005	0.0005	0.0005	0.005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005
Co	mg/L	0.0061	0.001	0.057	0.042	0.014	0.21	0.32	0.052	0.66	0.013	0.091													

Hole		TMF18-01 Solids																							
Sample Number		SA01	SA02	SA03	SA04	SA05	SA06	SA07	SA09	SA10	SA11	SA12	SA13	SA15	SA16	SA17	SA18	SA20	SA21	SA22	SA23	SA24	SA25	SA26	
Sample Elevation (mASL)		426.49	423.49	421.69	419.71	417.02	414.68	411.68	409.58	404.80	402.48	399.46	398.85	395.47	391.87	388.01	386.66	383.59	379.68	377.49	374.47	371.37	367.46	365.27	
Analyte	Units	424-427	421-424	421-424	418-421	415-418	412-415	409-412	409-412	403-406	400-403	397-400	397-400	394-397	391-394	388-391	385-388	382-385	379-382	376-379	373-376	370-373	365-370	365-370	
Al	ug/g	46100	48400	65600	62400	60800	72400	41100	46200	49300	59100	80300	78100	89600	67900	71800	77800	79600	49200	28400	73300	57900	54000	60900	
Sb	ug/g	29	25	19	6.9	3.5	3.3	2.1	1	2.7	9.7	1.9	2.3	2.5	1.6	1.8	1.9	1.8	3.2	1.6	4.4	3.7	19	8.1	
As	ug/g	1900	2220	2980	2470	899	4600	499	222	546	4600	282	296	442	330	319	288	324	693	362	1240	1350	4380	7400	
Ba	ug/g	3360	6300	160	160	84	480	47	45	77	480	240	280	590	200	240	180	100	330	64	300	200	290	3820	
Be	ug/g	18	13	2.8	2.7	2.5	2.8	1.5	1.6	2	2.6	4	4.8	3.6	3.6	3.3	4.1	4.1	3.2	1.7	4.5	3.3	2.8	5.7	
B	ug/g	420	330	250	260	240	300	160	170	200	230	320	380	310	270	240	300	290	200	140	270	210	230	290	
Cd	ug/g	1.5	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2	
Ca	ug/g	102000	94300	18700	8600	1800	63300	1000	800	6700	70100	7700	12500	9700	3600	7000	3900	4500	8000	760	3600	2200	17100	63100	
Cr	ug/g	70	65	260	320	260	150	270	320	300	130	260	360	250	260	260	280	260	240	320	240	280	340	74	
Co	ug/g	470	460	36	19	10	26	20	12	17	180	12	13	14	10	14	12	12	22	14	27	32	79	150	
Cu	ug/g	5700	5600	33	30	27	25	22	8.8	24	33	20	29	30	21	37	29	25	58	24	58	110	72	370	
Fe	ug/g	43300	69100	15200	15800	14000	23100	11900	8800	8500	16800	10500	11800	10600	11900	11600	12200	11300	19100	21500	17500	17600	18300	34300	
Pb	ug/g	14800	14800	420	290	250	370	110	47	110	390	590	810	1300	610	560	520	490	1600	540	1100	1100	630	4000	
Mg	ug/g	10700	8000	3800	3900	3800	4600	2300	2400	3900	4200	5200	5700	5700	4900	9000	7000	7600	4800	4000	9700	9000	4200	11500	
Mn	ug/g	340	350	130	100	80	160	65	49	72	180	120	110	140	120	100	120	130	280	80	160	130	180	460	
Mo	ug/g	613	771	82	76	45	164	41	19	32	117	124	216	242	110	119	141	122	109	61	174	92	102	67	
Ni	ug/g	1150	1590	2240	1720	640	3120	347	180	647	3590	250	272	327	248	360	257	246	702	395	1190	1060	2930	4260	
P	ug/g	900	690	180	200	150	220	130	160	120	190	160	190	240	140	200	180	190	170	100	200	150	200	980	
K	ug/g	9800	10300	18400	20200	19200	23400	12200	12600	15100	16300	20700	22400	22200	19100	17100	20000	20400	13100	7400	16600	13300	16000	16600	
Se	ug/g	73	49	4	2.3	1.7	3.5	0.5	0.3	1	3	7.4	10	9.5	5.8	8.9	8.2	9.7	12	6.4	15	29	5.1	42	
Ag	ug/g	6.5	6.4	1	0.8	0.4	0.9	0.3	0.2	0.5	1.4	1.7	2.2	1.6	0.9	1.2	1.6	1.3	1.2	1.3	2.2	2.2	1.4	7.6	
Na	ug/g	570	390	200	200	170	340	120	110	180	140	200	240	190	190	170	190	190	130	160	220	170	160	160	
Sr	ug/g	310	310	210	240	220	320	160	180	130	170	160	160	210	140	130	140	150	120	84	140	100	150	210	
Tl	ug/g	2.6	2.7	0.4	0.4	0.4	0.5	0.2	0.2	0.3	0.6	0.6	2	0.5	0.4	0.4	0.5	0.5	0.5	0.3	0.8	0.5	0.4	0.9	
Sn	ug/g	5.8	3.6	1.6	1.5	1.2	2.2	0.7	0.9	0.9	0.9	1.4	1.7	1.4	1.2	1.8	1.5	2.1	1.2	1	2.6	2.3	1.6	4.8	
Ti	ug/g	970	820	180	190	170	200	130	150	160	180	260	310	210	230	220	270	260	160	200	290	210	190	280	
U	ug/g	1100	822	142	135	155	145	95	42	55	122	137	160	214	1050	217	248	297	172	106	557	1540	125	987	
V	ug/g	590	920	530	550	430	650	240	230	400	730	980	1100	870	750	650	950	850	550	250	990	510	670	680	
Zn	ug/g	210	94	23	12	10	12	10	9.9	15	38	21	25	20	17	16	16	15	56	16	31	24	23	66	
Inorganic carbon	%		0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01		0.03	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	
Organic carbon	%		0.37	0.1	0.06	0.07	0.07	0.06	0.06	0.04	0.07	0.01		0.11	0.04	0.05	0.01	0.06	0.04	0.06	0.03	0.03	0.04	0.12	
F2 (C10-C16)	ug/g		370	4	10	4	72	4	4	13	4			110	4	8	4	1600	6	4	4	4	7	220	
F3 (C16-C34)	ug/g		18	5	5	5	5	5	5	6	5	5		7	5	5	5	21	5	5	5	5	5	15	
F4 (C34-C50)	ug/g		8	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	5	

Hole		TMF18-02 Solids																			
Sample Number		SA01	SA02	SA03	SA04	SA05	SA07	SA08	SA09	SA10	SA12	SA13	SA14	SA15	SA17	SA18	SA19	SA20	SA22	SA23	SA24
Sample Elevation (mASL)		427.58	424.58	423.58	418.58	415.61	412.28	408.76	406.49	403.80	400.70	397.70	394.30	392.10	389.40	386.70	382.40	379.70	376.60	373.60	370.50
Analyte	Units	427+	424-427	421-424	418-421	415-418	412-415	406-409	406-409	403-406	400-403	397-400	394-397	391-394	388-391	385-388	382-385	379-382	376-379	373-376	370-373
Al	ug/g	32500	32800	21100	49900	49100	41500	55000	56400	48000	41300	42400	66800	67000	46100	62800	64300	51400	63000	88700	95600
Sb	ug/g	18	14	12	11	8.5	3.1	2.2	2.7	3.8	5.5	0.8	1.6	2.3	1.2	1.8	2.7	2.3	6	5.8	7.6
As	ug/g	813	1380	712	3330	1130	531	468	643	822	2380	115	204	356	251	349	643	638	2070	1630	2180
Ba	ug/g	2300	2740	3460	270	52	58	61	120	81	220	65	180	610	60	140	300	280	940	2290	5300
Be	ug/g	12	9.1	5.6	3	2	1.9	2.2	2.5	2.6	2.3	2.1	3	4.1	2.6	3.7	4	2.7	5.2	4.8	5.1
B	ug/g	290	260	160	250	200	190	240	260	200	200	180	280	360	210	300	310	200	370	360	380
Cd	ug/g	0.3	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.3
Ca	ug/g	130000	128000	152000	13600	1800	1100	1400	1300	1900	38400	880	18900	20100	940	10500	7200	2100	9700	12700	20300
Cr	ug/g	43	44	25	280	260	280	250	240	310	220	260	290	210	300	240	220	260	230	220	80
Co	ug/g	190	440	160	62	14	12	5.5	7.6	9.5	24	4.5	8	14	9	13	17	17	54	43	47
Cu	ug/g	2400	7600	1810	60	16	14	9	9	13	22	7.9	16	30	30	41	40	35	86	96	140
Fe	ug/g	29500	49400	33400	15300	10900	11400	8400	11000	10100	10000	6800	9000	10100	11100	11400	16000	15600	26500	25500	24900
Pb	ug/g	13500	10300	6700	630	220	96	76	190	150	210	220	570	880	320	490	940	730	1200	4300	4800
Mg	ug/g	7700	7500	3100	4700	2600	2600	4200	3400	3200	4300	4000	5100	5800	6100	8200	7700	6600	6200	8400	9100
Mn	ug/g	250	300	140	160	67	72	77	86	100	98	56	75	130	68	95	120	110	300	340	320
Mo	ug/g	204	696	225	88	38	26	32	46	65	102	52	106	188	72	109	154	96	248	418	379
Ni	ug/g	652	892	464	2280	904	410	446	592	669	2310	94	184	312	238	295	455	468	2040	1160	1280
P	ug/g	400	370	230	200	140	140	130	120	130	130	120	160	220	130	190	260	210	240	440	450
K	ug/g	7600	7500	3800	17100	14500	14500	18800	17600	14000	16200	16600	20800	22500	15400	19500	20600	14900	18000	24800	28100
Se	ug/g	48	28	29	5.2	1.8	0.7	0.7	1.4	1.2	1.9	2.8	6.1	9	7.6	8.5	14	7.1	16	23	26
Ag	ug/g	4	6	3.3	1.4	0.6	0.3	0.5	0.6	0.8	1.2	0.4	0.9	1.6	0.9	1.3	1.6	1	2.4	3.2	3.8
Na	ug/g	240	220	160	170	140	140	150	130	130	120	110	150	180	210	200	210	250	220	300	320
Sr	ug/g	200	170	190	140	160	170	140	130	140	130	120	130	180	96	130	160	140	170	290	310
Tl	ug/g	1.5	1.7	1.2	0.5	0.3	0.3	0.4	0.4	0.6	0.6	0.3	0.4	0.6	0.4	0.5	0.6	0.4	0.7	1	0.8
Sn	ug/g	3.2	2.5	1.6	1.6	1.1	0.9	1.2	1.1	0.9	1.1	1	1.2	1.4	1.3	1.9	2.2	1.6	2.1	2.9	5
Ti	ug/g	610	540	390	160	160	150	170	160	150	240	150	210	250	180	210	240	150	280	260	250
U	ug/g	520	569	2060	132	101	124	107	197	401	107	325	220	157	288	180	430	179	269	361	455
V	ug/g	470	620	380	600	340	270	430	510	450	520	320	720	840	430	660	710	380	850	1000	1100
Zn	ug/g	87	100	58	22	13	12	16	19	21	23	10	18	16	9.2	13	17	17	43	50	45
Inorganic carbon	%	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01		0.06	0.01	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Organic carbon	%	0.18	0.17	0.13	0.02	0.07	0.06	0.11	0.05		0.12	0.09	0.01	0.02	0.09	0.04	0.02	0.06	0.1	0.2	0.18
F2 (C10-C16)	ug/g	140	160	63	180	4	4	4	4	7	4	4	28	4	6	19	4	31	820	620	
F3 (C16-C34)	ug/g	5	5	5	5	5	5	9	5	5	5	5	5	5	5	5	5	5	5	9	10
F4 (C34-C50)	ug/g	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Hole		TMF18-05 Solids												
Sample Number		SA01	SA02	SA03	SA05	SA07	SA08	SA09	SA11	SA13	SA14	SA15	SA16	SA17
Sample Elevation (mASL)		424.70	421.70	418.70	415.70	412.70	409.70	406.70	403.70	400.70	397.70	394.70	391.70	388.70
Analyte	Units	424-427	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391
Al	ug/g	46600	53000	39900	74700	89400	86800	70900	95400	67100	105000	86300	121000	106000
Sb	ug/g	31	27	50	90	39	8	12	3.1	15	1.7	2.9	5.5	4.2
As	ug/g	7100	1760	10000	12400	15800	10600	7900	4800	7900	666	425	1400	762
Ba	ug/g	4250	4280	510	1000	1390	1170	1050	1240	580	1020	1190	2490	1940
Be	ug/g	9.2	16	2.8	3.8	4.5	4	3.8	3.4	3.2	4.2	3.7	7.2	4.8
B	ug/g	280	450	200	320	390	430	360	460	310	470	360	600	430
Cd	ug/g	0.5	0.5	0.6	0.4	0.4	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.2
Ca	ug/g	63800	81600	40500	43600	26400	54800	62900	46900	63400	30400	12800	12400	15900
Cr	ug/g	44	76	190	70	78	95	110	110	150	170	130	160	140
Co	ug/g	900	340	190	130	190	52	120	28	180	16	15	33	19
Cu	ug/g	5400	3810	180	130	130	46	57	20	43	29	50	79	64
Fe	ug/g	63700	69100	31300	40100	51900	42100	27800	19300	25000	10100	10700	17400	13000
Pb	ug/g	11800	19400	620	1100	1300	1000	460	200	480	440	1600	2000	2600
Mg	ug/g	6000	11200	3800	5000	5200	5800	5500	5600	5900	7300	6400	7600	8000
Mn	ug/g	300	470	320	350	410	280	410	250	230	170	150	370	220
Mo	ug/g	597	587	197	394	563	366	264	202	136	93	374	540	532
Ni	ug/g	4490	1110	7100	8400	10800	6300	5000	3340	5500	563	418	959	624
P	ug/g	520	870	420	680	630	400	500	400	290	380	290	450	430
K	ug/g	8100	13200	12900	21900	25400	29800	24400	31800	21600	32600	25000	31200	29700
Se	ug/g	52	65	5.4	12	13	11	5	3.1	4.5	4.1	10	19	14
Ag	ug/g	7.8	5.6	2.7	2.9	3.7	2.4	1.7	0.9	2.2	1.1	1.7	3.4	2.2
Na	ug/g	280	440	280	330	360	260	220	220	160	200	190	270	220
Sr	ug/g	370	440	280	500	520	540	480	400	270	360	260	410	400
Tl	ug/g	3.2	2.4	0.7	0.8	1	0.8	0.6	0.5	0.7	0.5	0.6	1	0.7
Sn	ug/g	6.7	4.8	2.1	2.5	5.1	3.4	2.5	2.2	2.4	1.5	1.9	2	1.9
Ti	ug/g	460	930	180	220	230	220	210	210	200	240	240	350	250
U	ug/g	970	1160	168	415	676	323	142	202	206	167	371	373	350
V	ug/g	610	770	740	910	980	880	750	880	980	980	880	1700	1100
Zn	ug/g	100	98	49	45	39	15	30	16	40	28	20	31	25
Inorganic carbon	%											0.77		
Organic carbon	%											0.11		
F2 (C10-C16)	ug/g											130		
F3 (C16-C34)	ug/g											9		
F4 (C34-C50)	ug/g											5		

Hole		TMF18-07 Solids								TMF18-11					
Sample Number		SA01	SA03	SA04	SA06	SA07	SA09	SA10	SA12	SA02	SA03A	SA03			
Sample Elevation (mASL)		421.81	418.79	415.82	412.79	409.80	406.80	403.80	400.81	424.48		423.78			
Analyte	Units	421-424	418-421	415-418	412-415	409-412	406-409	403-406	400-403	424-427		421-424	Max	Min	Average
Al	ug/g	19000	54900	54300	63000	78400	95400	95900	87400	68100	71300	70500	125000	19000	67845.90
Sb	ug/g	16	59	10	24	6.2	7.4	7.8	19	32	38	36	170	0.6	14.81
As	ug/g	2850	7800	3990	10000	7600	11600	5800	13500	3610	5500	4170	16500	115	3837.61
Ba	ug/g	83	540	320	360	710	1150	1110	820	4690	6900	10700	10700	45	1327.66
Be	ug/g	1.2	3.1	2.7	3.6	3.4	4.1	3.7	4.3	22	22	22	22	1.2	4.91
B	ug/g	93	260	270	310	340	440	410	370	640	610	590	640	93	317.75
Cd	ug/g	0.3	0.3	0.1	0.2	0.2	0.2	0.3	0.4	1.4	1.4	1.3	1.5	0.1	0.29
Ca	ug/g	11500	23500	45200	40200	40000	52200	47700	48700	61300	47600	42000	156000	760	35286.39
Cr	ug/g	300	240	260	220	240	90	130	120	81	87	100	410	25	167.57
Co	ug/g	38	100	44	120	80	59	190	220	660	820	860	900	4.5	127.24
Cu	ug/g	72	72	39	79	55	49	81	66	12900	5700	9000	12900	7.9	826.50
Fe	ug/g	10600	25800	20700	36600	32500	42400	27800	39100	77500	104000	113000	113000	6500	25952.46
Pb	ug/g	230	670	480	1100	440	670	280	820	20400	26800	23900	26800	47	2896.77
Mg	ug/g	1500	3800	3400	3900	4200	5300	4300	6600	11300	15500	12500	15500	1500	5988.52
Mn	ug/g	85	220	130	250	190	250	260	280	490	610	570	610	44	213.66
Mo	ug/g	39	200	136	301	276	368	175	308	997	1220	761	1220	19	279.57
Ni	ug/g	2270	5700	2660	6700	4520	6700	3750	9700	2180	3420	2400	11200	94	2590.36
P	ug/g	140	400	250	370	350	380	360	360	1400	1200	1300	1400	100	374.92
K	ug/g	6700	19500	20600	22200	23100	28500	25400	22800	17100	15400	14100	38000	3800	19577.05
Se	ug/g	1.9	7.2	4.5	12	4.5	8.3	3.7	7.5	57	87	77	87	0.3	14.67
Ag	ug/g	1	2.1	1.1	2.6	1.3	2.2	1.2	3.6	9.9	10	9.7	10	0.2	2.47
Na	ug/g	150	310	360	300	1300	570	970	530	1000	820	520	1300	100	314.92
Sr	ug/g	95	260	250	280	370	540	350	270	420	440	550	560	84	261.30
Tl	ug/g	0.2	0.6	0.4	0.6	1.2	1.8	1	2.6	3.7	3.5	3.8	3.8	0.2	1.01
Sn	ug/g	0.6	1.7	1.9	3.3	3.6	3.7	1.9	3.1	9.3	7	6.5	9.3	0.3	2.49
Ti	ug/g	130	180	170	190	180	230	200	220	1060	1070	1160	1160	110	281.23
U	ug/g	63	205	128	468	272	384	121	548	1720	1710	2020	2060	42	405.42
V	ug/g	210	660	480	650	690	940	630	1400	980	1100	1200	1700	210	767.21
Zn	ug/g	13	36	18	26	20	17	29	65	200	150	130	210	9.2	38.59
Inorganic carbon	%												0.77	0.01	0.050
Organic carbon	%												0.37	0.01	0.09
F2 (C10-C16)	ug/g												1600	4	155.33
F3 (C16-C34)	ug/g												21	5	6.64
F4 (C34-C50)	ug/g												9	5	5.18

Pore Water by Weighted Average 3m Interval 2018																							Count	Min	Max	Average	Weighted Average	Standard Deviation
Interval	365-370	370-373	373-376	376-379	379-382	382-385	385-388	388-391	391-394	394-397	397-400	400-403	403-406	406-409	409-412	412-415	415-418	418-421	421-424	424-427	427+							
Number of Observations	2	3	4	3	5	5	5	6	6	4	7	7	7	7	8	8	8	8	8	8	2							
Average Sample Elevation	366.37	370.99	373.82	377.30	380.10	383.26	386.63	389.10	392.33	395.04	398.36	401.21	404.10	407.11	410.27	413.22	416.17	419.30	422.55	425.25	428.10							
Analyte	Units	Pore Water																										
pH (field)	pH units	7.32	7.96	7.81	7.37	7.52	7.42	7.68	7.43	7.52	7.06	7.34	7.60	7.31	7.40	7.50	7.31	7.16	7.25	7.82	7.64	8.00	121	7.06	8.00	7.47	7.47	0.25
Temp (field)	°C	16.70	17.40	18.13	15.67	18.90	19.30	17.32	18.10	18.32	16.40	19.66	18.49	17.96	19.10	18.19	18.55	18.84	18.38	19.39	18.78	17.95	121	15.66667	19.66	18.18	18.40	1.01
Eh (field)	mV	205.75	195.47	236.78	169.10	212.22	147.40	174.42	151.32	174.80	134.58	193.34	273.51	214.44	327.01	230.91	272.91	239.68	237.84	286.94	310.63	350.00	121	134.575	350.00	219.45	231.46	60.31
Spec. Cond. (field)	µS/cm	3240.00	3650.00	3527.50	3303.33	3270.00	3080.00	3032.00	3473.33	3526.67	3492.50	3535.71	3115.71	3240.00	3145.71	3192.50	3773.75	3923.75	3898.75	4097.50	4660.00	4505.00	121	3032	4660.00	3508.94	3578.26	451.41
D.O. (Field)	mg/L	5.18	5.69	4.80	5.32	5.31	5.73	6.05	5.88	5.27	4.95	6.02	5.62	5.55	5.57	5.20	5.62	5.32	5.88	5.88	5.12	5.34	119	4.8025	6.05	5.50	5.53	0.35
pH (lab)	pH units	7.76	7.83	7.99	7.94	7.82	7.78	7.88	7.90	7.95	7.90	7.62	7.76	7.59	7.65	7.73	7.68	7.63	7.50	7.72	7.66	7.92	120	7.5025	7.99	7.76	7.74	0.14
Spec. Cond. (lab)	µS/cm	3385.00	3715.00	3570.00	2750.00	3170.00	2916.00	3224.00	3453.33	2836.67	3322.50	2962.86	2725.71	2602.86	2830.00	2418.75	3478.75	3621.25	3881.25	4013.75	4485.00	1990.00	120	1990	4485.00	3268.13	3264.83	583.65
Ca 2+	mg/L	517.50	534.00	495.75	330.67	451.00	434.60	571.60	518.17	496.50	555.00	503.71	443.57	437.00	430.14	412.88	432.50	412.63	443.13	419.00	455.00	227.50	120	227.5	571.60	464.72	454.24	76.70
Mg 2+	mg/L	169.00	223.00	203.00	141.00	149.00	141.60	120.20	134.67	115.17	145.50	128.86	122.29	103.86	79.43	69.13	144.13	126.00	191.75	281.63	319.13	113.50	120	69.125	319.13	155.42	154.54	61.34
Na +	mg/L	110.50	129.50	154.75	101.33	103.20	91.60	117.60	201.50	125.50	117.25	111.43	83.71	115.00	124.57	175.50	291.75	273.50	281.88	217.75	325.75	89.50	120	83.71429	325.75	162.68	175.84	75.45
K +	mg/L	23.00	36.00	30.25	50.33	39.60	54.60	42.40	43.83	35.67	38.25	42.57	29.71	27.43	47.29	29.50	46.00	48.00	44.13	40.63	42.00	12.05	120	12.05	54.60	39.56	39.62	10.09
HCO3 -	mg/L	138.50	280.00	323.25	284.00	307.60	346.00	347.80	262.83	366.33	357.00	308.00	121.86	115.86	92.14	91.50	148.63	125.38	96.25	92.50	83.13	40.00	120	40	366.33	214.43	191.04	114.17
CO3 2-	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	120	1	1	1	1	0
Cl -	mg/L	71.00	100.00	57.25	81.00	63.00	61.20	50.60	67.17	48.83	50.75	54.29	37.14	38.29	47.29	26.63	71.50	59.13	79.75	71.00	103.25	45.50	120	26.63	103.25	61.95	60.39	19.40
OH -	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	120	1	1	1	1	0
SO4 2-	mg/L	2050.00	2185.00	2122.50	1393.33	1682.00	1564.00	1694.00	2073.33	1693.33	1940.00	1825.71	1665.71	1647.14	1585.71	1585.00	2111.25	2001.25	2373.75	2522.50	2957.50	1125.00	120	1125.00	2957.50	1933.65	1951.36	411.99
Total Hardness	mg/L	1985.00	2250.00	2070.00	1403.33	1738.00	1666.00	1770.00	1845.00	1711.33	1982.50	1786.14	1608.00	1516.86	1396.86	1313.88	1670.00	1546.25	1893.75	2202.50	2451.25	1031.50	120	1031.50	2451.25	1790.33	1761.88	337.02
Sum of Ions	mg/L	3090.00	3500.00	3407.50	2403.33	2810.00	2706.00	2898.00	3313.33	2898.33	3220.00	3011.43	2521.43	2497.14	2422.86	2403.75	3255.00	3055.00	3517.50	3655.00	4335.00	1659.50	120	1659.50	4335.00	3046.03	3041.31	573.42
Total Alkalinity	mg/L	113.50	229.50	265.00	232.67	252.20	283.80	285.00	215.67	300.50	292.75	252.57	100.00	95.00	75.57	75.13	121.75	102.75	78.88	75.75	68.00	33.00	120	33.00	300.50	175.80	156.63	93.61
P.Alkalinity	mg/L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	120	1	1	1	1	0
NO3 -	mg/L	0.04	0.04	0.04	0.04	0.062	0.04	0.04	0.04	0.1	0.73	0.04	0.04	0.061429	0.04	0.1475	0.04	0.04	0.04	0.04	0.04	0.04	119	0.04	0.73	0.09	0.08	0.15
NH3	mg/L	10.85	12.00	17.13	15.67	11.04	9.36	9.88	10.85	15.13	11.85	29.80	12.59	10.93	13.06	10.49	7.88	7.34	6.61	8.44	8.16	5.50	119	5.50	29.80	11.95	11.53	5.10
DOC	mg/L	5.45	6.70	7.60	8.40	5.58	5.68	6.46	7.30	8.10	6.18	6.06	3.50	4.03	3.67	3.40	4.15	4.28	5.79	8.79	13.81	5.40	119	3.40	13.81	6.25	6.16	2.37
COD	mg/L	20.50	24.50	26.25	27.33	18.80	22.80	22.60	23.50	25.33	21.50	24.57	13.57	18.29	19.29	15.63	17.38	19.13	27.71	36.13	55.50	34.50	119	13.57	55.50	24.01	24.56	9.02
Al	mg/L	0.0135	0.0290	0.0228	0.0293	0.0268	0.0246	0.0220	0.0265	0.0223	0.0138	0.0213	0.0133	0.0150	0.0160	0.0135	0.0098	0.0111	0.0193	0.0219	0.0447	0.0355	121	0.0098	0.0447	0.0208	0.02	0.0087
Sb	mg/L	0.0042	0.0020	0.0019	0.0023	0.0019	0.0026	0.0024	0.0026	0.0021	0.0020	0.0020	0.0027	0.0031	0.0027	0.0028	0.0069	0.0066	0.0071	0.0059	0.0066	0.0077	121	0.0019	0.0077	0.0035	0.0039	0.0021
As	µg/L	1540.00	5306.67	4845.00	7673.33	10114.00	16498.00	11028.00	8903.33	9016.67	6152.50	12694.29	1559.71	2452.57	870.29	952.63	2972.25	1528.75	1410.25	413.25	920.75	404.00	121	404.00	16498.00	5342.61	4720.32	4718.04
Ba	mg/L	0.0190	0.0300	0.0275	0.0330	0.0274	0.0316	0.0358	0.0277	0.0245	0.0193	0.021																



Orano Canada Inc.

McClean Lake Operation

Definition of Source Terms for Use in
Groundwater Flow and Contaminant
Transport Modelling

December 2025

Orano Canada Inc.

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1 Introduction

The geochemistry of the tailings in the JEB TMF is complex, and the deposited tailings evolve over time towards a stable long-term equilibrium. Despite this inherent complexity, the average pore water concentrations of environmentally important COPCs need to be estimated in order to iteratively update downstream modelling and long-term performance predictions. The TMF groundwater and contaminant transport model (Section 7) is updated every 5 years in conjunction with the Tailings TID, using source terms defined by the most recent TOVP sampling campaign (Section 5.2). The detailed calculation of the pore water source terms is described in this appendix.

The source terms of 18 COPCs are tracked. The selected COPCs are either known to be important geochemical markers, or have detrimental environmental effects if released in sufficient concentrations. To focus investigations and better categorize risk to the downstream environment, the COPCs are assigned to one of the following categories based on observations and current understanding:

- **Group 1: Insignificant COPCS (divided into two sub-categories):**
 - **Group 1a:** The COPCs in this category are predicted to have no environmental impacts, and are tracked for completeness and ongoing validation that pore water concentrations remain controlled over time. The COPCS in this category currently include: Chloride, Sulphate, Ammonium, Cadmium, Chromium, Cobalt, Iron, Vanadium, Zinc, Polonium-210, Radium-226, and Thorium-230. COPCs in this group must satisfy two criteria:
 - No significant trends are observed in pore water over time. Concentrations of these COPCs do not noticeably evolve over time, and are predicted to remain stable at current values.
 - Pore water concentrations are below the threshold of concern to the downstream environment.
 - **Group 1b:** The COPCs in this category are still considered insignificant (i.e. current modelling predicts that they remain below the threshold of environmental risk); however, changes in the pore water data are noted that require further understanding. COPCs in this category are elevated from Group 1a until they are further understood and the potential for evolution is determined. At this point, COPCs may be returned to Group 1a if considered low risk, or elevated further to Group 2 if further study is warranted. The COPCs in this category currently include: Copper, Lead, Nickel and Selenium.

- **Group 2: COPCs of Key Interest** are tracked closely, and are subject to operational controls. Targeted research programs have been initiated and are ongoing for the validation and refinement of these COPCs. COPCs in Group 2 are included under the following criteria:
 - Significant trends in pore water values are noted. Concentrations are known to evolve over time, and there is a need to identify final pore water concentrations which will persist at equilibrium over the long-term.
 - For areas with pore water concentrations out of equilibrium, there is a potential risk of approaching the threshold for downstream effects if COPCs are not adequately controlled.
 - Tailings preparation processes are in place to optimize the pore water value of these COPCs and validation of results is required.

2 Methodology

An important change in methodology occurred for the analysis of the 2023 TOVP data. In advancing the understanding the tailings pore water data over more than 20 years a variability in the tailings data has been identified as a key component to identify important areas of geochemical reactivity. Particularly with the inclusion of the Cigar Lake tailings data it is more there will be more variation in the tailings data set. To remain conservative in tailings pore water determinations, when processing the 2023 pore water data, although statistical analysis of the data was conducted, outliers were retained in the data set for the purposes of source term determination. This approach adds an additional level of conservatism to the source terms and ensures that no important data is excluded incorrectly as an outlier.

Data evaluation of the tailings pore water data is divided into two main steps:

- 1) **Statistical Evaluation:** A statistical evaluation of all pore water data is conducted to remove outliers. A small number of outliers are identified and originally were attributed to minor upsets in the mill process which have produced small areas of abnormal tailings or errors in the sampling or analytical process. In 2023 these values were included.
- 2) **Pore Water Weighted Average Calculation:** A weighted average pore water calculation is completed,
- 3) **Base Case Selection:**
 - **Group 1 COPCs:** The calculated weighted average pore water concentration is carried forward to groundwater and contaminant transport model calculations.

- **Group 2 COPCs:** Geochemical modelling and research results are considered in conjunction with the calculated weighted average pore water concentrations to select a conservative base case to be used in groundwater and contaminant transport model calculations.

4) **Bounding Case Selection:**

- **Group 1 COPCs:** The 95th percentile value of the dataset is used as the upper bound pore water case to be used in the groundwater and contaminant transport model.
- **Group 2 COPCs:** Geochemical modelling and research results are considered in conjunction with the 95th percentile value of the data set (outliers removed) to select a conservative upper bound pore water case to be used in groundwater and contaminant transport model calculations.

2.1 Statistical Evaluation

Presented here is the full procedure for the statistical evaluation, in cases where there are no outliers and cases where outliers are identified and removed. The following examples are used to illustrate the procedure:

- 1) No Outliers: Sulphate is presented as an example of a COPC where no outliers are identified.
- 2) Identification and Removal of Outliers: Chloride is presented as an example of when outliers are identified and removed.

Statistical evaluation is not conducted on data sets for COPCs where more than 85% of the values are at or below detection. In these cases, only the 95th percentile of the data is identified and all data is moved forward to be included in the weighted average.

2.1.1 Identification of Outliers

Outliers were identified using the interquartile range (IQR) of each data set. The IQR identifies how the data is spread about the median value. The data for each COPC is formatted as a list of values from least to highest concentration by ore type (JEB/Sue and Cigar Lake).

Step 1:

The IQR is calculated by the following equation:

$$\text{IQR} = \text{Q3} - \text{Q1}$$

Where (considering the data from the lowest to the highest value):

Q1 = $\frac{1}{4}$ point in the data set, and

Q3 = $\frac{3}{4}$ point in the data set.

Step 2:

Outliers which are lower than the calculated “lower outer fence value” are identified as:

Lower outliers < Lower Outer Fence Value ($Q1 - (3 \cdot IQR)$)

Outliers which are higher than the calculated “upper outer fence value” are identified as:

Upper outliers > Upper Outer Fence Value ($Q3 + (3 \cdot IQR)$)

Step 3:

Identified outliers are excluded from the data set.

2.1.2 Example with No Outliers: Sulphate

Histograms for sulphate in the JEB/Sue and Cigar Lake samples are shown in Figure 2.1-1. There were 141 total samples, 56 from Cigar Lake and 85 from JEB/Sue. Statistical summaries for each data set are shown in Table 2.1-2.

Figure 2.1-1: Sulphide histogram of Cigar Lake and JEB/Sue datasets.

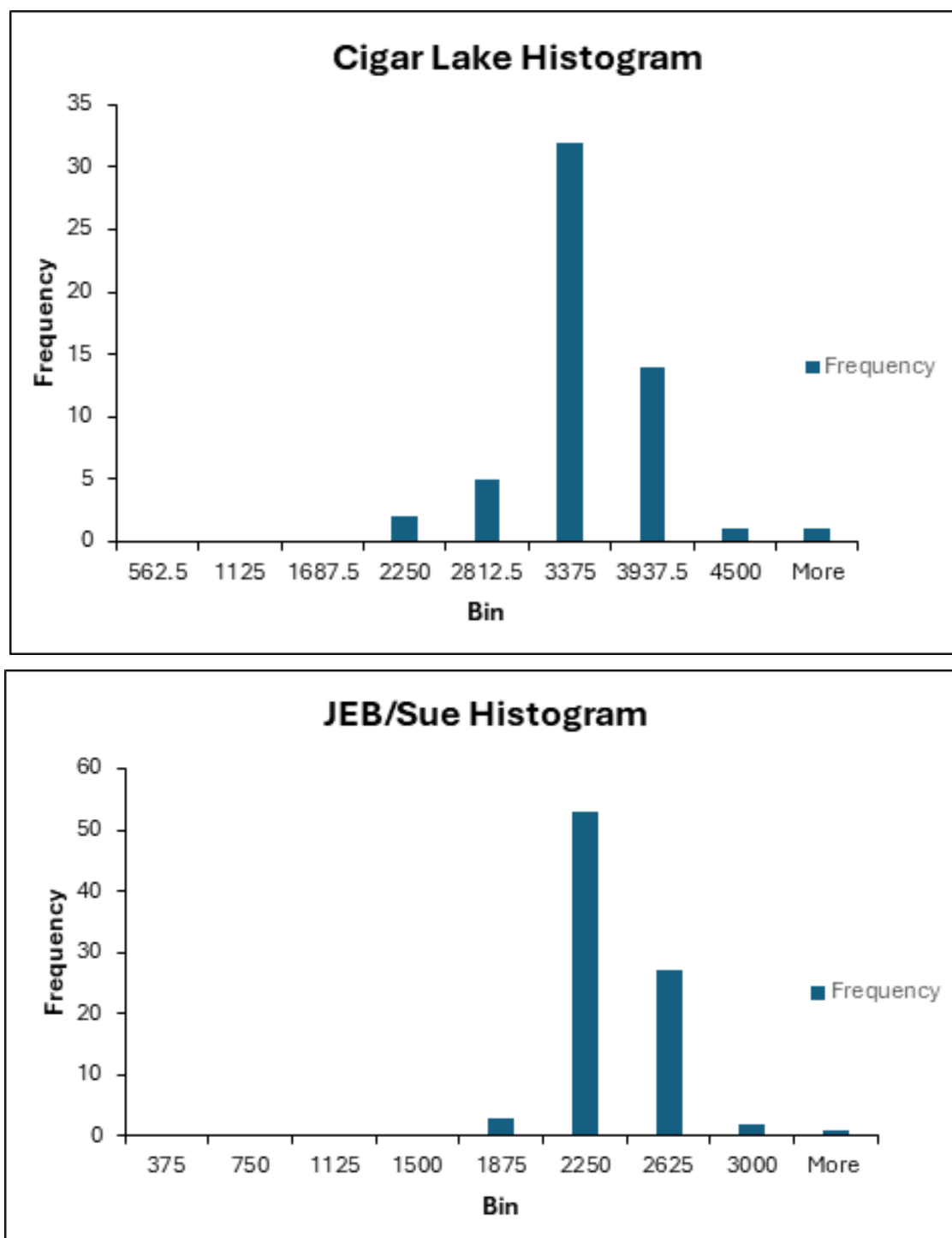


Table 2.1-1: Statistical summary of Sulphate data sets.

Sulphate		
	Cigar Lake	JEB/Sue
Mean	3210.18	2184.53
Standard Error	61.04	25.01
Median	3200	2130
Mode	3300	1960
Standard Deviation	452.68	231.96
Sample Variance	204920.34	53806.25
Kurtosis	2.79	1.61
Skewness	0.50	1.12
Range	2740	1190
Minimum	2060	1830
Maximum	4800	3020
Sum	176560	187870
Count	55	86
95th Percentile	3980	2576
Q1	3000	2020
Q3	3500	2315
IQR	500	295
3*IQR	1500	885
Outer Fence Low	1500	1135
Outer Fence High	5000	3200

Table 2.1-2: Data set of sulphate concentrations (mg/L) considered for weighted average evaluation

CigarLake	2060	2160	2430	2600	2600	2700	2800	2900	2910	2920	2960	2980
	3000	3000	3000	3000	3010	3040	3050	3060	3070	3100	3100	3100
	3100	3110	3200	3200	3200	3200	3200	3200	3300	3300	3300	3300
	3300	3300	3300	3400	3500	3500	3500	3500	3600	3600	3600	3600
	3600	3700	3700	3700	3900	4300	4800					
JEB/Sue	1830	1850	1870	1880	1900	1900	1920	1930	1950	1950	1960	1960
	1960	1960	1970	1980	1980	1980	1990	2000	2020	2020	2020	2030
	2030	2040	2040	2050	2060	2060	2070	2070	2080	2080	2090	2100
	2100	2100	2110	2110	2120	2130	2130	2130	2140	2140	2150	2160
	2160	2170	2180	2180	2180	2210	2230	2240	2260	2260	2260	2270
	2280	2290	2300	2310	2310	2330	2340	2340	2340	2350	2380	2400
	2420	2440	2480	2480	2500	2500	2510	2530	2540	2550	2590	2740
	2900	3020										

2.1.3 Example with Identification and Removal of Outliers: Chloride

Histograms for chloride data in the Cigar Lake and JEB/Sue tailings are shown in Figures 2.1-2 (all data vs outliers removed) and Figure 2.1-3 (all data) respectively. There were 141 total samples, 55 from Cigar Lake and 86 from JEB/Sue in the data set. Four outliers were identified and removed from the Cigar Lake data, no outliers were removed from the JEB/Sue data. A statistical summary based on the complete data sets for the Cigar and JEB/Sue tailings are shown in Table 2.1-3.

Figure 2.1-2: Chloride histogram of Cigar Lake data sets A: All Data, B: Outliers Removed

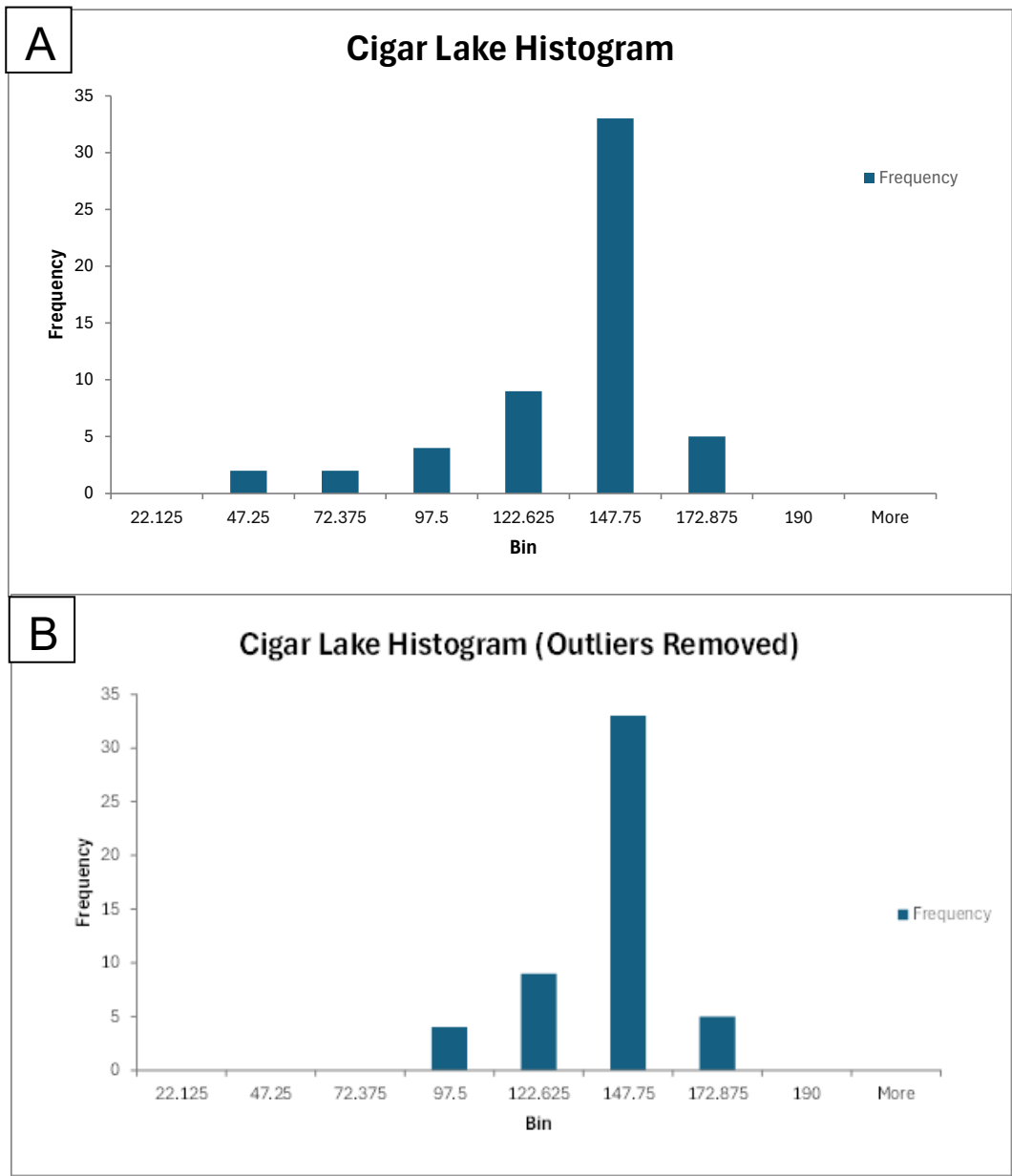


Figure 2.1-2: Chloride histogram of JEB/Sue data set

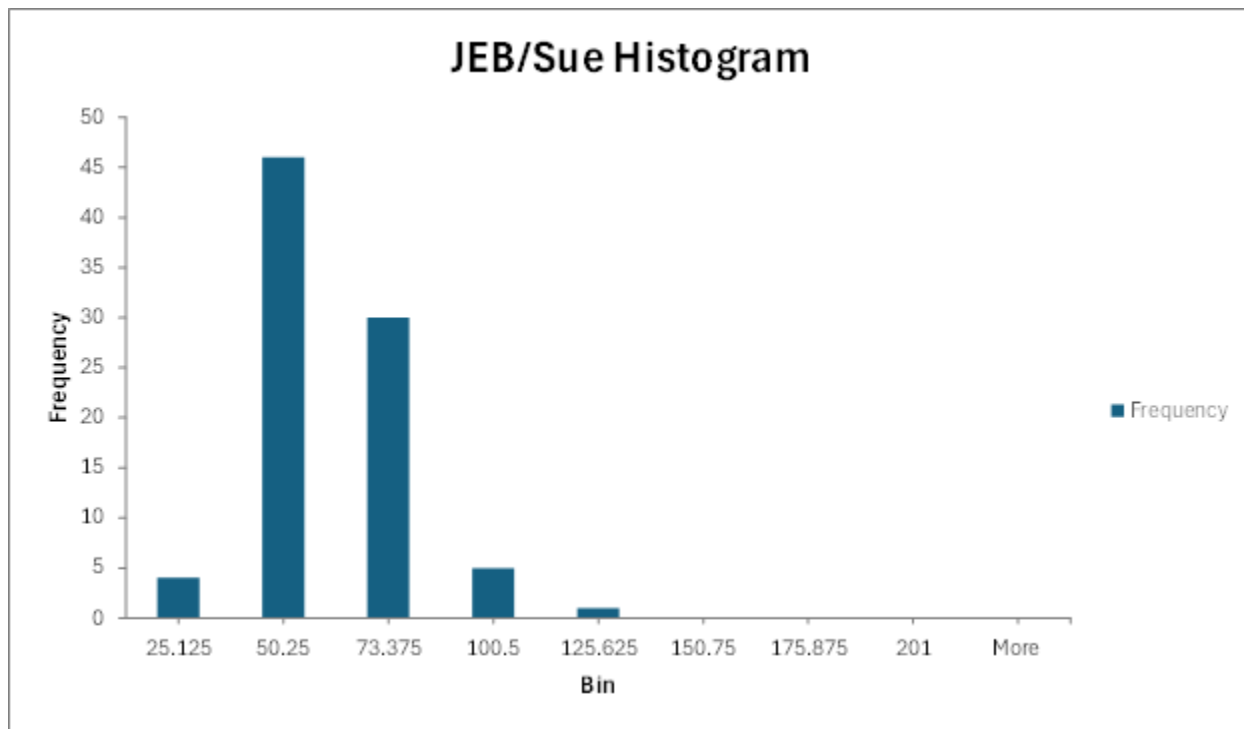


Table 2.1-2: Statistical summary of chloride data set.

Chloride		
	Cigar Lake	JEB/Sue
Mean	122.87	48.10
Standard Error	3.48	1.79
Median	129	48
Mode	120	63
Standard Deviation	25.84	16.62
Sample Variance	667.89	276.12
Kurtosis	3.16	1.46
Skewness	-1.71	0.97
Range	123	83
Minimum	41	21
Maximum	164	104
Sum	6758	4137
Count	55	86
95th Percentile	153.6	82.65
Q1	120	34
Q3	137	57
IQR	17	23
3*IQR	51	69
Outer Fence Low	69	-35
Outer Fence High	188	126

Table 2.1-4: Data set of chloride concentrations (mg/L) considered for weighted average evaluation with four outliers identified

Cigar Lake	41	47	48	61	84	91	92	97	110	113	113	115
	119	120	120	120	121	123	123	124	124	125	125	127
	127	128	128	129	129	130	130	132	132	133	133	134
	134	135	135	136	136	137	137	137	138	138	142	142
	143	145	148	151	152	160	164					
JEB/Sue	21	22	24	25	27	28	28	28	29	29	30	30
	30	31	32	32	32	33	33	34	34	34	34	36
	36	37	38	40	40	40	41	42	43	43	43	44
	44	45	46	46	47	48	48	48	48	49	49	50
	50	50	51	51	51	52	52	53	53	54	54	54
	54	55	56	56	57	57	57	58	58	59	59	60
	62	63	63	63	63	64	69	72	78	82	83	90
	99	104										

Pore Water Weighted Average Calculation

To calculate the average solute concentration, each sample was weighted by the volume of tailings it represented. This allows for the tailings samples collected to most accurately represent the entire tailings volume.

The weighted mean was calculated as follows:

$$\bar{x} = \frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i}$$

(1)

Where x1, x2,...,xn are the concentrations of constituents in each sample. w1, w2,...,wn are the associated weights.

All available sample results for chloride from the 2023 boreholes are presented in the table 2.1-5 below, along with their corresponding depth intervals. The samples representing Cigar Lake are highlighted in a separate table 2.1-6.

Table 2.1-5: All Chloride Data

Borehole	Sample Number	Sample Elevation (mASL)	Depth Interval	Chloride (mg/L)
TMF23-01	SA01	432.49	430-433	134
	SA02	429.49	427-430	148
	SA03	427.18	427-430	138
	SA04	426.49	424-427	135
	SA05	423.49	421-424	
	SA06	420.47	418-421	43
	SA07B	417.5	415-418	40
	SA08	414.68	412-415	36
	SA09A	411.68	409-412	104
	SA09B	411.05	409-412	
	SA10	408.43	406-409	90
	SA11	405.56	403-406	63
	SA12	402.48	400-403	52
	SA13	399.46	397-400	83
	SA14A	398.85	397-400	52
	SA14B	398.24	397-400	57
	SA15	395.47	394-397	
	SA16	391.87	391-394	82
	SA17	388.77	388-391	
	SA18	386.66	385-388	
	SA19	383.59	382-385	

Borehole	Sample Number	Sample Elevation (mASL)	Depth Interval	Chloride (mg/L)
TMF23-02	SA01	432.44	430-433	127
	SA02	429.98	427-430	130
	SA03	427.58	427-430	137
	SA04	424.58	424-427	120
	SA05	421.58	421-424	91
	SA06	418.58	418-421	28
	SA07	415.61	415-418	31
	SA08	412.28	412-415	44
	SA09	409.42	409-412	59
	SA10	406.45	406-409	59
	SA11	403.8	403-406	63
	SA12	400.58	400-403	57
	SA13	397.71	397-400	46
	SA14	394.3	394-397	40
	SA15	392.14	391-394	50
	SA16	389.4	388-391	56
	SA17	386.71	385-388	60
	SA18	381.79	379-382	54
	SA19A	379.7	379-382	
	SA19B	379.1	379-382	

Borehole	Sample Number	Sample Elevation (mASL)	Depth Interval	Chloride (mg/L)
TMF23-03	SA01	435.68	433+	129
	SA02	433.58	433+	129
	SA03	430.58	430-433	124
	SA03B	431.5	430-433	
	SA04	427.58	427-430	135
	SA05	424.58	424-427	125
	SA06	421.58	421-424	134
	SA07	419.38	418-421	54
	SA08	416.89	415-418	45
	SA09	414.37	412-415	40
	SA10	412.57	412-415	30
	SA11	411.37	409-412	48
	SA12	409.77	409-412	34
	SA13	406.78	406-409	38
	SA14	403.81	403-406	72
	SA15	401.37	400-403	69
	SA16	398.37	397-400	63
	SA17	392.2	391-394	50
	SA18	388.46	388-391	62
	SA19	386.08	385-388	58
	SA20	382.67	382-385	53
	SA21	381.17	379-382	55

Borehole	Sample Number	Sample Elevation (mASL)	Depth Interval	Chloride (mg/L)
TMF23-04	SA01	431.7	430-433	125
	SA02	432.7	430-433	124
	SA03	429.7	427-430	110
	SA04	426.7	424-427	43
	SA05	424.69	424-427	54
	SA06	421.57	421-424	51
	SA07	418.7	418-421	49
	SA08	415.7	415-418	48
	SA09	412.55	412-415	43
	SA10	409.5	409-412	53
	SA11	406.5	406-409	56
	SA12	403.81	403-406	37
	SA13	400.71	400-403	34
	SA14	397.69	397-400	28
	SA15	393.4	391-394	63
	SA16	390.3	388-391	51
	SA17	387.02	385-388	58
	SA18	383.92	382-385	49
	SA19	380.52	379-382	50
	SA20	377.8	376-379	42
	SA21	373.61	373-376	99

Borehole	Sample Number	Sample Elevation (mASL)	Depth Interval	Chloride (mg/L)
TMF23-05	SA01	434.99	433+	137
	SA02	433.1	433+	132
	SA03	430.71	430-433	121
	SA04	427.71	427-430	132
	SA05	424.71	424-427	128
	SA06	421.71	421-424	143
	SA07	418.71	418-421	84
	SA08	415.69	415-418	29
	SA09	412.69	412-415	29
	SA10	409.69	409-412	32
	SA11	406.701	406-409	27
	SA12	403.701	403-406	24
	SA13	400.681	400-403	21
	SA14	397.701	397-400	64
	SA15	394.681	394-397	78
	SA16	391.711	391-394	54
	SA17	388.711	388-391	48

Borehole	Sample Number	Sample Elevation (mASL)	Depth Interval	Chloride (mg/L)
TMF23-07	SA01	434.11	433+	138
	SA02	433.2	433+	136
	SA03	430.81	430-433	120
	SA04	427.7	427-430	115
	SA05	424.81	424-427	97
	SA06	421.81	421-424	
	SA07	418.79	418-421	33
	SA08	415.82	415-418	57
	SA09	412.79	412-415	36
	SA10	409.8	409-412	33
	SA11	406.8	406-409	34
	SA12	403.8	403-406	32
	SA13	400.81	400-403	25

Borehole	Sample Number	Sample Elevation (mASL)	Depth Interval	Chloride (mg/L)
TMF23-06	SA01	431.38	430-433	113
	SA02	428.71	427-430	130
	SA03	425.71	424-427	133
	SA04	422.71	421-424	145
	SA05	419.71	418-421	92
	SA06	416.71	415-418	
	SA07	413.68	412-415	28
	SA08	410.69	409-412	30
	SA09	407.69	406-409	32
	SA10	405	403-406	30
	SA11	401.69	400-403	22
	SA12	397.48	397-400	46
	SA13	395.7	394-397	41
	SA14A	392.7	391-394	47
	SA15	389.8	388-391	51
	SA16	386.71	385-388	44
	SA17	383.67	382-385	48

Table 2.1-6: All Cigar Lake Chloride Data

Borehole	Sample Number	Sample Elevation (mASL)	Depth Interval	Chloride (mg/L)
TMF23-01	SA01	434.16	433+	134
	SA02	432.49	430-433	148
	SA03	429.49	427-430	138
	SA04	426.49	424-427	135
	SA05	423.49	421-424	
TMF23-02	SA01	432.44	430-433	127
	SA02	429.98	427-430	130
	SA03	427.58	427-430	137
	SA04	424.58	424-427	120
	SA05	421.58	421-424	91
TMF23-03	SA01	435.675	433+	129
	SA02	432.97	433-436	129
	SA03	430.58	430-433	124
	SA04	427.58	427-430	135
	SA05	424.58	424-427	125
	SA06	421.58	421-424	134
TMF23-04	SA01	431.7	430-433	125
	SA02A	432.7	430-433	124
	SA03	429.7	427-430	110
TMF23-05	SA01	434.99	433+	137
	SA02	433.1	433+	132
	SA03	430.71	430-433	121
	SA04	427.71	427-430	132
	SA05	424.71	424-427	128
	SA06	421.71	421-424	143
	SA07	418.71	418-421	84
TMF23-06	SA01	431.38	430-433	113
	SA02	428.71	427-430	130
	SA03	425.71	424-427	133
	SA04	422.71	421-424	145
	SA05	419.71	418-421	92
	SA06	416.71	415-418	

Borehole	Sample Number	Sample Elevation (mASL)	Depth Interval	Chloride (mg/L)
TMF23-06	SA01	431.38	430-433	113
	SA02	428.71	427-430	130
	SA03	425.71	424-427	133
	SA04	422.71	421-424	145
	SA05	419.71	418-421	92
	SA06	416.71	415-418	
TMF23-07	SA01	434.112	433+	138
	SA02	433.2	433+	136
	SA03	430.81	430-433	120
	SA04	427.2	427-430	115
	SA05	424.81	424-427	97
	SA06	421.81	421-424	

Weighting Factors: Calculated using a GIS mesh of the TMF Pit and the tailings surface survey taken closest to the sample collection date (September 2023) the TMF is divided into seven areas to represent the area considered to be represented by each borehole. The TMF is then divided vertically into three meter intervals Table 2.1-7.

Table 2.1-7: Weighting Factors for 2025

Borehole / depth interval	433-436	430-433	427-430	424-427	421-424	418-421	415-418	412-415
TMF23-01	6837.69	6837.69	6837.69	6837.69	6837.69	6837.69	6837.69	6837.69
TMF23-02	17121.35	19491.74	19491.74	19491.74	19491.74	19491.74	19491.74	19491.74
TMF23-03	8281.43	9603.21	9603.21	9603.21	9603.21	9603.21	9603.21	9603.21
TMF23-04	11240.49	12552.87	12552.87	12552.87	12552.87	12552.87	12552.87	12552.87
TMF23-05	30650.29	57324.31	57192.32	55463.03	53184.51	49327.15	47107.67	44020.87
TMF23-06	47215.41	50440.16	47105.97	45437.47	42958.27	39904.13	38300.20	36940.93
TMF23-07	30766.18	47318.83	43033.57	38796.97	34323.91	28382.65	24125.06	21504.57
Borehole / depth interval	409-412	406-409	403-406	400-403	397-400	394-397	391-394	388-391
TMF23-01	6837.69	6837.69	6837.69	6837.69	6837.69	6837.69	6837.69	6837.69
TMF23-02	19491.74	19491.74	19491.74	19491.74	19491.74	19491.74	19491.74	19485.23
TMF23-03	9603.21	9603.21	9603.21	9603.21	9603.21	9603.21	9603.21	9603.21
TMF23-04	12552.87	12552.87	12552.87	12552.87	12552.87	12552.87	12552.87	12552.87
TMF23-05	39845.16	34393.68	30216.86	26173.35	20851.43	15682.82	11755.79	9113.90
TMF23-06	35429.86	33723.33	32335.21	31078.12	29533.76	26560.12	24845.68	21051.77
TMF23-07	20255.21	18516.81	17146.17	15993.75	14561.05	11722.93	10231.10	9051.03
Borehole / depth interval	385-388	382-385	379-382	376-379	373-376	370-373	365-370	
TMF23-01	6837.69	6837.69	6837.69	6837.69	6837.69	6837.69	9410.86	
TMF23-02	19007.30	18450.58	18019.44	17477.18	16836.29	14823.60	11304.98	
TMF23-03	9603.21	9603.21	9603.21	9594.97	9297.54	8739.38	5373.49	
TMF23-04	12552.87	12552.86	12546.18	12518.99	12355.13	9221.26	647.77	
TMF23-05	6312.75	4847.40	4157.18	3538.33	2902.59	2221.73	106.43	
TMF23-06	14171.23	9746.32	7013.67	3808.45	1240.62	545.65	192.80	
TMF23-07	7588.77	6362.88	5366.59	4379.44	2995.51	1098.40	49.00	

Example Calculations by Interval:

Example: 421-424 mASL

= **TMF23-01** (Average Interval Value COPC * Weighted Factor)+ **TMF23-02**(Average Interval Value COPC * Weighted Factor)+**TMF23-03**(Average Interval Value COPC * Weighted Factor)+**TMF23-05**(Average Interval Value COPC * Weighted Factor)+**TMF23-06** (Average Interval Value COPC * Weighted Factor)

Sum averages over 3m intervals:

=(427+)+(424-427)+(421-424)+(418+421)+(415-418)

= Total TMF weighted average pore water value

3 Weighted Average Concentrations

Once weighted average concentrations are calculated, they become inputs to groundwater and contaminant transport modelling (Section 7). Base and upper bound cases are selected as discussed below.

3.1 Group 1 a and b

Base Case: Weighted average of pore water values.

Upper Bound Case: 95th percentile value of the data set.

COPCs falling under Group 1b which have been identified for further observation/study are marked with an asterisk. A discussion of the pore water concentrations of these identified COPCs and/or proposed additional work to define the source terms is included in Section 5.7 of the main document. At this time, the weighted average source terms are used to remain conservative in advance of any investigations being performed.

Table 3.3-1: Weighted Average Tailings Pore Water Values for Group 1 COPCs Used as Inputs for Contaminant Transport Modelling

		Current predicted concentration based on 2023 in-situ sampling			
		JEB/Sue		Cigar Lake	
Parameter	Units	Base Case	Bounding Case	Base Case	Bounding Case
Chloride	mg/L	43.86	82.70	118.12	145.15
Sulfate	mg/L	2205.84	2578.00	3292.61	4325.00
NH ₃ ⁺ + NH ₄ ⁺	mg/L	11.69	24.40	13.29	35.55
Cadmium	mg/L	0.00090	0.0022	0.00041	0.0011
Cobalt	mg/L	0.15	0.47	0.047	0.27
Copper*	mg/L	0.0019	0.0046	0.004	0.017
Lead*	mg/L	0.0021	0.0142	0.0009	0.007
Nickel*	mg/L	2.37	8.11	0.168	0.63
Selenium*	mg/L	0.0095	0.052	0.007	0.032
Vanadium	mg/L	0.021	0.18	0.0043	0.0077
Zinc	mg/L	0.026	0.7	0.008	0.032
Lead-210	Bq/L	2.20	4.00	2.29	6.25
Polonium-210	Bq/L	0.75	3.55	0.51	0.62
Radium-226	Bq/L	4.63	16.00	4.11	7.70
Thorium-230	Bq/L	1.11	1.55	1.00	1.10

3.2 Group 2

For Group 2 COPCs, geochemical models have been developed to understand the evolution of the source term in the tailings pore water as it evolves towards geochemical equilibrium. There are three Group 2 elements, and for each a geochemical model is presented in Section 5 of the main document: Arsenic (Section 5.5.1); Molybdenum (Section 5.5.2); Uranium (Section 5.5.3). Based on the results of several years of modelling and study for each element, a long-term tailings pore water source term is proposed which reflects the predicted final concentrations of each element as the tailings reach geochemical equilibrium. The predicted source term is then used to inform the selection of base case and upper bound input values for inclusion in modelling.

3.2.1 Arsenic

Overview

Arsenic has been considered in two main areas in the TMF. The areas reflect changes in arsenic understanding and treatment after processing Sue C ore (described in detail in Section 5.5.1.3 of the main document):

Above 391 mASL: A weighted average concentration was used as the base case modelling input value, as arsenic values are low and controlled. In this area, optimizations to the preparation of tailings in the Tailings Preparation Circuit (TPC) improved the performance of the tailings with respect to the pore water concentrations of several COPCs, arsenic being the most important. The case for using arsenic values above 391 mASL remains valid, and is outlined in the geochemical model for arsenic evolution which is detailed in Section 5.5.1 of the main document.

Below 391 mASL: In tailings below 391 mASL, the arsenic pore water concentrations were not adequately controlled by the addition of sufficient ferric sulphate. Geochemical conditions were not driven towards fully oxidized, geochemical equilibrium in the TPC; rather, the tailings continued to evolve once placed in the TMF. As the placed tailings below 391 mASL are still observed to be actively evolving with respect to the oxidation state of arsenic, the use of a weighted average arsenic concentration is not appropriate. The weighted average, calculated based on the data of each sampling campaign, represents an instantaneous snap shot value of arsenic values and is not indicative of expected long-term concentrations.

To quantify the long-term concentration, the arsenic aging process has been studied in detail using various methods and a long-term pore water source term of less than 2 mg/L has been validated:

- Aging tests have been conducted on both JEB/Sue (Appendix D, Section D Subsection E), and Cigar Lake (Orano 2020b, Section 5.3.3) mill produced tailings. In both cases, final pore water arsenic concentrations were found to be controlled below 2 mg/L.

- In placed tailings above 391 mASL, weighted average in-situ arsenic pore water concentrations have been controlled to approximately 2 mg/L over fifteen years (2008: 1.98 mg/L; 2013: 2.37 mg/L; 2018: 1.69 mg/L; 2023: 1.27 mg/L).
- Analysis of the aqueous As^{5+} species in the pore water sampled from all tailings depths is controlled on average, below 2 mg/L. As^{5+} is the soluble arsenic species which will control arsenic pore water concentrations once the tailings have reached equilibrium (Section 5.5.1).

The geochemistry which defines the evolution of the long-term predicted equilibrium pore water arsenic concentrations is well understood through ongoing investigations. Validation of arsenic source terms will continue under the TOVP to inform groundwater modelling inputs.

The following sections describe how the JEB/Sue and Cigar Lake arsenic source terms are calculated, using the above division in arsenic behaviour.

JEB/Sue Values Selection

Base Case: Based on the continued validation of the arsenic model, the weighted average pore water values for arsenic above 391 mASL are used as the base case input for groundwater and contaminant transport modelling (1.27 mg/L).

Upper Bound Case: The whole tailings weighted average pore water values will be used (2.98 mg/L).

Cigar Lake Values Selection

The Cigar Lake tailings have been produced using the optimized TPP and so variations in the pore water values are expected to be minimal. No large evolution in pore water arsenic concentrations are expected, as the oxidation of arsenic in the tailings has been fully accounted for in the mill process.

Base Case: As little variation is expected in arsenic pore water concentrations, the weighted average value of all Cigar Lake samples is used (0.76 mg/L).

Upper Bound Case: The 95th percentile of the Cigar Lake data set (1.78 mg/L) is used. The values represent the second sampling campaign that has captured Cigar Lake in-situ pore water data. Validation of this data will continue with additional sampling in 2028.

3.2.2 Molybdenum

Overview

A detailed geochemical model has been developed and validated to follow the evolution of molybdenum to a stable endpoint at geochemical equilibrium in the TMF (Section 5.5.2). In summary, once deposited in the TMF, molybdenum undergoes a rapid increase in concentration, followed by a more gradual decreasing trend as pore water values are controlled by the solubility of a stable long-term mineral phase (i.e. powellite).

Molybdenum aging tests were conducted to investigate the stability of molybdenum precipitates in tailings, and confirmed that molybdenum concentrations had a rapid initial increase to approximately 18-30 mg/L, followed by a more gradual decrease to less than 5 mg/L.

Tailings pore water samples collected from placed tailings within the JEB TMF further validate this aging trend (Section 5.5.2). Stable values (5-6 mg/L on average) have been consistently observed in the tailings for over ten years.

JEB/ Sue Values Selection

Base Case: Considering the aging test and in-situ data that suggests a final molybdenum pore water concentration of approximately 5-6 mg/L, a value of 8.0 mg/L was conservatively chosen as the base case represent the long-term molybdenum concentration in JEB TMF tailings pore water.

Upper Bound Case: The weighted average molybdenum concentration for all tailings (14.09 mg/L) is applied.

Cigar Lake Values Selection

Molybdenum pore water concentrations in the Cigar Lake tailings have begun, as expected, to evolve over time. However, molybdenum concentrations remain lower in the Cigar Lake tailings than in the JEB/Sue tailings.

Base Case: Based on the results of the aging tests, the weighted average pore water value of the Cigar Lake samples is used as the base case scenario (5.34 mg/L).

Upper Bound Case: The 95th percentile value of the data set is used as the upper bound case (13.68 mg/L).

Pore water molybdenum values in the Cigar Lake tailings will continued to be validated with further sampling in 2028.

3.2.3 Uranium

Overview

A detailed geochemical model has been developed for uranium evolution in the tailings towards geochemical equilibrium (main document Section 5.5.3). Similarly to arsenic, the behaviour of uranium is separated into two areas that correspond to the elevation above Sue C tailings placement.

Below 391 mASL: An increase in uranium pore water values is noted. Uranium is pulled into solution through the formation of uranyl-carbonate complexes which are formed with bicarbonate ions produced from the oxidation of hydrocarbons entrained in the tailing solids. Unlike arsenic and molybdenum, uranium is *indirectly* controlled in solution through the precipitation of a solid mineral phase, which uses the bicarbonate ion rather than the uranyl ion.

As more bicarbonate is precipitated as solid carbonate minerals, less is available to form soluble complexes with uranium. Therefore, a geochemical upper bound to the bicarbonate concentration, and thus the uranium concentration, is observed. The equilibrium pore water concentration of bicarbonate is estimated to be approximately 168 mg/L. Observations of uranium values in the lower tailings, where the oxidation of hydrocarbons is primarily complete, conservatively suggest that uranium will be controlled to approximately 8.5 mg/L. The tailings in this area are approaching their equilibrium value.

Above 391 mASL: The relationship between uranium and bicarbonate is not a dominant control on uranium evolution in the pore water. The change corresponds to the implementation of peroxide (H_2O_2) treatment, which was a mill process refinement driven by TOVP findings. The addition of H_2O_2 is intended to oxidize any residual entrained organic carbon, and eliminate the majority of the source of HCO_3 (organic carbon) in the placed tailings pore water. The elimination of HCO_3 effectively controls the uranium source term.

The following sections describe how the JEB/Sue and Cigar Lake arsenic source terms are calculated, using the above division in uranium behaviour.

JEB/Sue Values Selection

Base Case: In 2023, the average weighted pore water value of the JEB/Sue tailings was 9.37 mg/L. As the actual weighted average value is close to the estimate long-term equilibrium pore water uranium value (8.5 mg/L), the observed value was conservatively chosen to carry forward into the groundwater and contaminant transport modelling.

Upper Bound Case: In previous TOVPs, the actual weighted average pore water value would have been presented as the upper bound case. As this value was used as the base case in this submission, the 95th

percentile value of the uranium data set was used, and therefore represents an extremely conservative upper bound case (53.36 mg/L).

Cigar Lake Values Selection

As in the case of arsenic, all Cigar Lake tailings have been produced with the incorporation of optimizations to the TPP based on past experience. The optimizations have eliminated the primary mechanism for uranium increase in the pore water.

Base Case: As process changes have been shown in the JEB/Sue tailings (above 391 mASL) to effectively eliminate the increases in uranium pore water source term with aging, the weighted average pore water values of uranium are used as the base case input (3.08 mg/L).

Upper Bound Case: The 95th percentile of the Cigar Lake data set is selected (7.59 mg/L).

Table 3.2-1: Pore Water Values of Group 2 COPCs Used as Inputs for Contaminant Transport Modelling

		Current predicted concentration based on 2023 in-situ sampling			
		JEB/Sue		Cigar Lake	
Parameter	Units	Base Case	Bounding Case	Base Case	Bounding Case
Arsenic	mg/L	1.27	2.98	0.76	1.78
Molybdenum	mg/L	8.00	14.09	5.34	13.68
Uranium	mg/L	9.37	53.36	3.08	7.59

4 Conclusions

Based on TOVP findings and past experience, optimizations have been made to the tailings preparation process (TPP) to improve controls on arsenic and uranium. The optimizations have now been established, through several tailings sampling campaigns, as being effective in mitigating the factors which contributed to increased pore water concentrations of arsenic and uranium. Additionally, the evolution of molybdenum has continued to evolve according to the predicted trend. For all three Group 2 COPCs, the continued validation of geochemical models has removed uncertainties in the pore water source terms presented for the JEB/Sue tailings.

For the Cigar Lake tailings, preliminary source terms are based on a well-established understanding of the JEB/Sue tailings. Twenty years of process improvements have been applied to the TPP, in order to ensure that pore water source terms of the Cigar Lake tailings will remain low and controlled.

The source terms will continue to be reviewed and refined every five years under the TOVP.



Contract CMS-528.015:

Arsenic K-edge X-ray Absorption Spectroscopy and Powder X-ray Diffraction Analyses of Tailings Samples from ORANO Canada

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1.0 EXECUTIVE SUMMARY

Synchrotron-based mineralogical assessments have been performed on a total of sixty-eight (68) samples supplied by Orano Canada.

All 68 samples were examined using powder X-ray diffraction (PXRD), with relative crystalline phase composition estimated using the reference-intensity ratio (RIR) method and total phase composition (including amorphous content) estimated using the Rietveld method with an internal standard. Gersdorffite (NiAsS) was observed in every RIR specimen, and all but one Rietveld specimen. The amorphous contents ranged from 8.7 to 49.9 wt.%. Gersdorffite was sparingly observed in most of the sample sets, but most prominently observed in the **TMF23-08** sample set.

Samples were assessed using X-ray absorption spectroscopy (XAS) at the arsenic (As) K-edge. X-ray absorption near-edge structure (XANES) linear combination fitting (LCF) analysis was employed to identify the arsenic-bearing minerals present in the samples by comparing the As K-edge XANES spectra of the samples to a database of arsenic-bearing standards. LCF analysis identified ferric arsenate ($\text{FeAsO}_4 \cdot x\text{H}_2\text{O}$; As^{5+}), scorodite ($(\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}; \text{As}^{5+})$), arsenite-adsorbed ferrihydrite ($\text{AsO}_3\text{-FeOOH}; \text{As}^{3+}$), and gersdorffite ($\text{NiAsS}; \text{As}^{1-}$) as the major arsenic-bearing minerals in the samples. The XANES and PXRD results were generally consistent, with both methods showing the highest concentrations of gersdorffite in the **TMF23-08** sample set.

Extended X-ray absorption fine structure (EXAFS) analysis was employed on two samples (**04-SA20** and **04-SA21**) to study the arsenic coordination environment. EXAFS analysis indicated that scorodite was not present in both samples and that arsenate species present in are likely arsenate adsorbed on ferrihydrite and/or ferric arsenate. Features in the EXAFS spectra also confirmed the presence of a minor arsenite species.

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2.0 METHODOLOGY

2.1 SAMPLE DESCRIPTION

Sixty-eight (68) samples were received from Orano Canada's Health, Safety, Environment and Regulatory Relations (HSERR) department for XANES and PXRD analysis, listed in **Table 2.1.1**.

Table 2.1.1: Samples measured using PXRD, As K-edge XANES, and As K-edge EXAFS.

Full Sample Name	Unique Label	PXRD	XANES	EXAFS
TMF23-01-SA01_DRUDGE	01-SA01	X	X	
TMF23-01-SA02	01-SA02	X	X	
TMF23-01-SA03	01-SA03	X	X	
TMF23-01-SA04	01-SA04	X	X	
TMF23-01-SA05	01-SA05	X	X	
TMF23-01-SA06	01-SA06	X	X	
TMF23-01-SA07	01-SA07	X	X	
TMF23-01-SA08	01-SA08	X	X	
TMF23-01-SA09A	01-SA09A	X	X	
TMF23-01-SA09B	01-SA09B	X	X	
TMF23-01-SA10	01-SA10	X	X	
TMF23-01-SA11	01-SA11	X	X	
TMF23-01-SA12	01-SA12	X	X	
TMF23-01-SA13	01-SA13	X	X	
TMF23-01-SA14A	01-SA14A	X	X	
TMF23-01-SA14B	01-SA14B	X	X	
TMF23-01-SA15	01-SA15	X	X	
TMF23-01-SA16	01-SA16	X	X	
TMF23-01-SA17	01-SA17	X	X	
TMF23-01-SA18	01-SA18	X	X	
TMF23-01-SA19	01-SA19	X	X	
TMF23-03-SA01_DRUDGE	03-SA01	X	X	
TMF23-03-SA02	03-SA02	X	X	
TMF23-03-SA03	03-SA03	X	X	
TMF23-03-SA04	03-SA04	X	X	
TMF23-03-SA05	03-SA05	X	X	
TMF23-03-SA06	03-SA06	X	X	
TMF23-03-SA07	03-SA07	X	X	
TMF23-03-SA08	03-SA08	X	X	
TMF23-03-SA09	03-SA09	X	X	
TMF23-03-SA10	03-SA10	X	X	
TMF23-03-SA11	03-SA11	X	X	

TMF23-03-SA12	03-SA12	X	X	
TMF23-03-SA13	03-SA13	X	X	
TMF23-03-SA14	03-SA14	X	X	
TMF23-03-SA15	03-SA15	X	X	
TMF23-03-SA16	03-SA16	X	X	
TMF23-03-SA17	03-SA17	X	X	
TMF23-03-SA18	03-SA18	X	X	
TMF23-03-SA19B	03-SA19B	X	X	
TMF23-03-SA20	03-SA20	X	X	
TMF23-03-SA21	03-SA21	X	X	
TMF23-04-SA20	04-SA20	X	X	X
TMF23-04-SA21	04-SA21	X	X	X
TMF23-06-SA01-DRUDGE	06-SA01	X	X	
TMF23-06-SA02	06-SA02	X	X	
TMF23-06-SA03	06-SA03	X	X	
TMF23-06-SA04	06-SA04	X	X	
TMF23-06-SA05	06-SA05	X	X	
TMF23-06-SA06	06-SA06	X	X	
TMF23-06-SA07	06-SA07	X	X	
TMF23-06-SA08	06-SA08	X	X	
TMF23-06-SA09	06-SA09	X	X	
TMF23-06-SA10	06-SA10	X	X	
TMF23-06-SA11	06-SA11	X	X	
TMF23-06-SA12	06-SA12	X	X	
TMF23-06-SA13	06-SA13	X	X	
TMF23-06-SA14	06-SA14	X	X	
TMF23-06-SA15	06-SA15	X	X	
TMF23-06-SA16	06-SA16	X	X	
TMF23-06-SA17	06-SA17	X	X	
TMF23-08-SA01	08-SA01	X	X	
TMF23-08-SA02B	08-SA02B	X	X	
TMF23-08-SA03	08-SA03	X	X	
TMF23-08-SA04	08-SA04	X	X	
TMF23-08-SA05	08-SA05	X	X	
TMF23-08-SA06	08-SA06	X	X	
TMF23-08-SA07	08-SA07	X	X	

2.2 STANDARD DESCRIPTION

The set of arsenic standards used in this work are listed in **Table 2.2.1**. The standards were selected based on previous studies on arsenic speciation of Orano samples and suggestions from Orano Canada [1]. All standards were characterized using synchrotron-based powder X-ray diffraction (PXRD) analysis to confirm if they were phase-pure or only contained a single crystalline arsenic-containing compound.

Table 2.2.1: List of arsenic standards used in the As K-edge XANES LCF analysis.

Compound	Chemical Formula	As Oxidation State
Skutterudite	CoAs ₃	-1
Gersdorffite	NiAsS	-1
Niccolite	NiAs	-1
Arsenopyrite	FeAsS	-1
5 mM Arsenic (III) oxide	As ₂ O ₃	+3
Tooeleite	Fe ₆ (AsO ₃) ₄ SO ₄ (OH) ₄	+3
Sodium Arsenite	NaAsO ₂	+3
Arsenite-adsorbed Ferrihydrite	AsO ₃ -Fe(OH) ₃	+3
Arsenate-adsorbed Ferrihydrite	AsO ₄ -Fe(OH) ₃	+5
Scorodite	FeAsO ₄ ·2H ₂ O	+5
Ferric Arsenate	FeAsO ₄	+5
5mM Sodium Arsenate	Na ₃ AsO ₄	+5
Monomethylarsonic Acid (MMA ^V)	CH ₅ AsO ₃	+5
Dimethylarsinic Acid (DMA ^V)	C ₂ H ₇ AsO ₂	+5
Trimethylarsine Oxide (TMAO)	C ₃ H ₉ AsO	+5

2.3 POWDER X-RAY DIFFRACTION (PXRD)

Two different types of PXRD analyses were performed in this work. Initial semi-quantitative estimates of the relative crystalline phase composition (relative weight percentage, or rel. wt%) were obtained for all samples with the reference-intensity ratio (RIR) method [2]. Rietveld refinement [3] was also performed on all samples using an internal standard, in order to obtain an estimate of the total phase composition, including amorphous content (weight percentage, or wt%).

For RIR analysis data collection, sample were lightly ground with an agate mortar and pestle. The ground powders were mounted in polyimide capillaries (with inner diameter of 0.3 mm) for data collection at ambient temperature (293 K). The powders ground at this stage were also used for preparation of the homogenized Rietveld specimens.

For Rietveld analysis data collection, the powders were lightly ground with an agate mortar and pestle, weighed and subsequently mixed with measured amounts of a corundum internal standard (MSE Supplies® High Purity Al₂O₃, 500 nm [4], 15 to 20 wt% to each sample). The powders were re-ground and homogenized with an agate mortar and pestle. Homogenized powder specimens were mounted in polyimide capillaries (with inner diameter of 0.5 mm) for data collection.

All PXRD patterns were collected using the Brockhouse X-ray Diffraction and Scattering High Energy Wiggler (BXDS-WHE) at the Canadian Light Source (CLS) [5]. BXDS-WHE employed a Si (111) side bounce Laue monochromator. Data were collected using a photon energy of 35.88 keV (wavelength λ = 0.3456 Å) and a sample-detector distance of ~ 571 mm. Two-dimensional (2D) diffraction patterns were collected on a Varex XRD 4343RF detector with an active area of 430 mm x 430 mm, and a pixel size of 150 x 150 μm^2 .

The 2D PXRD patterns were calibrated and integrated using the GSASII software package [6]. The sample-detector distance, detector offset and detector tilt were calibrated using an image from a lanthanum hexaboride (LaB₆) standard reference material (NIST SRM 660a LaB₆) [7] and the calibration parameters were applied to all patterns. After calibration, the 2D patterns were integrated to obtain standard 2 θ -Intensity powder diffraction patterns. The pattern from an empty capillary was subtracted from the sample data during integration.

Search/match was performed on the integrated PXRD patterns using the Powder Diffraction File (PDF-4+) [8] to determine the crystalline phases present.

Reference-intensity ratio (RIR) analyses [2] were performed using the RIR values (specifically the I/I_c values, or intensity compared to the intensity of corundum) obtained from the appropriate PDF cards identified during search/match phase identification, using an overall scale factor for each PDF standard pattern. The overall scale factors were based on peak heights (hence the semi-quantitative nature of the result) for each phase. Therefore, the clays and poorly crystalline minerals tend to be underestimated in the RIR analyses, while the coarse, highly crystalline minerals like quartz tend to be overestimated.

Rietveld refinement quantitative phase analysis (QPA) was performed with GSASII [6]. The final refinements included scale factors for each phase in the mixture, lattice parameters for the most abundant phases, parameters for the background (a multi-term Chebyshev polynomial), plus crystallite size and/or microstrain broadening parameters for appropriate phases.

For each sample, the internal standard content was used to normalize the relative crystalline phase composition obtained from the final Rietveld refinement and the amorphous content was estimated indirectly by difference [9].

2.4 X-RAY ABSORPTION SPECTROSCOPY

2.4.1 Arsenic K-edge Data Collection

Samples were ground to a fine powder using an agate mortar and pestle, packed into sample holders and sealed with 7.5-micron thick adhesive Kapton® tape. Samples were stored at room temperature before and after preparation steps.

The As K-edge XAS spectra were collected on the BioXAS-spectroscopy (07ID-2) beamline [10]. BioXAS utilizes a 2.1 T wiggler and a double-crystal Si (220) monochromator with a Rh-coated mirror to deliver an X-ray beam in the spectral range 5–32 keV. Samples were positioned in front of the X-ray beam at a 45° angle. All arsenic standards except the adsorbed standards were collected in transmission mode. All samples and the adsorbed standards were collected in fluorescence mode using two 32-element Ge detectors mounted in-plane with the sample and perpendicular to the X-ray beam. All XANES spectra were collected from -200 eV to ~375 eV ($k = \sim 10 \text{ \AA}^{-1}$) above the As K-edge absorption edge (~11867 eV) with a step size of 0.5 eV near the edge and a beam size of 1 x 3 mm. EXAFS spectra were collected up to ~980 eV ($k = \sim 16 \text{ \AA}^{-1}$). A gold foil reference standard was placed between the second and third ion chamber and the gold L_3 -edge (11919 eV) transmission spectrum was measured concurrently for energy calibration. All ion chambers were filled with N_2 gas. Two scans were collected for each sample and later averaged prior to data analysis. All samples and standards were collected under cryogenic conditions (i.e., ~80K).

2.4.2 Spectral Analysis

The averaged XAS spectra were analyzed using the Athena software package version 0.9.26 [11]. All As K-edge XAS spectra were first calibrated against gold foil with the maximum of the first peak in the K-edge first derivative spectrum set to 11919 eV. The pre- and post-edge regions were normalized using standard techniques [12]. XAS can be divided into two regions, XANES and EXAFS, as illustrated in **Figure 2.1**. XANES is the lower energy portion of the XAS spectrum and provides information on oxidation states and chemical speciation. The As K-edge XANES spectra of all samples were analyzed using the Athena software package version 0.9.26 [11]. EXAFS is the high energy portion of the XAS spectrum and provides

information on the interatomic distances and coordination number between the absorbing atoms and the various scattering atoms. The As K-edge EXAFS of **04-SA20** and **04-SA21** were analyzed using the Artemis software package version 0.9.26 [11]. EXAFS spectra as a function of the wavenumber k (i.e. k -space EXAFS) were produced by subtracting the background from the normalized XAS spectra using a linear fit through the pre-edge region and a cubic spline through the spectrum above the absorption edge. The normalized k^2 -weighted EXAFS spectra were filtered over a k -range of 2–13 Å⁻¹ and Fourier-transformed to produce a radial structure function (i.e. R -space EXAFS).

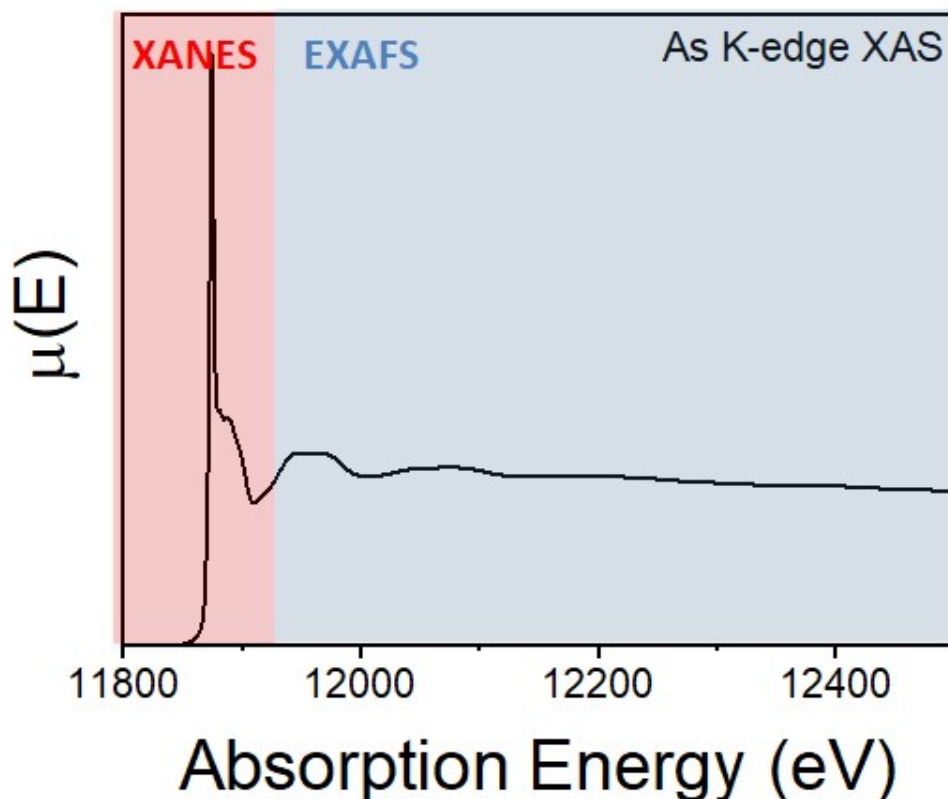


Figure 2.1. A diagram of a XAS spectrum, highlighting the XANES (low energy) and EXAFS (high energy).

2.4.2.1 X-ray Absorption Near-Edge Structure (XANES) Analysis

The XANES data was analyzed using LCF. LCF analysis is used to identify the predominant arsenic species present in the samples. The LCF analysis fits a sample spectrum with a weighted mixture of standard spectra, which are representative of the chemical species thought to be present in the samples, to identify different arsenic species in the samples. The relative concentrations of the different arsenic species are obtained from the LCF. The LCF is accurate only if the selected standard compounds correctly represent the species present in the samples. For the LCF analysis presented here, the standards used are the arsenic species listed in **Table 2.2.1**. A number of constraints are applied in the LCF analysis. The weights of the components used in the fit are allowed to vary between 0 and 1 with the total sum of the weighted components restricted to 1. Also, it was assumed that components in the fit with weights less than the calculated error were not present in the sample and were removed from the LCF. For each spectrum, several different combinations standards were tested. The goodness of the fit was quantified using the R-factor. The R-factor measures the discrepancy between the data and the fit. The R-factor used in this analysis is calculated as the sum over all N measured points of the squared difference between each data point and the fit, normalized by the sum over all measured data points ($R\text{-factor} = (\sum |data - fit|^2) / \sum (data)^2$). A

general guideline for interpreting the R-factor is shown in **Table 2.4.1**. A number of constraints were applied in the LCF analysis. In general, an R-factor less than 0.02 is considered a good fit with standards that are representative of the species in the sample. Our guideline for including n number of components in the fit is that the R-factor should improve n -fold compared to a $(n-1)$ component fit. For example, a third component is included in the final fitting results if its inclusion results in a three-fold improvement in the R-factor when compared to a two component fit.

Table 2.4.1: Guidelines for the interpretation of R-factor values obtained from a LCF.

R-factor range	Interpretation
< 0.02	This represents a good fit.
0.02 – 0.05	Consistent with data but either the details of the model are incorrect or the data is of poor quality.
0.05 – 0.10	Serious flaws in the model or extremely low quality data.
> 0.10	Model is likely incorrect.

2.4.2.2 Extended X-ray Absorption Fine-Structure (EXAFS) Analysis

The As K-edge EXAFS spectra were analyzed by fitting key parameters in the EXAFS equation:

$$X(k) = \sum_j S_0^2 N_j \frac{f_j(k) e^{\frac{-2R_j}{\lambda(k)}} e^{-2k^2 \sigma_j^2}}{k R_j^2} \sin(2k R_j + \delta_j(k))$$

These parameters are described in detail elsewhere [13,14]. In the fitting, $F_j(k)$, $\delta_j(k)$, and λ were calculated for each set of scattering pairs in a given cluster using the FEFF6 code [15]. Other parameters were fitted using a least-squares refinement. A summary of key parameters that are modelled in the least-squared fitting process can be found in **Table 2.4.2**. These parameters affect either the amplitude of the EXAFS oscillations (N , S_0^2 , σ^2) or the phase of the oscillations (ΔE_0 , ΔR). Fit quality is monitored using a R-factor that is defined in a similar manner as the R-factor in a XANES LCF analysis. A R-factor less than 0.05 is indicative of a good fit.

Table 2.4.2: Description of EXAFS Fitting Parameters.

EXAFS Fitting Parameter	Description
S_0^2	The amplitude reduction factor that describes the effect of intrinsic losses on the EXAFS spectrum. Typical values are obtained between 0.70 to 1.1. Often a single global value for S_0^2 is used for all paths.
ΔE_0	A component of the electron momentum (k), typically a few electron volts (-10 to 10 eV). Often a single global value of ΔE_0 is used for all paths.
σ^2	The Debye-Waller factor that represents the static (positional) and thermal disorder in each scattering path. Typical values are obtained between 0.002 to 0.030 Å ² . A low σ^2 corresponds to focused directional strong bonds while the upper range represents very disordered bonds. There are special fitting strategies to fit σ^2 for multiple scattering paths.
R	The distance between the absorbing atom and the scattering atom. R is typically derived from scattering paths obtained from structural refinement data of models used as a starting point in the EXAFS fitting.
N	The path degeneracy, equivalent to the coordination number for single scattering paths.
R-factor	Typical values of a reasonable fit are < 0.05, values in the range 0.05 to 0.1 may indicate low quality data or a flawed fit.

Scattering clusters for the FEFF calculation were generated to represent the common arsenic scattering paths in the standards listed in **Table 2.2.1**. The scattering clusters were generated from structural refinement data for scorodite ($\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$; As-O and As-Fe single scattering paths). All samples were fitted over a R-space range of 1 to 4 Å.

3.0 RESULTS

3.1 POWDER X-RAY DIFFRACTION (PXRD)

3.1.1 Reference-Intensity Ratio (RIR) Results

Search/match phase identification results are illustrated for the PXRD patterns obtained from all 68 samples in **Figures 5.1 to 5.68** in **Appendix 1**, with the raw data compared to 2θ – Intensity (2θ -I) standard plots for representative minerals. A list of the observed minerals with formulas, PDF entries and unit cell information is given in **Table 5.1**. The semi-quantitative phase composition estimates of the crystalline phases obtained with the RIR method are given in **Tables 3.1.1 to 3.1.7**.

Multiple minerals were observed in nearly every sample (minimum 65 of 68 samples), including gypsum, quartz, illite/muscovite, anatase and hematite. Gypsum varied from less than 1 rel. wt.% (multiple samples) to ~84 rel. wt.% (**03-SA03** and **08-SA06**). Quartz varied from ~2 rel. wt.% (**01-SA02**) to ~96 rel. wt.% (**03-SA07**).

The illite/muscovite clay phase varied from less than 5 rel. wt.% (**03-SA03** and **03-SA07**) to ~37 rel. wt.% (**03-SA20**). Consistent with previous work [16-21], the exact nature of this phase is not conclusive, but an illite standard pattern and crystal structure (PDF card 04-017-0520) was used in all the phase identification plots and subsequent Rietveld refinements. It is believed that this pattern is still an approximation of the true structure, which likely contains extensive disorder and stacking faults that influence the observed intensities. Clinocllore and/or kaolinite were also observed in many of the patterns (each below 10 rel. wt.%). It should be noted that kaolinite is challenging to detect because the strongest Bragg peak overlaps with clinocllore (at $2\theta = 2.77^\circ$, $d = 7.155 \text{ \AA}$) in addition to numerous other reflections that are also compromised by overlapping peaks. Consistent with previous work [16-21], a monoclinic polymorph of clinocllore has been used to characterize this phase. Illite and clinocllore estimates with the semi-quantitative RIR method tend to be lower than the Rietveld estimates due to significant broadening of their peaks that isn't accounted for with the RIR method.

A number of samples (the most prominent examples include **01-SA01**, **01-SA02**, **01-SA05** and **03-SA04**) exhibited a large, broad, low angle reflection at 2θ values from 1.26° to 1.28° (d -spacing values from 15.7 $\text{\AA}$ to 15.3 $\text{\AA}$) that was not attributable to clinocllore. Some possible explanations include another Chlorite-type clay phase (possibly vermiculite), or a Smectite-type clay phase (possibly nontronite or montmorillonite). Due to the uncertainty in the identification, these peaks were omitted from the RIR analysis, and the peaks were generally not reproduced in the Rietveld specimens.

Gersdorffite (NiAsS) was generally observed sparingly in most of the sample series, but was prominently observed in the **TMF23-08** sample set (all seven samples, including the sample with the highest concentration, **08-SA02B**). In every sample series, gersdorffite was most commonly observed in the lowest number samples (typically **SA01** to **SA08**), with minor exceptions. Both of these observations were generally consistent with the XANES and Rietveld analyses.

Multiple iron oxide, sulfide and carbonate minerals were observed in the samples including hematite (Fe_2O_3), pyrite (FeS_2), chalcopyrite (CuFeS_2) and siderite (FeCO_3). Pseudorutile ($\text{Ti}_{8.33}\text{Fe}_{5.56}\text{O}_{25}$) and magnetite (Fe_3O_4)/ulvöspinel (TiFe_2O_4) were each observed in a single sample (**01-SA03** and **08-SA04**, respectively). Magnetite and ulvöspinel consistently present an identification issue due to their presence in low quantities and peak overlap with other phases, notably illite/muscovite. Since these two minerals have similar spinel-type crystal structures with a subtle change in lattice parameter (and peak positions) based on the titanium content, magnetite and ulvöspinel were grouped together for quantification purposes.

Table 3.1.1. Relative crystalline phase composition results (rel. wt.%) obtained with the RIR method for the **01-SA01** to **01-SA10** samples.

Mineral Phase	01-SA01	01-SA02	01-SA03	01-SA04	01-SA05	01-SA06	01-SA07	01-SA08	01-SA09A	01-SA09B	01-SA10
Albite											
Anatase	0.4	0.2	1.4	0.3	0.5	0.9	0.7	0.2	0.3	0.2	0.6
Anglesite										0.4	
Baryte	3.8	0.9	0.8	3.6	1.7				0.9	3.5	1.0
Chalcopyrite	1.5	0.9	1.3	1.9	1.5						
Clinocllore	1.9		2.0	1.8				1.2	0.8	1.1	1.6
Corkite											
Galena	0.2		0.1	0.1	0.1			0.1		0.1	
Gersdorffite	0.9	2.0	0.7	0.4	0.5	0.3		0.2			
Gypsum	58.8	88.1	52.1	77.9	63.1	14.1	20.8	1.2	1.1	1.7	3.1
Hematite	2.2		0.9	0.8	2.7	1.1	1.0	0.4	0.5	0.5	0.9
Illite/Muscovite	13.0	5.3	7.1	7.1	17.0	19.2	15.9	8.9	10.0	10.4	21.1
Ilmenite											
Kaolinite	2.2				1.5	2.8	1.4	2.3	2.7	1.4	9.0
Magnetite/ Ulvöspinel											
Pseudorutile			10.4								
Pyrite	1.0		5.3	0.6	1.0						
Quartz	11.9	2.2	16.2	5.2	9.7	60.2	60.2	85.5	83.4	80.8	62.4
Rutile	1.8	0.5	0.6	0.5	0.7	1.3		0.2	0.4		0.2
Scorodite											
Siderite			0.9								
Wulfenite	0.5										

Wulfenite (PbMoO_4) was observed in two samples (**01-SA01** and **03-SA02**). This mineral was tricky to identify due to the overlap of its strongest Bragg reflection with the strongest reflection for rutile. While wulfenite has not been formally identified in past work [16-21], it has probably been present in samples in the past.

Table 3.1.2. Relative crystalline phase composition results (rel. wt.%) obtained with the RIR method for the **01-SA11** to **01-SA19** samples.

Mineral Phase	01-SA11	01-SA12	01-SA13	01-SA14A	01-SA14B	01-SA15	01-SA16	01-SA17	01-SA18	01-SA19
Albite	1.8					6.1		1.3		
Anatase	0.3	0.4	0.2	0.3	0.9	0.2	0.8	0.6	0.3	0.8
Anglesite										
Baryte			0.4	0.4	0.7			1.6		
Chalcopyrite										0.1
Clinochlore	1.1	1.7	1.0	1.0	2.6	0.9	1.7	0.9	1.1	4.9
Corkite										
Galena										0.1
Gersdorffite										
Gypsum	23.1	2.7	0.9	8.4	34.5	0.6	3.3	3.0	0.8	8.6
Hematite	0.3	0.6	0.4	0.5	1.0	0.2	0.4	0.4	0.5	0.7
Illite/Muscovite	13.3	17.4	8.8	16.4	18.1	10.1	20.3	17.5	14.4	22.0
Ilmenite										
Kaolinite	2.4	3.5	5.3	2.9	5.4	1.3	3.6	2.2	1.7	4.0
Magnetite/ Ulvöspinel										
Pseudorutile										
Pyrite		0.5	0.4							
Quartz	57.5	72.8	82.4	69.8	36.5	80.5	69.6	72.2	81.1	58.9
Rutile	0.2	0.3	0.2	0.4	0.2	0.1	0.2	0.2	0.2	
Scorodite										
Siderite		0.2	0.2							
Wulfenite										

Table 3.1.3. Relative crystalline phase composition results (rel. wt.%) obtained with the RIR method for the **03-SA01** to **03-SA10** samples.

Mineral Phase	03-SA01	03-SA02	03-SA03	03-SA04	03-SA05	03-SA06	03-SA07	03-SA08	03-SA09	03-SA10
Albite										
Anatase	0.3	0.3	0.7	0.3	0.9	0.6		0.1	0.3	0.3
Anglesite										
Baryte	0.6	0.9	0.5	0.2	0.5	0.7		0.2	0.6	0.8
Chalcopyrite	1.4	1.1	0.9	2.3	0.9					
Clinochlore	1.6			0.6	1.5	2.8				
Corkite				0.2	0.2					
Galena			0.1	0.2	0.1	0.3				
Gersdorffite	0.7		2.6	0.2				0.4		
Gypsum	70.7	70.5	84.3	76.9	76.1	76.4	2.3	17.0	30.5	30.3
Hematite	0.9	1.4	0.8	0.5	1.4	1.9		0.6	2.0	1.7
Illite/Muscovite	15.4	15.6	4.5	7.2	11.5	11.7	1.8	7.2	24.5	22.5
Ilmenite										
Kaolinite								1.1	3.2	4.5
Magnetite/ Ulvöspinel										
Pseudorutile										
Pyrite				0.3	0.6					
Quartz	7.7	8.0	5.5	8.6	5.1	4.8	96.0	72.8	38.3	38.8
Rutile	0.6	1.8	0.3	0.7	1.3	1.0		0.1	0.2	0.3
Scorodite								0.4	0.6	0.8
Siderite				1.7						
Wulfenite		0.3								

Table 3.1.4. Relative crystalline phase composition results (rel. wt.%) obtained with the RIR method for the **03-SA11** to **03-SA21** samples.

Mineral Phase	03-SA11	03-SA12	03-SA13	03-SA14	03-SA15	03-SA16	03-SA17	03-SA18	03-SA19B	03-SA20	03-SA21
Albite					1.9						
Anatase	0.3	0.2	0.3	0.3	0.7	0.4	0.3	0.4	0.5	1.0	0.8
Anglesite											
Baryte	0.5	0.4			0.3					0.7	0.7
Chalcopyrite	0.2										
Clinochlore				1.0	1.0	2.1	0.7	1.1		1.1	2.2
Corkite											
Galena										0.1	
Gersdorffite		0.5									
Gypsum	28.0	36.0	15.8	8.3	6.4	4.0	0.5	2.7	21.9	11.0	22.0
Hematite	1.0	1.6	1.1	0.3	0.3		0.2	0.5	0.7	0.4	1.1
Illite/Muscovite	19.9	25.1	13.5	11.4	13.2	21.7	13.0	10.2	17.5	37.4	32.4
Ilmenite											
Kaolinite	3.4	3.8	4.5	3.8	4.4	3.9	2.4	2.7	2.2	5.7	5.8
Magnetite/ Ulvöspinel											
Pseudorutile											
Pyrite		3.4	0.4								
Quartz	46.1	28.8	64.4	74.8	71.8	67.8	82.7	82.5	57.2	42.2	34.6
Rutile	0.2	0.1	0.1	0.2	0.2	0.2	0.1			0.4	0.4
Scorodite	0.5										
Siderite							0.1				
Wulfenite											

Table 3.1.5. Relative crystalline phase composition results (rel. wt.%) obtained with the RIR method for the **04-SA20** to **06-SA08** samples.

Mineral Phase	04-SA20	04-SA21	06-SA01	06-SA02	06-SA03	06-SA04	06-SA05	06-SA06	06-SA07	06-SA08
Albite										
Anatase	0.8	0.5	0.5	0.5	0.3	0.3	0.3	0.7	0.4	0.4
Anglesite										
Baryte	0.6	0.6	1.8	0.7	0.5	0.8	0.7	0.7	0.5	0.6
Chalcopyrite			1.2	2.0	1.1	0.9		0.6		
Clinocllore	2.6	3.4	1.9	2.7	0.6			1.4		1.9
Corkite			0.4							
Galena			0.2	0.1	0.3	0.1		0.1	0.1	
Gersdorffite		0.4	0.6	0.9	1.9			0.2	0.7	0.4
Gypsum	14.0	22.5	59.6	60.4	55.0	81.5	82.2	80.4	27.8	42.0
Hematite	0.8	2.3	2.2	4.2	1.5	1.2	1.4	0.9	1.5	1.3
Illite/Muscovite	25.5	19.9	15.8	18.6	9.8	7.9	10.5	10.5	23.9	19.4
Ilmenite					1.5					
Kaolinite	6.6	7.1	1.8	2.2		1.0			4.6	3.9
Magnetite/ Ulvöspinel										
Pseudorutile										
Pyrite		0.6	0.7	1.1	1.3	0.8	0.8	0.5	0.6	
Quartz	48.7	42.2	11.0	5.6	25.8	5.1	3.9	3.6	39.1	29.3
Rutile	0.3	0.5	1.6	1.0	0.5	0.4	0.4	0.5	0.2	0.3
Scorodite									0.7	0.5
Siderite			0.9							
Wulfenite										

Table 3.1.6. Relative crystalline phase composition results (rel. wt.%) obtained with the RIR method for the **06-SA09** to **06-SA17** samples.

Mineral Phase	06-SA09	06-SA10	06-SA11	06-SA12	06-SA13	06-SA14A	06-SA15	06-SA16	06-SA17
Albite									
Anatase	0.2	0.4	0.8	0.5	0.5	0.7	0.6	0.7	0.9
Anglesite									
Baryte	0.3	0.8	0.3	0.4	0.5	0.8	0.5	0.7	0.9
Chalcopyrite									
Clinocllore			1.0	1.4		2.5		2.2	2.8
Corkite									
Galena									
Gersdorffite									
Gypsum	31.6	45.7	30.2	39.8	35.2	22.9	22.5	22.3	10.8
Hematite	0.7	1.7	0.5	0.7	0.8	0.6	0.3	0.2	0.3
Illite/Muscovite	14.5	24.1	18.5	17.9	27.8	29.5	28.0	22.8	34.5
Ilmenite									
Kaolinite	4.0	5.5	2.6	5.4	7.7	9.4	6.0	5.3	7.4
Magnetite/ Ulvöspinel									
Pseudorutile									
Pyrite	0.4		0.4						
Quartz	48.0	20.9	45.4	33.4	26.8	33.4	41.7	45.6	41.8
Rutile	0.1	0.2	0.1	0.2	0.3	0.4	0.4	0.3	0.5
Scorodite	0.2	0.8	0.2	0.4	0.4				
Siderite									
Wulfenite									

Table 3.1.7. Relative crystalline phase composition results (rel. wt.%) obtained with the RIR method for the **08-SA01** to **08-SA07** samples.

Mineral Phase	08-SA01	08-SA02B	08-SA03	08-SA04	08-SA05	08-SA06	08-SA07
Albite							
Anatase	0.4	0.4	0.5	7.6	0.3	0.3	0.1
Anglesite							0.2
Baryte	1.2	0.6	0.6	0.6	0.8	0.9	0.2
Chalcopyrite	2.2	1.4	0.7	2.4	1.6	0.6	
Clinochlore	2.4	1.3	1.6	2.5			0.9
Corkite							
Galena	0.1	0.1	0.1		0.2	0.1	
Gersdorffite	0.9	5.7	3.2	0.7	0.3	0.3	0.2
Gypsum	63.7	16.2	36.3	37.1	81.2	84.4	10.1
Hematite	1.2	0.6	0.9	1.5	1.4	0.8	0.5
Illite/Muscovite	12.7	10.5	21.1	27.5	5.7	7.3	6.5
Ilmenite							
Kaolinite					0.7	1.0	1.0
Magnetite/ Ulvöspinel				4.3			
Pseudorutile							
Pyrite		1.8	0.6	0.5	0.6	0.5	
Quartz	13.6	61.2	27.8	13.5	6.0	3.6	80.0
Rutile	1.6	0.3	4.6	0.6	0.6	0.4	0.2
Scorodite							0.2
Siderite			2.1	1.4	0.7		
Wulfenite							

3.1.2 Rietveld Refinement Results

Plots of the final Rietveld refinements for all 68 samples homogenized with a measured amount of Al_2O_3 internal standard are illustrated in **Figures 5.69 to 5.136**. The total phase composition estimates, including amorphous content, obtained from the Rietveld refinements are given in **Tables 3.1.8 to 3.1.14**. Agreement indices for the refinements are given in each table including the reduced chi-squared (Red. χ^2) and weighted R-factor (wR) values. The refinements and difference curves look reasonable and the agreement indices are reasonable [3] with weighted R-factor (wR) values between 3.11% and 8.29%.

The wR values tended to be lowest for the samples with the lowest illite/muscovite content, suggesting this mineral was the most challenging to properly fit with the Rietveld refinements. The lowest illite/muscovite contents were generally observed in the lowest number samples for each sample set (typically **SA01 to SA05**), with the exception being the **TMF23-08** sample set, where the lowest illite/muscovite contents were observed in samples **08-SA05 to 08-SA07**. Similarly, kaolinite tended to be absent in the lowest number samples of each set (typically **SA01 to SA05**), but present in the higher number samples.

The amorphous contents varied significantly across the 68 samples, ranging from ~8.7 to 49.9 wt.% (the average amorphous content was 25.8 wt.%). None of the individual sample sets exhibited an obvious trend in the amorphous contents with sample number.

Similar to previous work [17-20], bassanite was observed in number of the Rietveld specimens after not being observed in the corresponding RIR specimens. This suggests that some gypsum likely dehydrated during subsequent sample preparation and homogenization required for the Rietveld analyses with the internal standard.

A comparison between the RIR and Rietveld results suggests they are generally consistent with minor discrepancies, often related to minor or trace phases. Gersdorffite was observed in slightly fewer of the Rietveld specimens compared to the RIR specimens. The results generally agree with the XANES analyses that found the highest gersdorffite content in the **TMF23-08** sample series. Scorodite was also observed in some of the middle number samples from the **TMF23-03** sample set (**03-SA08 to 03-SA10**) and the **TMF23-06** sample set (**06-SA07 to 06-SA10, 07-SA12**). These observations were generally consistent with the RIR specimens, although scorodite was also observed in a few additional RIR specimens.

Given the clay and amorphous contents present in every sample, the complexity of the mixtures (including both low and highly absorbing phases), and small specimen volumes examined, viewing all the Rietveld results as semi-quantitative is probably the most reasonable approach to considering the results. With this in mind, the Rietveld results can still be regarded as significantly more accurate with lower systemic biases than the previously discussed RIR estimates.

Table 3.1.8. Total phase composition including amorphous content (wt%) obtained with Rietveld refinement for the **01-SA01** to **01-SA10** samples. The final refinements are plotted in **Figures 5.69** to **5.79**.

	Unique Label										
	01-SA01	01-SA02	01-SA03	01-SA04	01-SA05	01-SA06	01-SA07	01-SA08	01-SA09A	01-SA09B	01-SA10
Red. χ^2	3.03	2.62	5.16	1.82	3.04	4.33	4.89	5.90	4.25	7.79	5.00
wR (%)	3.89	3.66	5.05	3.51	4.03	5.57	6.12	5.15	5.64	5.47	5.56
Phase	Phase Composition (wt.%)										
Albite											
Anatase	0.2	0.2	0.8	0.2	0.3	0.5	0.5	0.2	0.3	0.2	0.2
Anglesite											
Baryte	1.2			1.8	0.6				0.3	3.2	0.1
Bassanite			0.8	1.5							
Chalcopyrite	0.9	0.5	1.6	0.4	0.3						
Clinocllore	4.4	2.8	3.5	2.2	2.6	1.1	1.3	0.6	0.6		0.9
Corkite											
Galena	0.1	0.1	0.1								
Gersdorffite		1.1	0.3	0.3		0.1					
Gypsum	29.4	75.8	42.6	50.3	26.0	7.2	22.6	0.3	0.3	0.4	0.5
Hematite	0.9	0.3	0.5	0.3	1.5	1.0	0.4	0.2	0.4	0.4	0.3
Illite/Muscovite	13.1	8.2	14.4	10.3	16.5	27.2	30.1	9.9	14.9	13.0	14.4
Kaolinite						1.9	0.6	1.2	2.7	2.0	2.9
Magnetite/ Ulvöspinel											
Pseudorutile											
Pyrite	0.4	0.4	1.1	0.2	0.2						0.1
Quartz	2.8	1.3	13.7	2.5	1.3	51.6	28.6	71.9	63.0	65.8	69.0
Rutile	1.1	0.4	0.4	0.4	0.8	0.1	0.1			0.1	
Scorodite											
Siderite		0.3	0.7								
Wulfenite											
Amorphous	45.7	8.7	19.5	29.8	49.9	9.5	15.9	15.7	17.4	14.8	11.5

Table 3.1.9. Total phase composition including amorphous content (wt%) obtained with Rietveld refinement for the **01-SA11** to **01-SA19** samples. The final refinements are plotted in **Figures 5.80** to **5.89**.

	Unique Label									
	01-SA11	01-SA12	01-SA13	01-SA14A	01-SA14B	01-SA15	01-SA16	01-SA17	01-SA18	01-SA19
Red. χ^2	4.16	7.90	3.29	7.43	3.54	6.13	8.57	8.07	6.59	7.56
wR (%)	5.19	6.48	5.16	6.35	5.85	6.08	6.51	6.15	6.20	6.66
Phase	Phase Composition (wt.%)									
Albite								1.1	0.8	
Anatase	0.3	0.4	0.3	0.6	0.6	0.3	0.6	0.4	0.5	0.8
Anglesite										
Baryte			0.1					1.1		
Bassanite	1.0									
Chalcopyrite	0.1				0.1					0.2
Clinocllore	0.9	1.2	1.1	1.5	1.9	1.2	1.8	1.7	2.6	2.8
Corkite										
Galena										
Gersdorffite								0.3		
Gypsum	7.8	0.6	0.2	3.6	13.6	0.2	1.1	1.3	0.4	2.6
Hematite	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.4	0.3	0.3
Illite/Muscovite	15.7	19.4	15.8	24.9	28.2	15.8	23.7	18.5	18.9	25.8
Kaolinite	1.3	1.8	1.5	2.2	2.3	1.9	1.6	1.4	1.8	1.6
Magnetite/ Ulvöspinel										
Pseudorutile										
Pyrite			0.1	0.1		0.1				0.1
Quartz	50.6	53.8	64.4	45.1	25.8	57.9	53.5	62.7	53.5	46.7
Rutile	0.1	0.1	0.1	0.1	0.2		0.1	0.1	0.1	0.2
Scorodite										
Siderite										
Wulfenite										
Amorphous	22.0	22.6	16.3	21.7	27.2	22.3	17.4	11.0	21.2	19.0

Table 3.1.10. Total phase composition including amorphous content (wt%) obtained with Rietveld refinement for the **03-SA01** to **03-SA10** samples. The final refinements are plotted in **Figures 5.90** to **5.99**.

	Unique Label									
	03-SA01	03-SA02	03-SA03	03-SA04	03-SA05	03-SA06	03-SA07	03-SA08	03-SA09	03-SA10
Red. χ^2	3.46	1.38	3.49	3.39	2.68	3.51	3.30	3.47	7.28	8.71
wR (%)	3.39	3.11	4.18	3.94	4.09	3.59	4.11	5.21	5.55	6.21
Phase	Phase Composition (wt.%)									
Albite										
Anatase	0.3	0.2	0.2	0.2	0.5	0.7	0.2	0.3	0.3	0.3
Anglesite										
Baryte	0.2	0.3	0.2	0.1	0.3	0.3				0.1
Bassanite	1.3	0.6	2.6				1.2			
Chalcopyrite	1.3	0.8	0.8	0.7	0.6	0.6				
Clinocllore	1.5	1.9	1.2	2.2	2.5	2.5	1.0		1.4	0.9
Corkite										
Galena		0.1	0.1							
Gersdorffite	0.5		0.7	0.5	0.1			0.1		0.1
Gypsum	40.9	39.4	46.8	57.0	46.2	49.2	8.9	14.2	22.2	16.5
Hematite	0.7	0.8	0.6	0.3	1.1	1.2	0.7	0.6	1.0	0.9
Illite/Muscovite	9.4	9.5	9.3	10.8	14.1	11.8	8.4	10.0	22.1	21.4
Kaolinite							0.7	1.4	3.2	3.2
Magnetite/ Ulvöspinel										
Pseudorutile										
Pyrite	0.6	0.3	0.6	0.8	0.7	0.7				0.1
Quartz	9.1	3.3	3.7	3.5	1.5	4.2	64.7	48.6	13.0	10.9
Rutile	0.6	0.6	0.2	0.8	1.0	0.6			0.1	0.2
Scorodite								0.9	1.0	1.3
Siderite	0.5		0.4	0.2						0.1
Wulfenite		0.2								
Amorphous	33.2	42.0	32.5	23.0	31.5	28.2	14.3	24.0	35.7	43.9

Table 3.1.11. Total phase composition including amorphous content (wt%) obtained with Rietveld refinement for the **03-SA11** to **03-SA21** samples. The final refinements are plotted in **Figures 5.100** to **5.110**.

	Unique Label										
	03-SA11	03-SA12	03-SA13	03-SA14	03-SA15	03-SA16	03-SA17	03-SA18	03-SA19B	03-SA20	03-SA21
Red. χ^2	0.95	15.81	6.39	5.06	7.49	9.06	7.66	10.25	5.33	11.23	6.84
wR (%)	4.13	7.20	6.55	5.95	6.95	7.14	6.77	6.98	5.93	7.61	7.58
Phase	Phase Composition (wt.%)										
Albite						0.9					
Anatase	0.3	0.5	0.4	0.4	0.5	0.5	0.3	0.4	0.6	0.6	0.7
Anglesite											
Baryte											
Bassanite		2.8							1.5		
Chalcopyrite											
Clinocllore	1.1			1.0	1.9	2.9	2.0	2.5	1.6	4.5	3.2
Corkite											
Galena											0.1
Gersdorffite											
Gypsum	18.0	18.4	10.1	3.6	3.3	1.6	0.5	1.9	18.1	10.4	10.6
Hematite	0.5	1.5	0.9	0.2	0.2	0.2	0.2	0.2	0.3	0.7	0.8
Illite/Muscovite	24.6	26.3	16.5	17.3	20.5	24.9	18.6	20.8	24.0	34.4	29.2
Kaolinite	1.8	2.2	3.1	2.0	2.0	2.5	2.5	1.9	1.9	4.3	3.2
Magnetite/ Ulvöspinel											
Pseudorutile											
Pyrite											
Quartz	16.2	22.3	49.1	57.2	52.7	45.8	56.3	52.2	24.9	17.1	12.2
Rutile	0.2	0.1							0.2	0.3	0.6
Scorodite											
Siderite											
Wulfenite											
Amorphous	37.4	26.0	20.0	18.5	18.9	20.7	19.6	20.1	26.9	27.7	39.4

Table 3.1.12. Total phase composition including amorphous content (wt%) obtained with Rietveld refinement for the **04-SA20** to **06-SA08** samples. The final refinements are plotted in **Figures 5.111** to **5.120**.

	Unique Label									
	04-SA20	04-SA21	06-SA01	06-SA02	06-SA03	06-SA04	06-SA05	06-SA06	06-SA07	06-SA08
Red. χ^2	9.04	7.69	4.51	6.37	2.51	2.51	1.77	3.05	5.93	7.13
wR (%)	7.75	7.08	4.43	4.67	4.41	3.72	3.35	3.87	5.64	5.91
Phase	Phase Composition (wt.%)									
Albite										
Anatase	0.8	0.7	0.3	0.4	0.9	0.4	0.2	0.3	0.5	0.4
Anglesite										
Baryte			0.6	0.1		0.3	0.2	0.4	0.1	
Bassanite										
Chalcopyrite			0.9	2.0	0.6	0.9	0.3	0.4		
Clinochlore	3.6	4.9	3.7	5.0	4.5	2.3	1.3	2.1	0.6	1.2
Corkite			0.2							
Galena	0.1	0.1		0.1	0.1	0.1			0.1	
Gersdorffite					0.8					
Gypsum	5.5	12.2	25.8	38.3	35.8	58.2	70.7	48.1	11.6	27.3
Hematite	0.3	2.2	1.1	3.2	2.0	1.9	1.0	1.0	1.3	0.6
Illite/Muscovite	32.6	33.6	17.3	19.1	19.0	9.3	8.8	12.1	21.8	23.8
Kaolinite	2.8	3.1							4.9	2.8
Magnetite/ Ulvöspinel										
Pseudorutile										
Pyrite			0.8	0.7	0.4	0.3	0.1	0.2	0.1	
Quartz	18.6	22.0	2.8	1.2	9.1	2.2	0.9	0.5	15.4	13.2
Rutile	0.5	1.3	1.5	1.3	0.6	0.6	0.2	0.8	0.2	0.1
Scorodite									2.1	1.2
Siderite			0.2	1.0	0.3	0.1	0.1			
Wulfenite										
Amorphous	35.2	20.0	44.8	27.7	25.9	23.5	16.2	34.2	41.4	29.3

Table 3.1.13. Total phase composition including amorphous content (wt%) obtained with Rietveld refinement for the **06-SA09** to **06-SA17** samples. The final refinements are plotted in **Figures 5.121** to **5.129**.

	Unique Label								
	06-SA09	06-SA10	06-SA11	06-SA12	06-SA13	06-SA14A	06-SA15	06-SA16	06-SA17
Red. χ^2	6.73	7.84	7.14	3.72	9.55	11.43	10.46	14.17	5.27
wR (%)	5.67	6.28	5.83	5.03	7.74	8.12	7.45	8.29	8.19
Phase	Phase Composition (wt.%)								
Albite									
Anatase	0.4	0.4	0.6	0.5	0.6	0.7	0.6	0.7	0.8
Anglesite									
Baryte									
Bassanite			2.7	1.6					
Chalcopyrite									
Clinocllore	1.2	1.0	1.7	2.1	1.7	2.5	3.2	2.9	2.6
Corkite									
Galena	0.1						0.1		0.1
Gersdorffite									
Gypsum	25.8	22.1	19.6	23.7	16.0	9.6	13.6	13.3	3.3
Hematite	0.6	0.6	0.4	0.4	0.3	0.3	0.3	1.2	1.3
Illite/Muscovite	19.3	28.4	23.0	23.8	33.6	37.2	33.8	33.9	37.5
Kaolinite	4.5	2.7	1.7	2.5	3.4	4.3	3.8	3.0	5.0
Magnetite/ Ulvöspinel									
Pseudorutile									
Pyrite			0.2					0.2	
Quartz	26.6	7.5	28.4	14.9	11.8	13.2	15.7	19.2	11.0
Rutile		0.1		0.2	0.2	0.4	0.5	0.4	1.0
Scorodite	0.9	1.0		1.1					
Siderite									
Wulfenite									
Amorphous	20.6	36.2	21.7	29.3	32.6	31.9	28.6	25.4	37.6

Table 3.1.14. Total phase composition including amorphous content (wt%) obtained with Rietveld refinement for the **08-SA01** to **08-SA07** samples. The final refinements are plotted in **Figures 5.130 to 5.136**.

	Unique Label						
	08-SA01	08-SA02B	08-SA03	08-SA04	08-SA05	08-SA06	08-SA07
Red. χ^2	4.28	5.91	7.81	9.62	2.49	2.58	2.96
wR (%)	4.01	5.64	5.56	6.73	3.77	3.53	4.53
Phase	Phase Composition (wt.%)						
Albite							
Anatase	0.3	0.4	0.4	0.9	0.4	0.2	0.2
Anglesite							
Baryte	0.5					0.4	
Bassanite							
Chalcopyrite	1.6	1.4	1.7	1.2	2.3	0.4	0.1
Clinochlore	3.4	3.7	3.5	9.0	2.0	1.7	0.4
Corkite							
Galena	0.1	0.1	0.1		0.1		
Gersdorffite	0.3	2.4	1.3	0.7	0.3	0.1	
Gypsum	38.9	10.3	24.4	21.8	67.7	44.7	6.7
Hematite	0.5	0.4	1.1	1.2	0.5	0.4	0.8
Illite/Muscovite	15.3	20.4	19.7	26.4	10.8	11.0	11.3
Kaolinite							1.3
Magnetite/ Ulvöspinel				1.1			
Pseudorutile							
Pyrite	0.3	1.2	0.7	1.0	1.2	0.2	0.1
Quartz	4.4	37.0	23.8	14.3	3.0	1.0	58.7
Rutile	1.0	1.2	0.3	1.6	0.7	0.4	0.1
Scorodite							
Siderite		0.4	0.6	0.9	0.2		
Wulfenite							
Amorphous	33.4	21.1	22.5	20.1	10.9	39.5	20.4

3.2 ARSENIC K-EDGE X-RAY ABSORPTION SPECTROSCOPY

3.2.1 Arsenic K-edge X-ray Absorption Near-Edge Structure (XANES) Spectroscopy

The As K-edge XANES spectra of the samples are shown in **Figures 6.1** (TMF23-01 samples) and **6.2** (TMF23-03 samples), **6.3** (TMF23-06 samples), and **6.4** (TMF23-04 and TMF23-08 samples) in **Appendix 2**. The As K-edge XANES spectra of the standards are shown in **Figure 6.5** in **Appendix 2**. There are two major features in the As K-edge. The first feature (~11865–11875 eV) corresponds to a dipole allowed transition of a 1s electron into unoccupied 4p states. The absorption energy of this feature is sensitive to the oxidation state of arsenic, shifting to higher energy with increasing oxidation state [22]. For example, the representative As K-edge spectra shown in **Figure 6.6** in **Appendix 2** (top) contain three distinct peaks. When compared to arsenic standards of different oxidation states (**Figure 6.6** in **Appendix 2**, bottom), these three features are characteristic of As⁵⁺ (11874.2 eV), As³⁺ (11870.8 eV), and As¹⁻ (11867.5 eV). The relative intensities of these peaks vary from sample to sample, indicating changes in the overall relative composition of arsenic species. In general, the peak corresponding to As⁵⁺ peak is more intense in most samples, suggesting that the majority of arsenic in the samples is present as As⁵⁺.

The second major feature in the As K-edge is a broad feature found at higher absorption energy (~11875–11895 eV). This feature consists of significant contributions from multiple scattering resonances (MSR), which is a low-energy EXAFS phenomenon that is dependent on the local structure of the absorbing atom [23]. The lineshape of this feature varies from sample to sample, suggesting changes in speciation and crystallinity.

3.2.1.1 Linear Combination Fitting (LCF)

LCF analysis was used to identify and quantify the arsenic species present in the samples. Results of the LCF analysis are tabulated in **Tables 3.2.1** (TMF23-01 samples), **3.2.2** (TMF23-03 samples), **3.2.3** (TMF23-04 samples), **3.2.4** (TMF23-06 samples), and **3.2.5** (TMF23-08 samples). The fitted As K-edge XANES spectra are shown in **Figures 6.7 to 6.74** in **Appendix 2**. All fits had an R-factor less than 0.02, indicating a good quality fit, could be obtained using two or three components consisting of As⁵⁺, As³⁺ and/or As¹⁻ species. Good fits were obtained using gersdorffite (As¹⁻), arsenite-adsorbed ferrihydrite (As³⁺), ferric arsenate (As⁵⁺), and scorodite (As⁵⁺) as the standards. These results are consistent with previous work [1, 17, 21].

Table 3.2.1 A summary of the results of the LCF analysis of the **TMF23-01** sample series.

Unique Label	Ferric Arsenate (at%)	Scorodite (at%)	Arsenite-Ads. Ferrihydrite (at%)	Gersdorffite (at%)	R-factor (x10 ³)
01-SA01	63		22	14	3.0
01-SA02	54		6	40	3.2
01-SA03	39		17	44	1.0
01-SA04	76		23		3.1
01-SA05	66		25	10	1.4
01-SA06	82		18		3.0
01-SA07	58	30	13		2.7
01-SA08	76		24		2.4
01-SA09A	47		16	38	4.9
01-SA09B	67		21	13	3.0
01-SA10	73		27		2.3
01-SA11	31	47	22		2.8
01-SA12	49		51		3.2
01-SA13	37	24	39		3.9
01-SA14A	41		46	13	1.4
01-SA14B	56		38	7	1.5
01-SA15	53	19	28		3.7
01-SA16	71		29		4.1
01-SA17		41	16	43	2.7
01-SA18	57		43		1.9
01-SA19	16	51	33		1.5

Table 3.2.2 A summary of the results of the LCF analysis of the **TMF23-03** sample series.

Unique Label	Ferric Arsenate (at%)	Scorodite (at%)	Arsenite-Ads. Ferrihydrite (at%)	Gersdorffite (at%)	R-factor (x10 ³)
03-SA01	42	22		36	3.7
03-SA02	45	55			4.2
03-SA03	53		11	36	1.8
03-SA04	67		18	15	1.7
03-SA05	69		8	23	4.9
03-SA06	65		14	21	5.5
03-SA07	69		31		1.6
03-SA08	46	45	9		2.3
03-SA09	33	46	21		1.7
03-SA10	20	68	12		2.2
03-SA11	43	45	12		1.9
03-SA12	75		14	11	2.0
03-SA13	76		24		1.8

03-SA14	64	28	8	1.2
03-SA15	61	39		1.6
03-SA16	51	49		3.1
03-SA17	64	36		2.5
03-SA18	61	39		2.4
03-SA19B	55	36	10	1.6
03-SA20	61	39		1.4
03-SA21	73	27		1.9

Table 3.2.3 A summary of the results of the LCF analysis of the **TMF23-04** sample series.

Unique Label	Ferric Arsenate (at%)	Scorodite (at%)	Arsenite-Ads. Ferrihydrite (at%)	Gersdorffite (at%)	R-factor (x10³)
04-SA20	72		28		5.9
04-SA21	74		26		4.5

Table 3.2.4 A summary of the results of the LCF analysis of the **TMF23-06** sample series.

Unique Label	Ferric Arsenate (at%)	Scorodite (at%)	Arsenite-Ads. Ferrihydrite (at%)	Gersdorffite (at%)	R-factor (x10³)
06-SA01	64		21	15	1.4
06-SA02	75		14	11	1.5
06-SA03	26		7	67	2.5
06-SA04	63		15	22	1.1
06-SA05	64		17	19	1.2
06-SA06	80		7	13	1.2
06-SA07	40	32	28		2.0
06-SA08	46	27	27		5.1
06-SA09	83		17		1.8
06-SA10	43	36	21		1.6
06-SA11	83		17		1.7
06-SA12	58	26	17		1.5
06-SA13	44	29	27		1.5
06-SA14	64		36		2.4
06-SA15	67		33		1.5
06-SA16	66		34		2.6
06-SA17	70		30		2.2

Table 3.2.5 A summary of the results of the LCF analysis of the **TMF23-08** sample series.

Unique Label	Ferric Arsenate (at%)	Scorodite (at%)	Arsenite-Ads. Ferrihydrite (at%)	Gersdorffite (at%)	R-factor (x10 ³)
08-SA01		85		15	7.9
08-SA02B		34		66	3.4
08-SA03		22		78	6.6
08-SA04		35	18	48	3.5
08-SA05	54		12	35	3.9
08-SA06	56		18	26	1.5
08-SA07		82		18	10.2

The majority of the arsenic in the tailings samples exists as As⁵⁺ species and is observed in all samples. The As⁵⁺ species in the samples were best represented by ferric arsenate (FeAsO₄·xH₂O) and scorodite in the LCF. Good fits could also be obtained using arsenate adsorbed on ferrihydrite (AsO₄-Fe(OH)₃), as illustrated in **Figure 6.75** in **Appendix 2**. The overall results are consistent with previous XANES analysis of the tailings samples, which indicated that the As⁵⁺ content in the tailings samples consisted of a non-crystalline (i.e. ferric arsenate) and crystalline component (i.e. scorodite) [1,21]. The concentration of ferric arsenate ranged from 26–83 %. The concentration of scorodite ranged from 19–85 %. Relatively higher concentrations of scorodite was observed in the **TMF23-08** sample set. Note that scorodite was observed in several of the same samples in PXRD analysis (see **Section 3.1**), particularly with respect to the **TMF23-03** and **TMF23-06** sample sets. Scorodite was not found in the PXRD analysis of the **TMF23-08** sample set.

As³⁺ species were best represented by arsenite adsorbed on ferrihydrite (AsO₄-Fe(OH)₃) in the fits and was observed in most samples with a concentration range of 6–51 %. Relatively higher concentrations of arsenite adsorbed on ferrihydrite was observed in the **TMF23-01** and **TMF23-03** sample sets.

As¹⁻ species were best represented by gersdorffite in the fits and was observed in all sample sets except **TMF23-04** with a concentration range of 7–78 %. Gersdorffite was also the only arsenide species observed in the PXRD analysis (see **Section 3.1**), Good fits could be obtained using other As¹⁻ standards in samples containing a low concentration of As¹⁻ (less than 20 at%). However, as shown in **Figure 6.76** in **Appendix 2**, better fits were obtained using gersdorffite as the As¹⁻ standard in samples containing high concentrations of As¹⁻.

3.3 ARSENIC K-EDGE EXTENDED X-RAY ABSORPTION FINE STRUCTURE (EXAFS) SPECTROSCOPY

The As K-edge EXAFS spectra were analysed to obtain information on the local coordination environment of As atoms in the tailings samples. The As K-edge EXAFS spectra (k-space and R-space) of the **04-SA20** and **04-SA21** and representative standard (i.e. scorodite, ferric arsenate, arsenate adsorbed on ferrihydrite, and arsenite adsorbed on ferrihydrite) are shown in **Figures 7.1** in **Appendix 3**. Standards were selected based on the results of the LCF analysis, which indicated that both samples consisted of arsenite and arsenate species (see **Section 3.2**). The background subtracted k-space As K-edge EXAFS spectra (**Figure 7.1a** in **Appendix 3**) of the samples have very similar lineshapes arsenate-adsorbed ferrihydrite. However, XANES analysis indicated that both samples consisted of ~30% arsenite species which may result in broadening of features in the k-space EXAFS spectra. The R-space As K-edge EXAFS spectra (**Figure 7.1b** in **Appendix 3**) of the samples consists of two major features corresponding to the first (~1.4

Å) and second (~2.3–2.9 Å) coordination shells around the absorbing As atoms. For the iron-based arsenates, the first shell corresponds to a As-O scattering path and the second coordination sphere corresponds to As-Fe scattering paths [24,25]. Note that the As-O scattering path is slightly longer for arsenite species compared to arsenate species. The Fe-As scattering path length varies depending on the crystallinity and arsenic oxidation state. For example, scorodite contain the longest As-Fe single scattering paths an arsenite adsorbed on ferrihydrite has the shorter Fe-As single scattering paths.

The As K-edge EXAFS spectra of **04-SA20** and **04-SA21** were fitted to determine the structural parameters for the various scattering paths. Results of the EXAFS fittings of the arsenate standards Results of the EXAFS fittings are shown in **Table 3.3.1**. Results from the As K-edge EXAFS fitting of the standards, obtained from previous studies, are also shown in **Table 3.3.1** for comparison [25,26]. The fitted As K-edge EXAFS spectra (k-space and R-space) are shown in **Figures 7.2** and **7.3** in **Appendix 3**. The R-factor for all fits was less than 0.05, indicating good quality fits. Fits were performed allowing the coordination number N to vary due to the presence of multiple arsenic species (arsenite and arsenate species) in both samples. S_0^2 and ΔE_0 were fixed parameters that were determined by fitting the As K-edge EXAFS spectrum of scorodite (not shown). An As-O-O multiple scattering (MS) path was also included in the fits based on previous work [24, 25]. The parameters for the multiple scattering path were constructed using geometric considerations and based on the mean square relative displacement of the first shell single scattering paths and therefore did not require any additional variables for modelling.

Table 3.3.1. Summary of EXAFS fitting results.

Standard or Sample	N ^a	R (Å) ^b	σ^2 (Å ²)	S_0^2	ΔE_0 (eV)	R-factor
04-SA20				0.93 ^c	2.04 ^c	0.021
As-O	3.7	1.70	0.001			
As-Fe	0.3	2.88	0.008			
As-Fe	1.2	3.31	0.008			
As-O-O (MS)	12 ^c	3.18	0.004			
04-SA21				0.93 ^c	2.04 ^c	0.023
As-O	3.7	1.69	0.001			
As-Fe	0.2	2.87	0.006			
As-Fe	1.3	3.32	0.006			
As-O-O (MS)	12 ^c	3.15	0.005			
Scorodite^d				1.06	6.66	0.013
As-O	4 ^c	1.69	0.003			
As-Fe	3	3.38	0.006			
As-Fe	1	3.42	0.006			
Ferric Arsenate^d				1.06	6.66	0.038
As-O	4 ^c	1.68	0.003			
As-Fe	4	3.33	0.011			
As-O-O (MS1)	12	3.21	0.003			
As-O-O (MS2)	3	3.36	0.011			
Arsenate Adsorbed on Ferrihydrite^d				1.06	6.66	0.029
As-O	4 ^c	1.70	0.003			
As-Fe	2	3.31	0.008			
As-O-O (MS)	12	3.21	0.003			
Arsenite Adsorbed on Ferrihydrite^e					18	
As-O	2.8	1.76	0.007			
As-Fe	0.6	2.92	0.009			
As-Fe	0.98	3.40	0.009			

As-O-O (MS)	6	3.15
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^aN = $\pm 20\%$

^bR = ± 0.02 Å

^cFixed Parameter

^dsee Ref 25

^esee Ref 26

The first shell for both samples was best fitted to As-O single scattering path with a path length of 1.69-1.70 Å, which is consistent with the presence of arsenate species. The As-O coordination number was determined to be 3.7 for both samples. The As-O coordination number is slightly less than that expected for arsenate species, which is typically 4 for the tetrahedral [AsO₄]³⁻ anion [24,25]. The lower coordination number is likely a consequence of the minor arsenite species present in both samples. As³⁺ cations in the arsenite anion have a coordination number of 3. Attempts were made to fit the As K-edge EXAFS spectra of the samples to a second As-O single scattering path to account for the arsenite species. However, the inclusion of a second component in the fit resulted in a minimal decrease in the R-factor. This is likely a consequence of the broad first coordination shell peak in the EXAFS spectra.

The second shell for both samples was best fitted to two As-Fe scattering paths with path lengths of 2.87-2.88 Å and 3.31-3.32 Å. The longer As-Fe single scattering path is similar to that observed in ferric arsenate (3.33 Å) and arsenate adsorbed on ferrihydrite (3.31 Å) [25]. Interestingly, the coordination number is significantly less at 1.3 (**04-SA20**) and 1.2 (**04-SA21**). This may again be due to the minor arsenite species in the sample. Arsenite adsorbed on ferrihydrite exhibits a As-Fe single scattering path at 3.40 Å with a coordination number of 1 [26]. Note that the shorter As-Fe single scattering path 2.87-2.88 Å is similar to that observed in arsenite adsorbed on ferrihydrite. Regardless, the longer As-Fe single scattering path is shorter than the As-Fe single scattering path expected for scorodite (3.38 Å), suggesting that scorodite is not present in either sample. Overall, the EXAFS analysis of samples **04-SA20** and **04-SA21** indicated that arsenite species are likely present as minor species and arsenate species in the samples are more structurally similar to arsenate adsorbed on ferrihydrite and ferric arsenate.

4.0 REFERENCES

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5.0 APPENDIX 1: PXRD FIGURES

Table 5.1. Names, formulas, PDF entry numbers and unit cell information tabulated for representative examples of the main minerals observed or considered with PXRD in this work.

Mineral Name, Formula (PDF Number)	Crystallographic Unit Cell
Albite, NaAlSi ₃ O ₈ (01-083-1606)	Triclinic, C-1 (2) a = 8.161(1) Å, b = 12.875(2) Å, c = 7.110(1) Å, α = 93.53(1)°, β = 116.46(1)°, γ = 90.24(1)°
Anatase, TiO ₂ (01-084-1285)	Tetragonal, I4 ₁ /amd (141) a = 3.78479(3) Å, c = 9.51237(12) Å
Anglesite, PbSO ₄ (01-075-6774)	Orthorhombic, Pbnm (62) a = 6.9549(9) Å, b = 8.4723(11) Å, c = 5.3973(8) Å
Baryte, BaSO ₄ (04-007-7651)	Orthorhombic, Pnma (62) a = 8.848(2) Å, b = 5.441(1) Å, c = 7.132(1) Å
Bassanite, CaSO ₄ ·0.5H ₂ O (01-087-2787)	Monoclinic, I2 (5) a = 12.0350(5) Å, b = 6.9294(3) Å, c = 12.6705(4) Å, β = 90.266(3)°
Chalcopyrite, CuFeS ₂ (01-075-6866)	Tetragonal, I-42d (122) a = 5.289(1) Å, c = 10.423(1) Å
Clinochlore-1M, Mg _{4.56} Mn _{0.01} Fe _{0.46} Al _{2.12} Si _{2.85} O ₁₀ (OH) ₈ (04-022-0007)	Monoclinic, C2/m (12) a = 5.327(2) Å, b = 9.227(2) Å, c = 14.327(5) Å, β = 96.81(3)°
Corkite, PbFe ₃ (PO ₄)(SO ₄)(OH) ₆ (04-012-6225)	Rhombohedral, R3m (160) a = 7.280(1) Å, c = 16.821(1) Å
Galena, PbS (04-004-4329)	Cubic, Fm-3m (225) a = 5.934(1) Å
Gersdorffite, NiAsS (01-071-4757)	Cubic, P2 ₁ 3 (198) a = 5.69 Å
Gersdorffite, NiAs _{1.23} S _{0.77} (04-011-6592)	Cubic, Pa-3 (205) a = 5.7053(3) Å
Gypsum, CaSO ₄ ·2H ₂ O (04-010-9409)	Monoclinic, C2/c (15) a = 6.284(1) Å, b = 15.200(1) Å, c = 6.523(1) Å, β = 127.41(1)°
Hematite, Fe ₂ O ₃ (01-073-3825)	Rhombohedral, R-3c (167) a = 5.03794(3) Å, c = 13.738987(3) Å

Table 5.1. (cont.) Names, formulas, PDF entry numbers and unit cell information tabulated for representative examples of the main minerals observed or considered with PXRD in this work.

Mineral Name, Formula (PDF Number)	Crystallographic Unit Cell
Illite, $K_{0.7}Na_{0.01}Ca_{0.01}Mg_{0.15}Fe_{0.04}Al_{2.59}Si_{3.27}O_{10}(OH)_2$ (04-017-0520)	Monoclinic, C2 (5) $a = 5.1973(9) \text{ \AA}$, $b = 8.999(1) \text{ \AA}$, $c = 10.147(2) \text{ \AA}$, $\beta = 99.00(1)^\circ$
Ilmenite, $TiFeO_3$ (04-002-2594)	Rhombohedral, R-3 (148) $a = 5.0832 \text{ \AA}$, $c = 14.0256 \text{ \AA}$
Kaolinite, $Al_2Si_2O_5(OH)_4$ (01-080-0885)	Triclinic, C1 (1) $a = 5.1555(9) \text{ \AA}$, $b = 8.9438(16) \text{ \AA}$, $c = 7.4051(12) \text{ \AA}$, $\alpha = 91.70(1)^\circ$, $\beta = 104.84(1)^\circ$, $\gamma = 89.83(2)^\circ$
Magnetite, Fe_3O_4 (04-005-4319)	Cubic, Fd-3m (227) $a = 8.3958(2) \text{ \AA}$
Muscovite-2M1, $KAl_2.9Si_{3.1}O_{10}(OH)_2$ (01-084-1302)	Monoclinic, C2/c (15) $a = 5.200(4) \text{ \AA}$, $b = 9.021(7) \text{ \AA}$, $c = 20.07(2) \text{ \AA}$, $\beta = 95.71(7)^\circ$
Pseudorutile, $Ti_{8.33}Fe_{5.56}O_{25}$ (04-011-6764)	Hexagonal, P6 ₃ 22 (182) $a = 14.375(6) \text{ \AA}$, $c = 4.615(3) \text{ \AA}$
Pyrite, FeS_2 (04-006-6835)	Cubic, Pa-3 (205) $a = 5.4188(8) \text{ \AA}$
Quartz, SiO_2 (04-014-7568)	Hexagonal, P3 ₂ 21 (154) $a = 4.91502(2) \text{ \AA}$, $c = 5.40684(2) \text{ \AA}$
Rutile, TiO_2 (04-003-0648)	Tetragonal, P4 ₂ /mnm (136) $a = 4.594(3) \text{ \AA}$, $c = 2.959(2) \text{ \AA}$
Scorodite, $FeAsO_4(H_2O)_2$ (04-014-7858)	Orthorhombic, Pbca (61) $a = 8.942(7) \text{ \AA}$, $b = 10.075(8) \text{ \AA}$, $c = 10.339(8) \text{ \AA}$
Siderite, $FeCO_3$ (04-015-6716)	Rhombohedral, R-3c (167) $a = 4.6916(4) \text{ \AA}$, $c = 15.3796(16) \text{ \AA}$
Ulvöspinel, $Ti_{0.755}Fe_{2.245}O_4$ (04-016-9477)	Cubic, Fd-3m (227) $a = 8.5079(4) \text{ \AA}$
Wulfenite, $PbMoO_4$ (04-006-0107)	Tetragonal, I4 ₁ /a (88) $a = 5.424 \text{ \AA}$, $c = 12.076 \text{ \AA}$

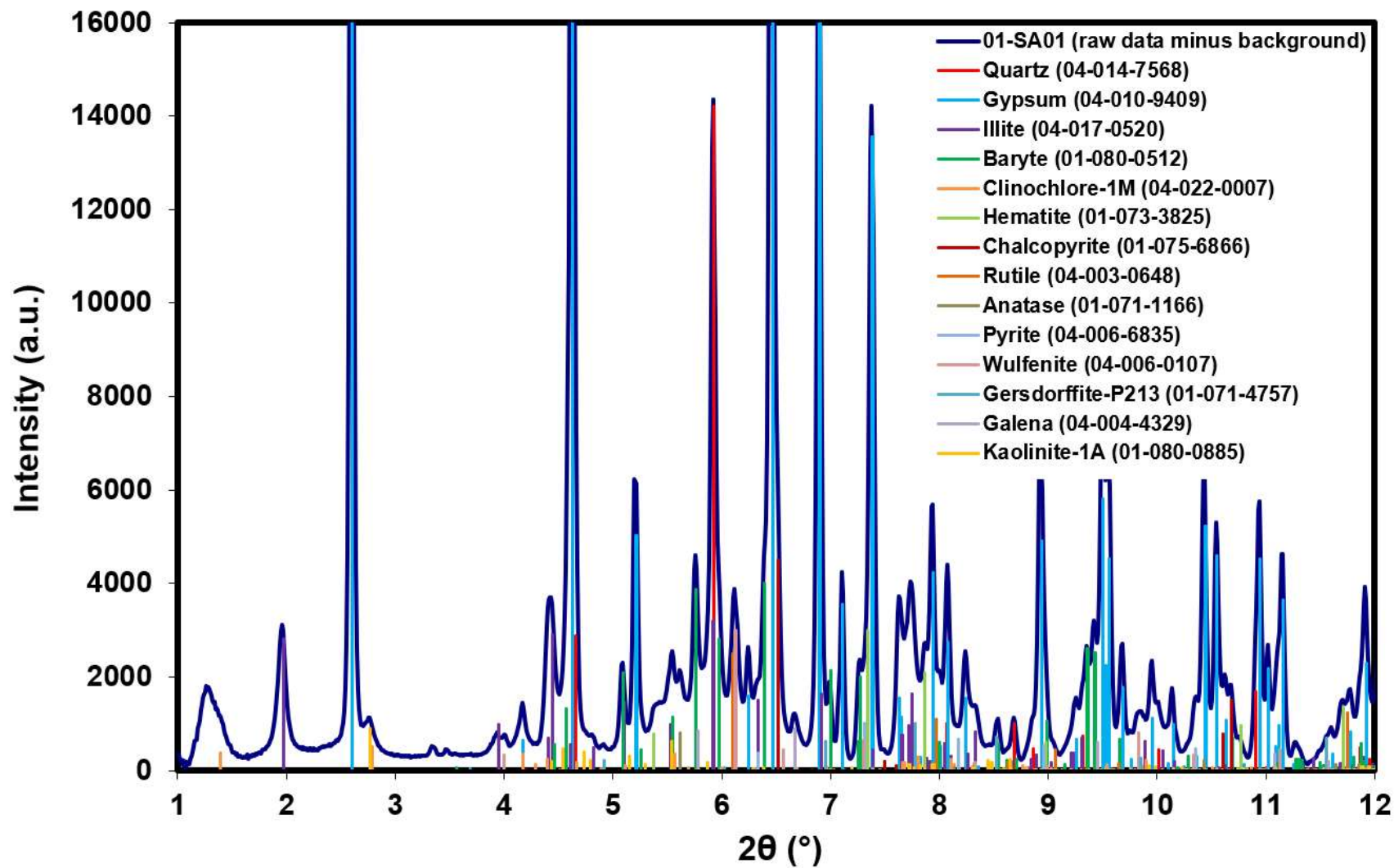


Figure 5.1. Phase identification results obtained for **01-SA01**, focusing on the low angle region near the background.

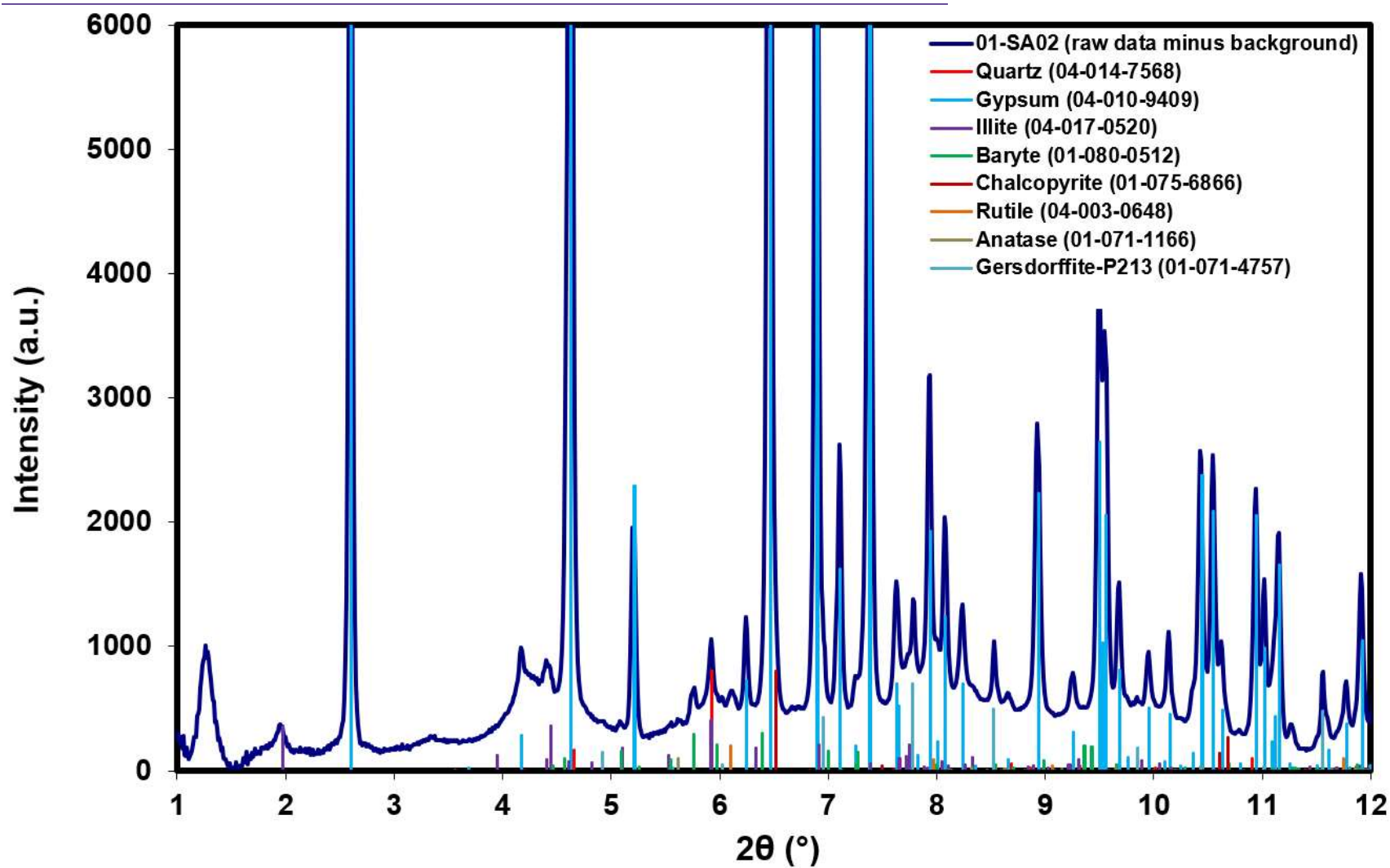


Figure 5.2. Phase identification results obtained for **01-SA02**, focusing on the low angle region near the background.

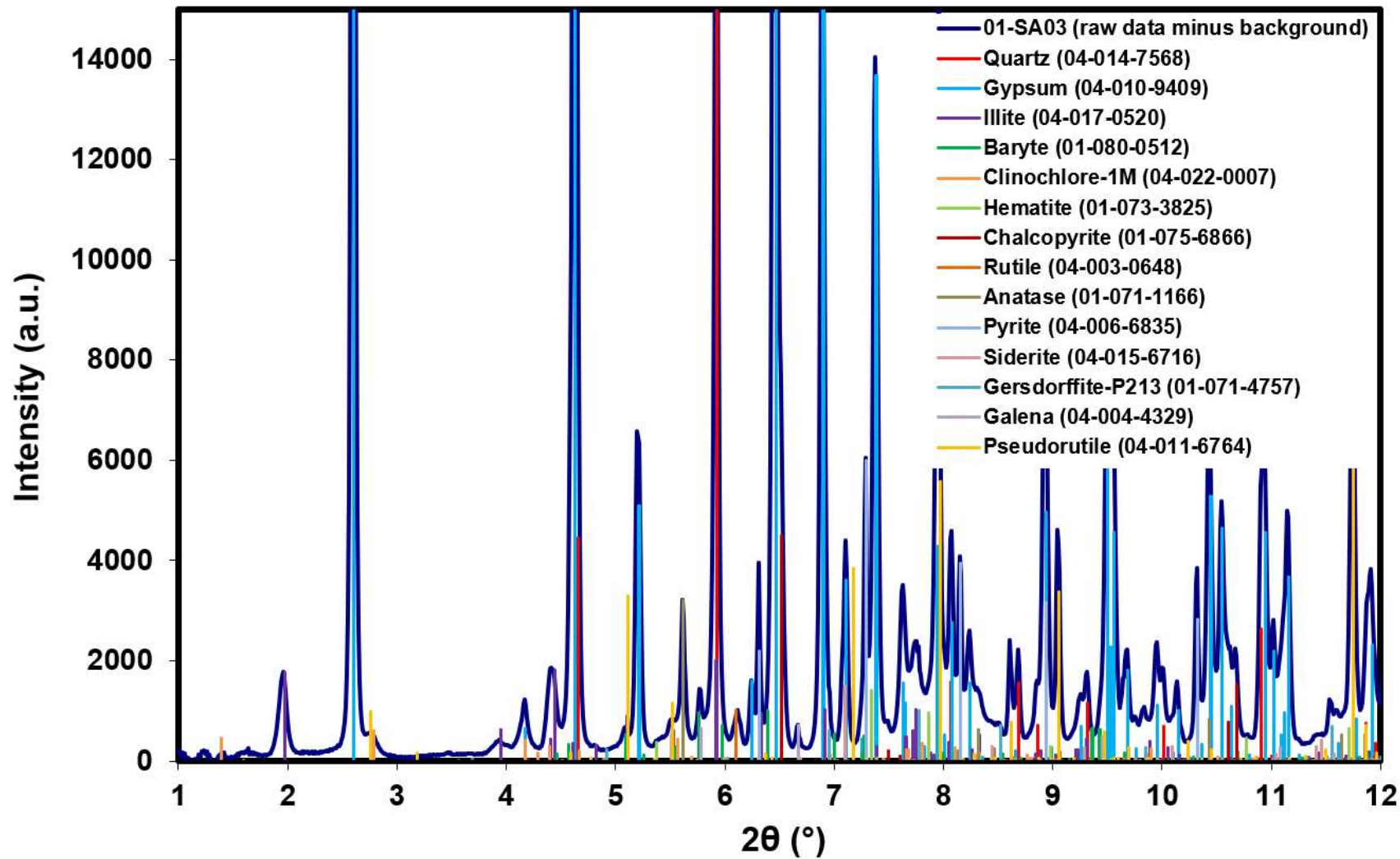


Figure 5.3. Phase identification results obtained for **01-SA03**, focusing on the low angle region near the background.

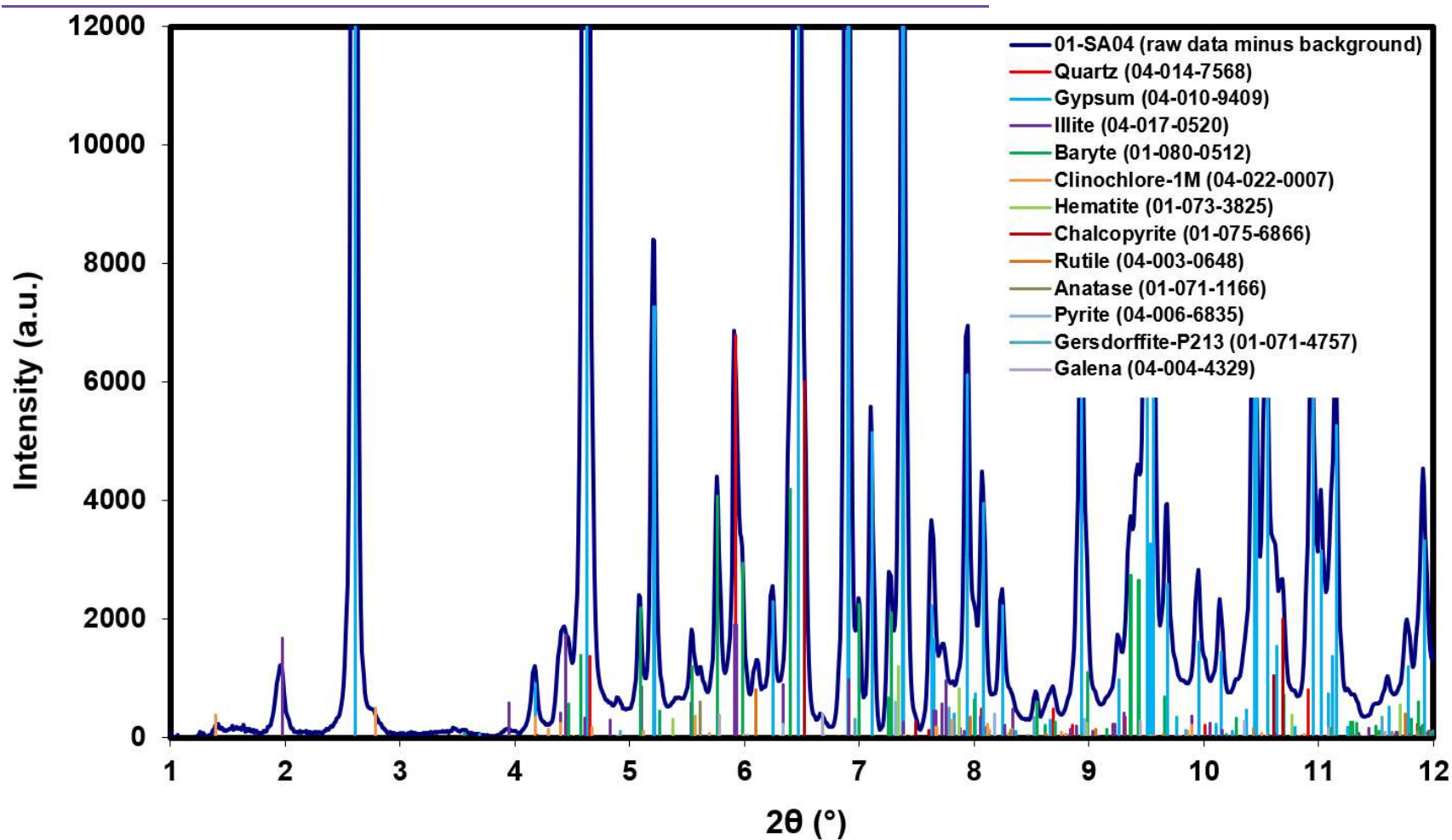


Figure 5.4. Phase identification results obtained for **01-SA04**, focusing on the low angle region near the background.

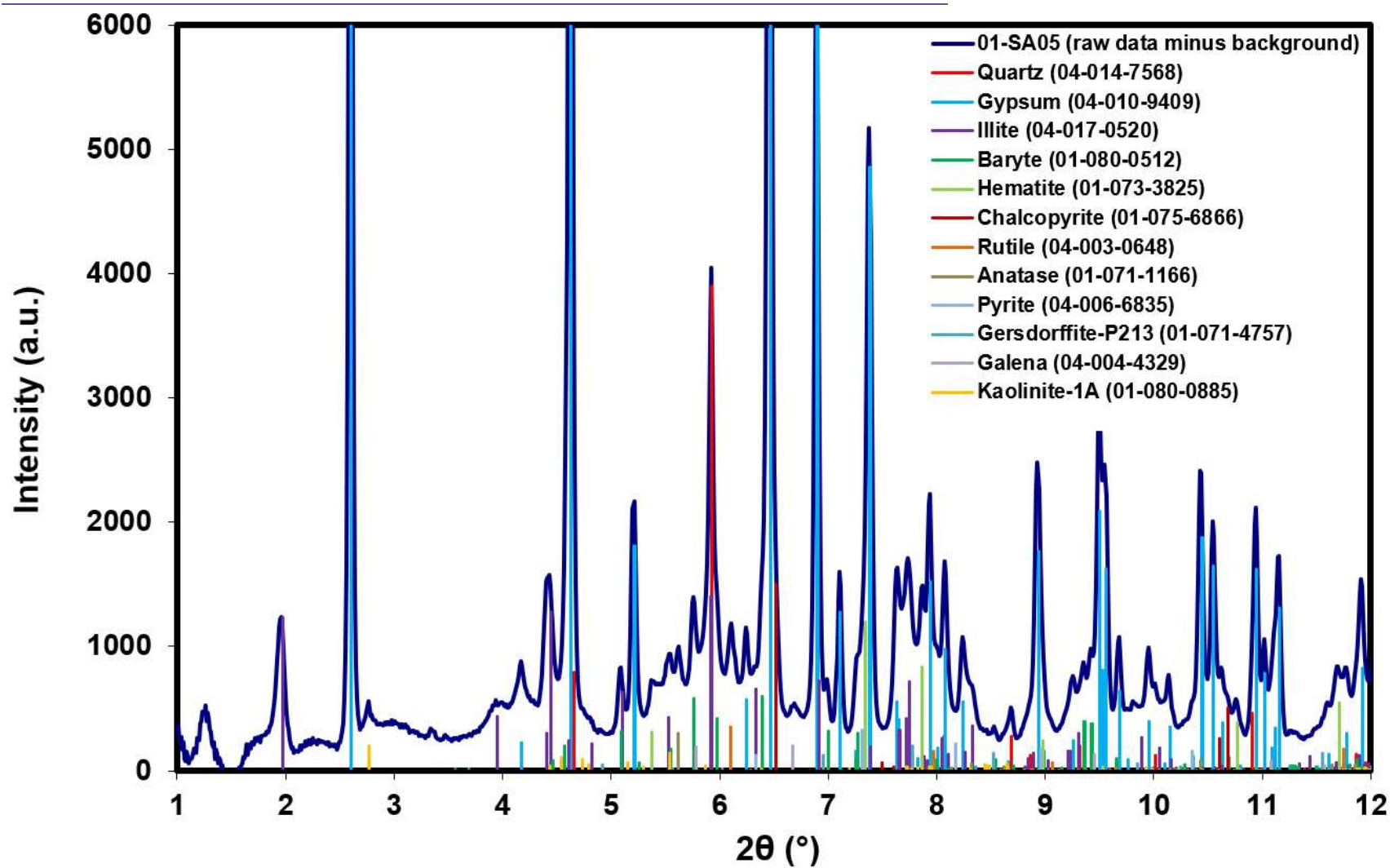


Figure 5.5. Phase identification results obtained for **01-SA05**, focusing on the low angle region near the background.

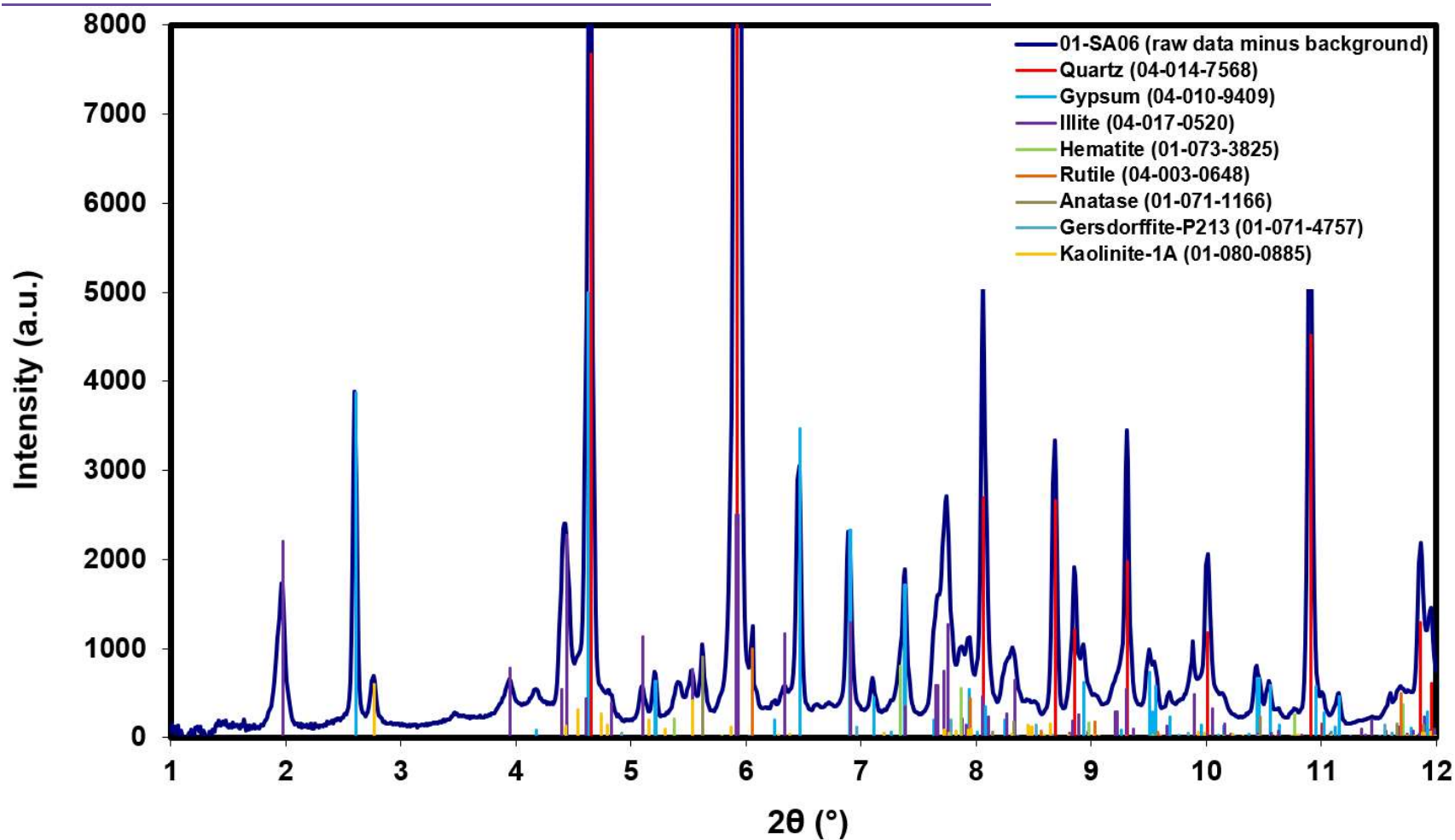


Figure 5.6. Phase identification results obtained for **01-SA06**, focusing on the low angle region near the background.

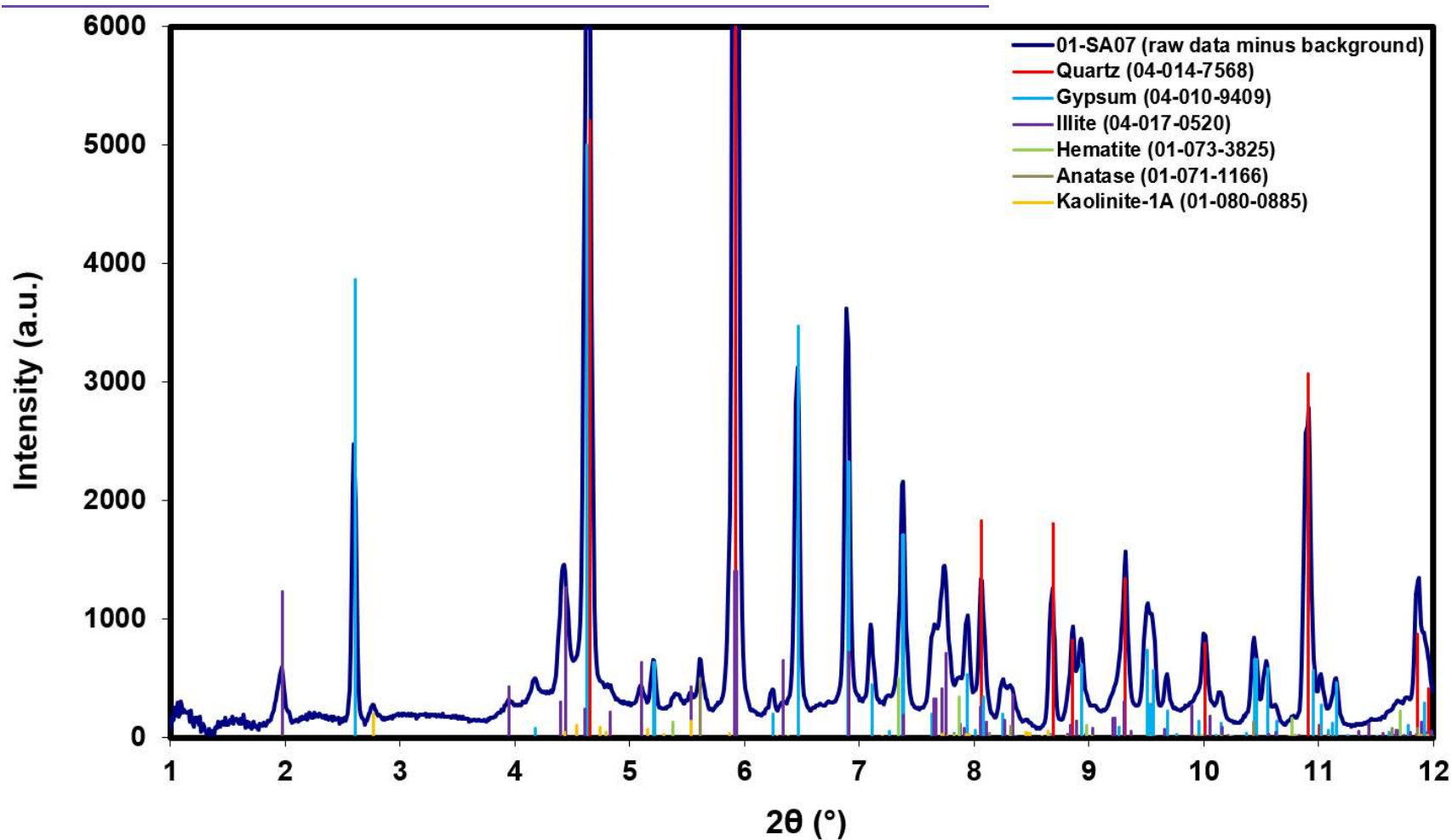


Figure 5.7. Phase identification results obtained for **01-SA07**, focusing on the low angle region near the background.

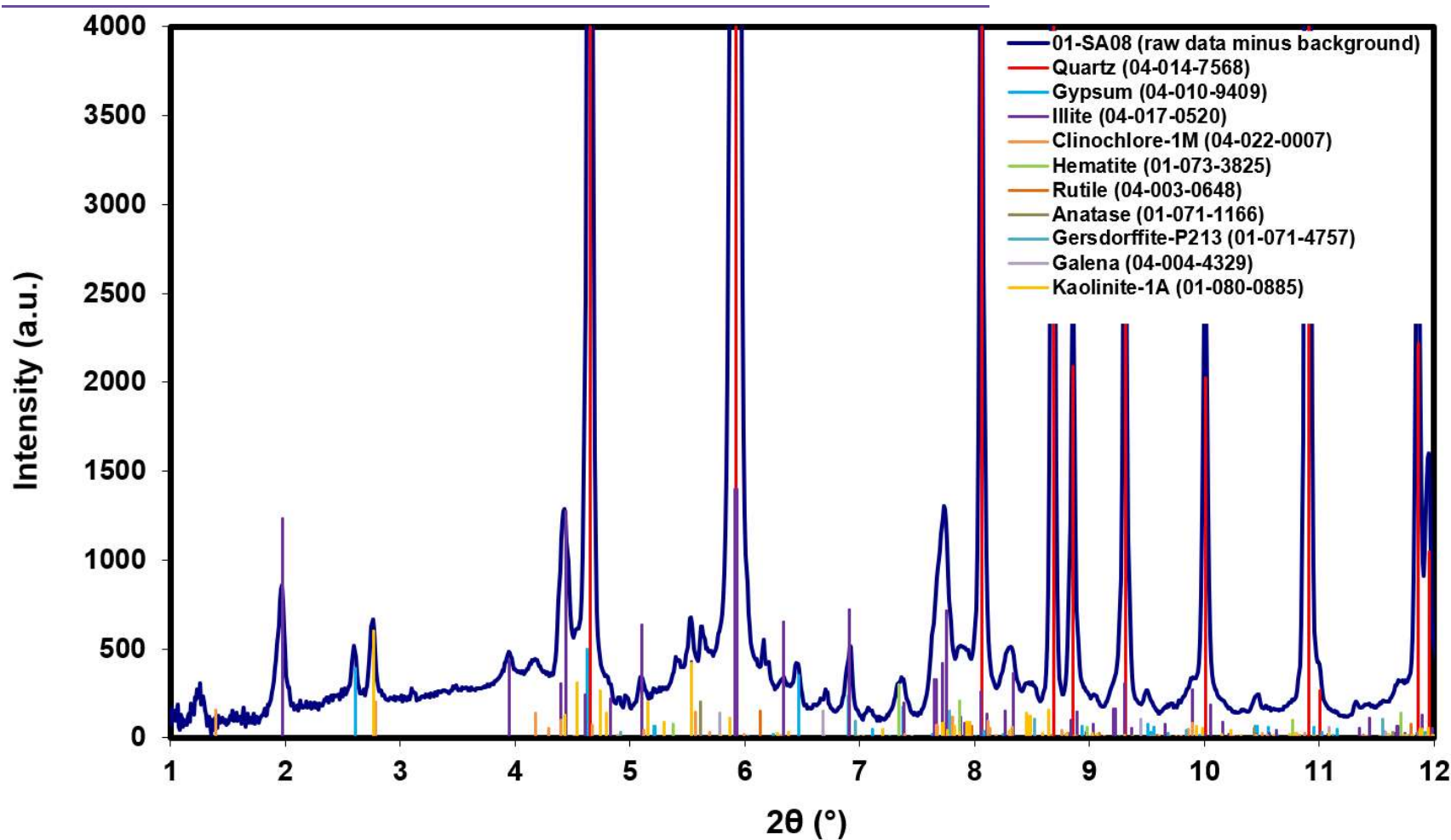


Figure 5.8. Phase identification results obtained for **01-SA08**, focusing on the low angle region near the background.

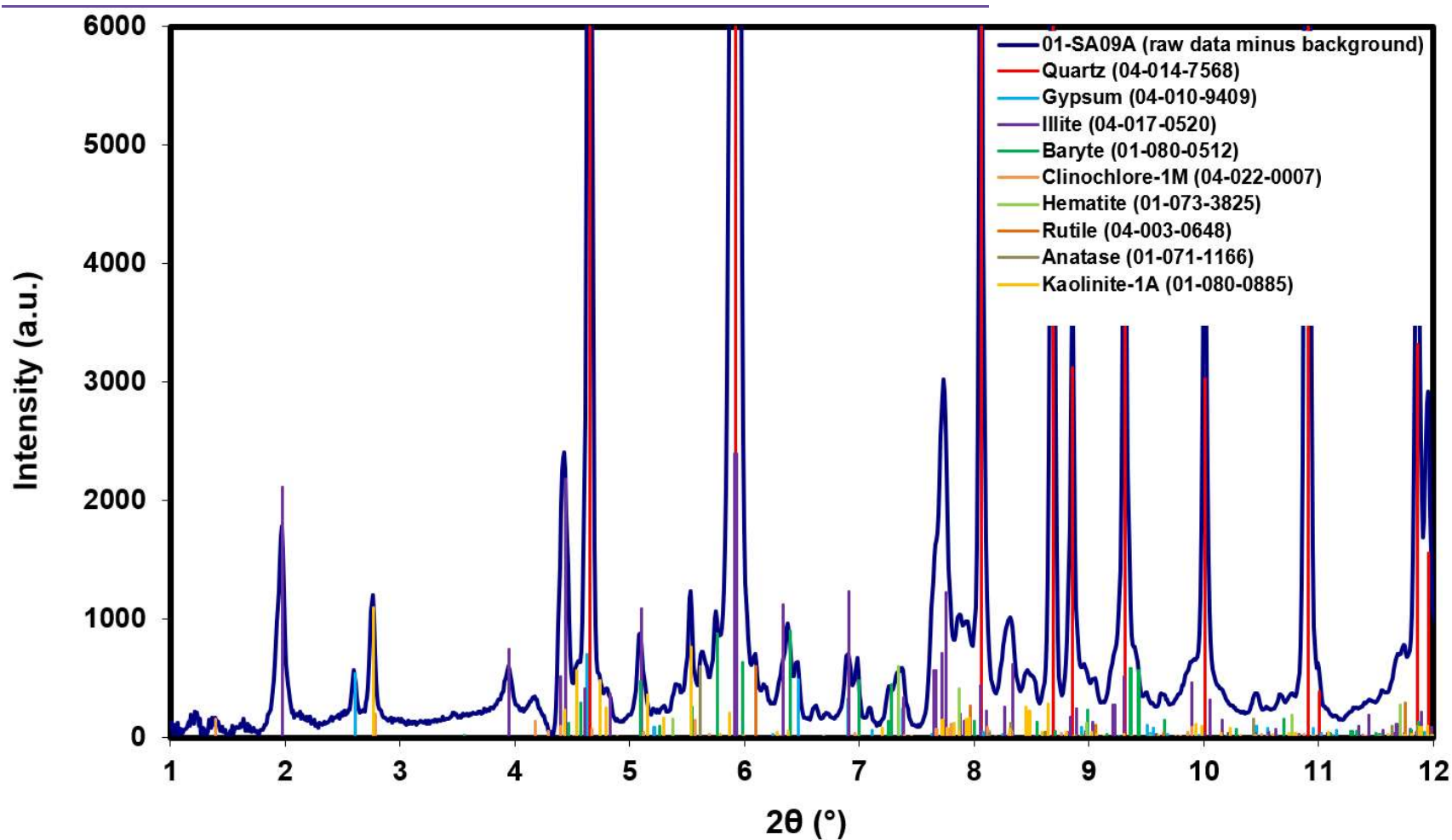


Figure 5.9. Phase identification results obtained for **01-SA09A**, focusing on the low angle region near the background.

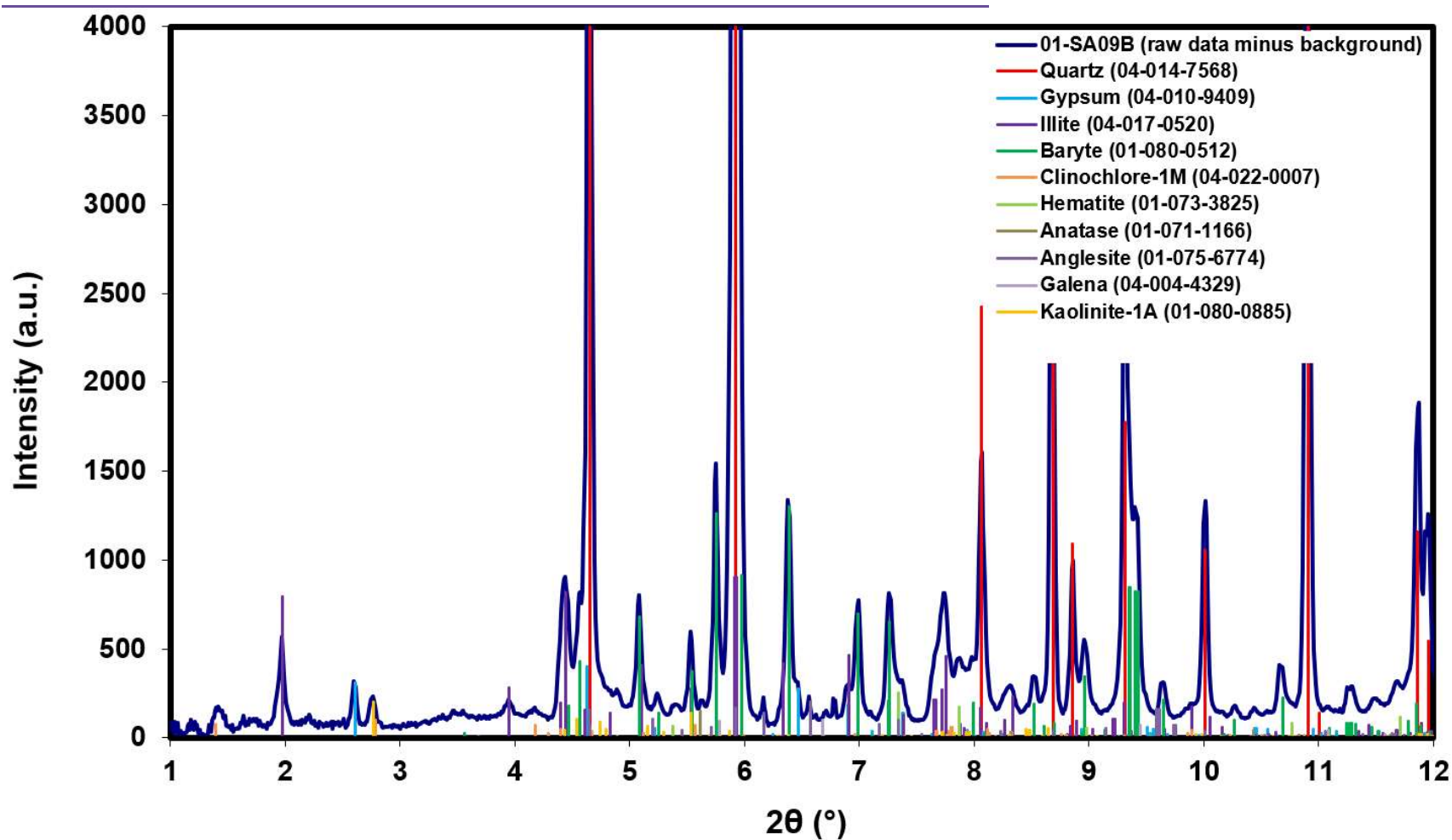


Figure 5.10. Phase identification results obtained for **01-SA09B**, focusing on the low angle region near the background.

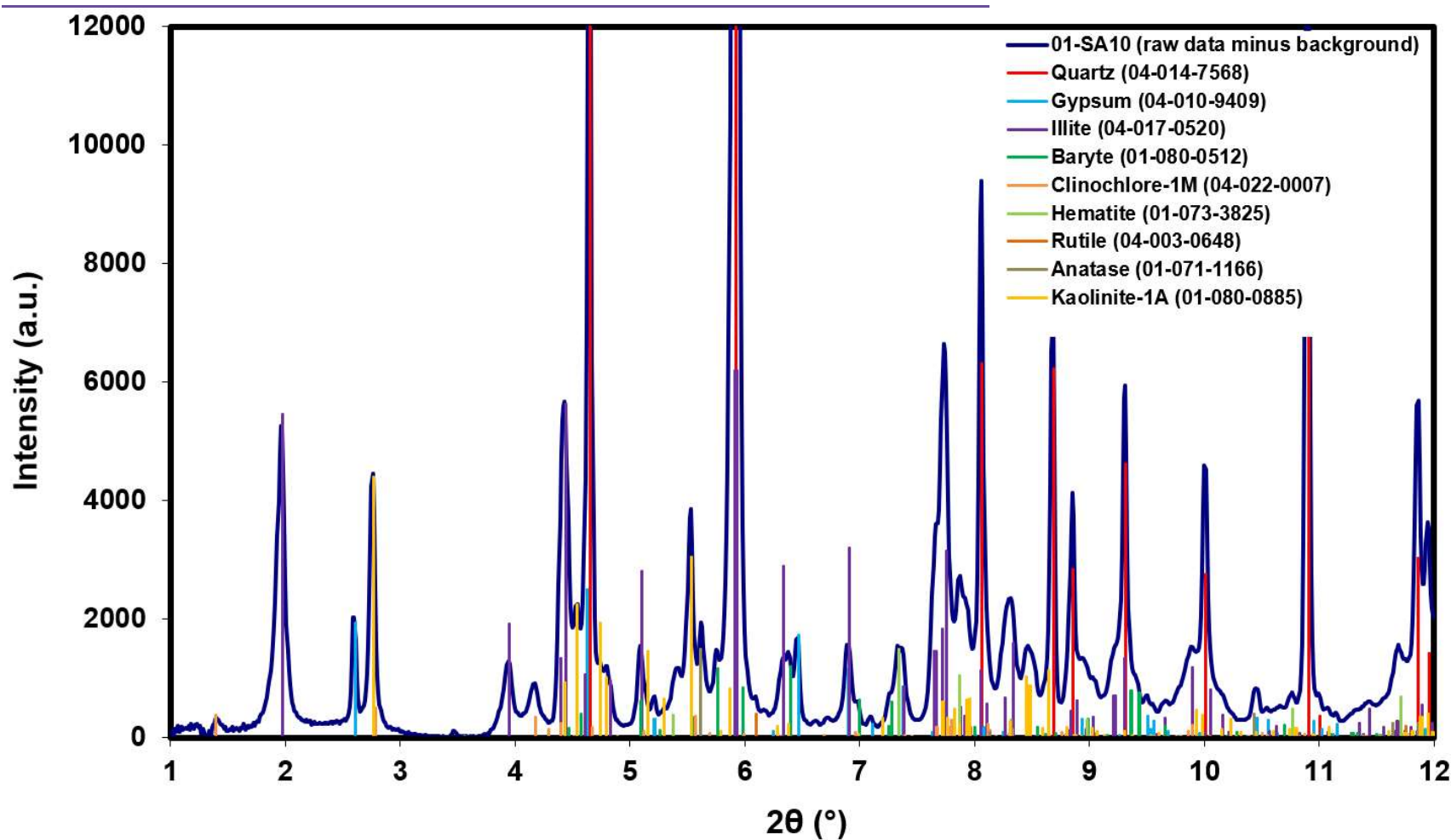


Figure 5.11. Phase identification results obtained for **01-SA10**, focusing on the low angle region near the background.

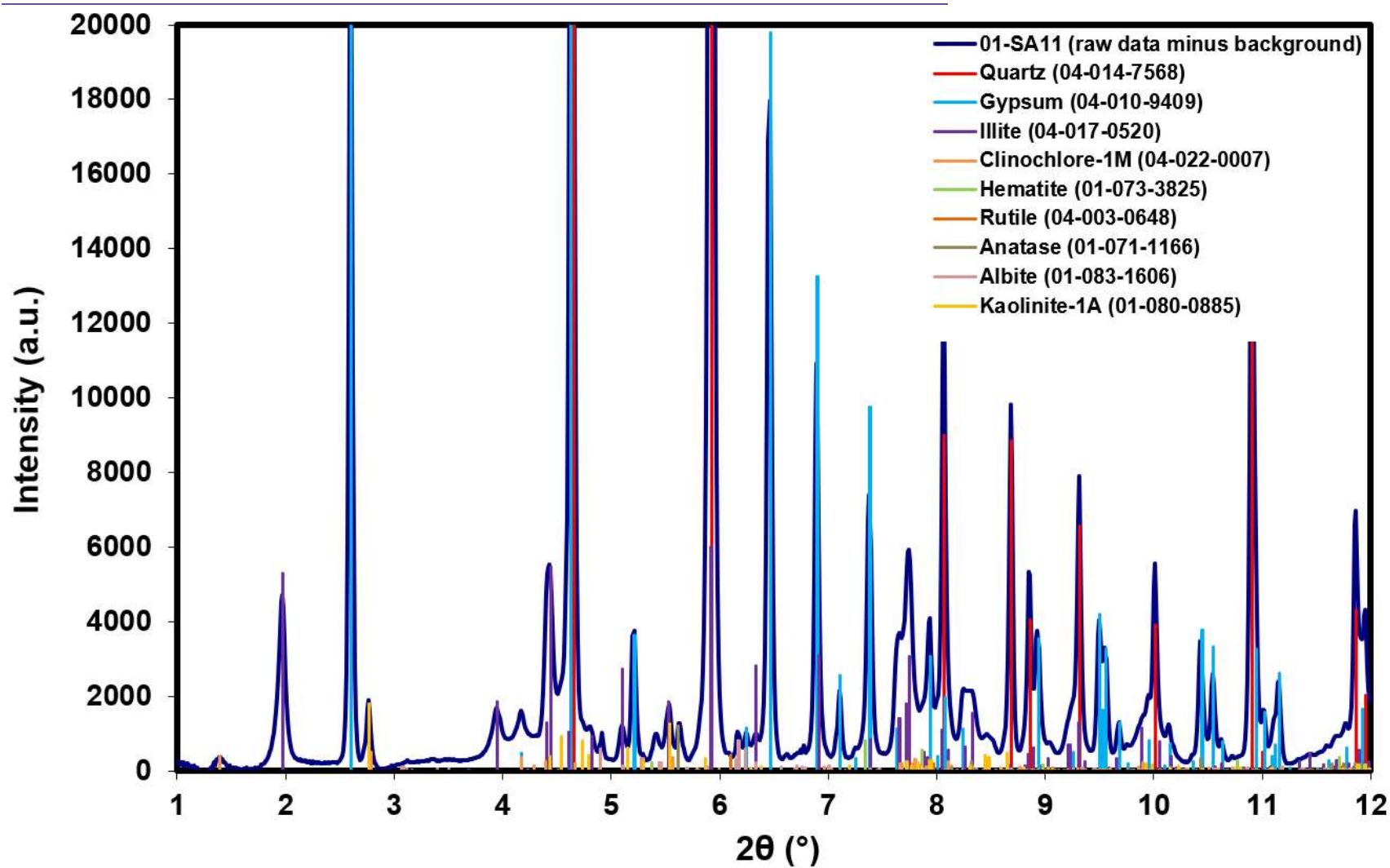


Figure 5.12. Phase identification results obtained for **01-SA11**, focusing on the low angle region near the background.

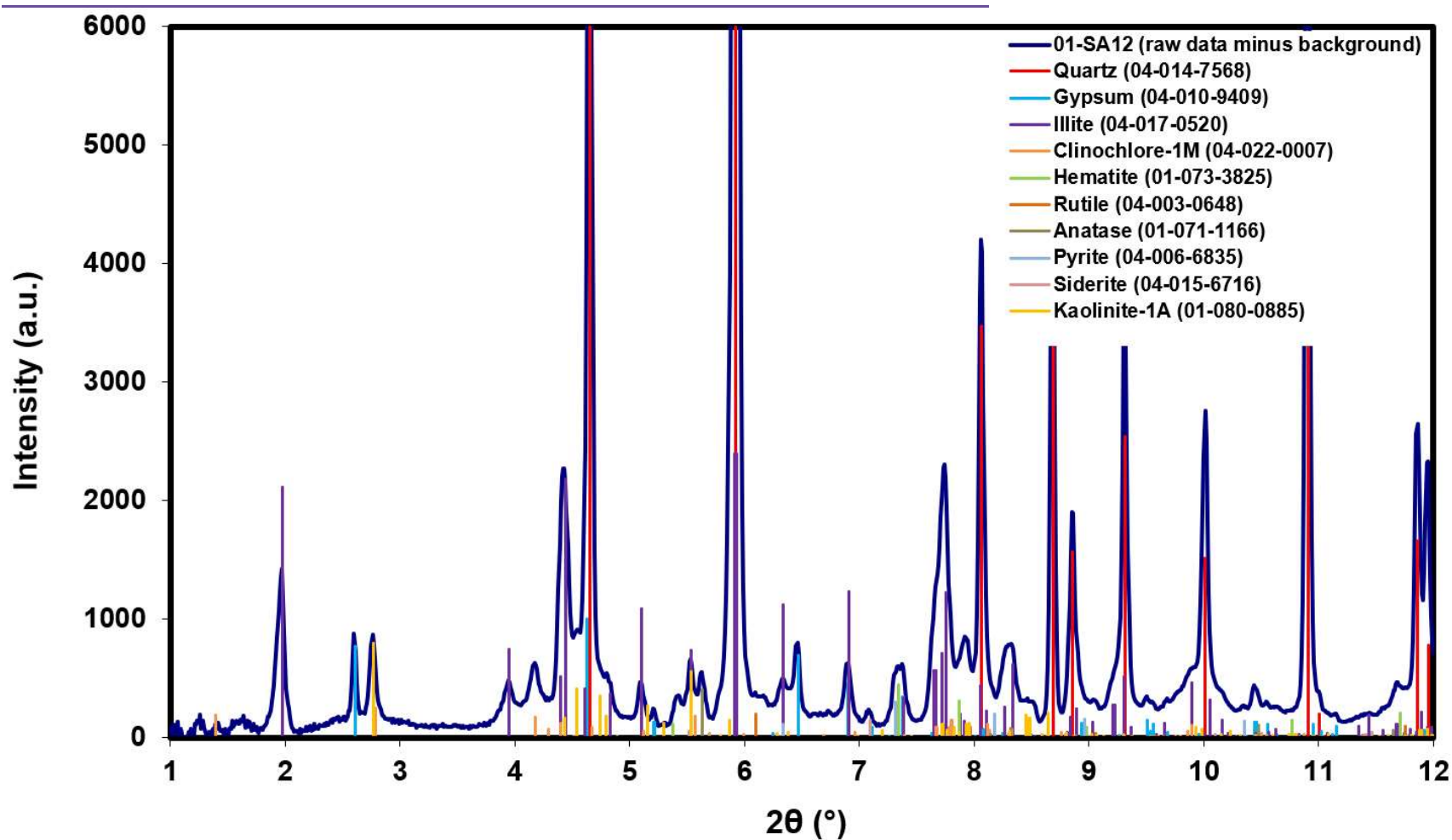


Figure 5.13. Phase identification results obtained for **01-SA12**, focusing on the low angle region near the background.

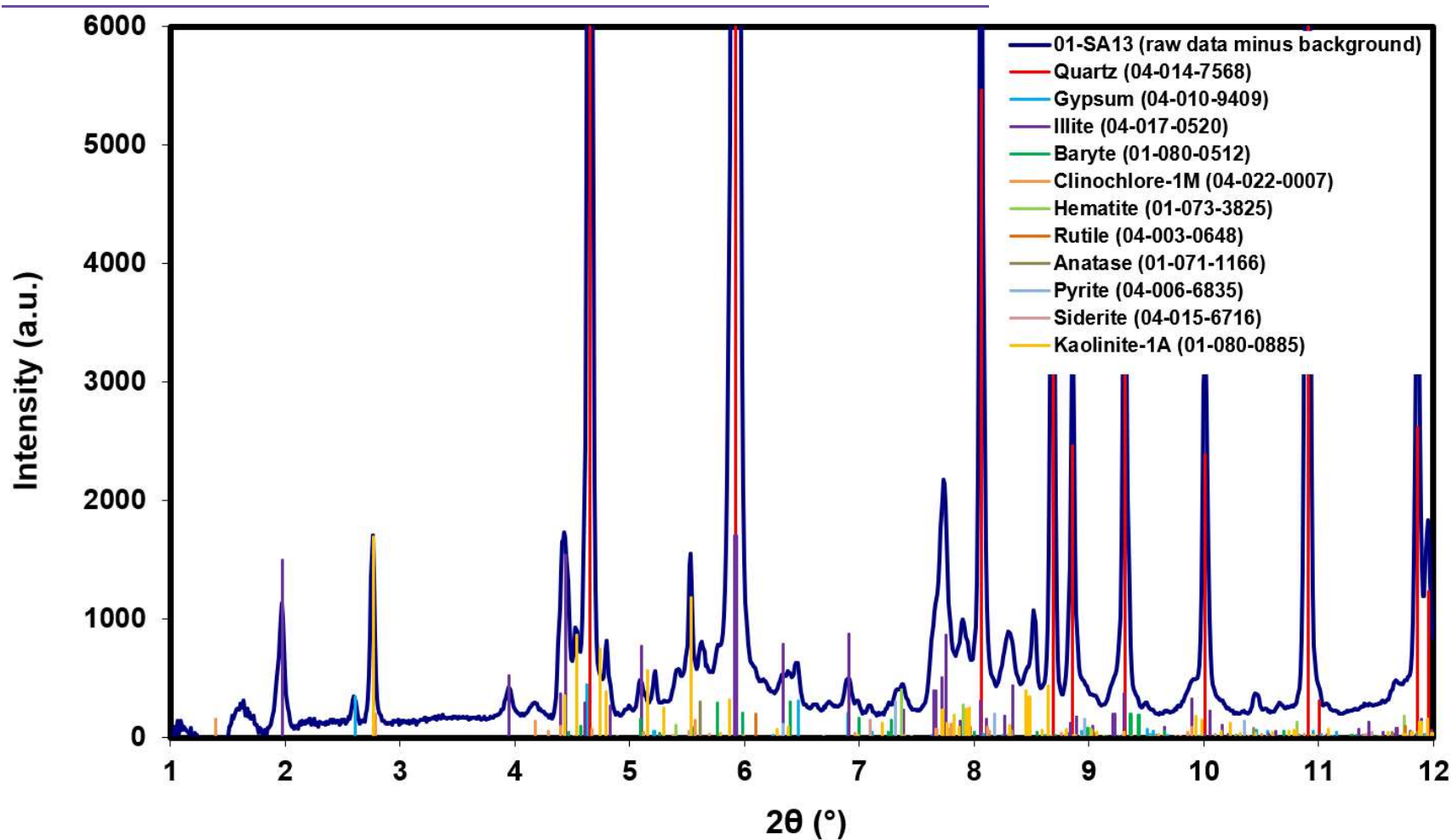


Figure 5.14. Phase identification results obtained for **01-SA13**, focusing on the low angle region near the background.

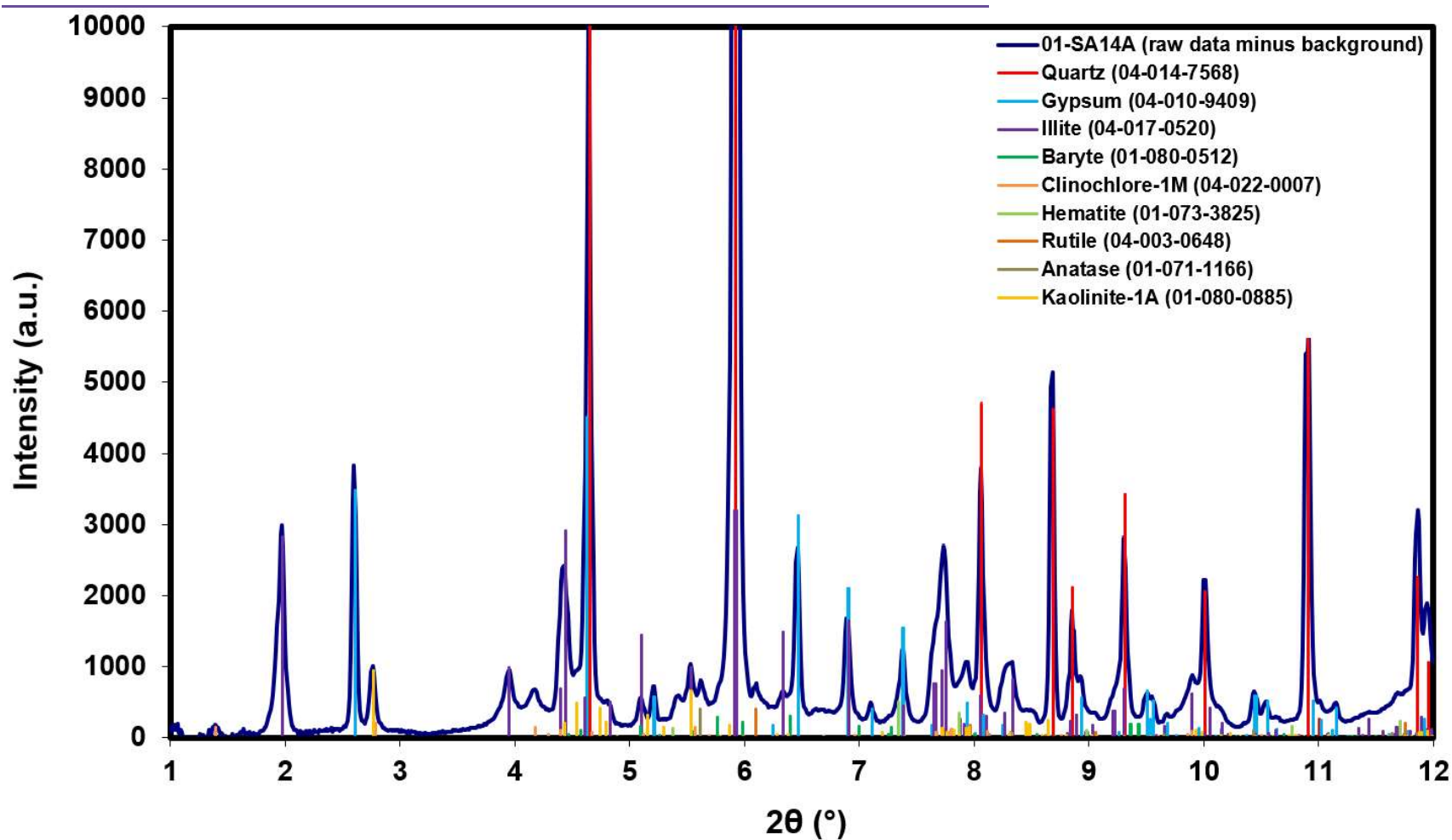


Figure 5.15. Phase identification results obtained for **01-SA14A**, focusing on the low angle region near the background.

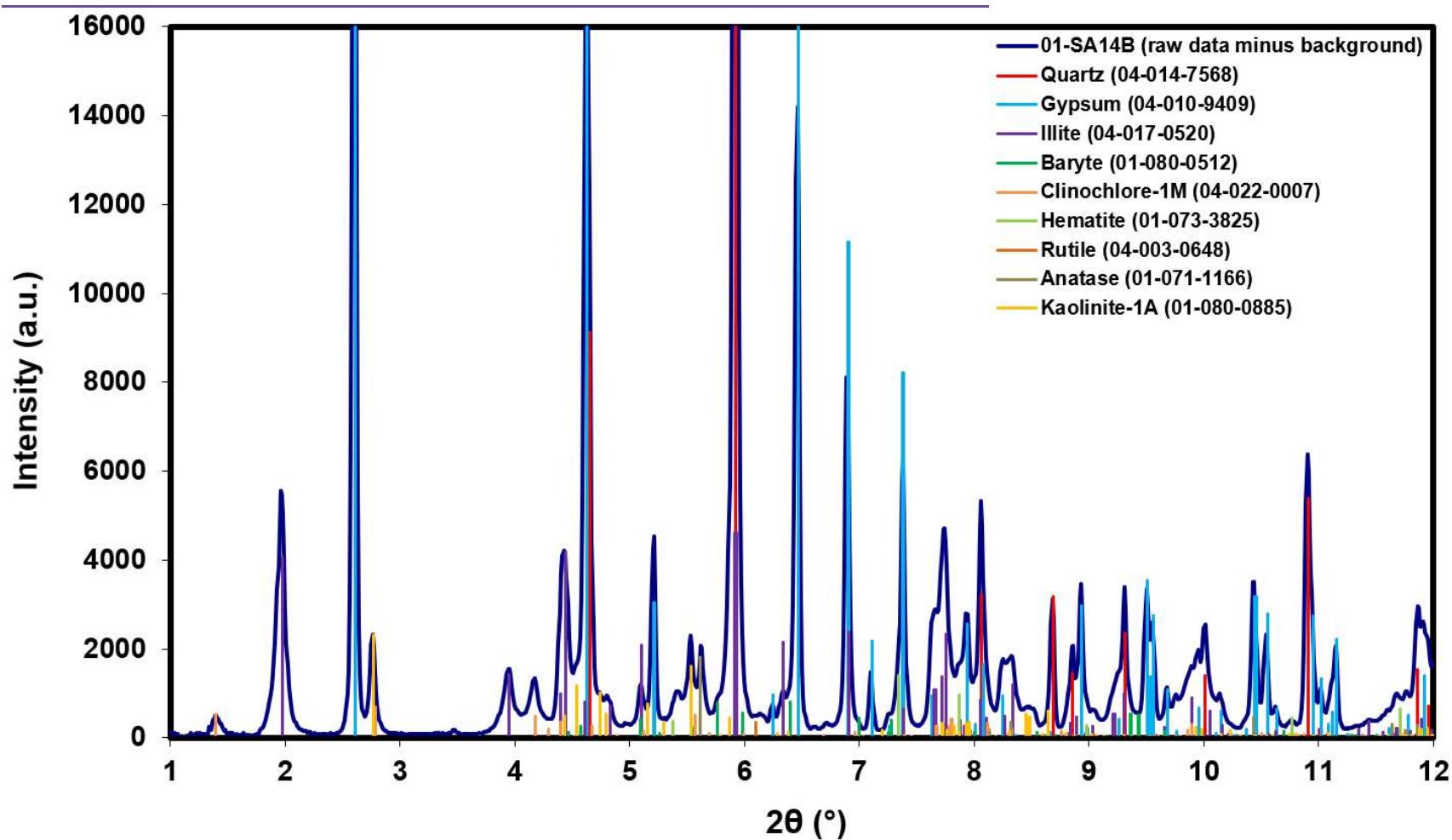


Figure 5.16. Phase identification results obtained for **01-SA14B**, focusing on the low angle region near the background.

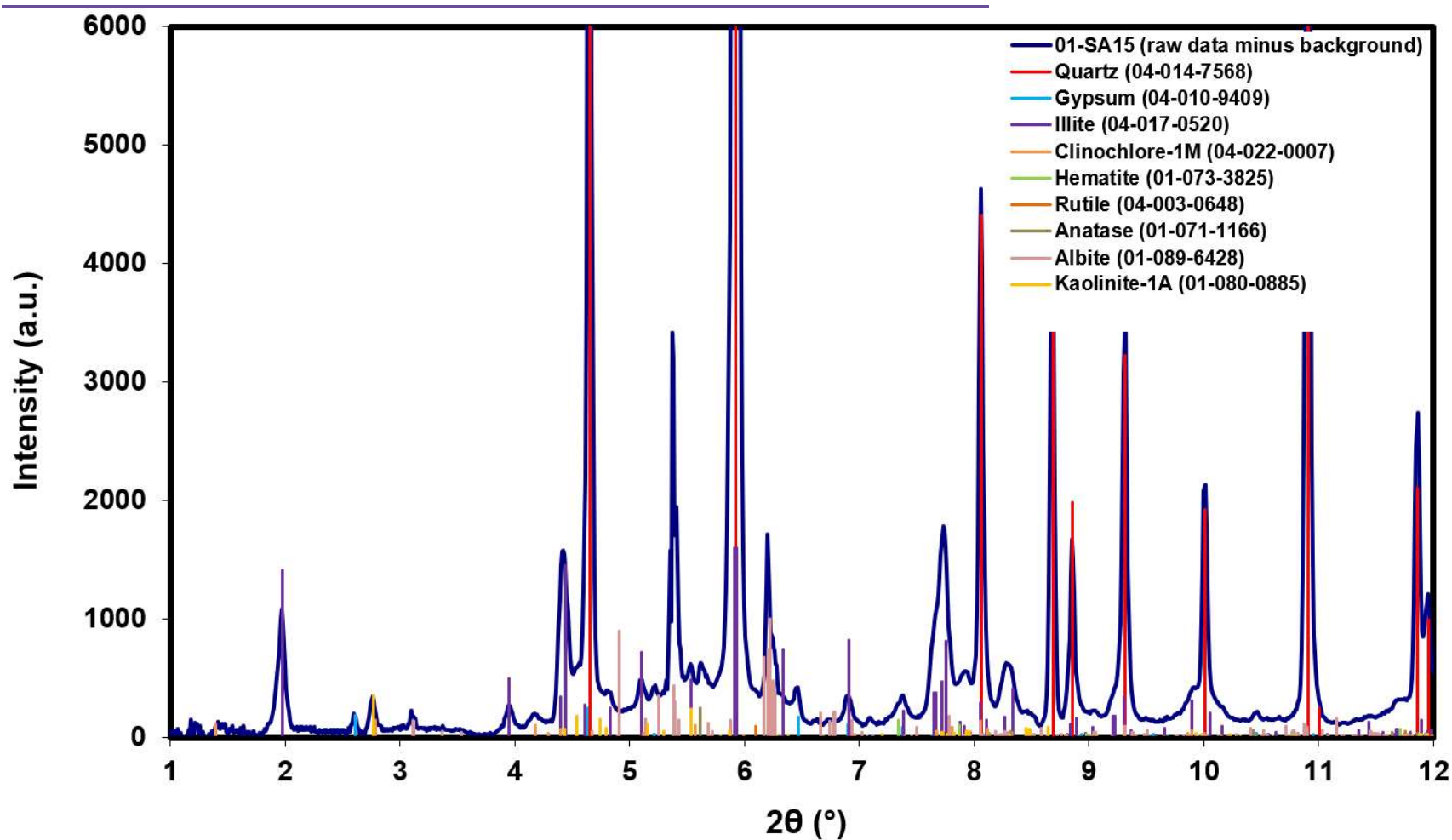


Figure 5.17. Phase identification results obtained for **01-SA15**, focusing on the low angle region near the background.

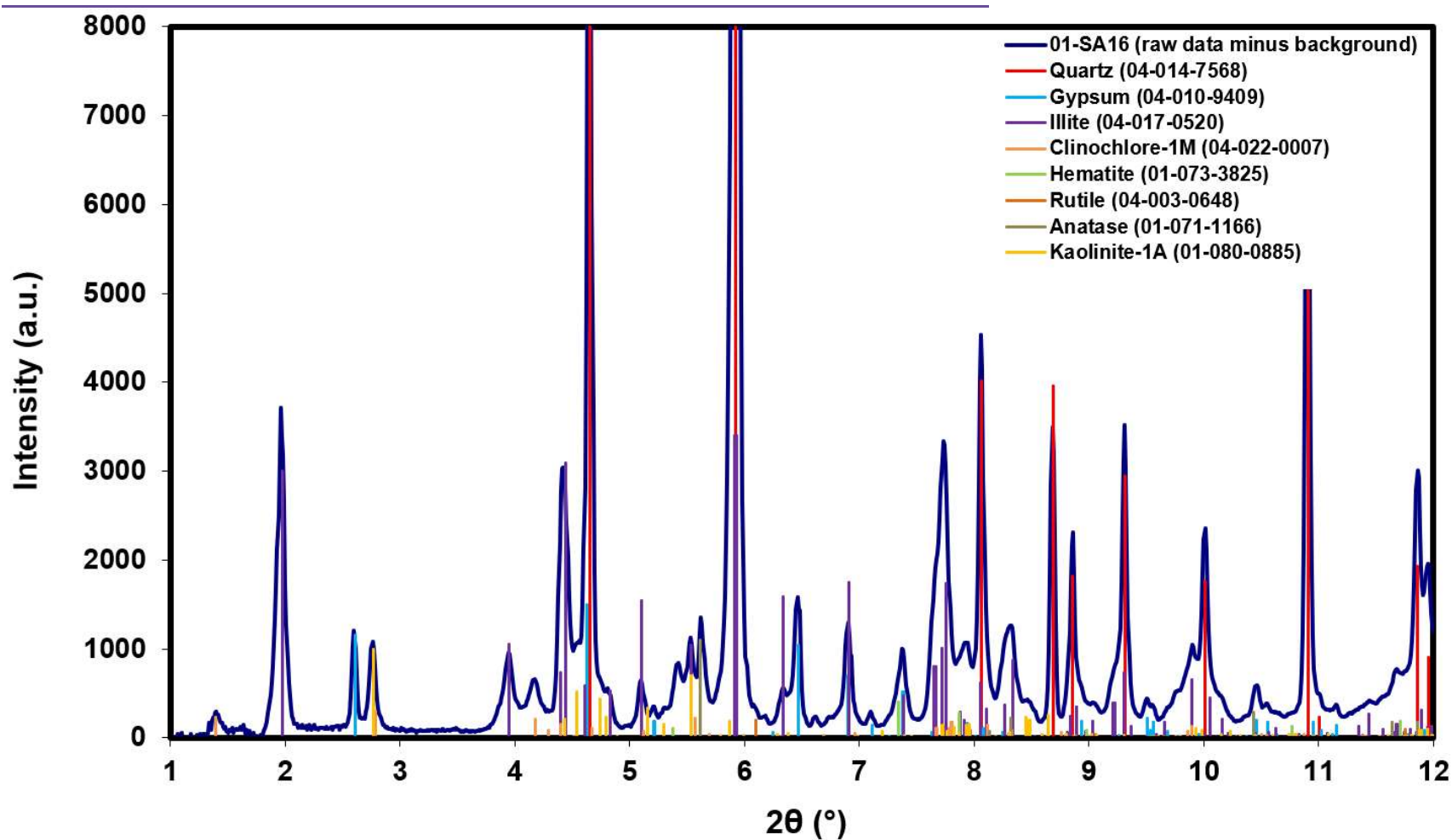


Figure 5.18. Phase identification results obtained for **01-SA16**, focusing on the low angle region near the background.

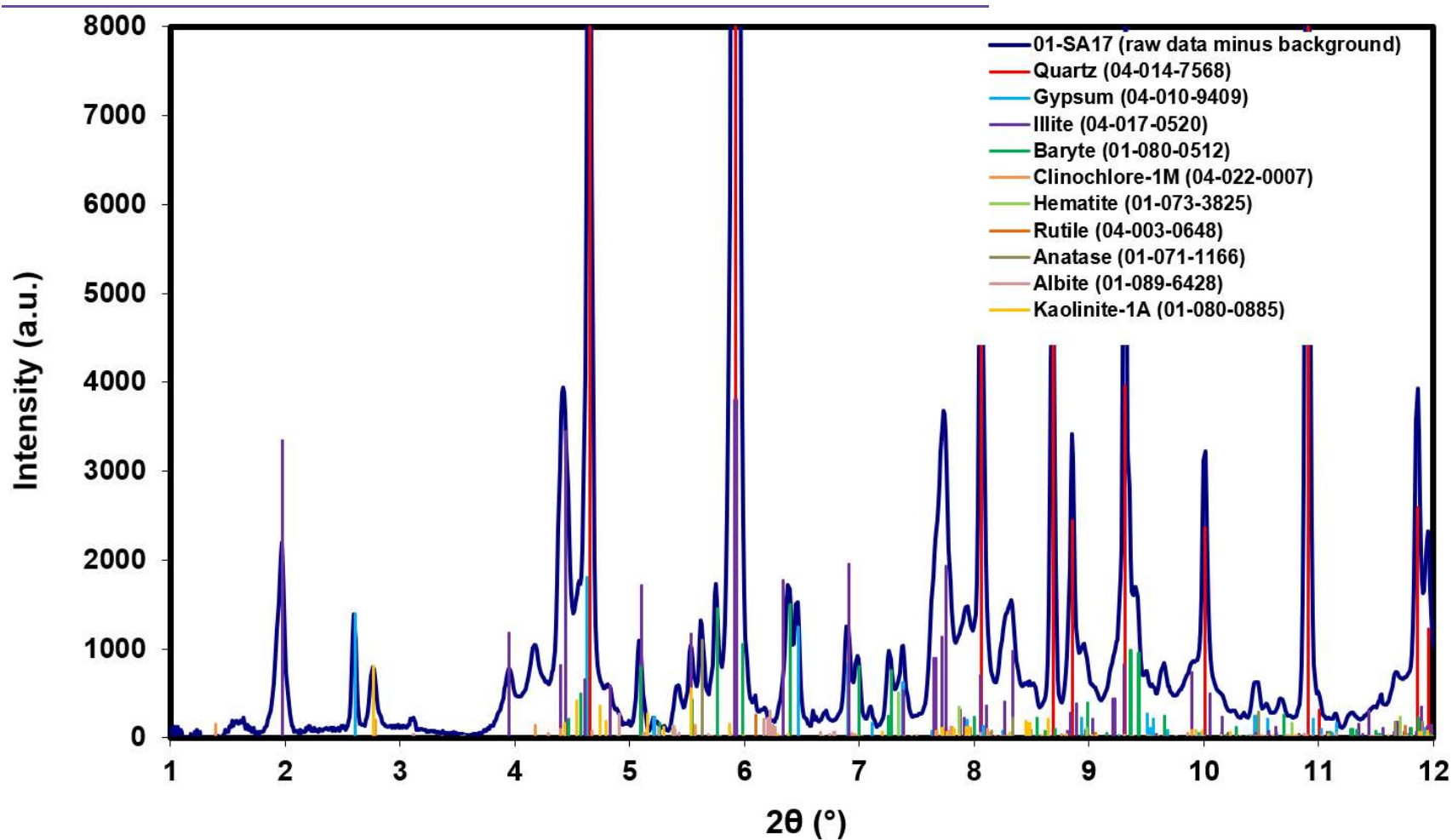


Figure 5.19. Phase identification results obtained for **01-SA17**, focusing on the low angle region near the background.

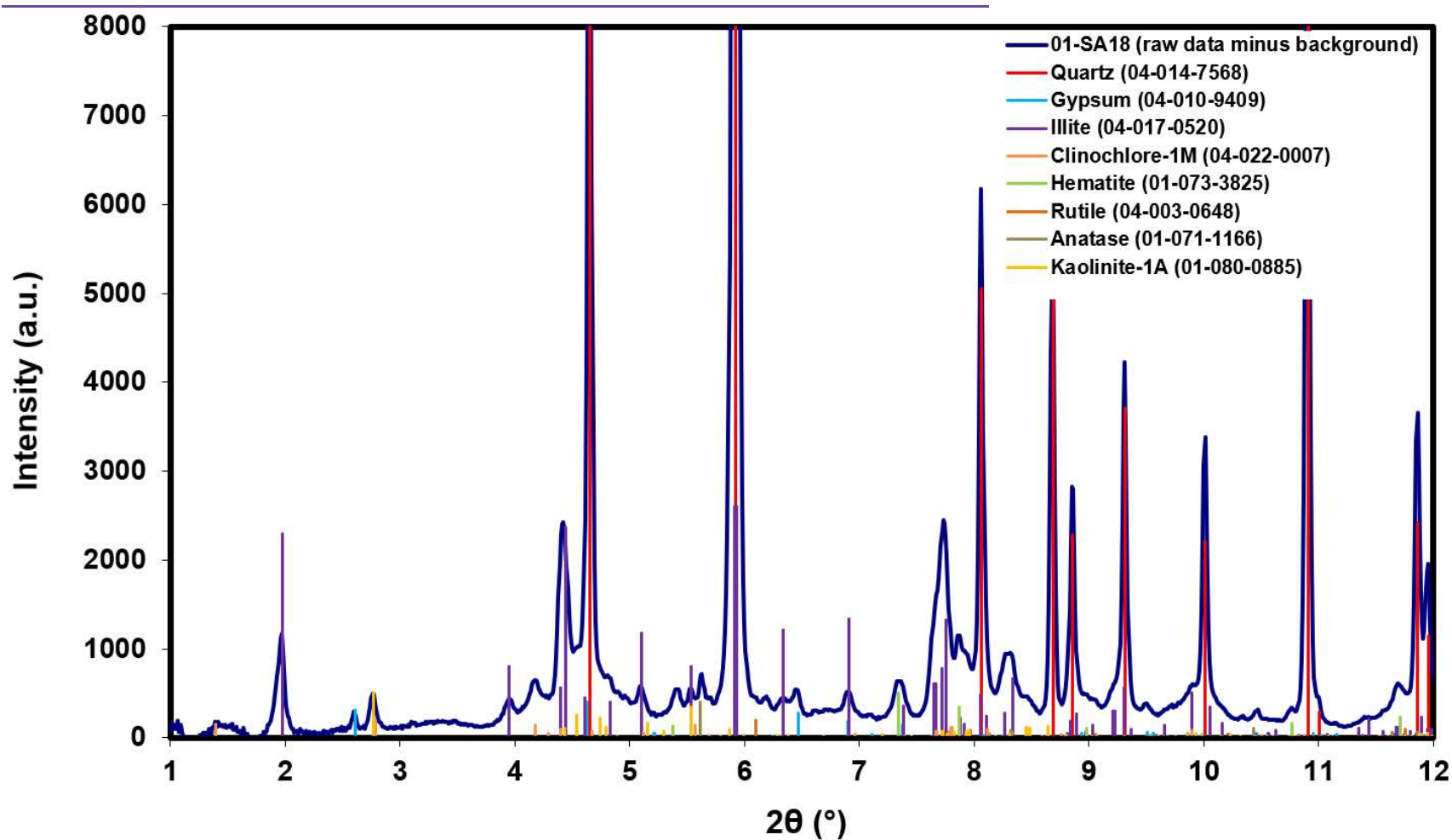


Figure 5.20. Phase identification results obtained for **01-SA18**, focusing on the low angle region near the background.

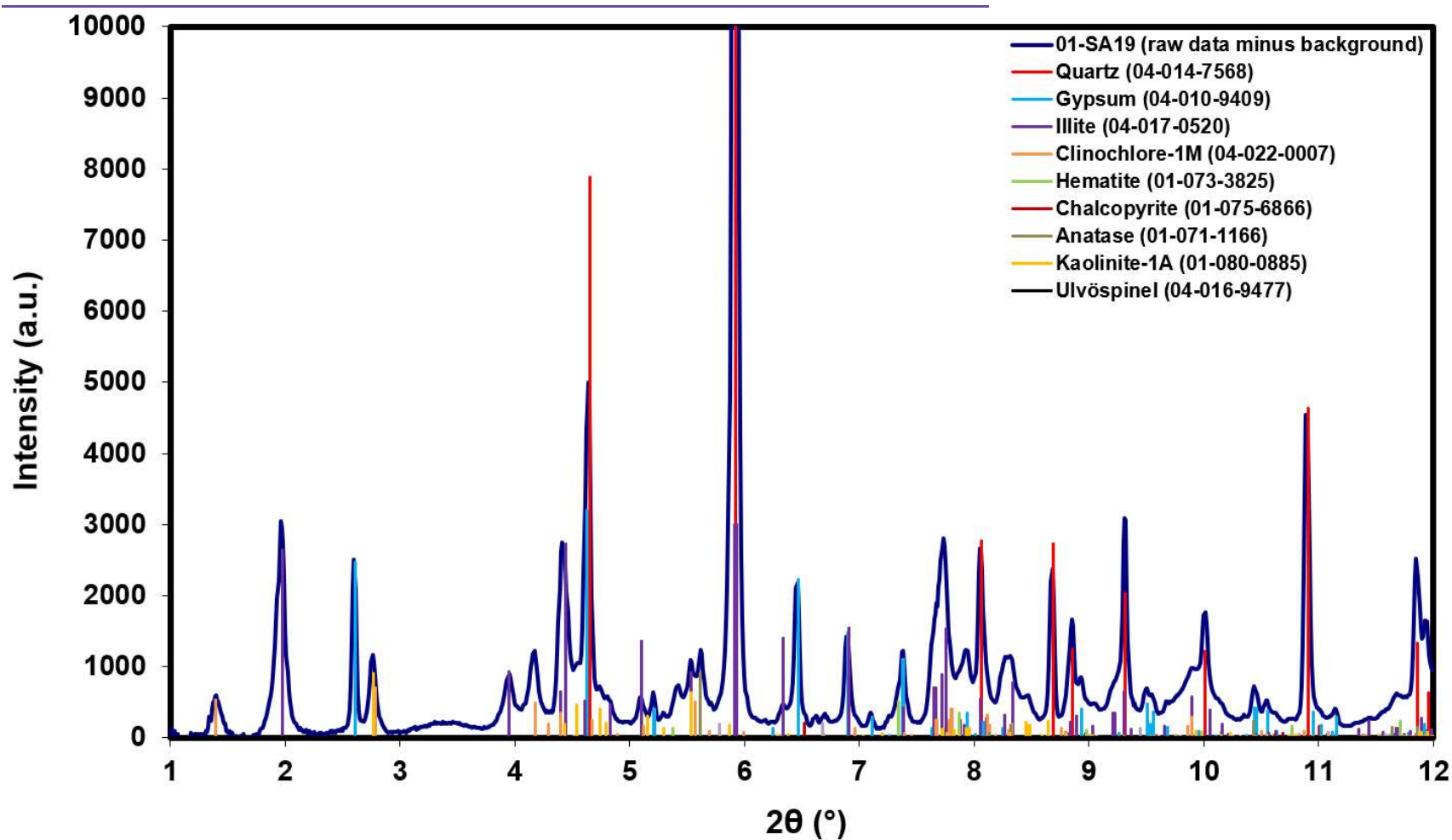


Figure 5.21. Phase identification results obtained for **01-SA19**, focusing on the low angle region near the background.

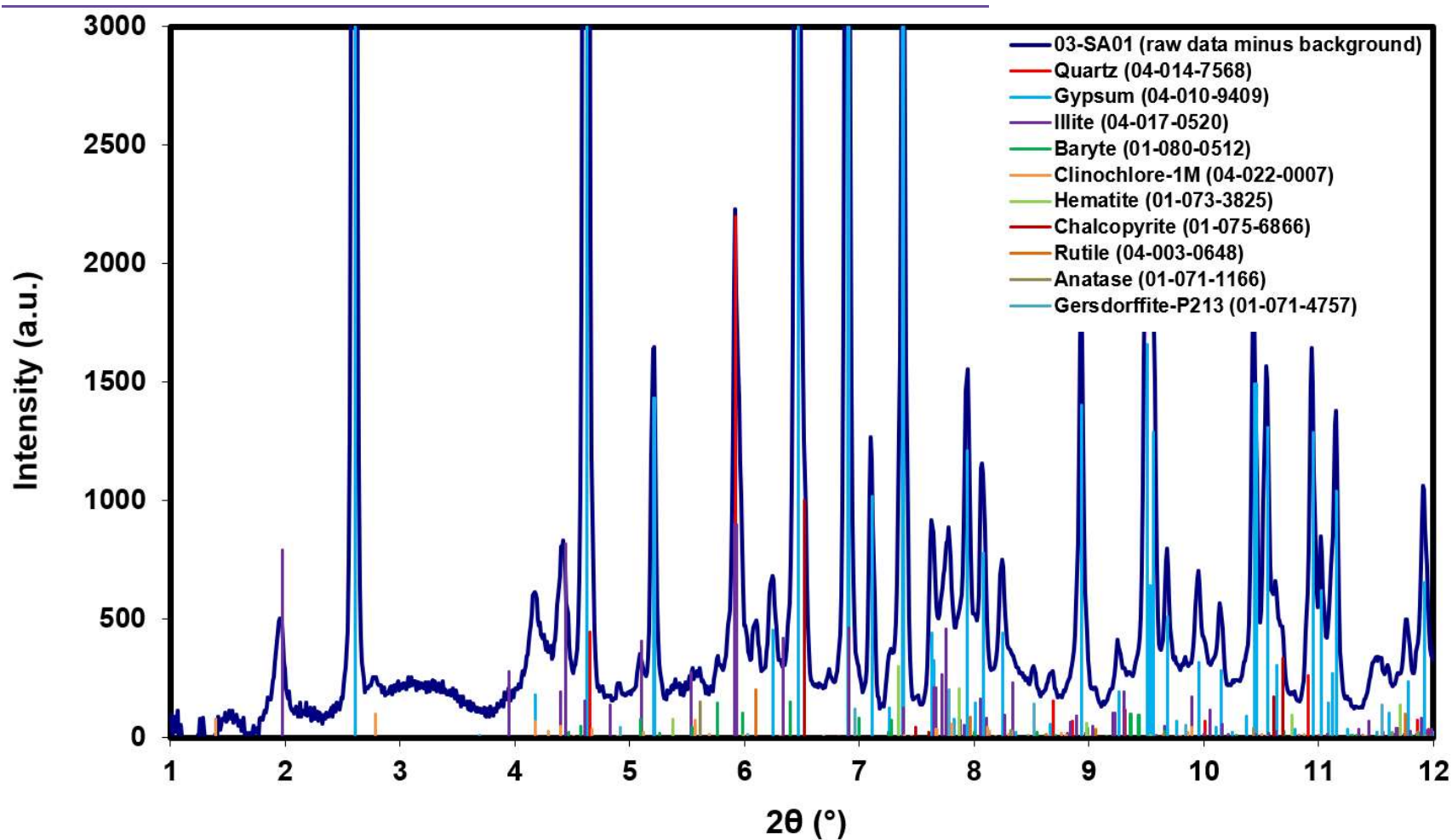


Figure 5.22. Phase identification results obtained for **03-SA01**, focusing on the low angle region near the background.

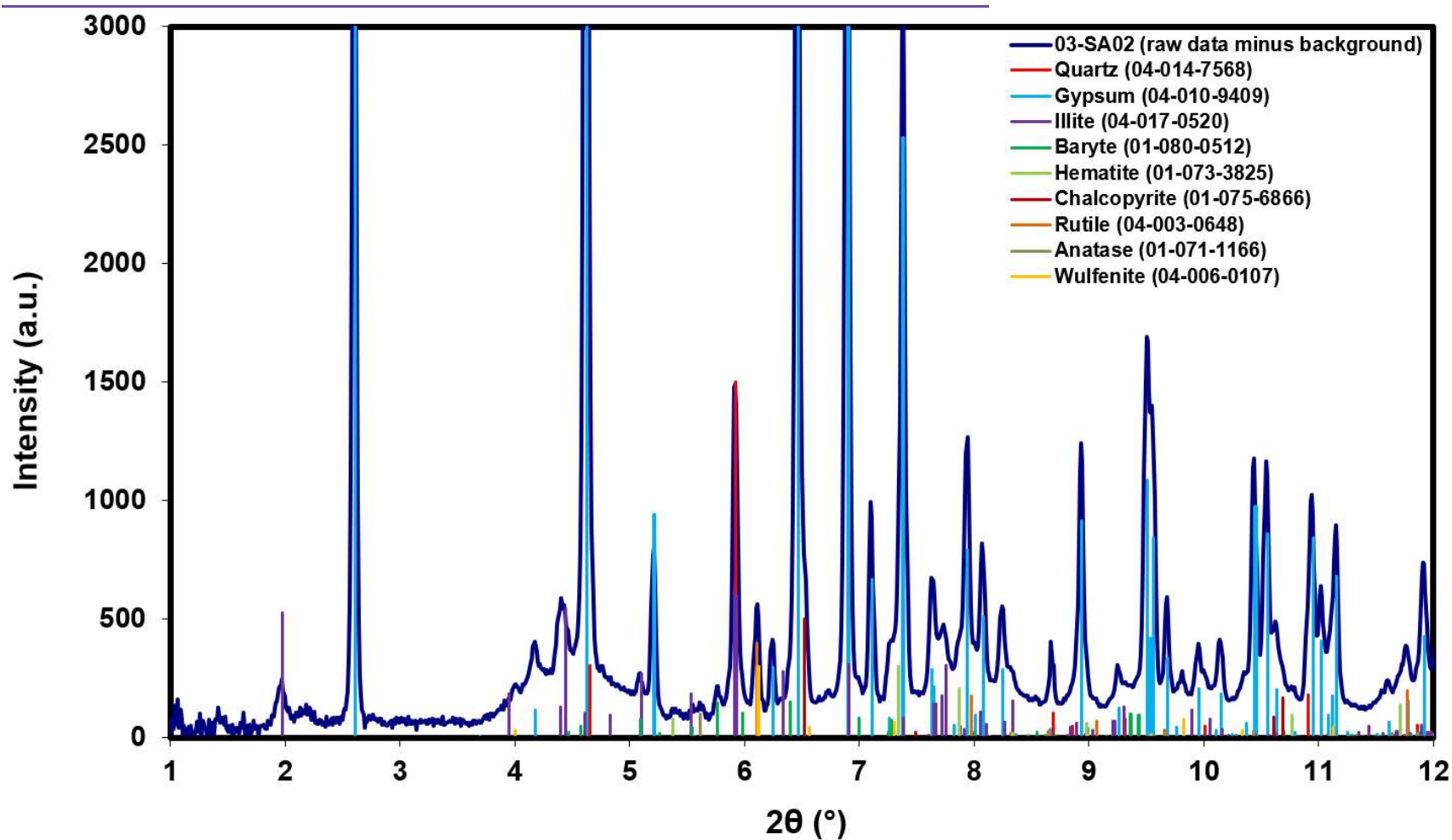


Figure 5.23. Phase identification results obtained for **03-SA02**, focusing on the low angle region near the background.

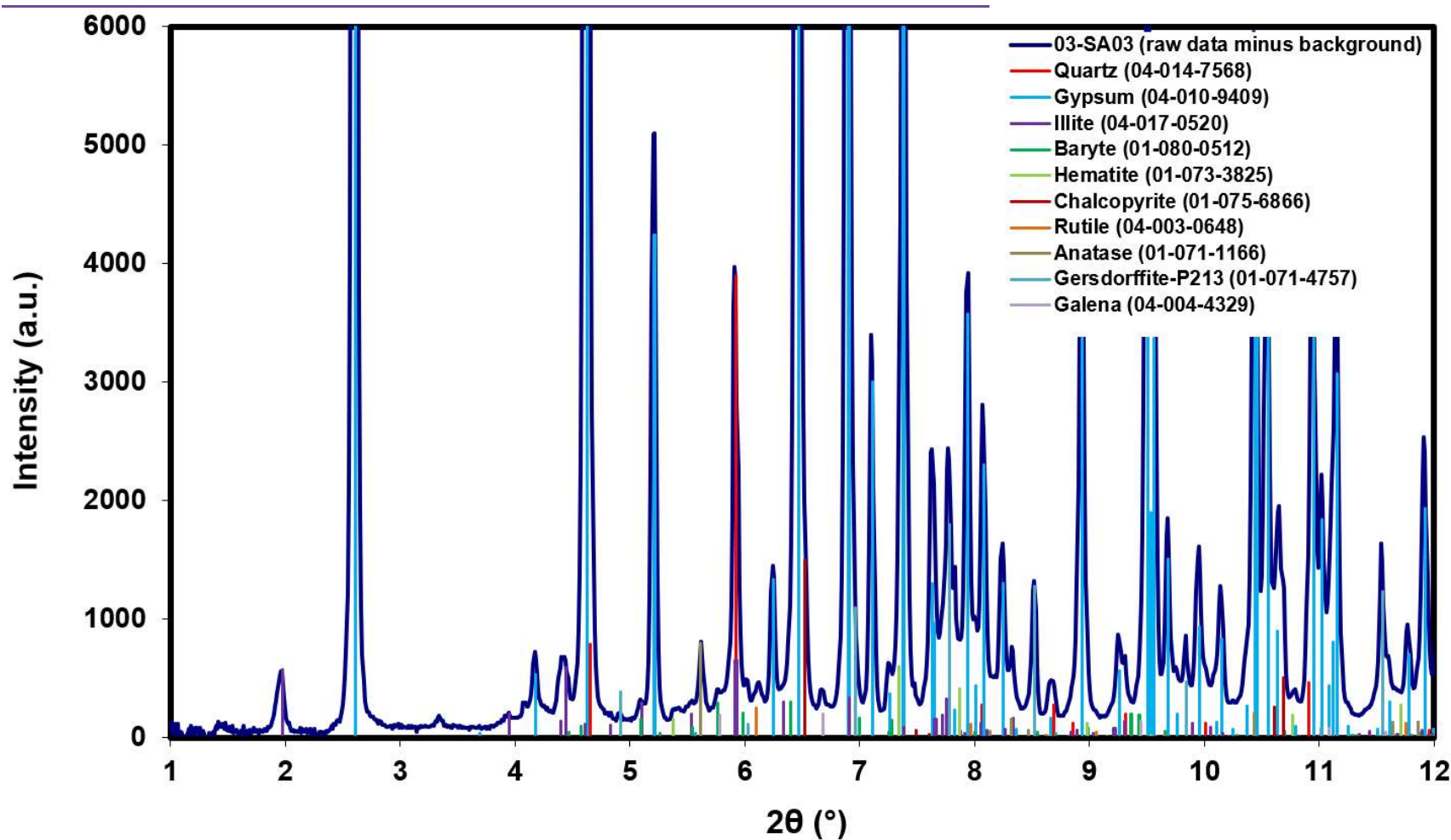


Figure 5.24. Phase identification results obtained for **03-SA03**, focusing on the low angle region near the background.

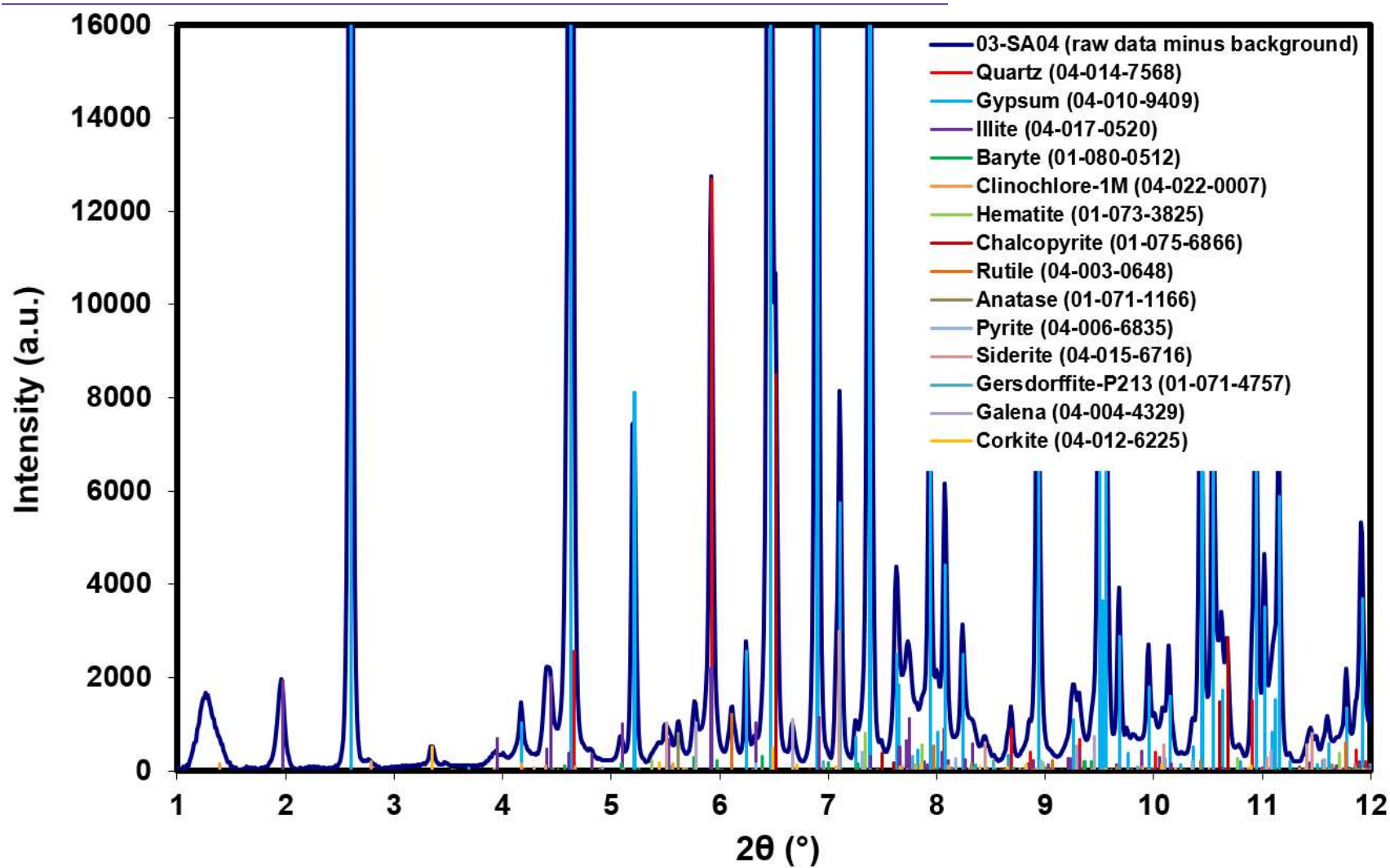


Figure 5.25. Phase identification results obtained for **03-SA04**, focusing on the low angle region near the background.

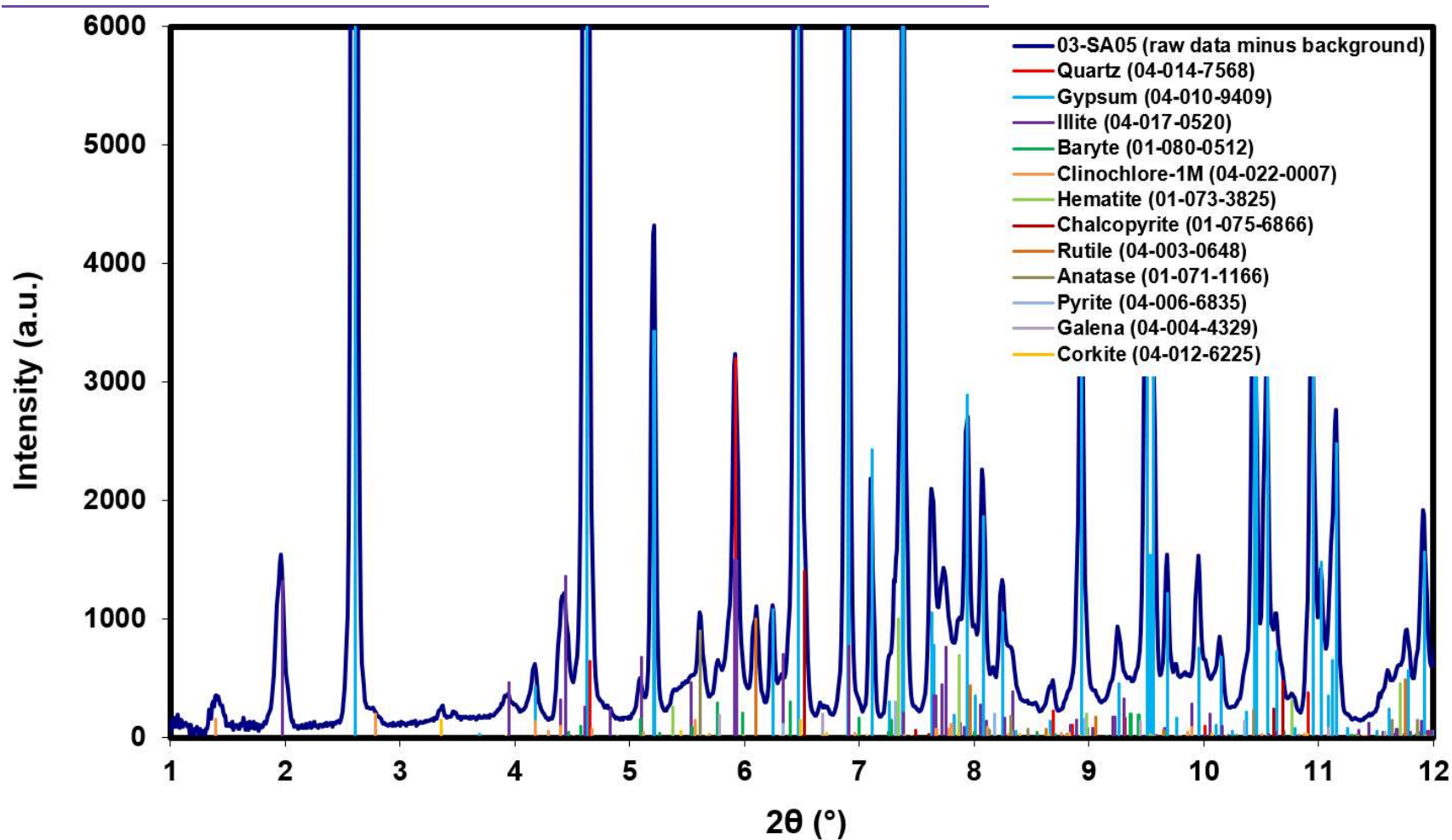


Figure 5.26. Phase identification results obtained for **03-SA05**, focusing on the low angle region near the background.

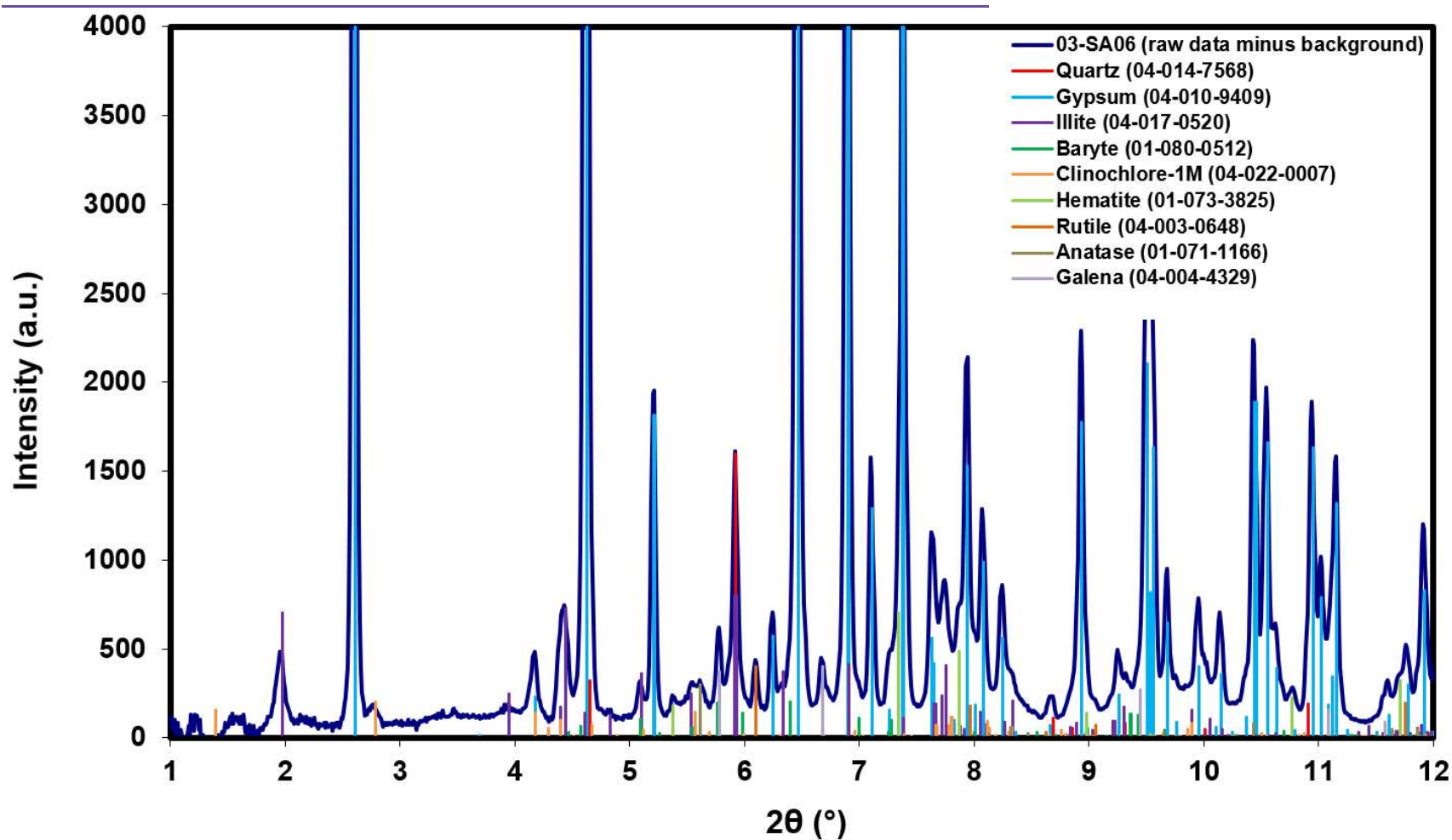


Figure 5.27. Phase identification results obtained for **03-SA06**, focusing on the low angle region near the background.

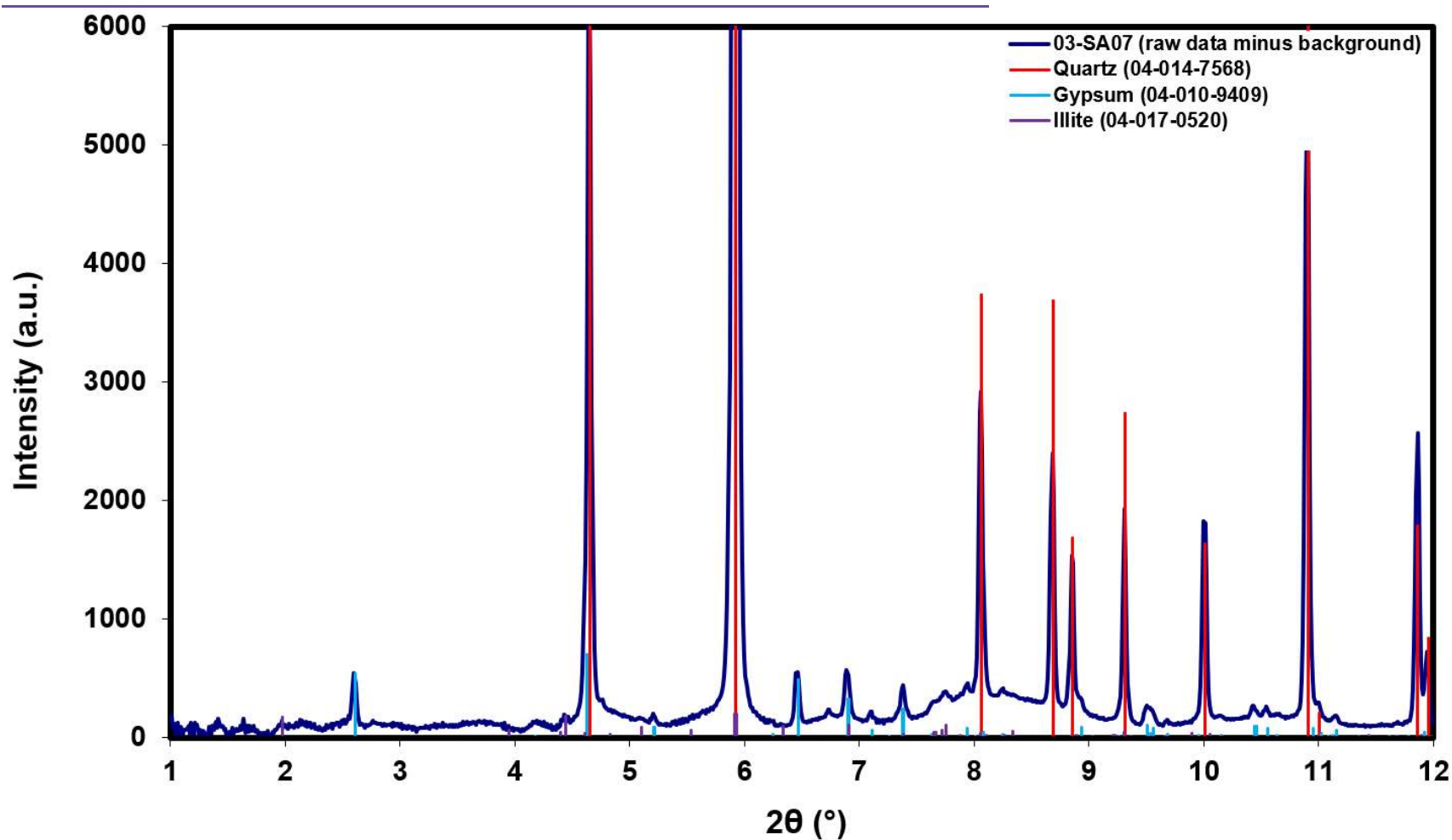


Figure 5.28. Phase identification results obtained for **03-SA07**, focusing on the low angle region near the background.

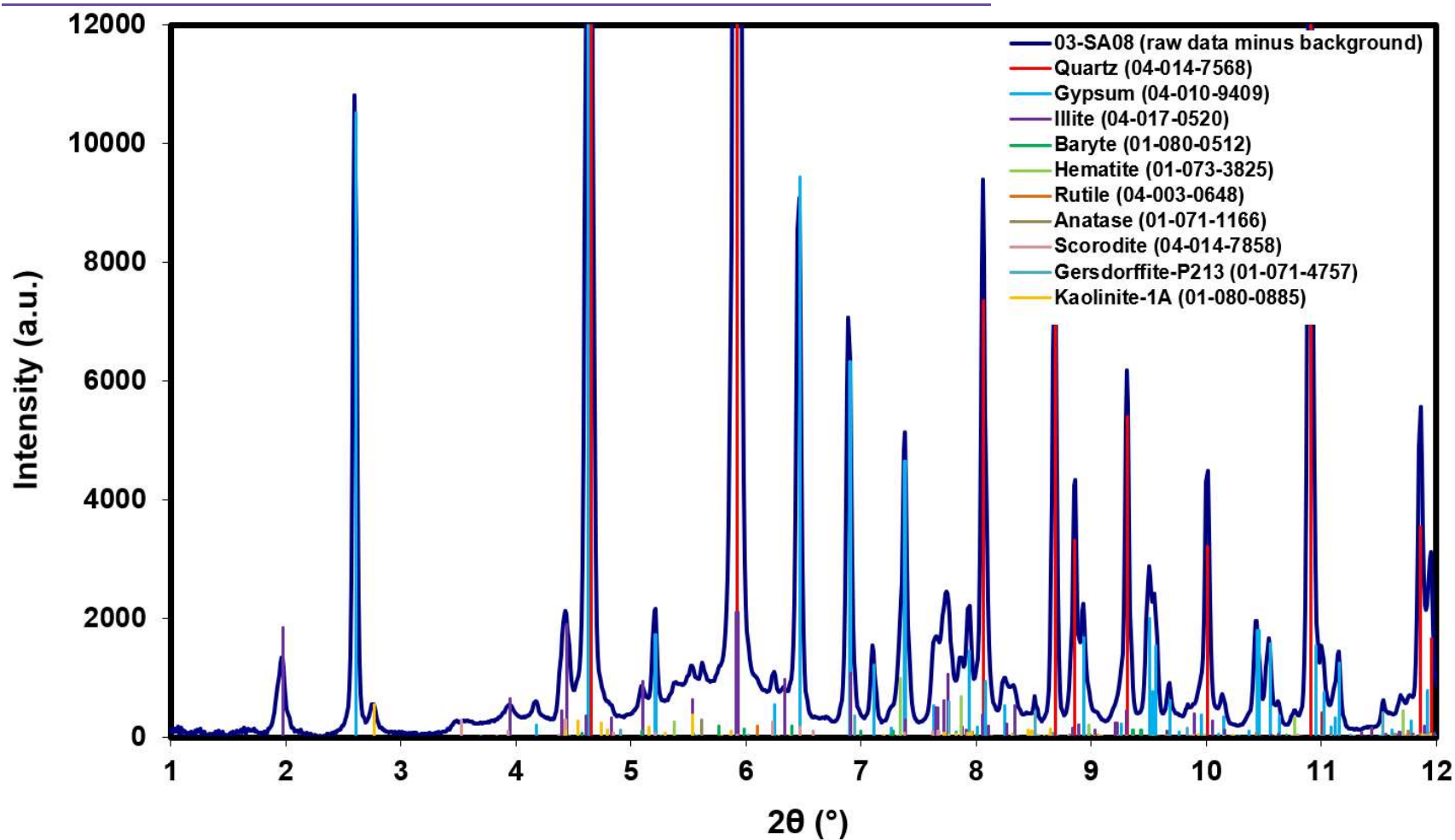


Figure 5.29. Phase identification results obtained for **03-SA08**, focusing on the low angle region near the background.

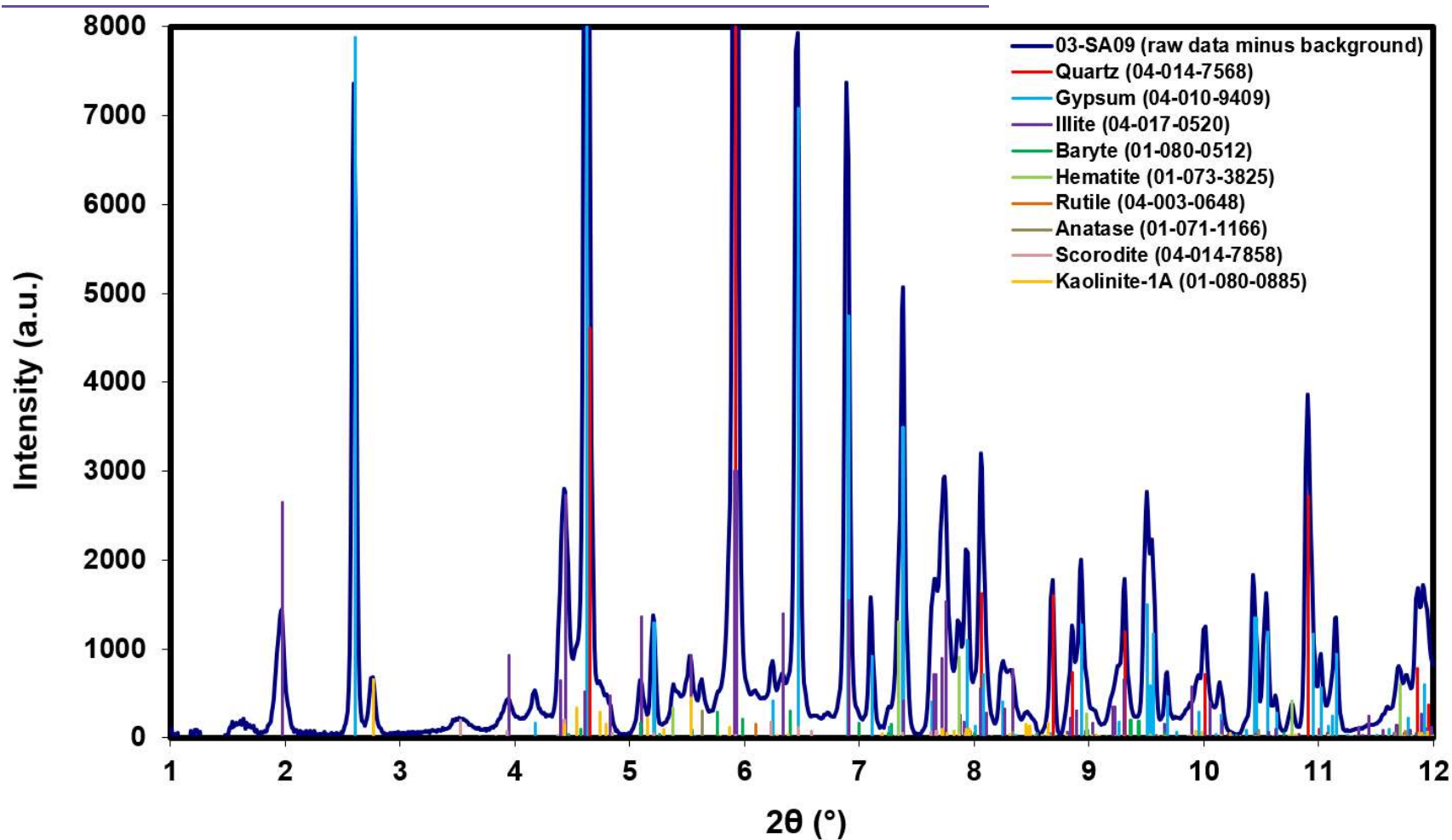


Figure 5.30. Phase identification results obtained for **03-SA09**, focusing on the low angle region near the background.

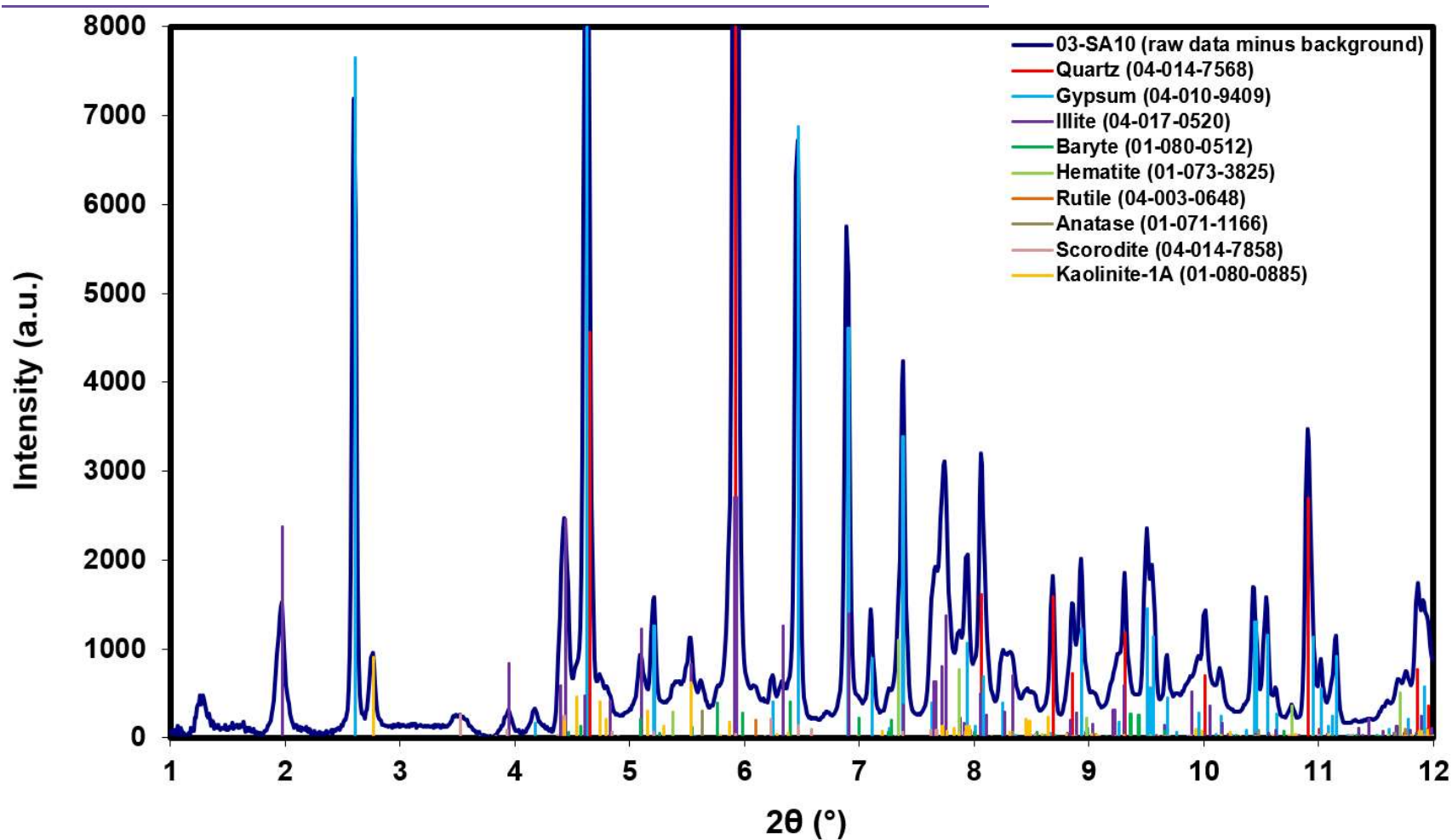


Figure 5.31. Phase identification results obtained for **03-SA10**, focusing on the low angle region near the background.

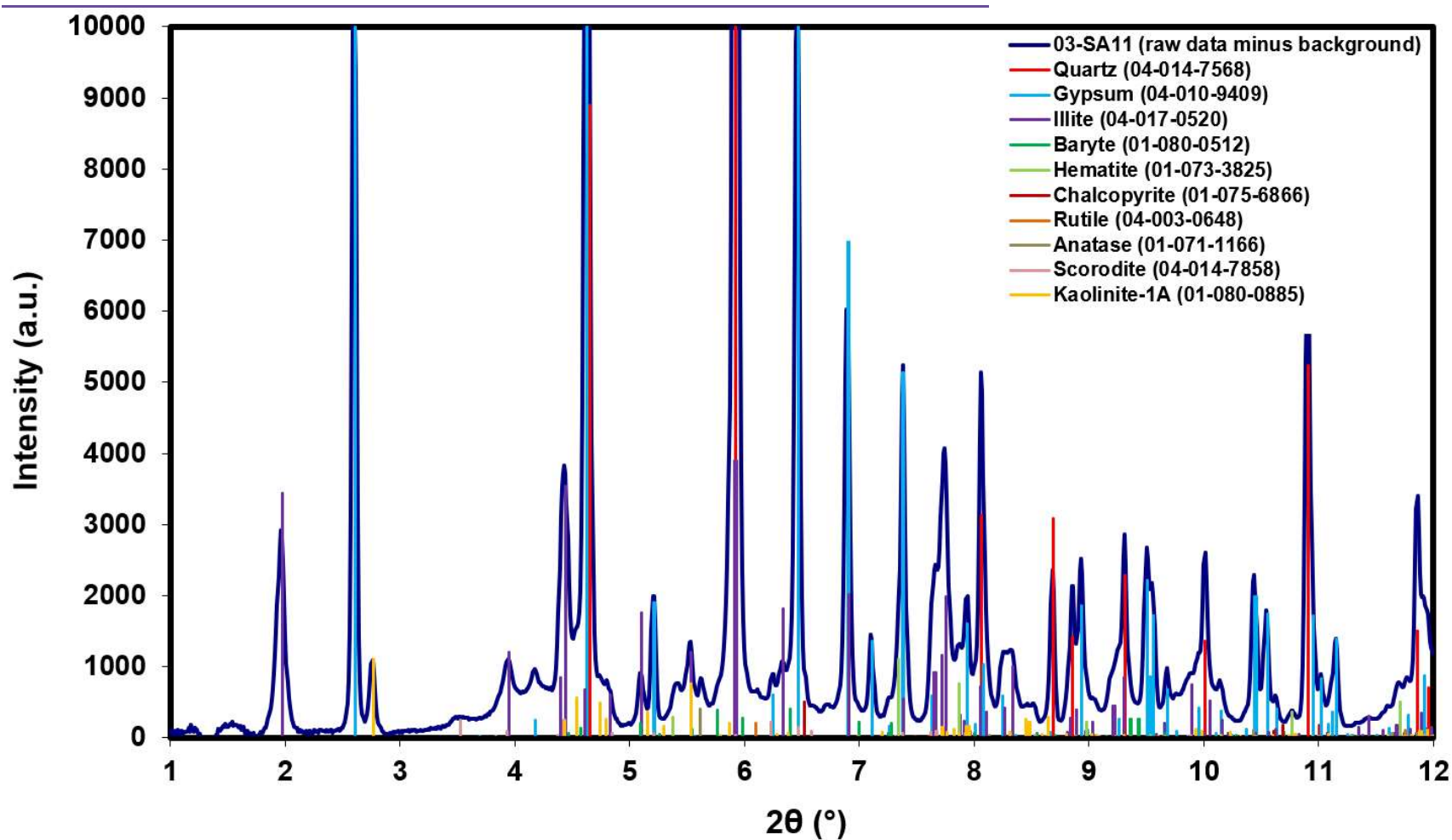


Figure 5.32. Phase identification results obtained for **03-SA11**, focusing on the low angle region near the background.

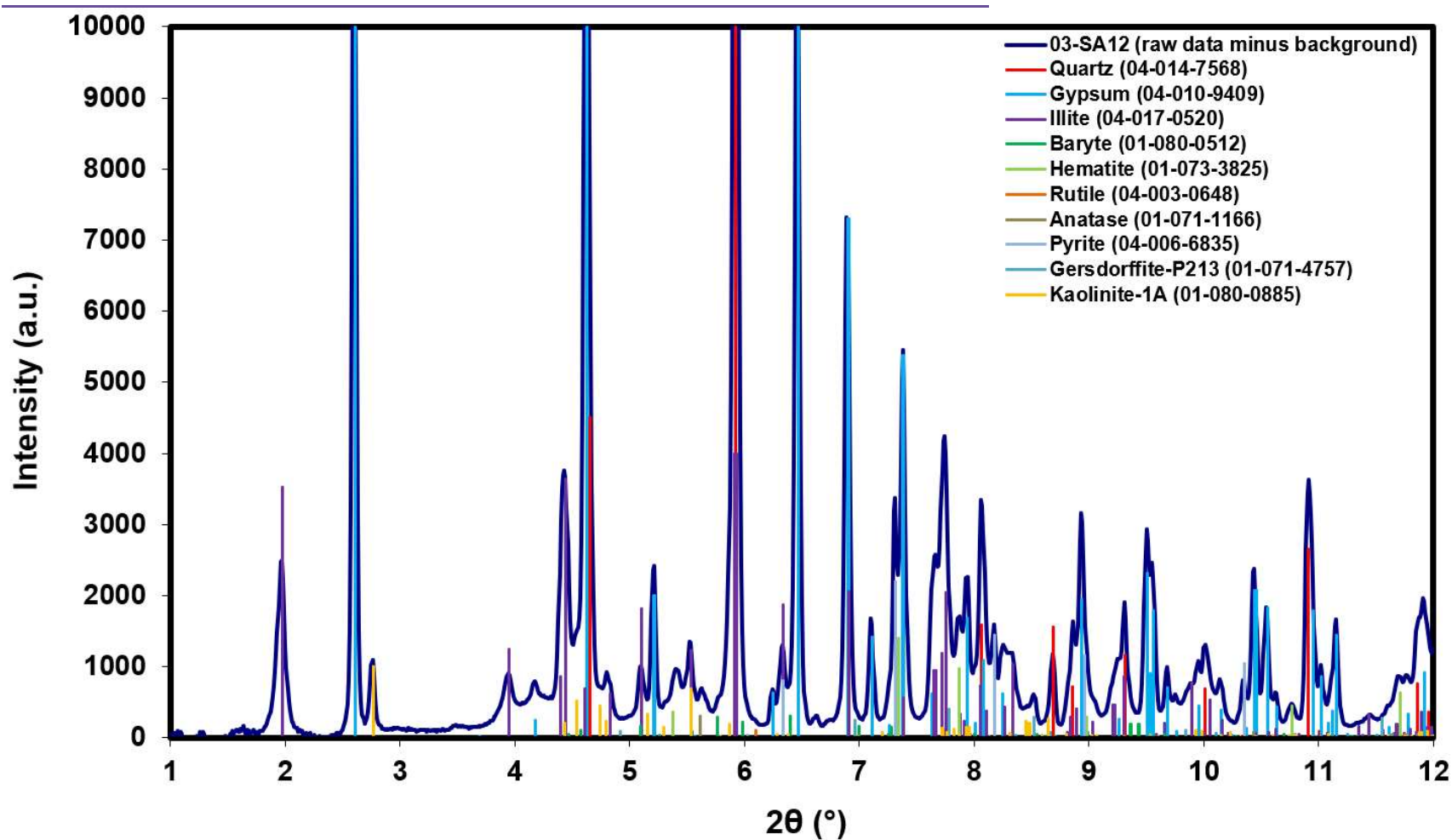


Figure 5.33. Phase identification results obtained for **03-SA12**, focusing on the low angle region near the background.

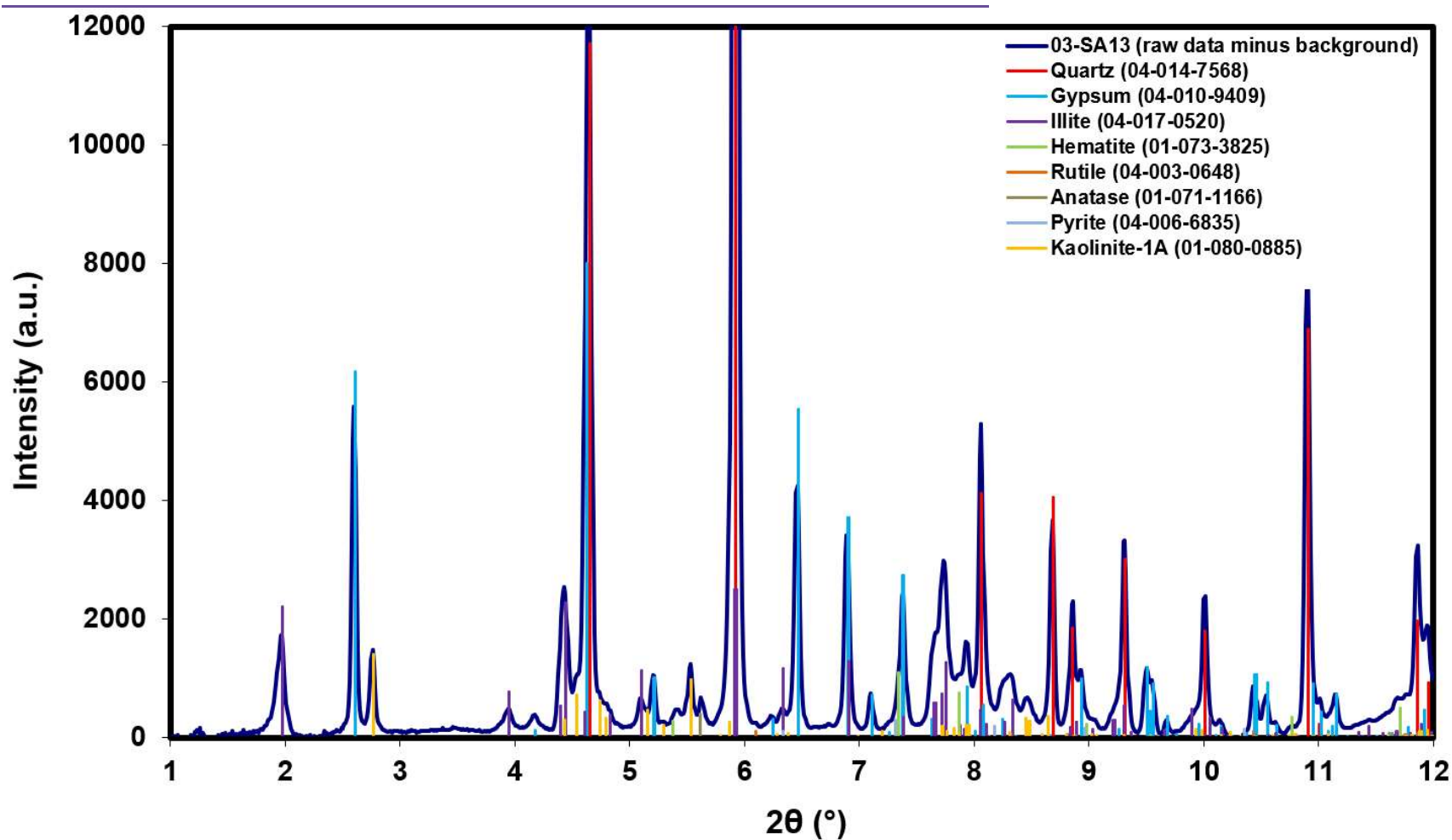


Figure 5.34. Phase identification results obtained for **03-SA13**, focusing on the low angle region near the background.

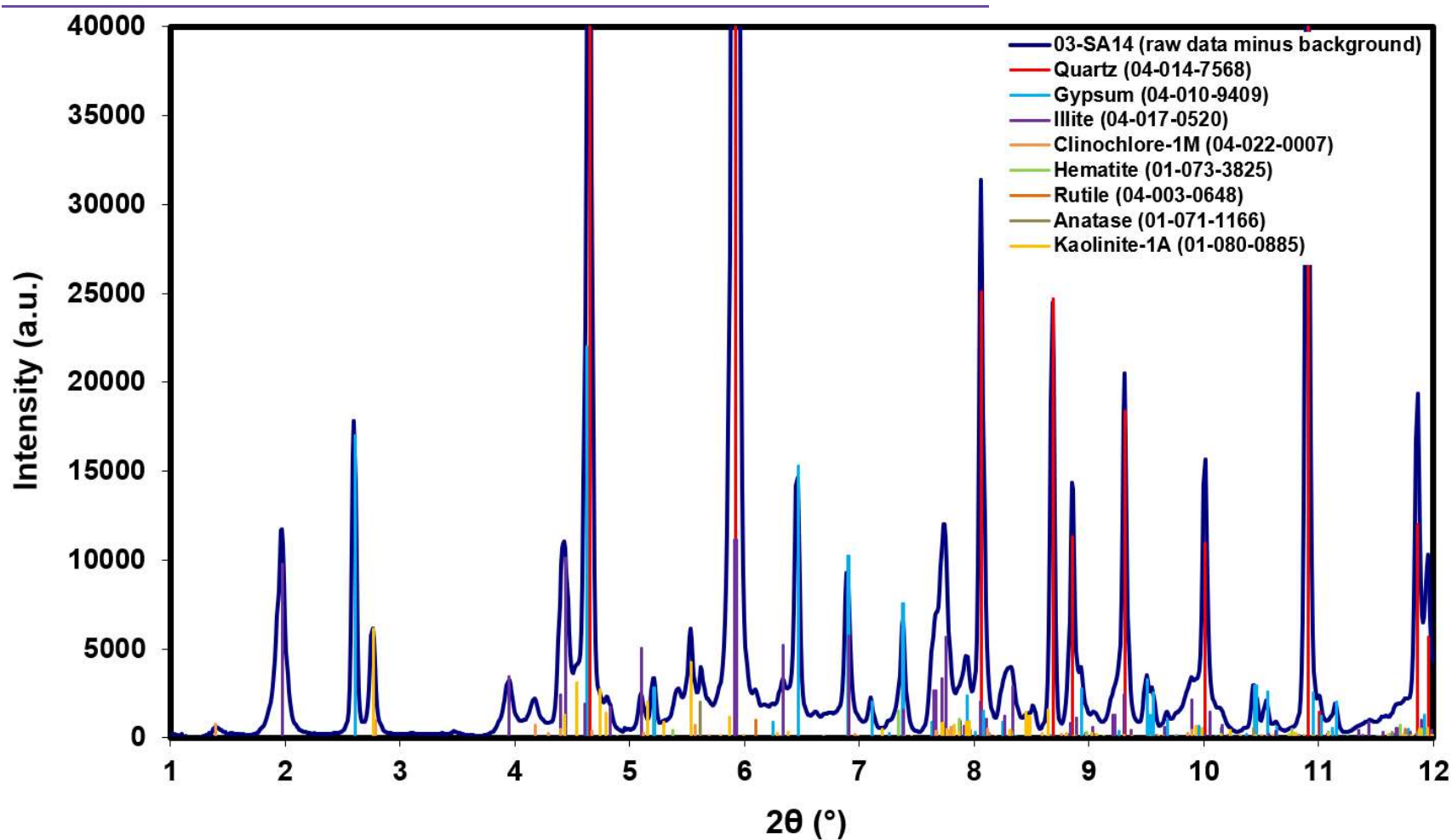


Figure 5.35. Phase identification results obtained for **03-SA14**, focusing on the low angle region near the background.

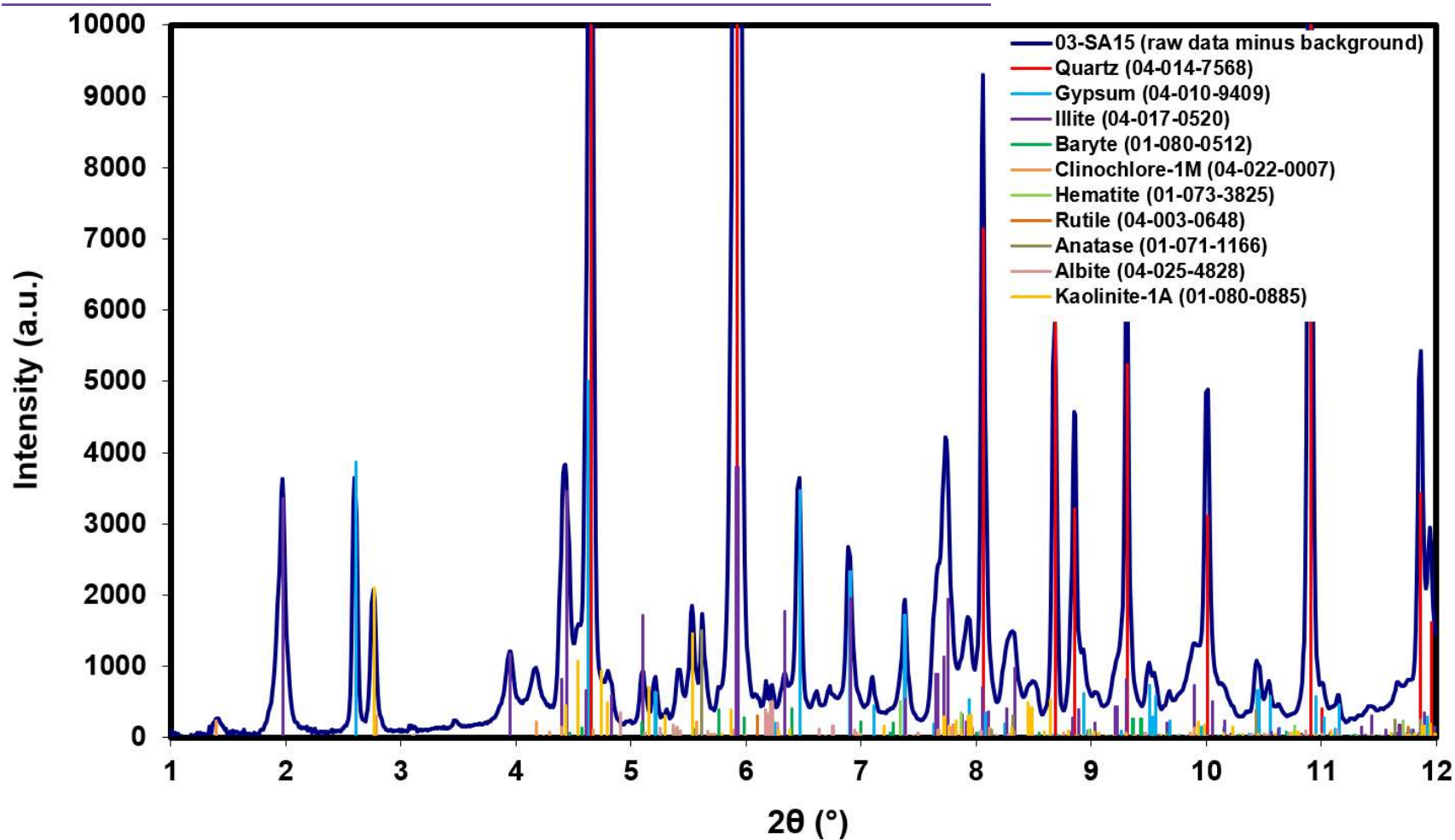


Figure 5.36. Phase identification results obtained for **03-SA15**, focusing on the low angle region near the background.

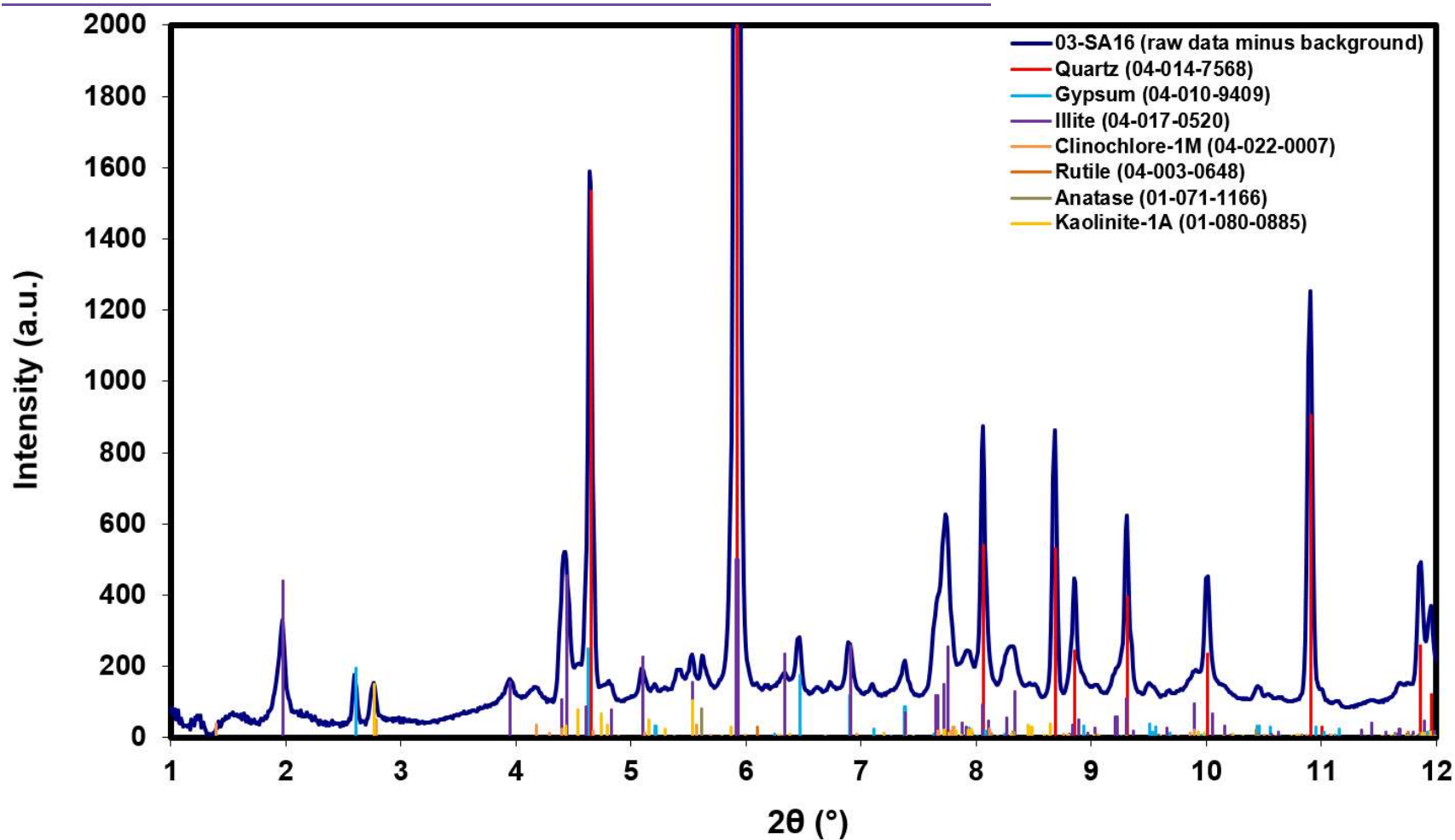


Figure 5.37. Phase identification results obtained for **03-SA16**, focusing on the low angle region near the background.

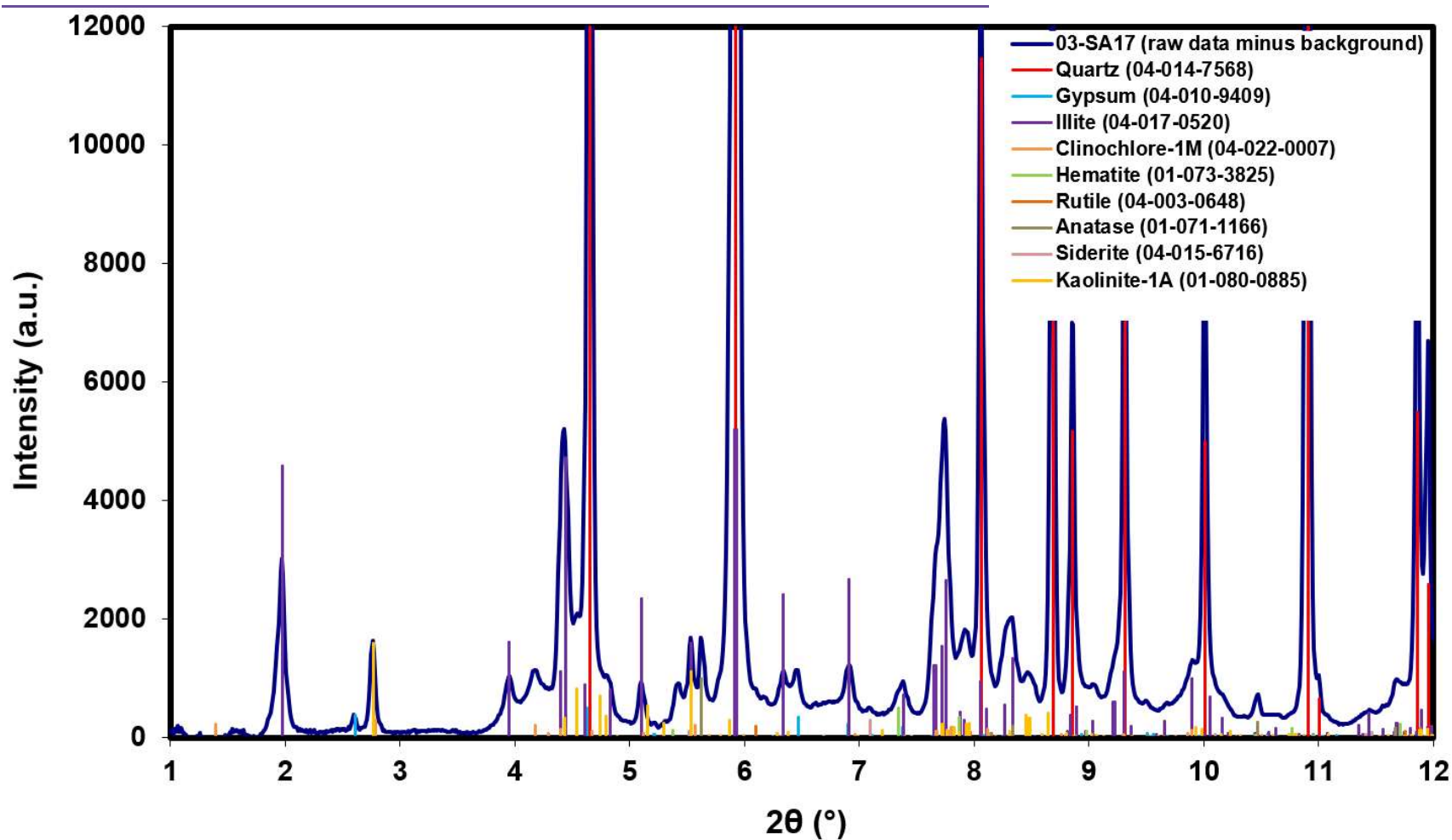


Figure 5.38. Phase identification results obtained for **03-SA17**, focusing on the low angle region near the background.

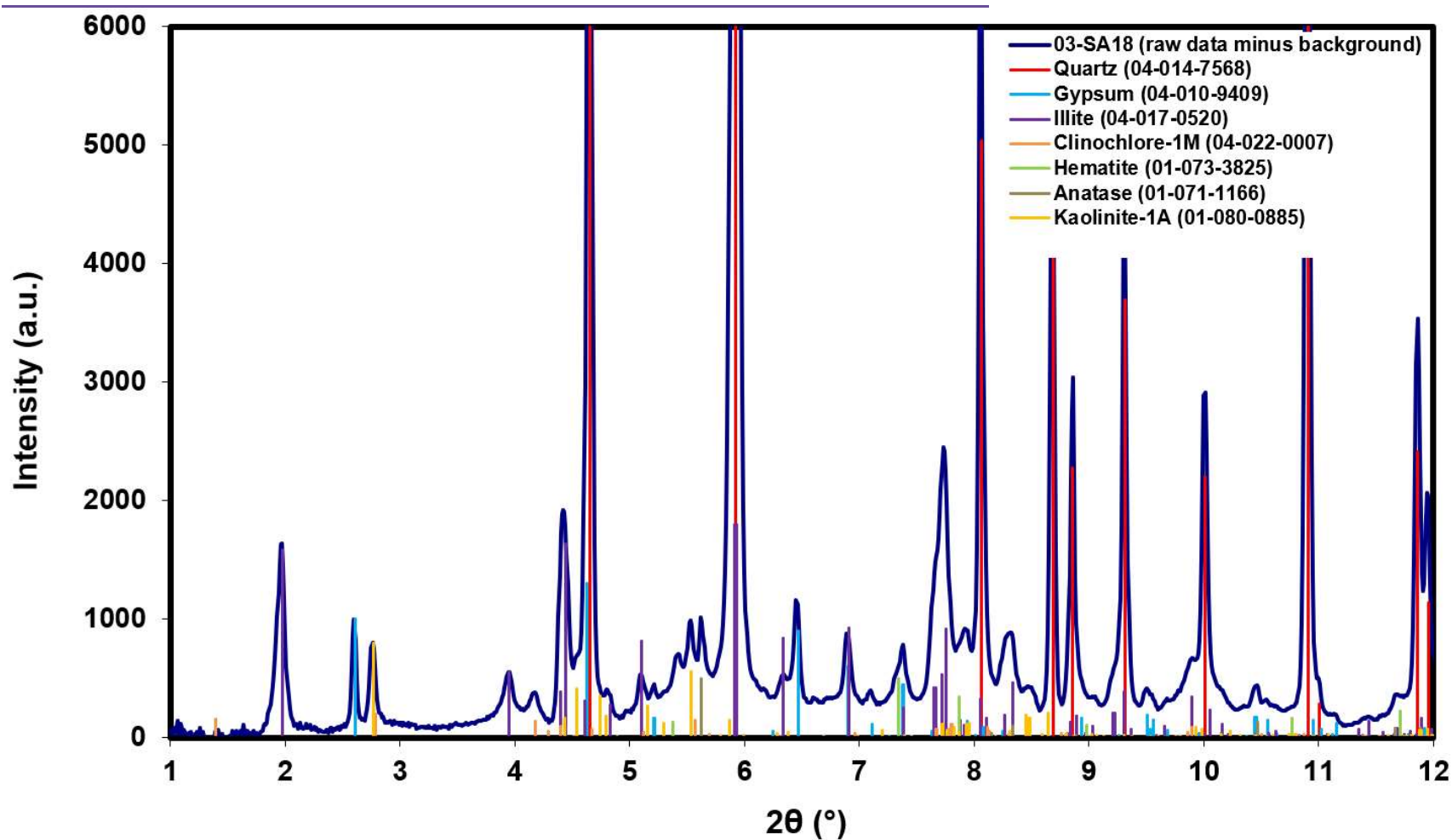


Figure 5.39. Phase identification results obtained for **03-SA18**, focusing on the low angle region near the background.

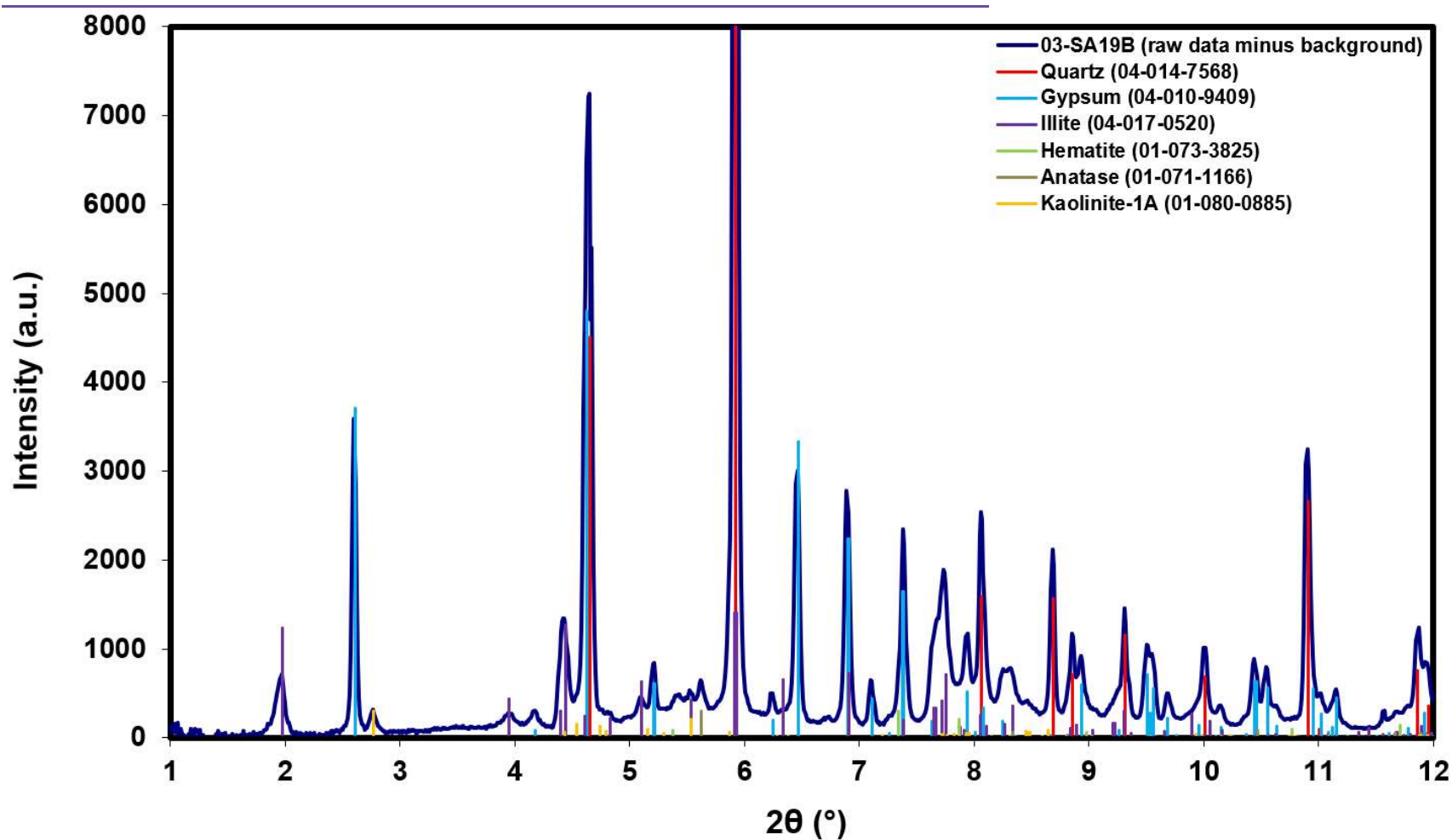


Figure 5.40. Phase identification results obtained for **03-SA19B**, focusing on the low angle region near the background.

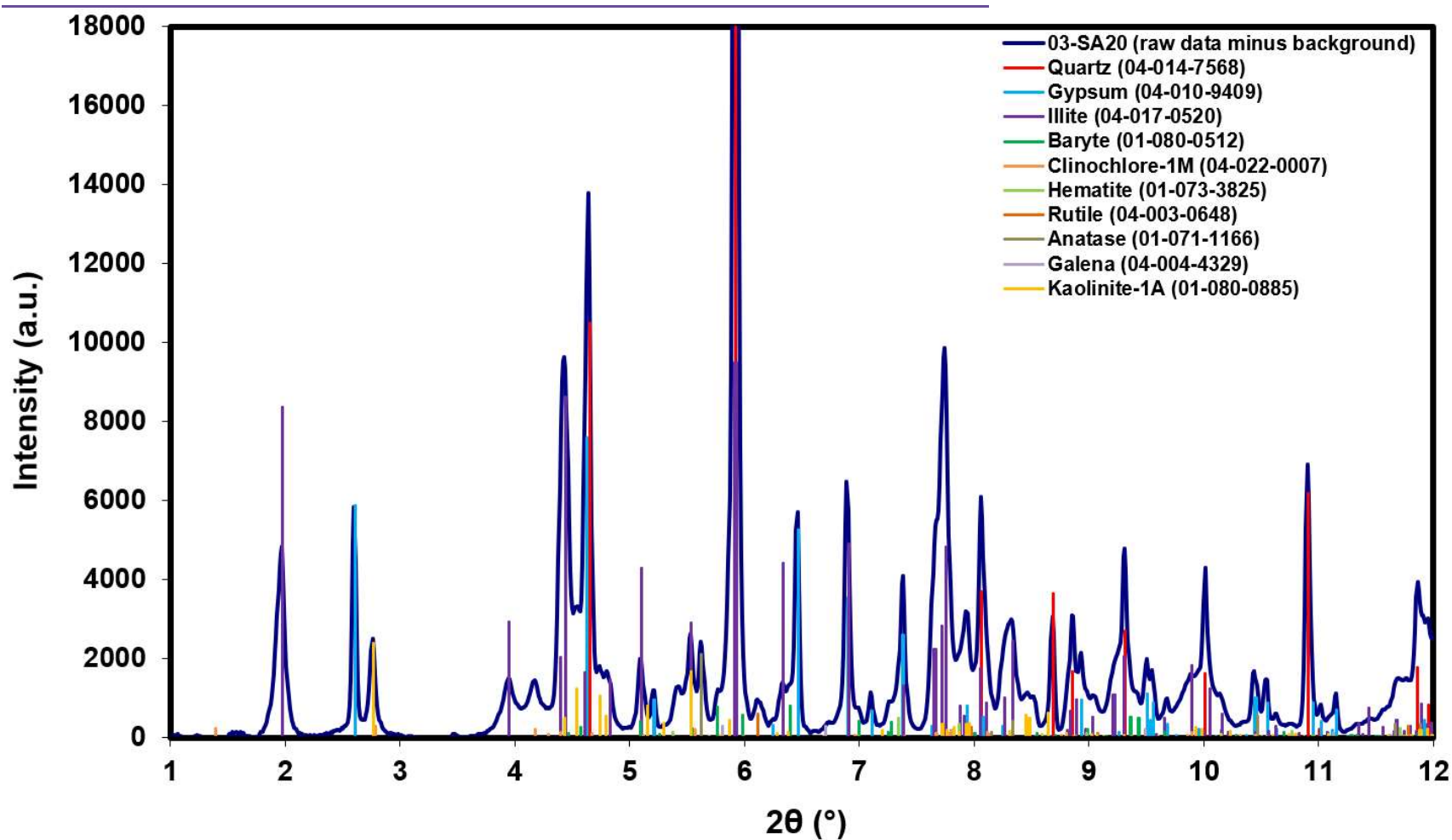


Figure 5.41. Phase identification results obtained for **03-SA20**, focusing on the low angle region near the background.

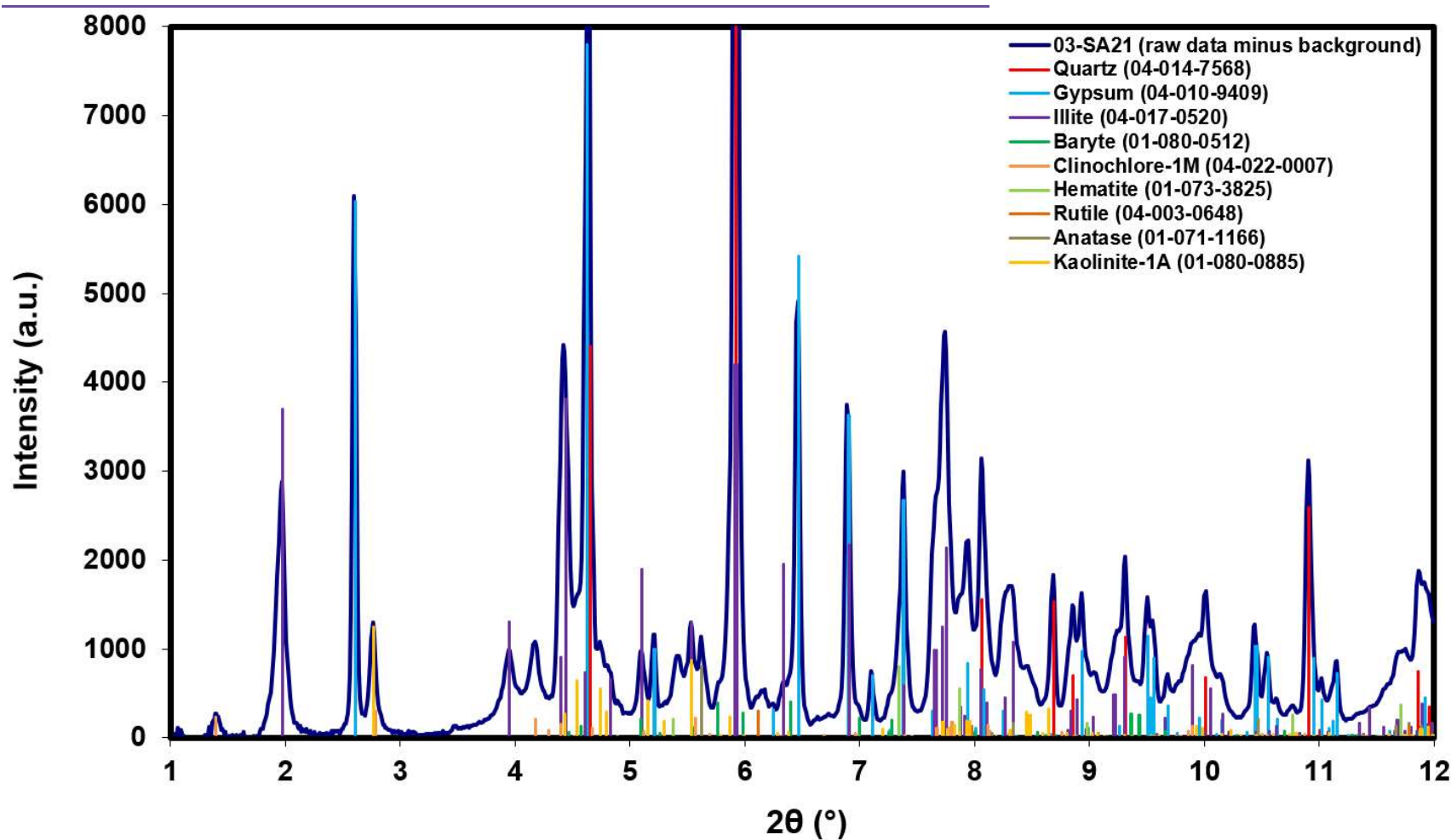


Figure 5.42. Phase identification results obtained for **03-SA21**, focusing on the low angle region near the background.

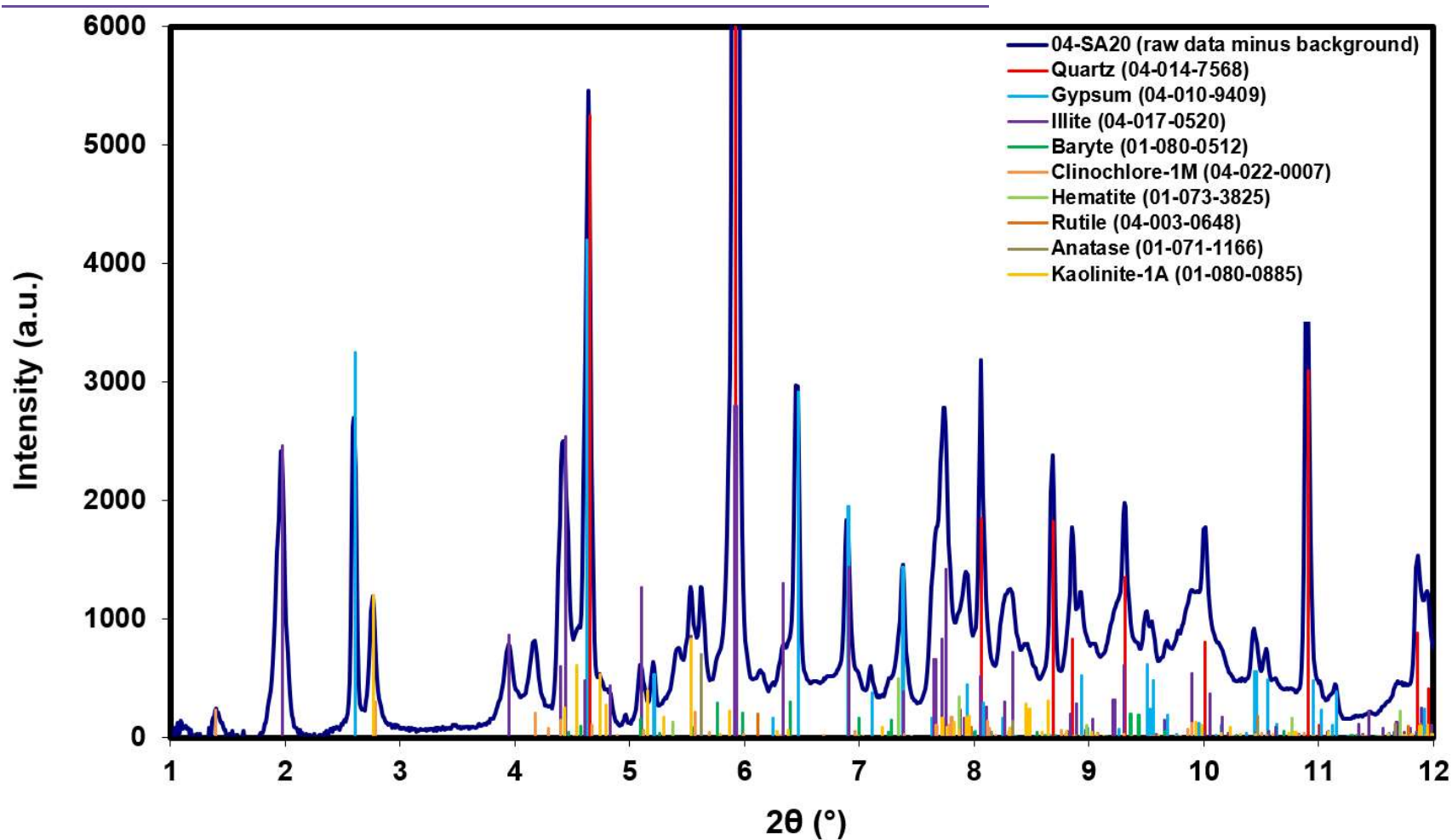


Figure 5.43. Phase identification results obtained for **04-SA20**, focusing on the low angle region near the background.

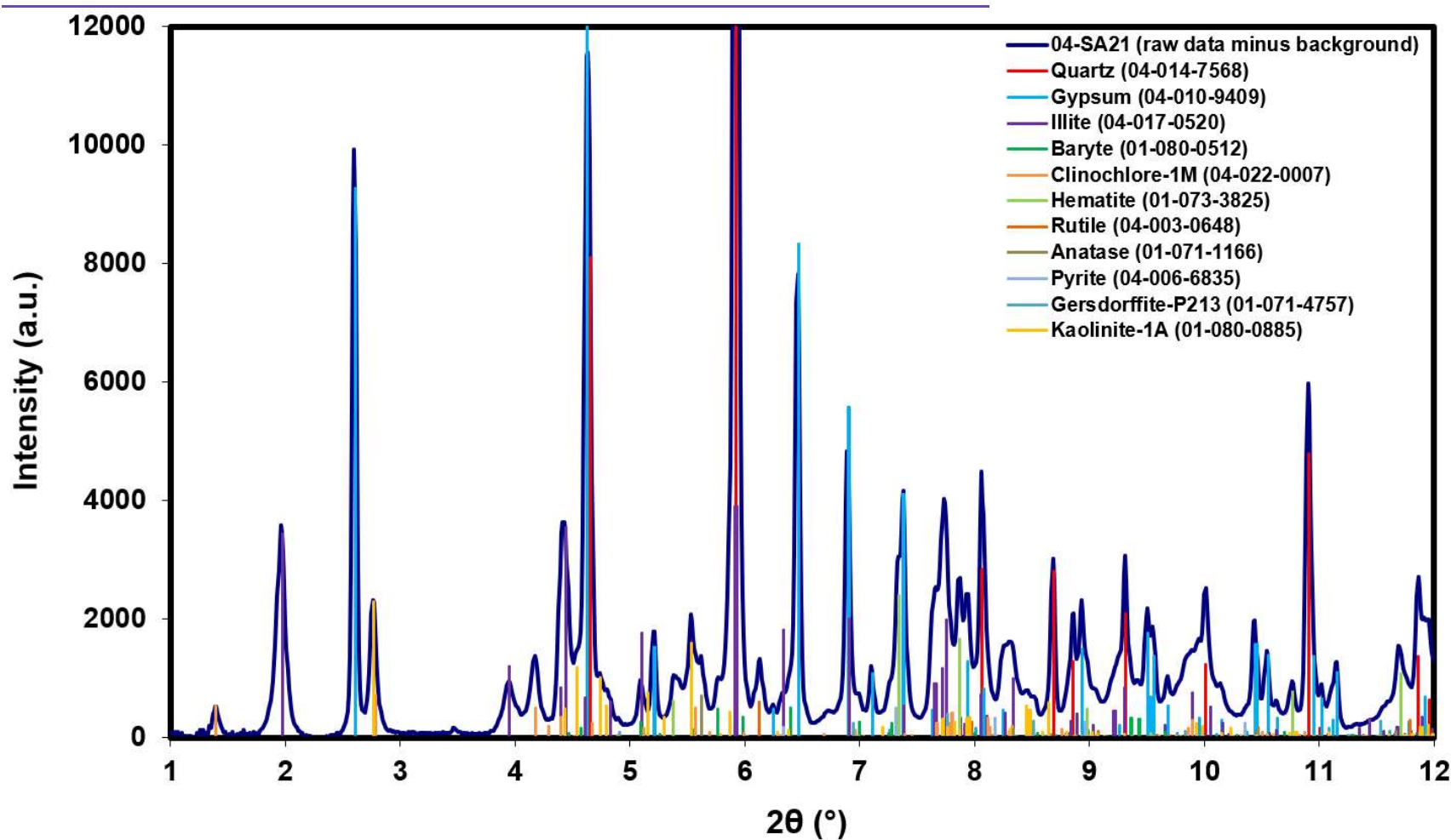


Figure 5.44. Phase identification results obtained for **04-SA21**, focusing on the low angle region near the background.

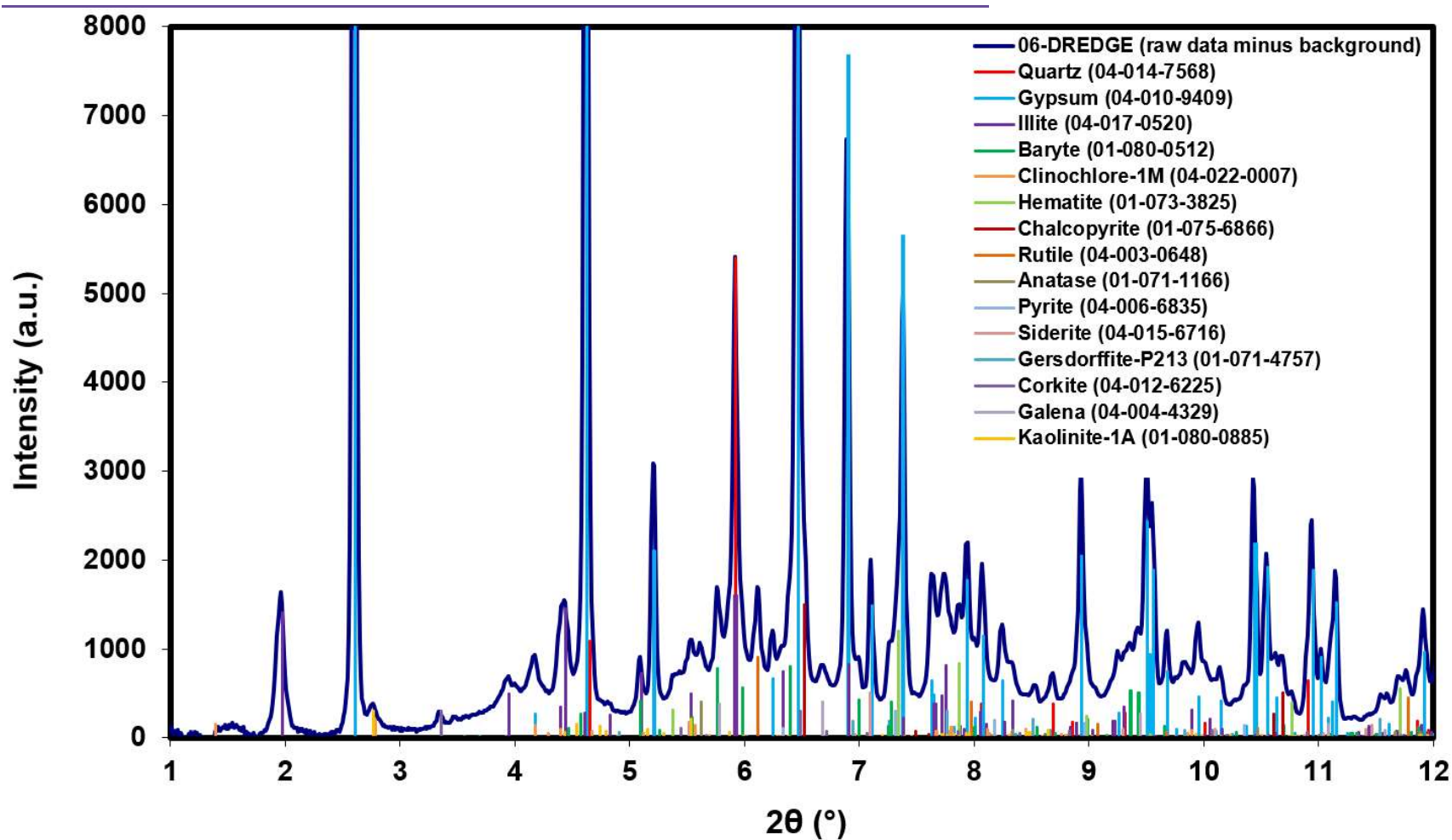


Figure 5.45. Phase identification results obtained for **06-SA01**, focusing on the low angle region near the background.

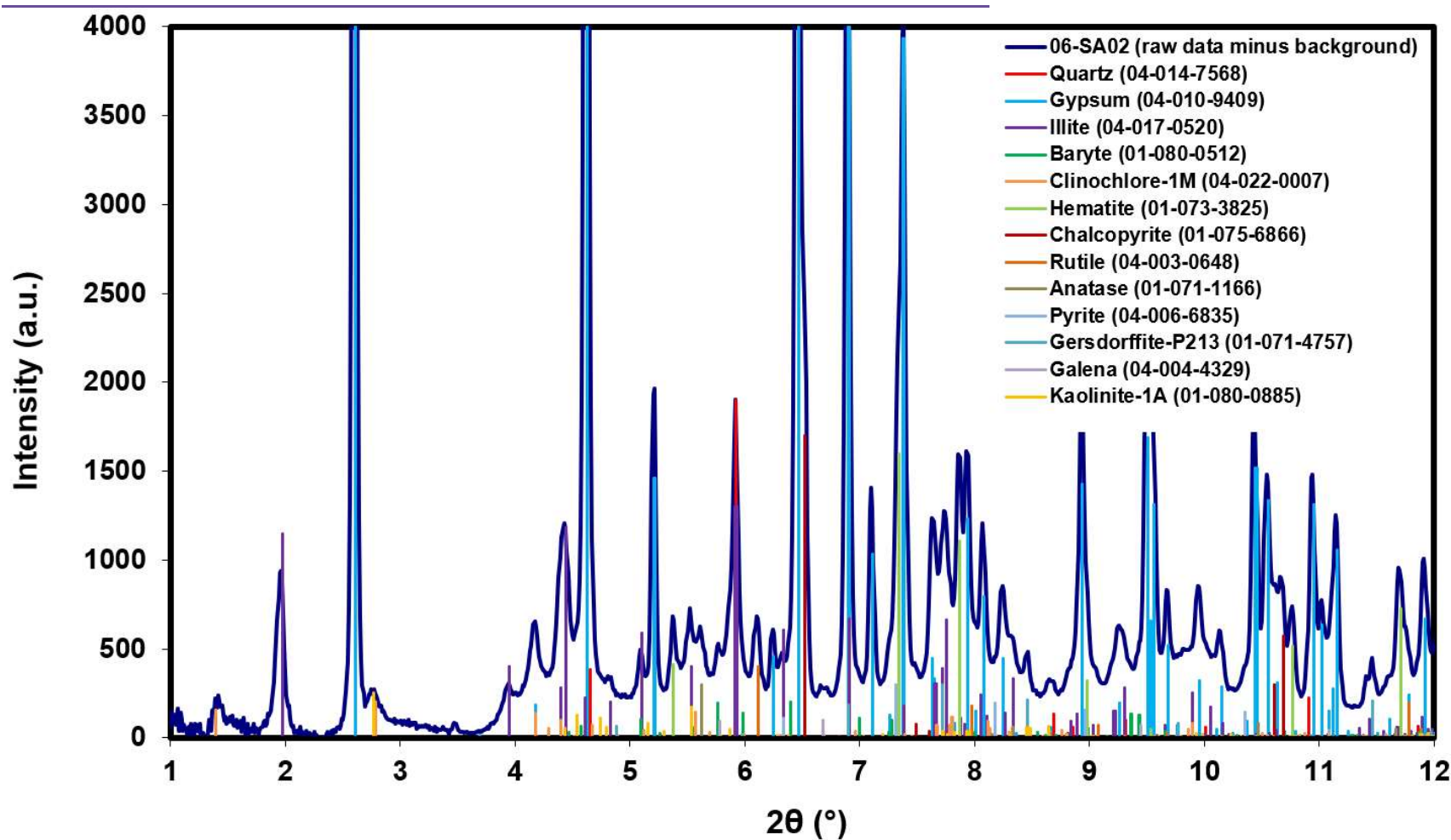


Figure 5.46. Phase identification results obtained for **06-SA02**, focusing on the low angle region near the background.

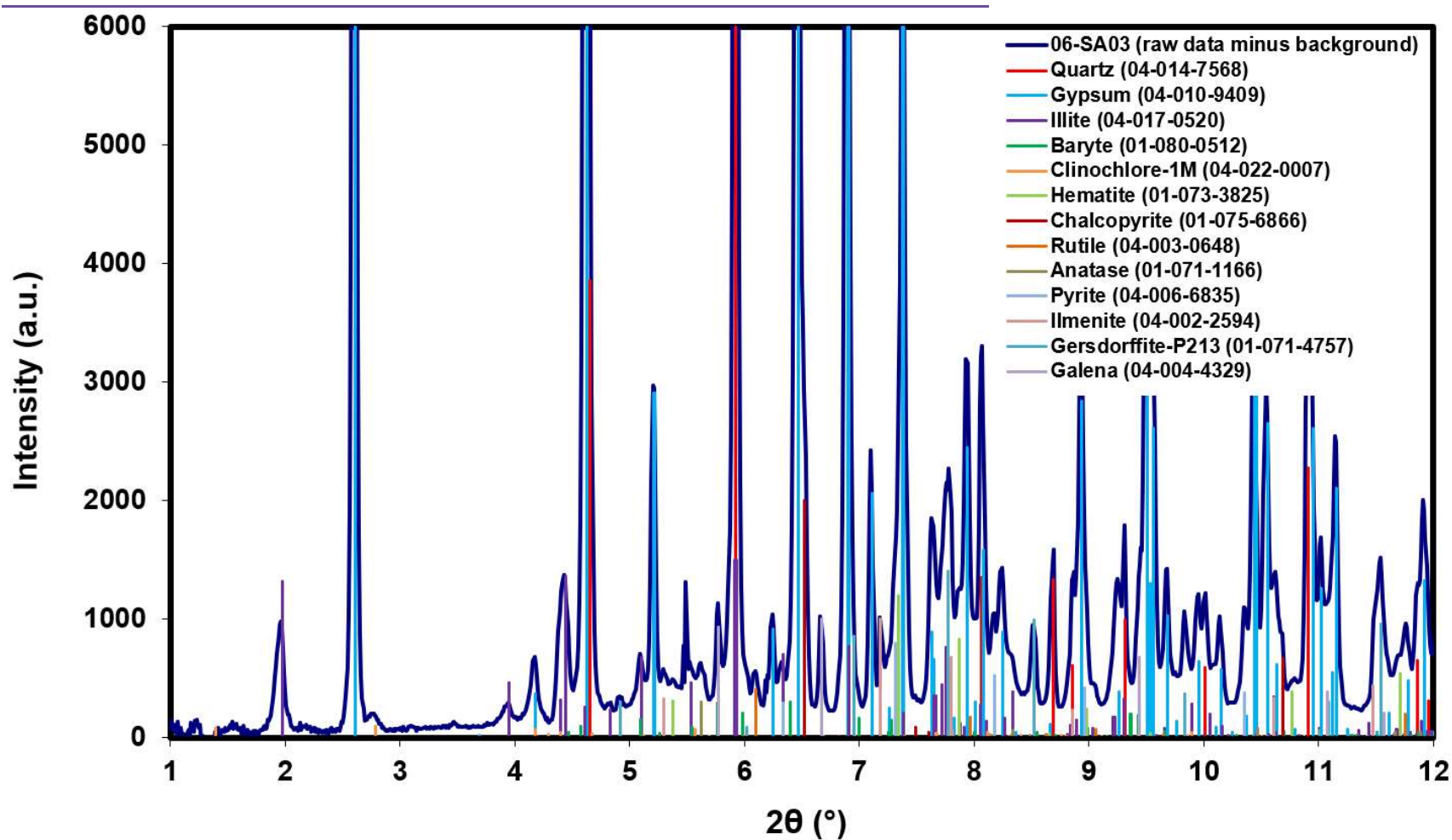


Figure 5.47. Phase identification results obtained for **06-SA03**, focusing on the low angle region near the background.

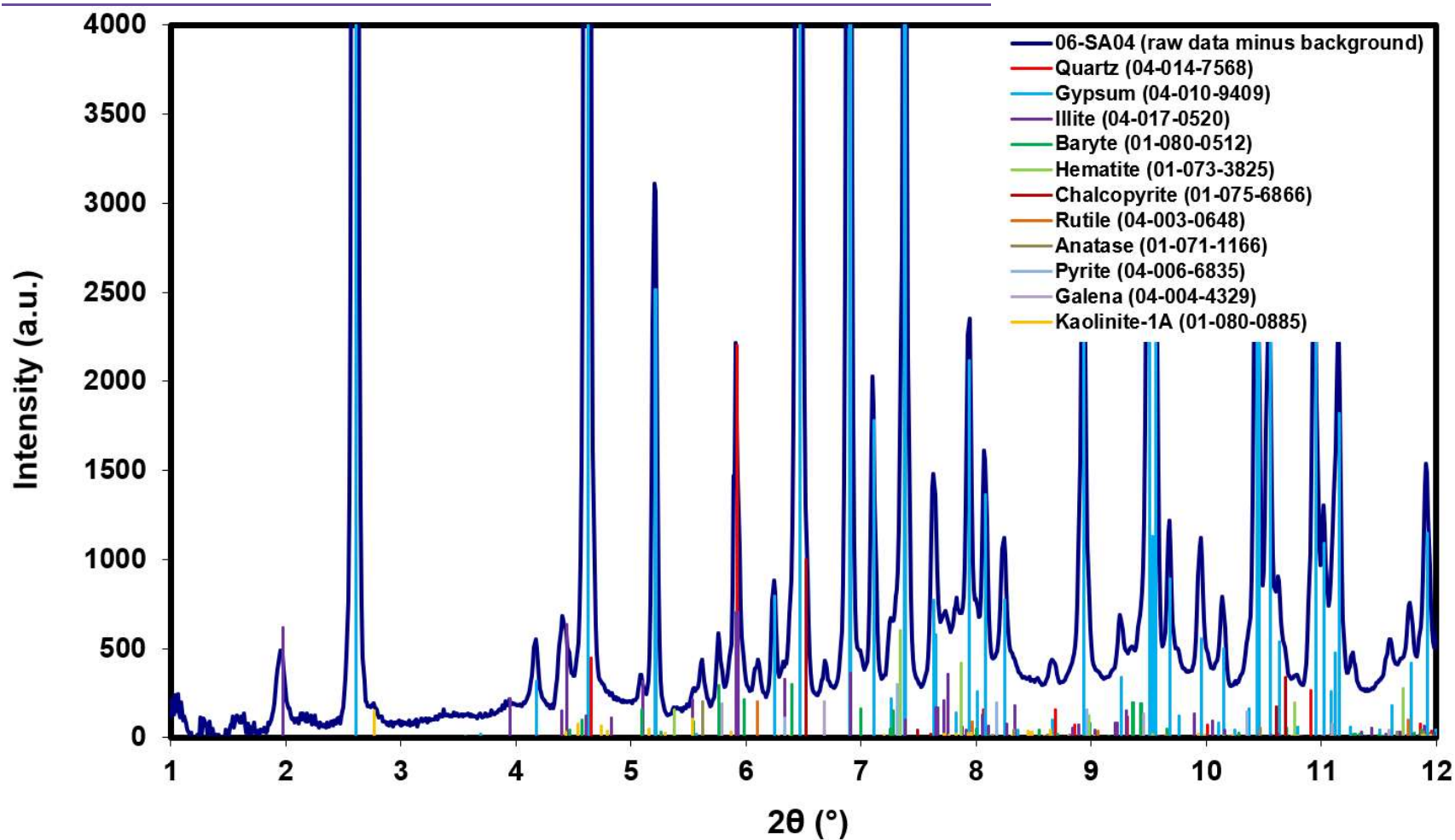


Figure 5.48. Phase identification results obtained for **06-SA04**, focusing on the low angle region near the background.

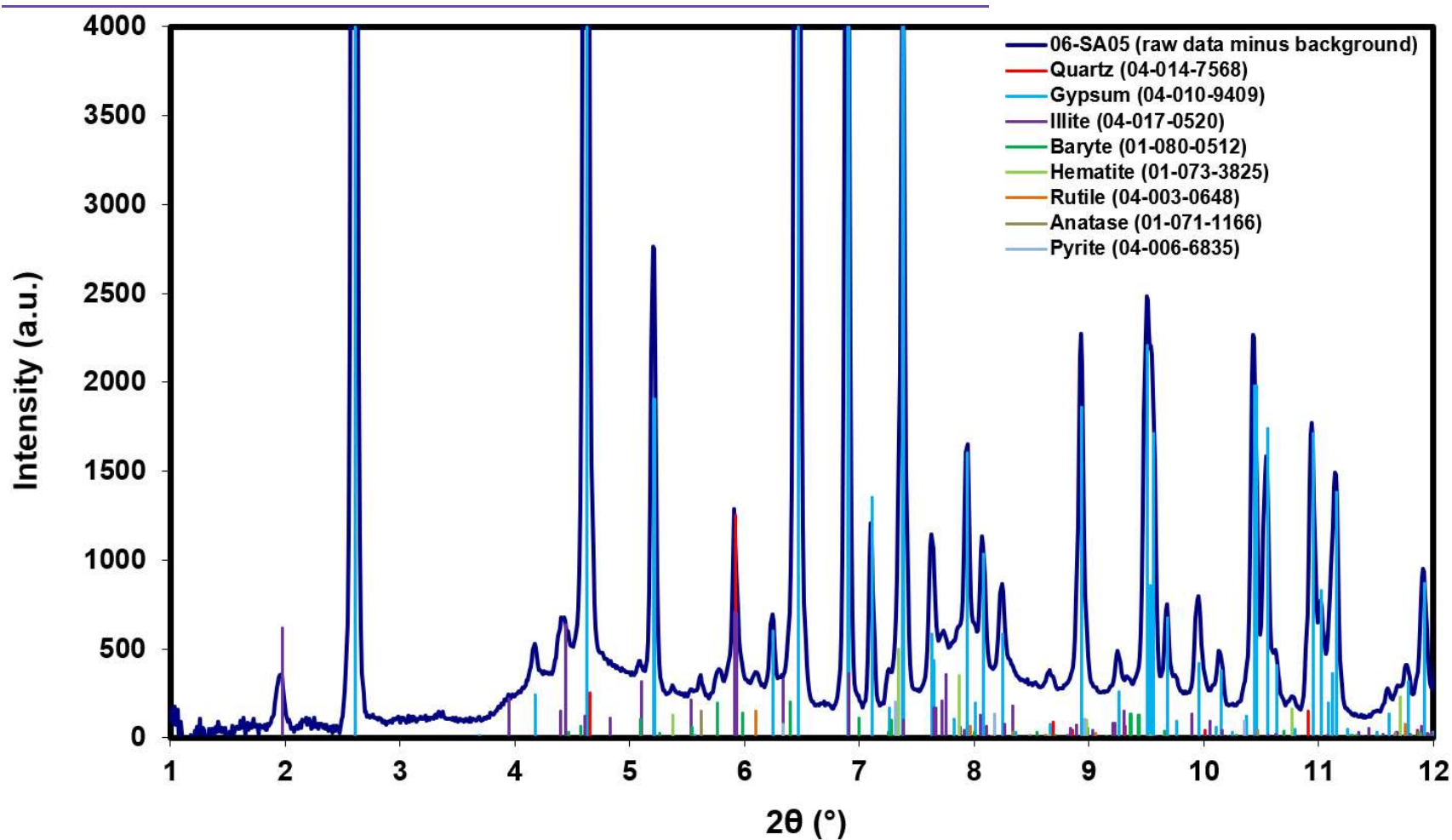


Figure 5.49. Phase identification results obtained for **06-SA05**, focusing on the low angle region near the background.

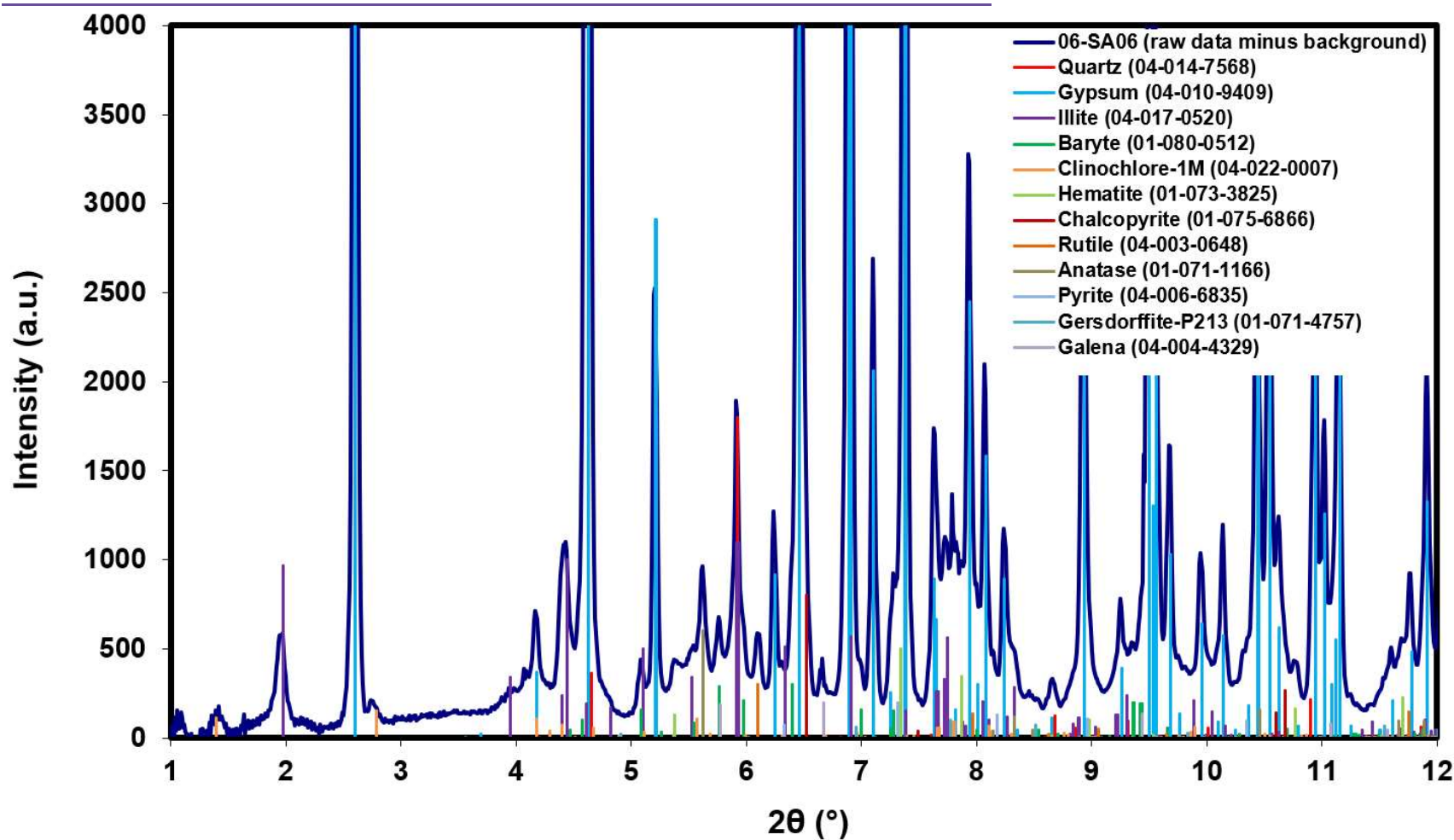


Figure 5.50. Phase identification results obtained for **06-SA06**, focusing on the low angle region near the background.

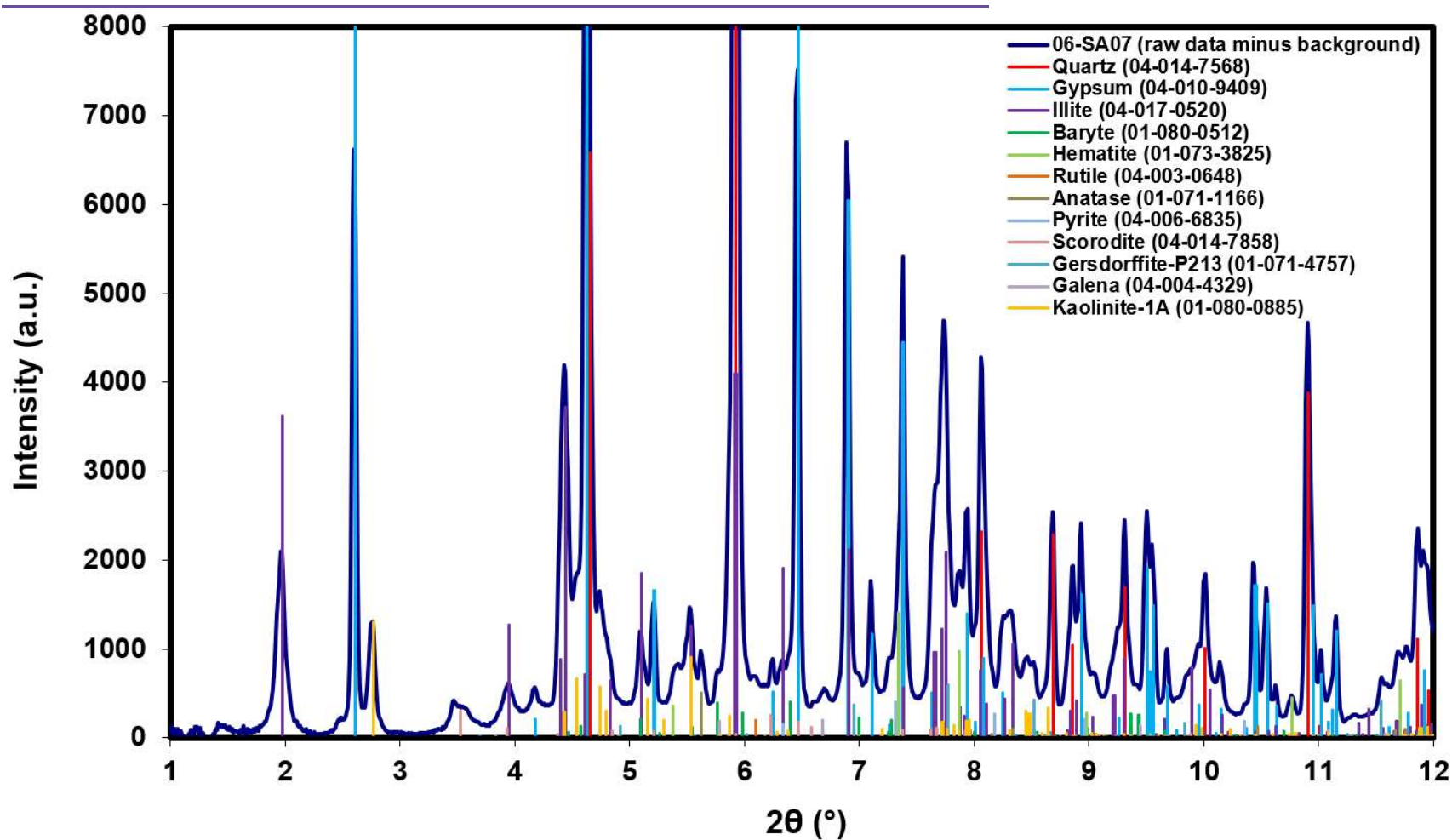


Figure 5.51. Phase identification results obtained for **06-SA07**, focusing on the low angle region near the background.

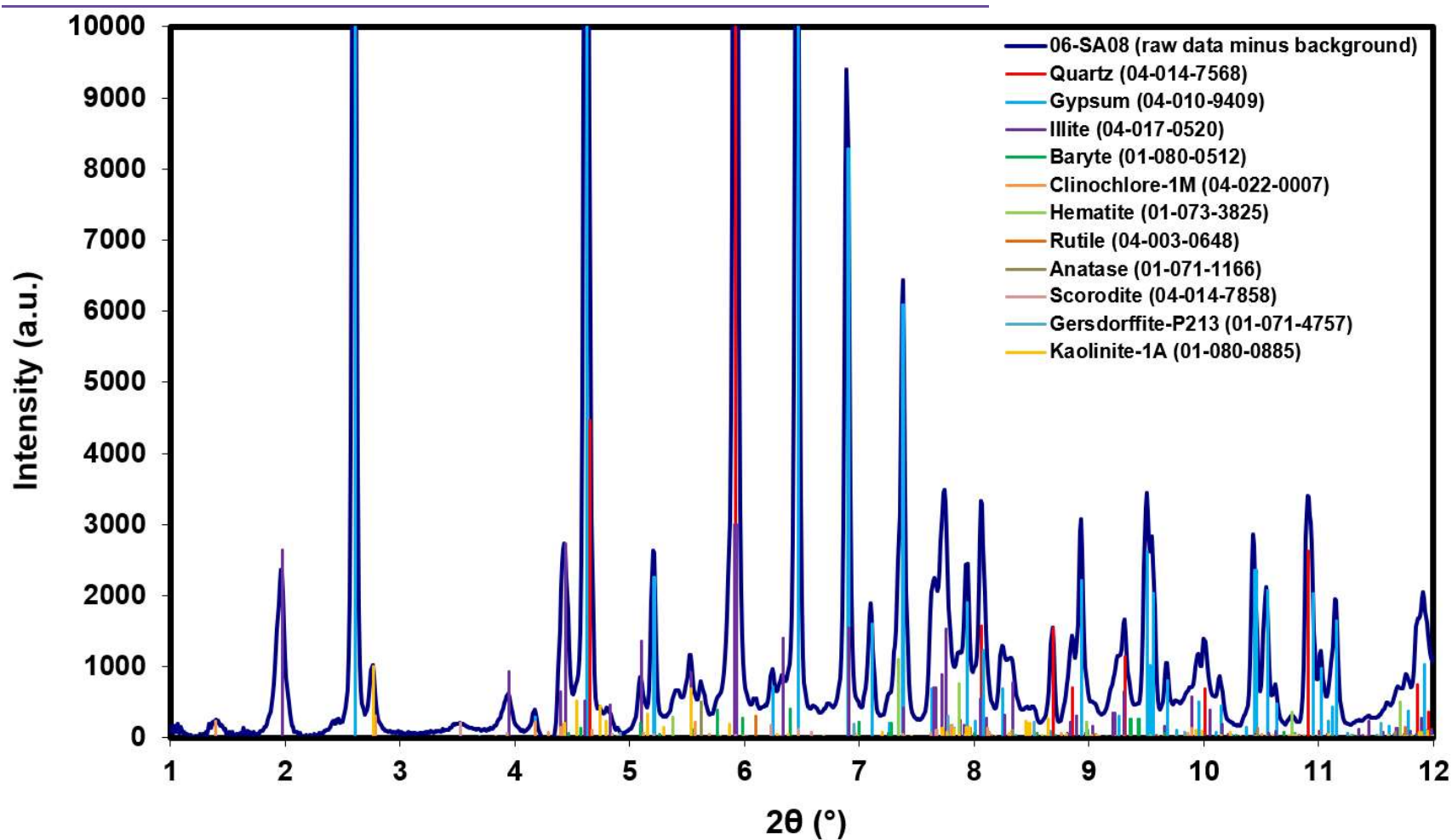


Figure 5.52. Phase identification results obtained for **06-SA08**, focusing on the low angle region near the background.

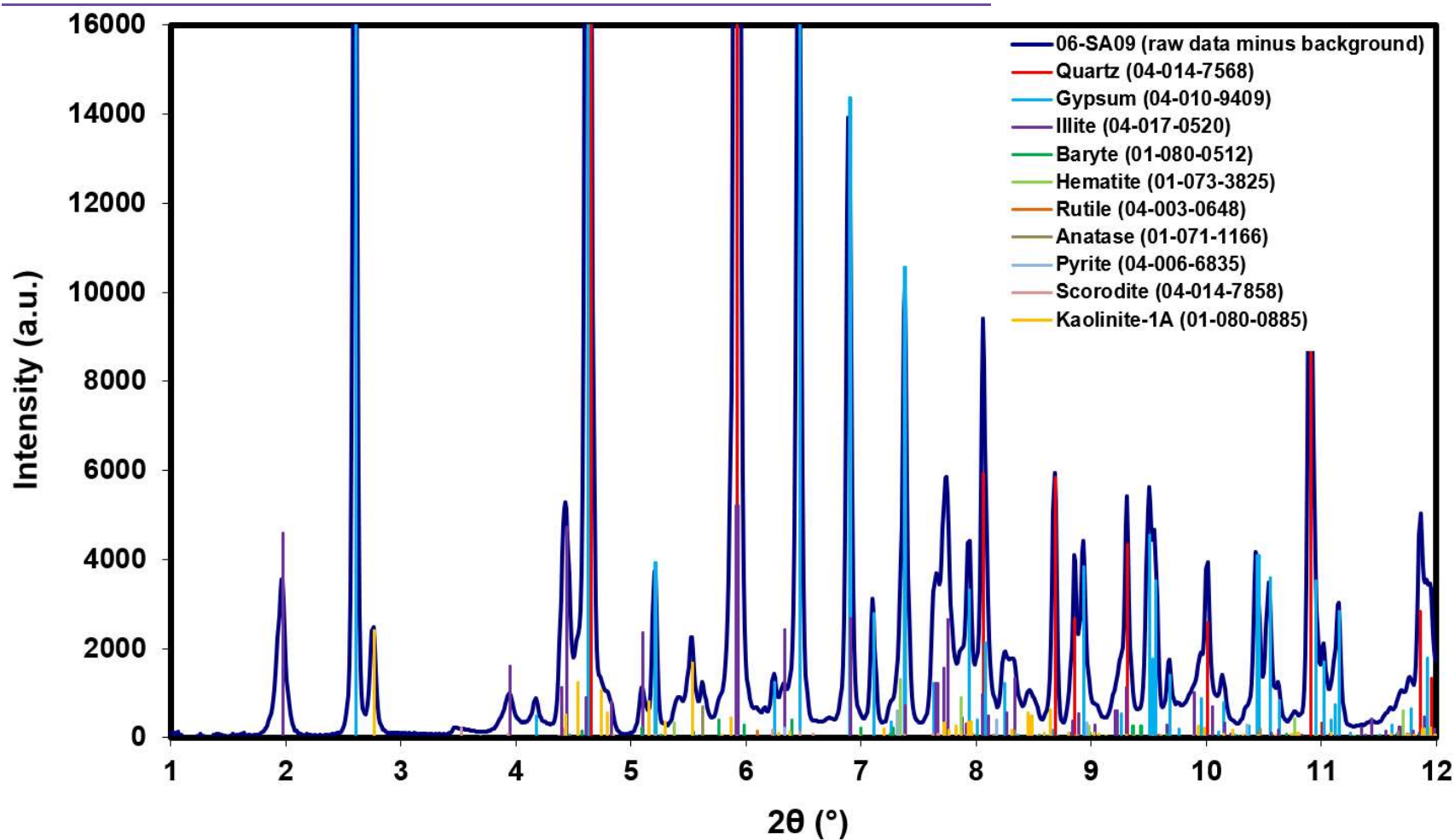


Figure 5.53. Phase identification results obtained for **06-SA09**, focusing on the low angle region near the background.

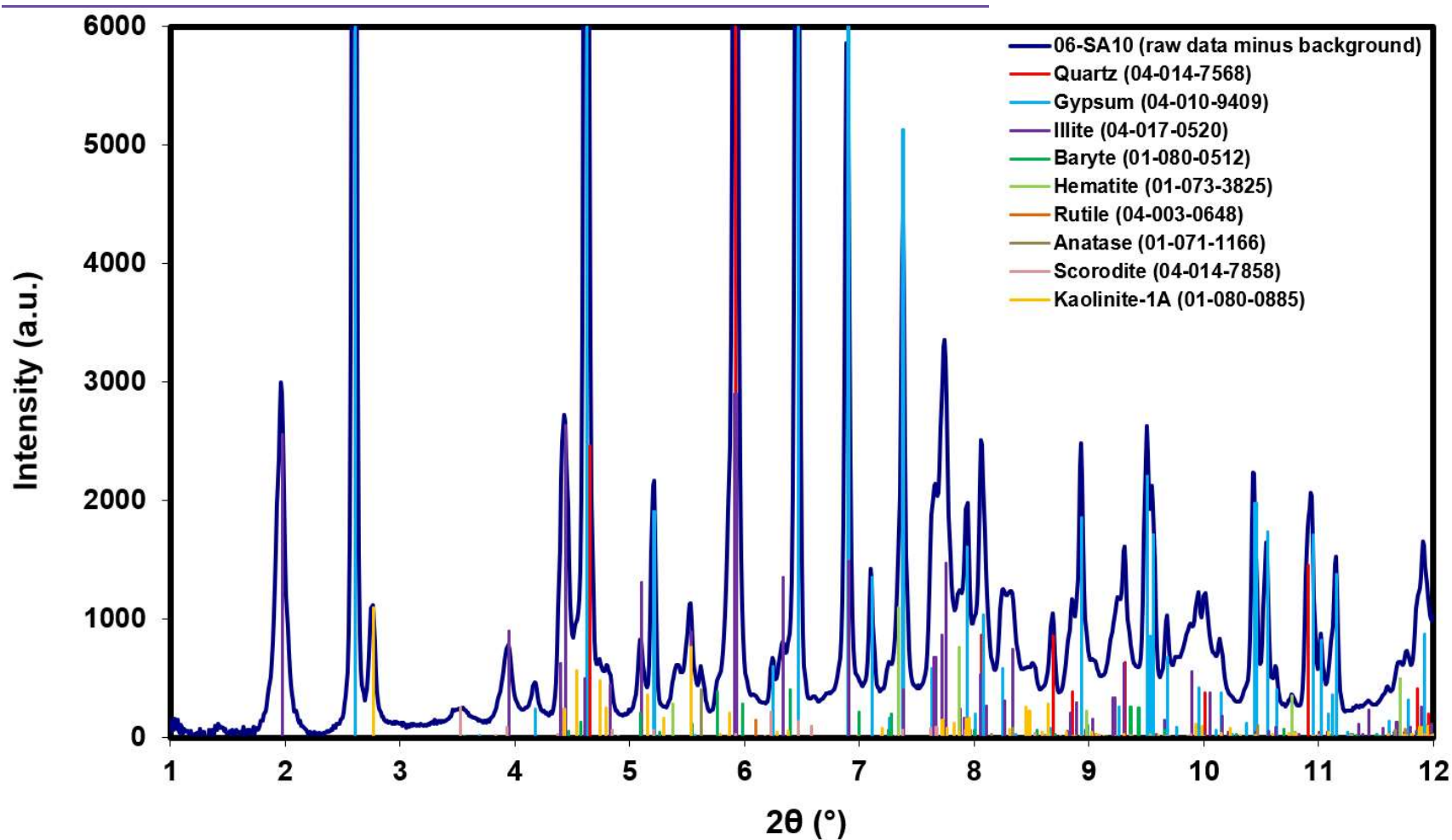


Figure 5.54. Phase identification results obtained for **06-SA10**, focusing on the low angle region near the background.

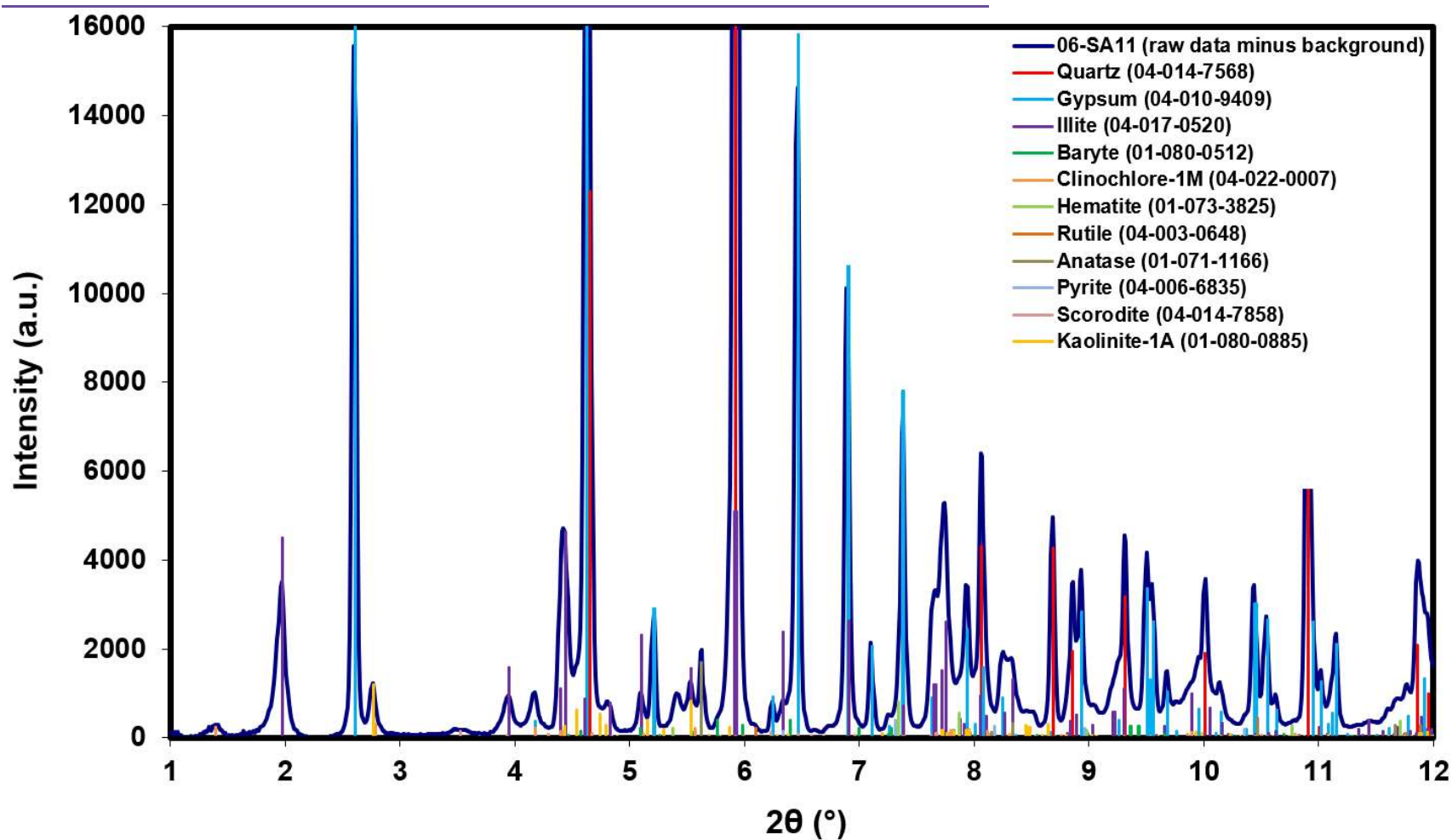


Figure 5.55. Phase identification results obtained for **06-SA11**, focusing on the low angle region near the background.

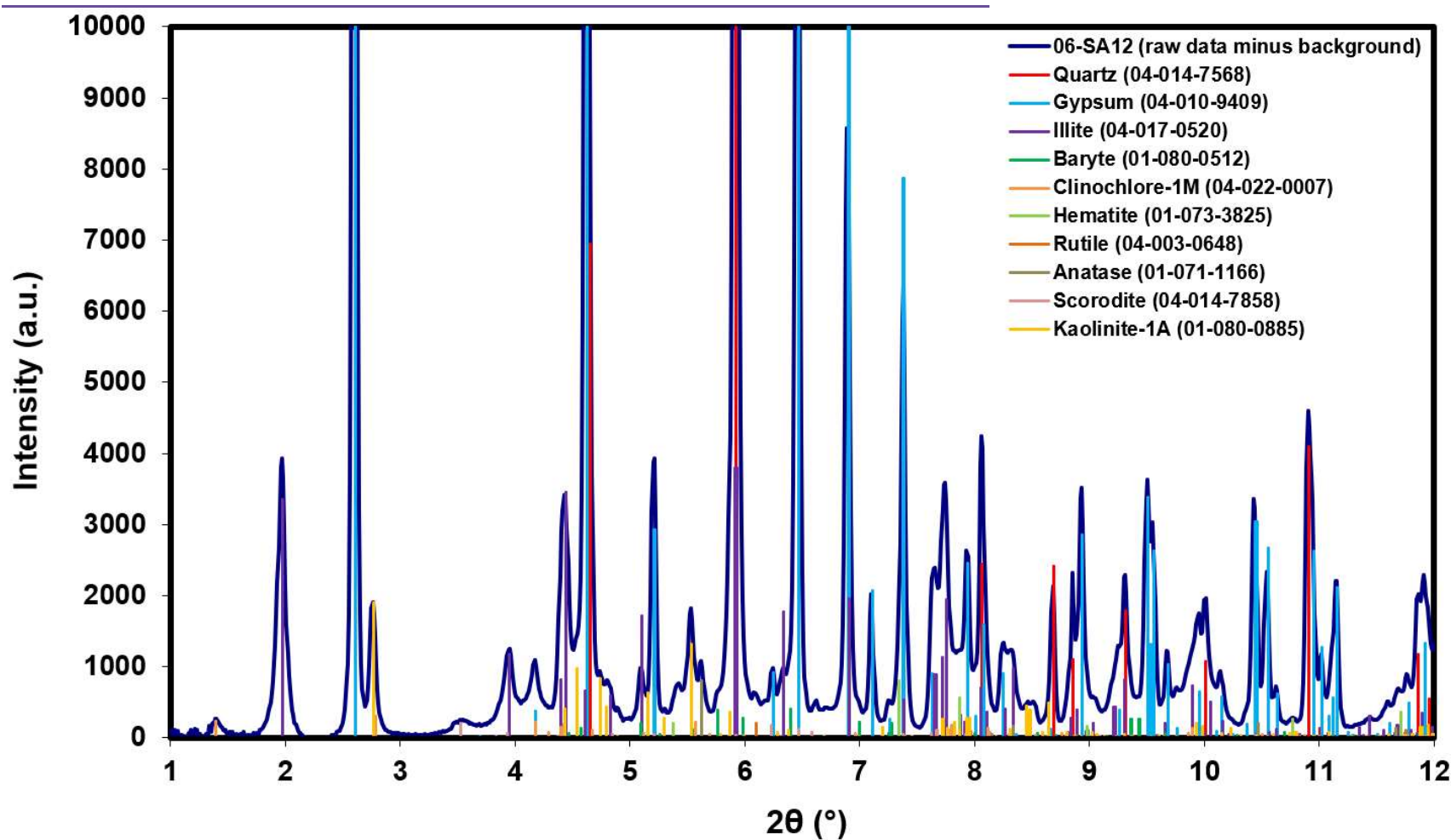


Figure 5.56. Phase identification results obtained for **06-SA12**, focusing on the low angle region near the background.

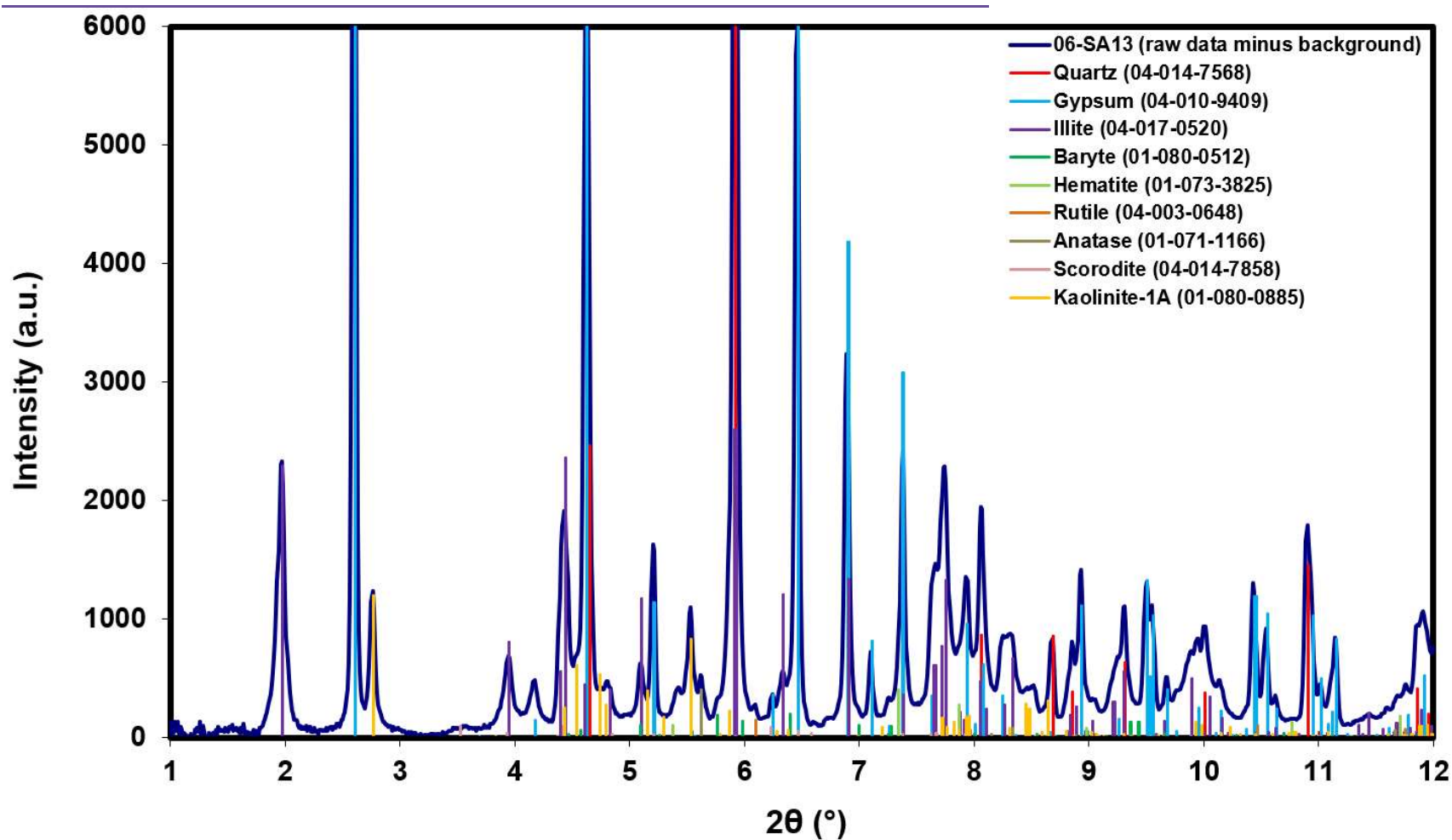


Figure 5.57. Phase identification results obtained for **06-SA13**, focusing on the low angle region near the background.

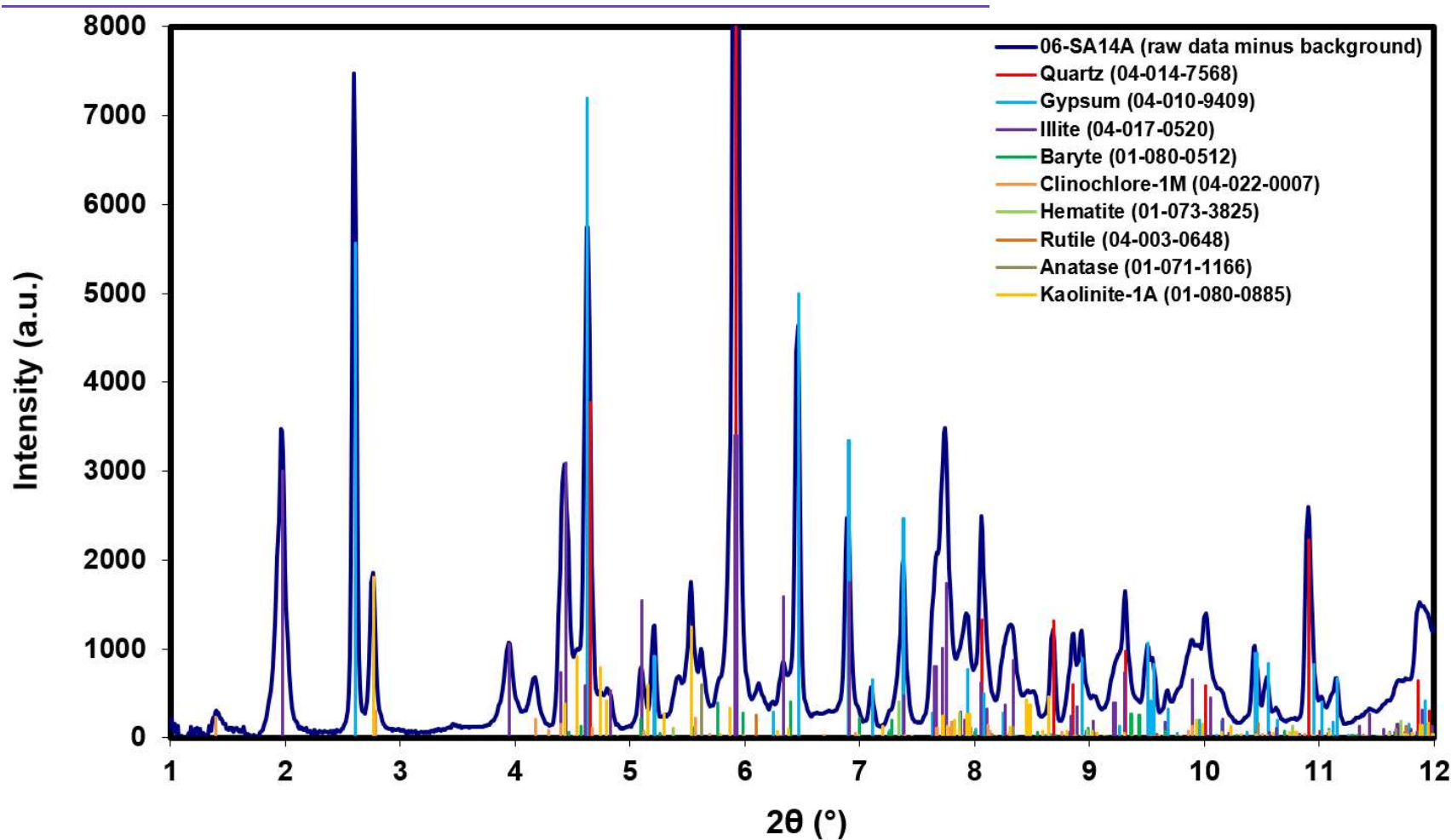


Figure 5.58. Phase identification results obtained for **06-SA14A**, focusing on the low angle region near the background.

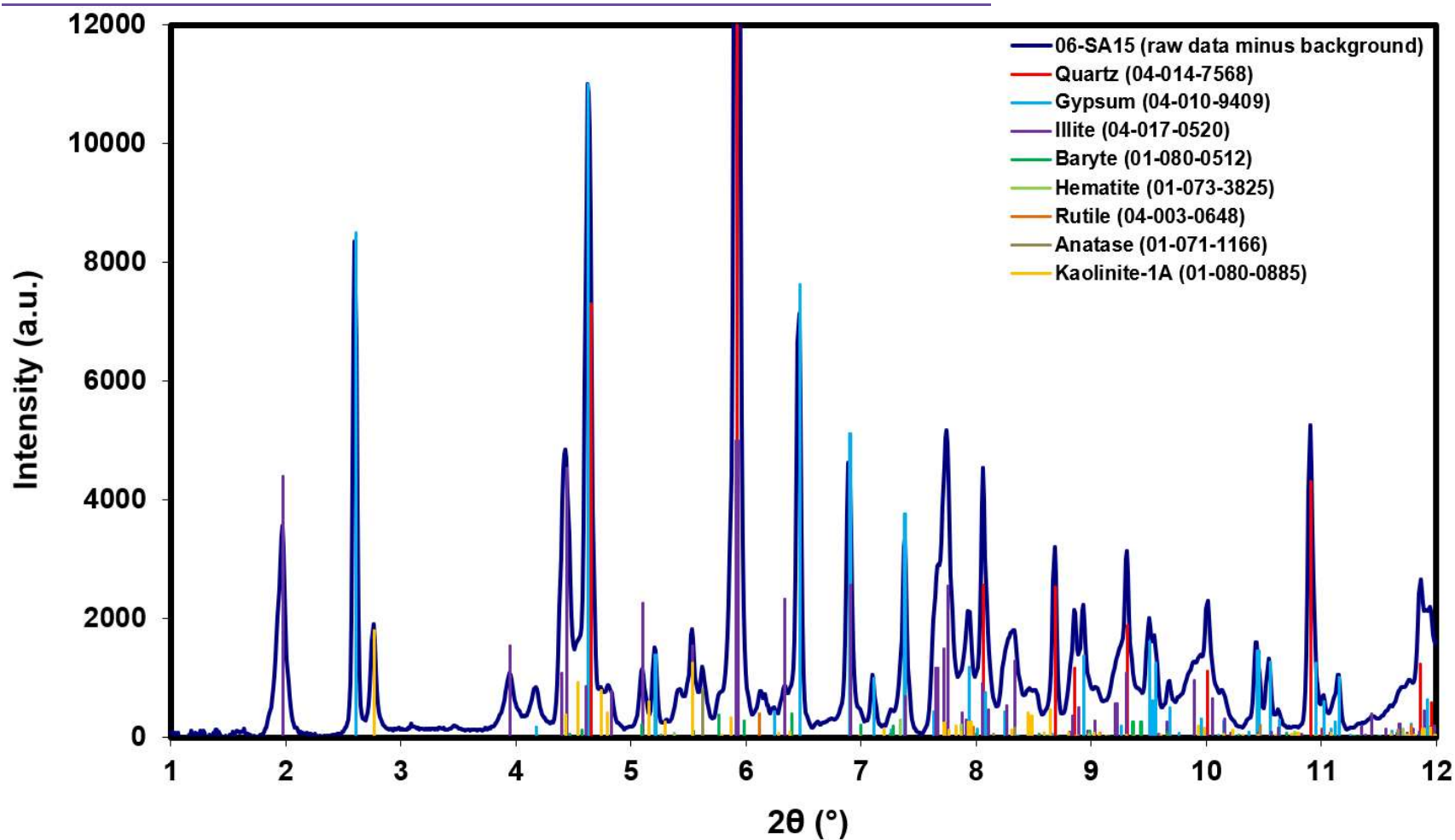


Figure 5.59. Phase identification results obtained for **06-SA15**, focusing on the low angle region near the background.

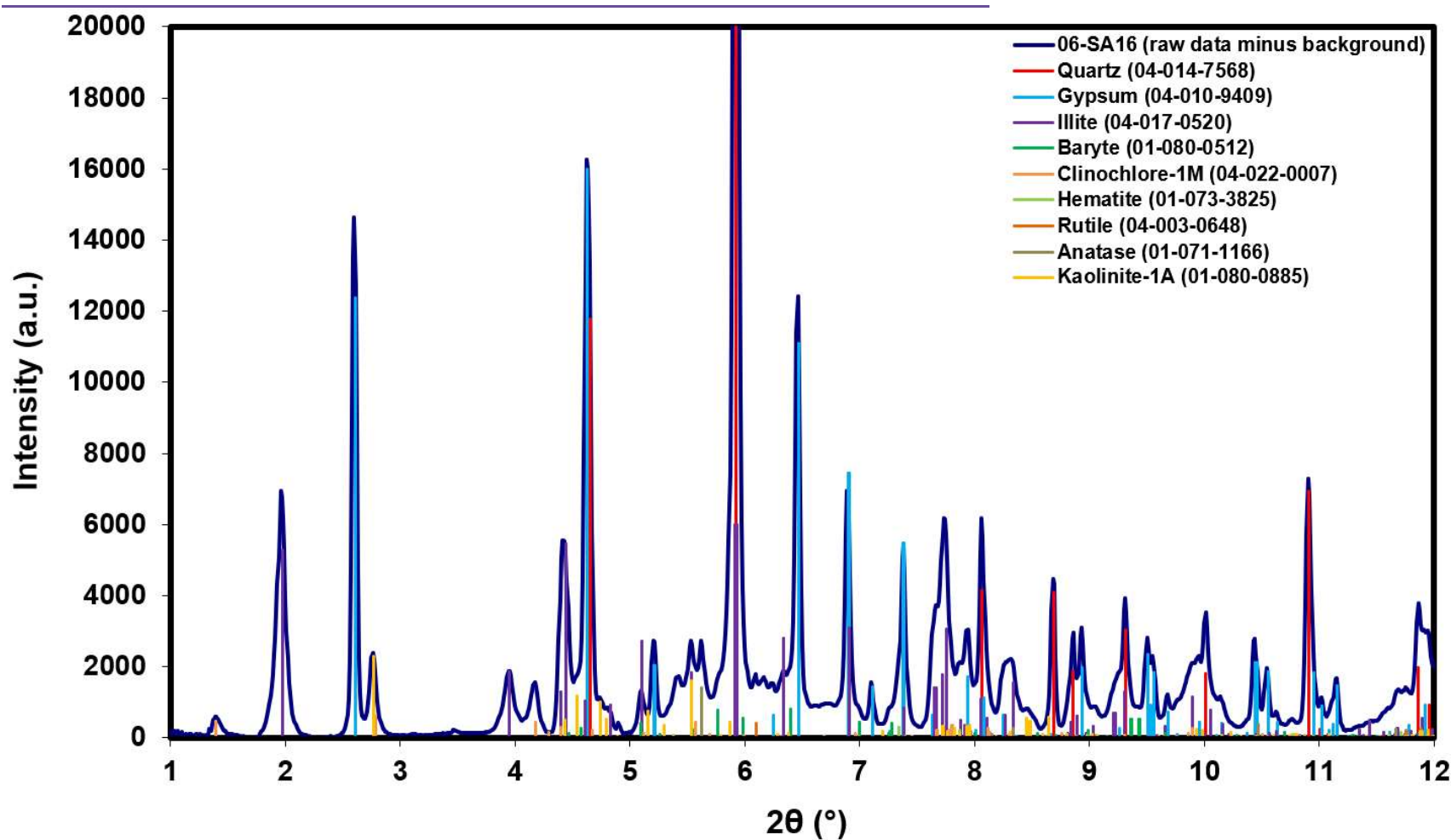


Figure 5.60. Phase identification results obtained for **06-SA16**, focusing on the low angle region near the background.

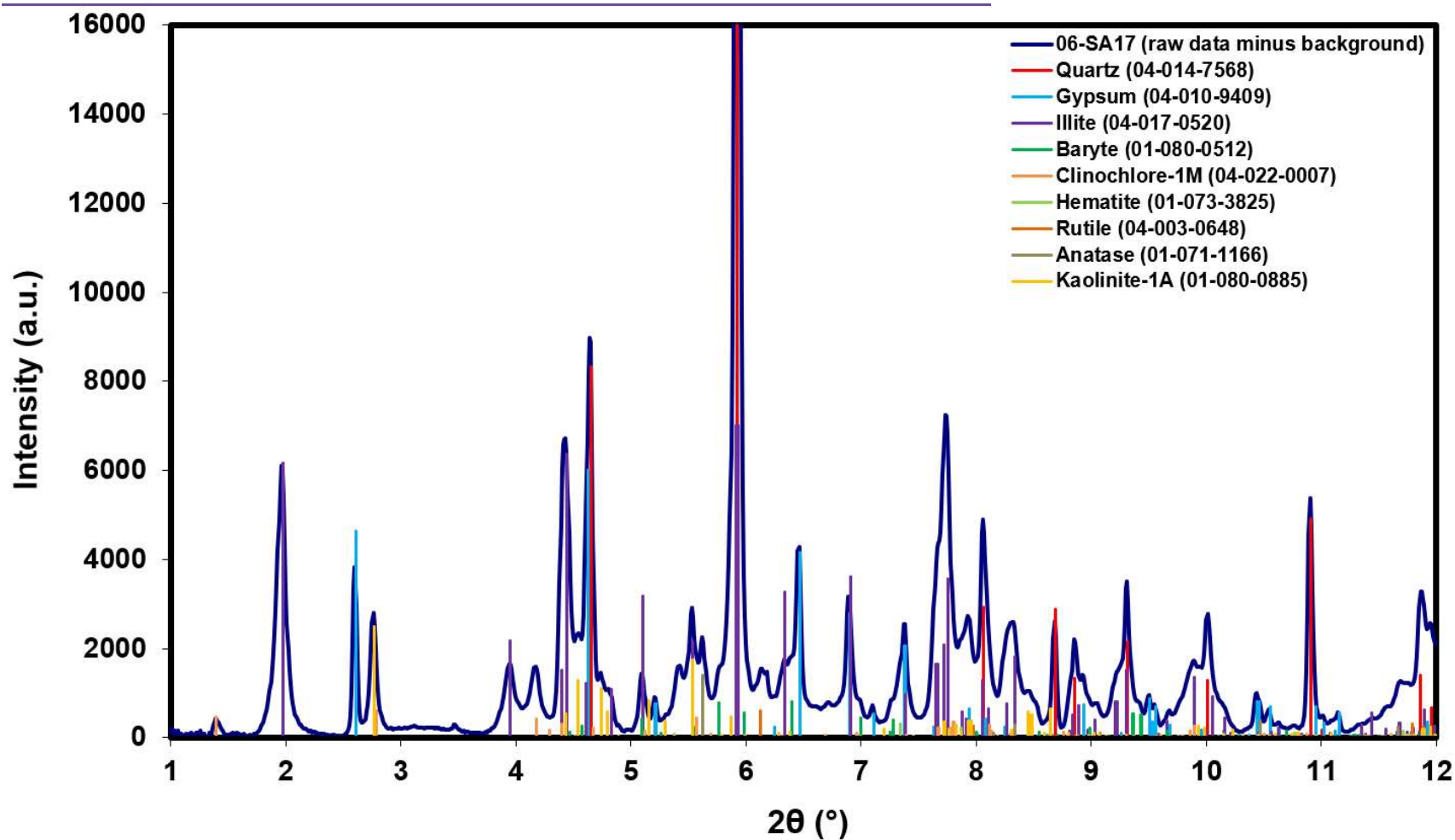


Figure 5.61. Phase identification results obtained for **06-SA17**, focusing on the low angle region near the background.

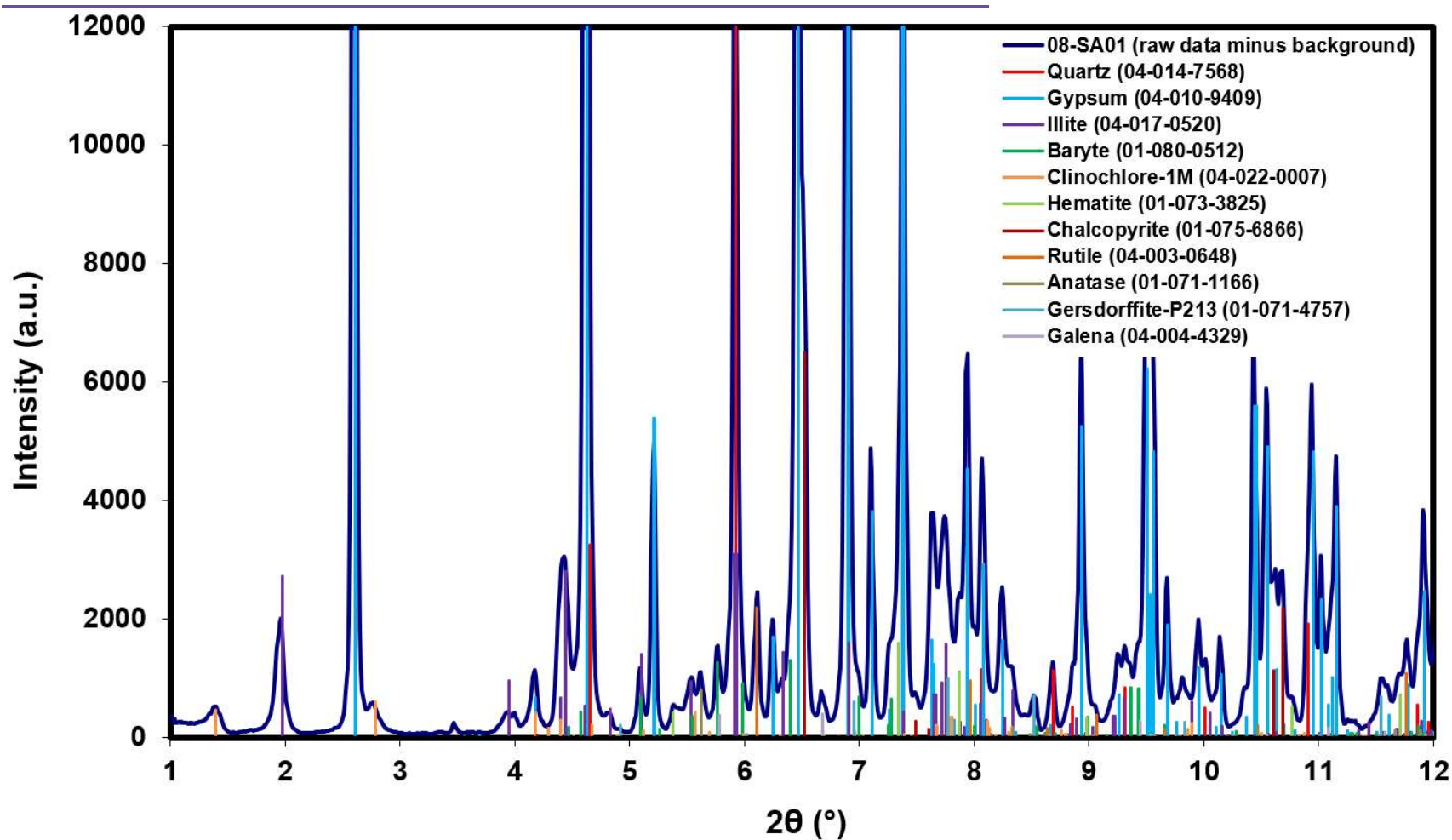


Figure 5.62. Phase identification results obtained for **08-SA01**, focusing on the low angle region near the background.

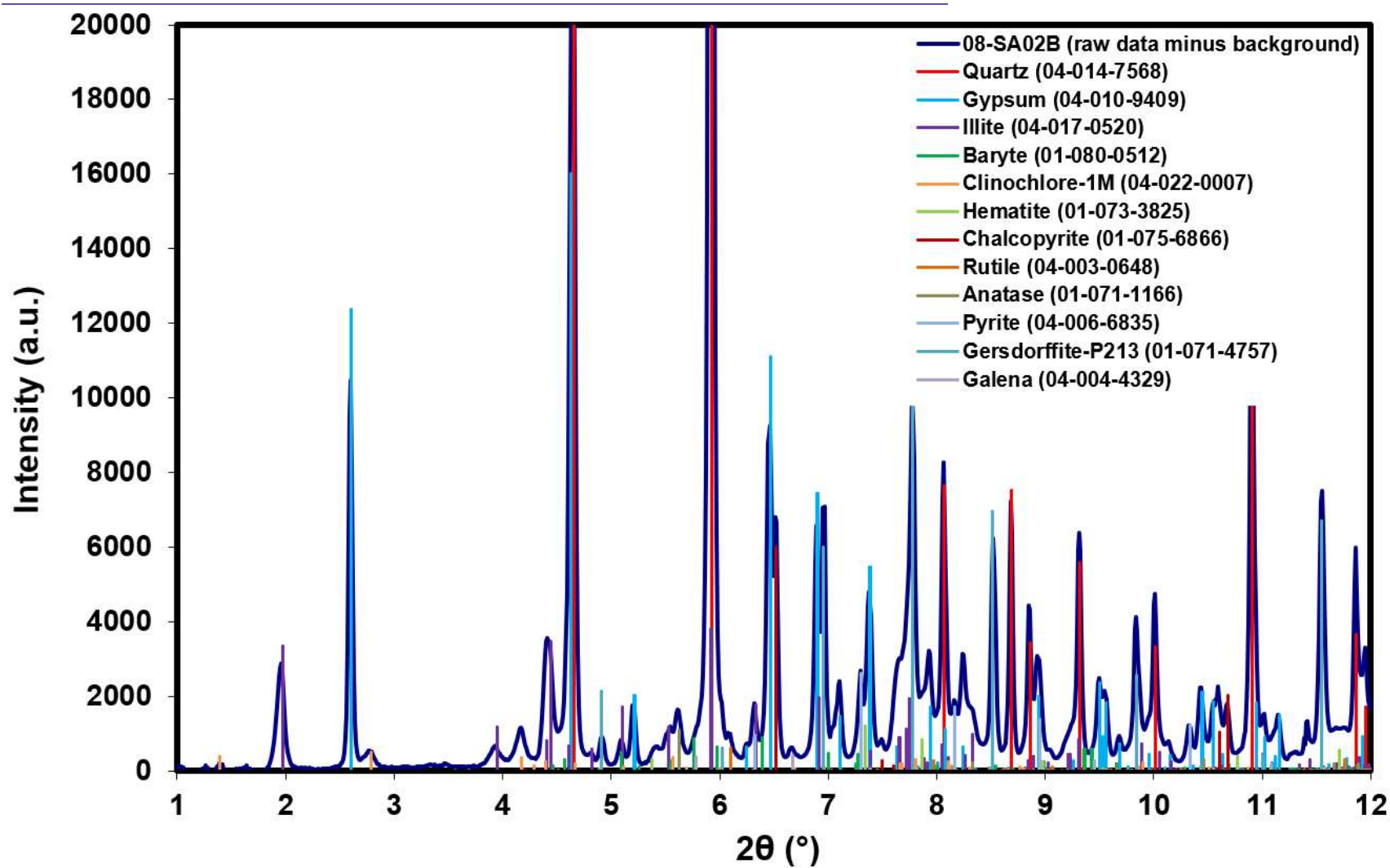


Figure 5.63. Phase identification results obtained for **08-SA02B**, focusing on the low angle region near the background.

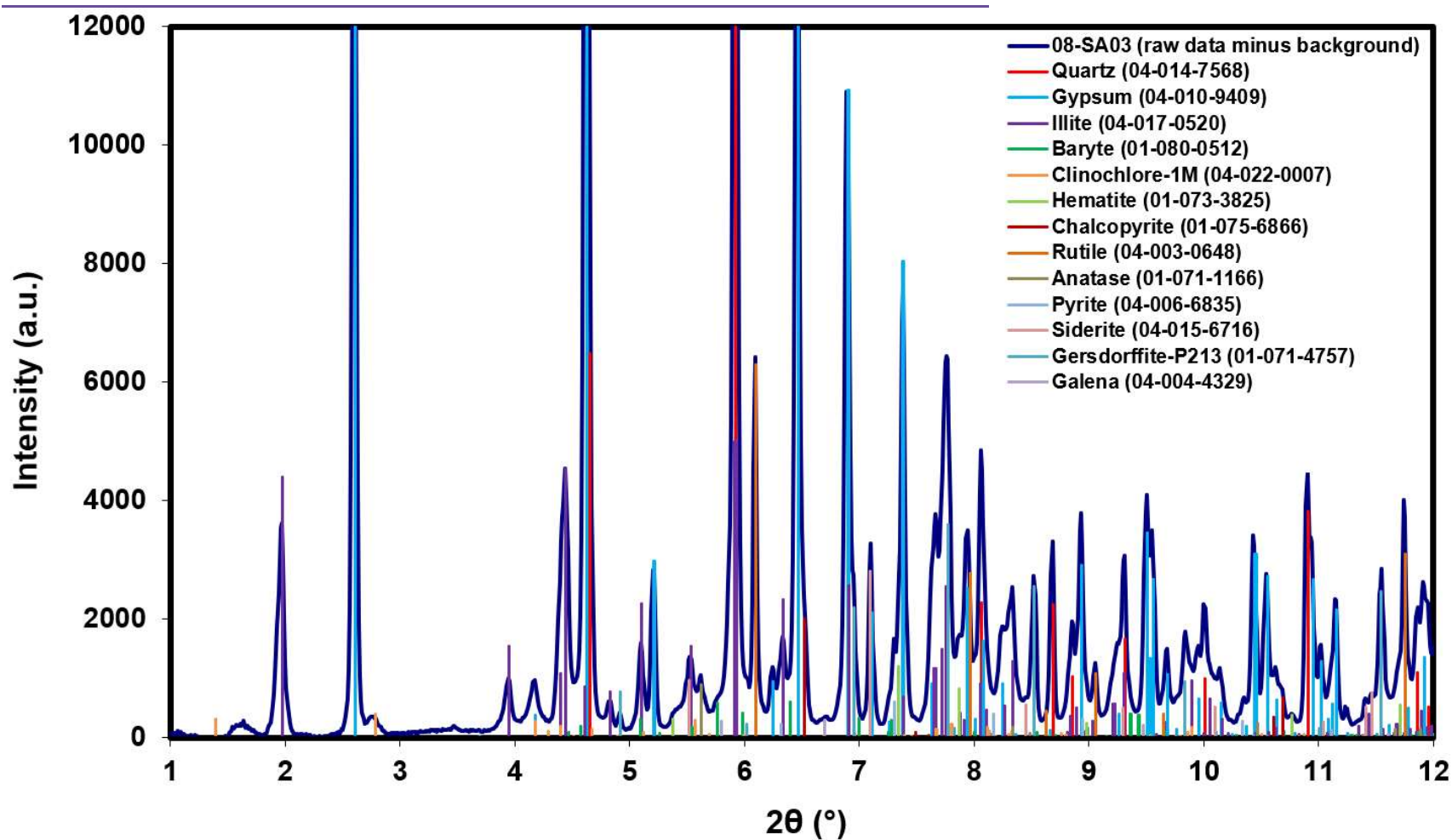


Figure 5.64. Phase identification results obtained for **08-SA03**, focusing on the low angle region near the background.

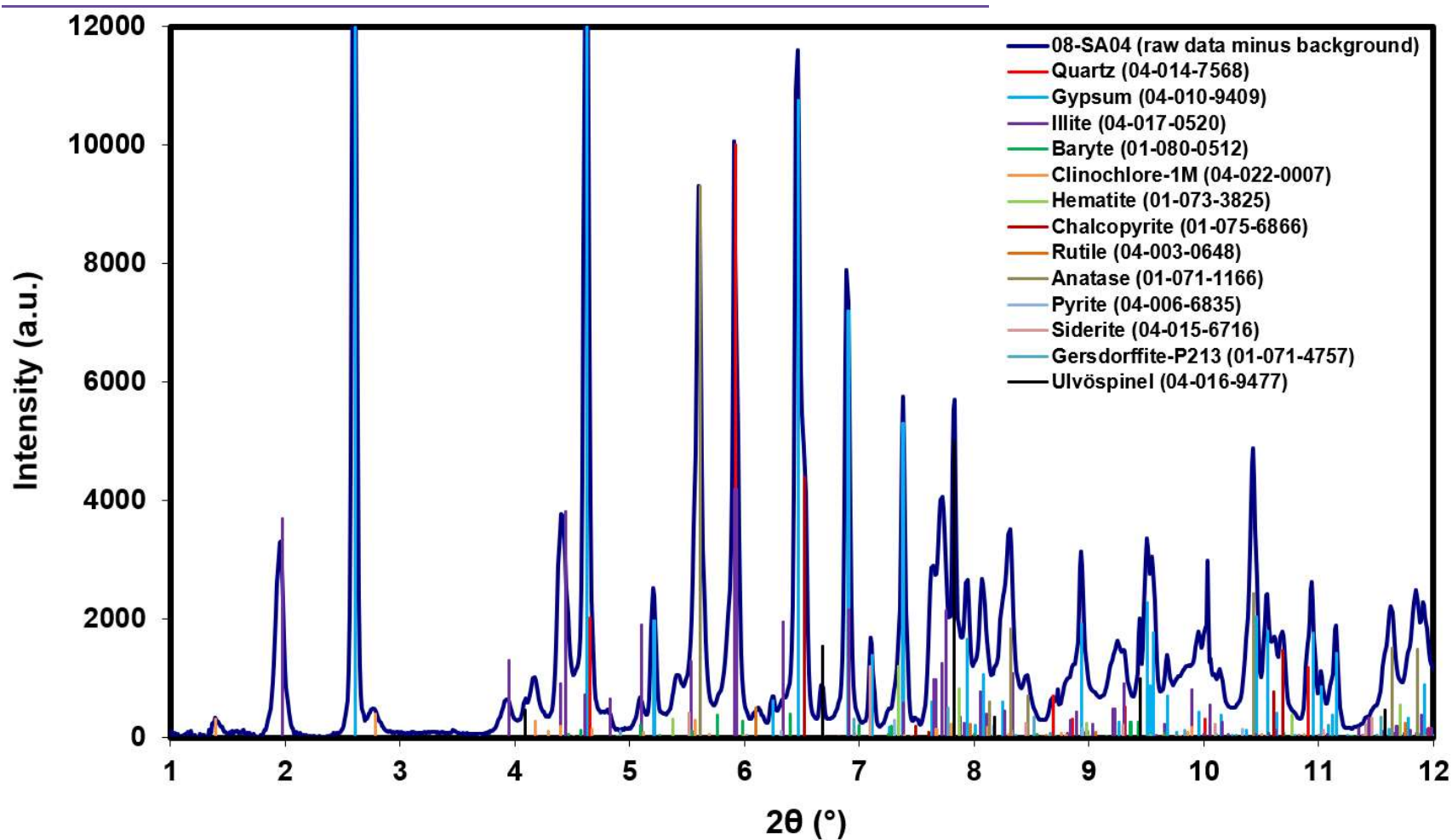


Figure 5.65. Phase identification results obtained for **08-SA04**, focusing on the low angle region near the background.

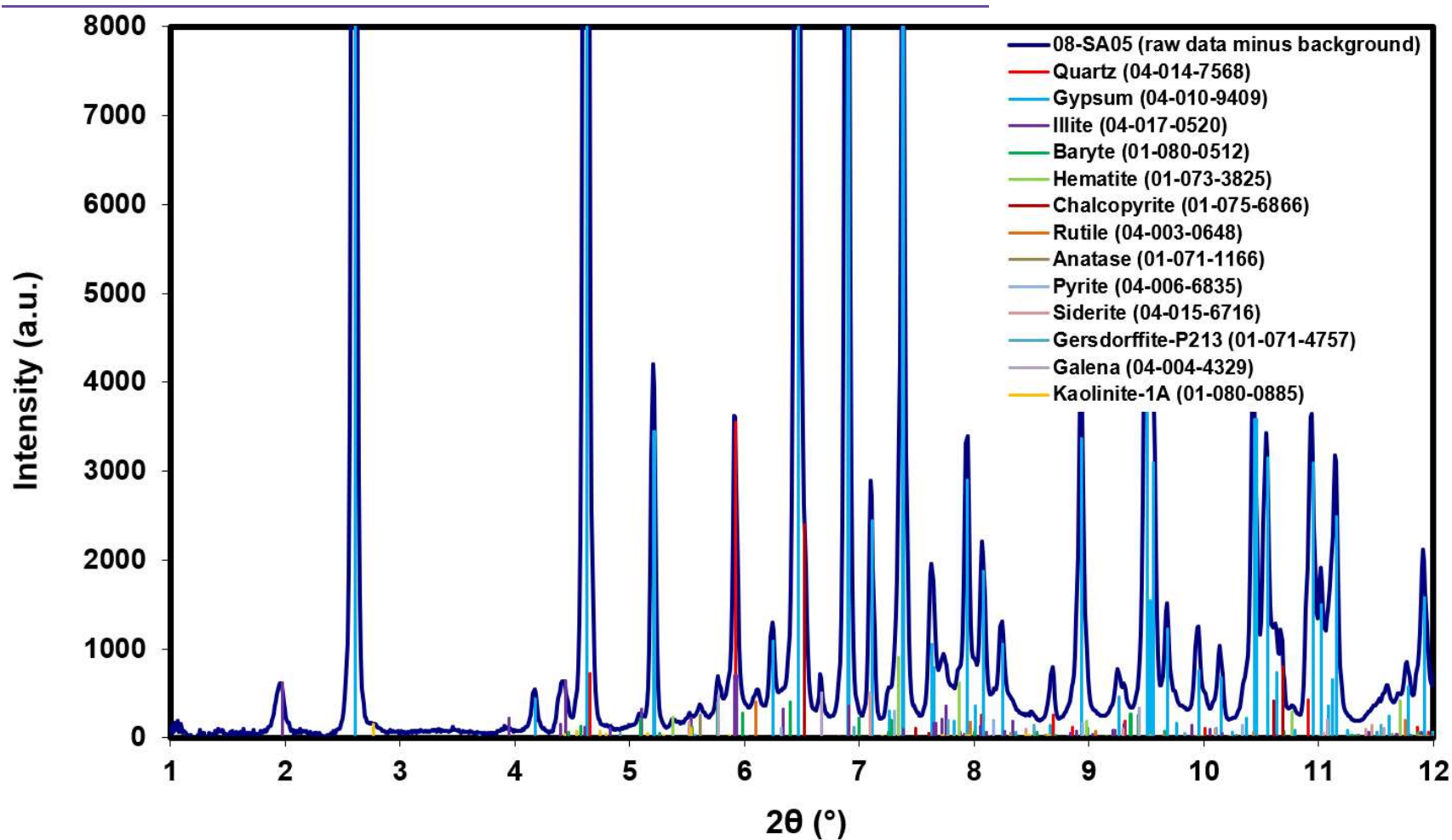


Figure 5.66. Phase identification results obtained for **08-SA05**, focusing on the low angle region near the background.

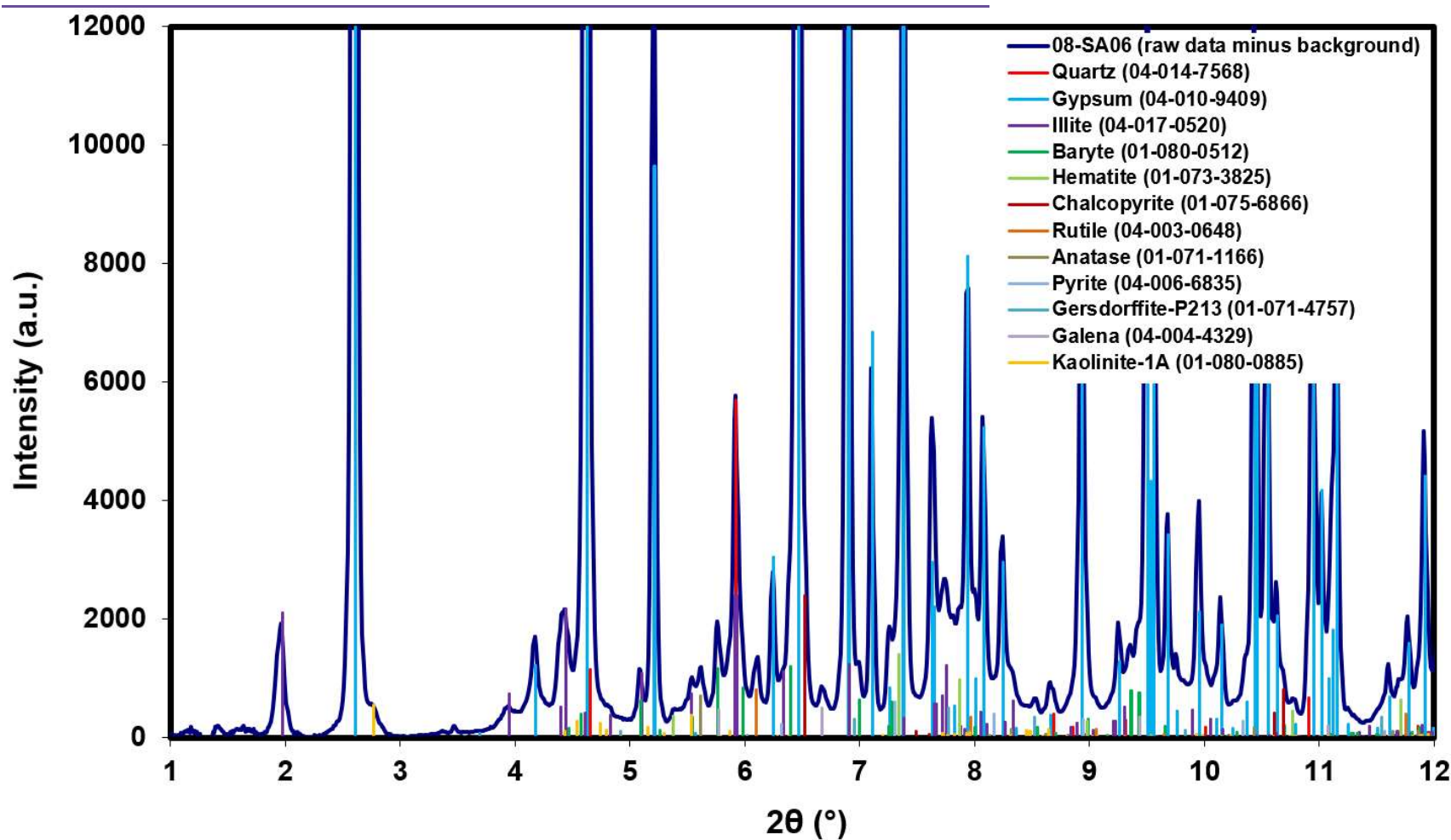


Figure 5.67. Phase identification results obtained for **08-SA06**, focusing on the low angle region near the background.

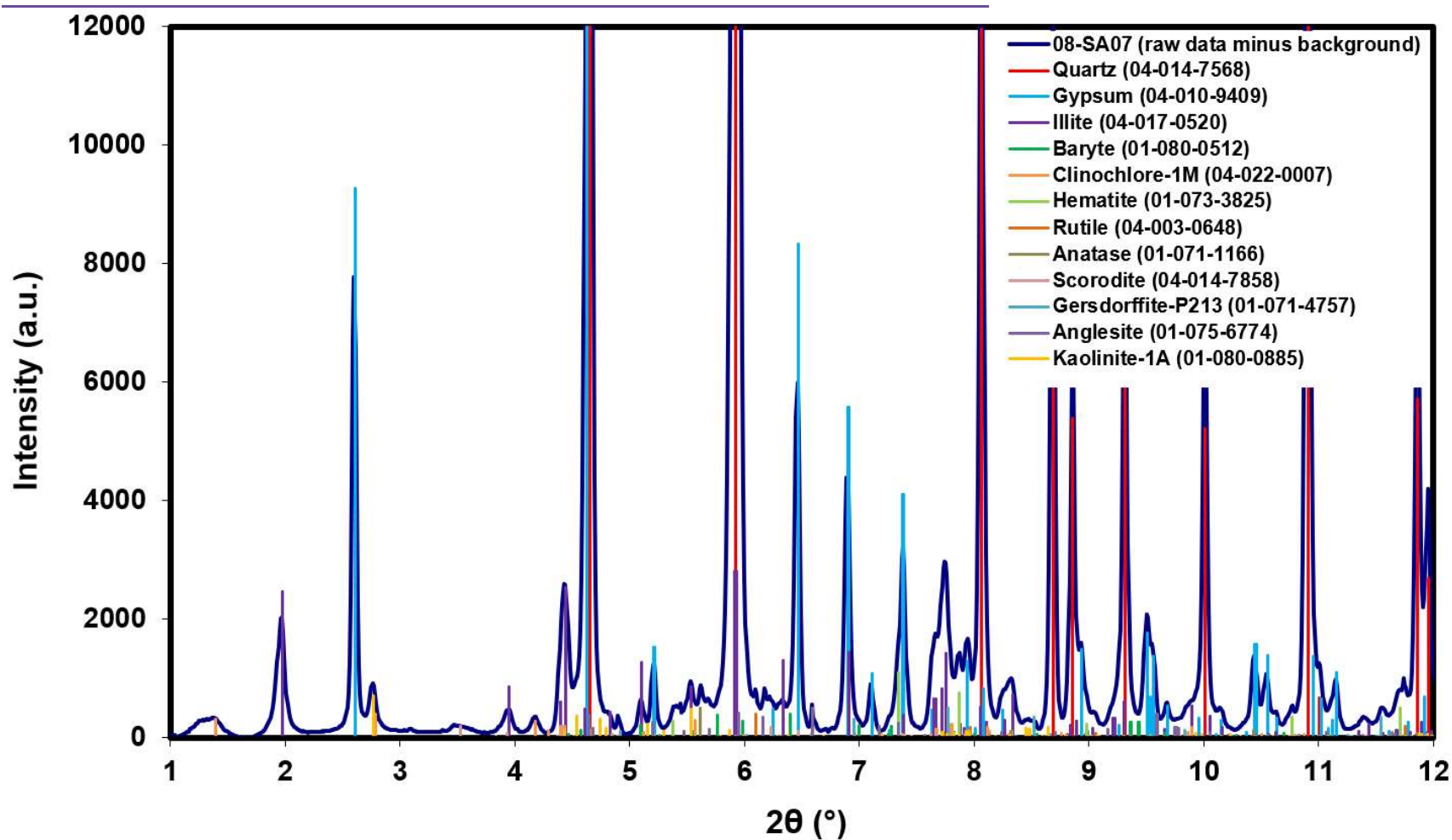


Figure 5.68. Phase identification results obtained for **08-SA07**, focusing on the low angle region near the background.

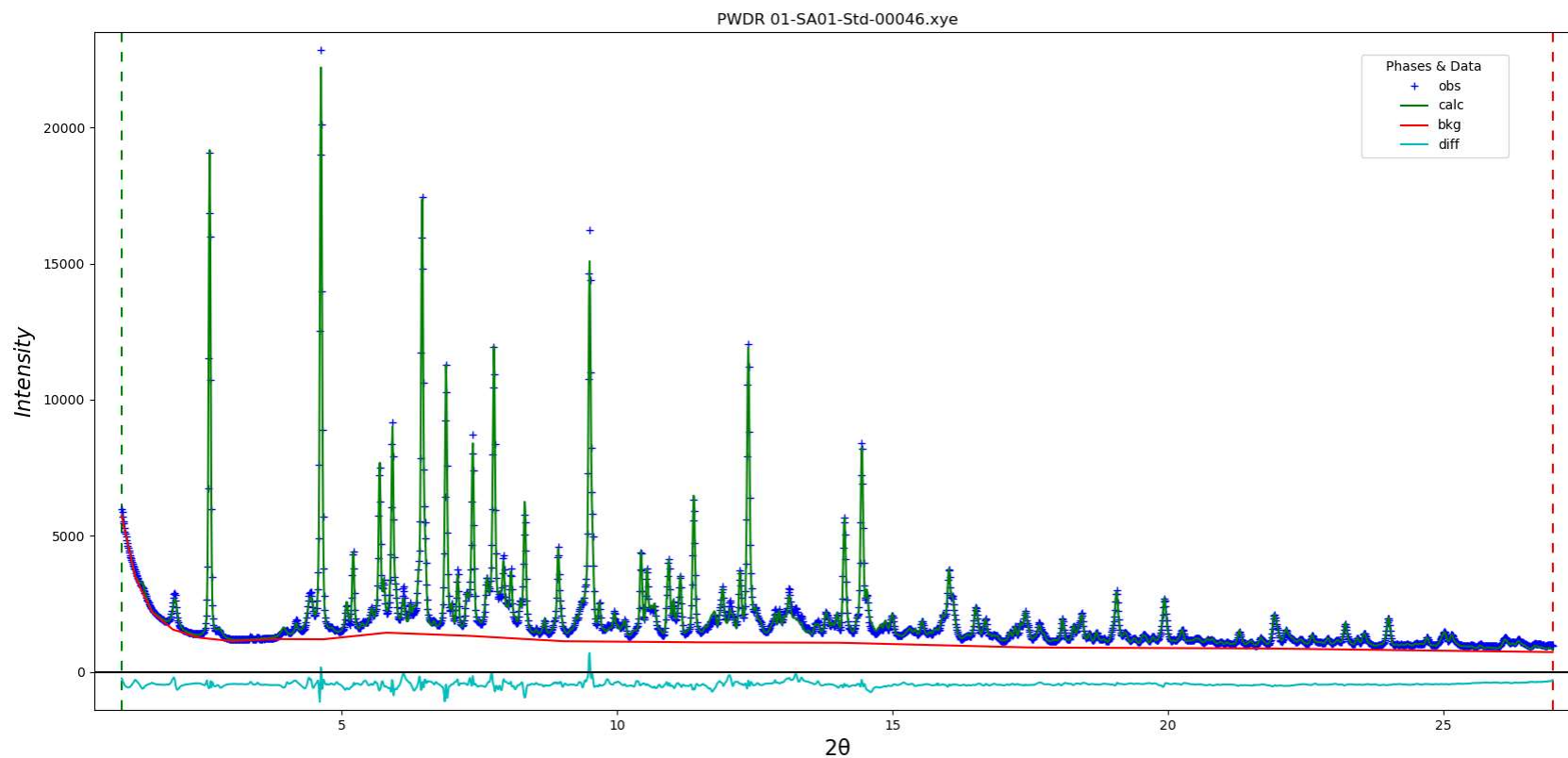


Figure 5.69. A plot of the final Rietveld refinement obtained for the **01-SA01** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

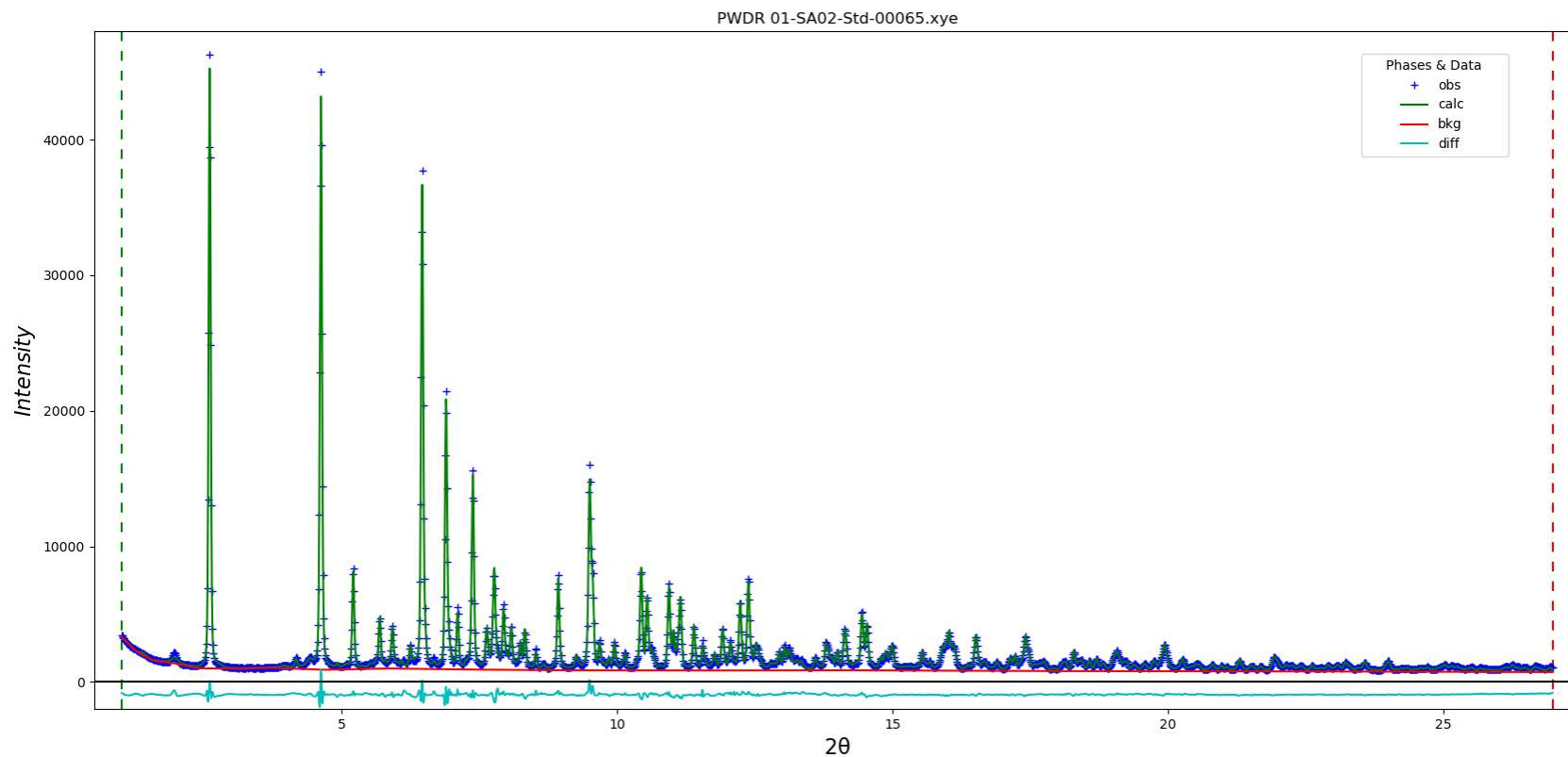


Figure 5.70. A plot of the final Rietveld refinement obtained for the **01-SA02** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

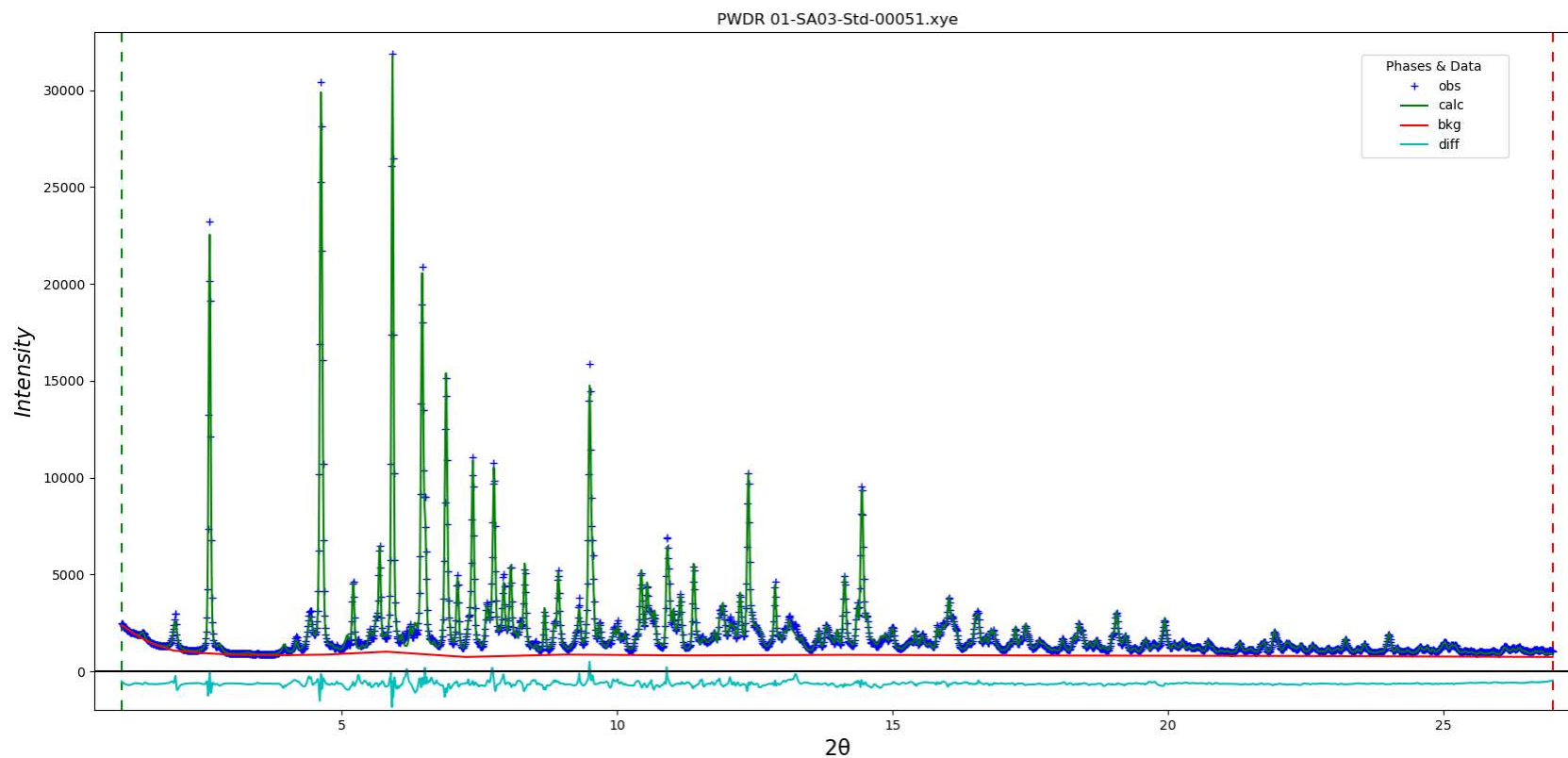


Figure 5.71. A plot of the final Rietveld refinement obtained for the **01-SA03** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

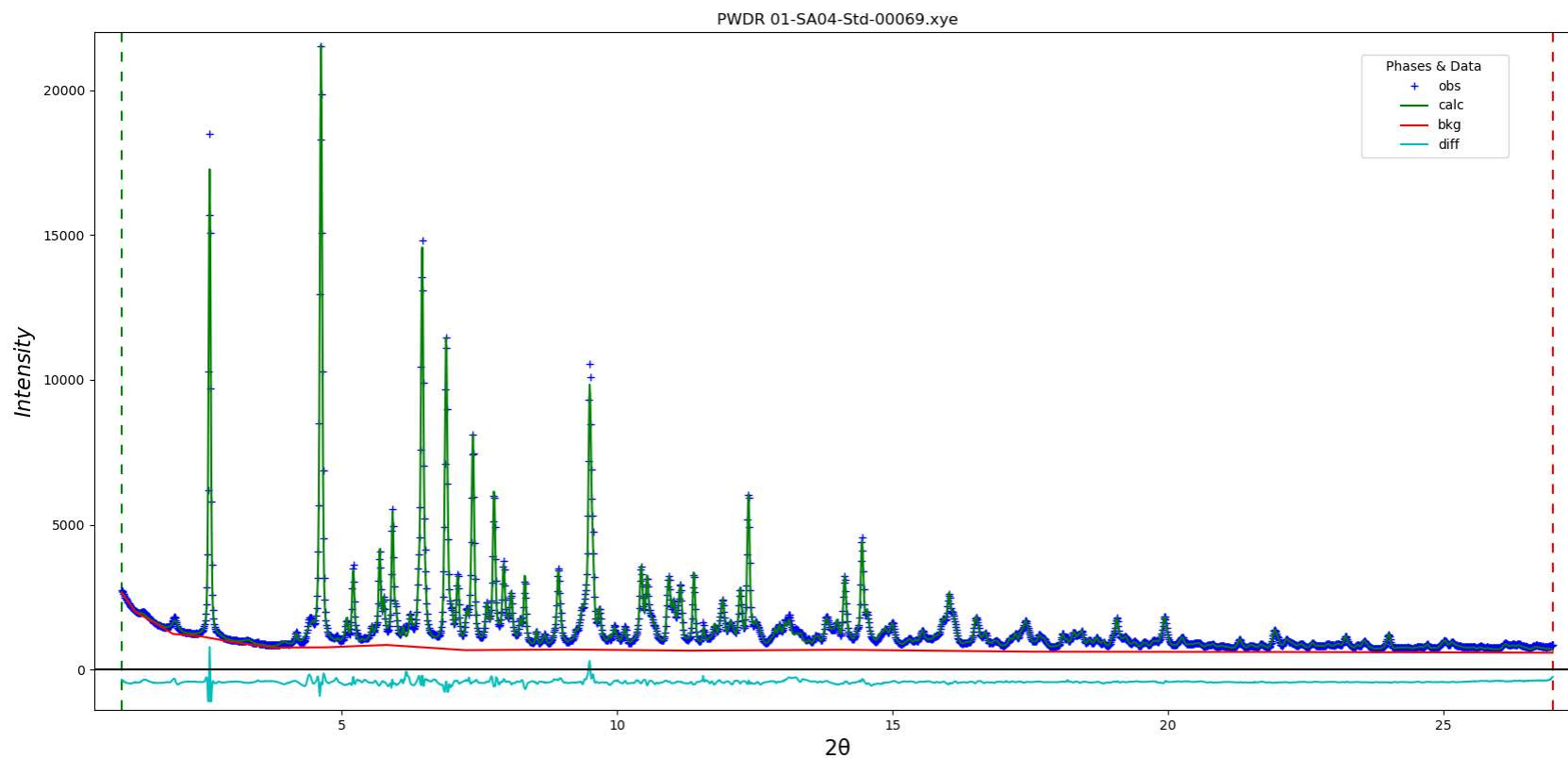


Figure 5.72. A plot of the final Rietveld refinement obtained for the **01-SA04** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

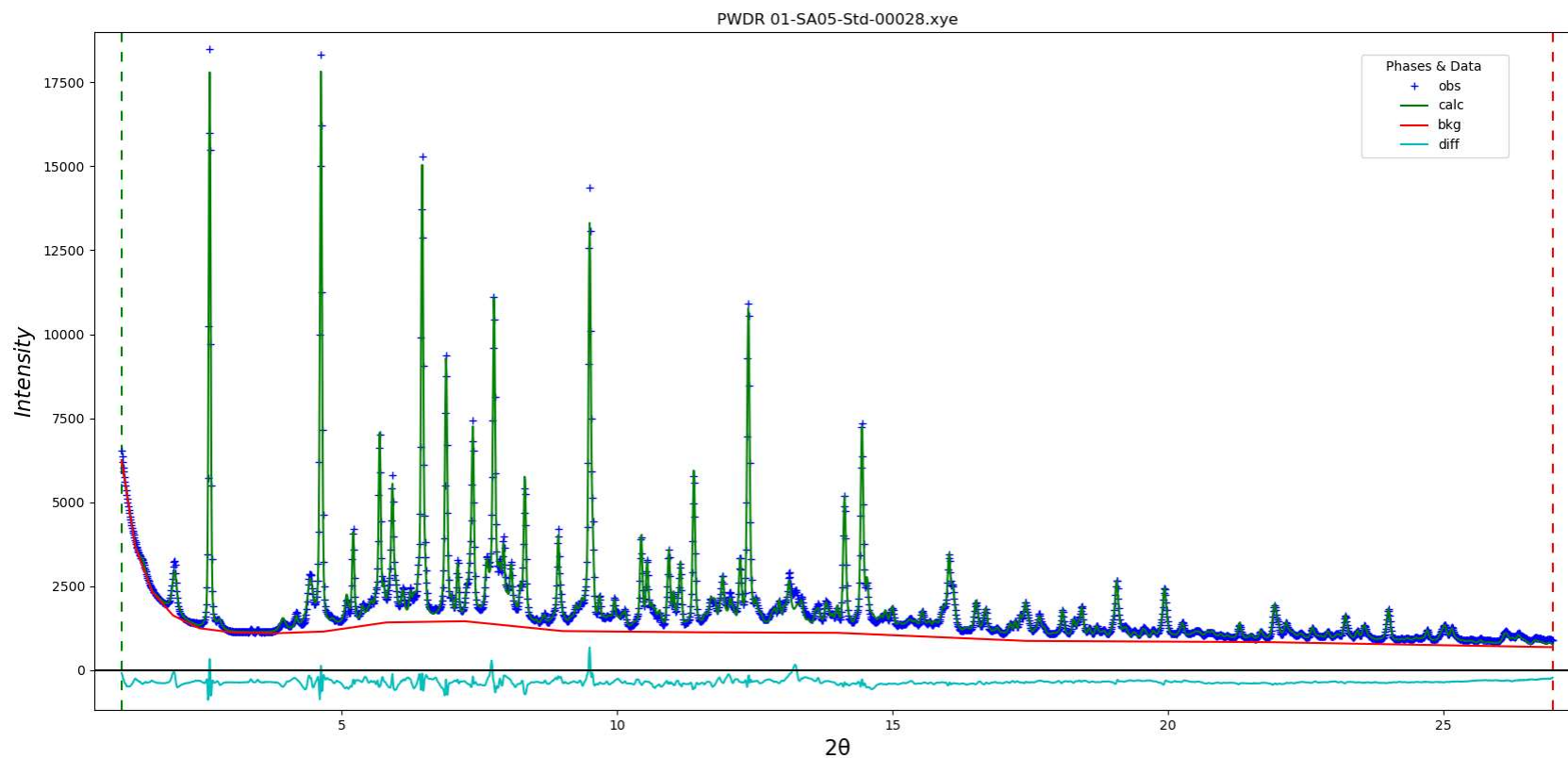


Figure 5.73. A plot of the final Rietveld refinement obtained for the **01-SA05** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

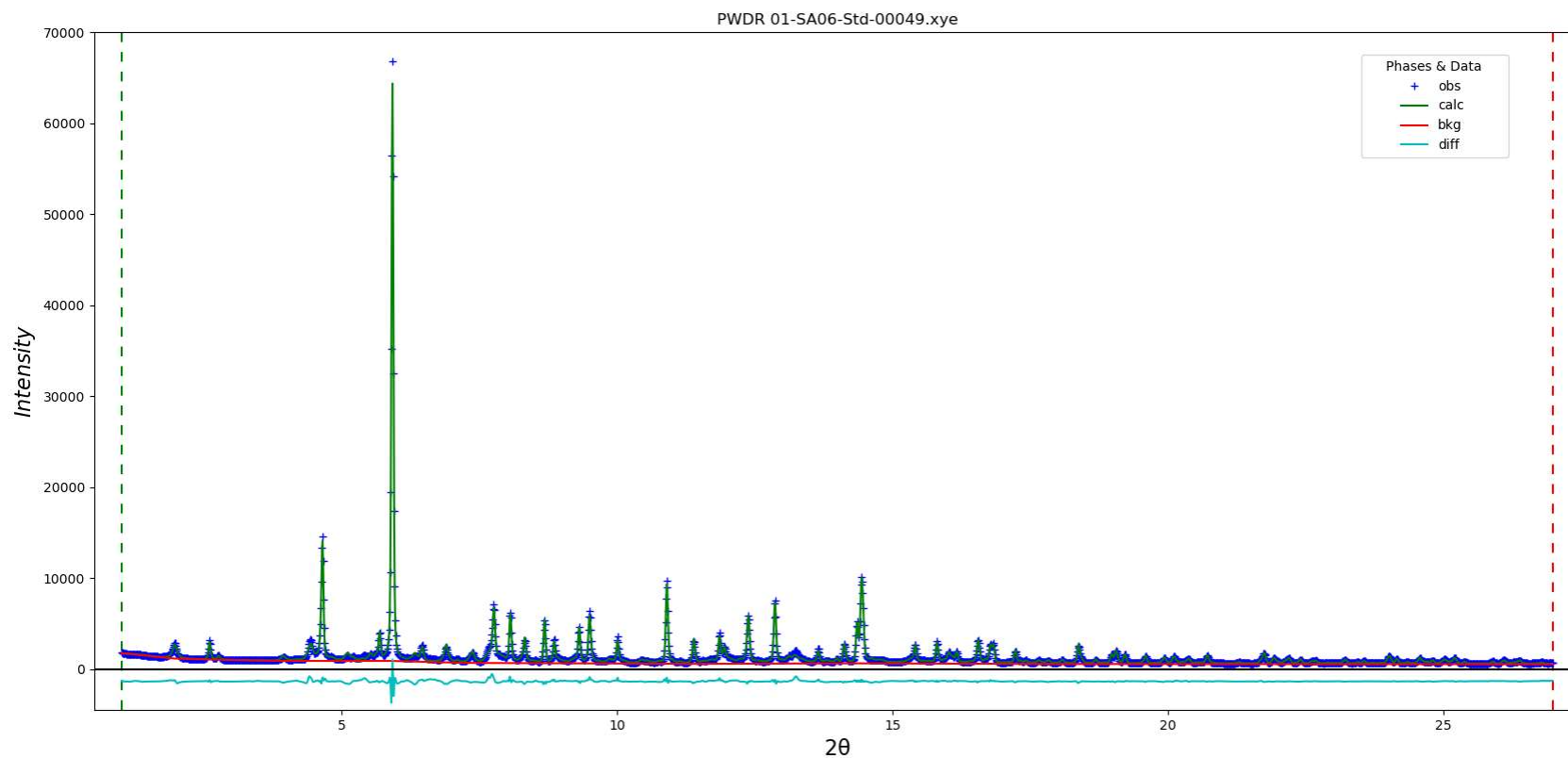


Figure 5.74. A plot of the final Rietveld refinement obtained for the **01-SA06** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

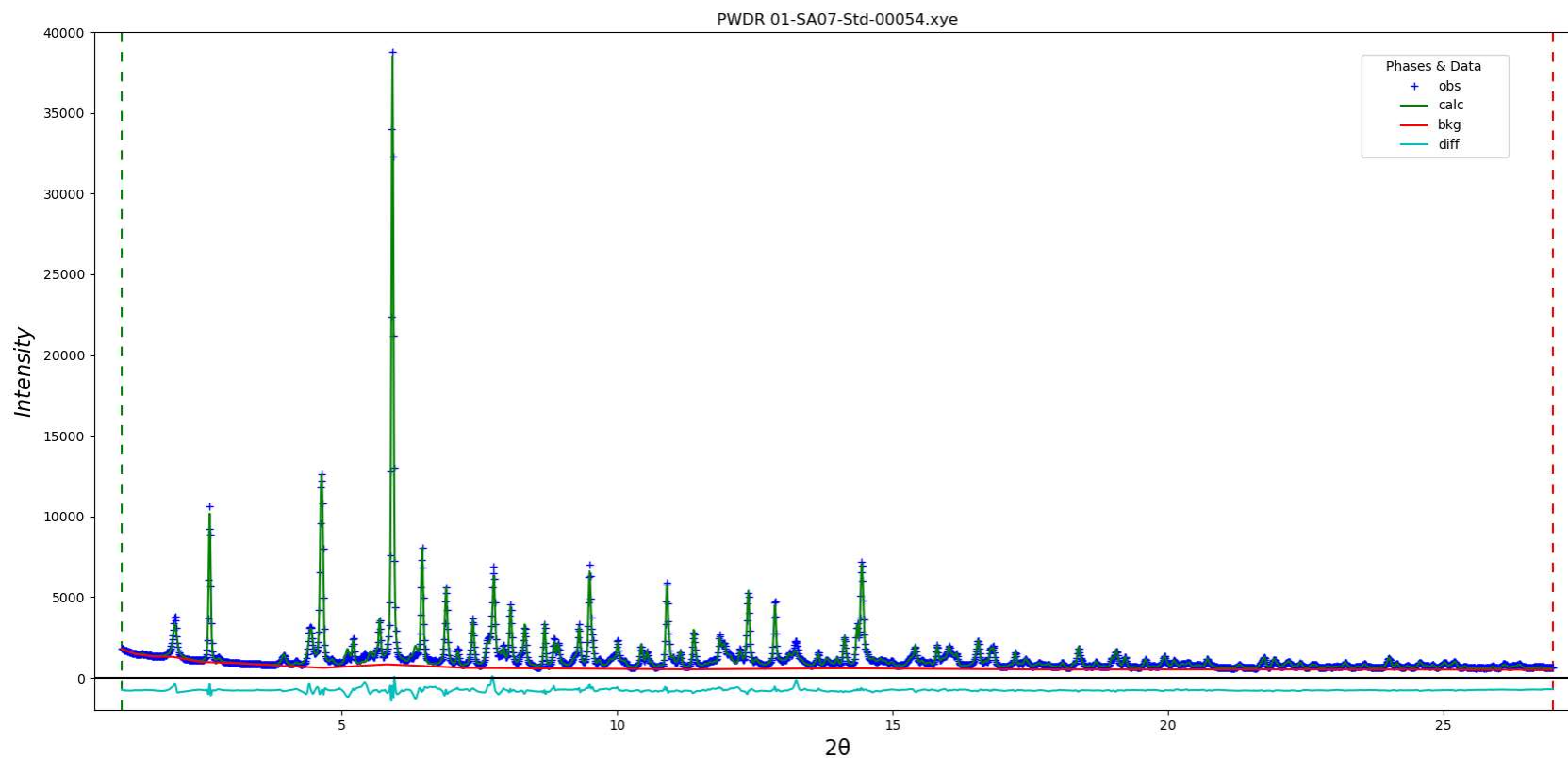


Figure 5.75. A plot of the final Rietveld refinement obtained for the **01-SA07** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

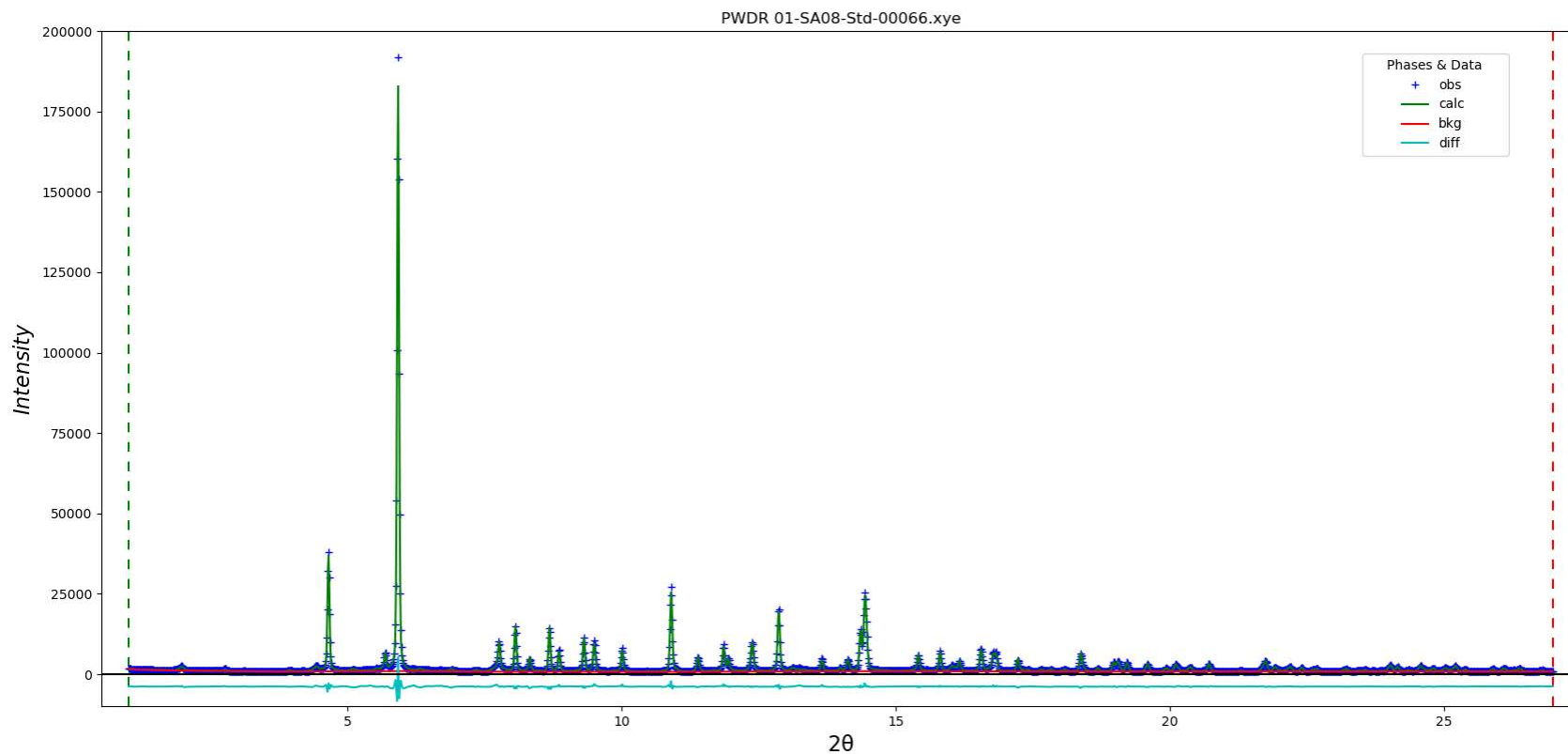


Figure 5.76. A plot of the final Rietveld refinement obtained for the **01-SA08** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

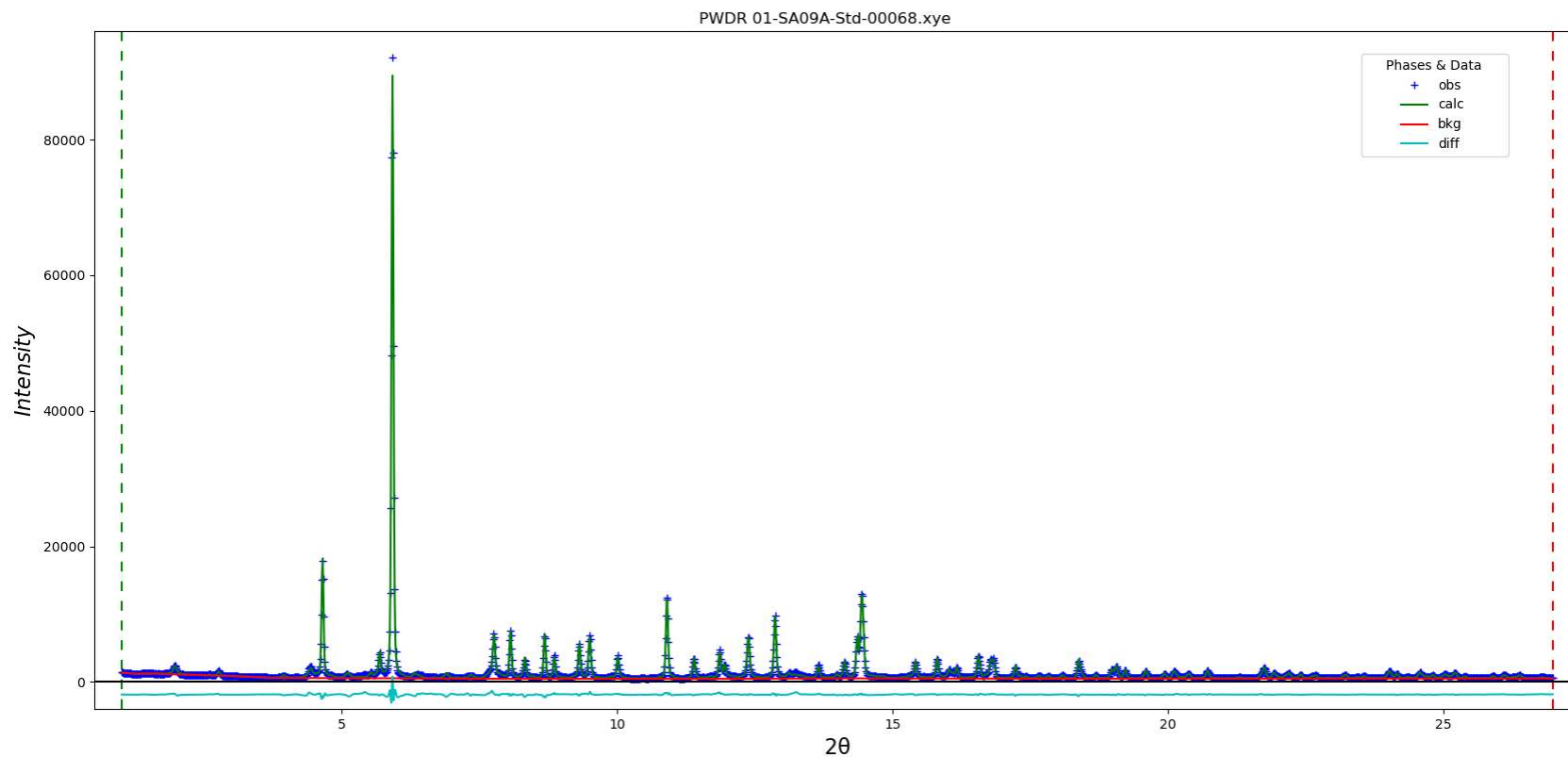


Figure 5.77. A plot of the final Rietveld refinement obtained for the **01-SA09A** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

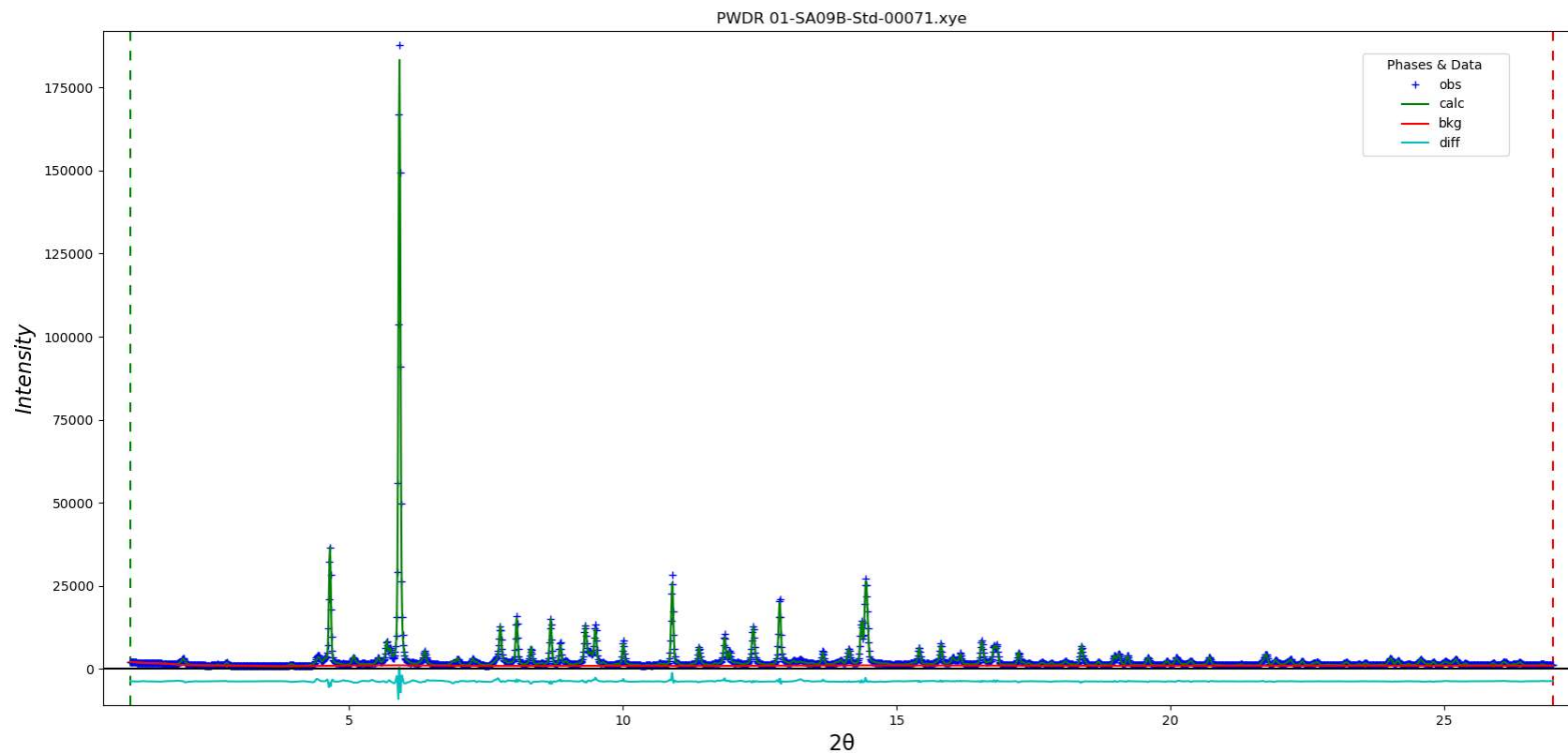


Figure 5.78. A plot of the final Rietveld refinement obtained for the **01-SA09B** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

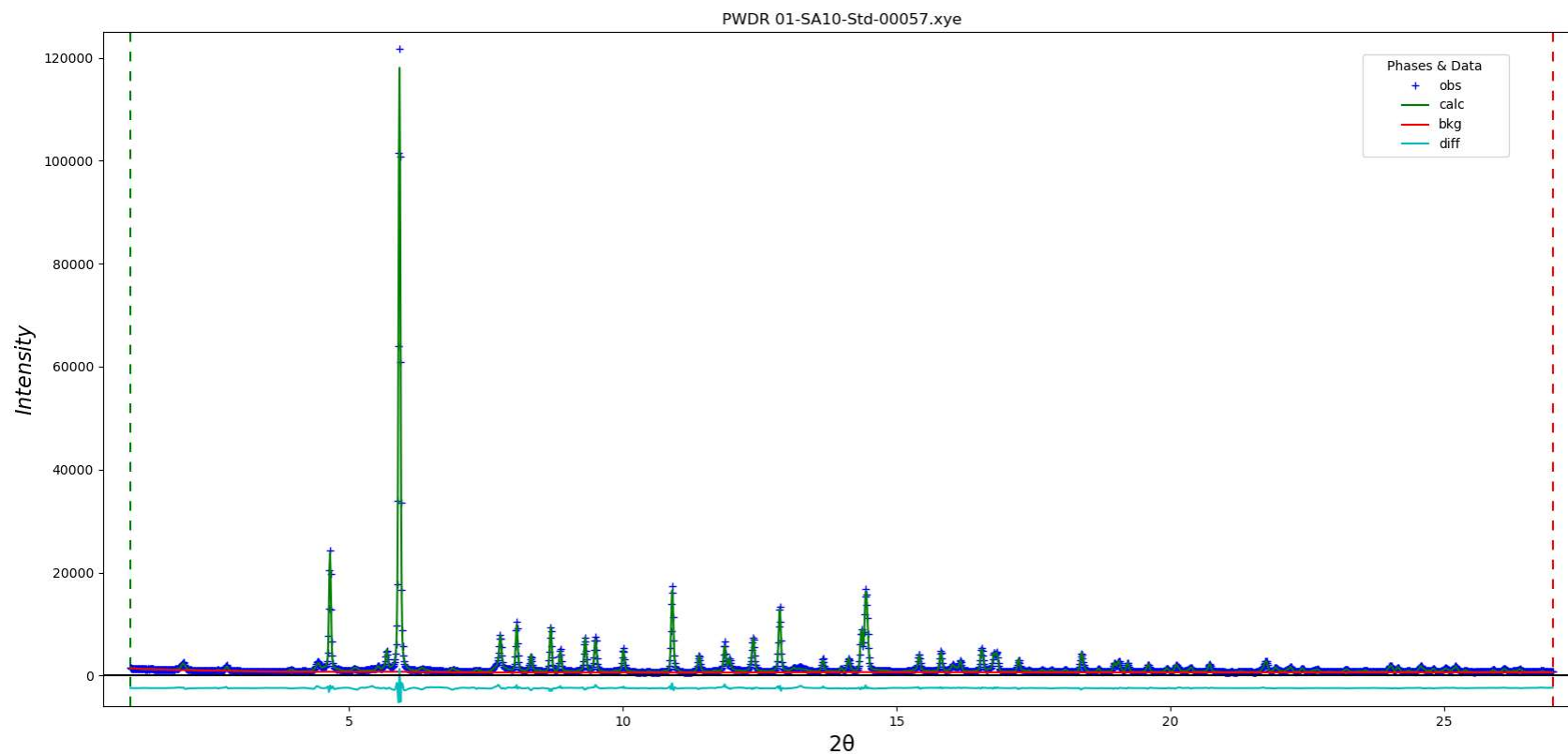


Figure 5.79. A plot of the final Rietveld refinement obtained for the **01-SA10** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

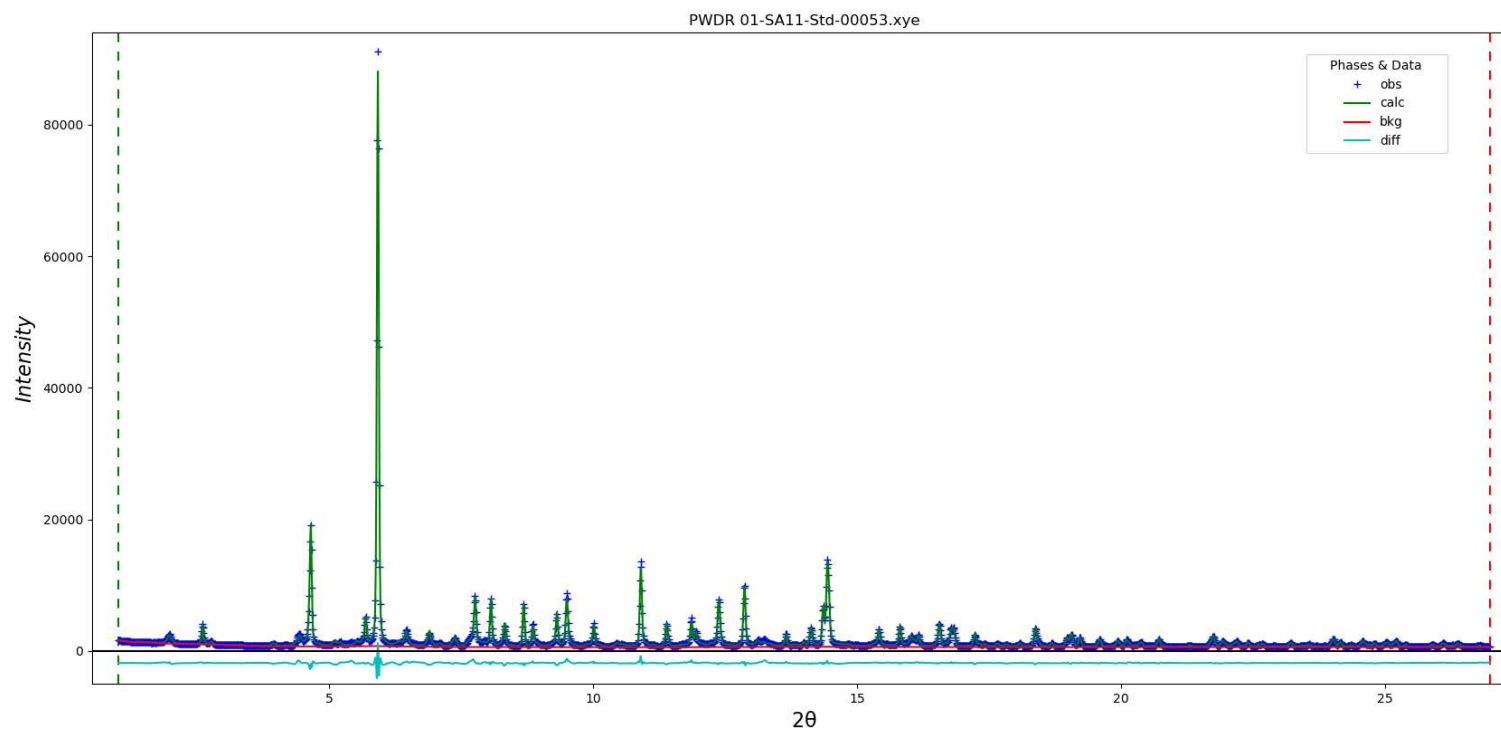


Figure 5.80. A plot of the final Rietveld refinement obtained for the **01-SA11** sample with the Al_2O_3 internal standard, illustrating the raw data (**blue '+' points**), calculated pattern (**green line**), background (**red line**) and difference plot (**aqua line**).

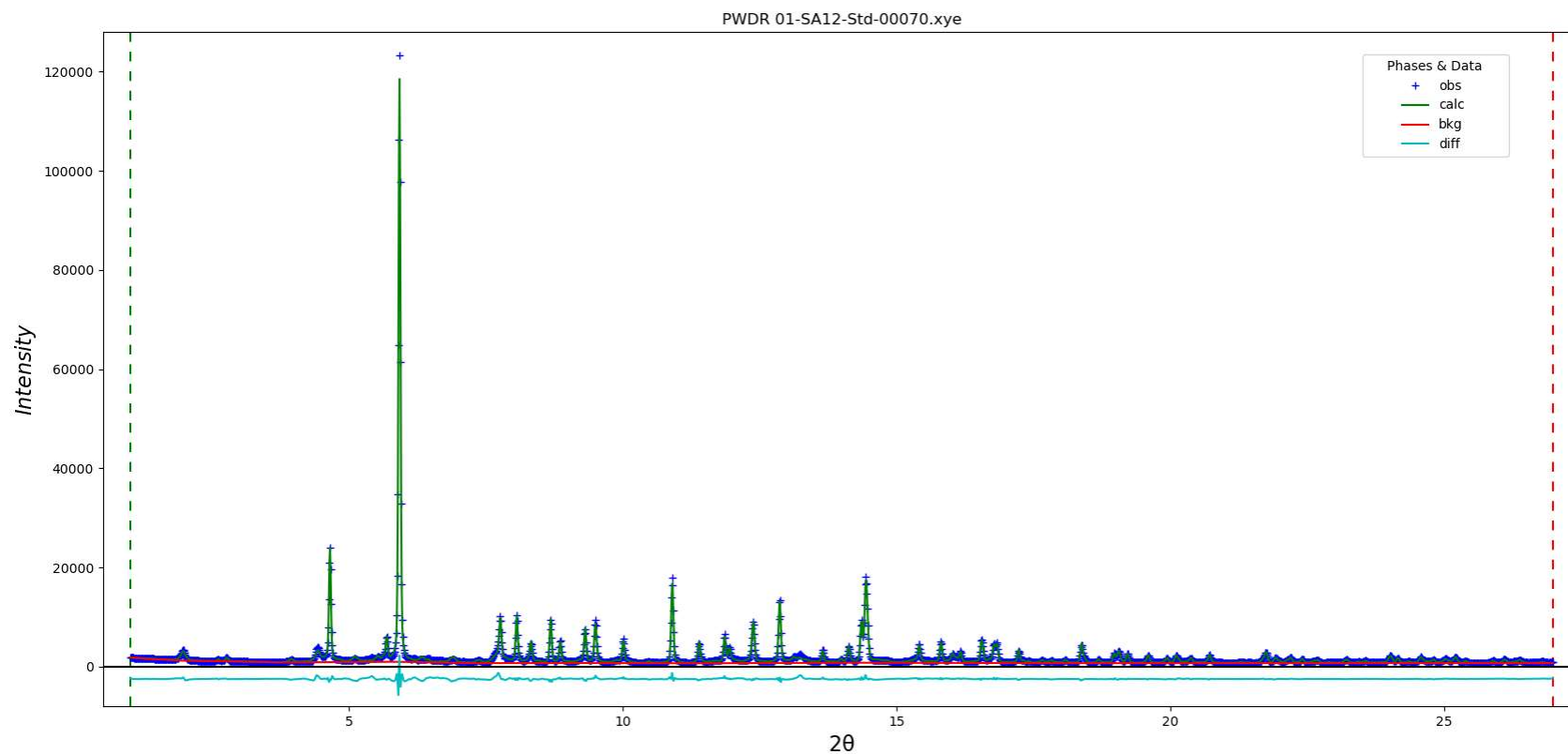


Figure 5.81. A plot of the final Rietveld refinement obtained for the **01-SA12** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

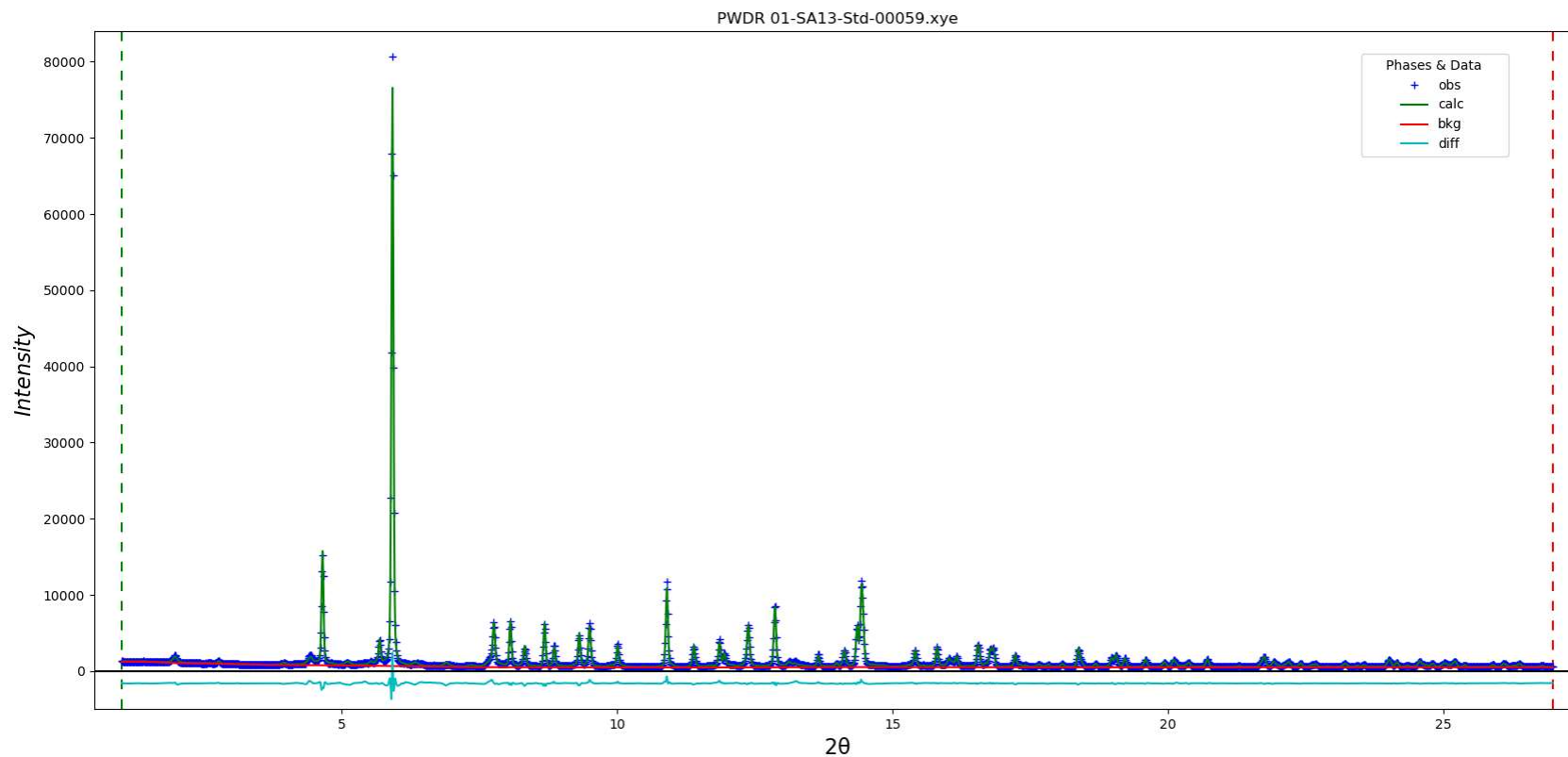


Figure 5.82. A plot of the final Rietveld refinement obtained for the **01-SA13** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

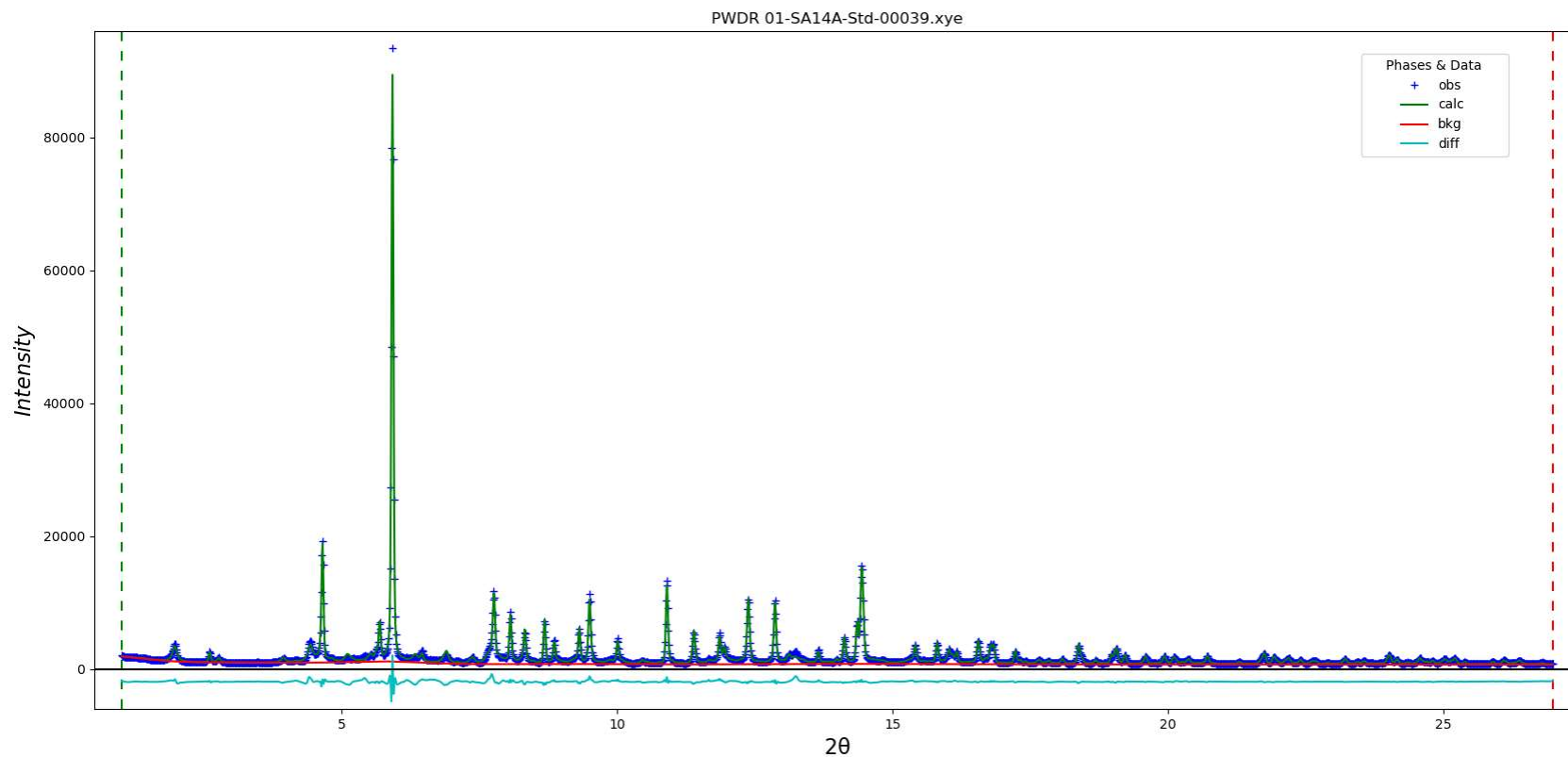


Figure 5.83. A plot of the final Rietveld refinement obtained for the **01-SA14A** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

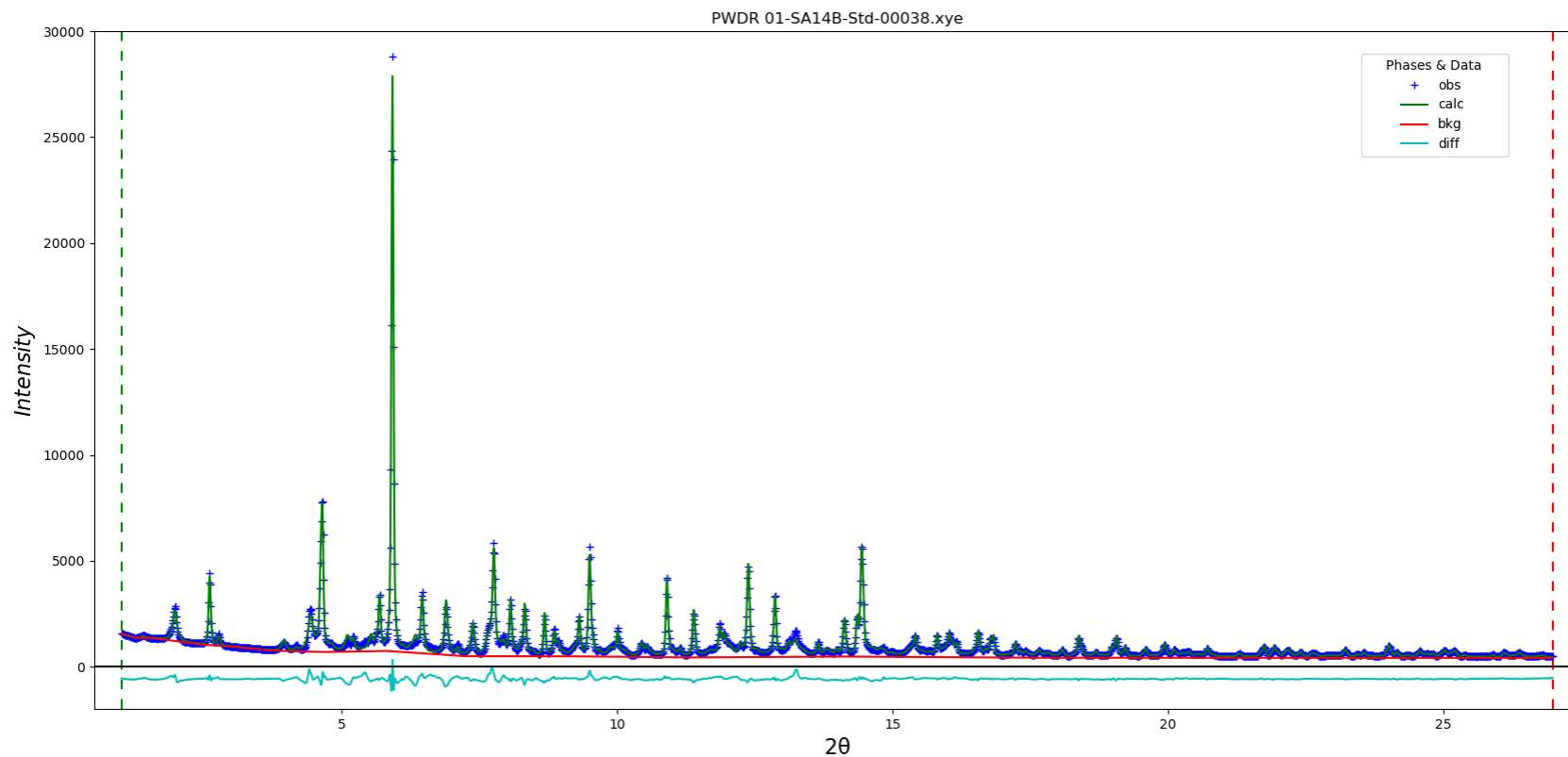


Figure 5.84. A plot of the final Rietveld refinement obtained for the **01-SA14B** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

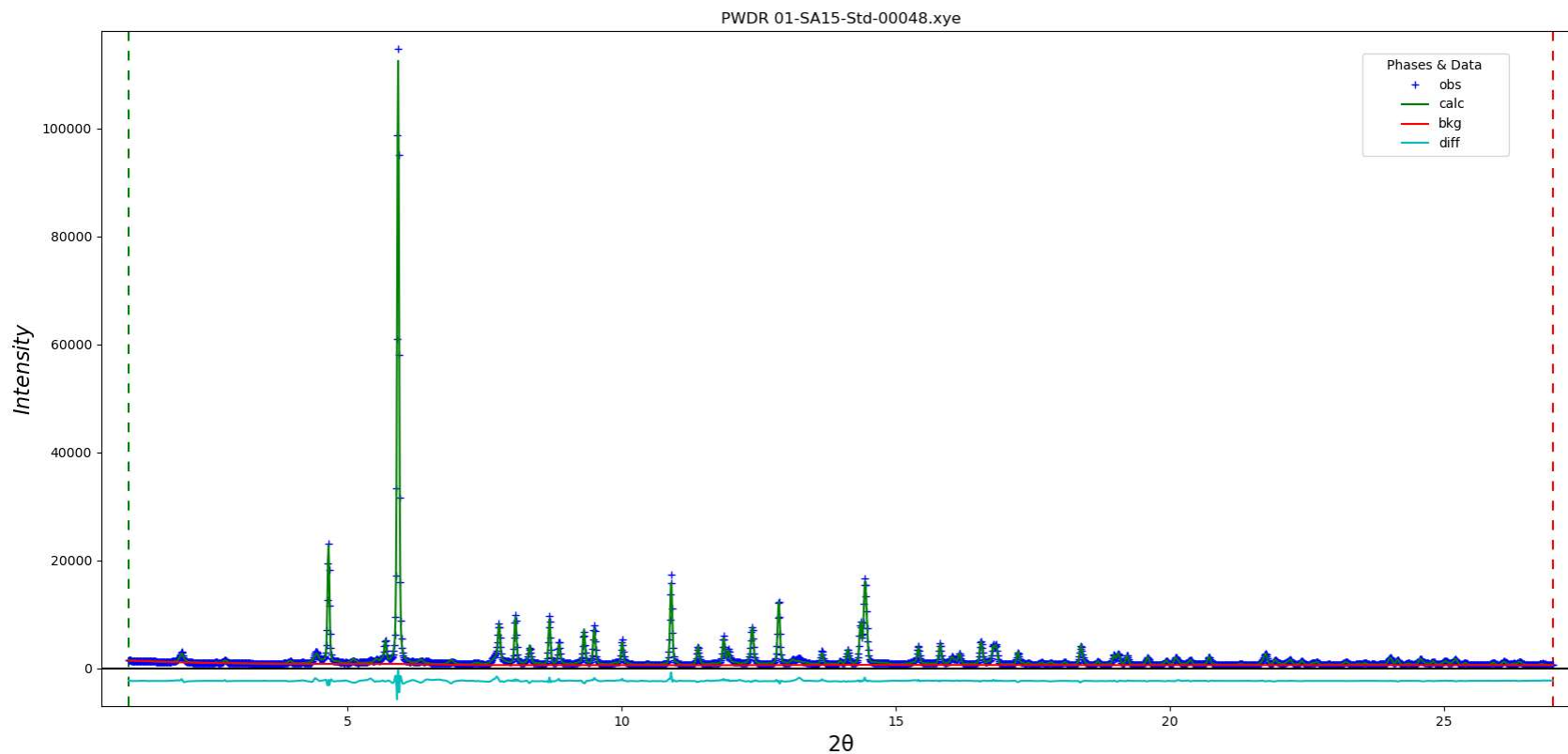


Figure 5.85. A plot of the final Rietveld refinement obtained for the **01-SA15** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

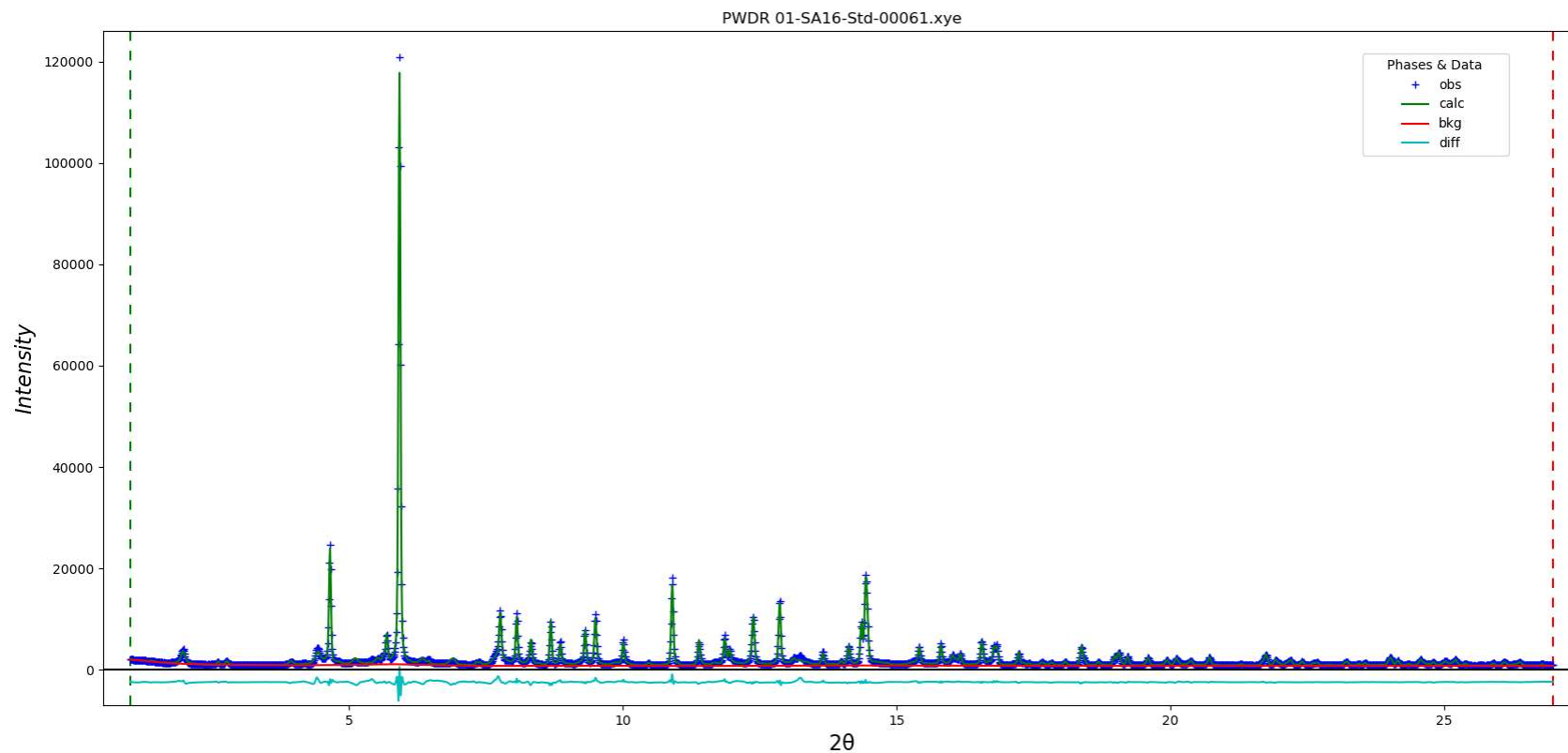


Figure 5.86. A plot of the final Rietveld refinement obtained for the **01-SA16** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

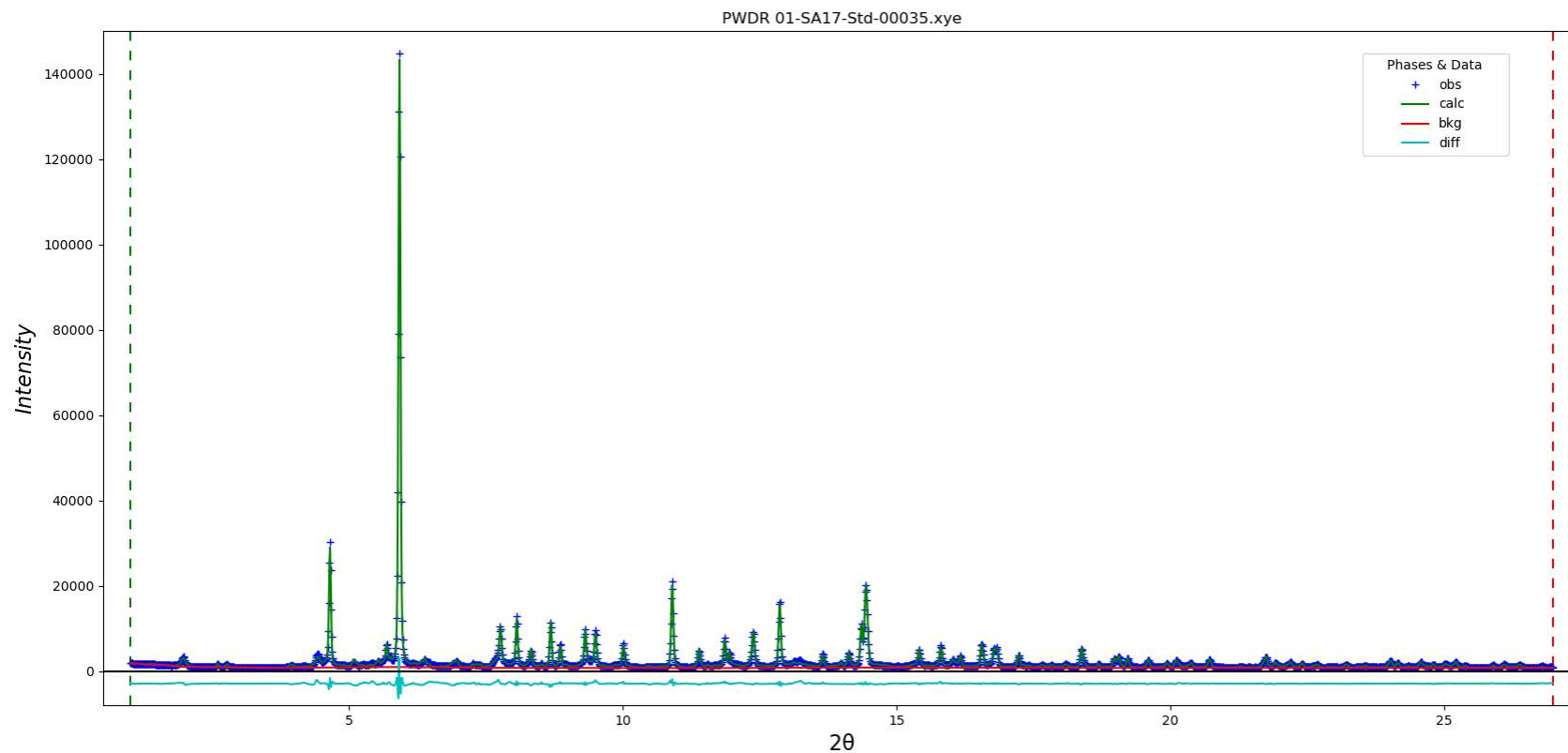


Figure 5.87. A plot of the final Rietveld refinement obtained for the **01-SA17** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

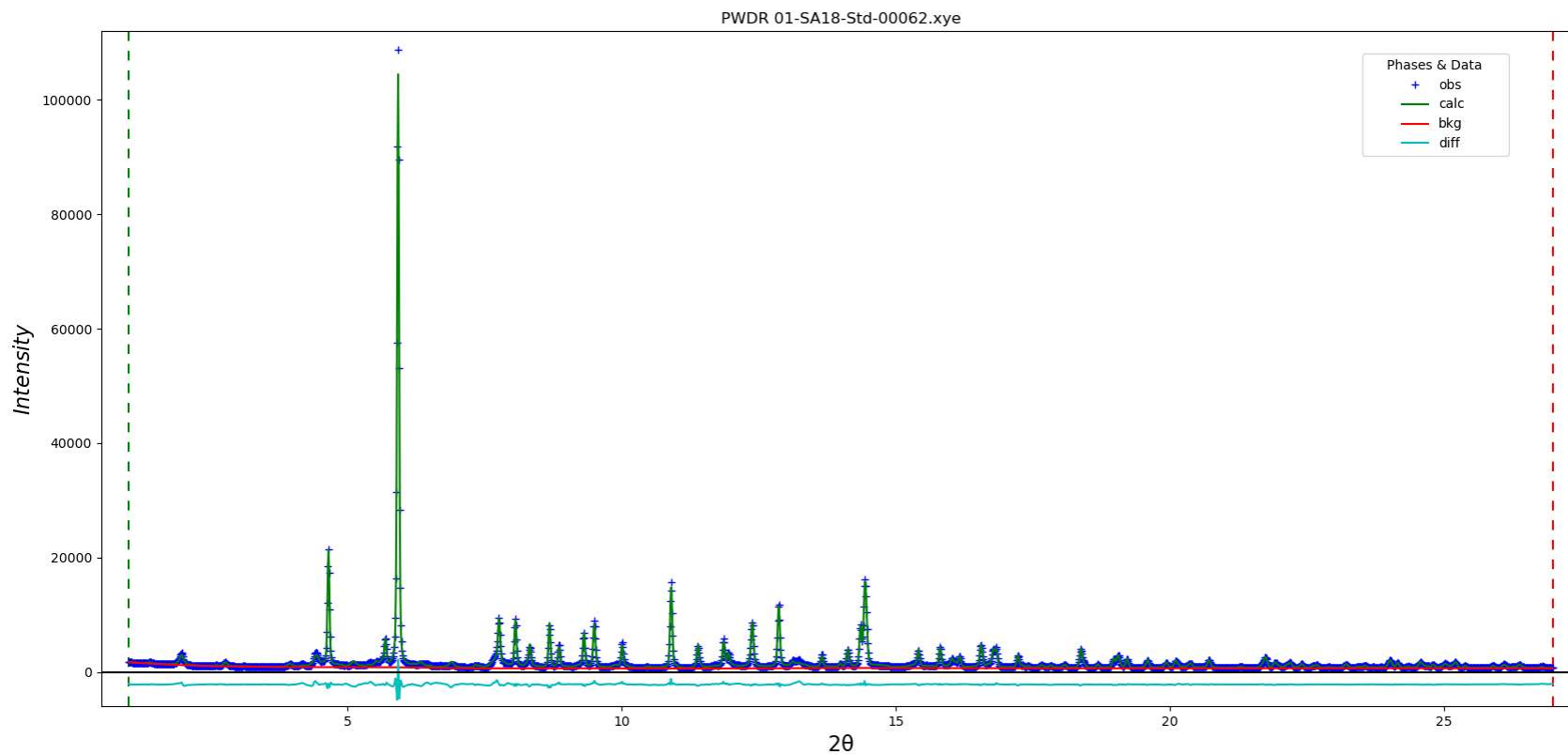


Figure 5.88. A plot of the final Rietveld refinement obtained for the **01-SA18** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

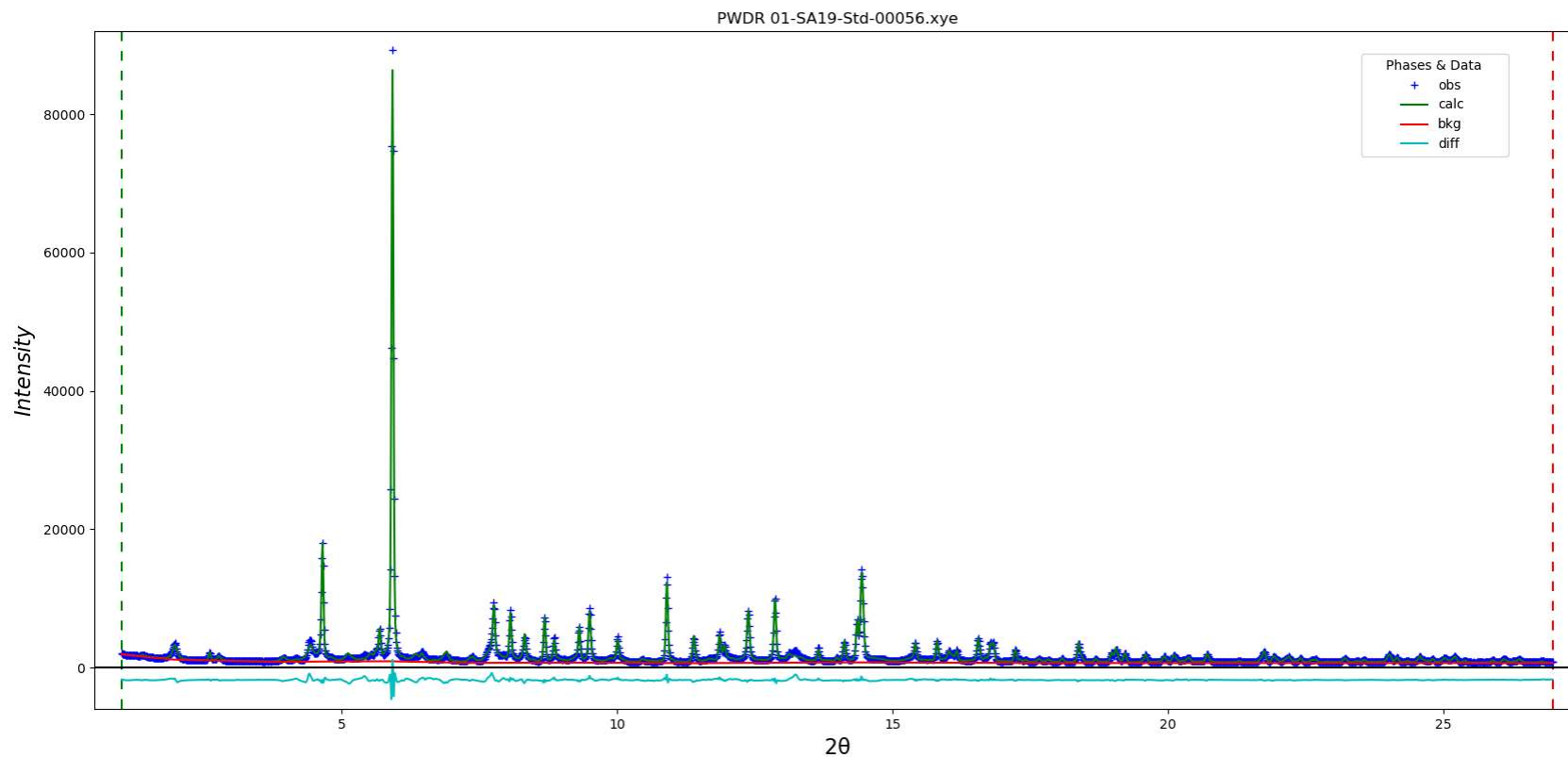


Figure 5.89. A plot of the final Rietveld refinement obtained for the **01-SA19** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

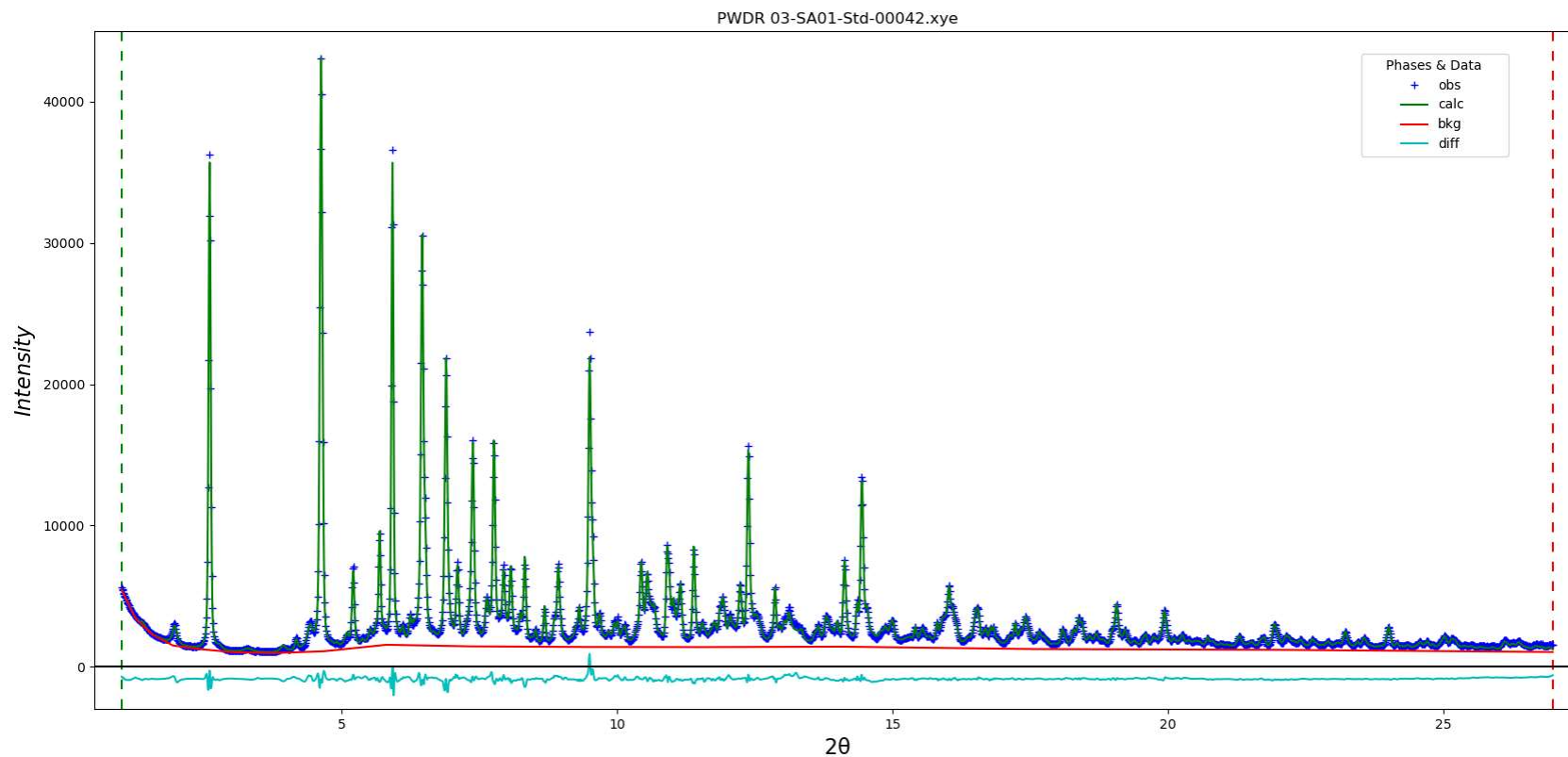


Figure 5.90. A plot of the final Rietveld refinement obtained for the **03-SA01** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

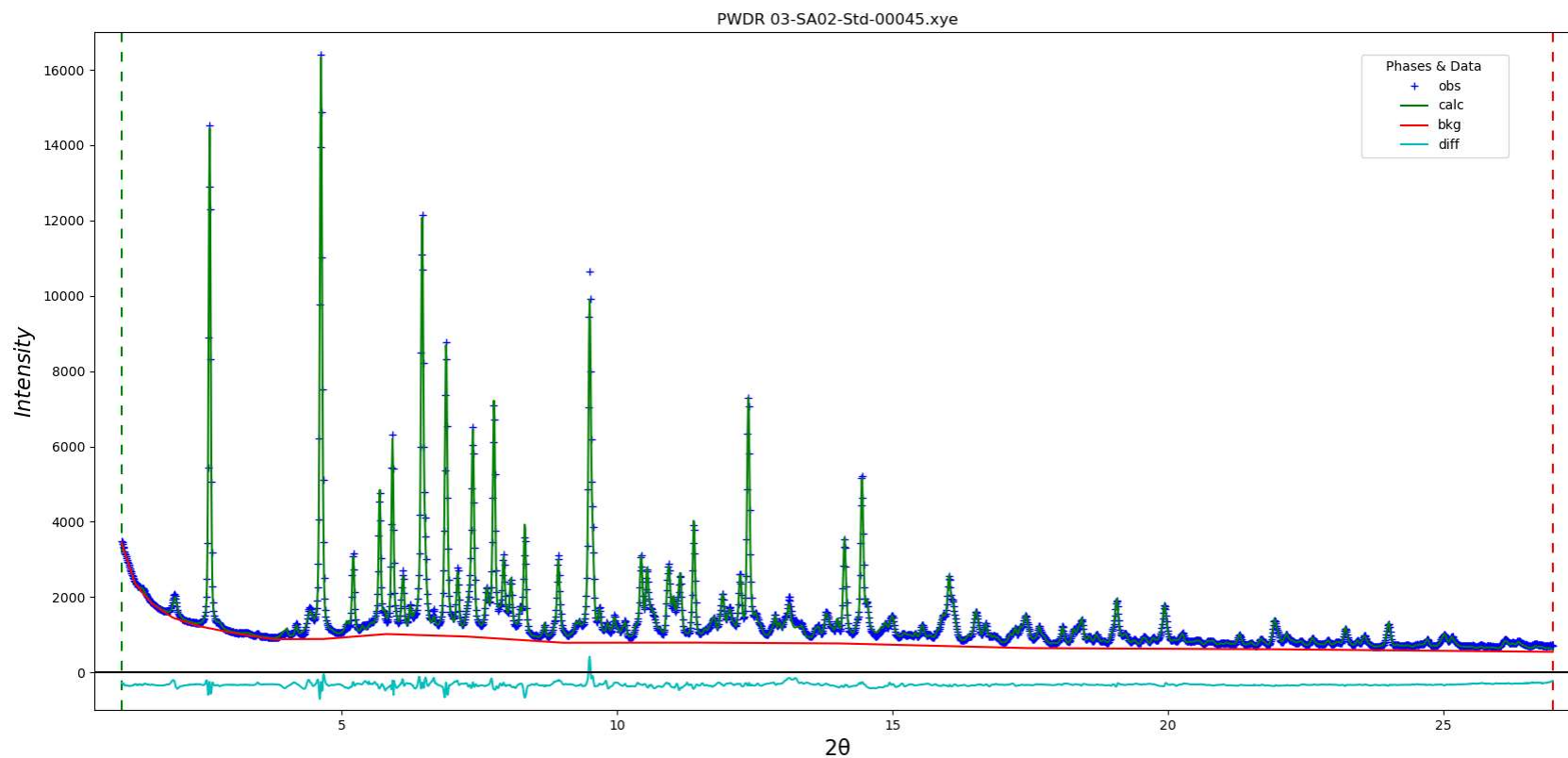


Figure 5.91. A plot of the final Rietveld refinement obtained for the **03-SA02** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

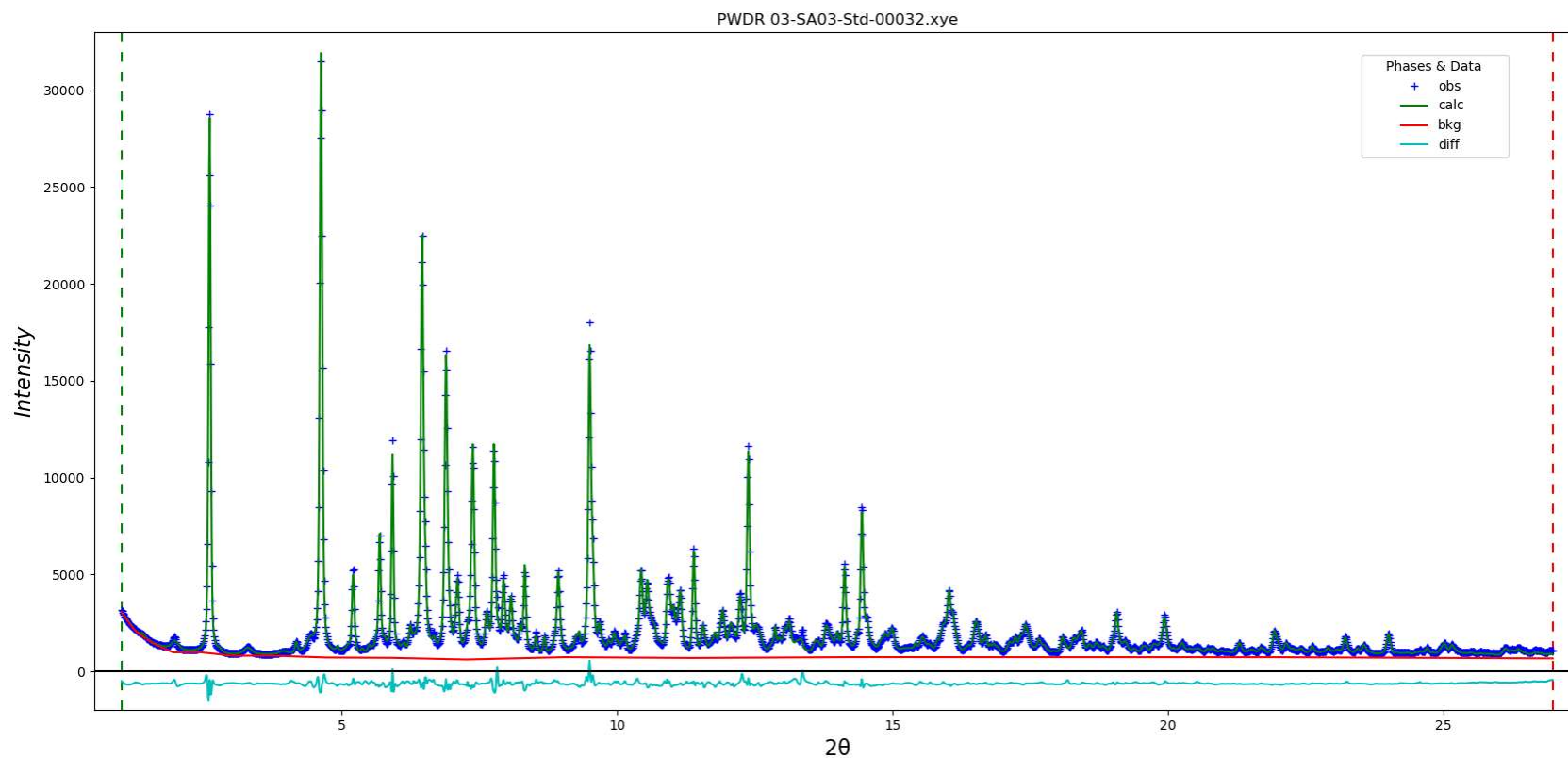


Figure 5.92. A plot of the final Rietveld refinement obtained for the **03-SA03** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

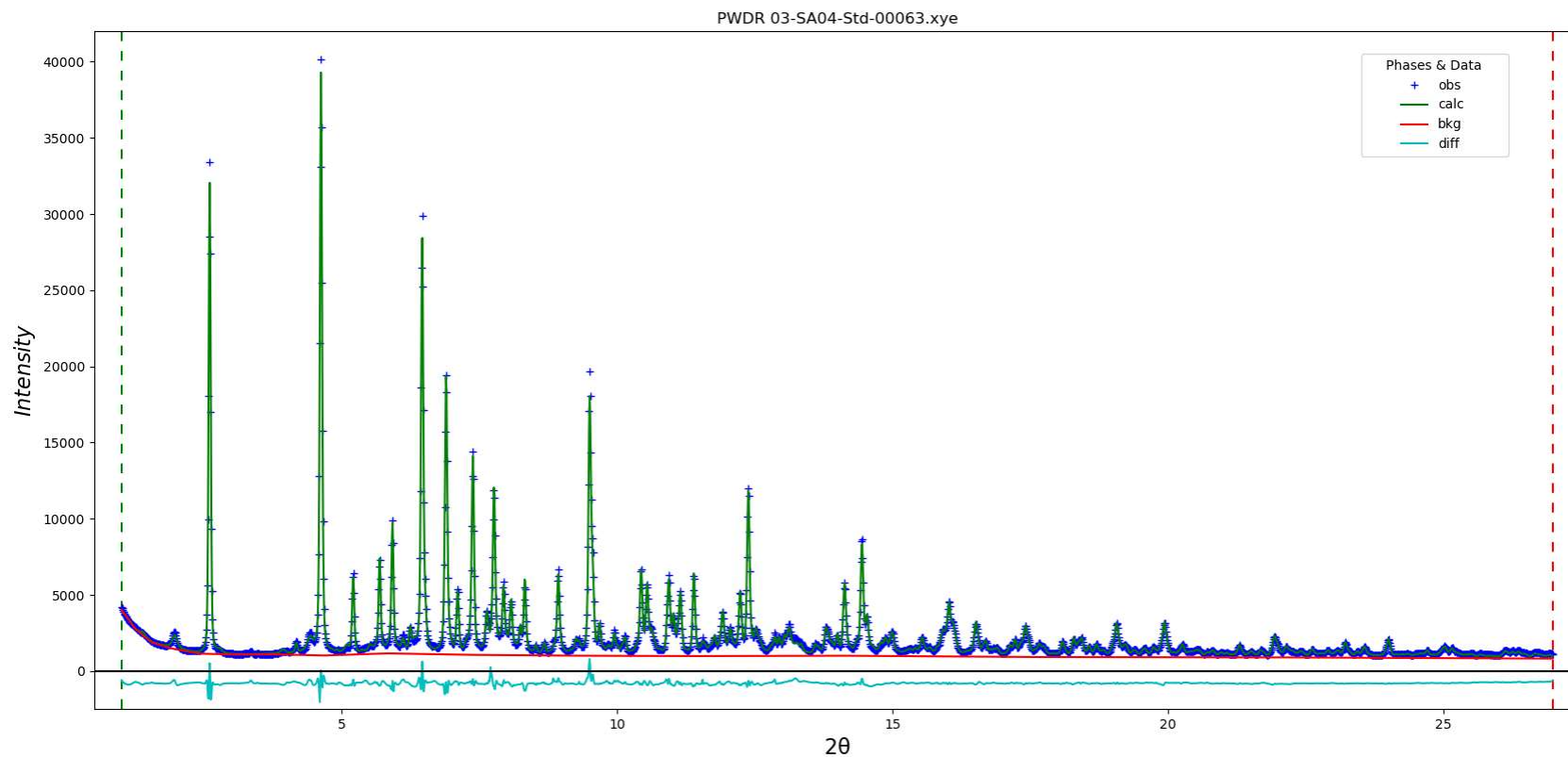


Figure 5.93. A plot of the final Rietveld refinement obtained for the **03-SA04** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

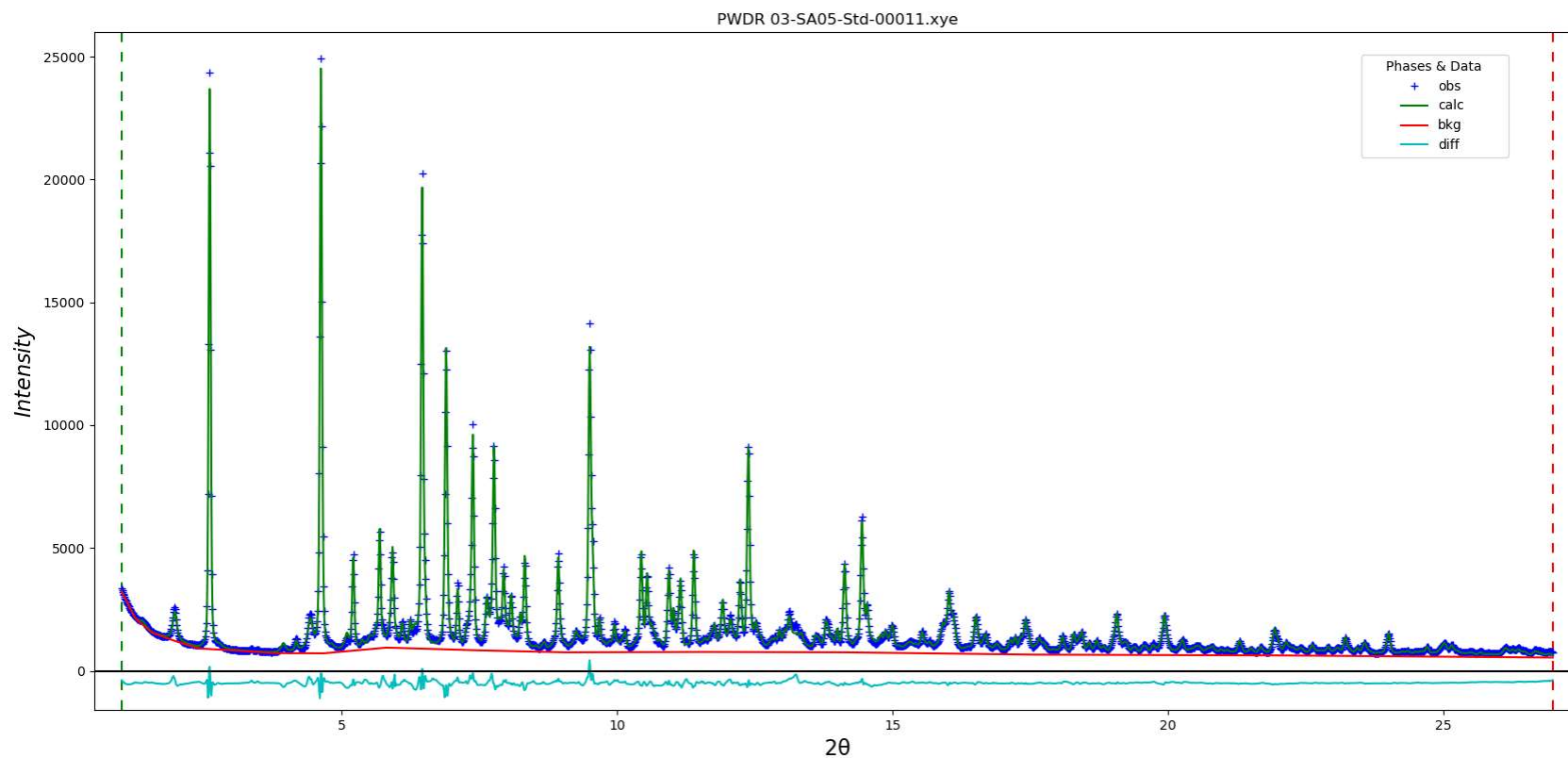


Figure 5.94. A plot of the final Rietveld refinement obtained for the **03-SA05** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

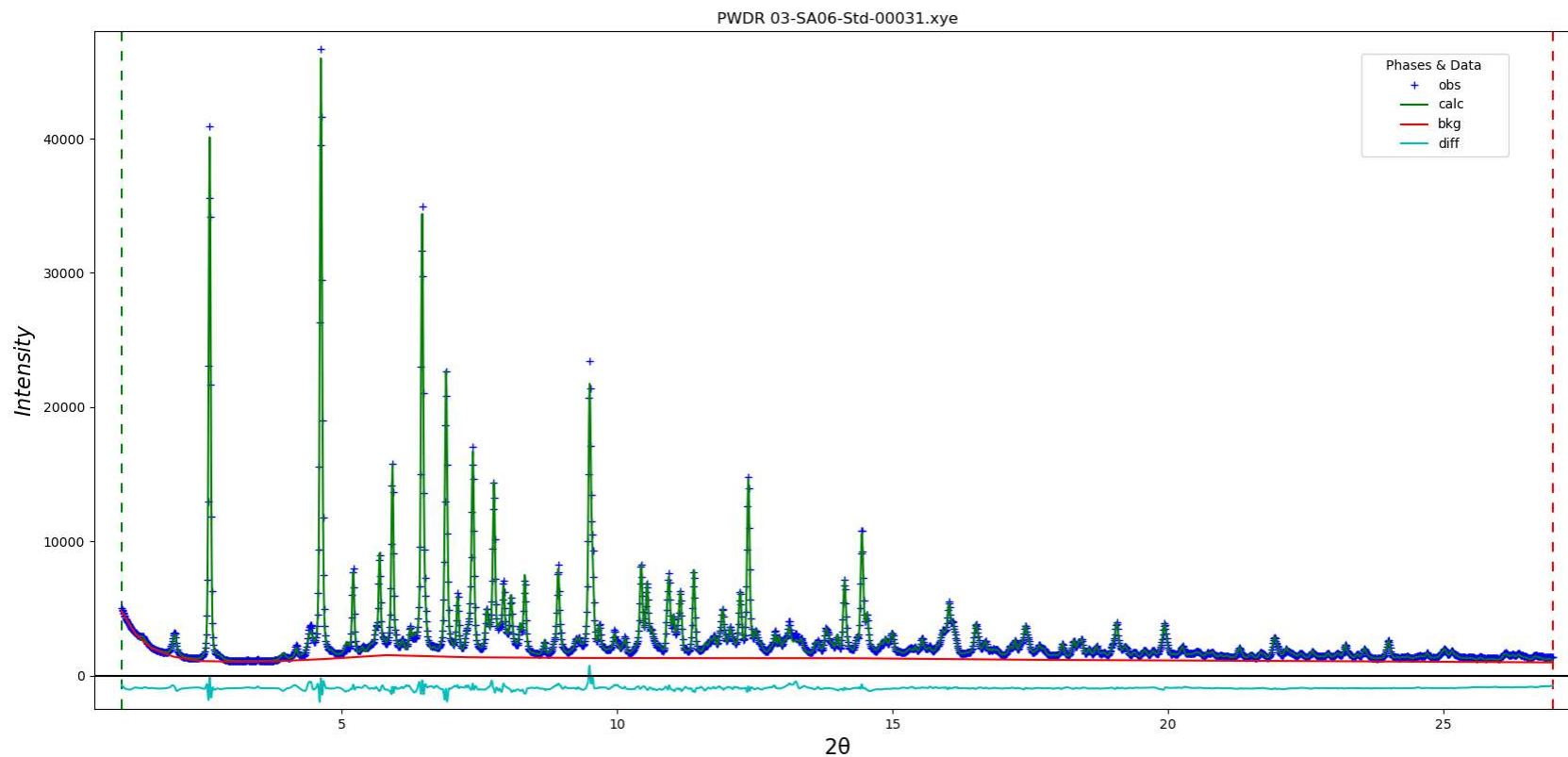


Figure 5.95. A plot of the final Rietveld refinement obtained for the **03-SA06** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

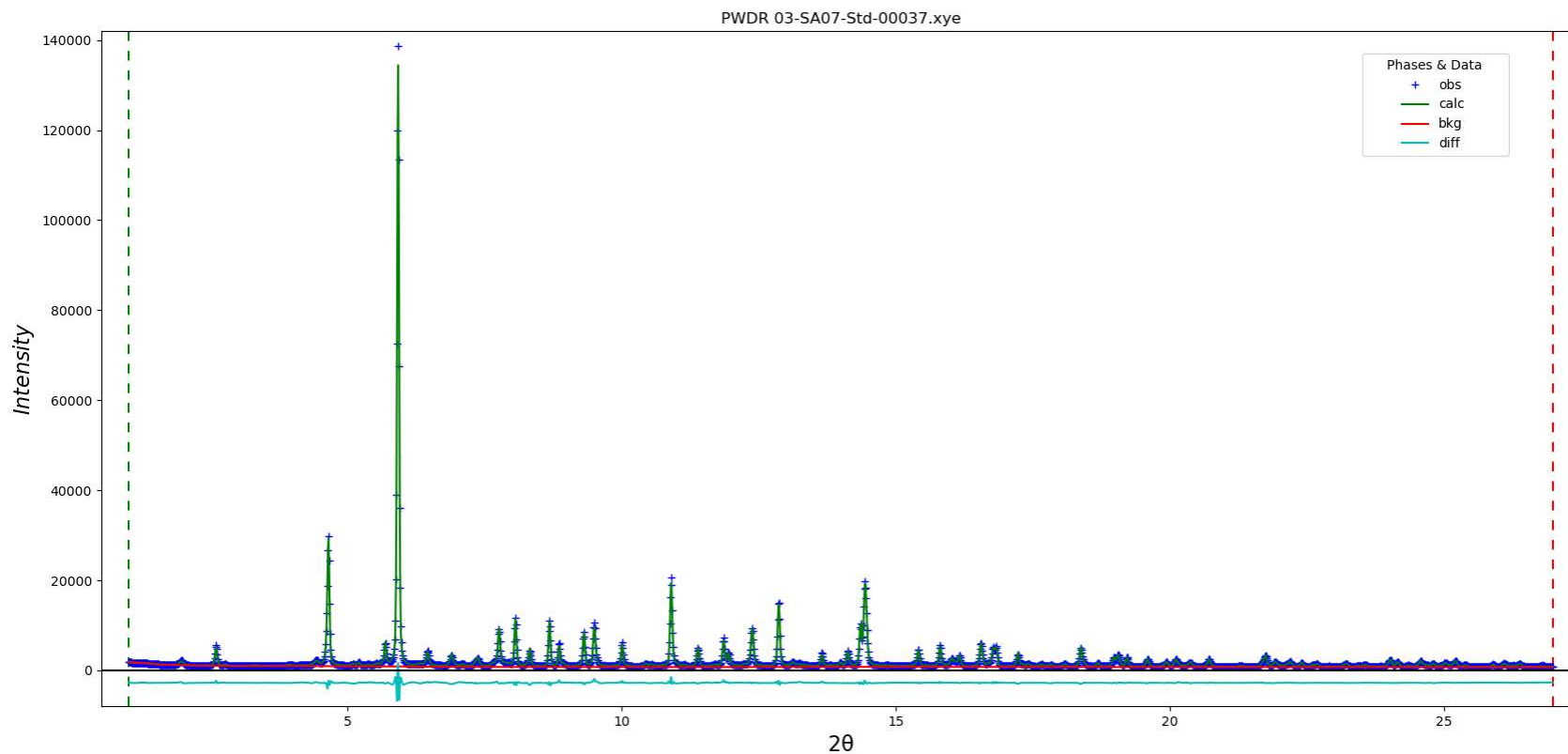


Figure 5.96. A plot of the final Rietveld refinement obtained for the **03-SA07** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

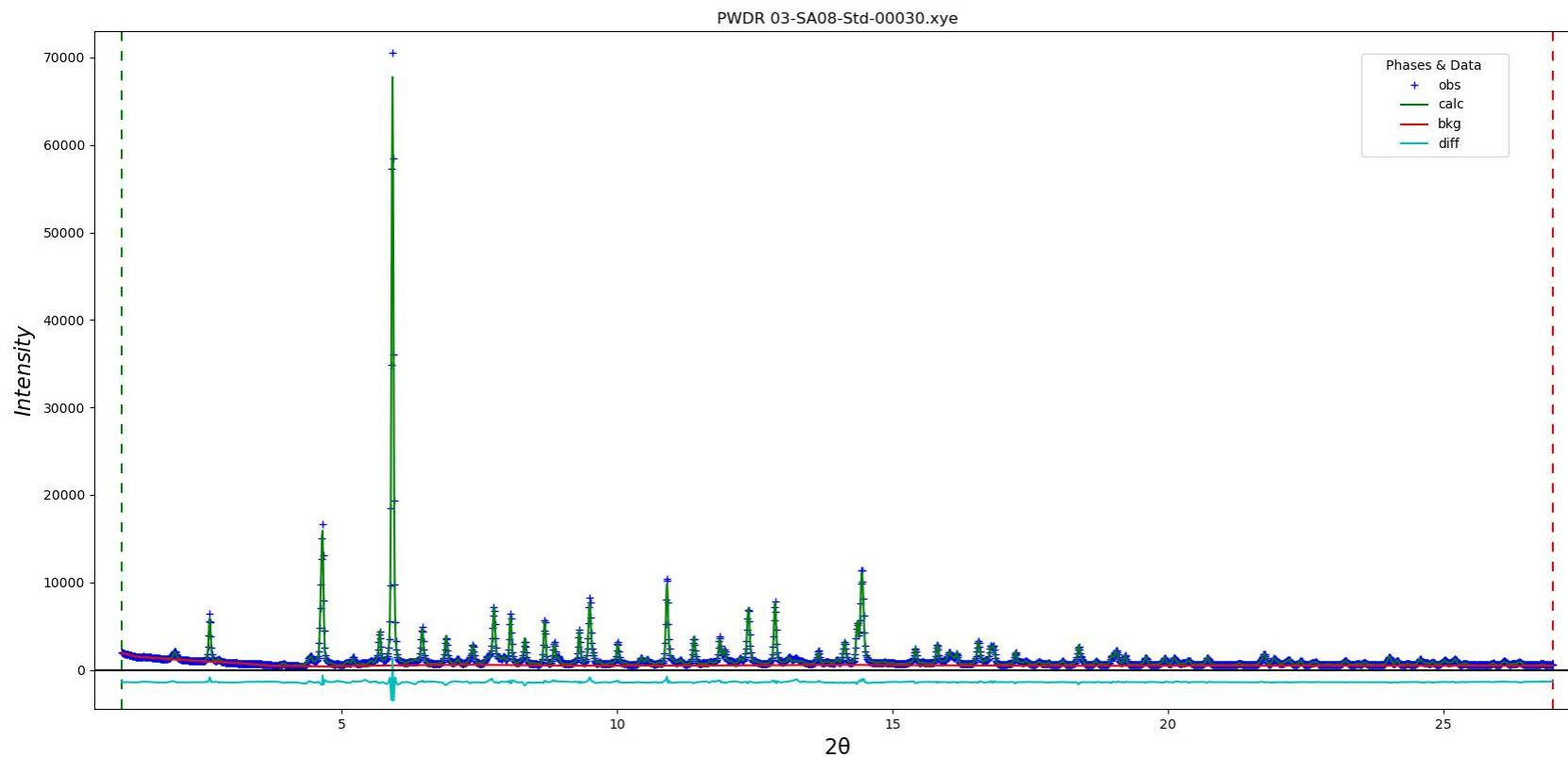


Figure 5.97. A plot of the final Rietveld refinement obtained for the **03-SA08** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

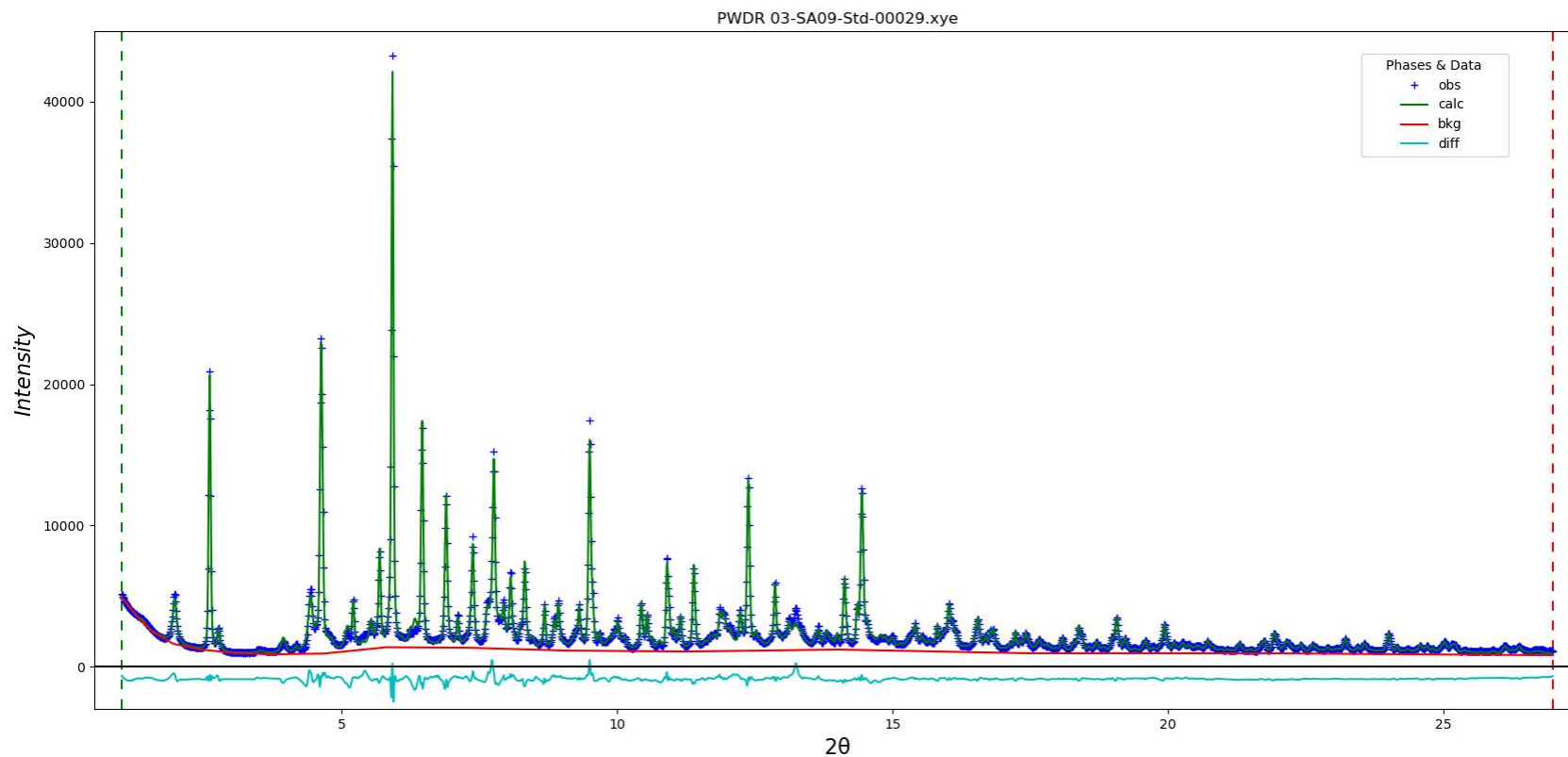


Figure 5.98. A plot of the final Rietveld refinement obtained for the **03-SA09** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

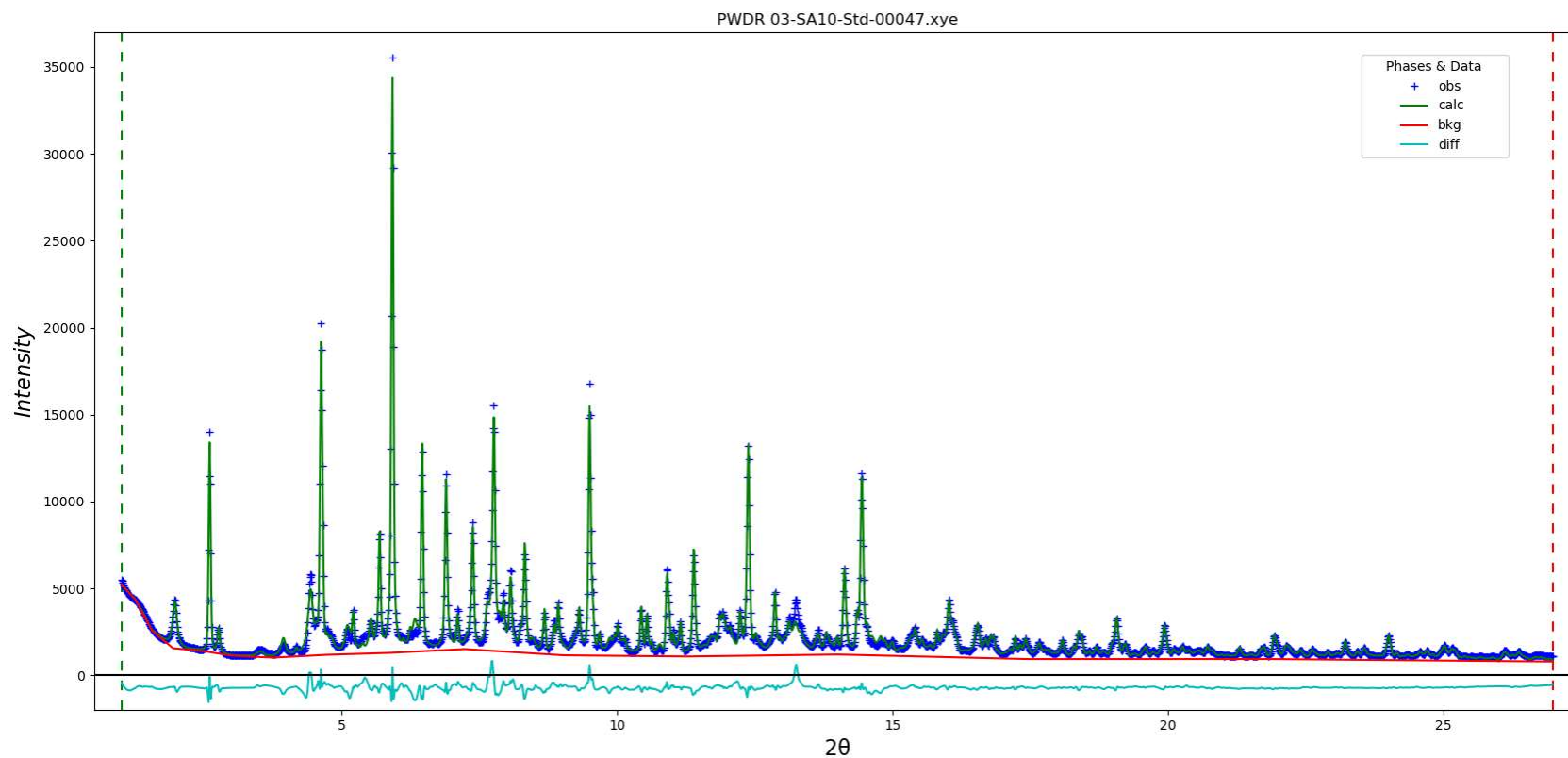


Figure 5.99. A plot of the final Rietveld refinement obtained for the **03-SA10** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

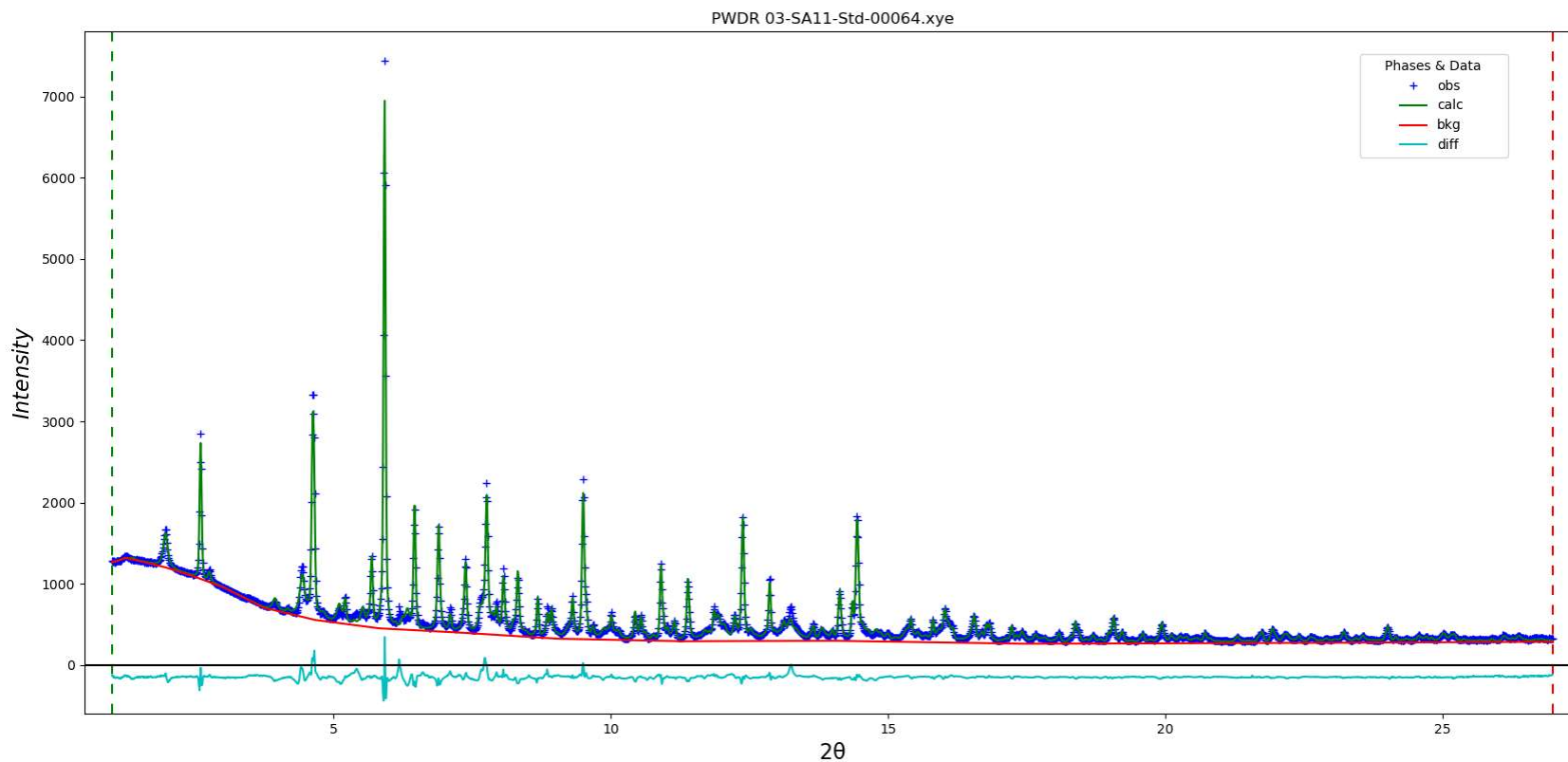


Figure 5.100. A plot of the final Rietveld refinement obtained for the **03-SA11** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

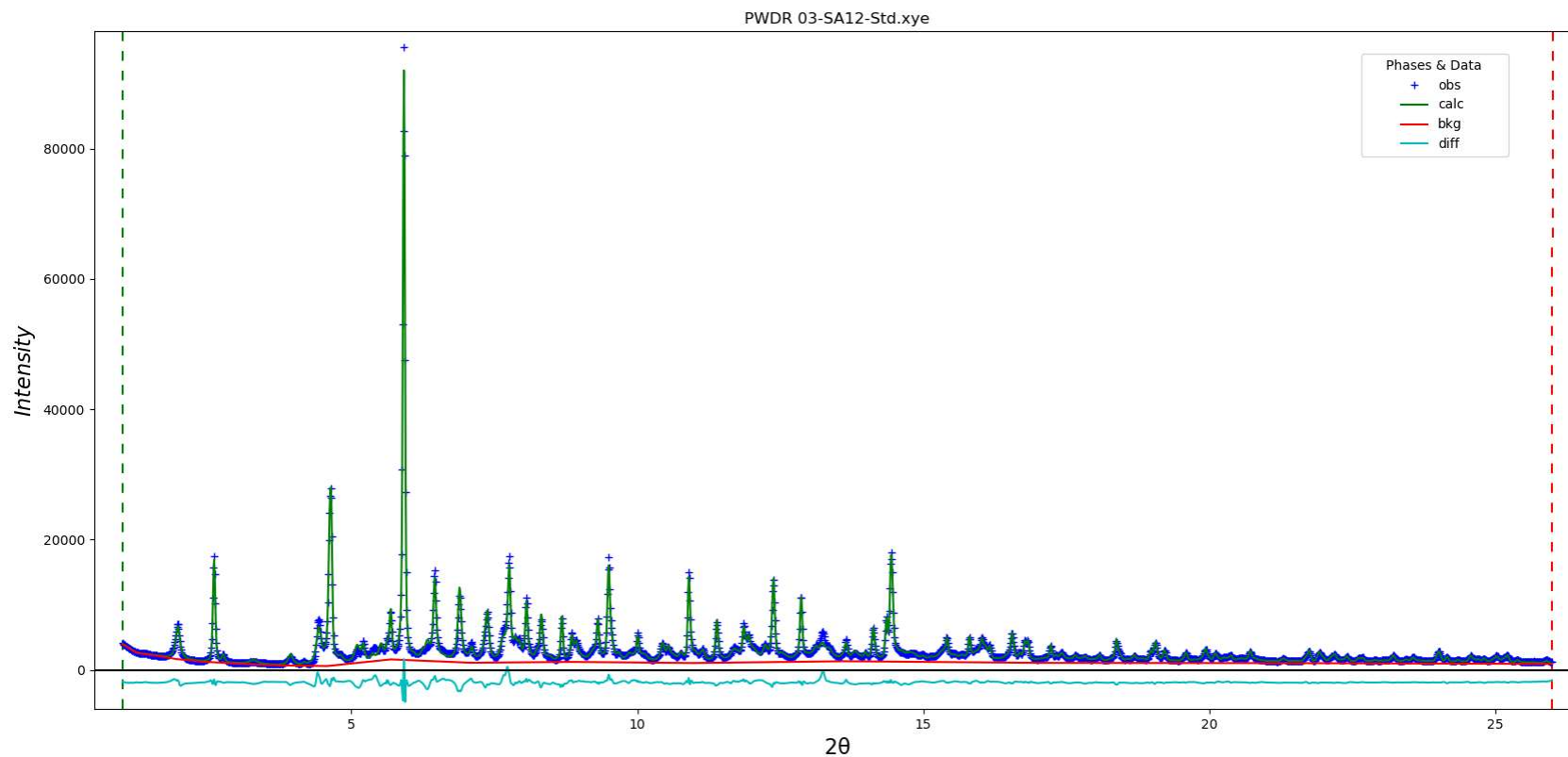


Figure 5.101. A plot of the final Rietveld refinement obtained for the **03-SA12** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

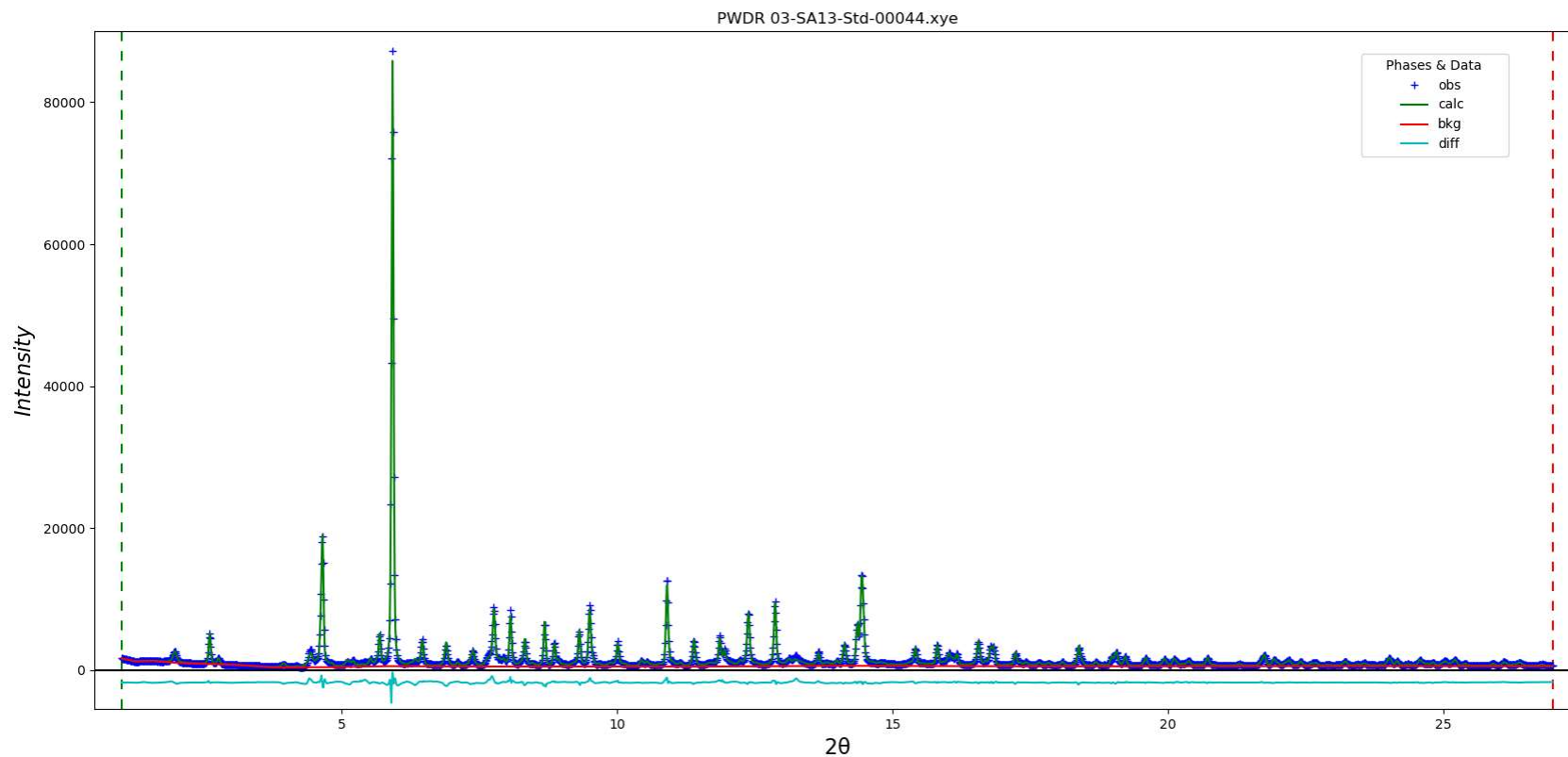


Figure 5.102. A plot of the final Rietveld refinement obtained for the **03-SA13** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

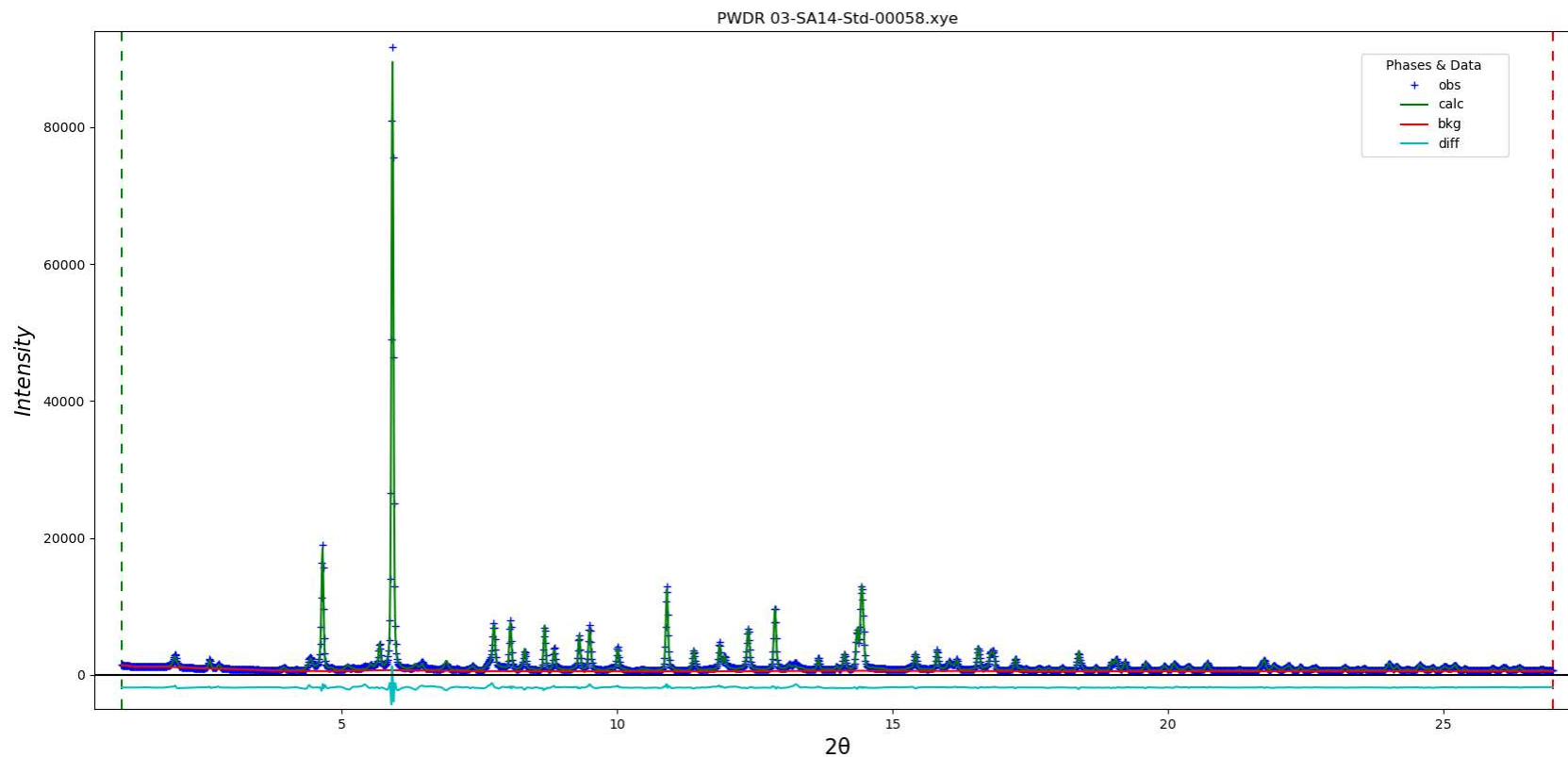


Figure 5.103. A plot of the final Rietveld refinement obtained for the **03-SA14** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

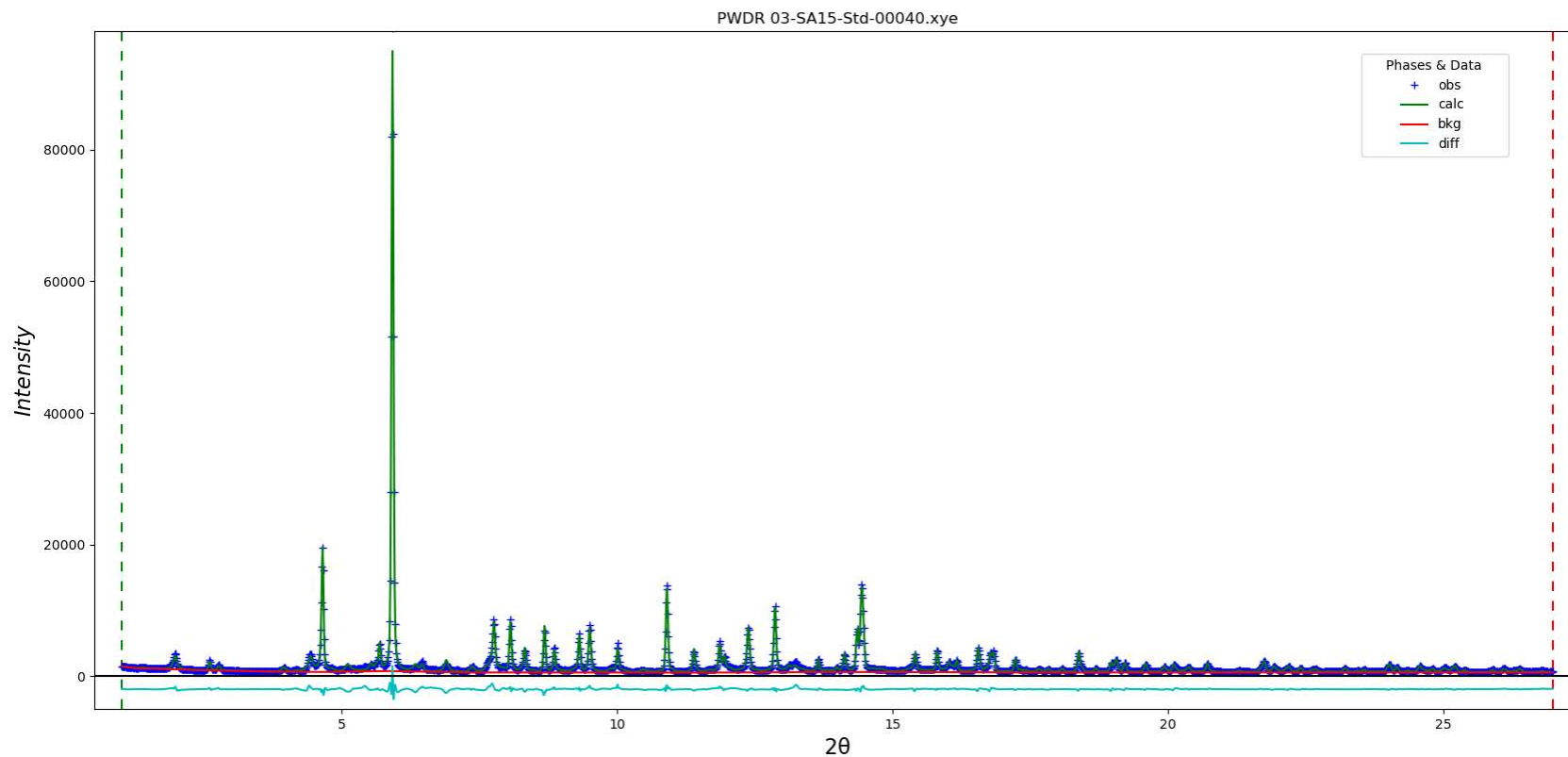


Figure 5.104. A plot of the final Rietveld refinement obtained for the **03-SA15** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

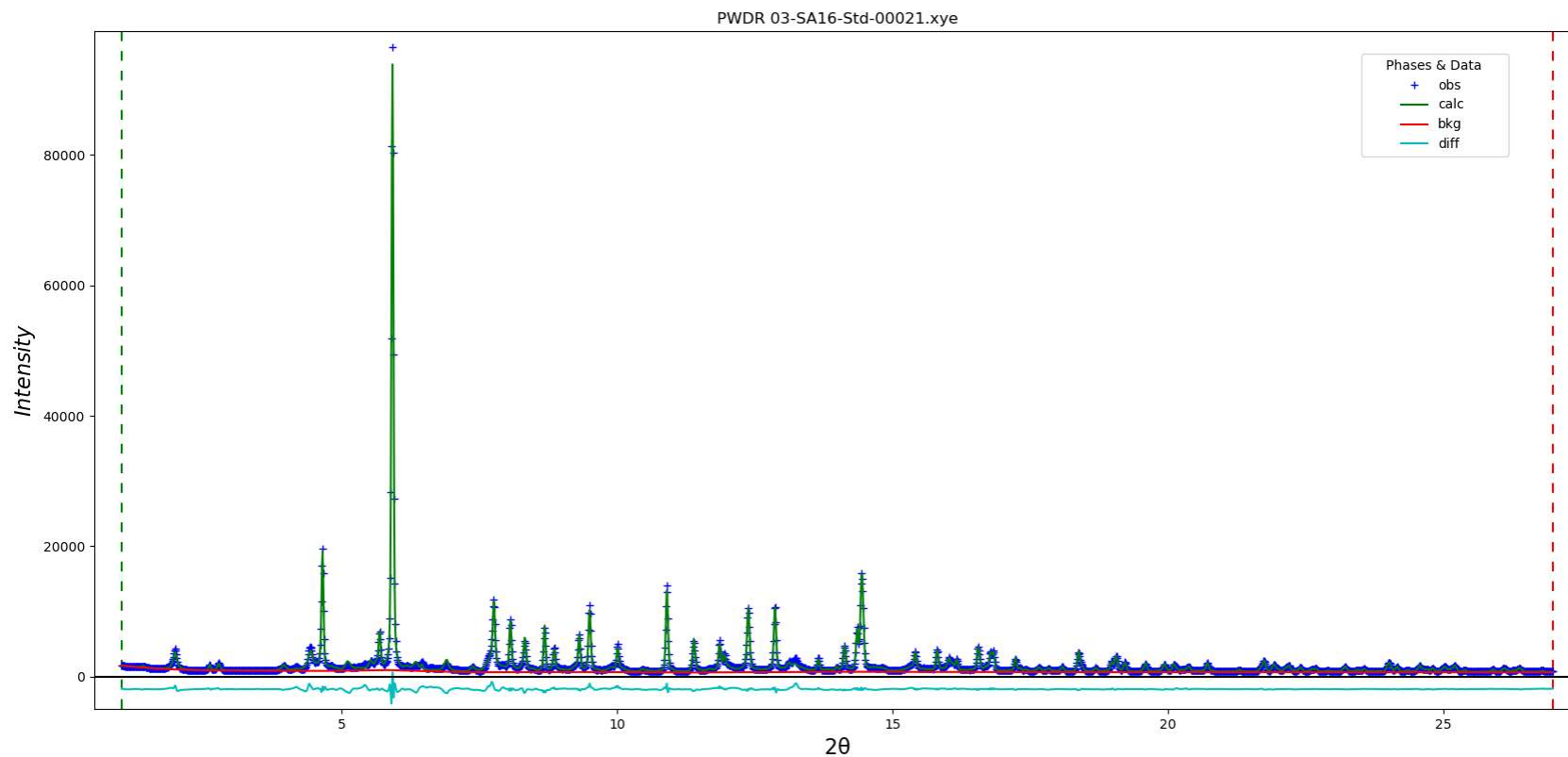


Figure 5.105. A plot of the final Rietveld refinement obtained for the **03-SA16** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

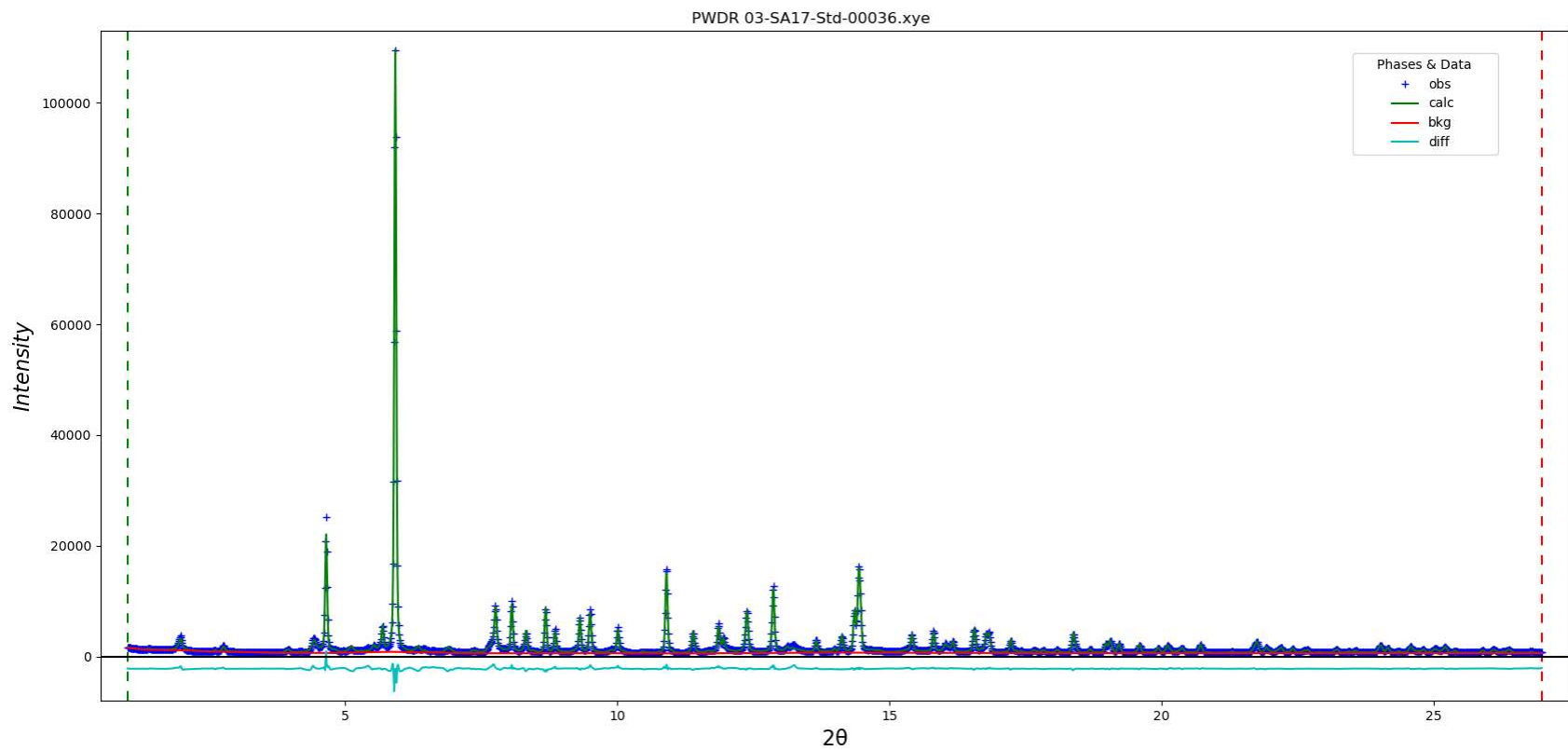


Figure 5.106. A plot of the final Rietveld refinement obtained for the **03-SA17** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

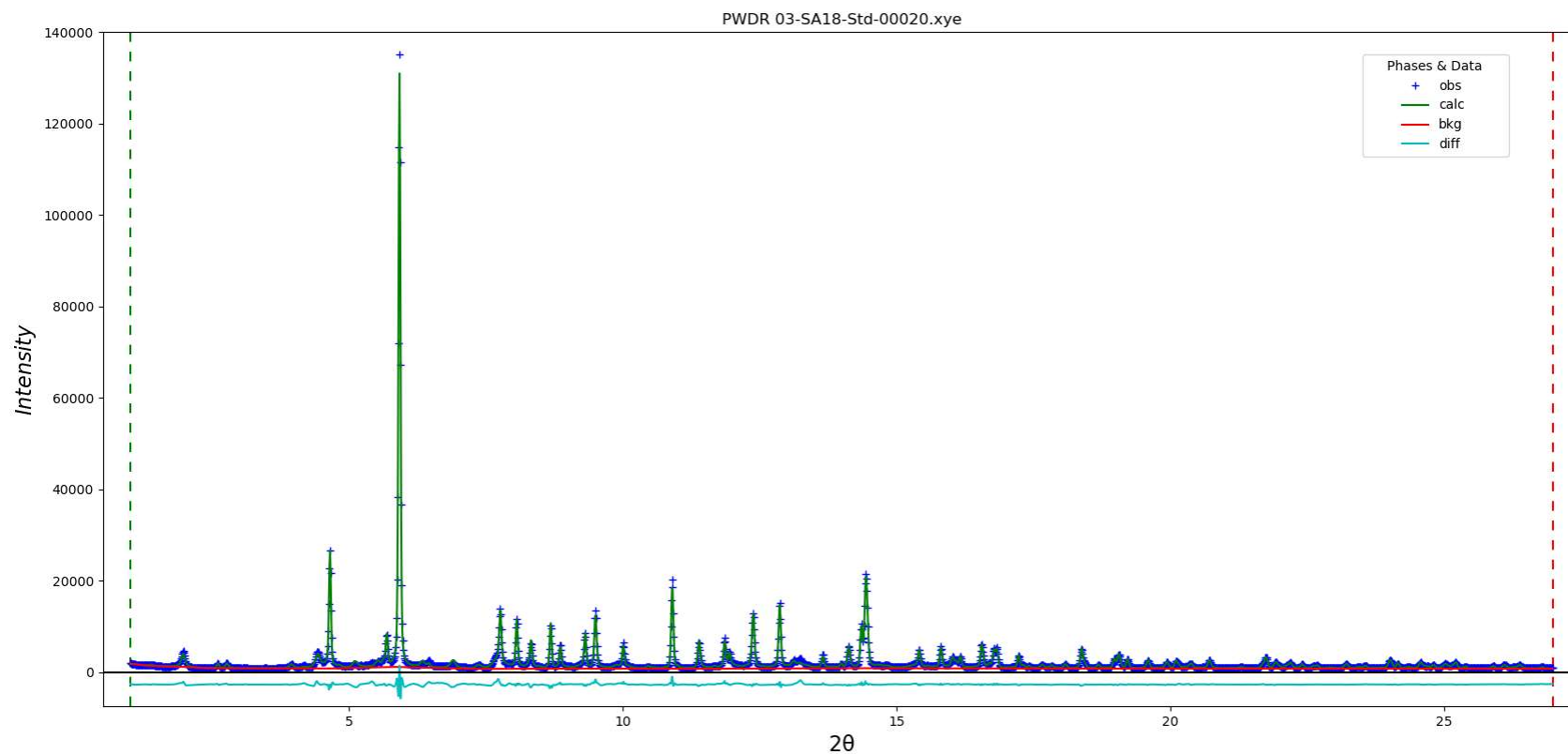


Figure 5.107. A plot of the final Rietveld refinement obtained for the **03-SA18** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

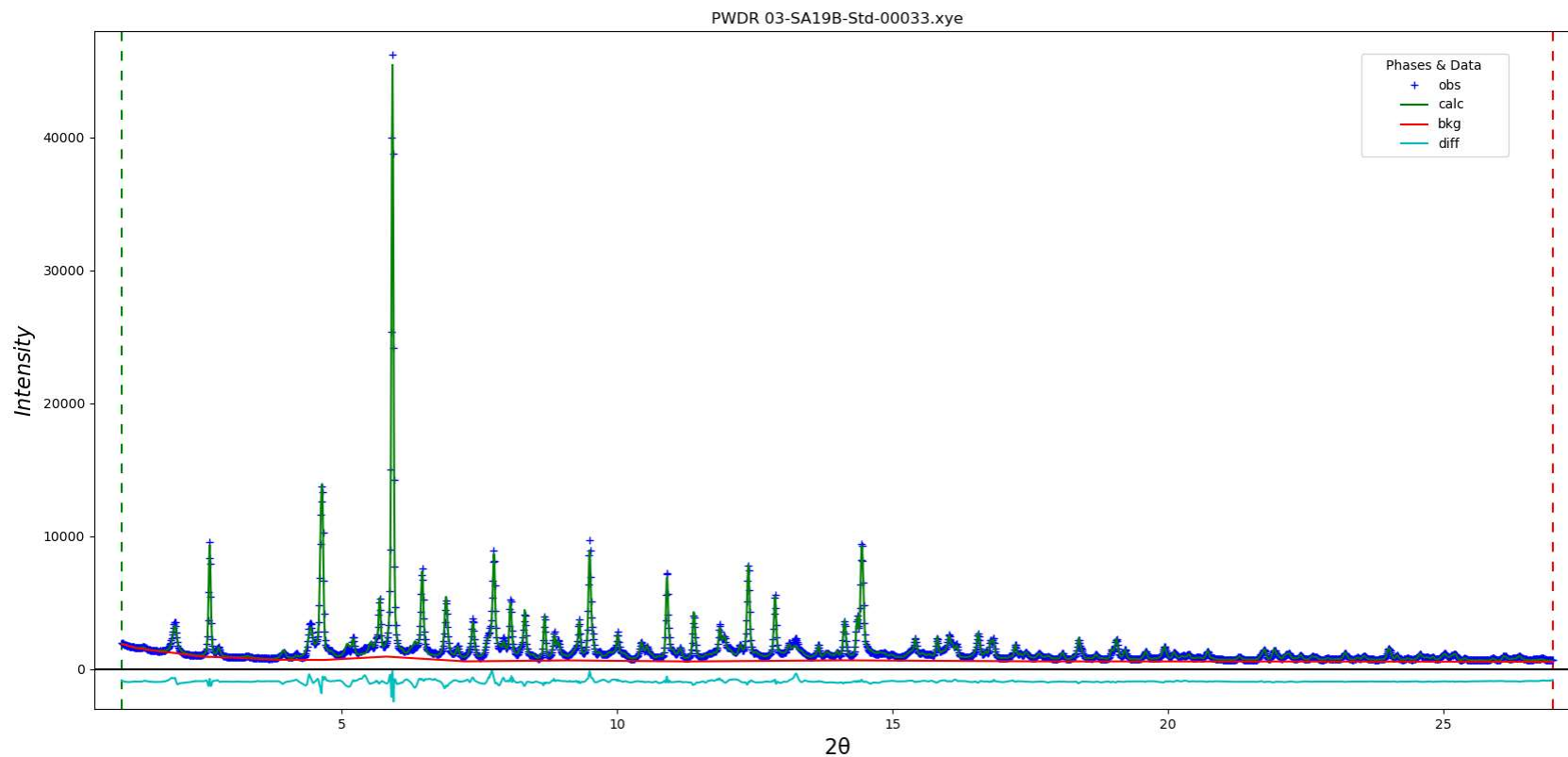


Figure 5.108. A plot of the final Rietveld refinement obtained for the **03-SA19B** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

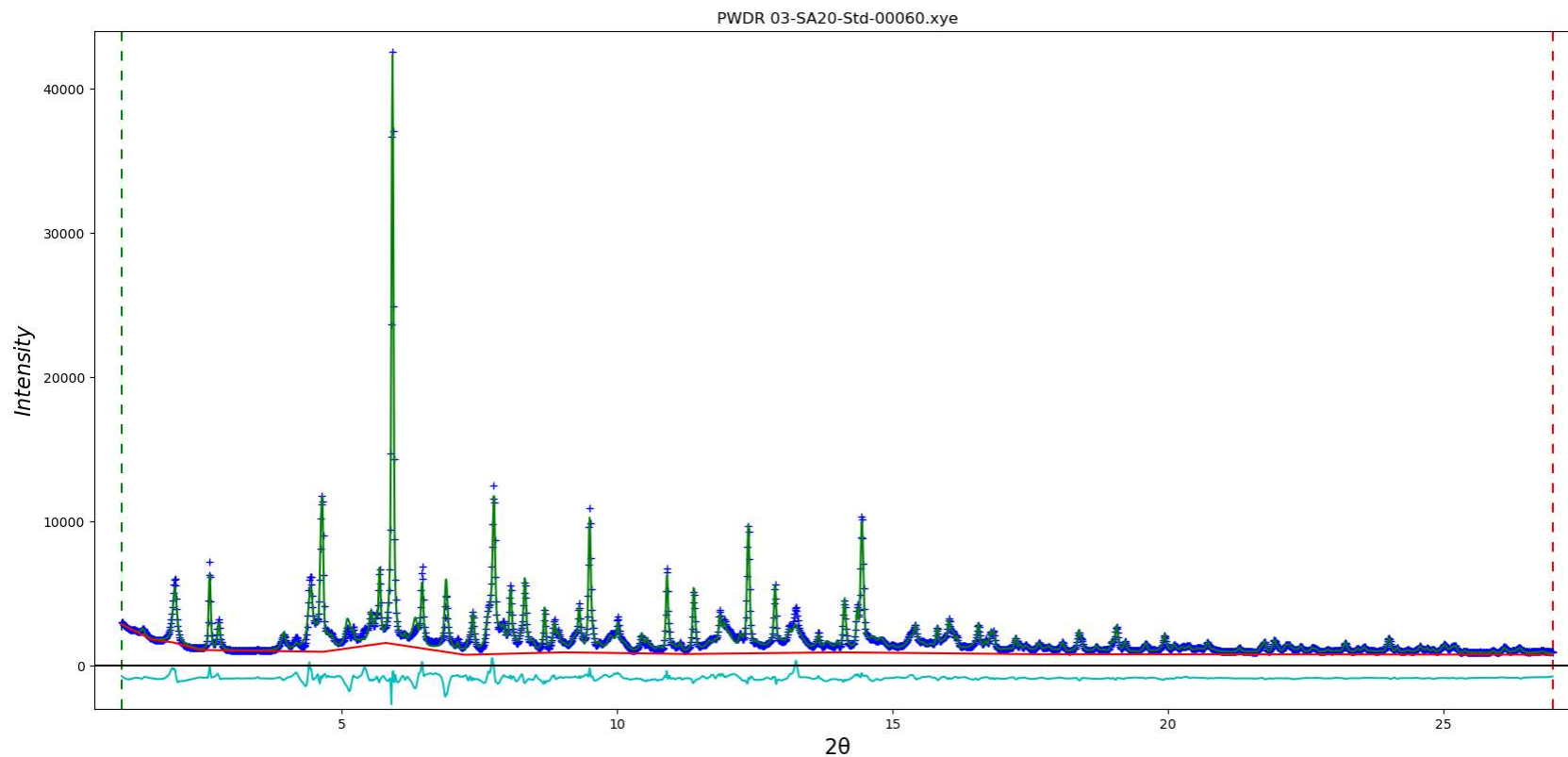


Figure 5.109. A plot of the final Rietveld refinement obtained for the **03-SA20** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

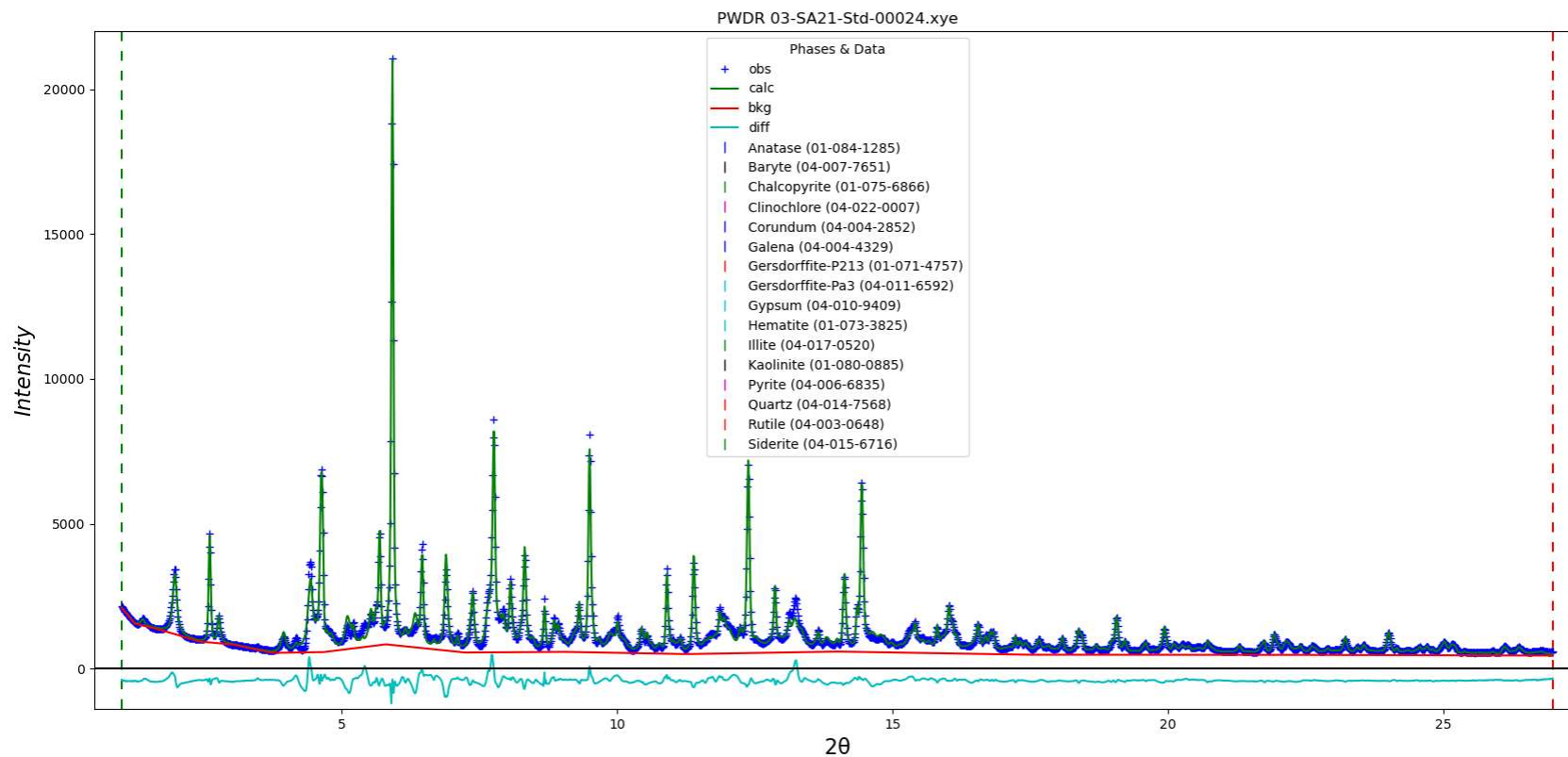


Figure 5.110. A plot of the final Rietveld refinement obtained for the **03-SA21** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

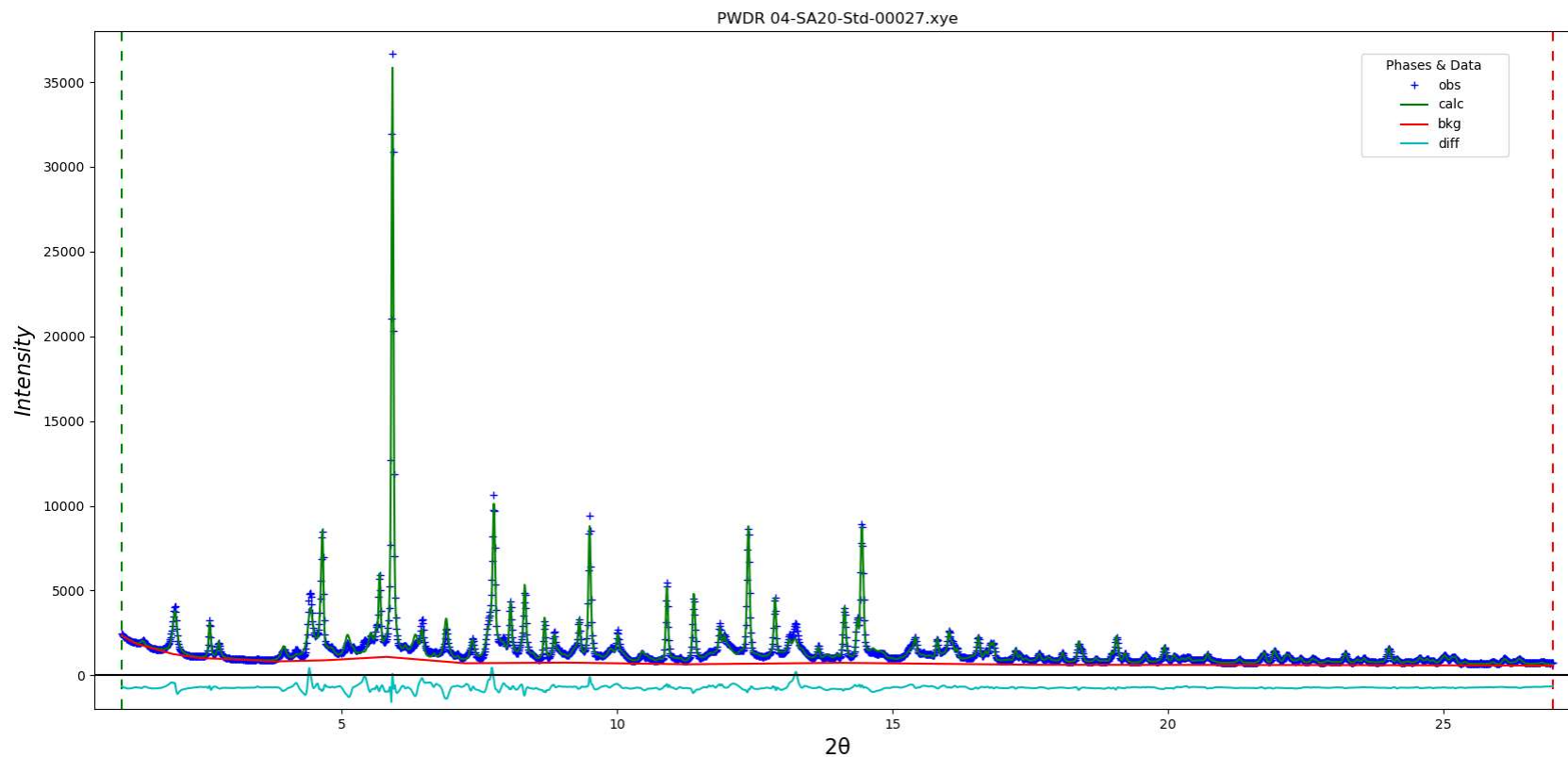


Figure 5.111. A plot of the final Rietveld refinement obtained for the **04-SA20** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

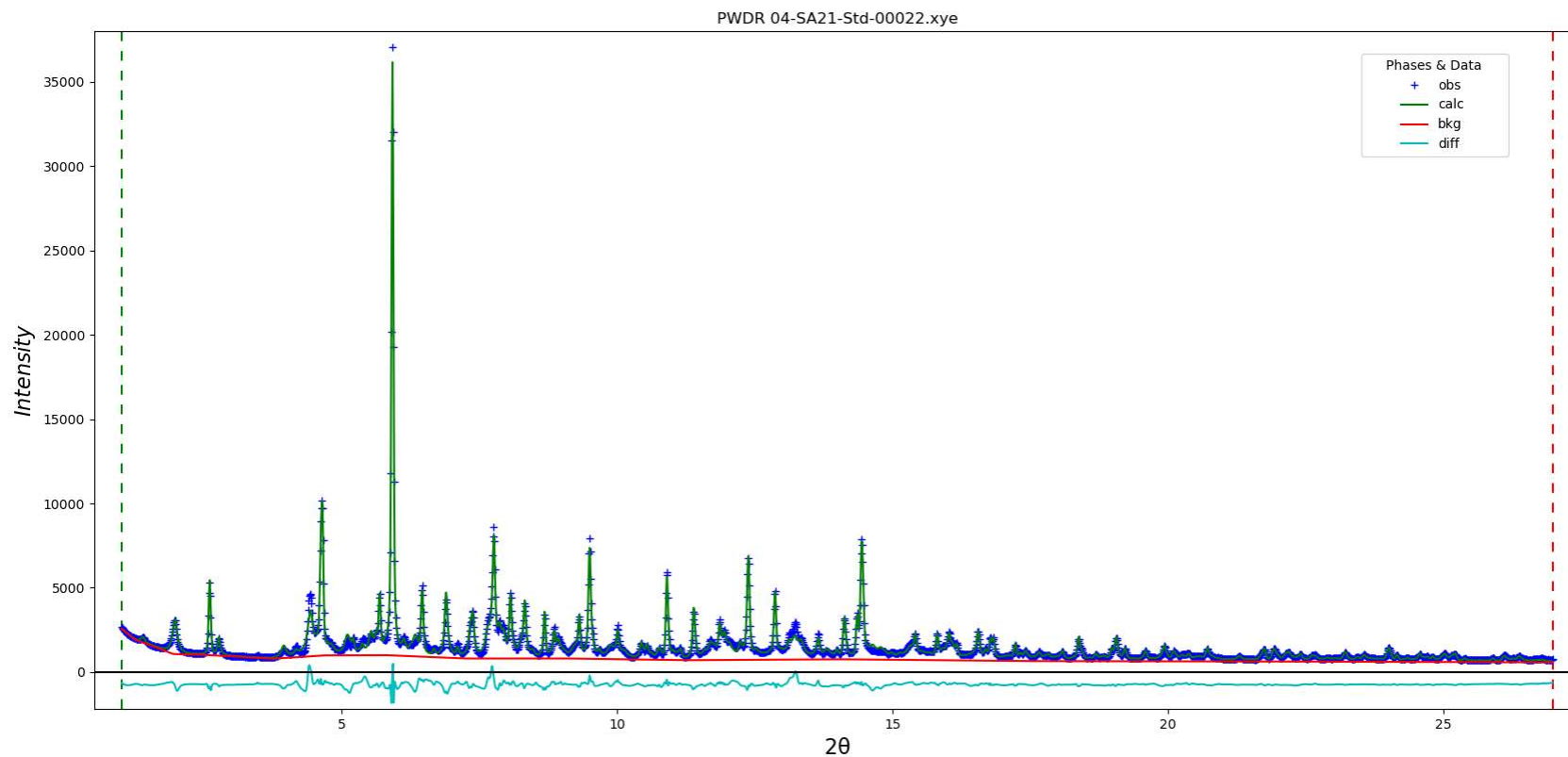


Figure 5.112. A plot of the final Rietveld refinement obtained for the **04-SA21** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

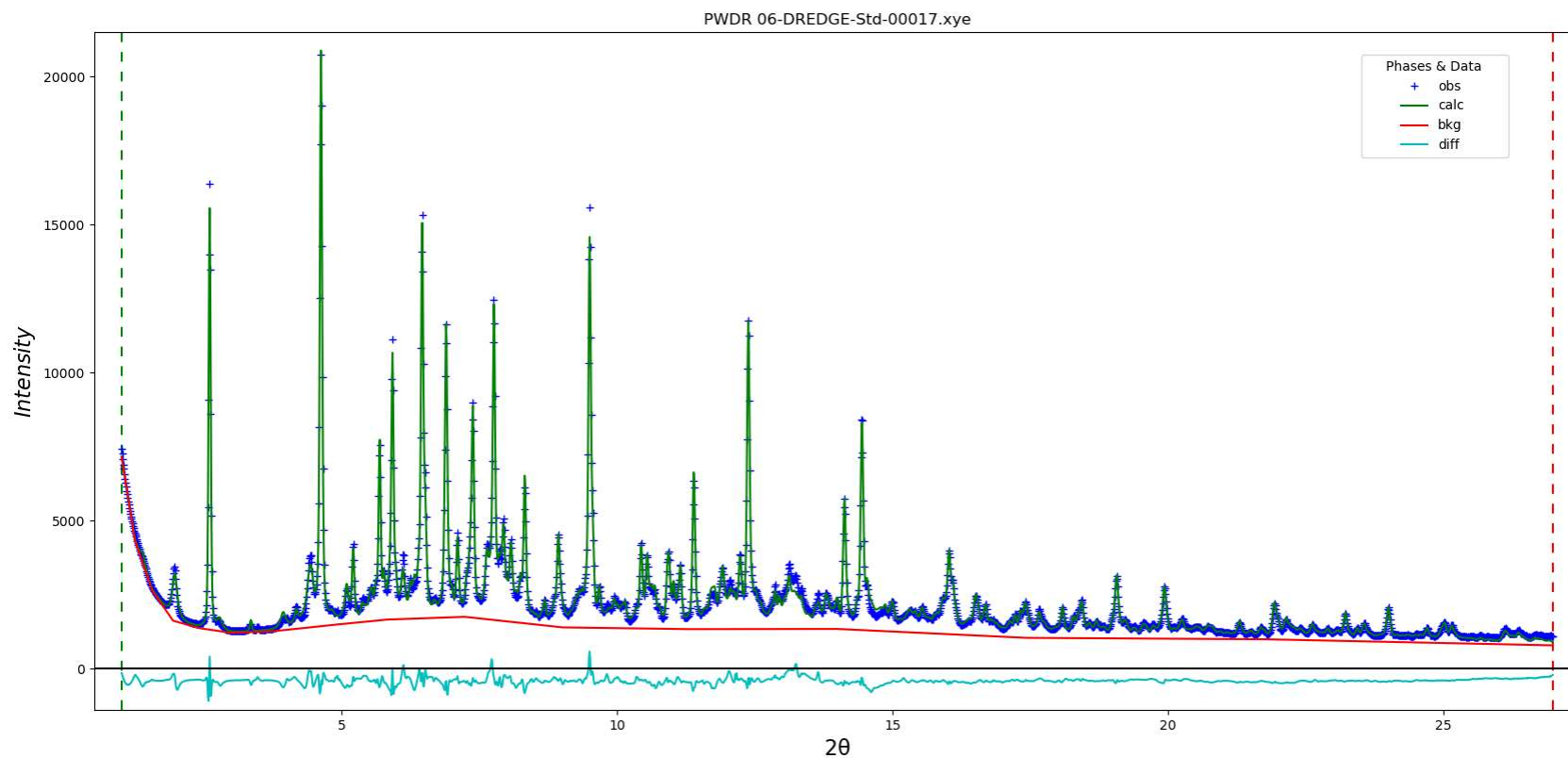


Figure 5.113. A plot of the final Rietveld refinement obtained for the **06-SA01** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

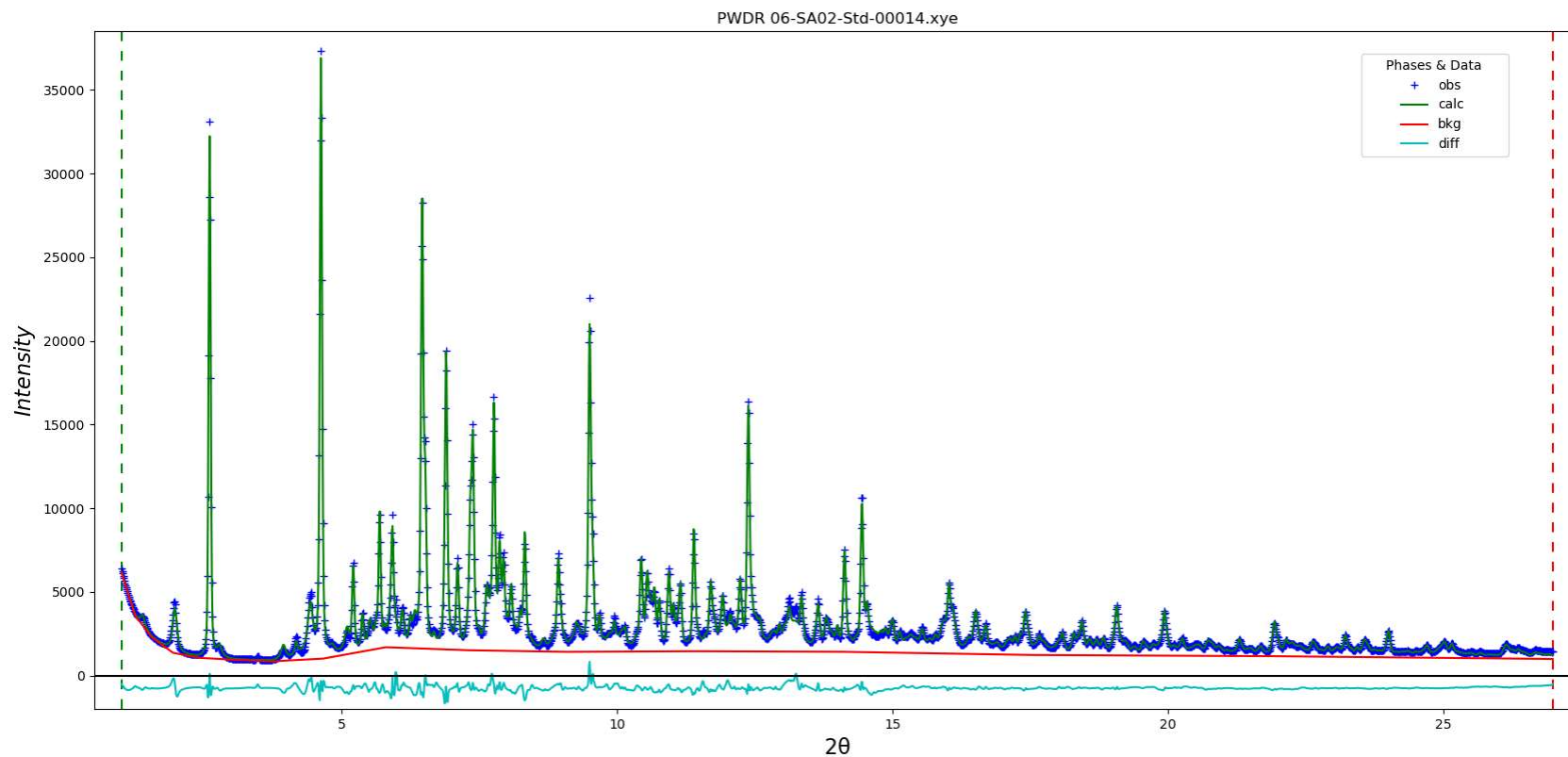


Figure 5.114. A plot of the final Rietveld refinement obtained for the **06-SA02** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

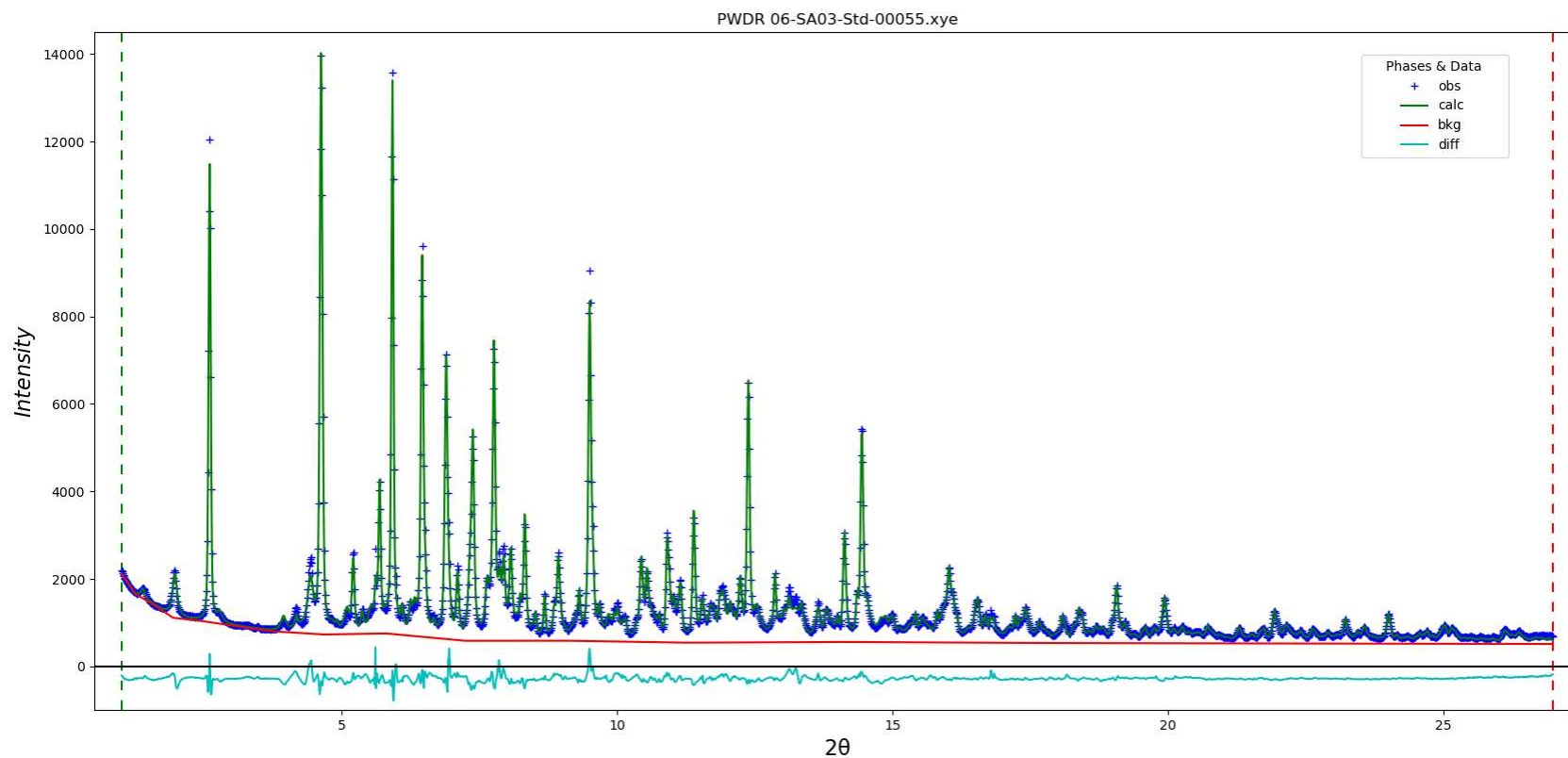


Figure 5.115. A plot of the final Rietveld refinement obtained for the **06-SA03** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

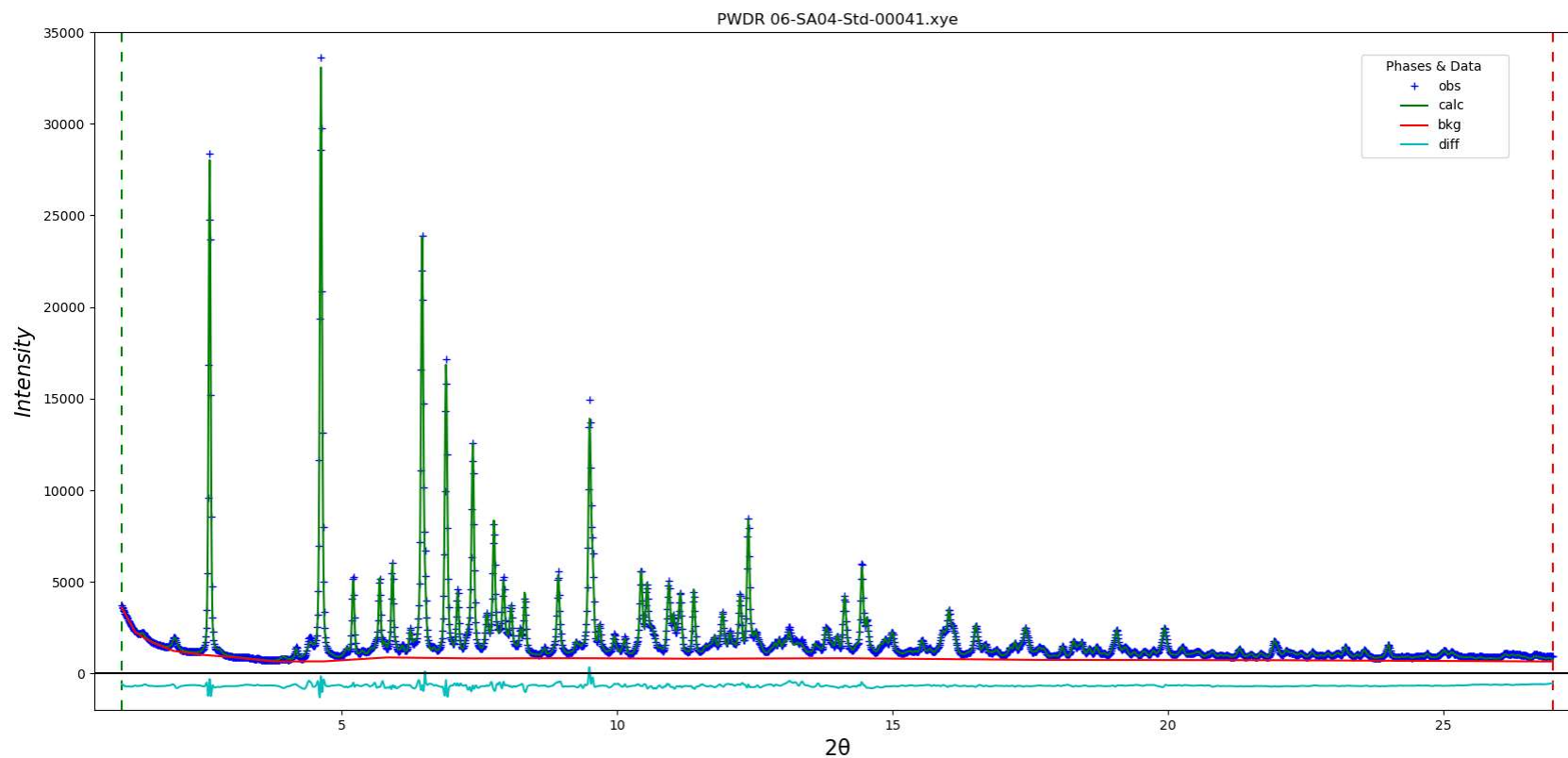


Figure 5.116. A plot of the final Rietveld refinement obtained for the **06-SA04** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

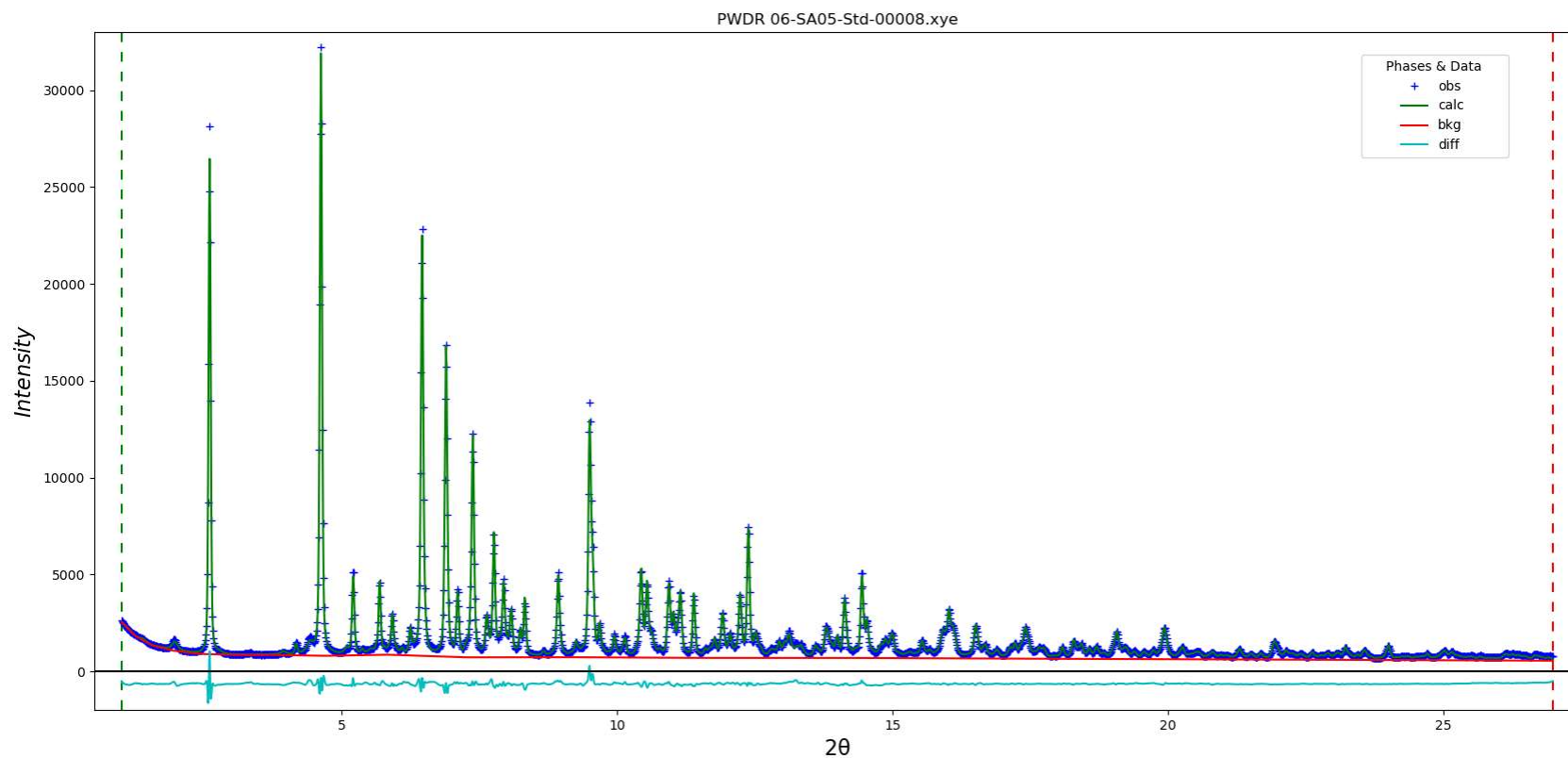


Figure 5.117. A plot of the final Rietveld refinement obtained for the **06-SA05** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

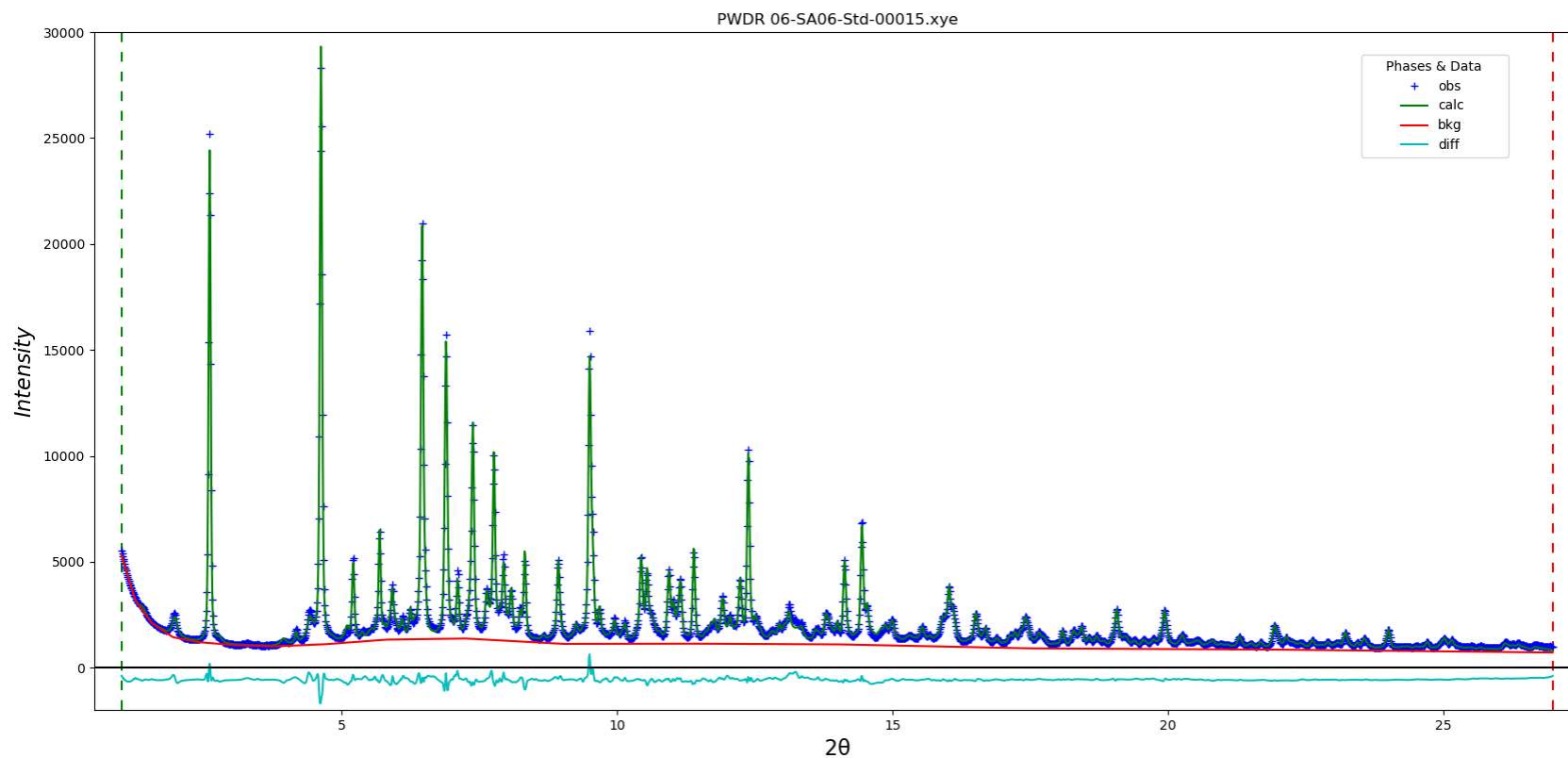


Figure 5.118. A plot of the final Rietveld refinement obtained for the **06-SA06** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

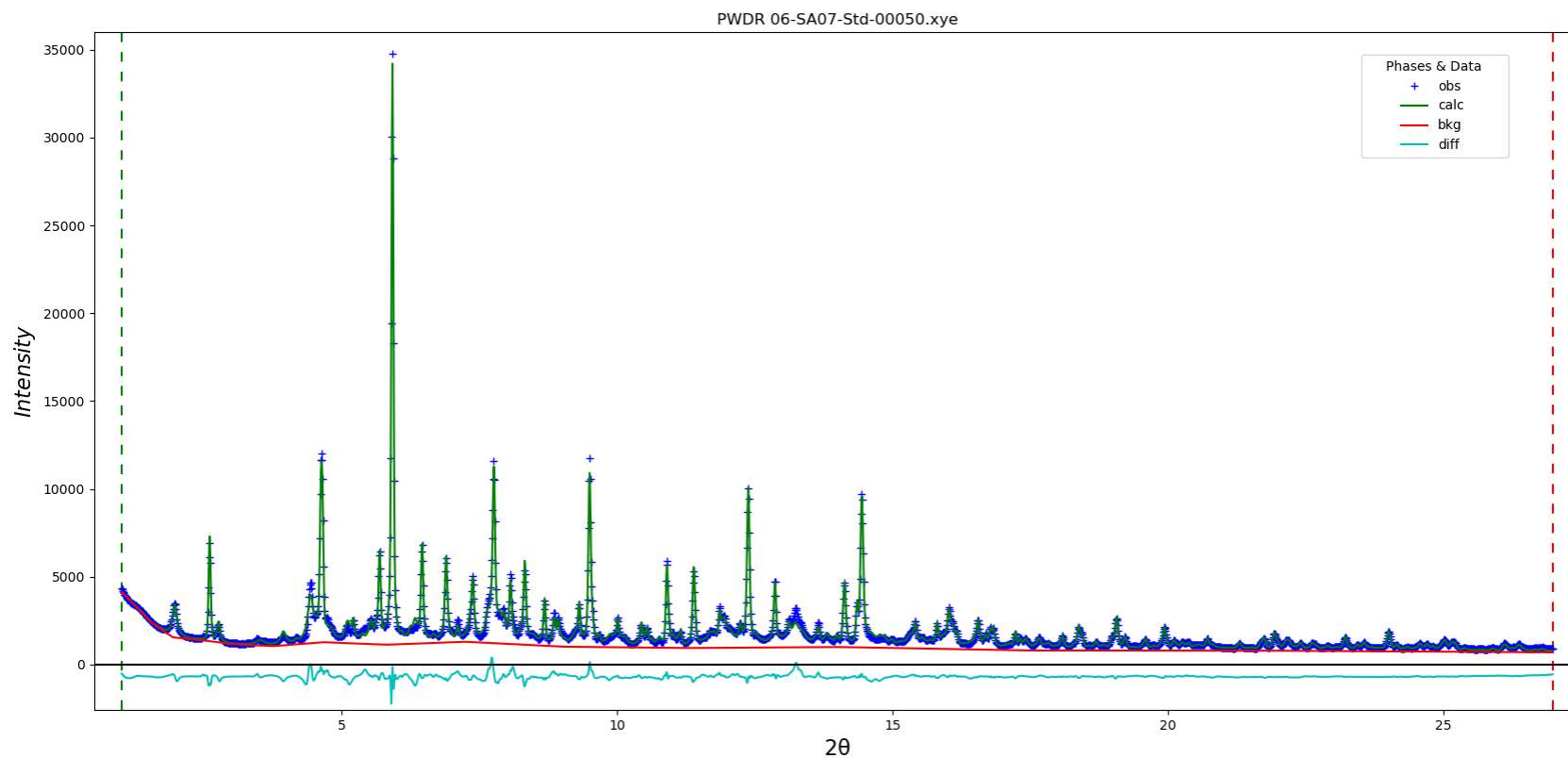


Figure 5.119. A plot of the final Rietveld refinement obtained for the **06-SA07** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

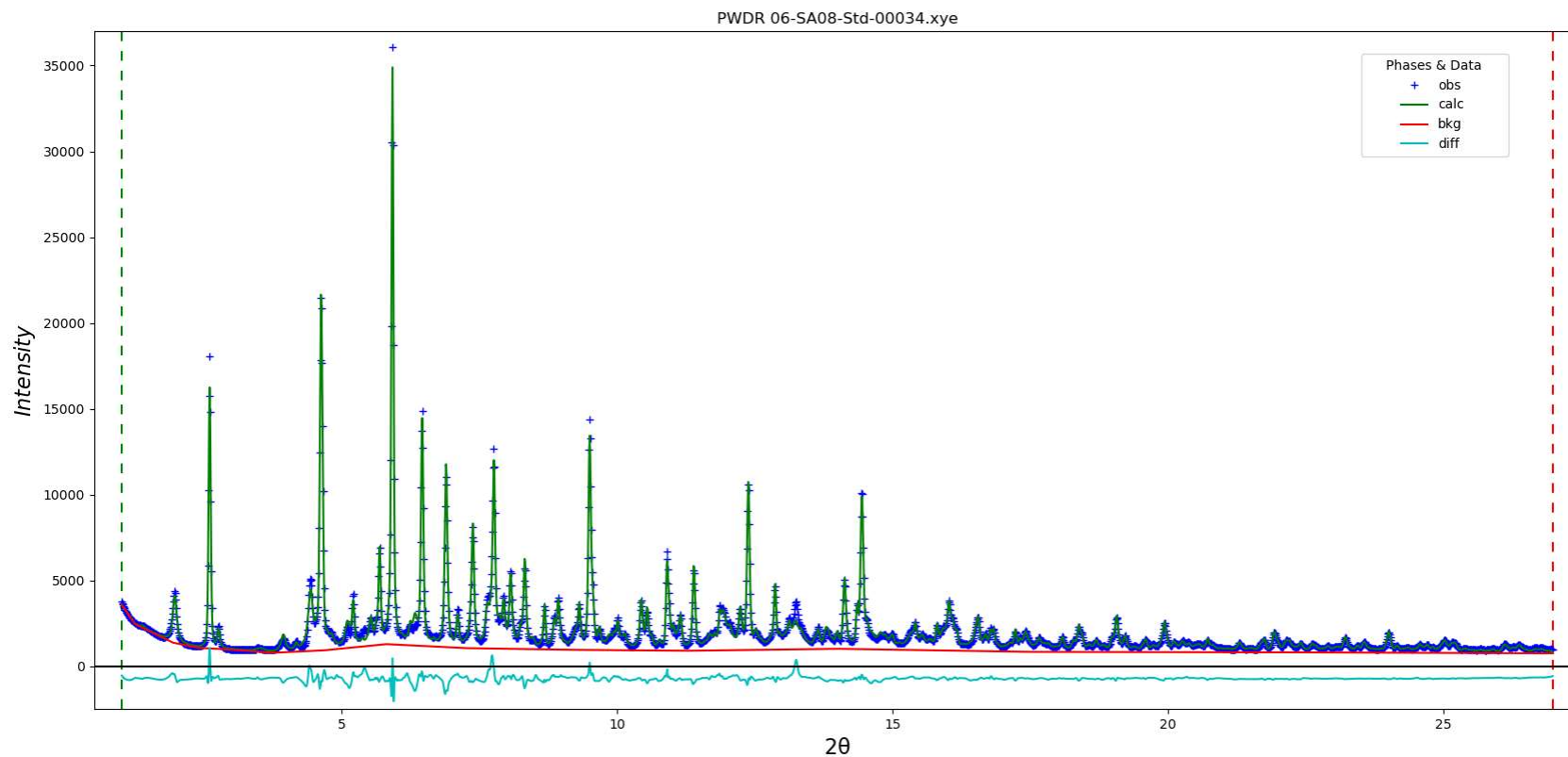


Figure 5.120. A plot of the final Rietveld refinement obtained for the **06-SA08** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

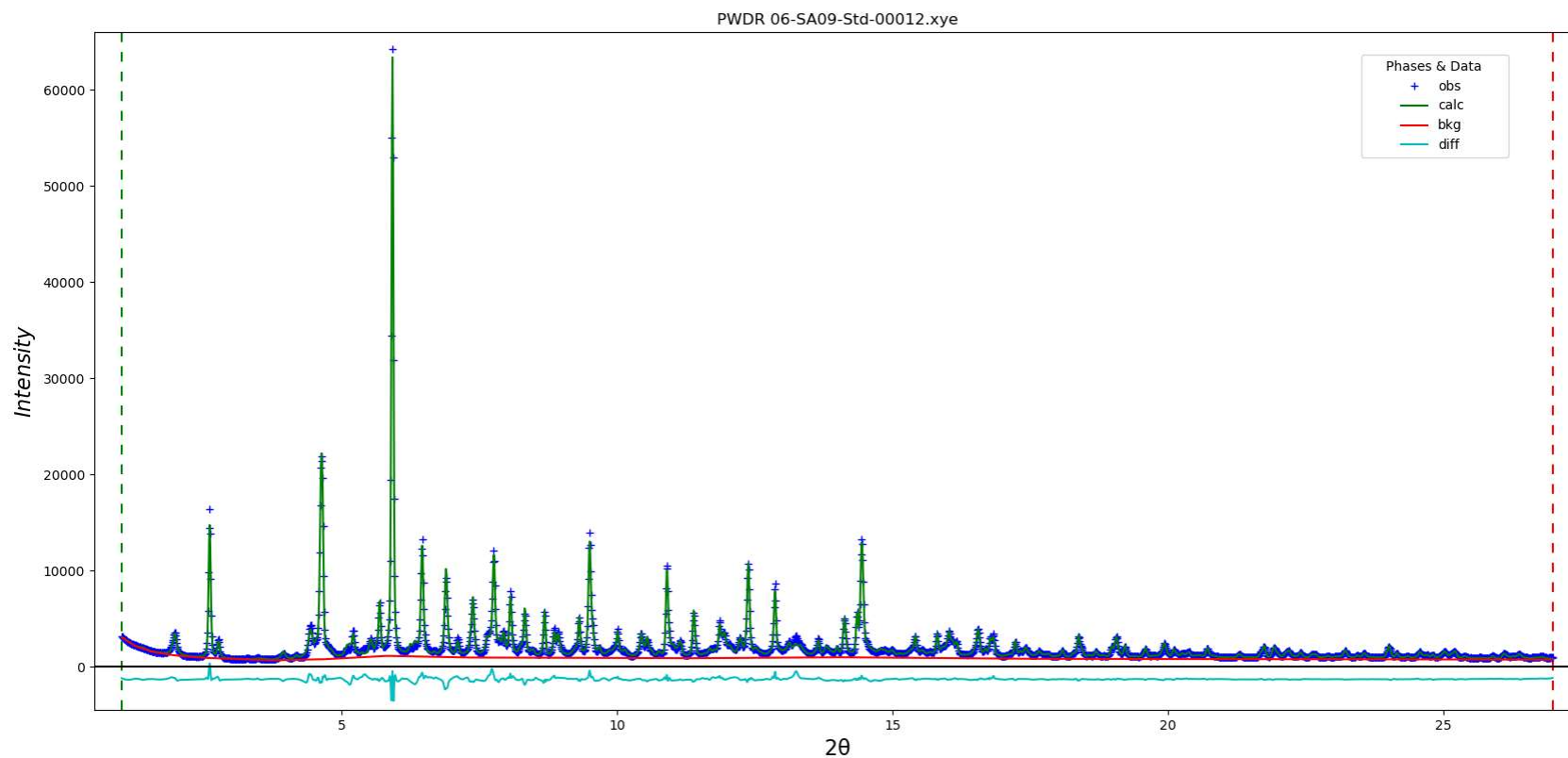


Figure 5.121. A plot of the final Rietveld refinement obtained for the **06-SA09** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

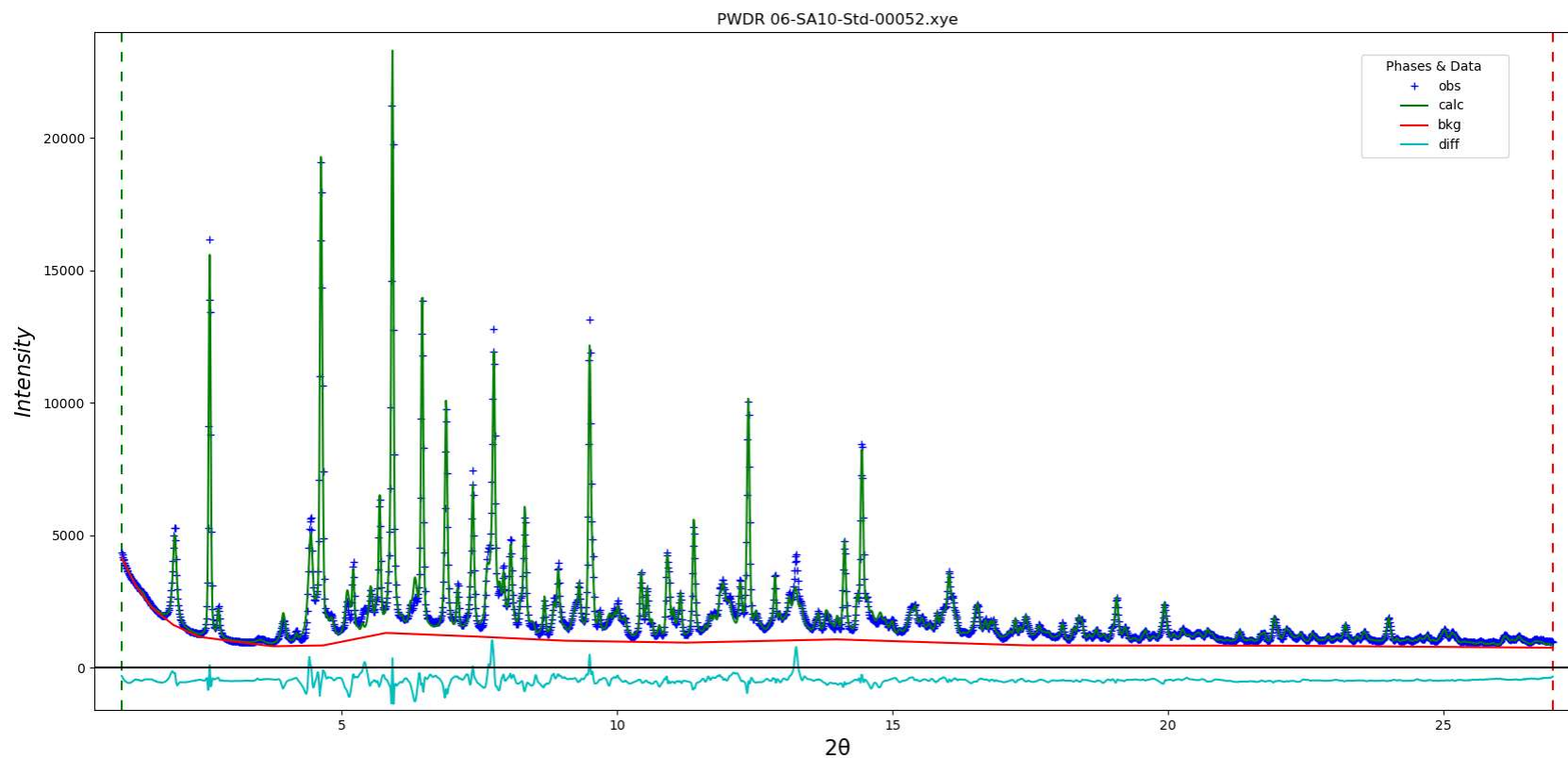


Figure 5.122. A plot of the final Rietveld refinement obtained for the **06-SA10** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

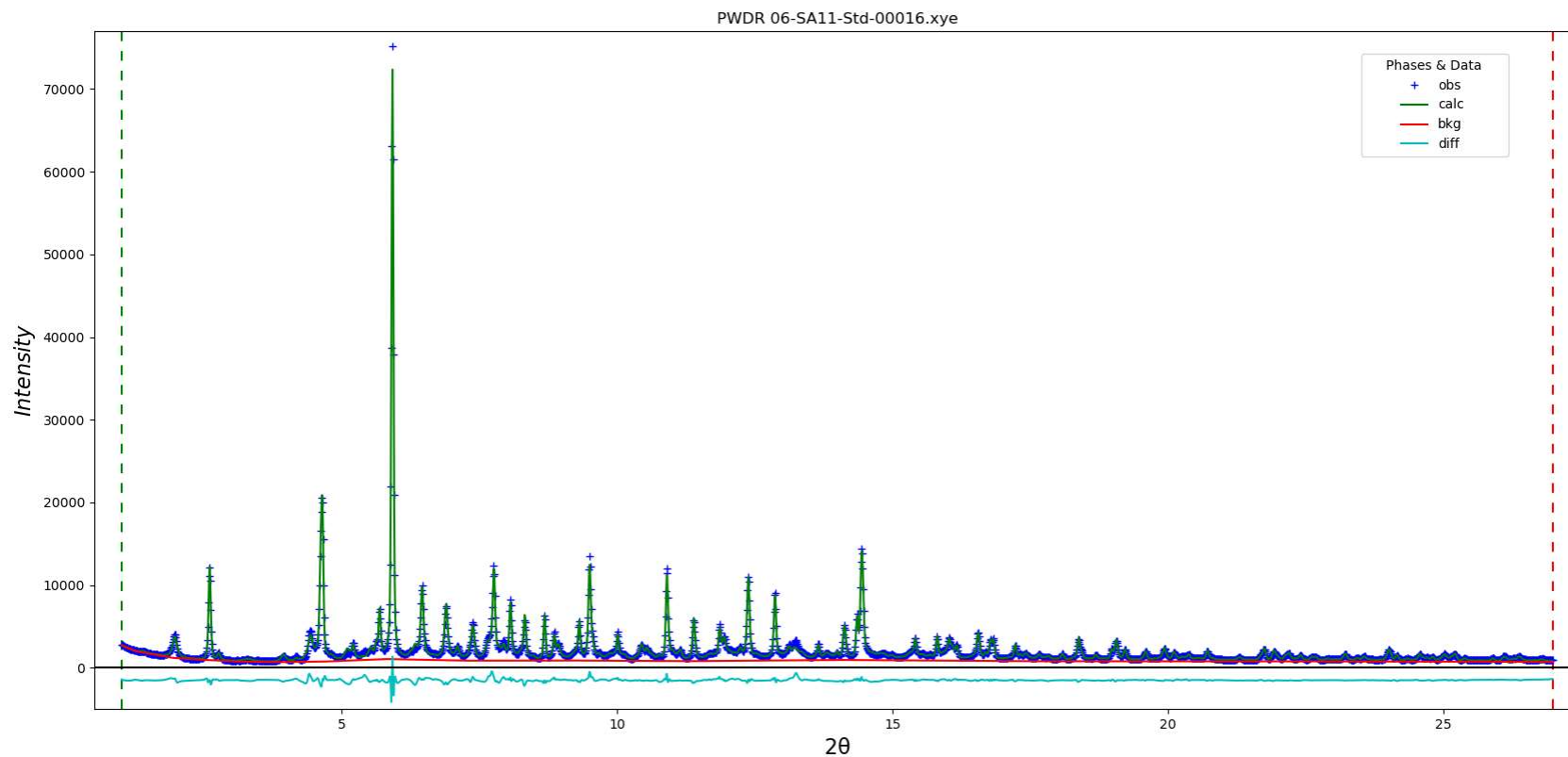


Figure 5.123. A plot of the final Rietveld refinement obtained for the **06-SA11** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

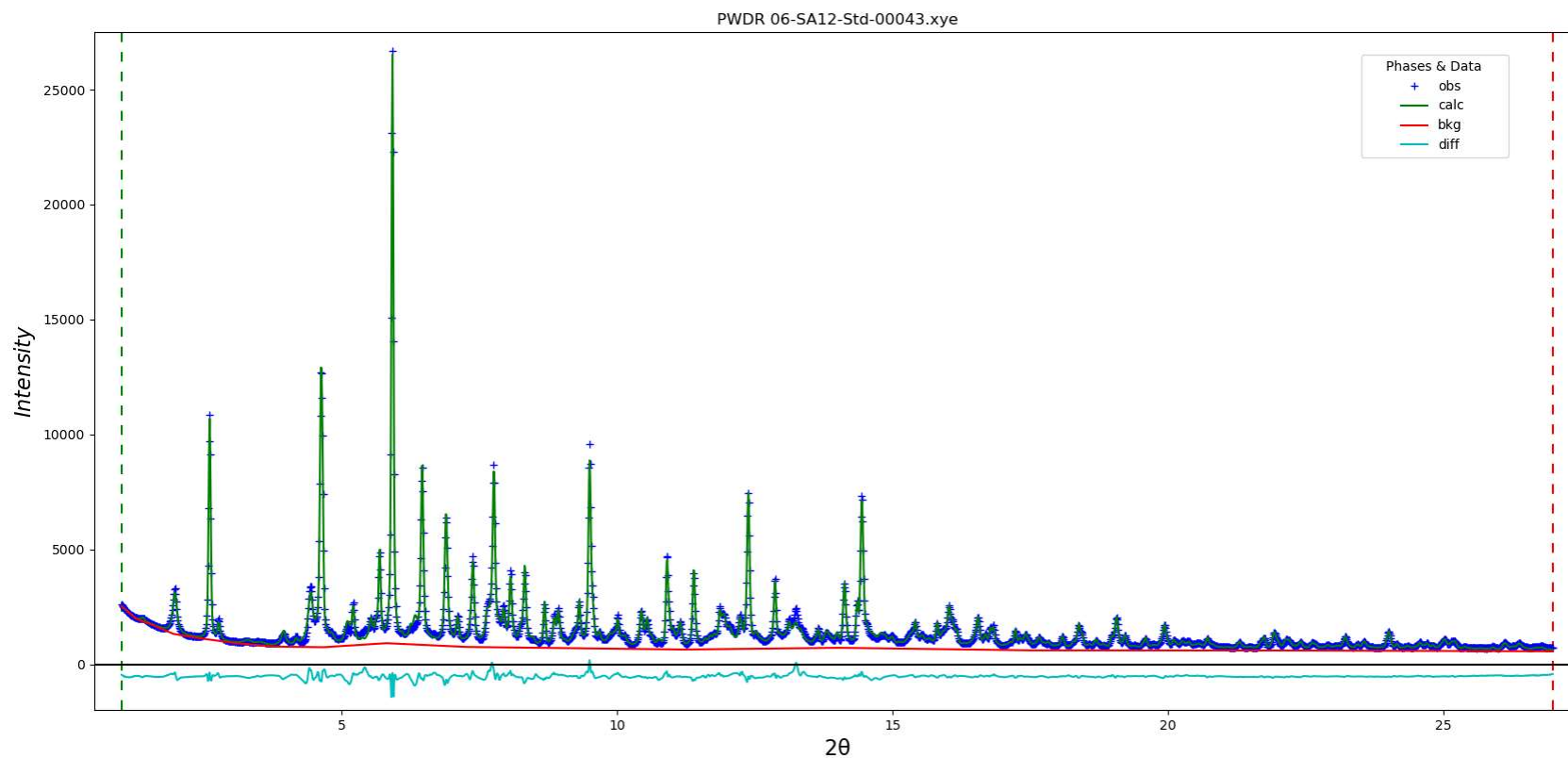


Figure 5.124. A plot of the final Rietveld refinement obtained for the **06-SA12** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

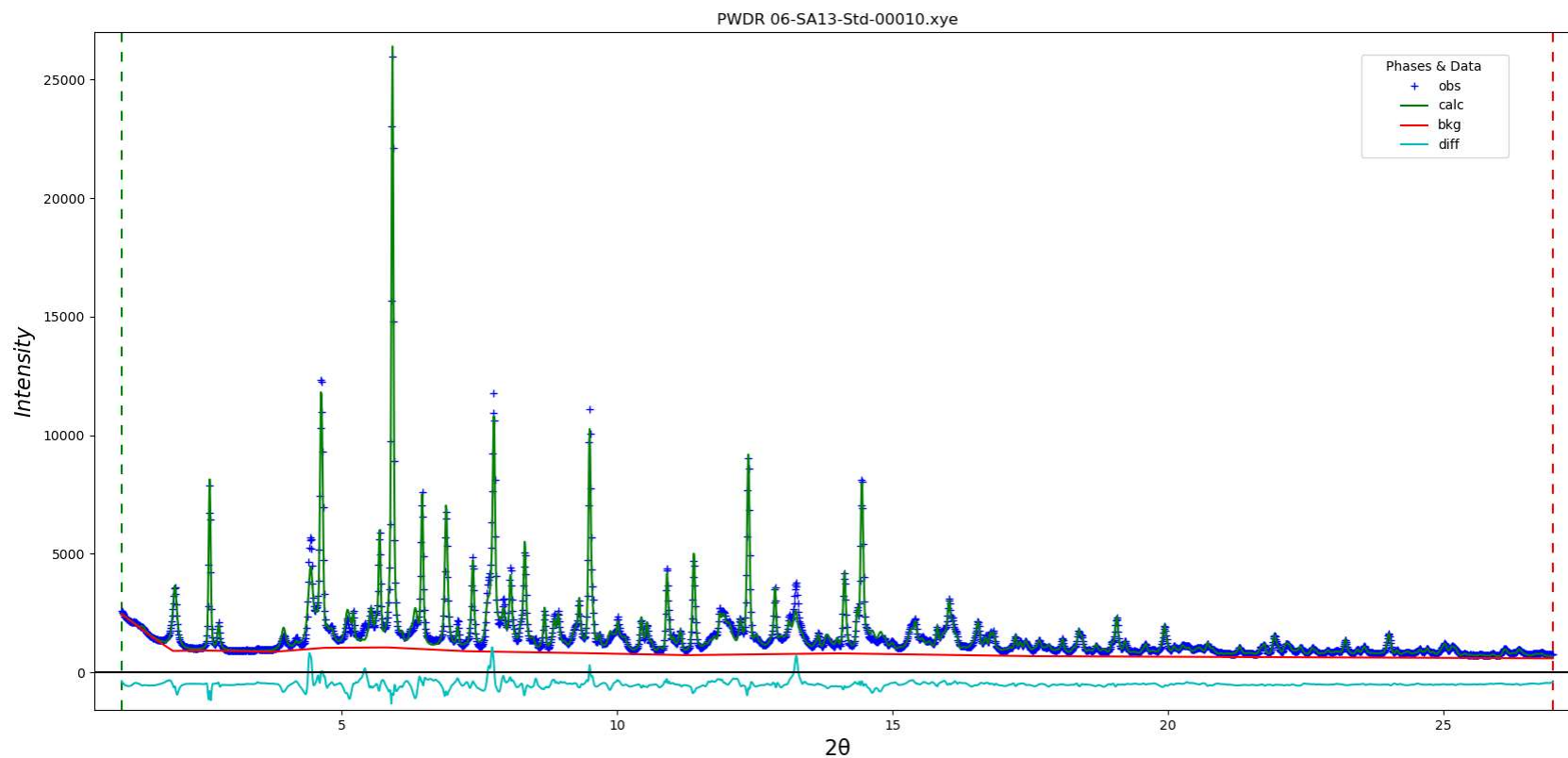


Figure 5.125. A plot of the final Rietveld refinement obtained for the **06-SA13** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

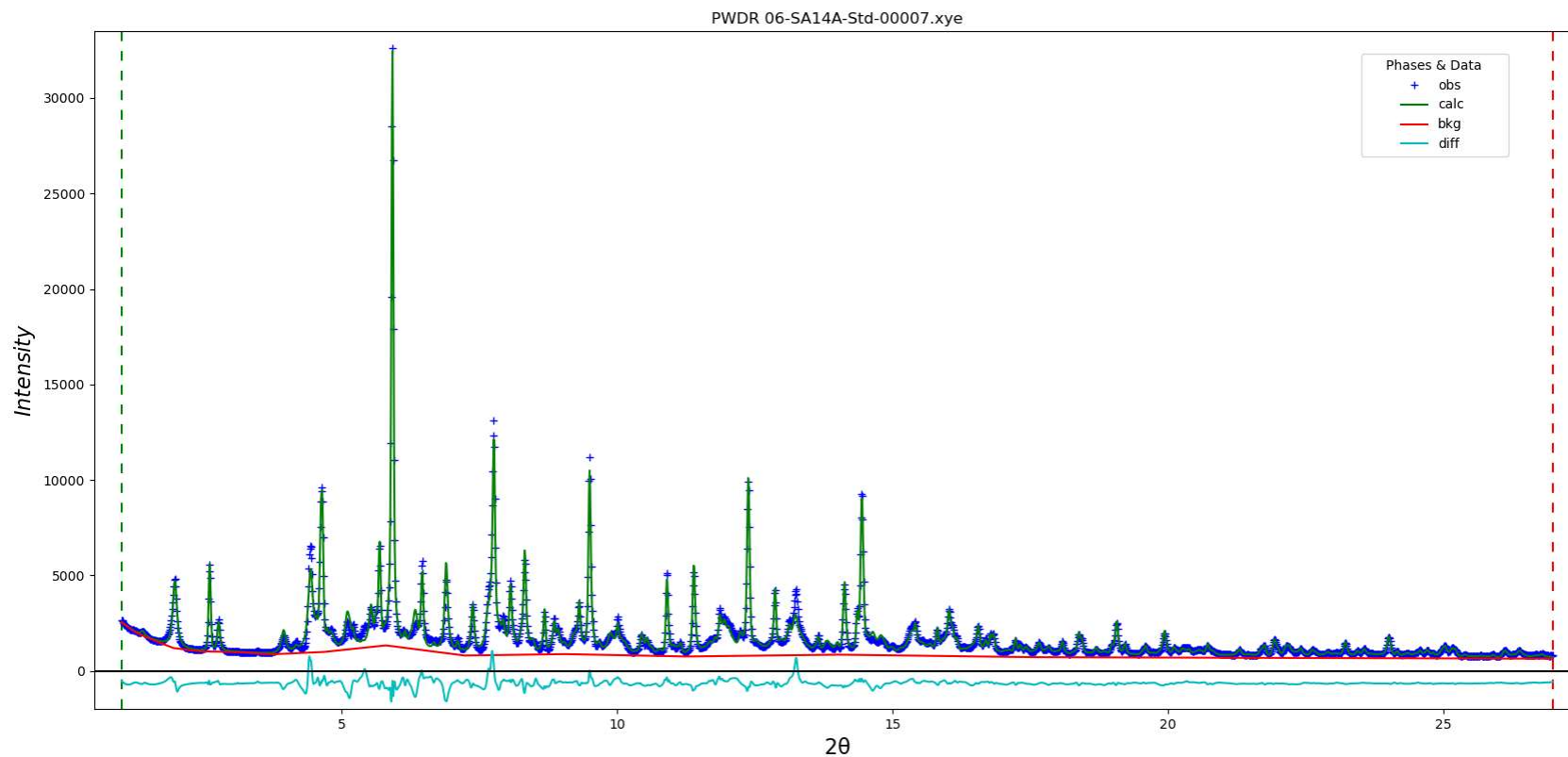


Figure 5.126. A plot of the final Rietveld refinement obtained for the **06-SA14A** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

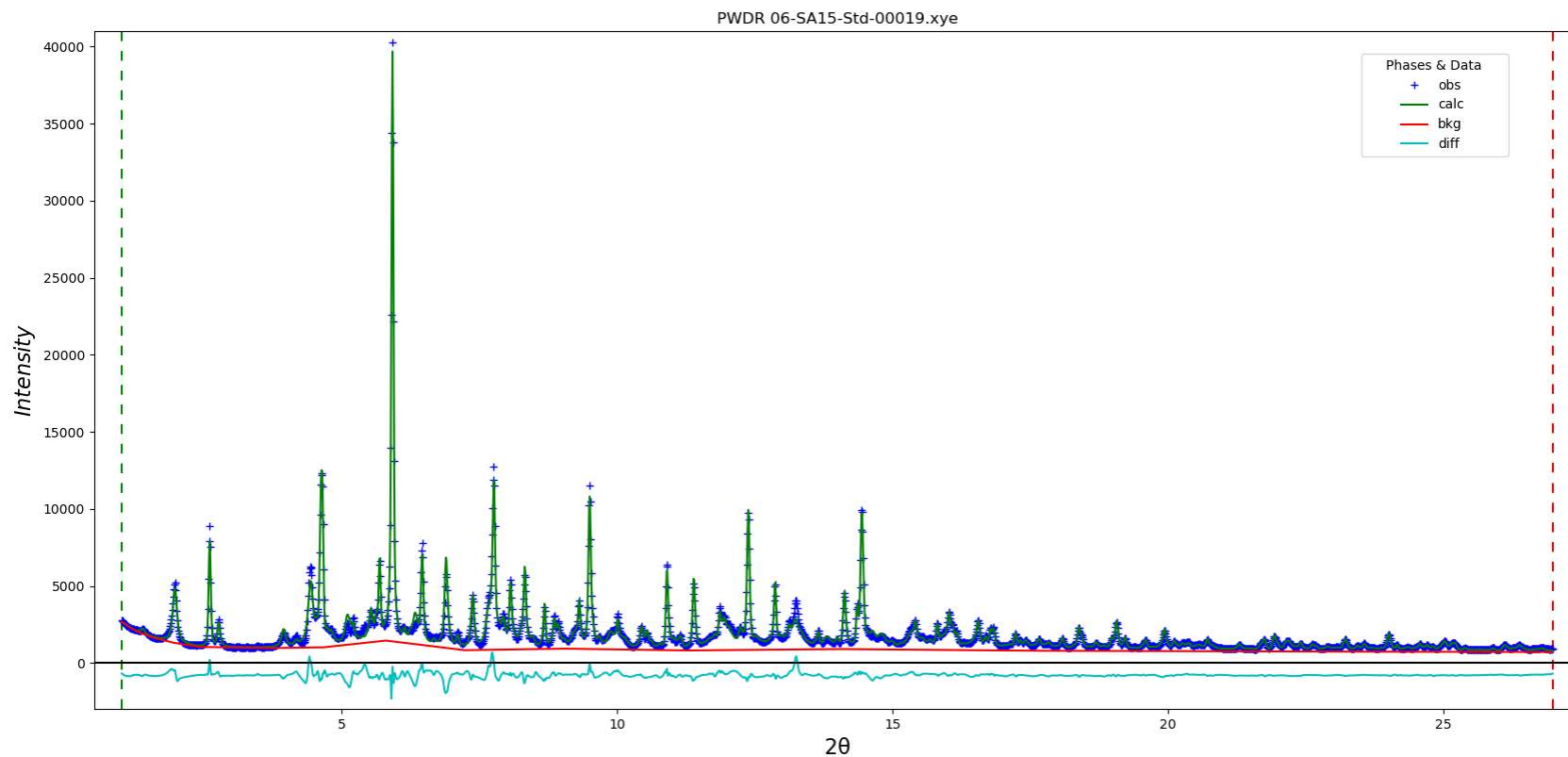


Figure 5.127. A plot of the final Rietveld refinement obtained for the **06-SA15** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

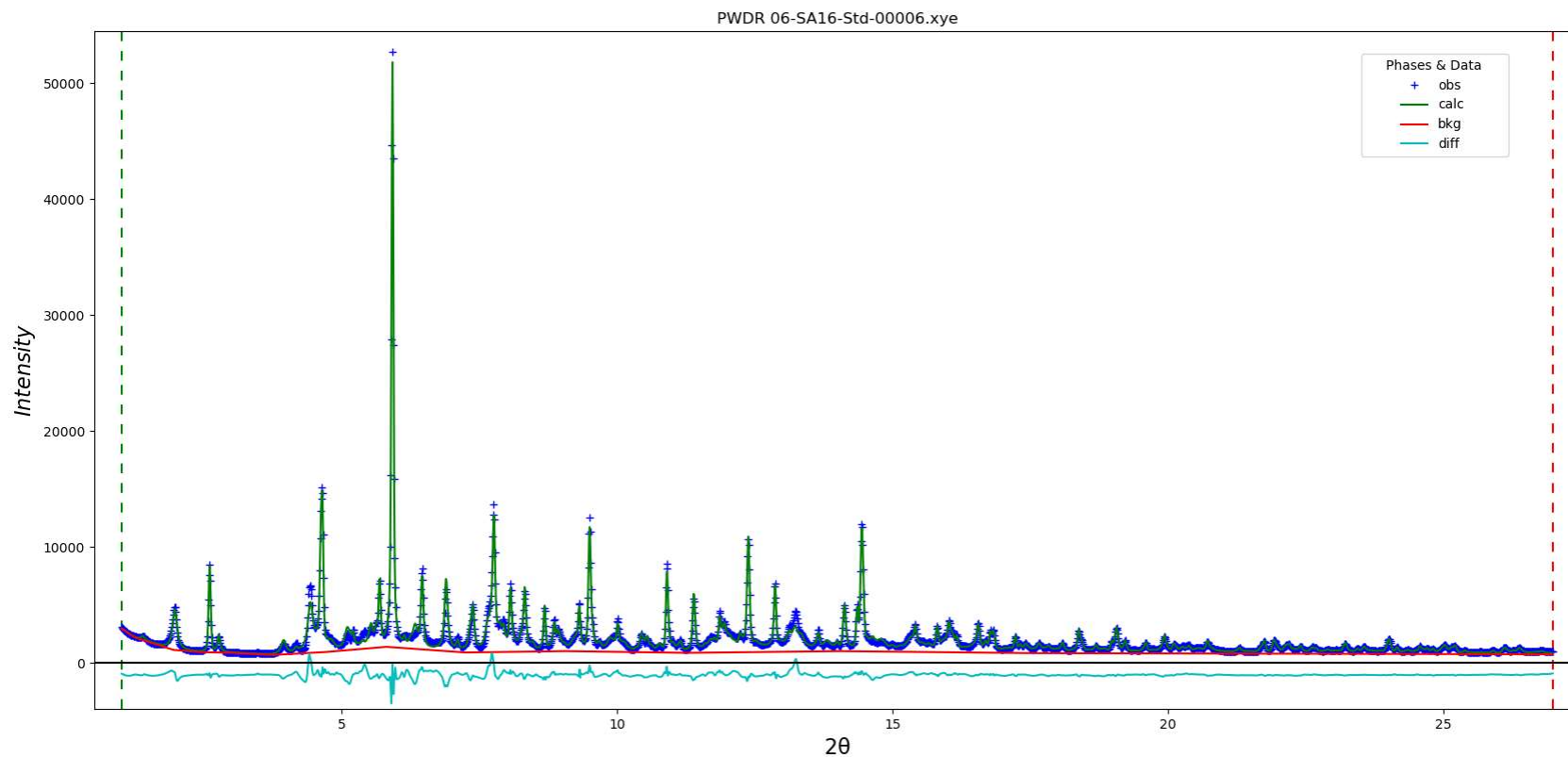


Figure 5.128. A plot of the final Rietveld refinement obtained for the **06-SA16** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

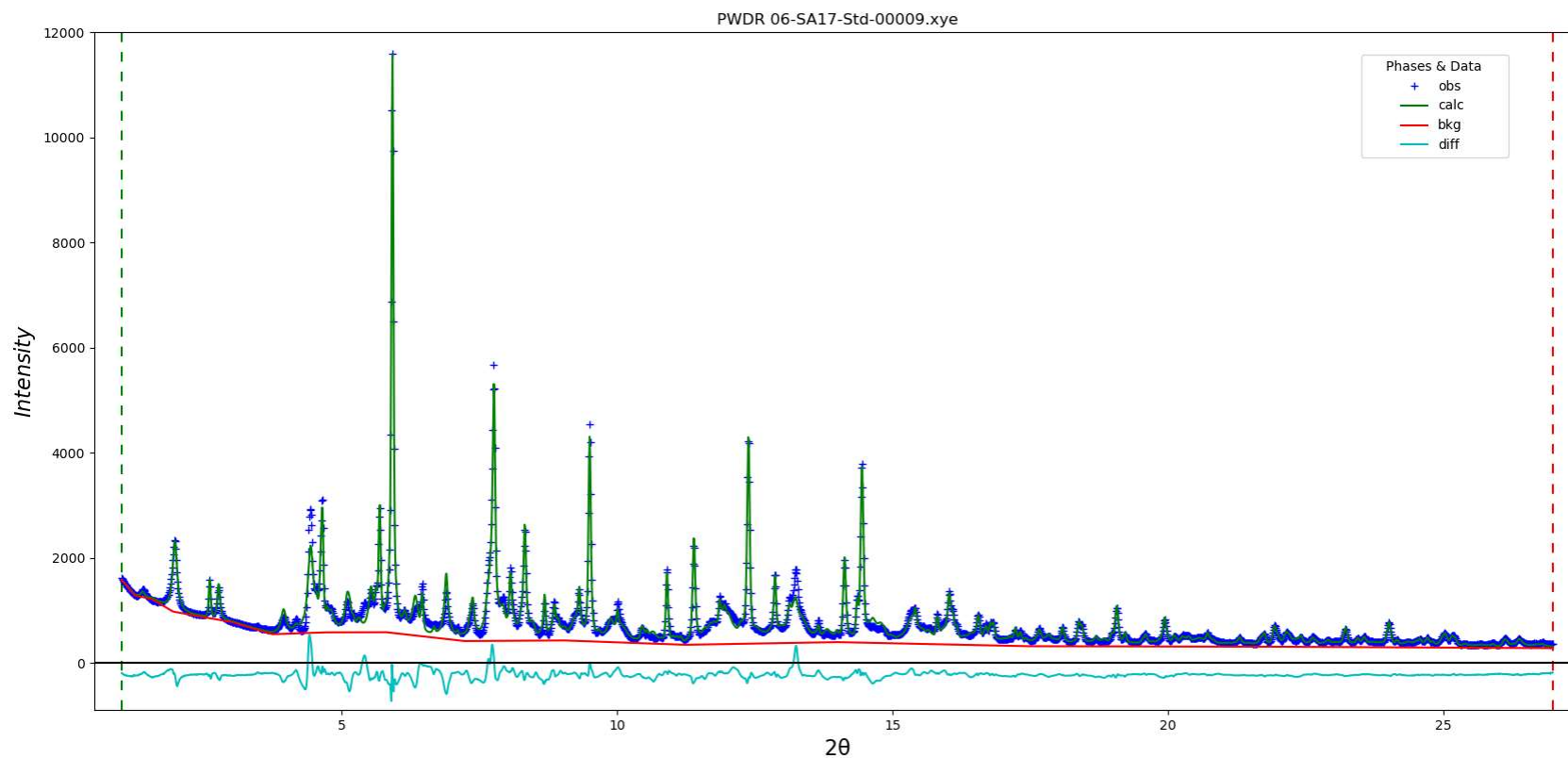


Figure 5.129. A plot of the final Rietveld refinement obtained for the **06-SA17** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

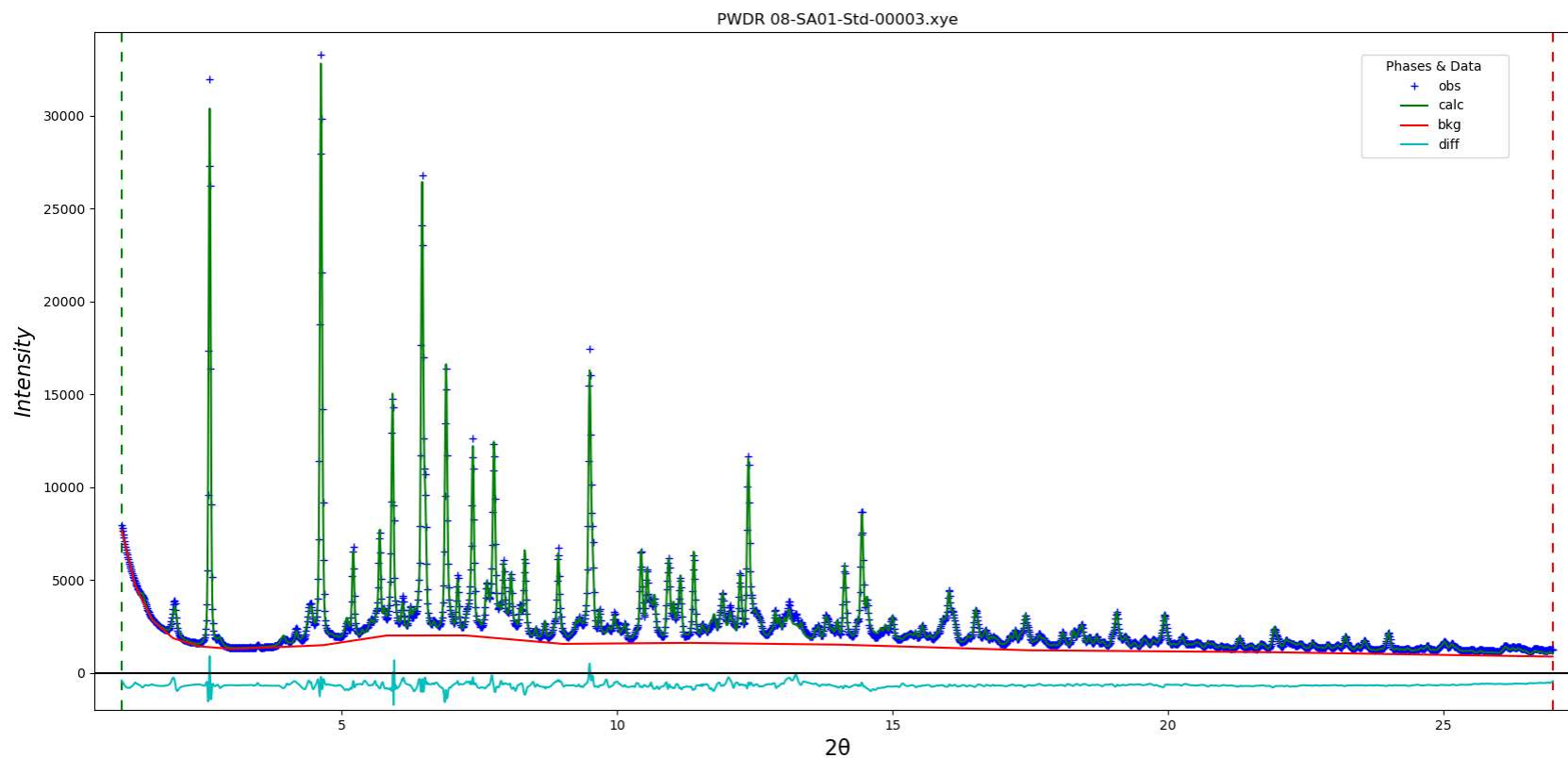


Figure 5.130. A plot of the final Rietveld refinement obtained for the **08-SA01** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

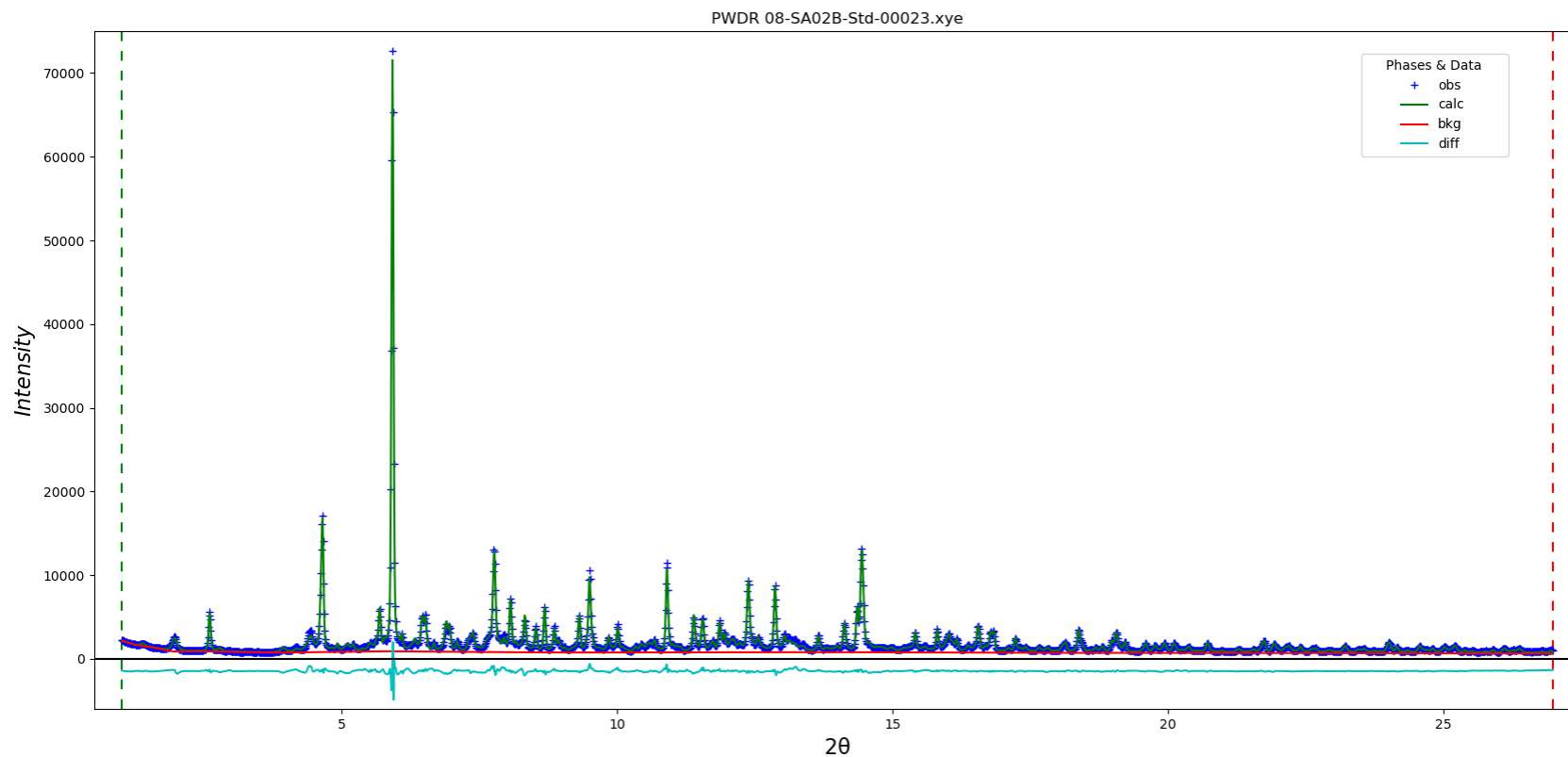


Figure 5.131. A plot of the final Rietveld refinement obtained for the **08-SA02B** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

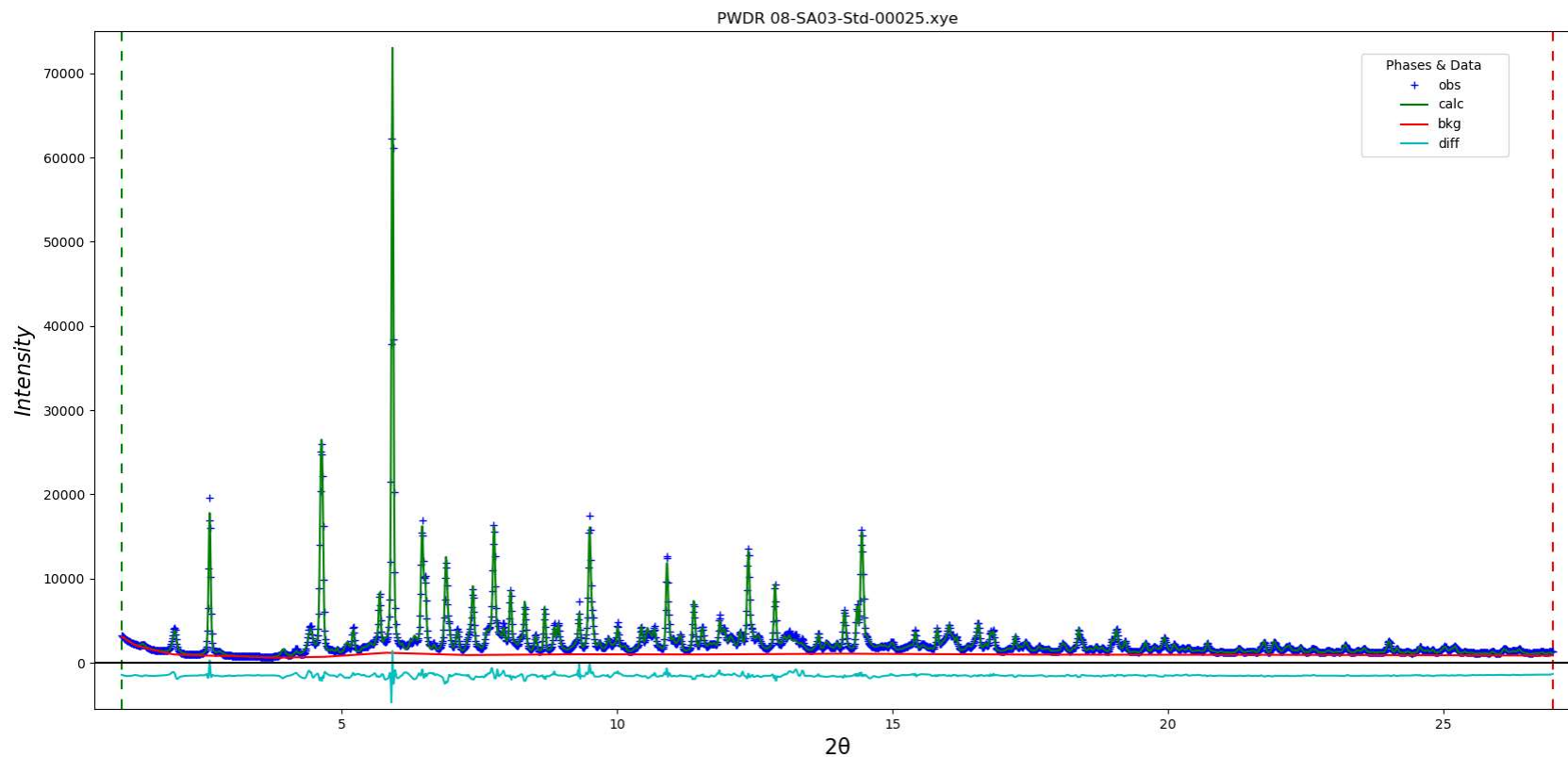


Figure 5.132. A plot of the final Rietveld refinement obtained for the **08-SA03** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

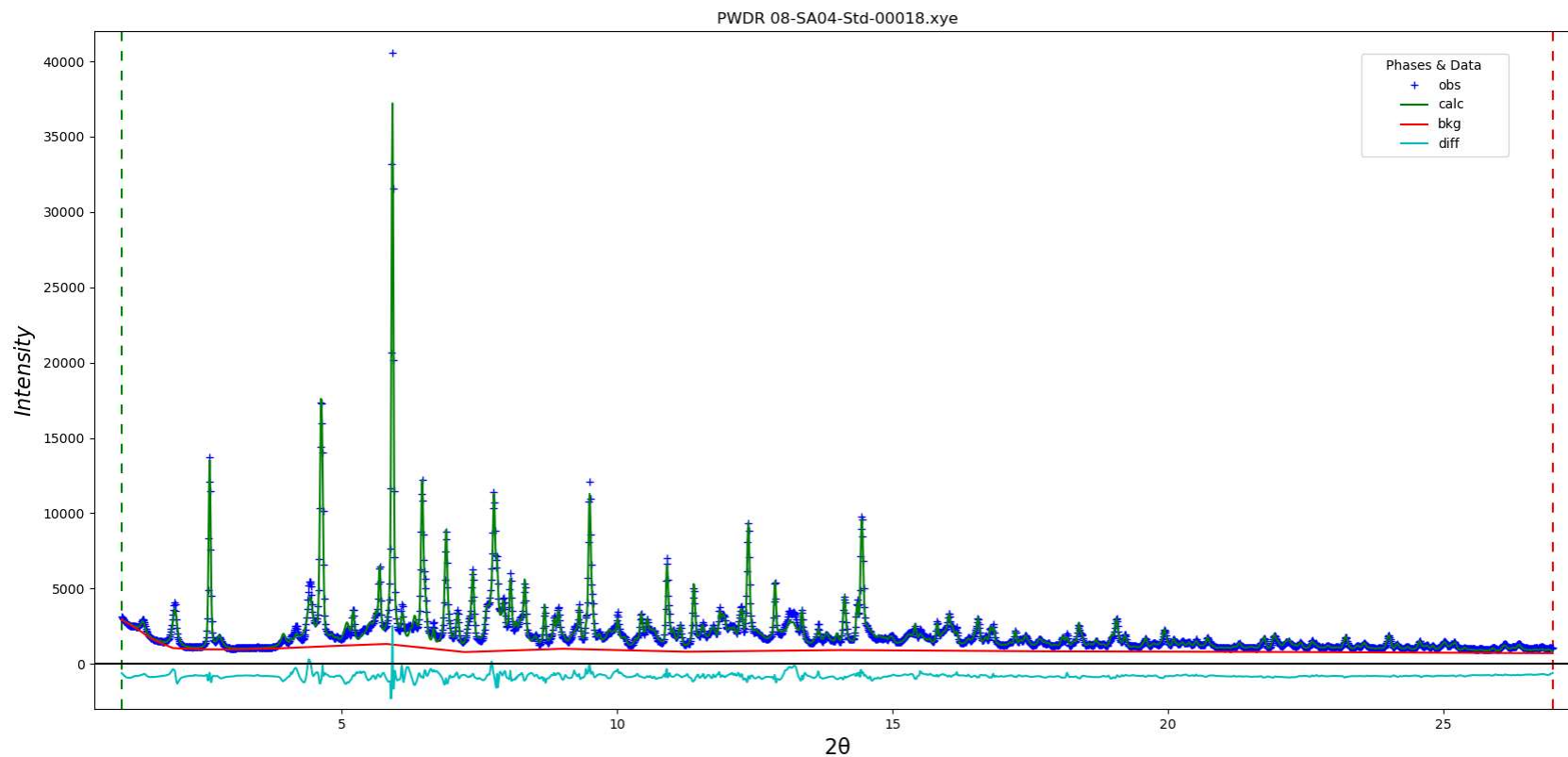


Figure 5.133. A plot of the final Rietveld refinement obtained for the **08-SA04** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

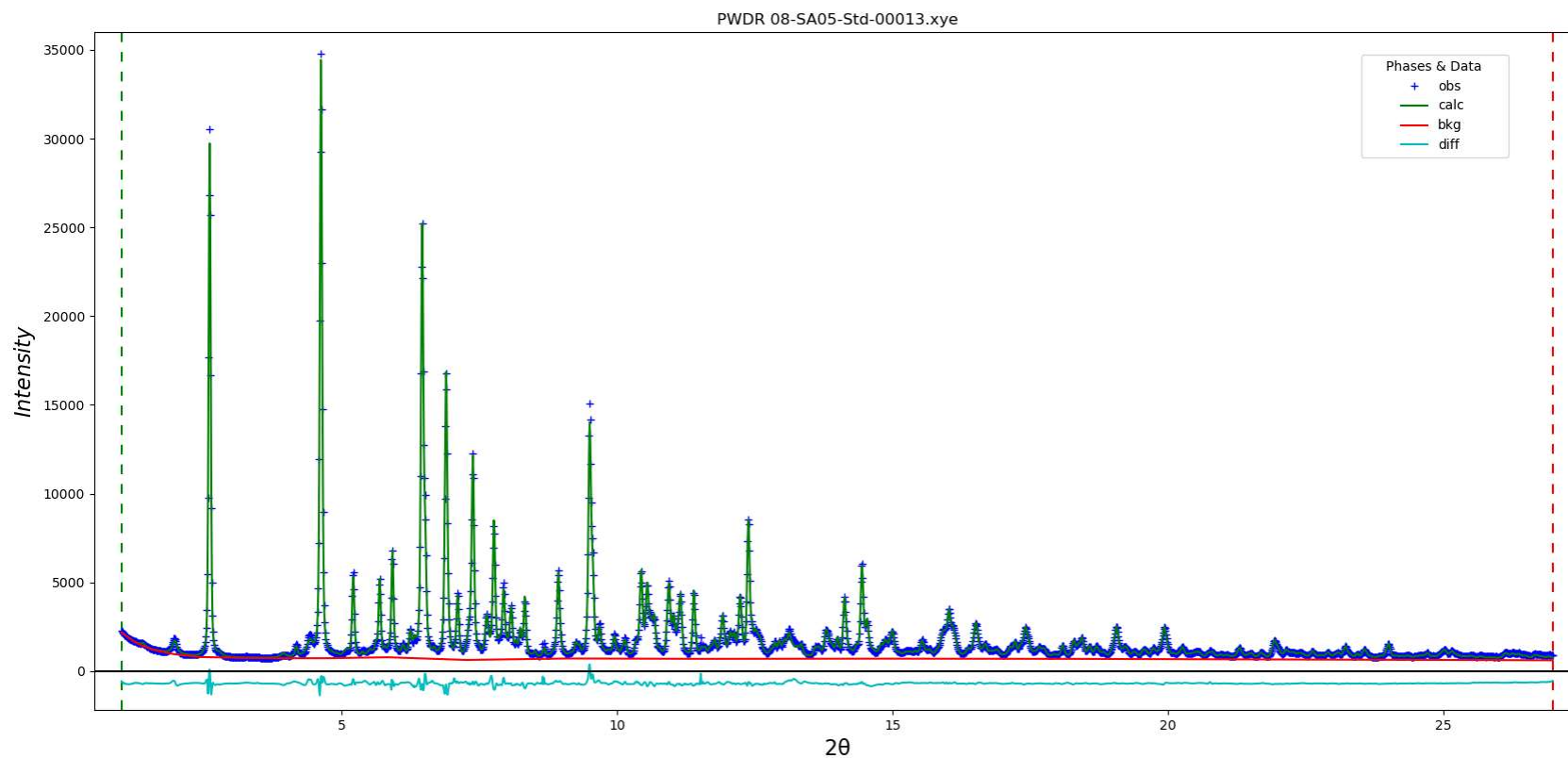


Figure 5.134. A plot of the final Rietveld refinement obtained for the **08-SA05** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

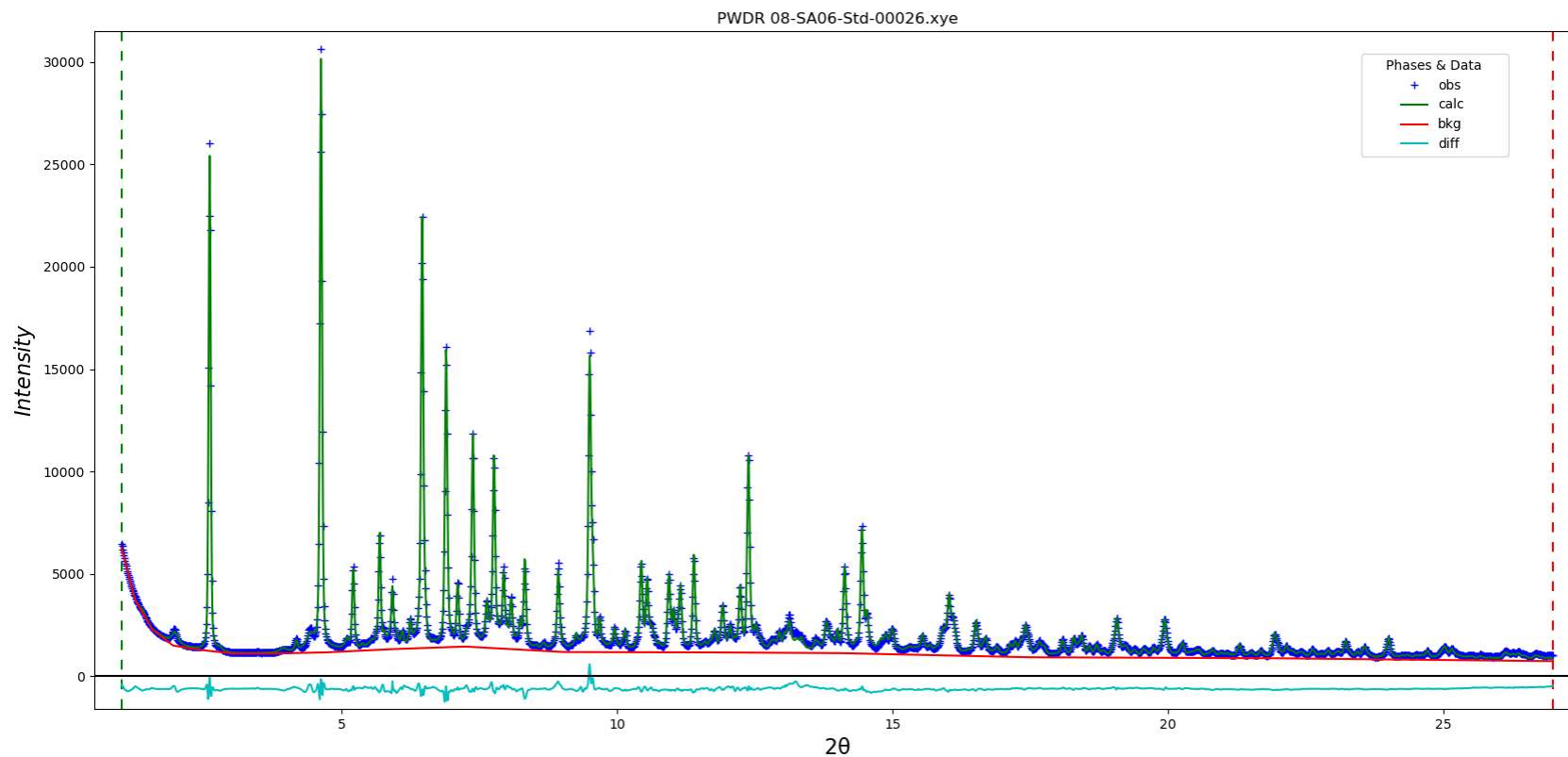


Figure 5.135. A plot of the final Rietveld refinement obtained for the **08-SA06** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

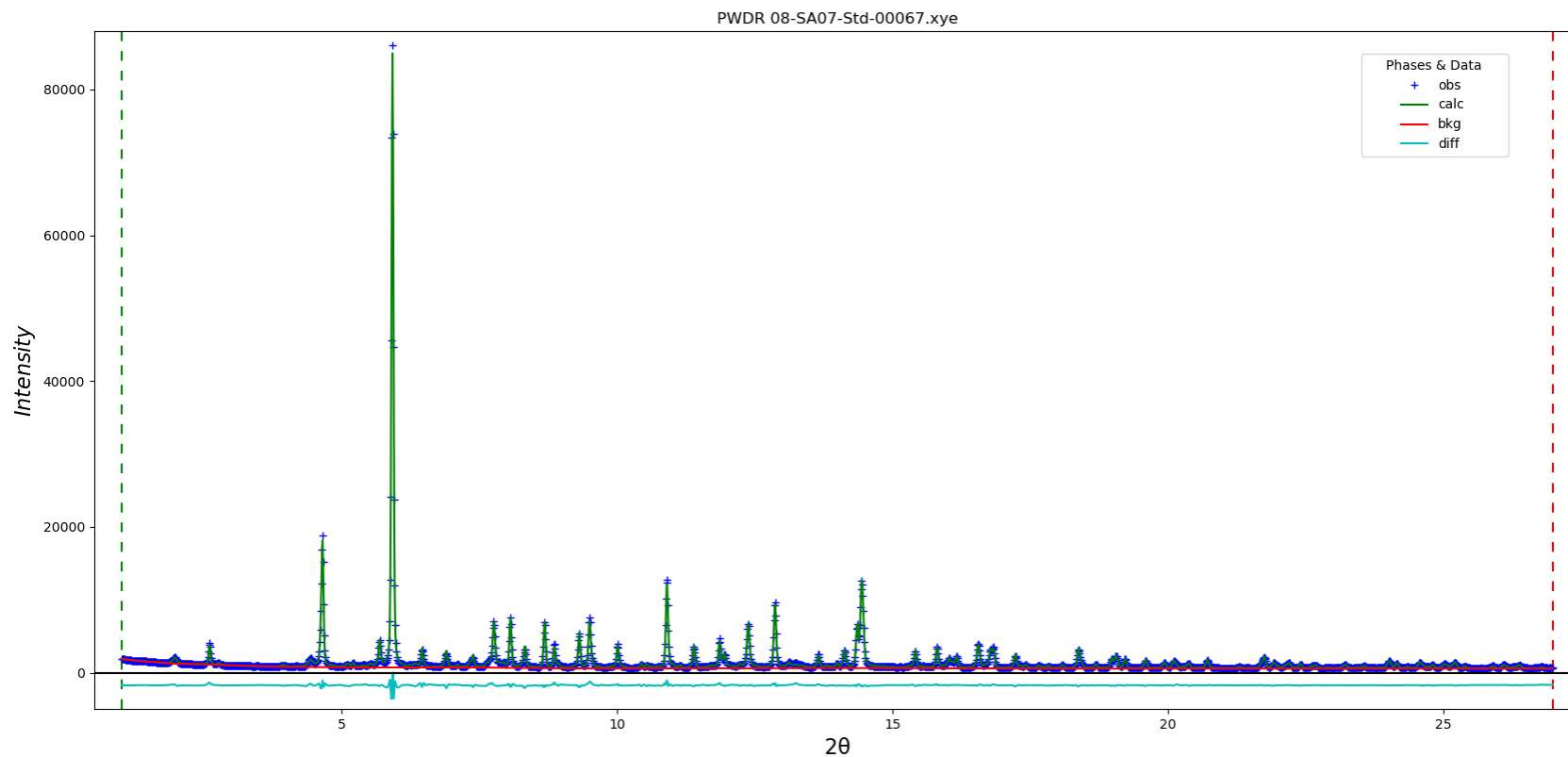


Figure 5.136. A plot of the final Rietveld refinement obtained for the **08-SA07** sample with the Al_2O_3 internal standard, illustrating the raw data (blue '+' points), calculated pattern (green line), background (red line) and difference plot (aqua line).

6.0 APPENDIX 2: ARSENIC K-EDGE XANES FIGURES

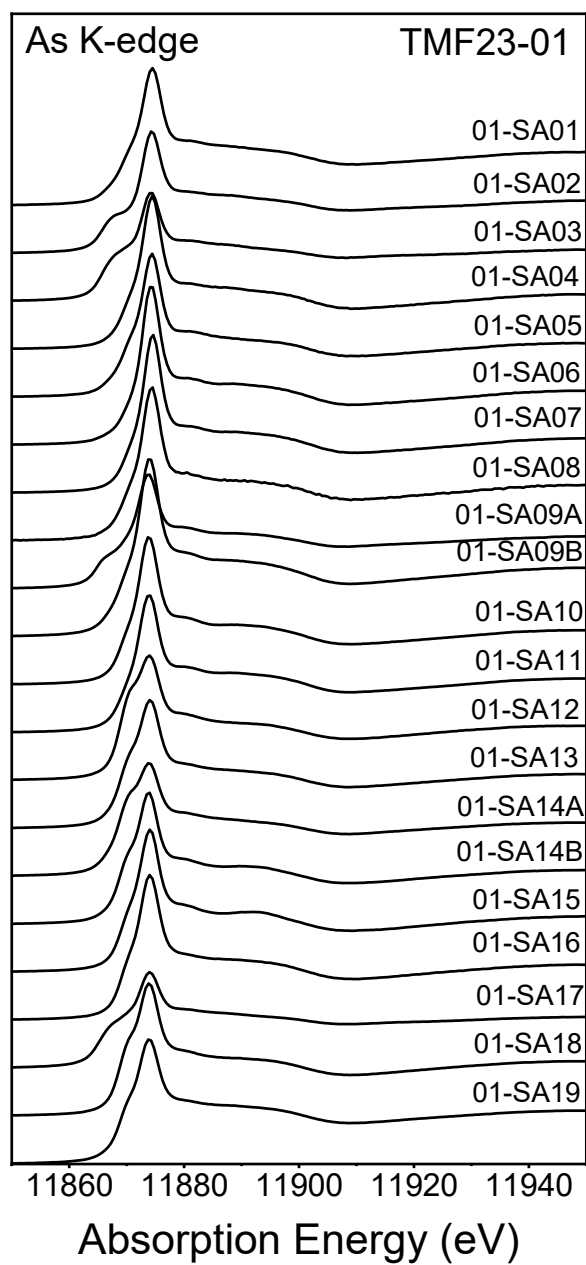


Figure 6.1. As K-edge XANES spectra of the **TMF23-01** sample set.

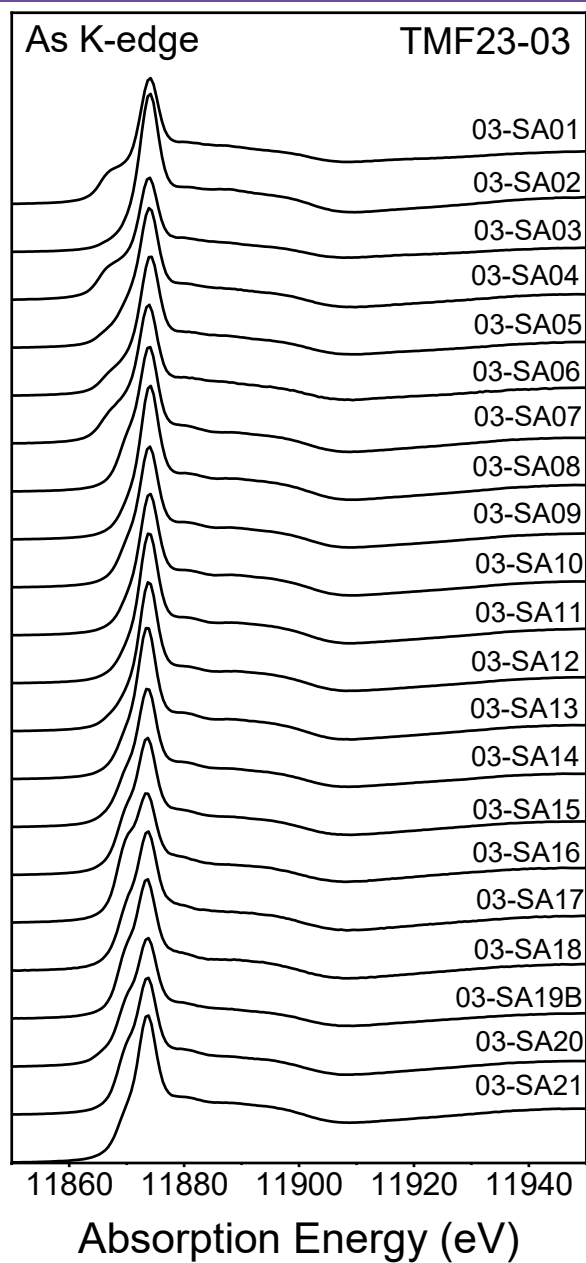


Figure 6.2. As K-edge XANES spectra of the **TMF23-03** sample set.

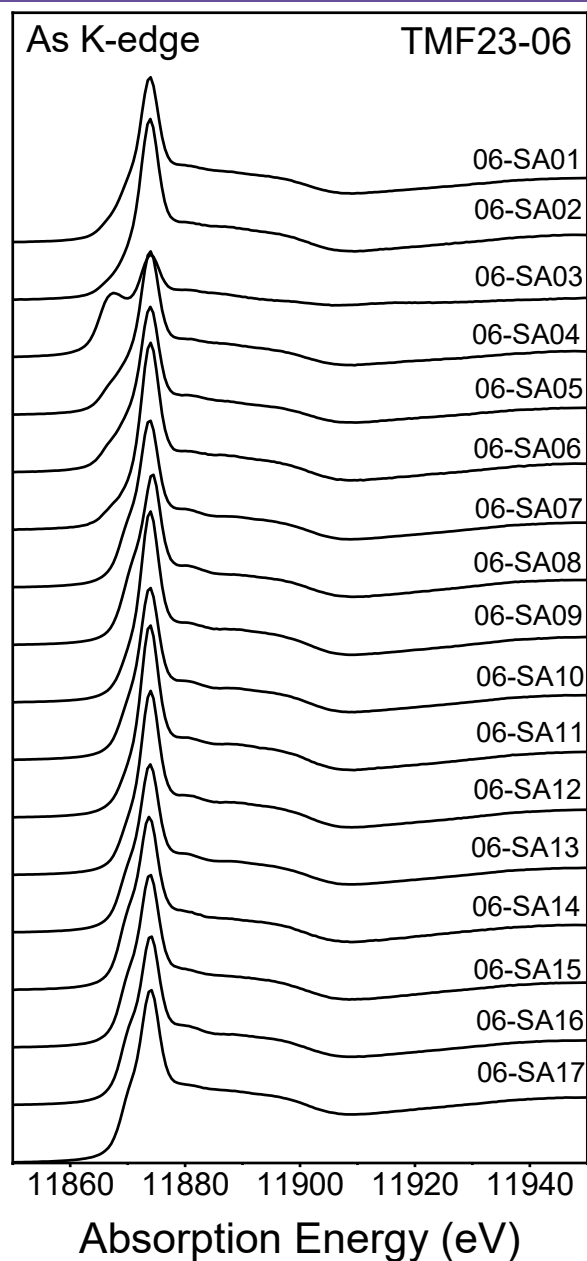


Figure 6.3. As K-edge XANES spectra of the **TMF23-06** sample set.

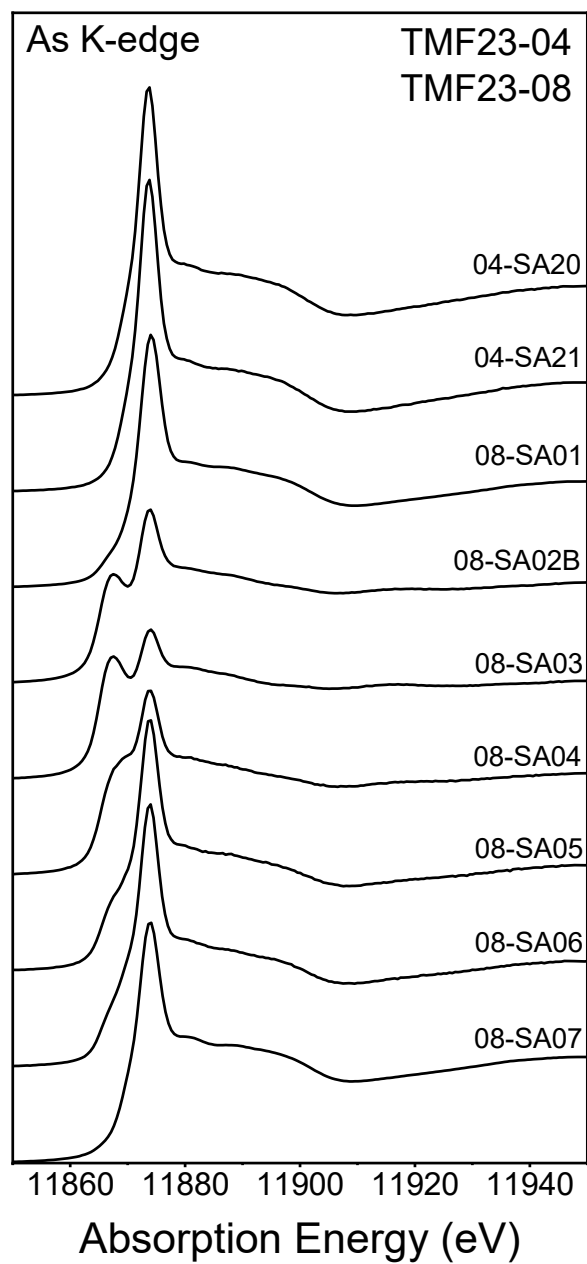


Figure 6.4. As K-edge XANES spectra of the **TMF23-04** and **TMF23-08** sample sets.

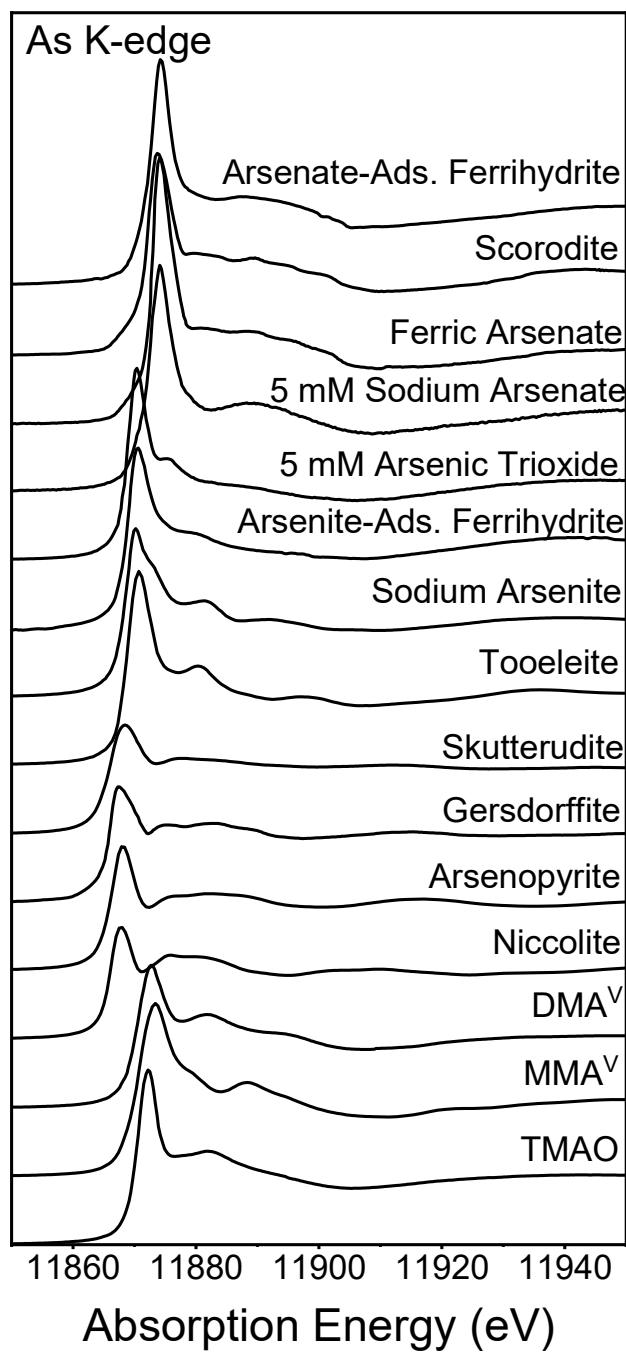


Figure 6.5. As K-edge XANES spectra of arsenic standards.

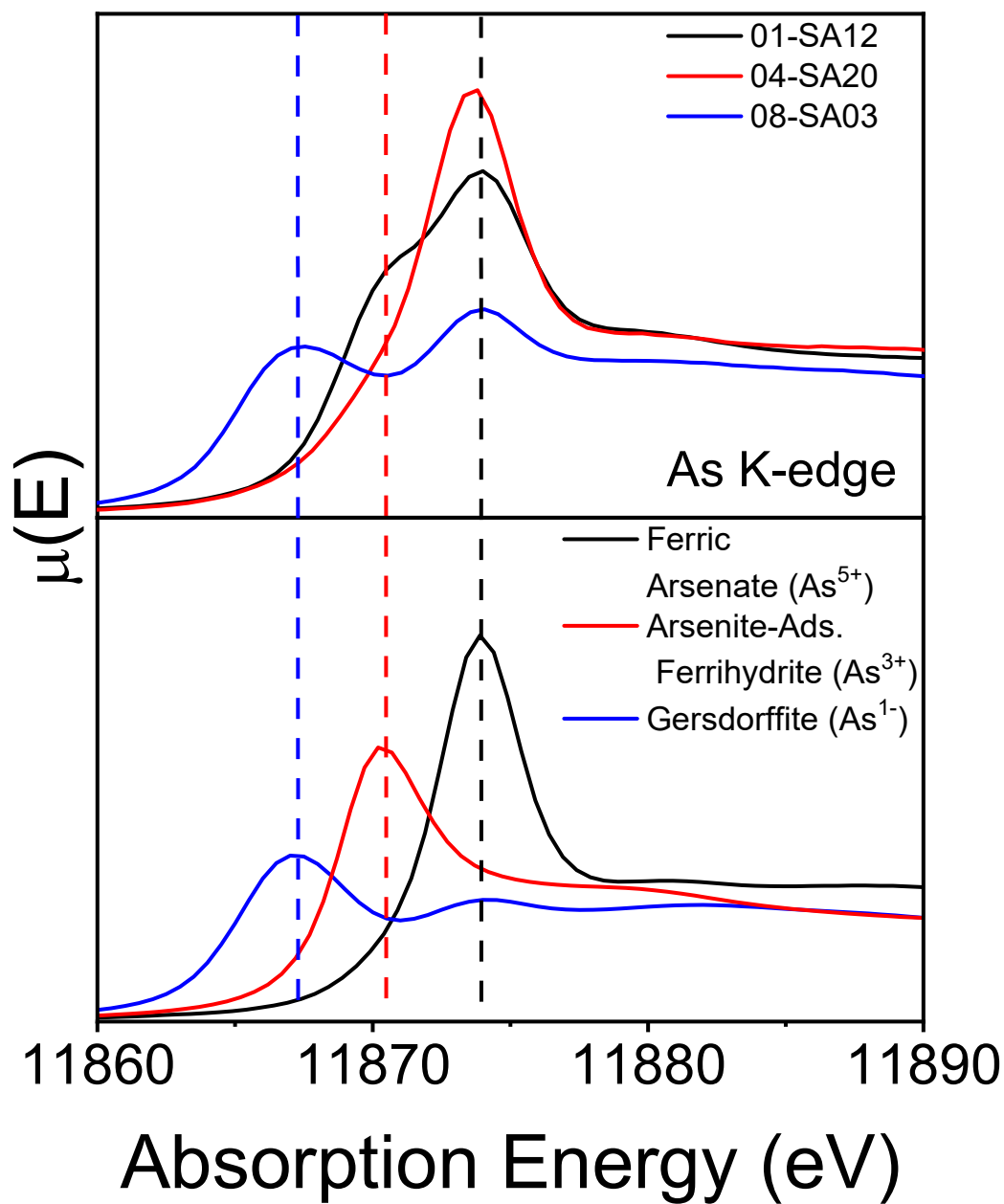


Figure 6.6. The As K-edge XANES spectra of (top) representative samples and (bottom) arsenic mineral standards highlighting spectral features that correspond to As^{5+} (11873.9 eV; black line), As^{3+} (11870.4 eV; red line), and As^{1-} (11867.5 eV; blue line).

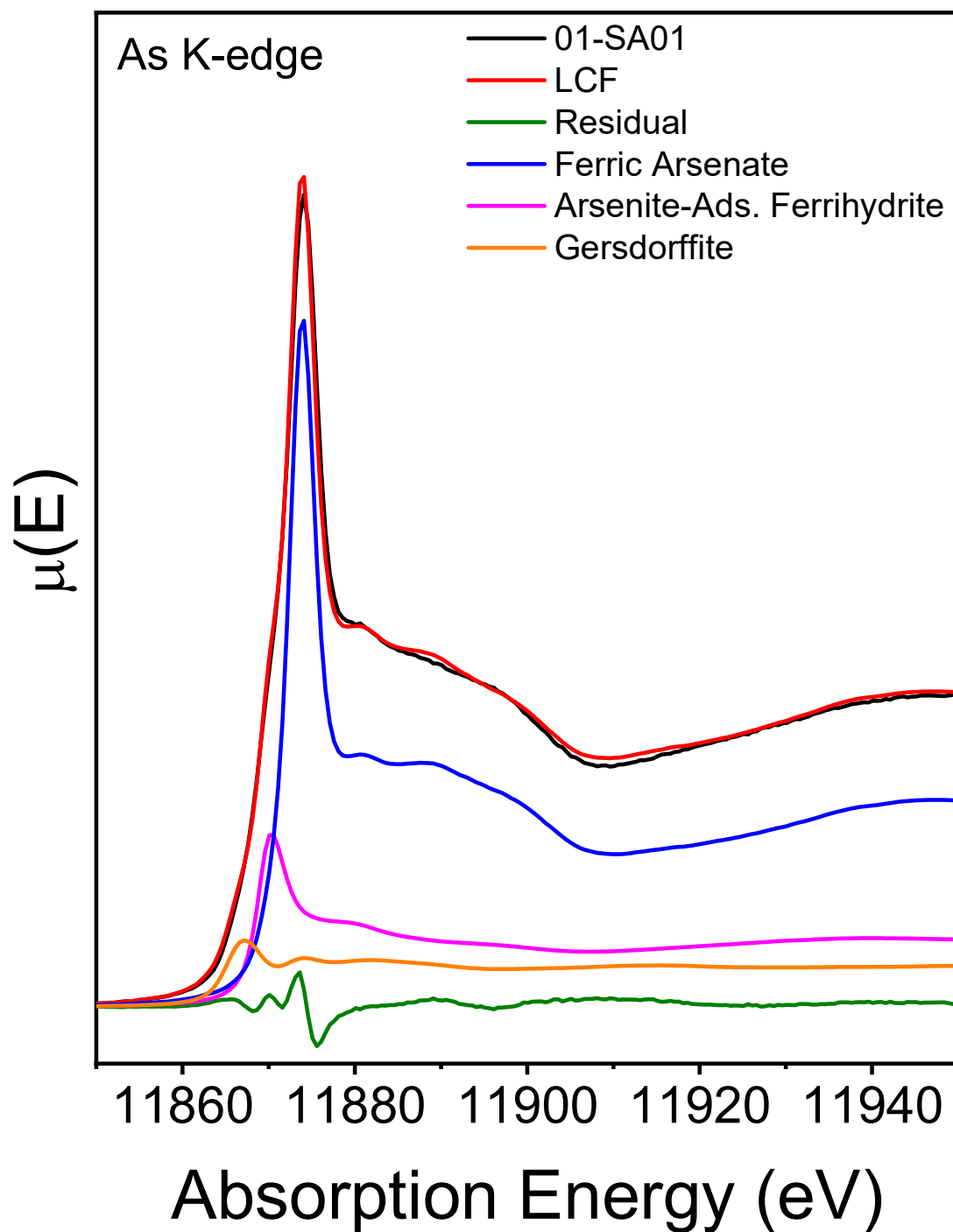


Figure 6.7. As K-edge XANES spectrum of **01-SA01** showing the component spectra and final fit with residual.

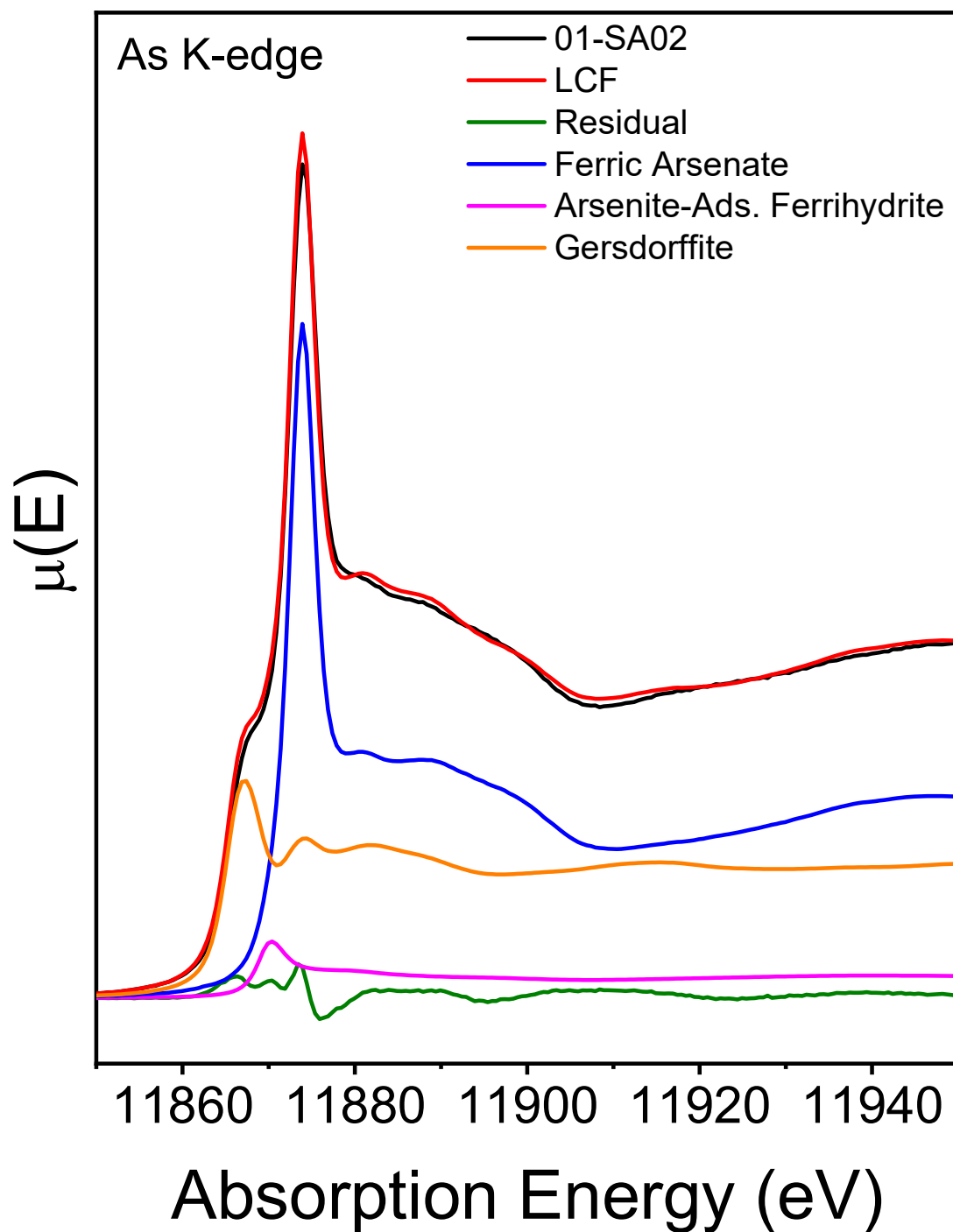


Figure 6.8. As K-edge XANES spectrum of **01-SA02** showing the component spectra and final fit with residual.

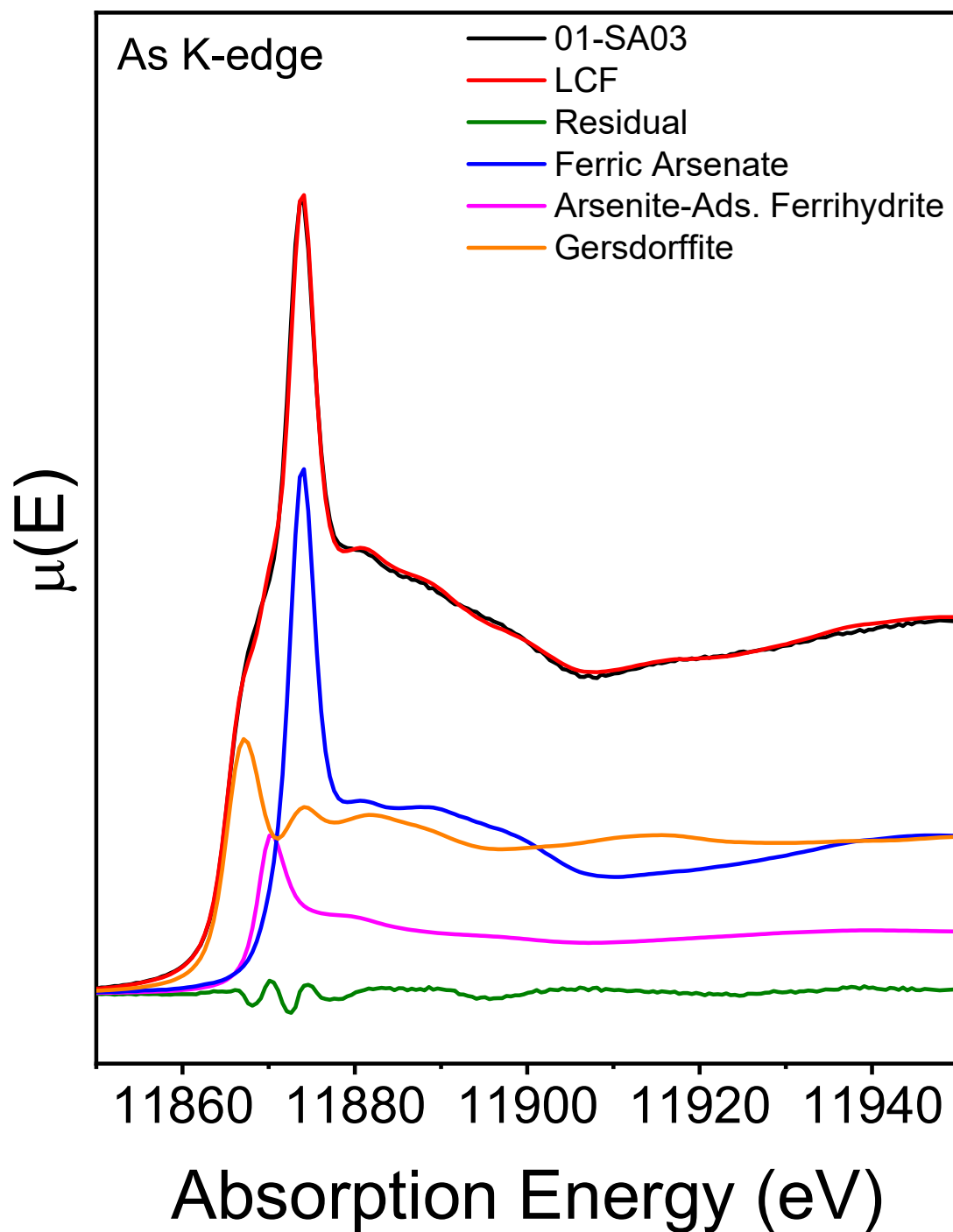


Figure 6.9. As K-edge XANES spectrum of **01-SA03** showing the component spectra and final fit with residual.

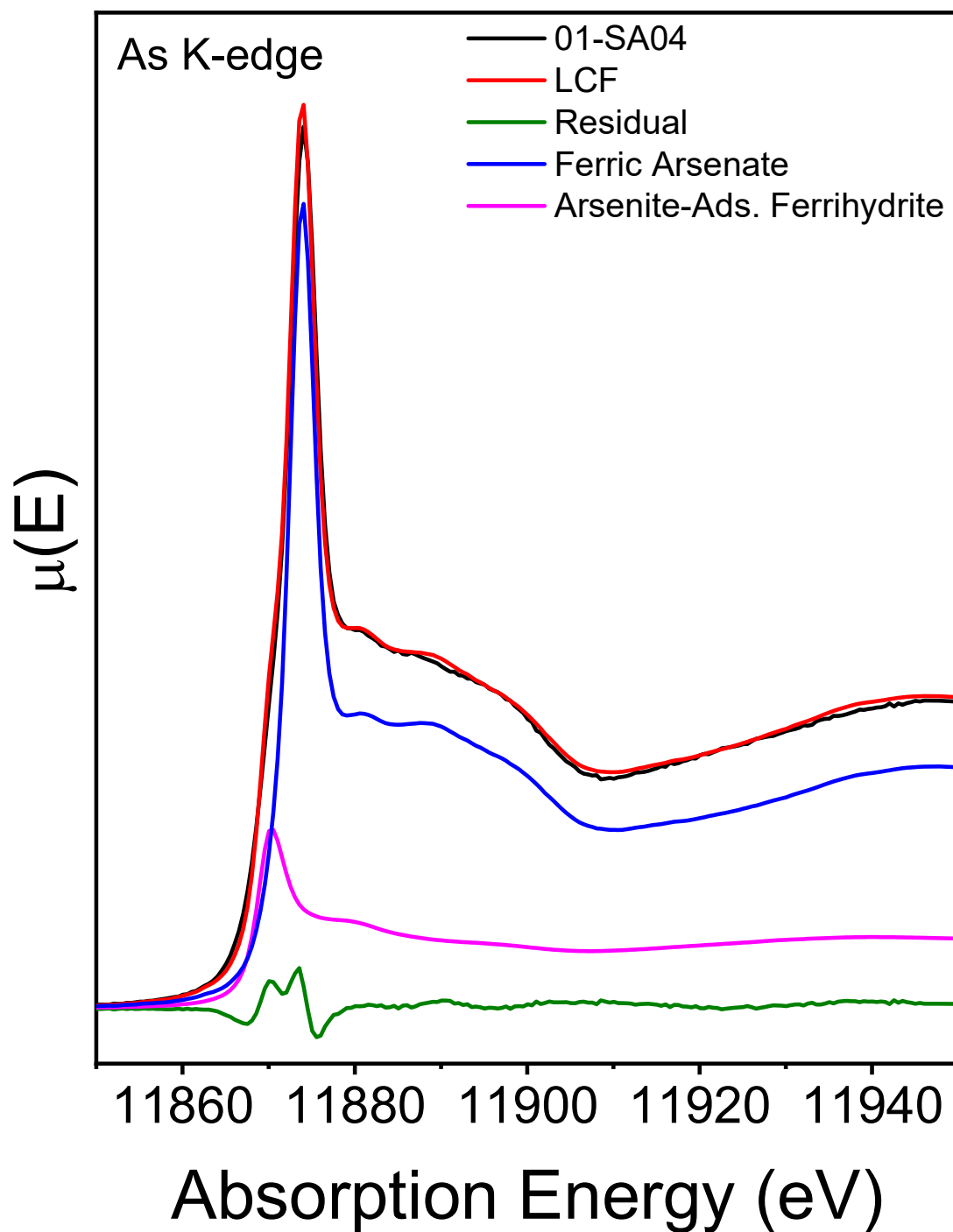


Figure 6.10. As K-edge XANES spectrum of **01-SA04** showing the component spectra and final fit with residual.

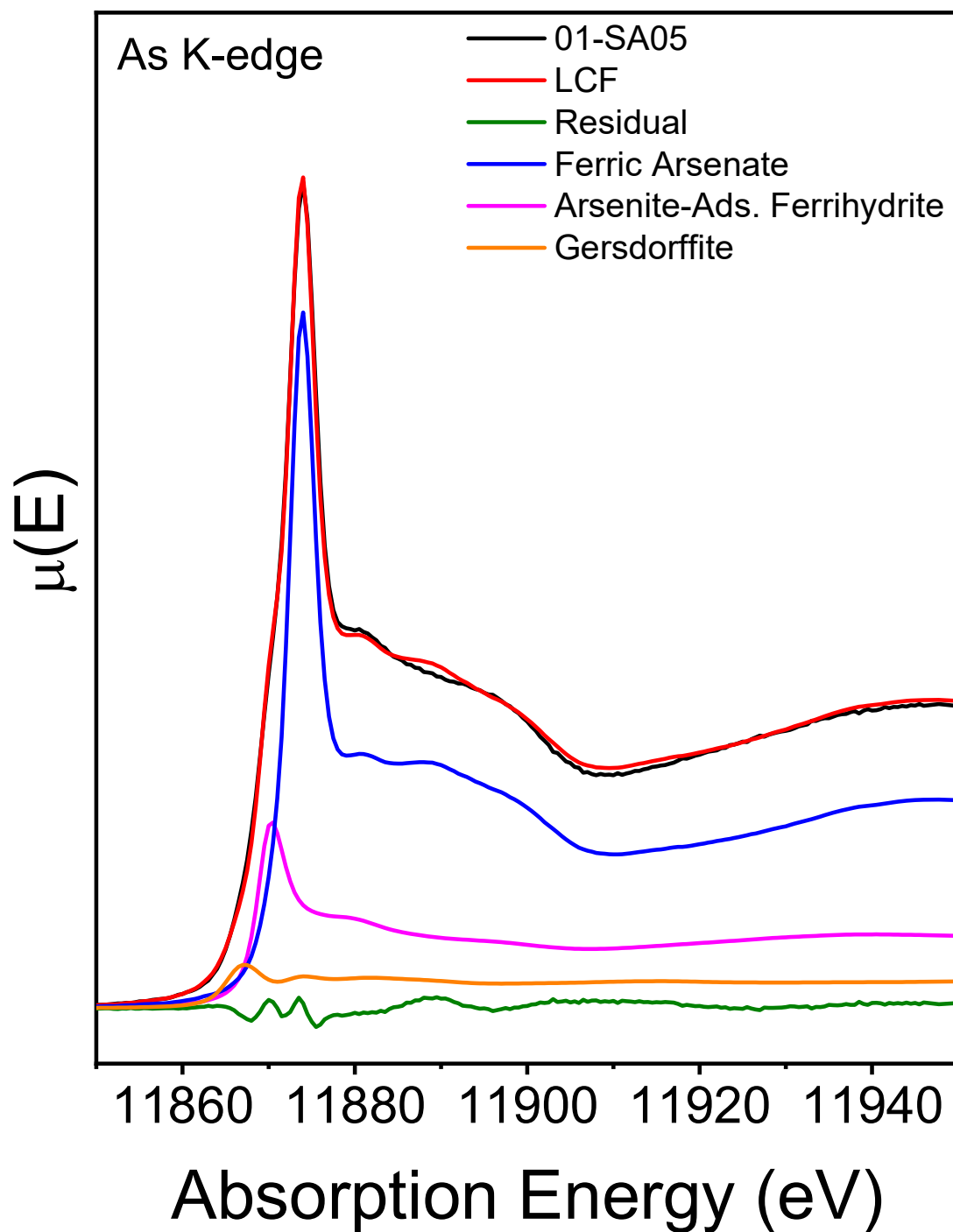


Figure 6.11. As K-edge XANES spectrum of **01-SA05** showing the component spectra and final fit with residual.

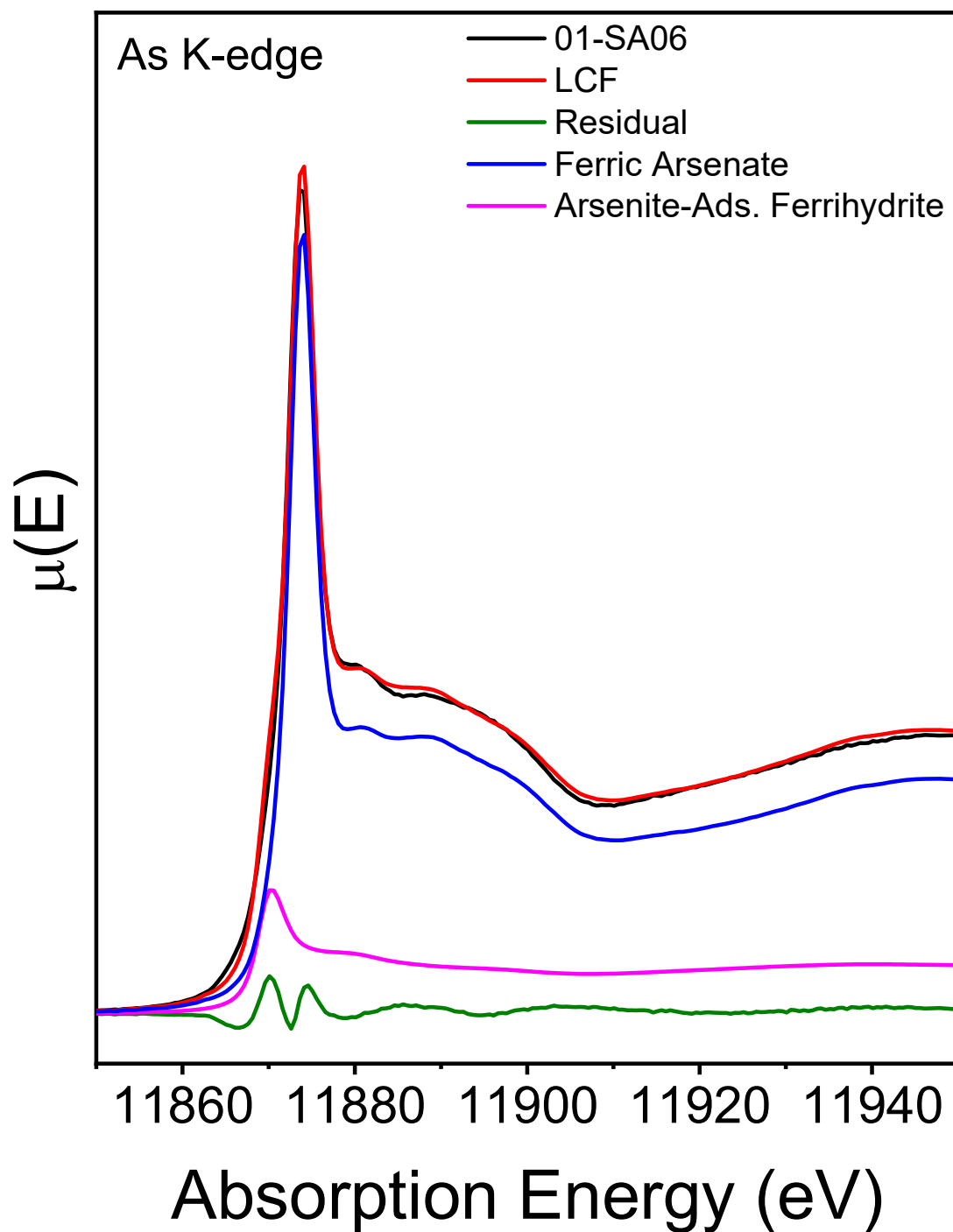


Figure 6.12. As K-edge XANES spectrum of **01-SA06** showing the component spectra and final fit with residual.

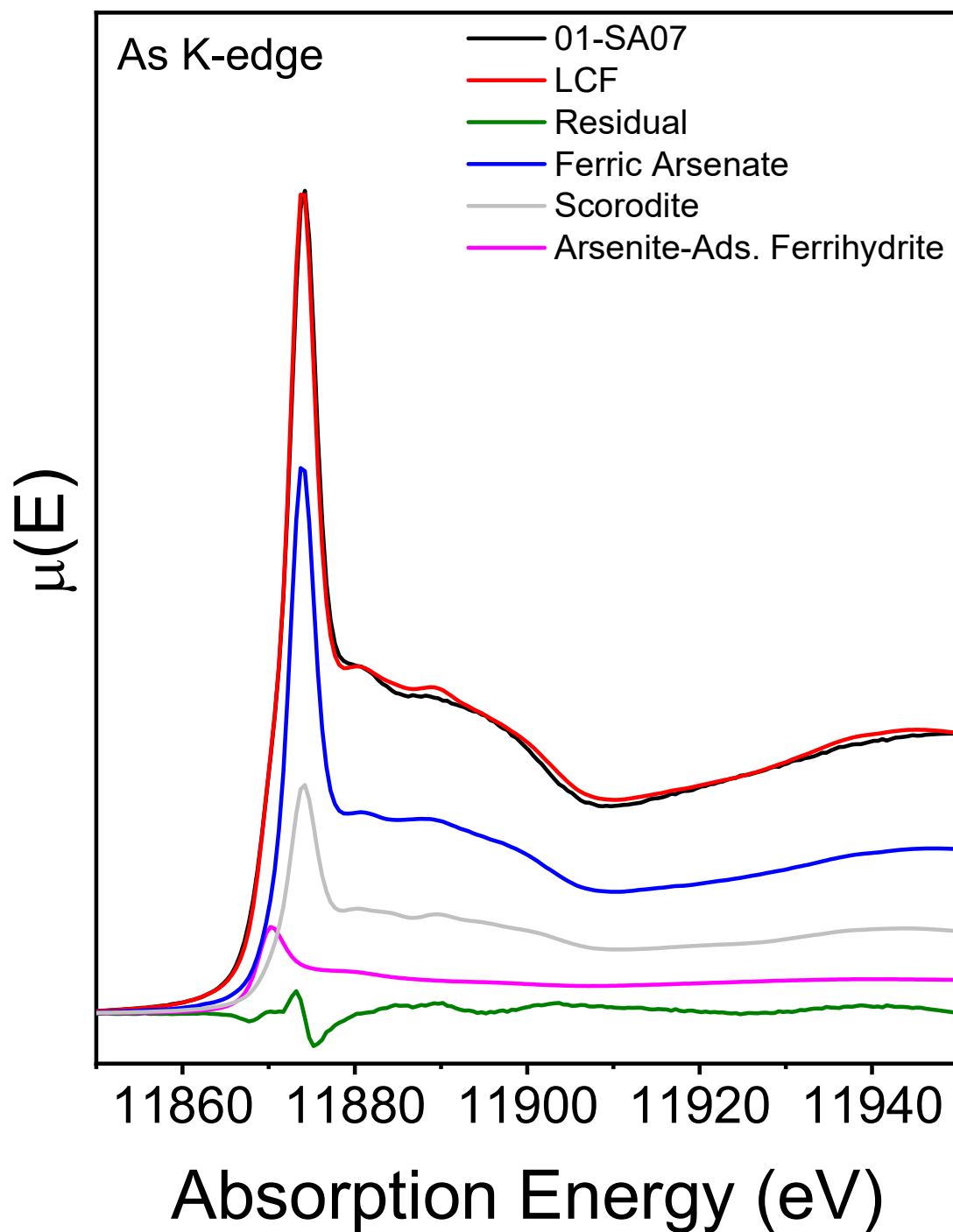


Figure 6.13. As K-edge XANES spectrum of **01-SA07** showing the component spectra and final fit with residual.

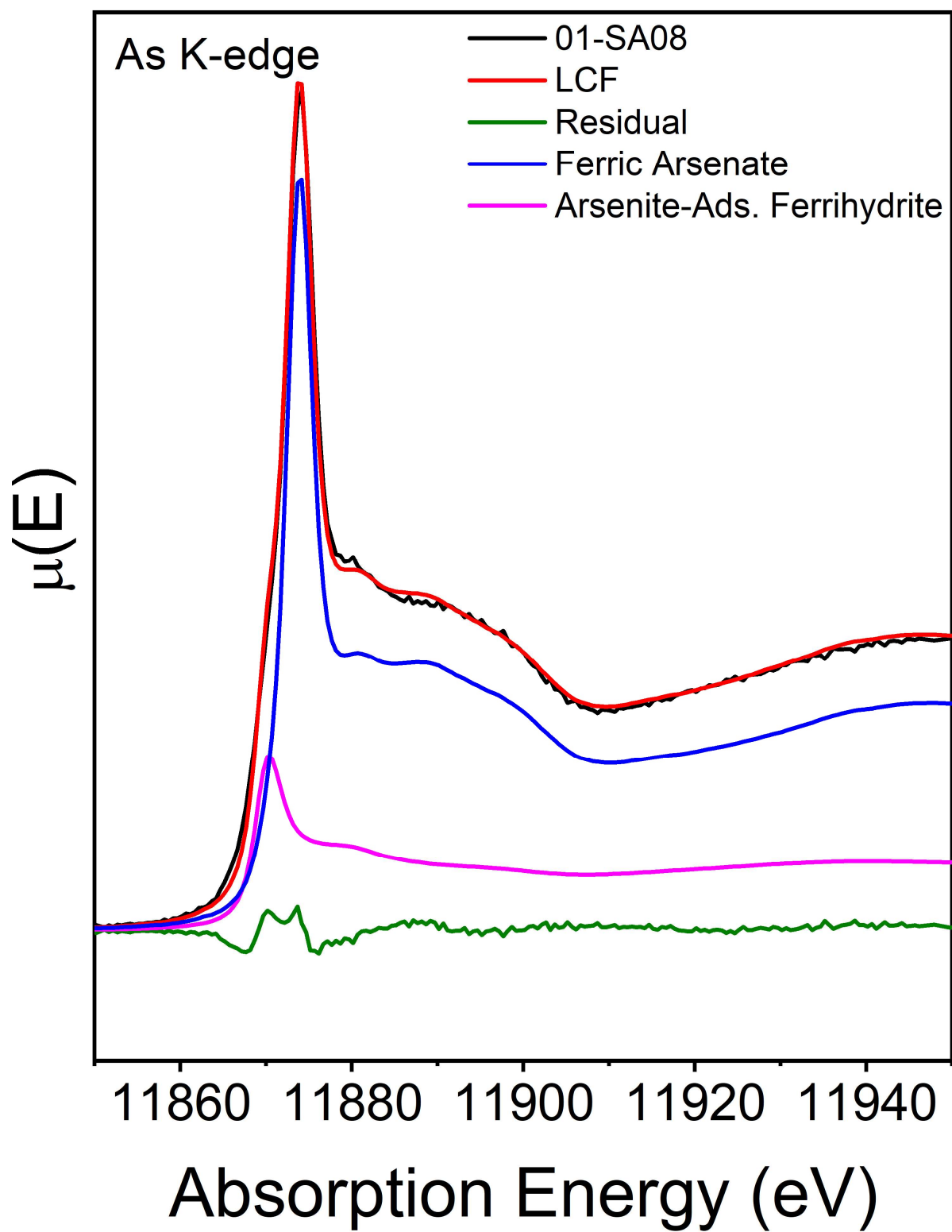


Figure 6.14. As K-edge XANES spectrum of **01-SA08** showing the component spectra and final fit with residual.

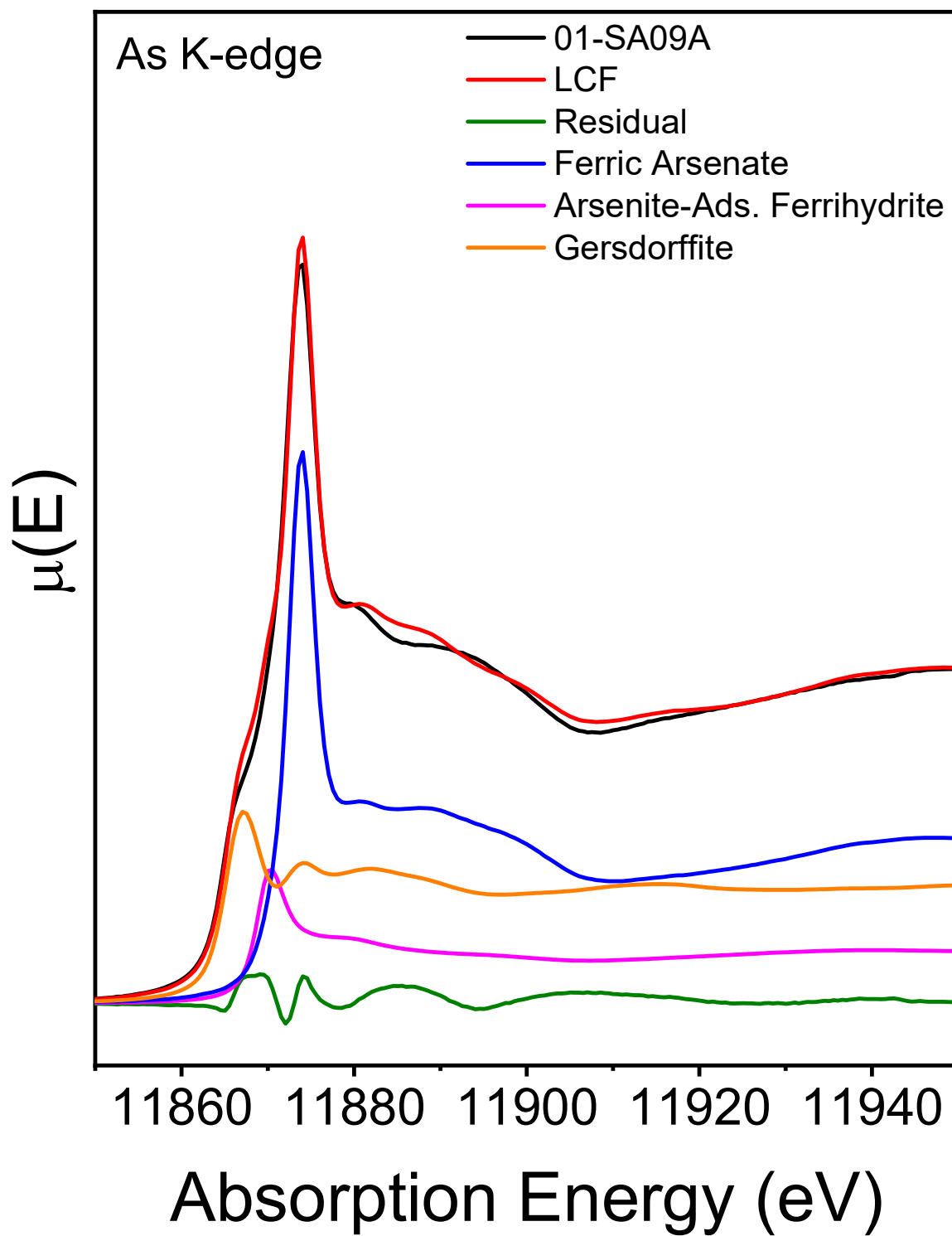


Figure 6.15. As K-edge XANES spectrum of **01-SA09A** showing the component spectra and final fit with residual.

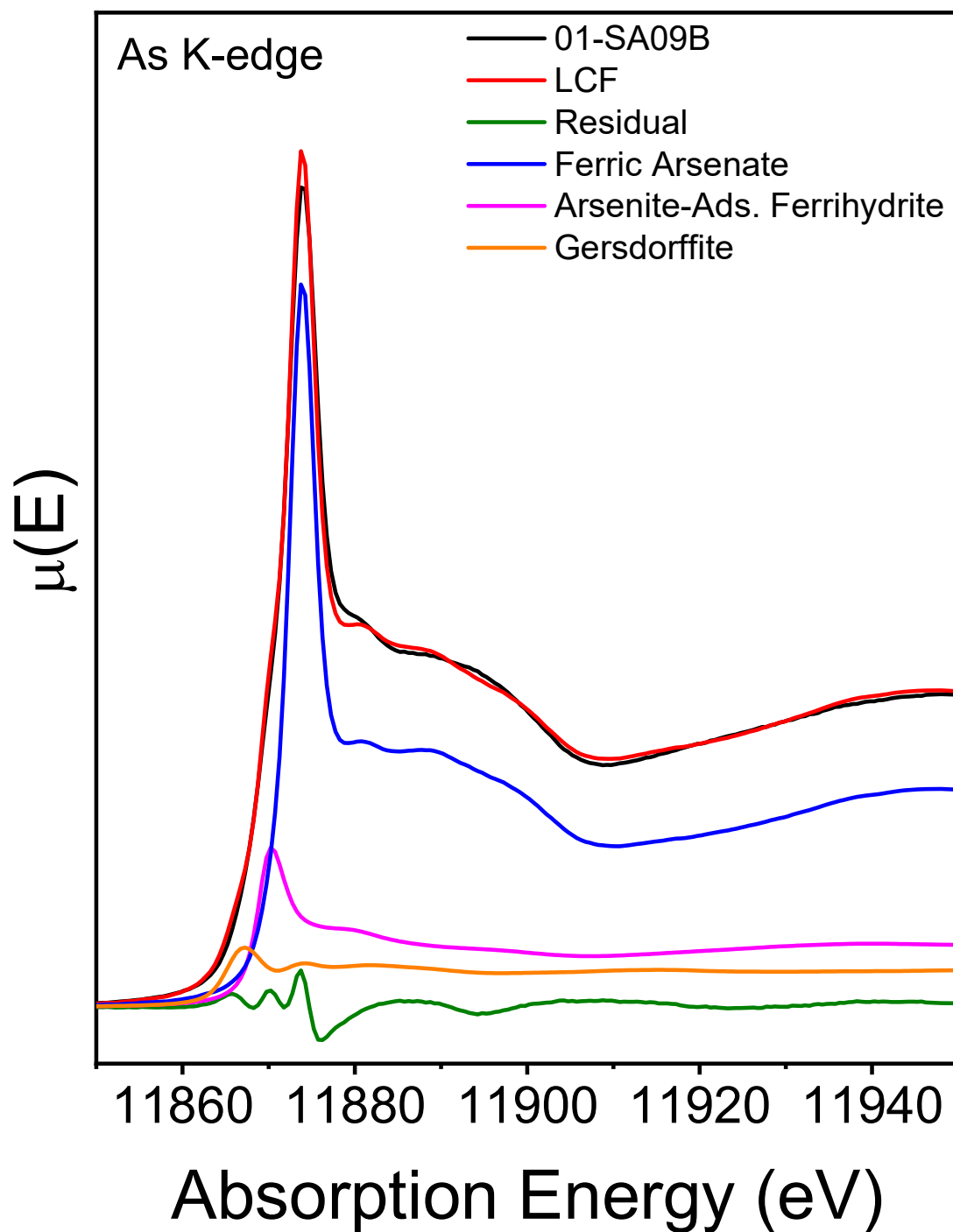


Figure 6.16. As K-edge XANES spectrum of **01-SA09B** showing the component spectra and final fit with residual.

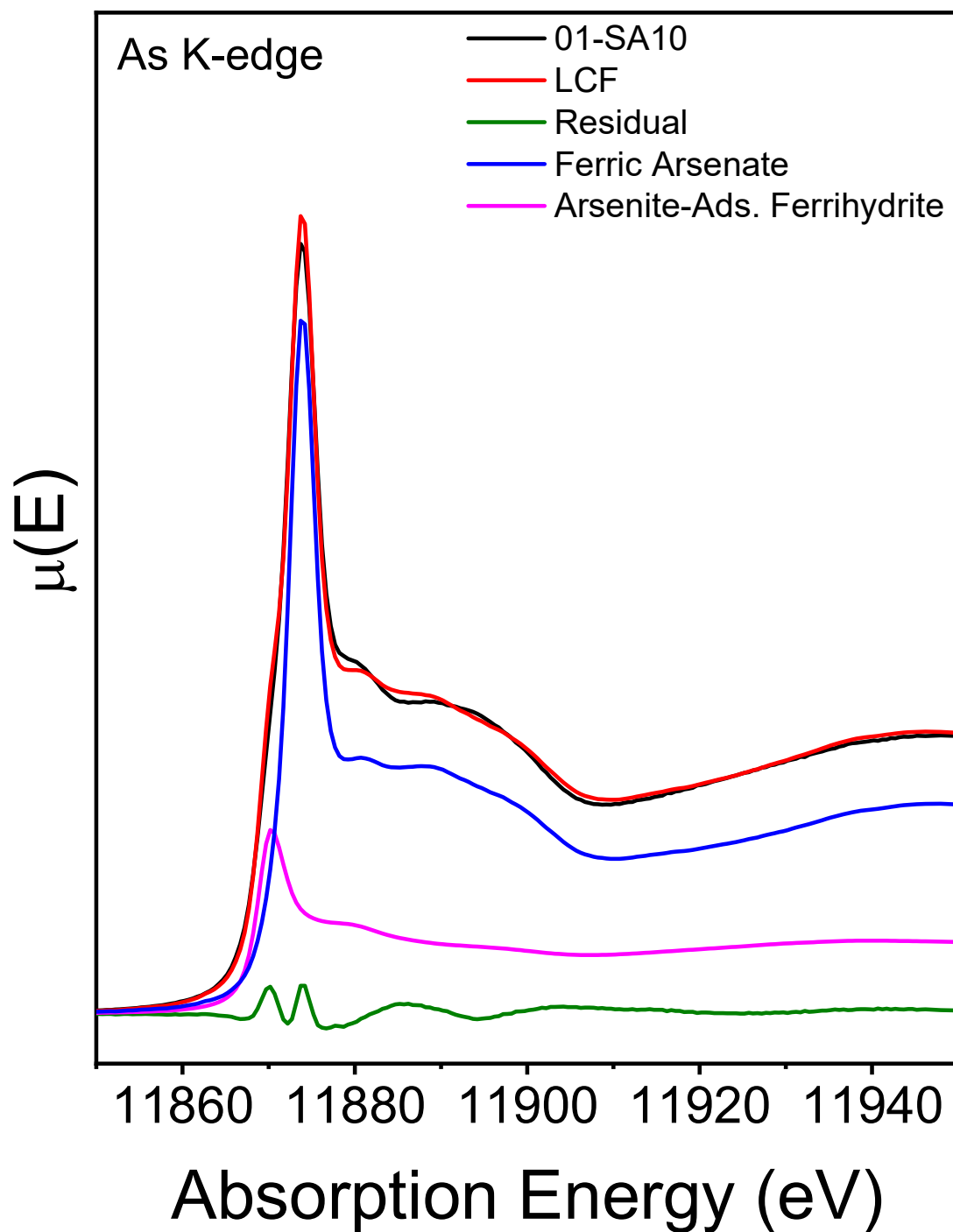


Figure 6.17. As K-edge XANES spectrum of **01-SA10** showing the component spectra and final fit with residual.

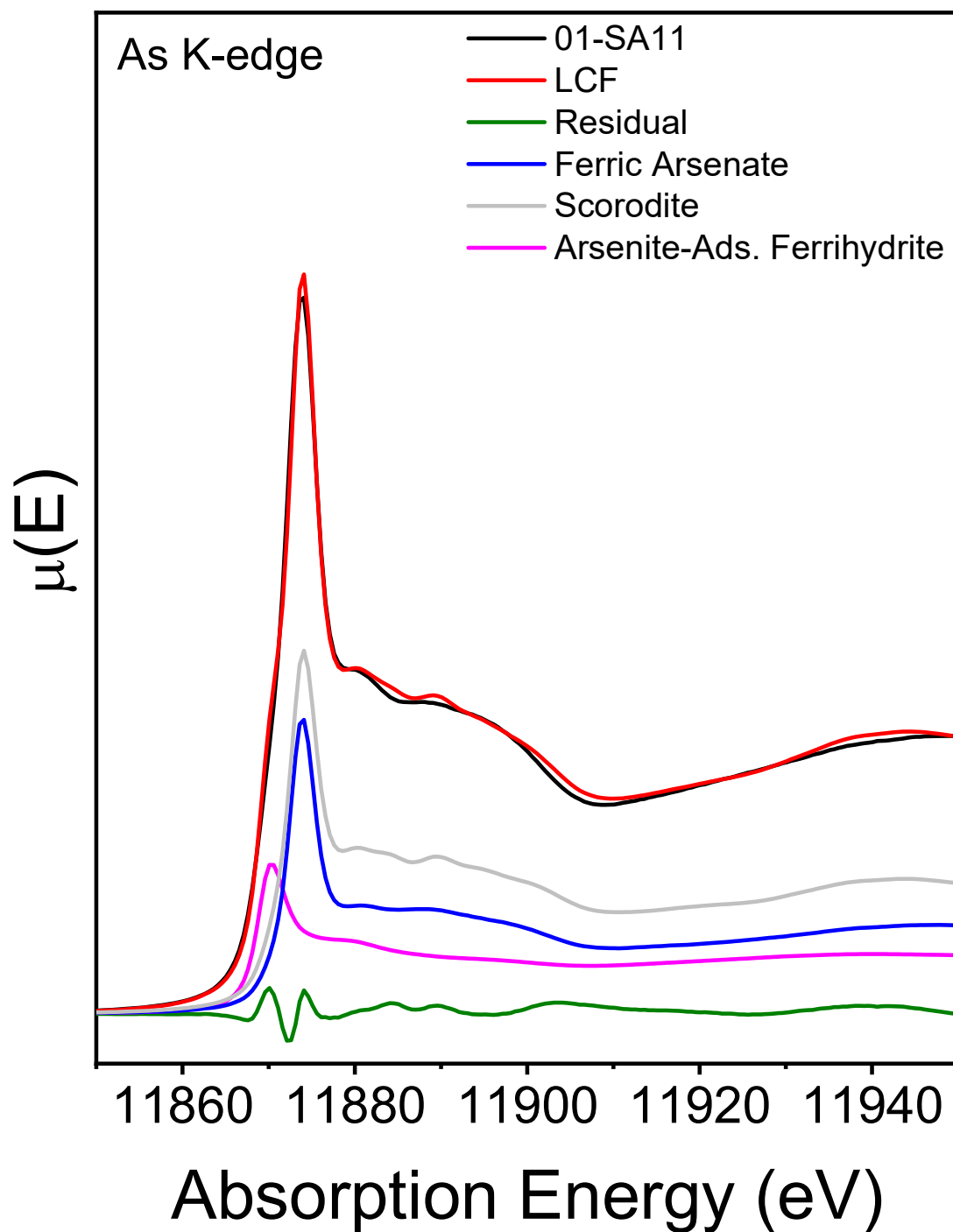


Figure 6.18. As K-edge XANES spectrum of **01-SA11** showing the component spectra and final fit with residual.

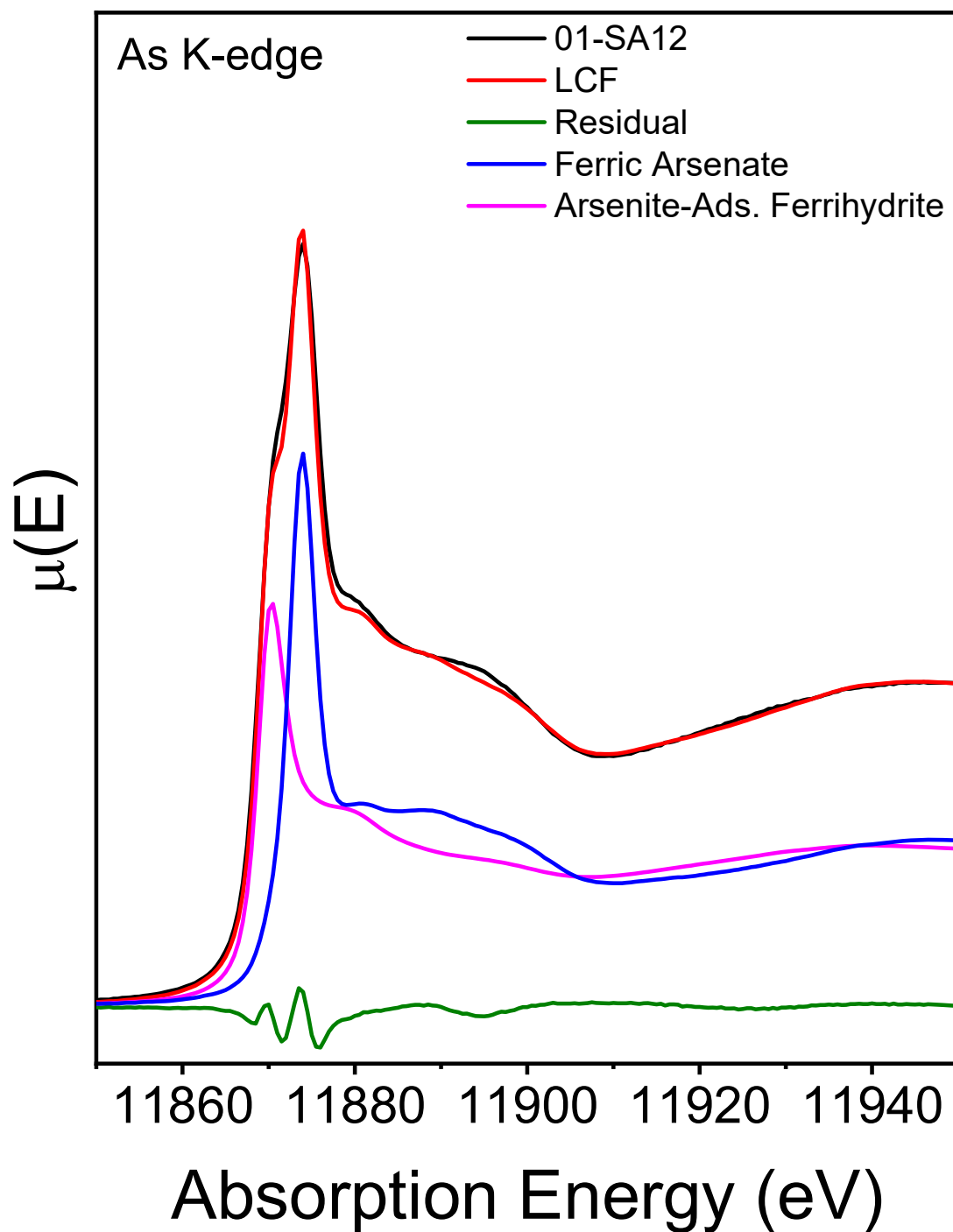


Figure 6.19. As K-edge XANES spectrum of **01-SA12** showing the component spectra and final fit with residual.

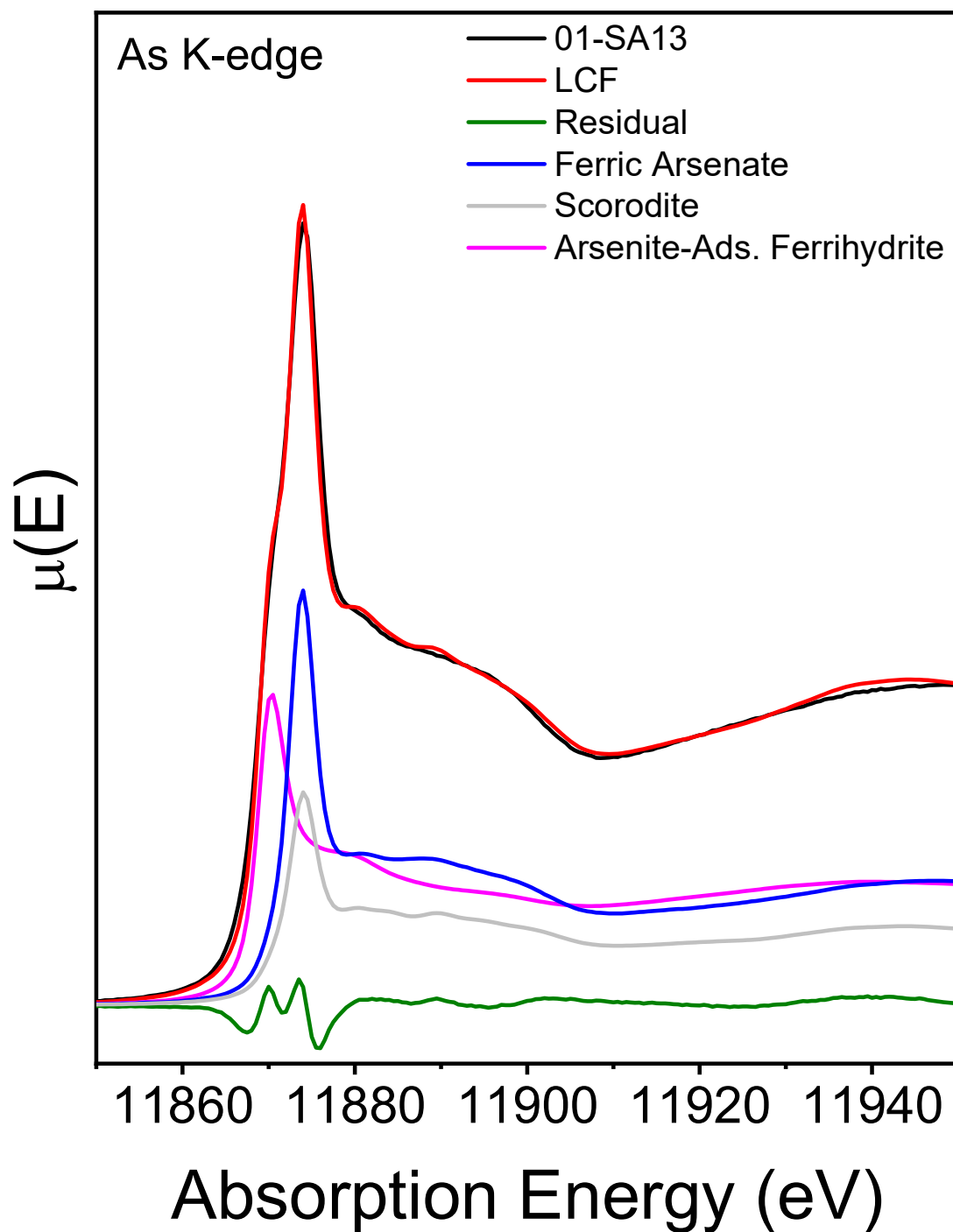


Figure 6.20. As K-edge XANES spectrum of **01-SA13** showing the component spectra and final fit with residual.

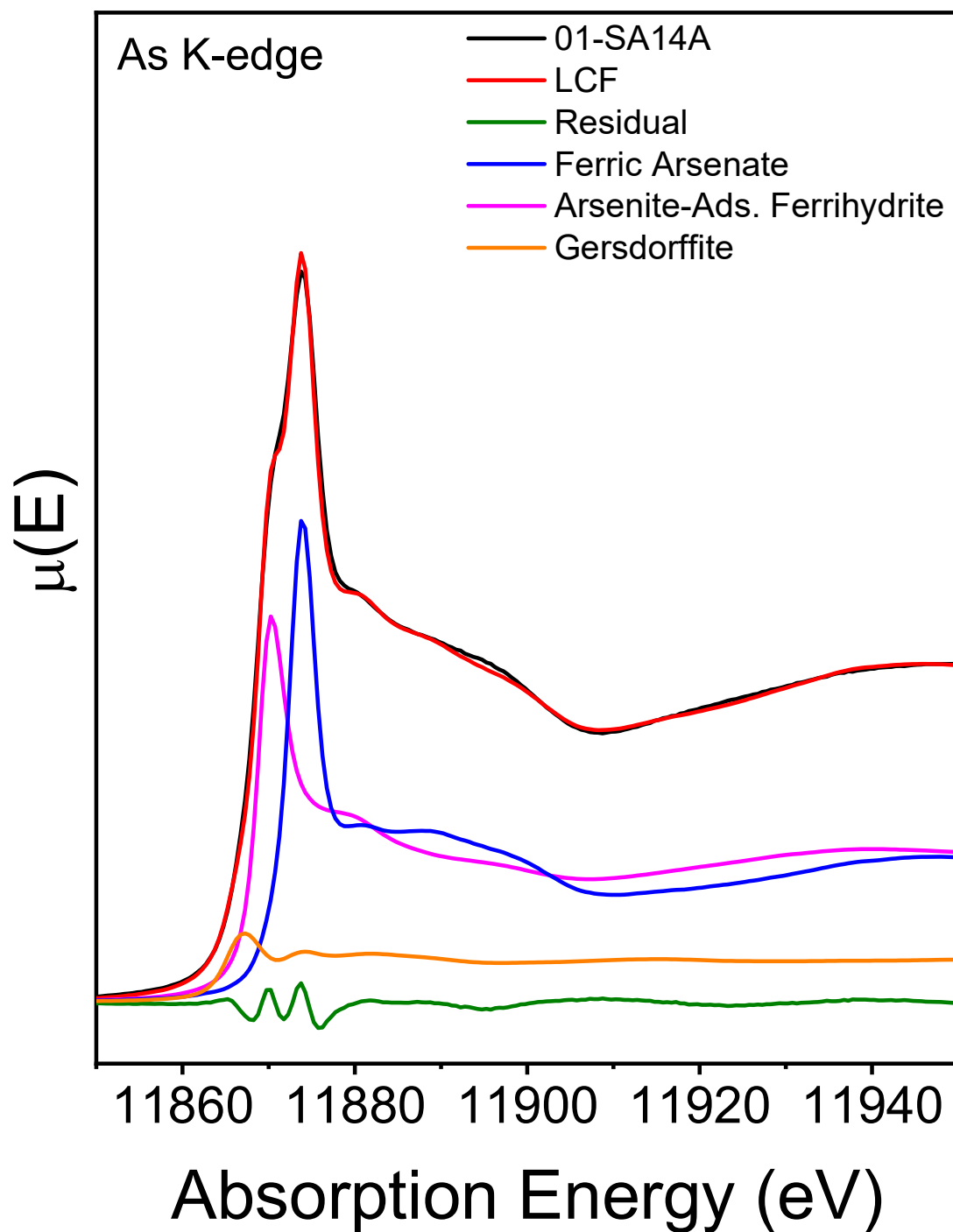


Figure 6.21. As K-edge XANES spectrum of **01-SA14A** showing the component spectra and final fit with residual.

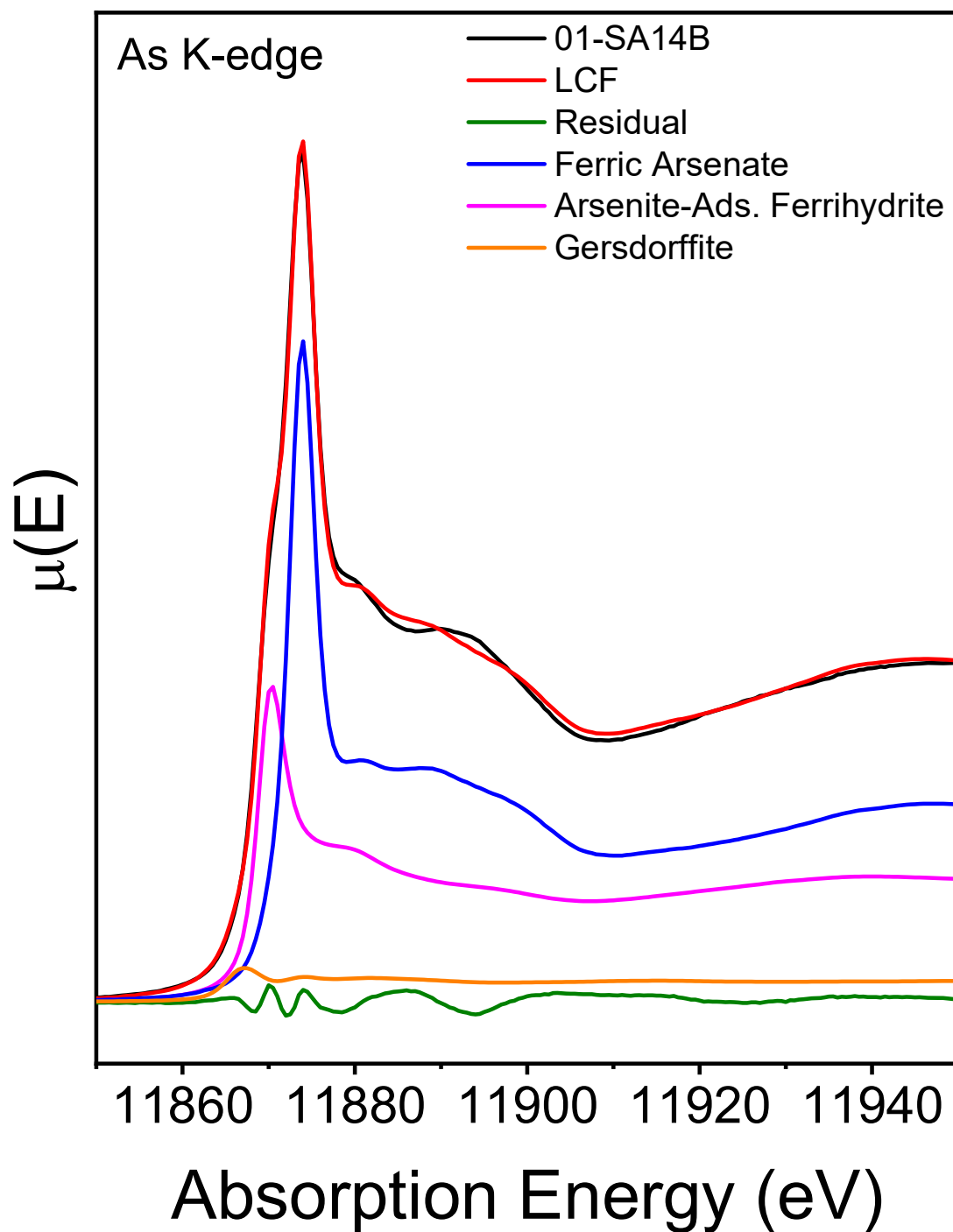


Figure 6.22. As K-edge XANES spectrum of **01-SA14B** showing the component spectra and final fit with residual.

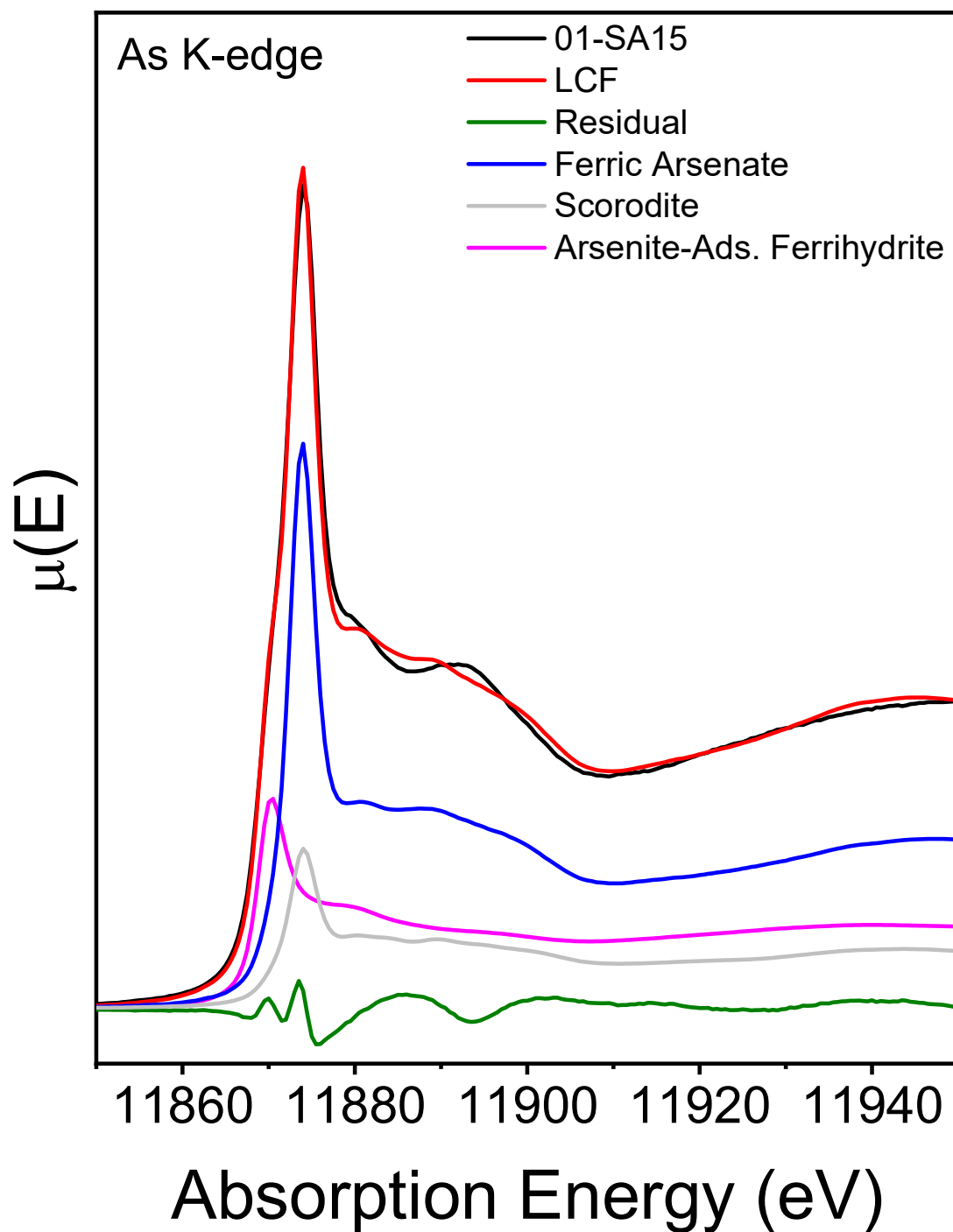


Figure 6.23. As K-edge XANES spectrum of **01-SA15** showing the component spectra and final fit with residual.

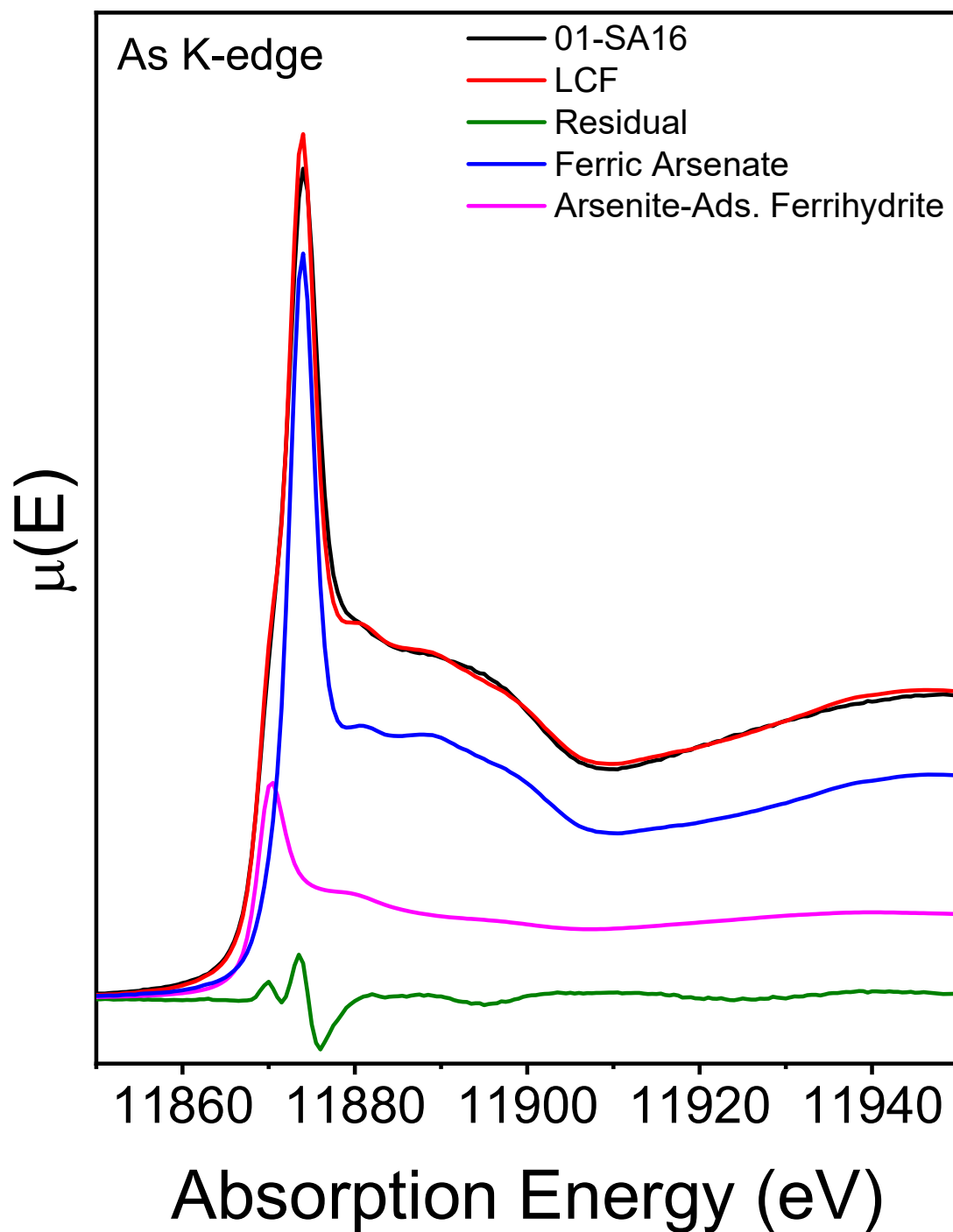


Figure 6.24. As K-edge XANES spectrum of **01-SA16** showing the component spectra and final fit with residual.

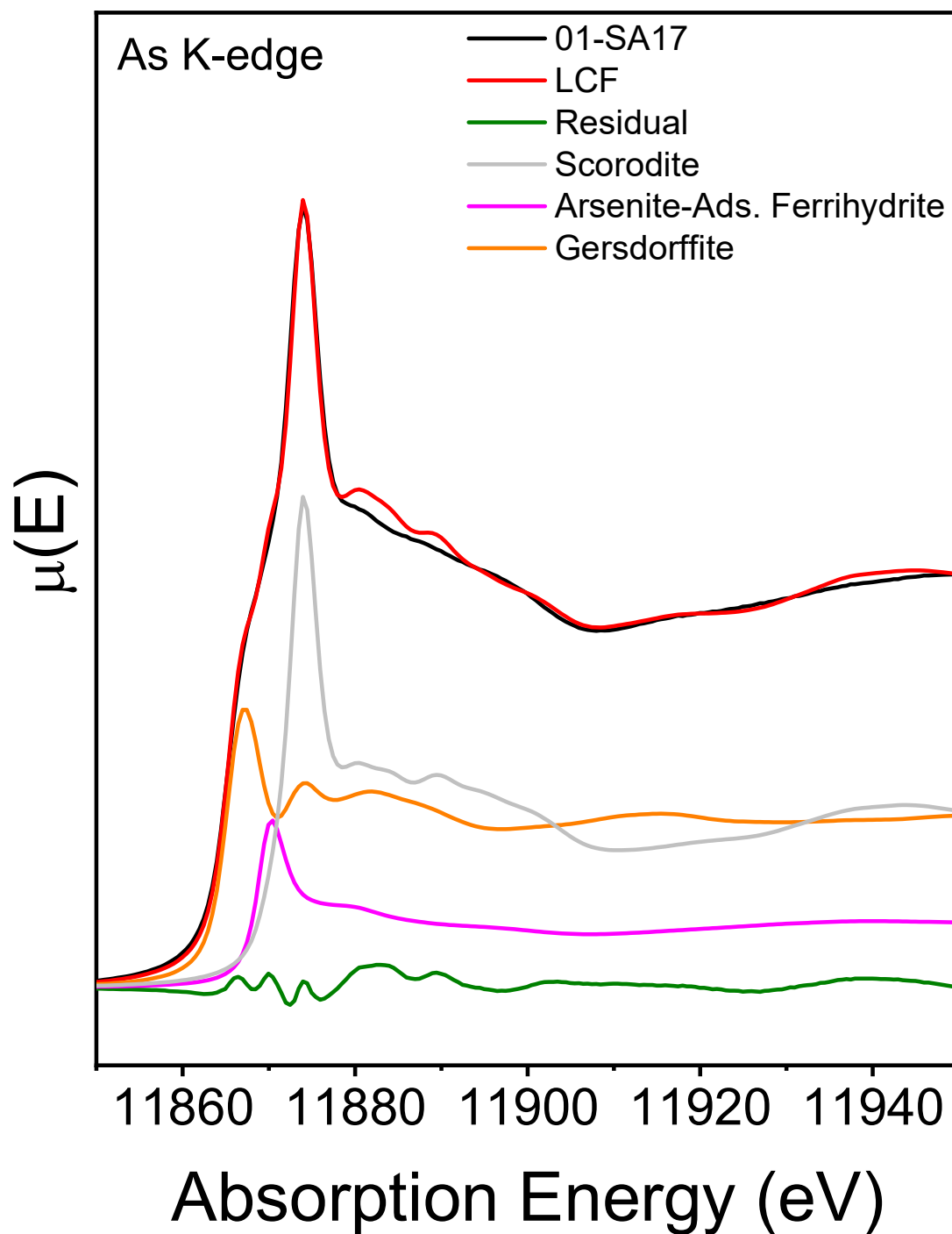


Figure 6.25. As K-edge XANES spectrum of **01-SA17** showing the component spectra and final fit with residual.

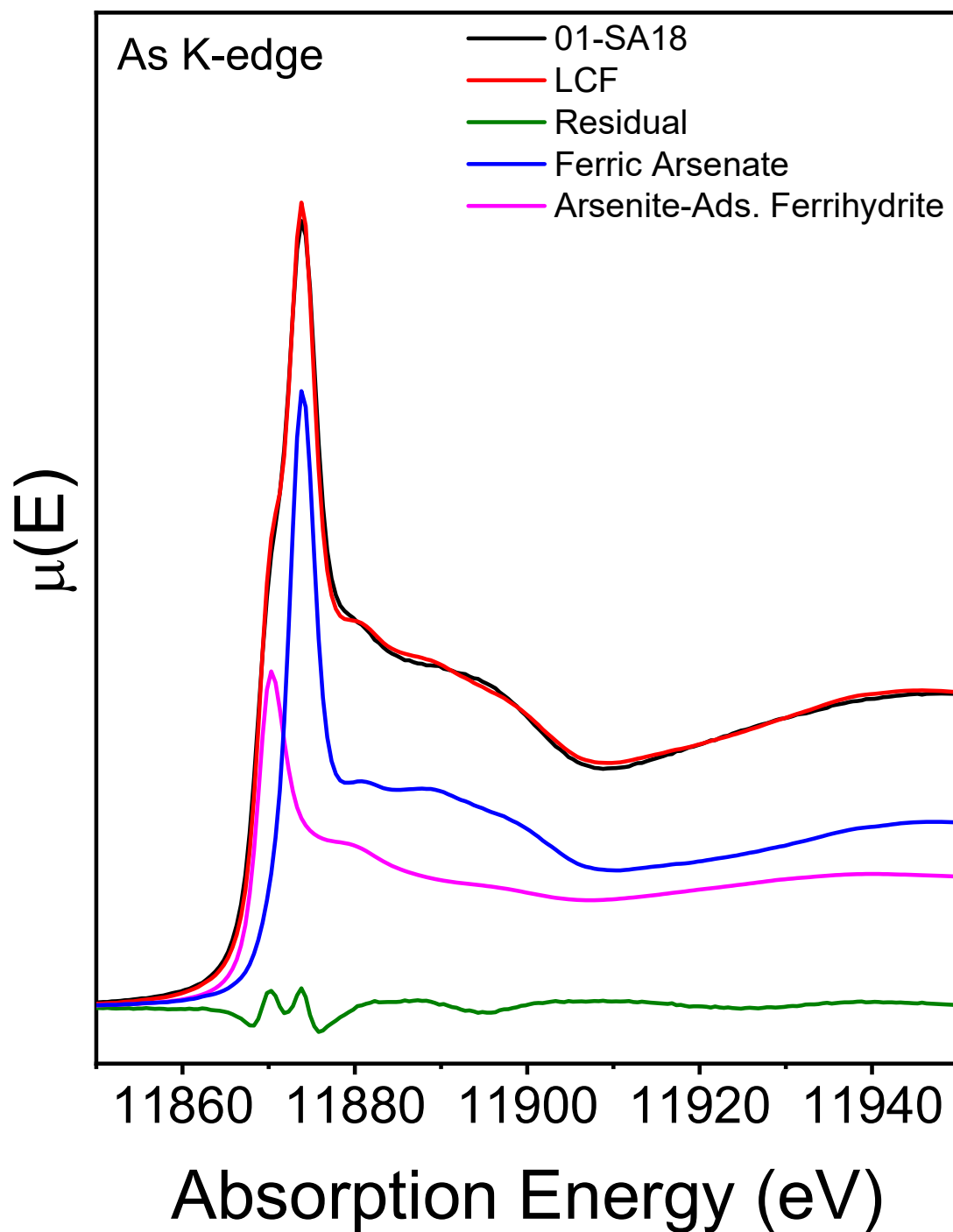


Figure 6.26. As K-edge XANES spectrum of **01-SA18** showing the component spectra and final fit with residual.

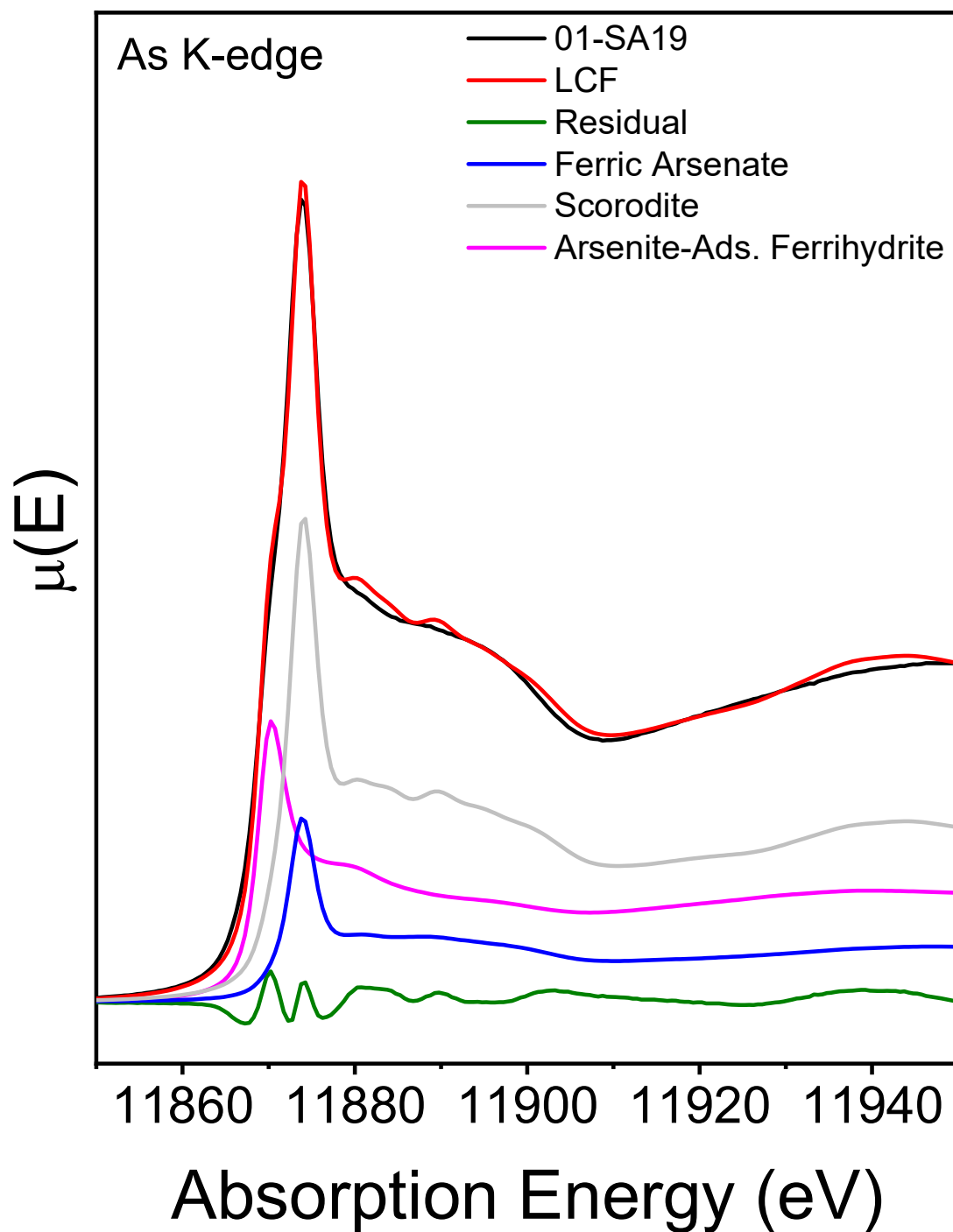


Figure 6.27. As K-edge XANES spectrum of **01-SA19** showing the component spectra and final fit with residual.

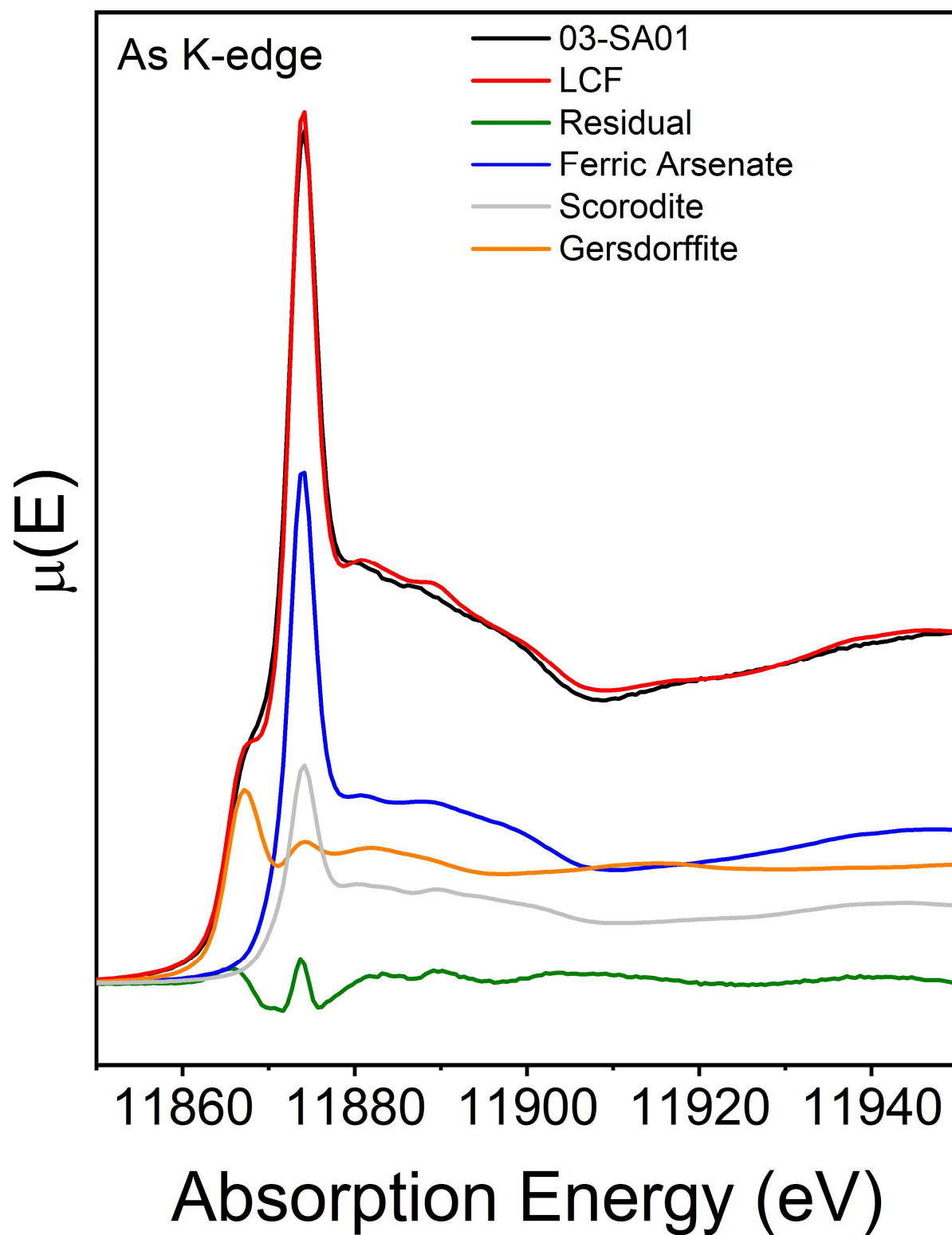


Figure 6.28. As K-edge XANES spectrum of **03-SA01** showing the component spectra and final fit with residual.

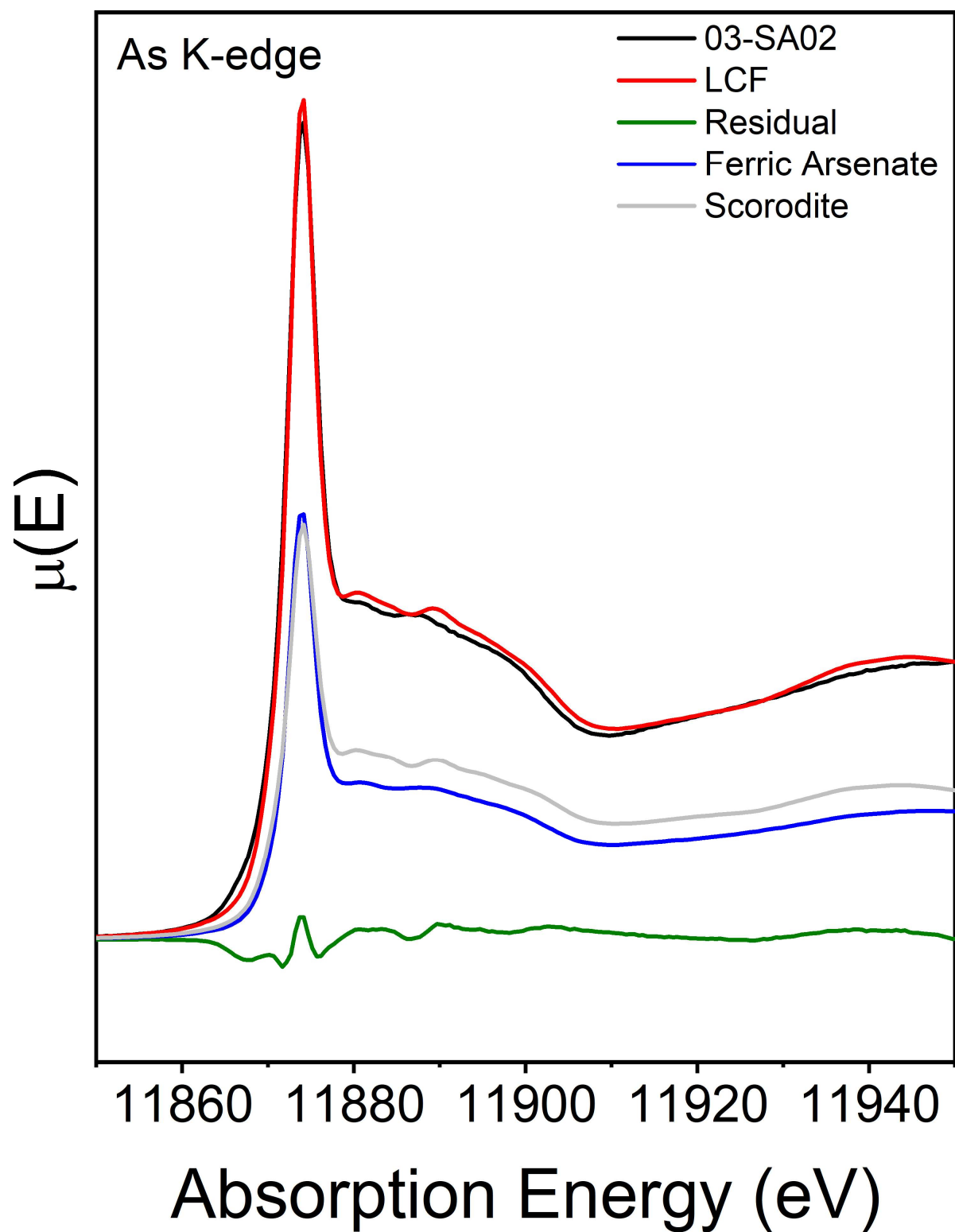


Figure 6.29. As K-edge XANES spectrum of **03-SA02** showing the component spectra and final fit with residual.

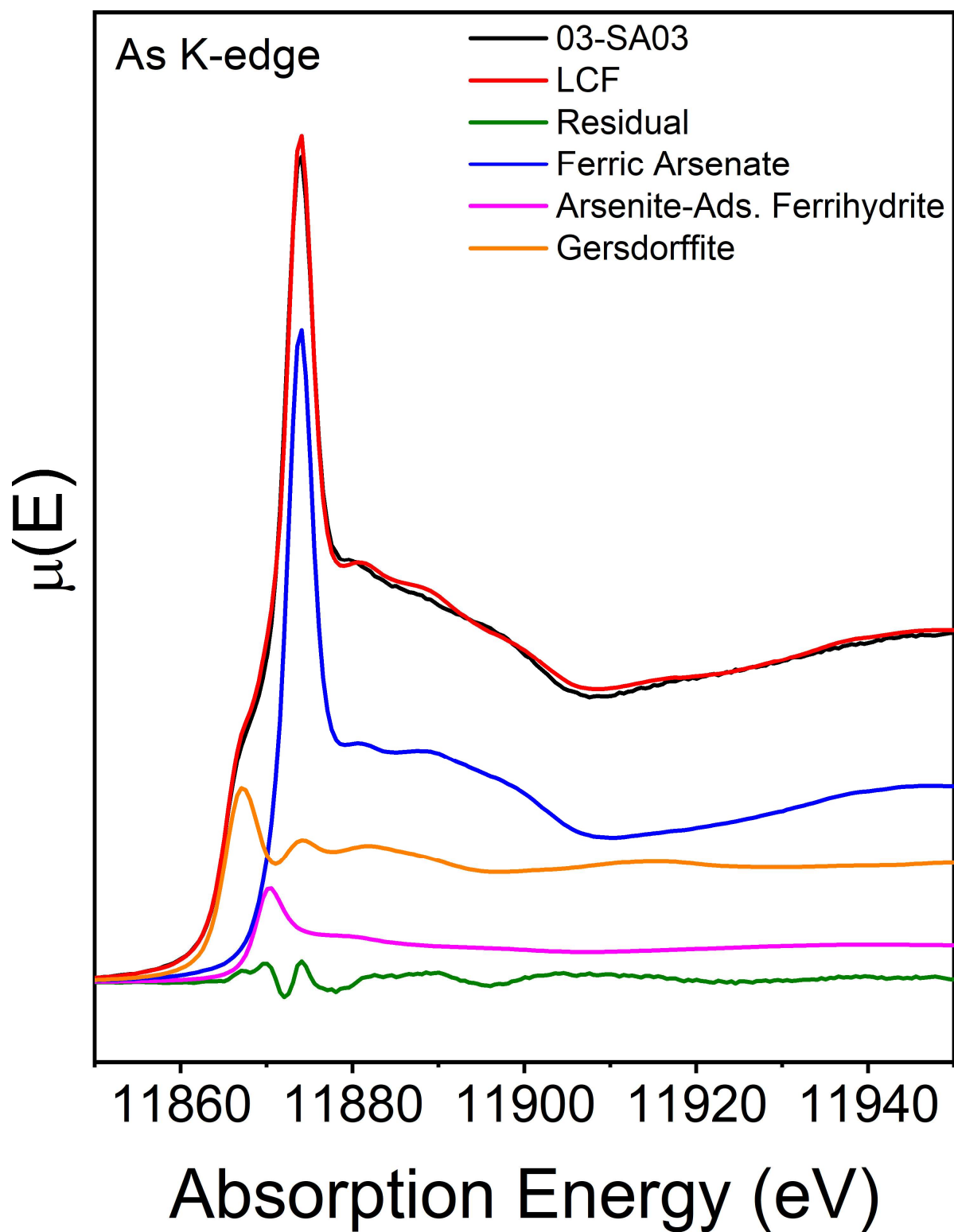


Figure 6.30. As K-edge XANES spectrum of **03-SA03** showing the component spectra and final fit with residual.

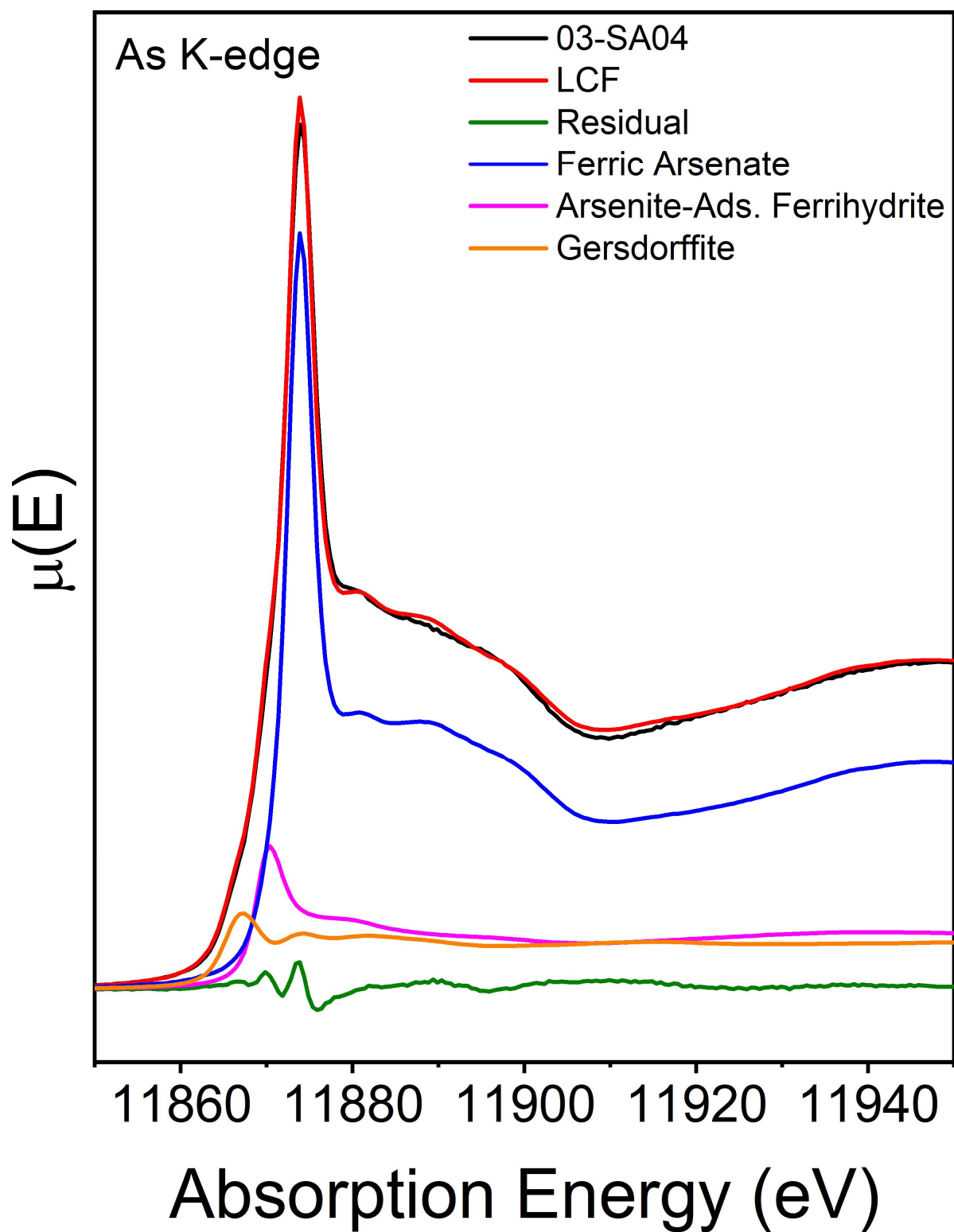


Figure 6.31. As K-edge XANES spectrum of **03-SA04** showing the component spectra and final fit with residual.

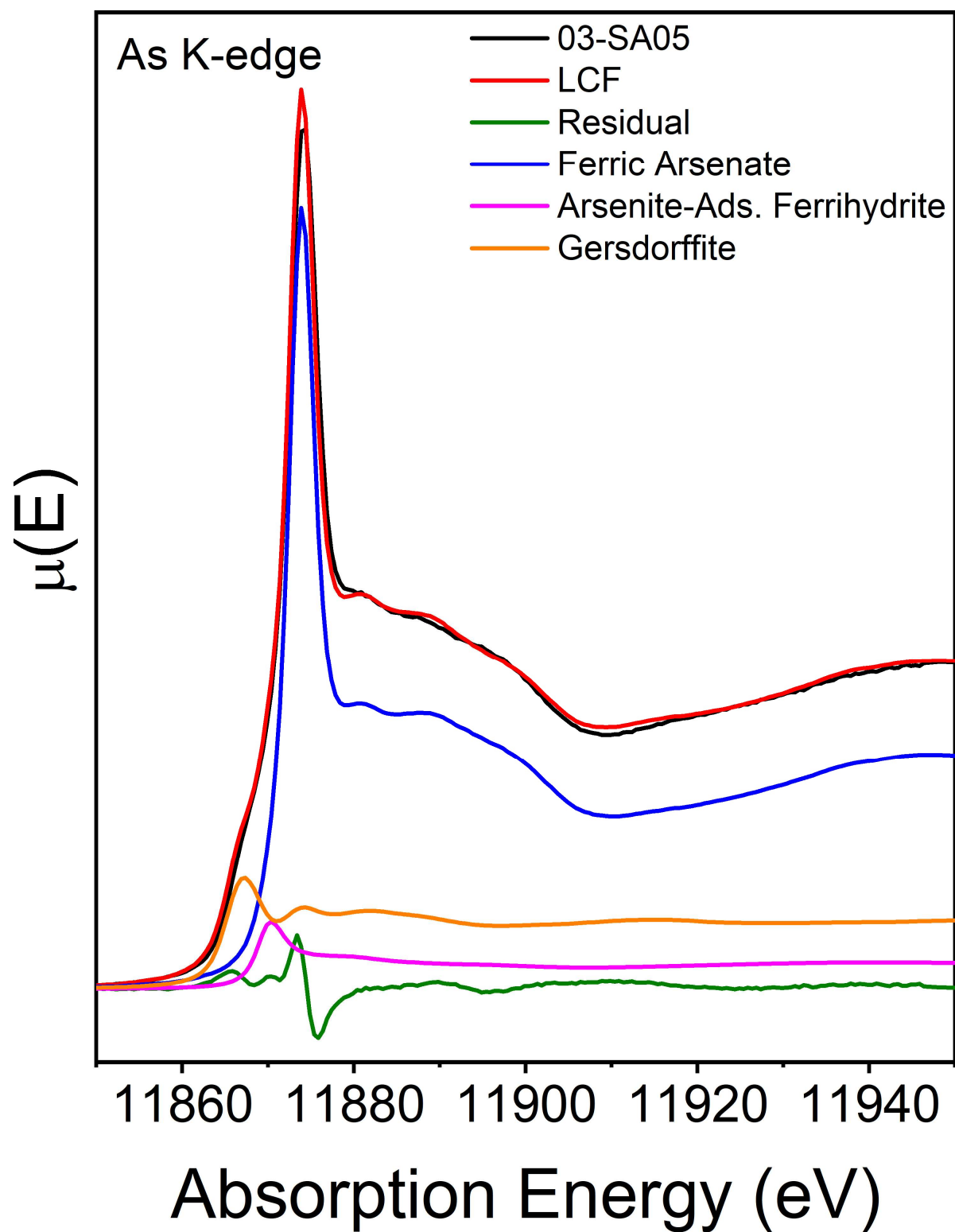


Figure 6.32. As K-edge XANES spectrum of **03-SA05** showing the component spectra and final fit with residual.

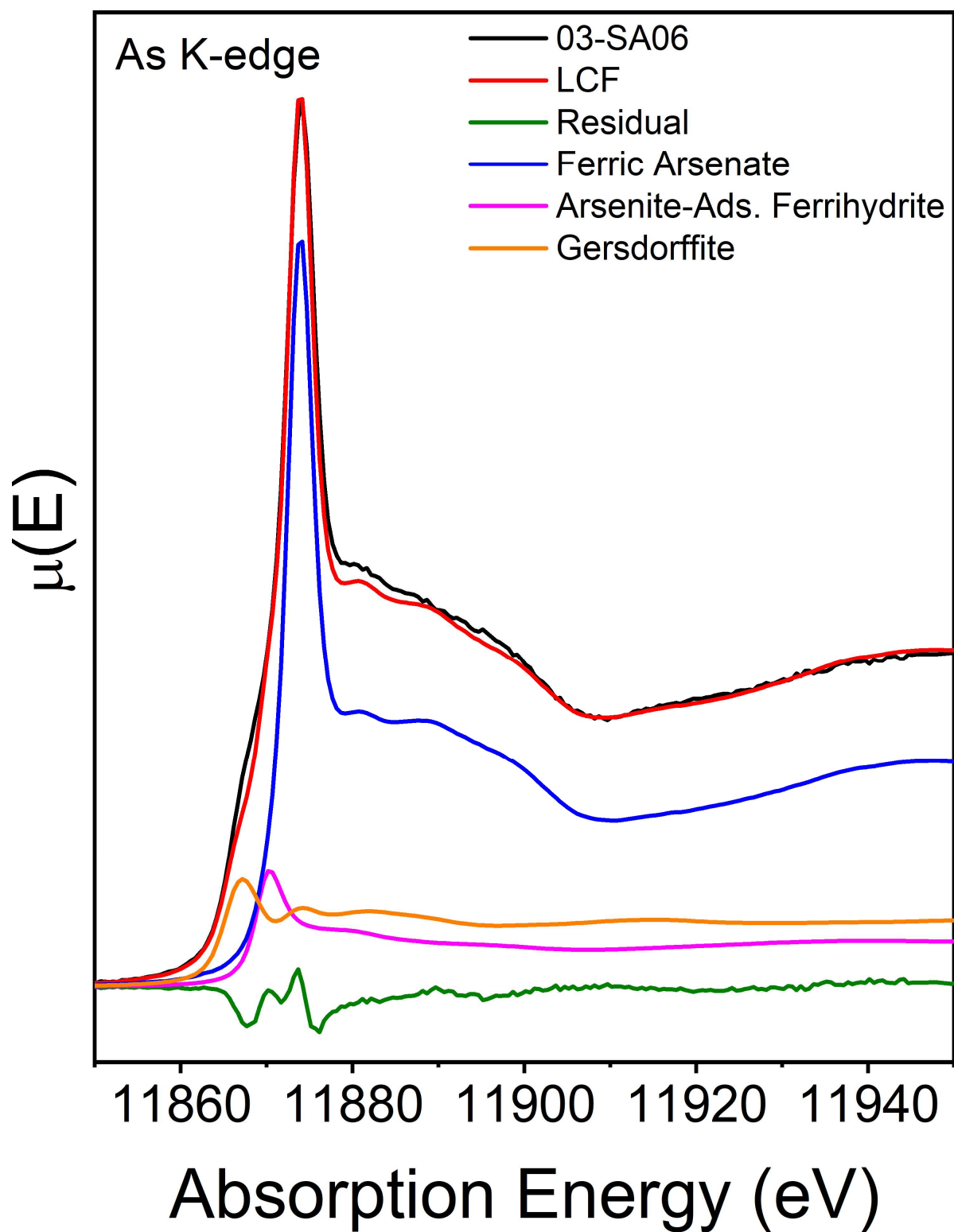


Figure 6.33. As K-edge XANES spectrum of **03-SA06** showing the component spectra and final fit with residual.

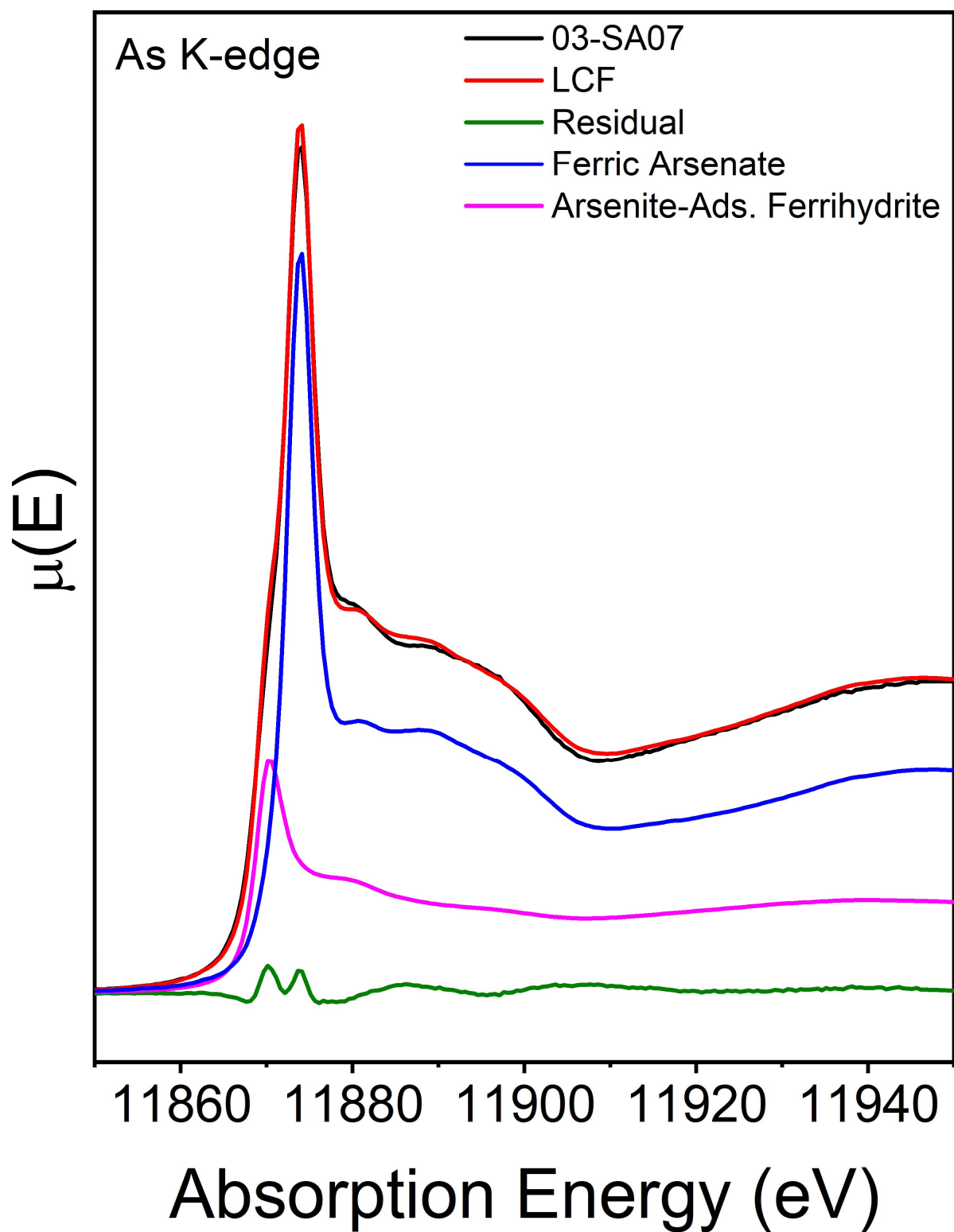


Figure 6.34. As K-edge XANES spectrum of **03-SA07** showing the component spectra and final fit with residual.

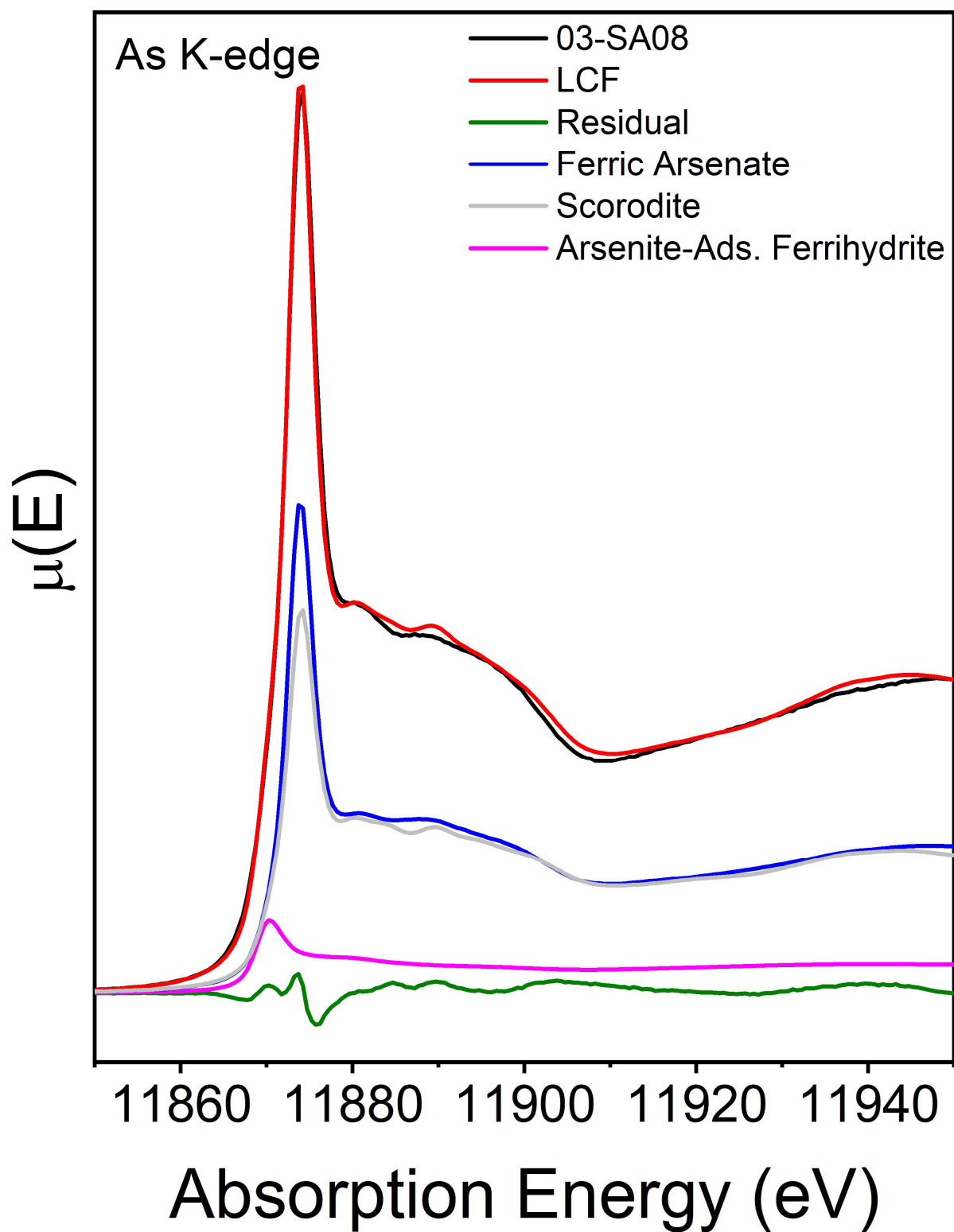


Figure 6.35. As K-edge XANES spectrum of **03-SA08** showing the component spectra and final fit with residual.

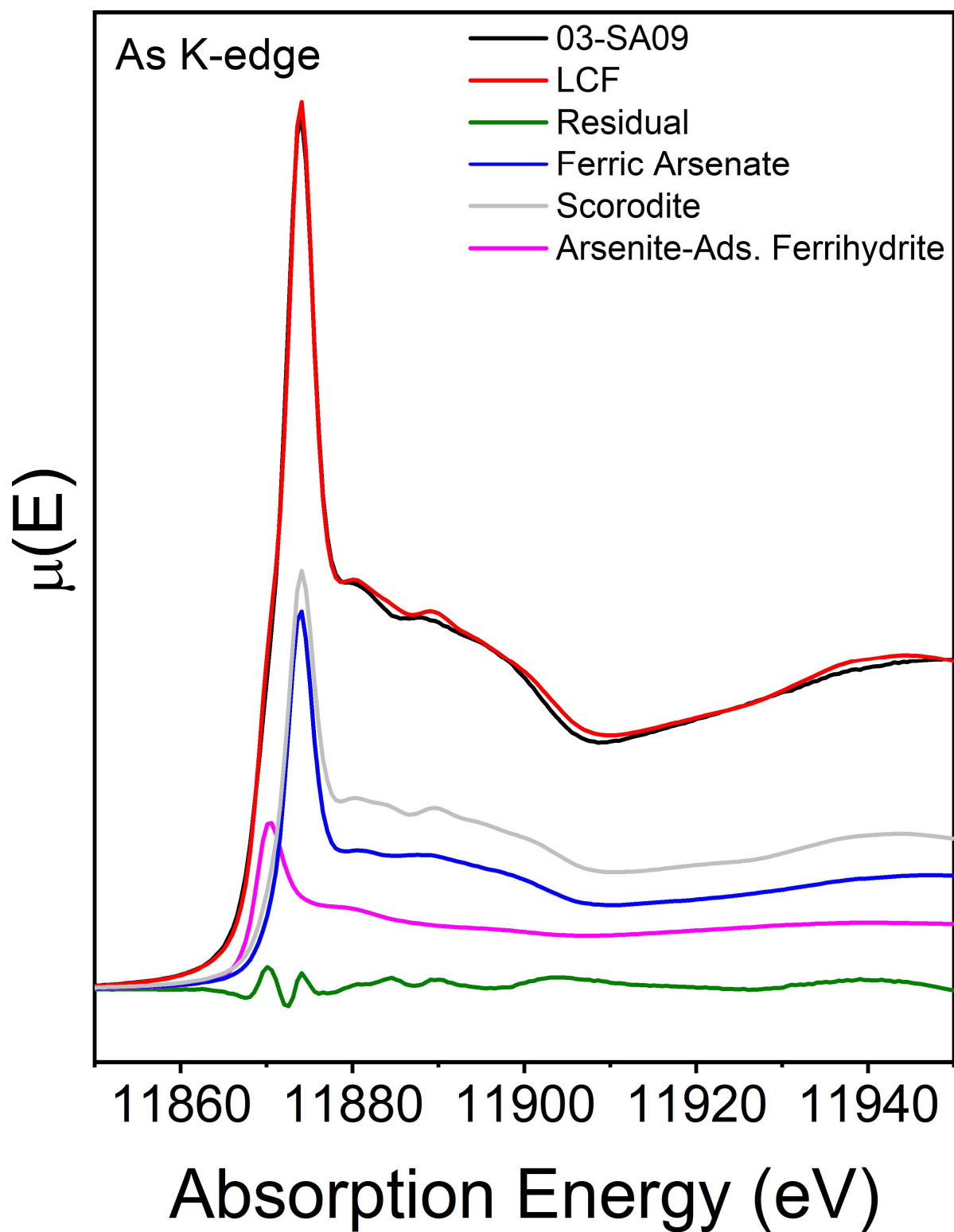


Figure 6.36. As K-edge XANES spectrum of **03-SA09** showing the component spectra and final fit with residual.

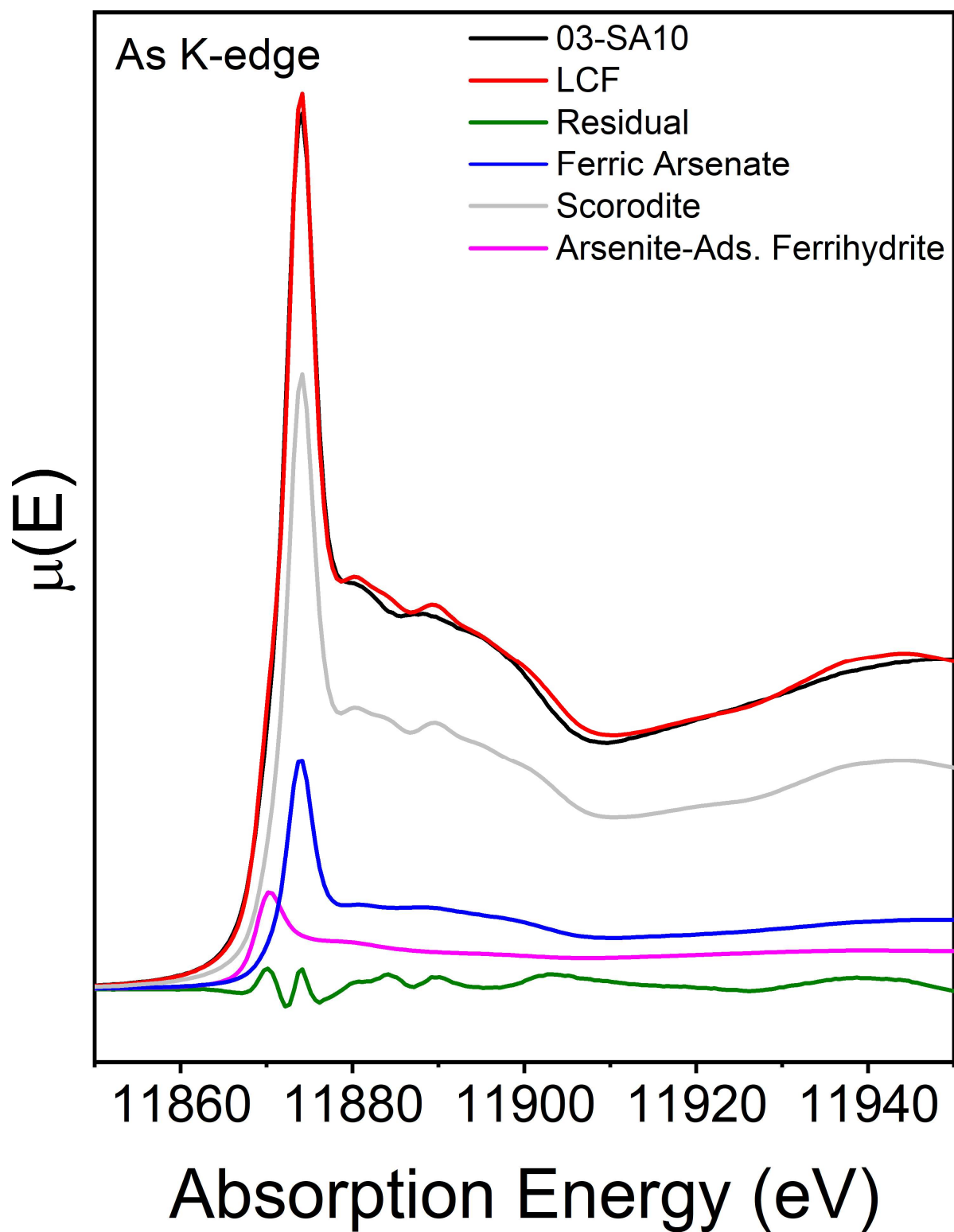


Figure 6.37. As K-edge XANES spectrum of **03-SA10** showing the component spectra and final fit with residual.

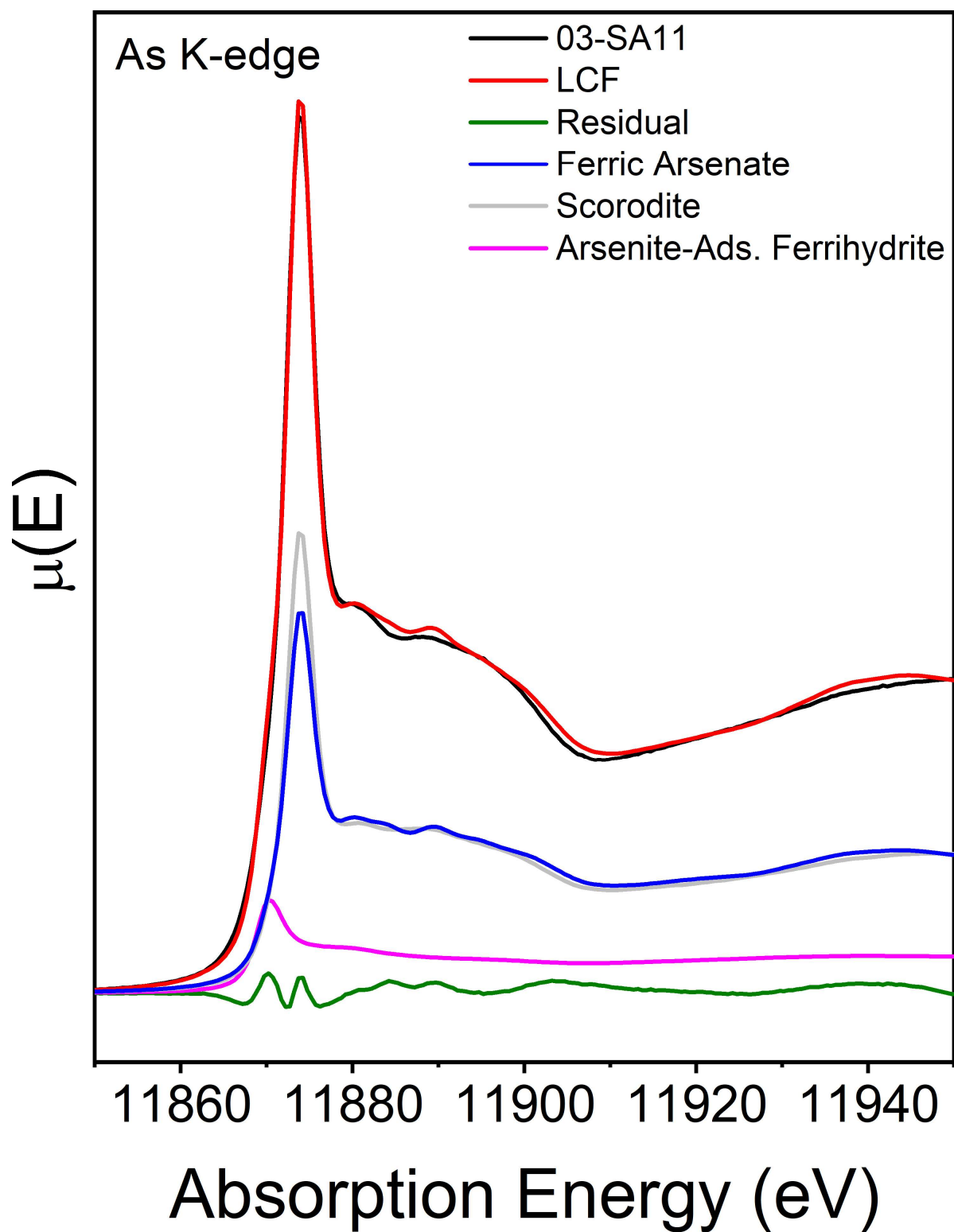


Figure 6.38. As K-edge XANES spectrum of **03-SA11** showing the component spectra and final fit with residual.

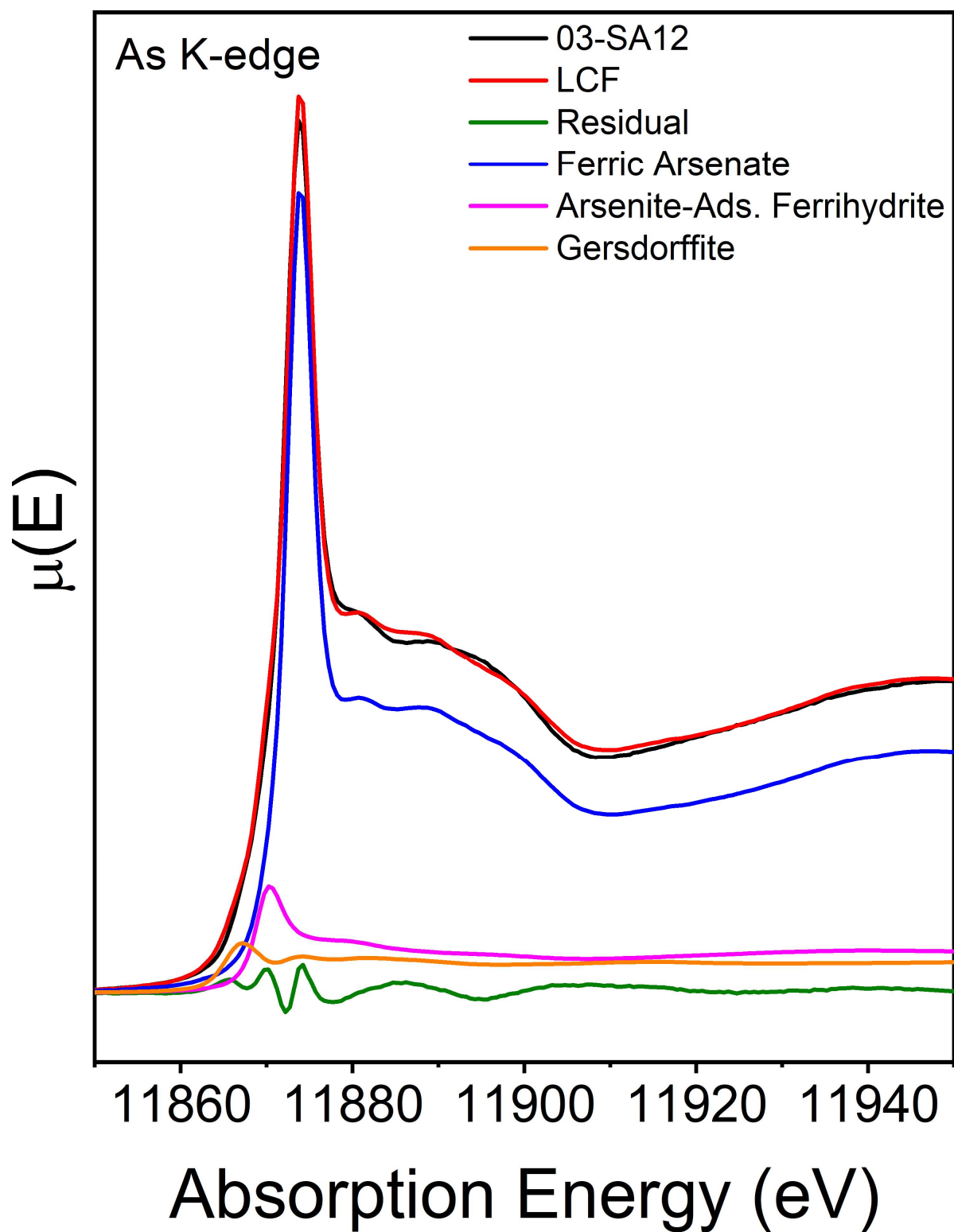


Figure 6.39. As K-edge XANES spectrum of **03-SA12** showing the component spectra and final fit with residual.

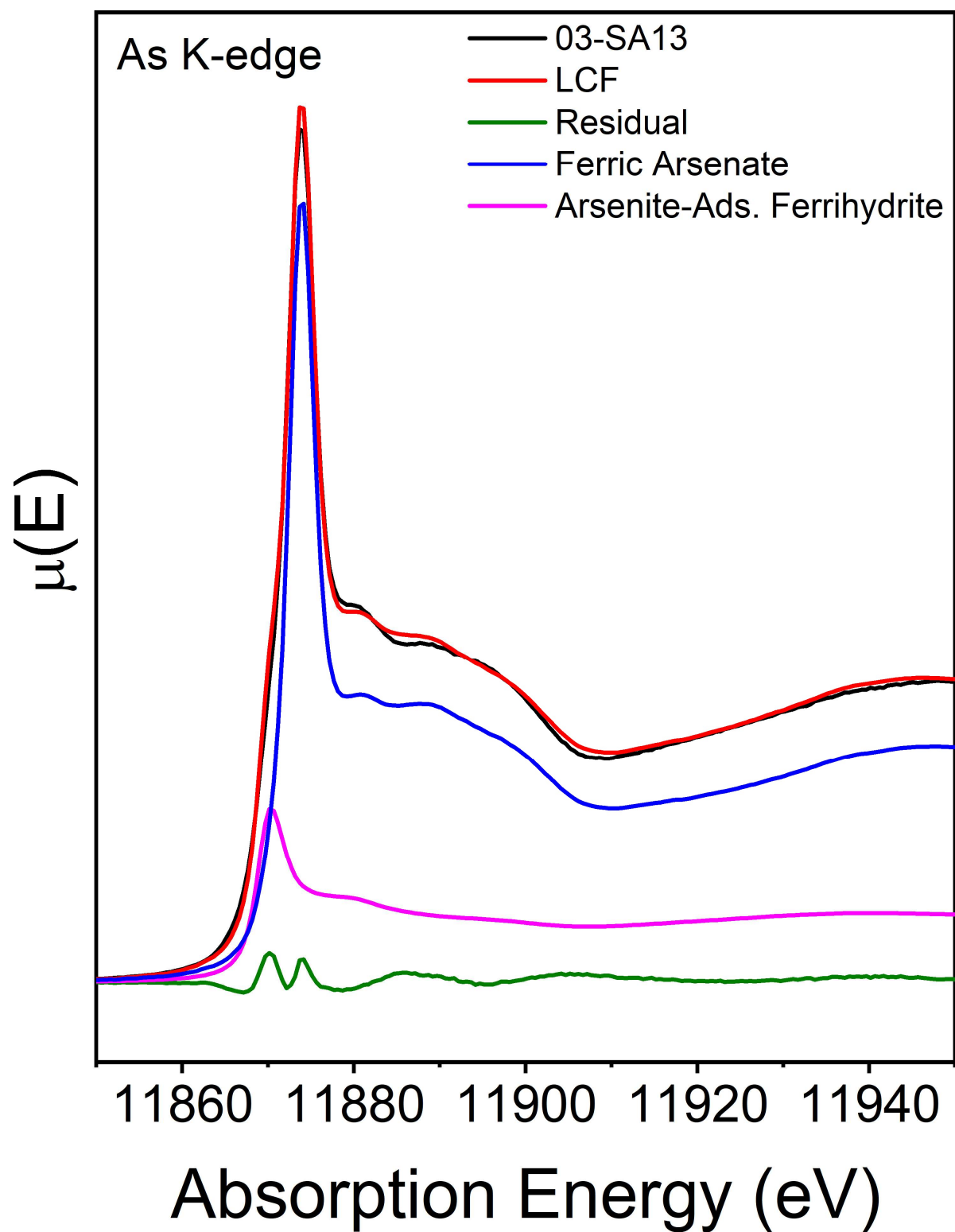


Figure 6.40. As K-edge XANES spectrum of **03-SA13** showing the component spectra and final fit with residual.

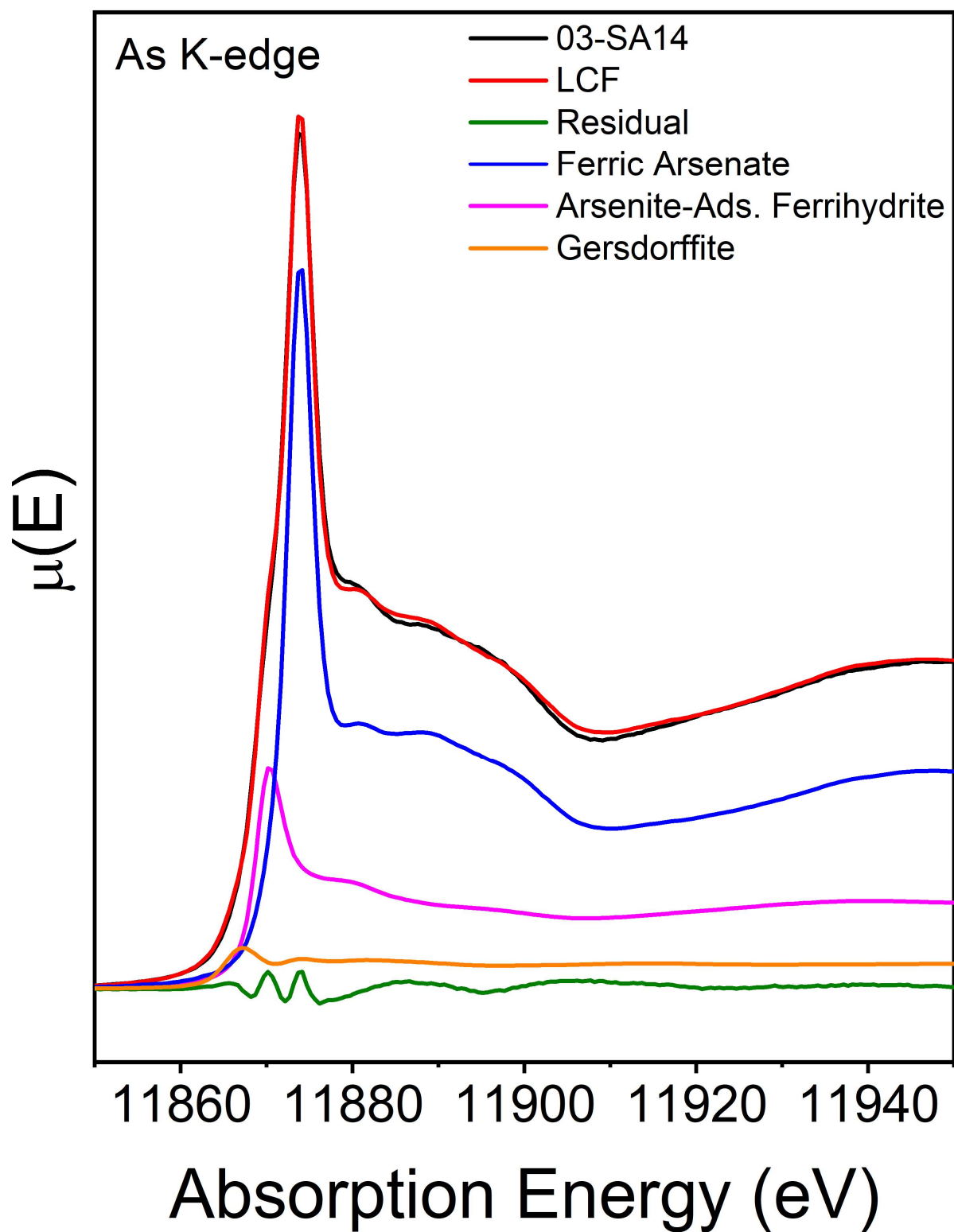


Figure 6.41. As K-edge XANES spectrum of **03-SA14** showing the component spectra and final fit with residual.

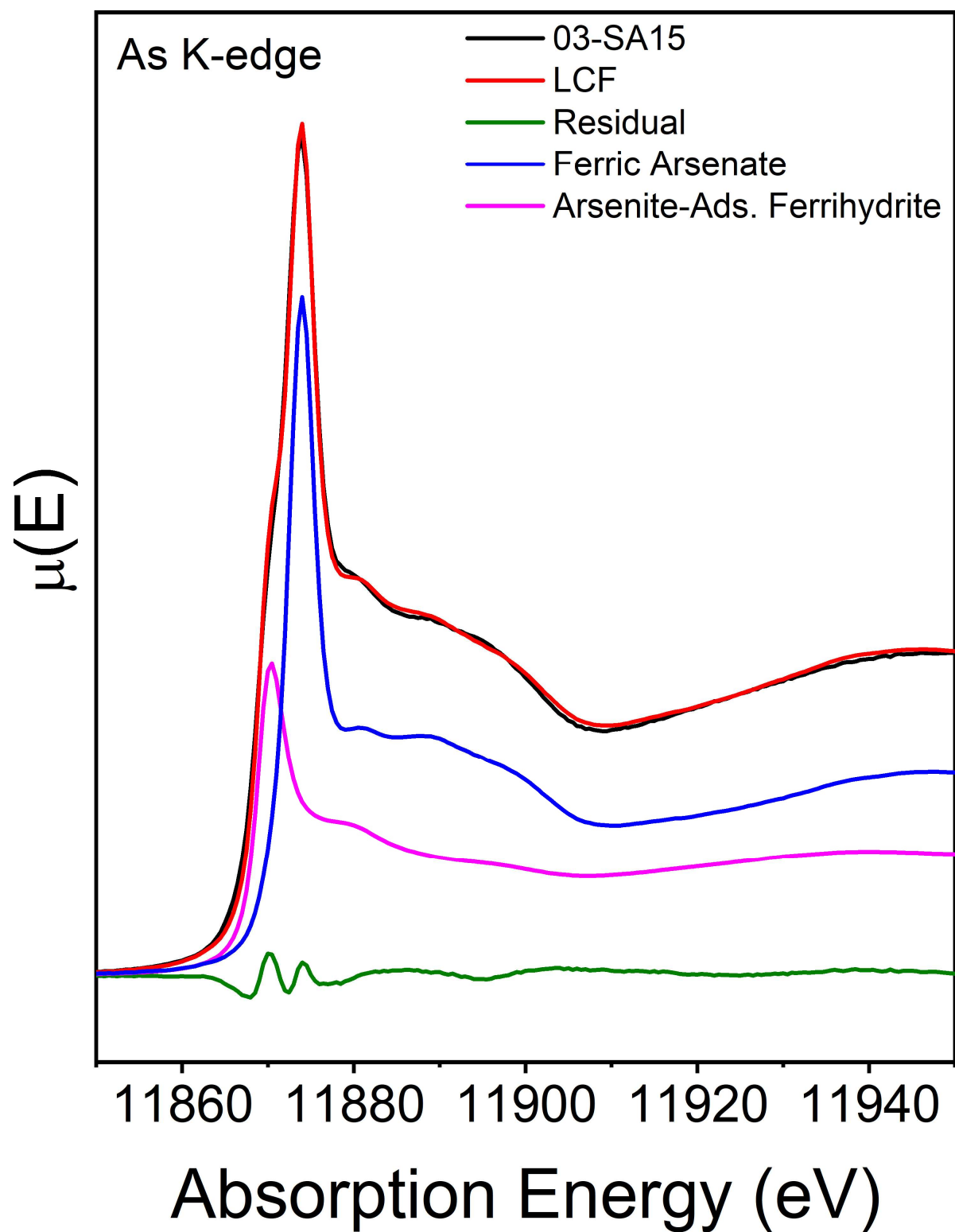


Figure 6.42. As K-edge XANES spectrum of **03-SA15** showing the component spectra and final fit with residual.

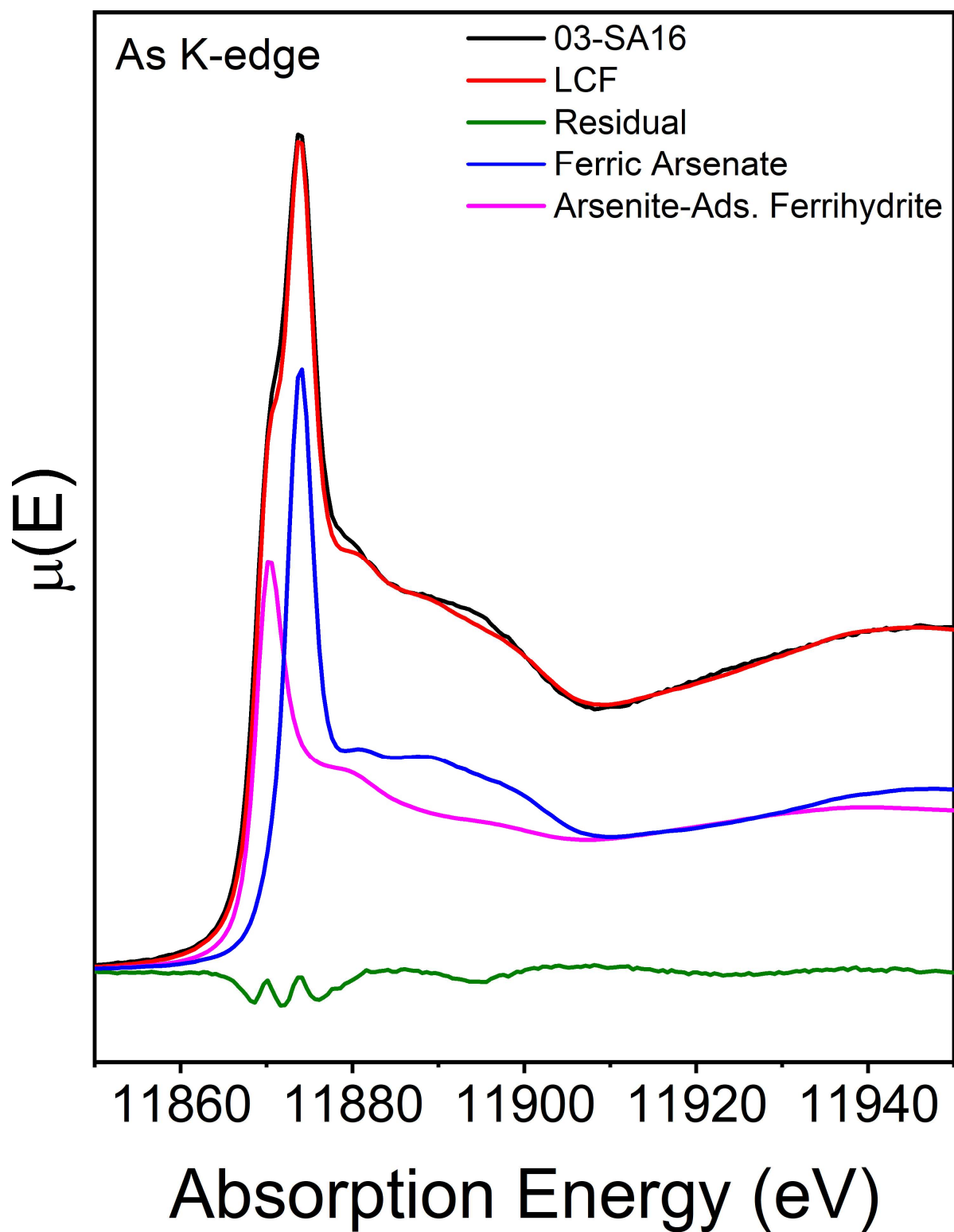


Figure 6.43. As K-edge XANES spectrum of **03-SA16** showing the component spectra and final fit with residual.

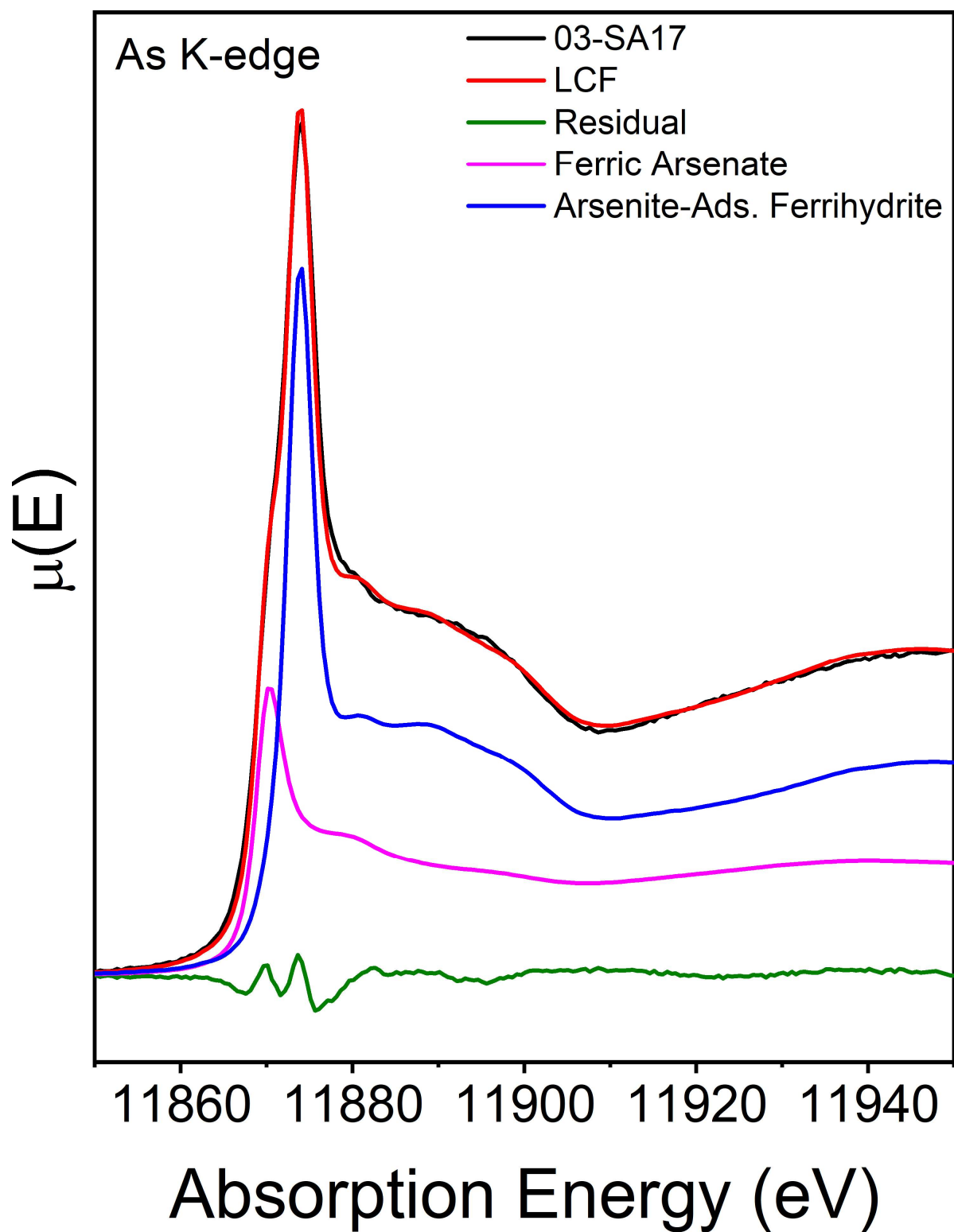


Figure 6.44. As K-edge XANES spectrum of **03-SA17** showing the component spectra and final fit with residual.

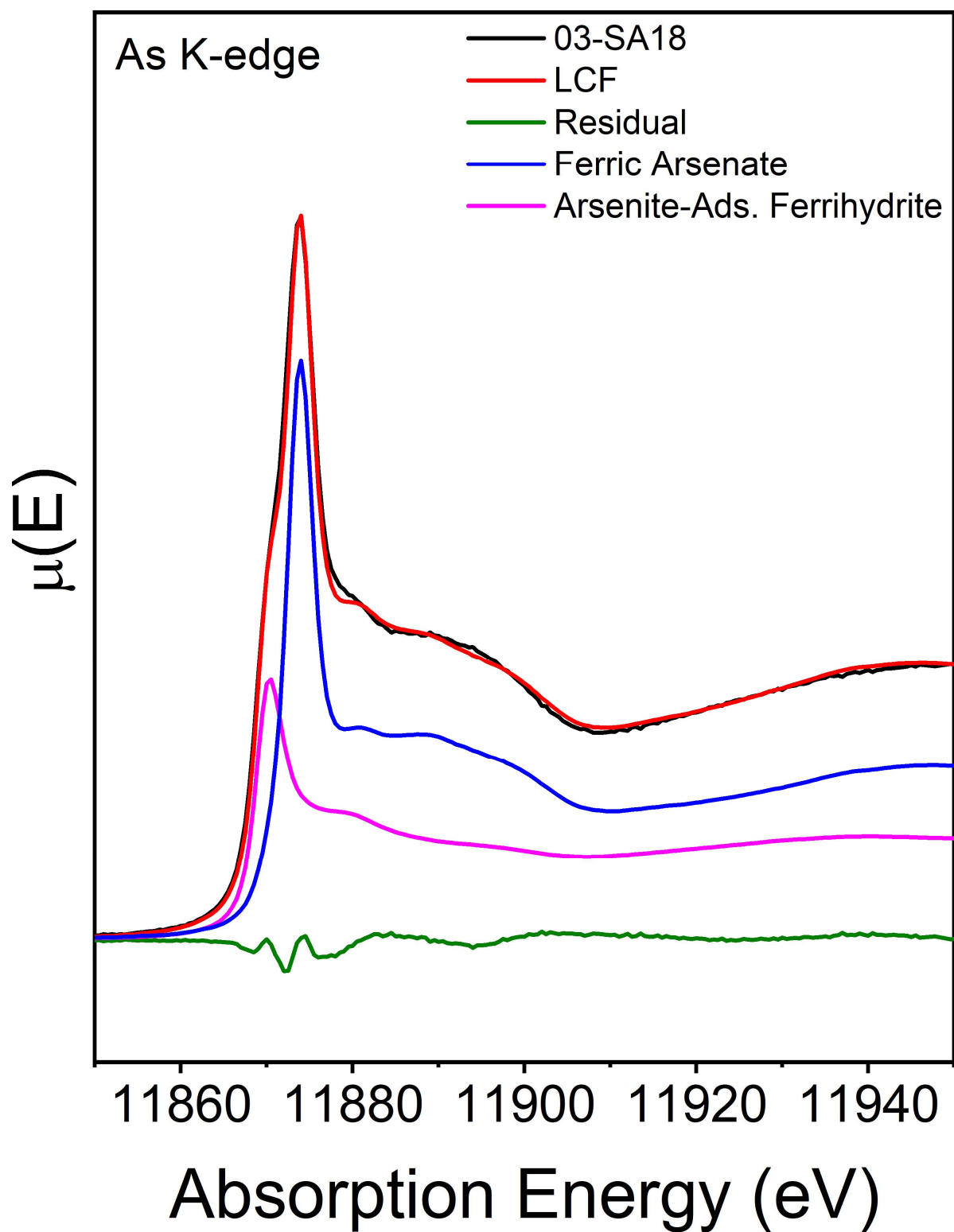


Figure 6.45. As K-edge XANES spectrum of **03-SA18** showing the component spectra and final fit with residual.

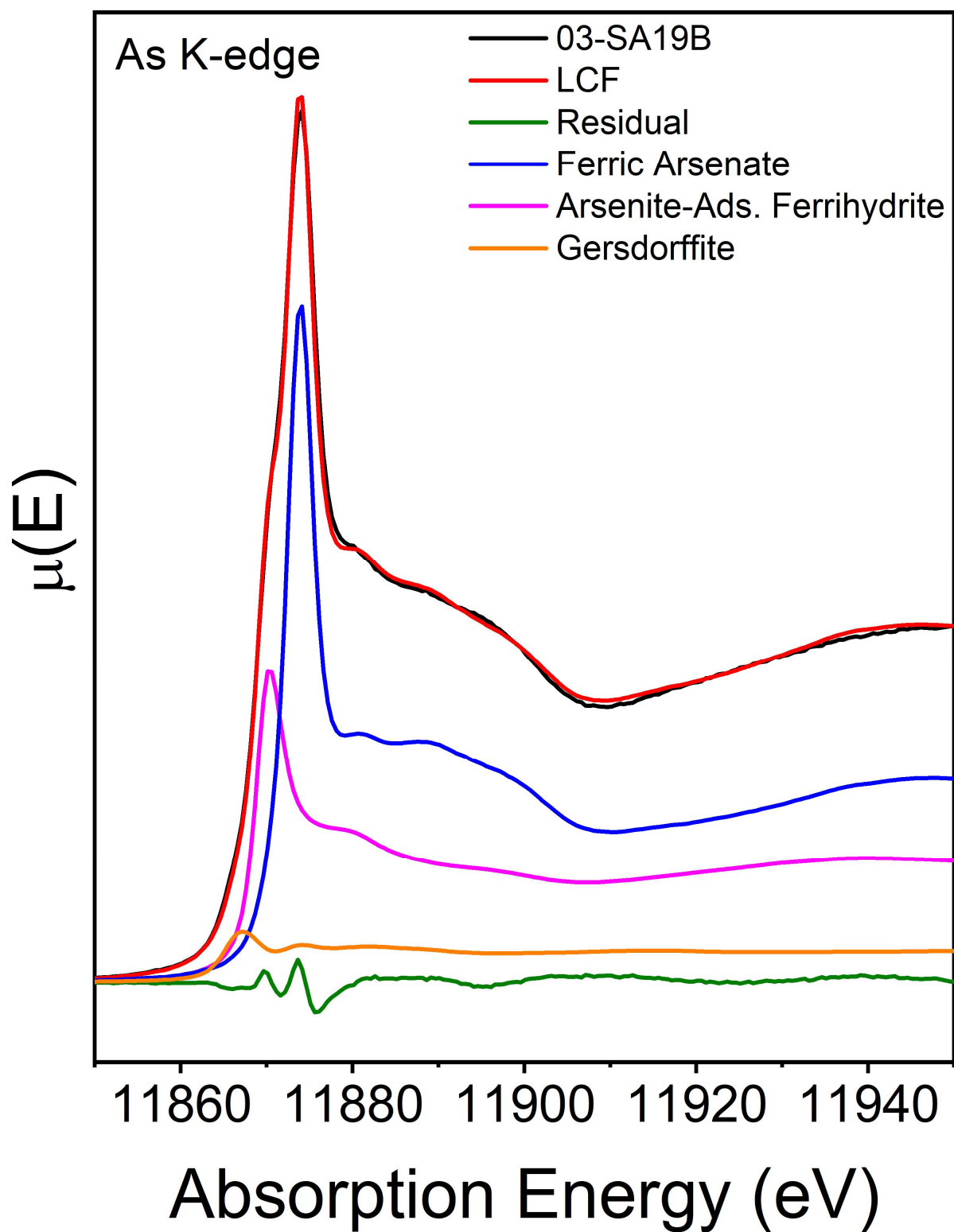


Figure 6.46. As K-edge XANES spectrum of **03-SA19B** showing the component spectra and final fit with residual.

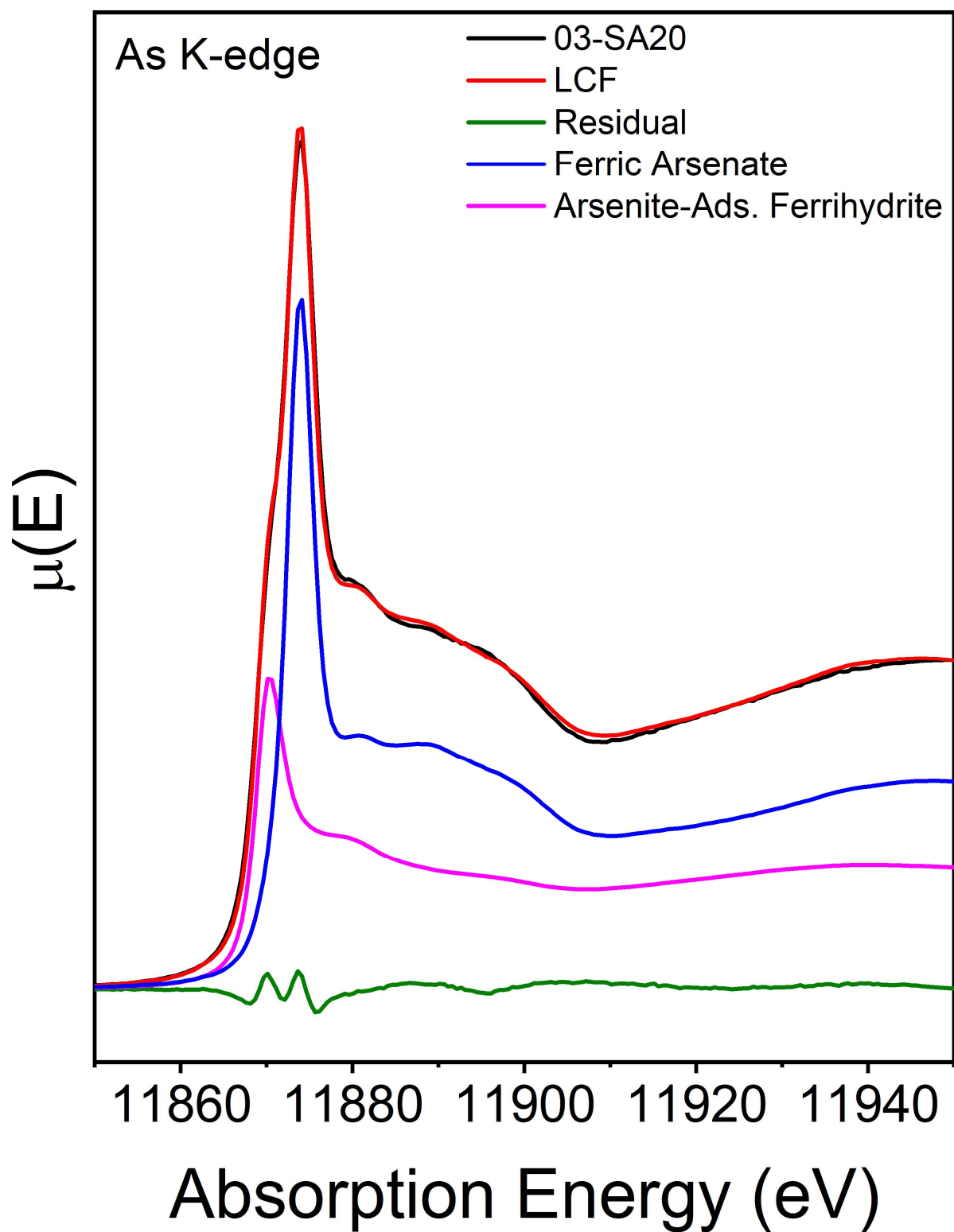


Figure 6.47. As K-edge XANES spectrum of **03-SA20** showing the component spectra and final fit with residual.

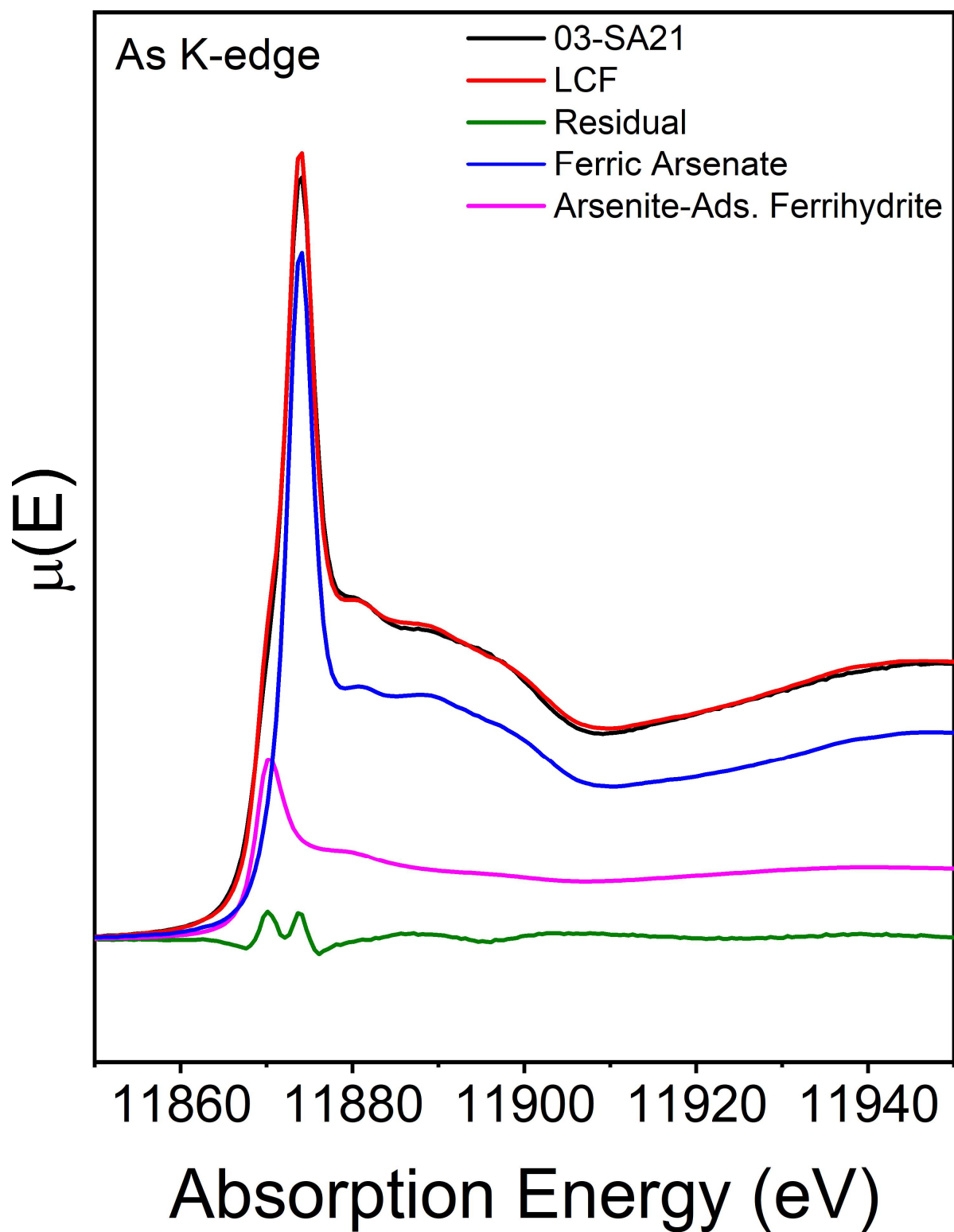


Figure 6.48. As K-edge XANES spectrum of **03-SA21** showing the component spectra and final fit with residual.

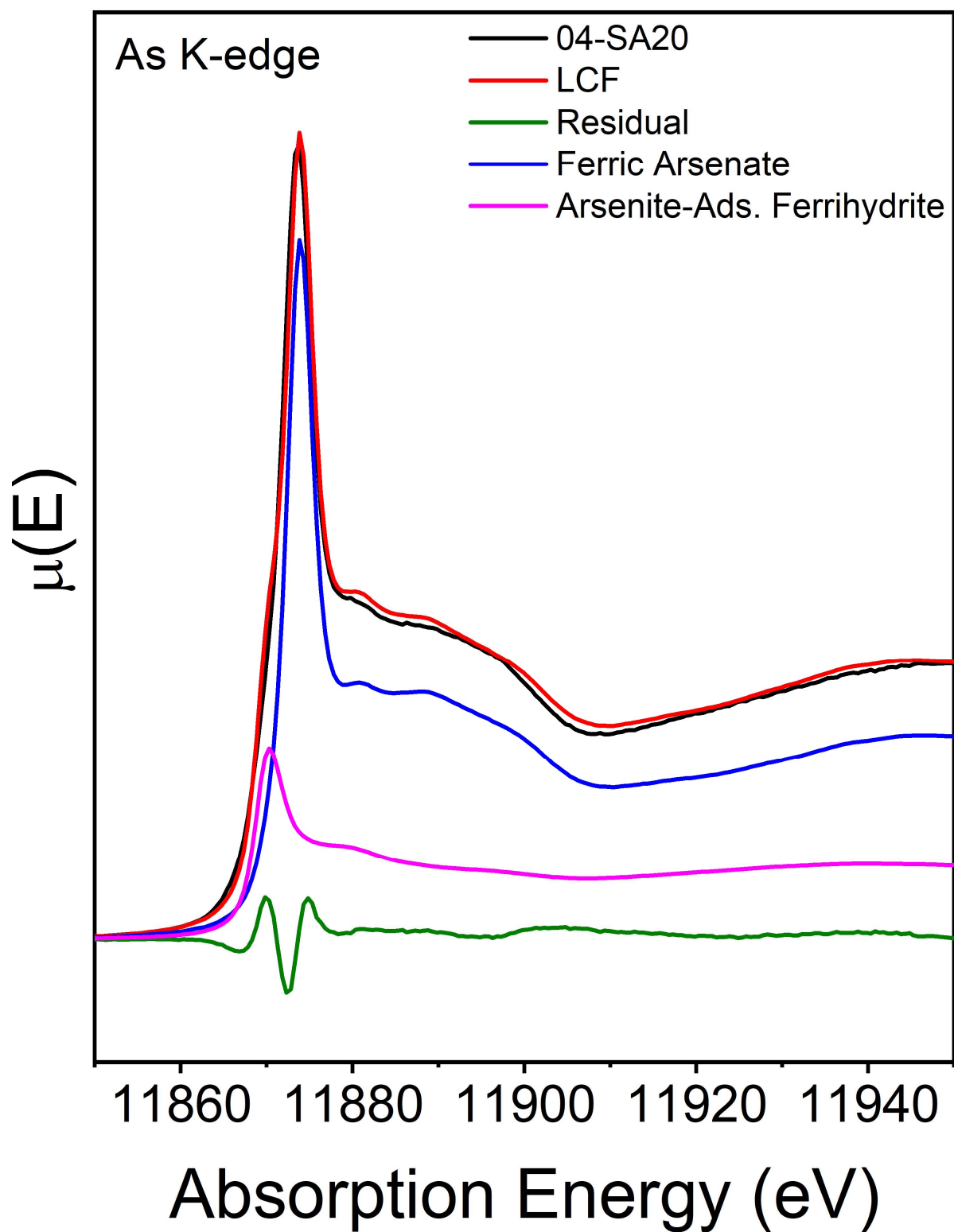


Figure 6.49. As K-edge XANES spectrum of **04-SA20** showing the component spectra and final fit with residual.

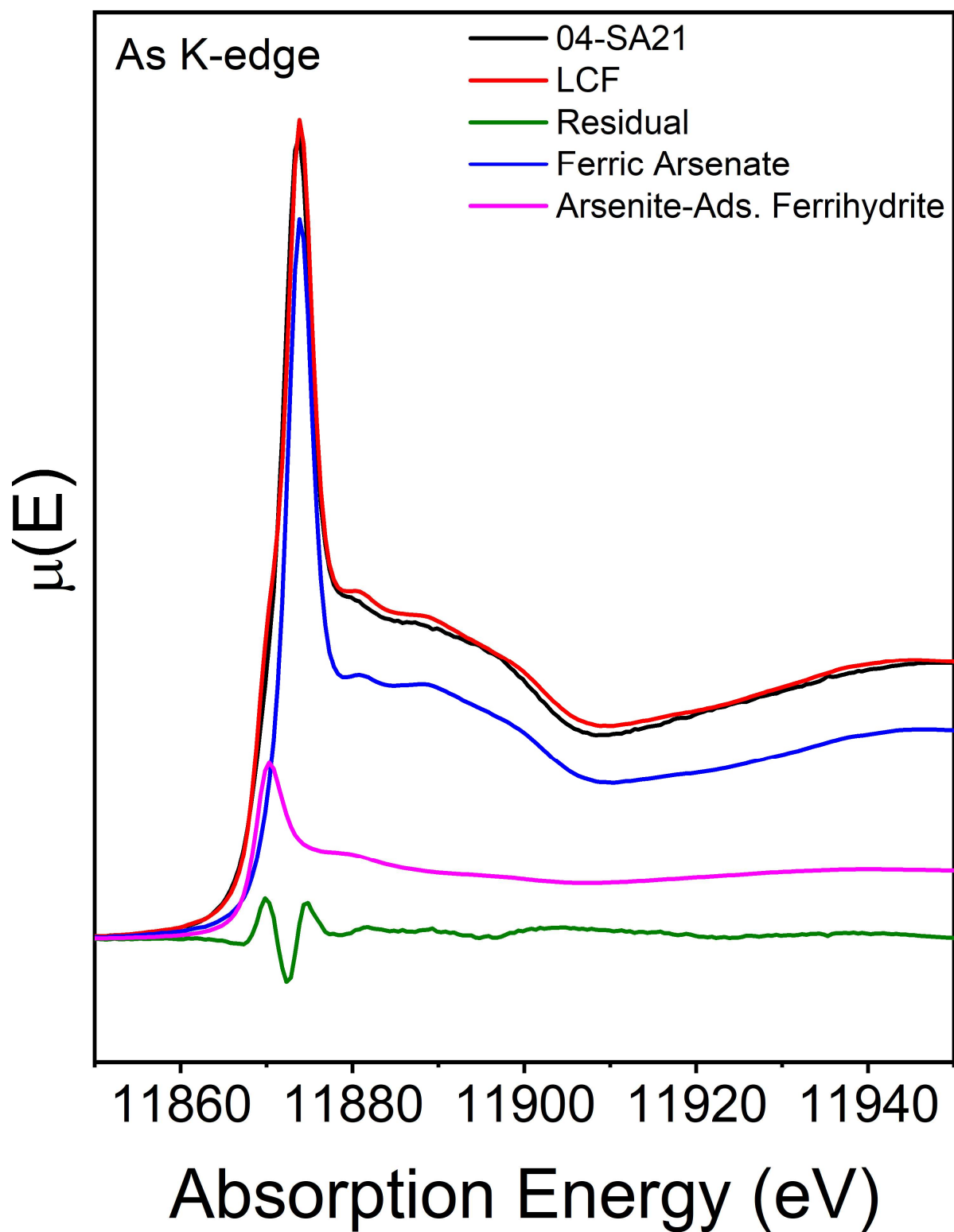


Figure 6.50. As K-edge XANES spectrum of **04-SA21** showing the component spectra and final fit with residual.

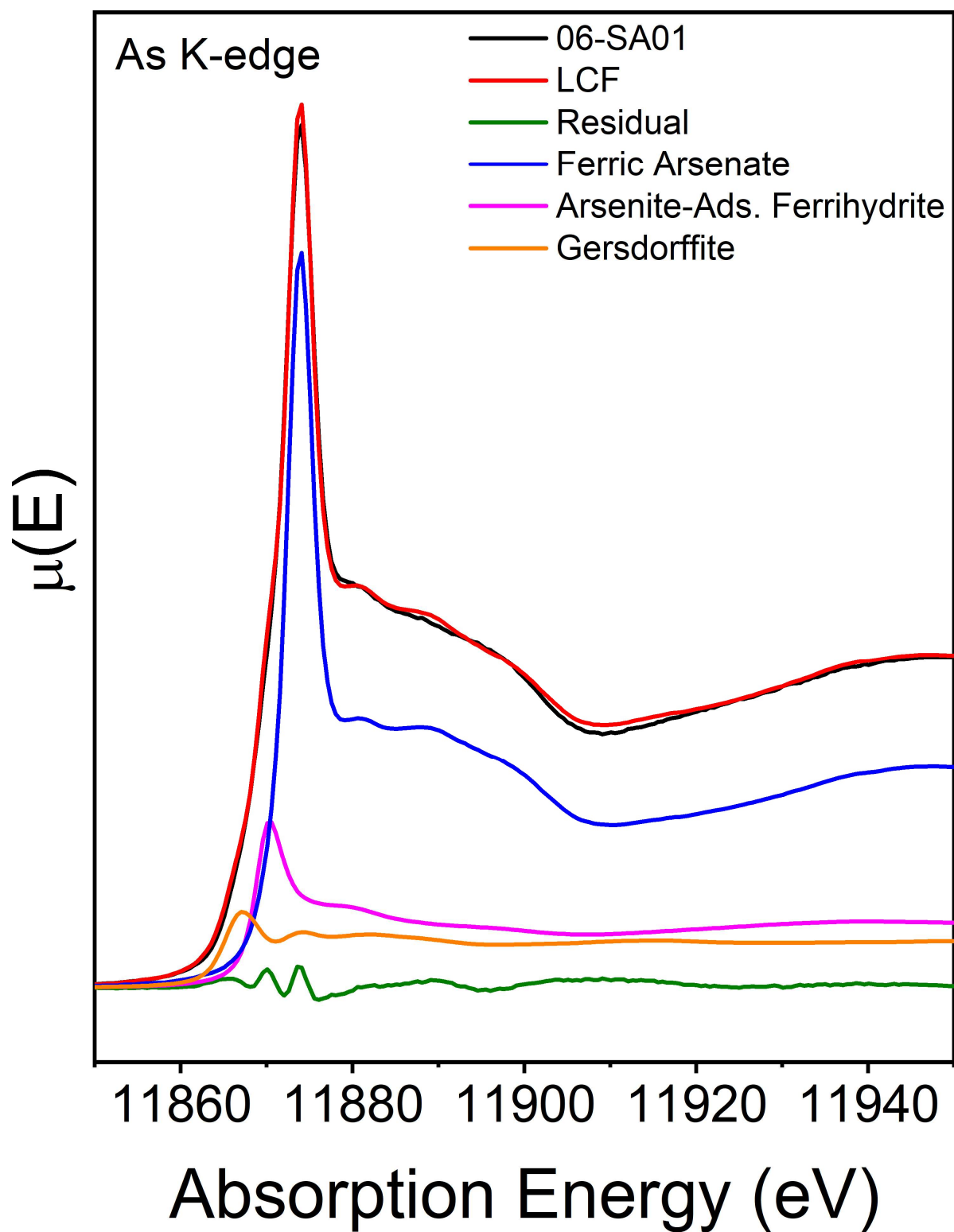


Figure 6.51. As K-edge XANES spectrum of **06-SA01** showing the component spectra and final fit with residual.

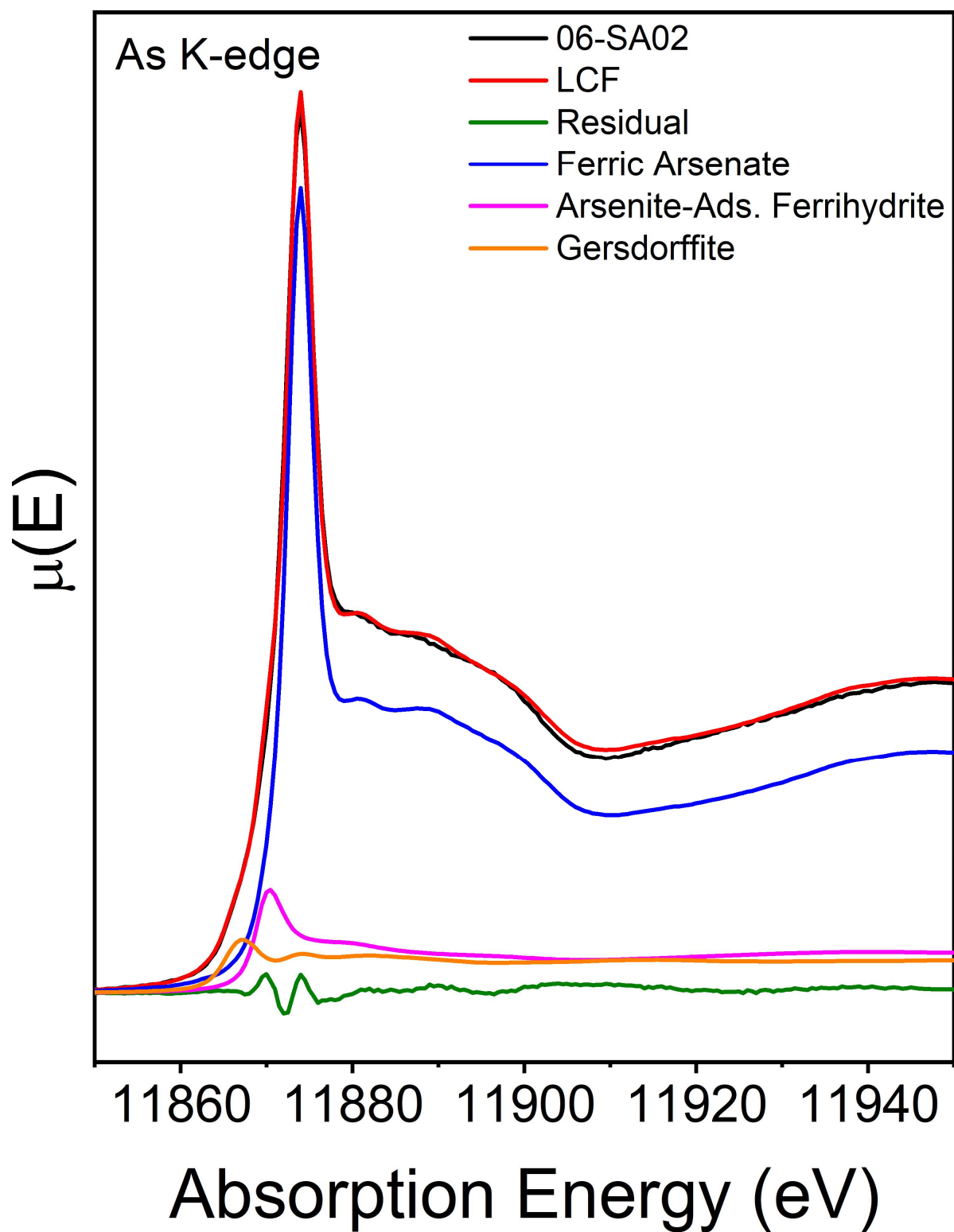


Figure 6.52. As K-edge XANES spectrum of **06-SA02** showing the component spectra and final fit with residual.

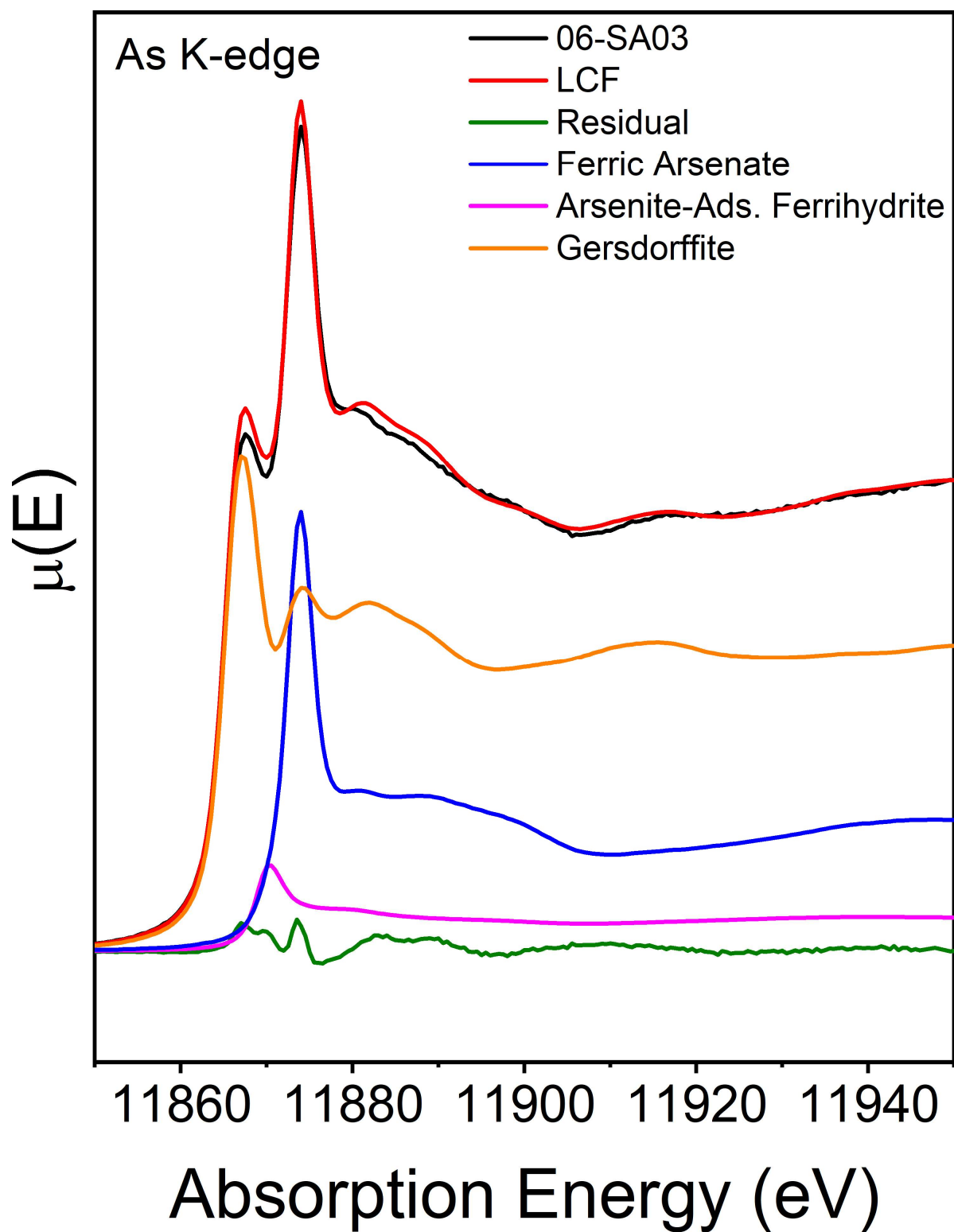


Figure 6.53. As K-edge XANES spectrum of **06-SA03** showing the component spectra and final fit with residual.

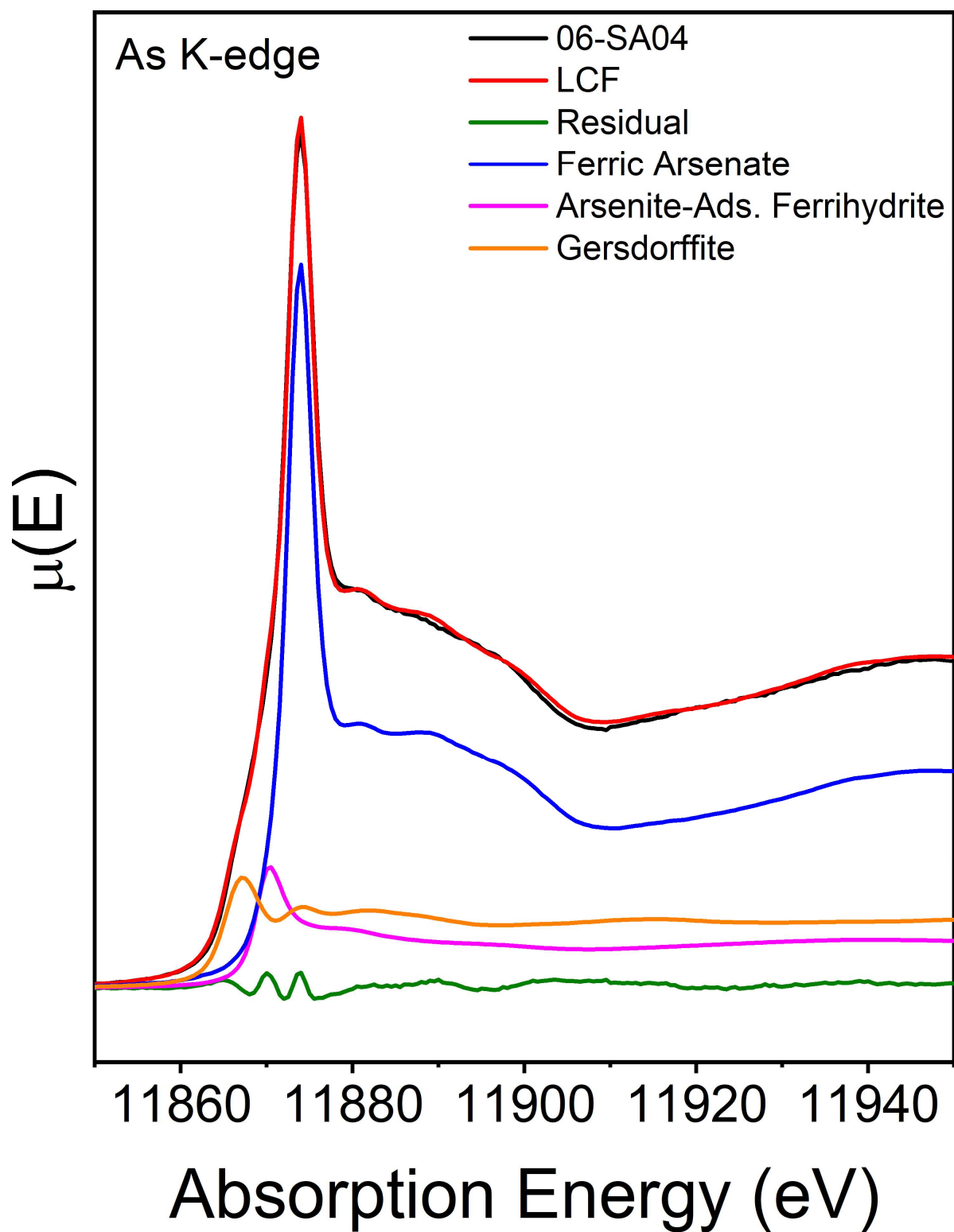


Figure 6.54. As K-edge XANES spectrum of **06-SA04** showing the component spectra and final fit with residual.

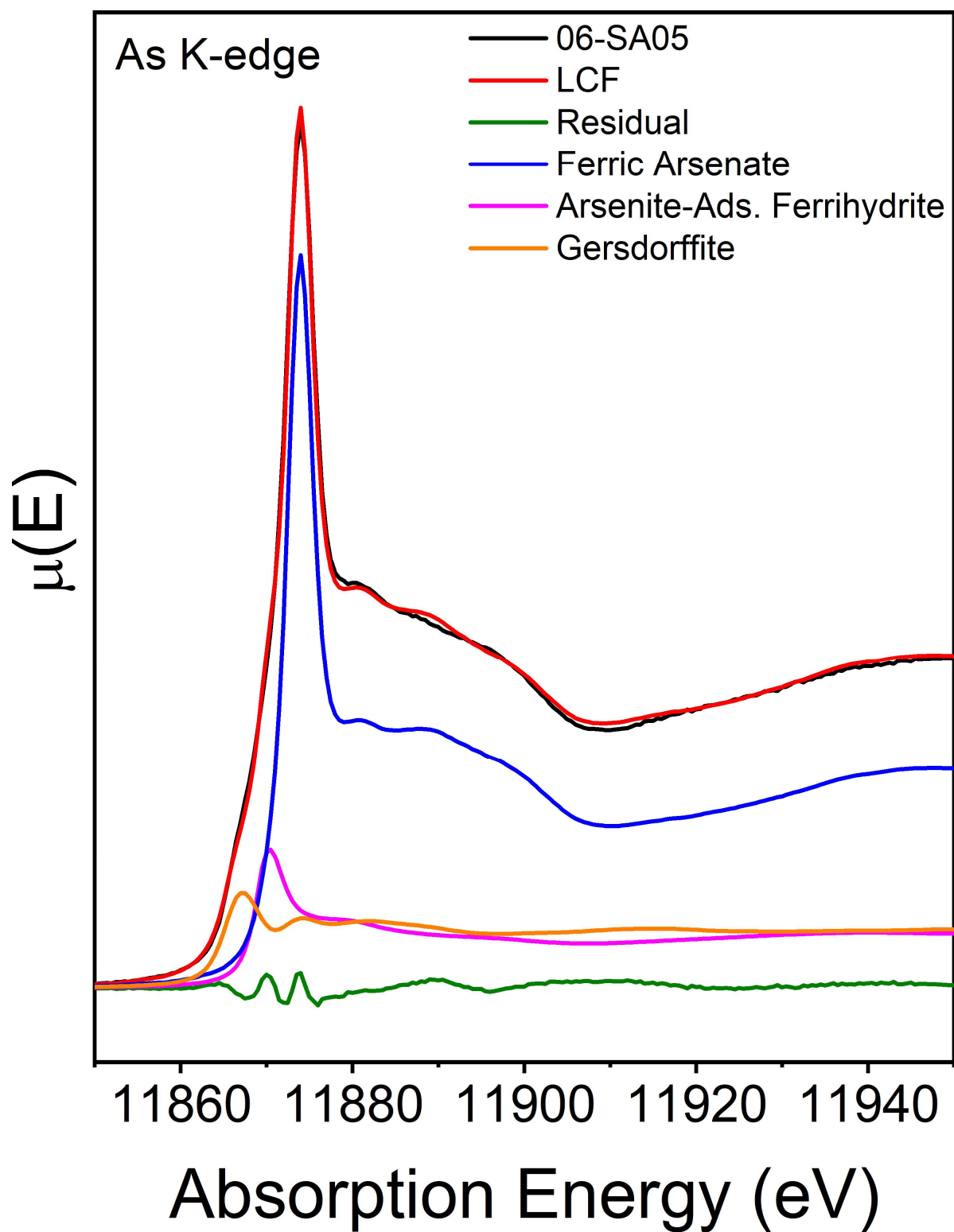


Figure 6.55. As K-edge XANES spectrum of **06-SA05** showing the component spectra and final fit with residual.

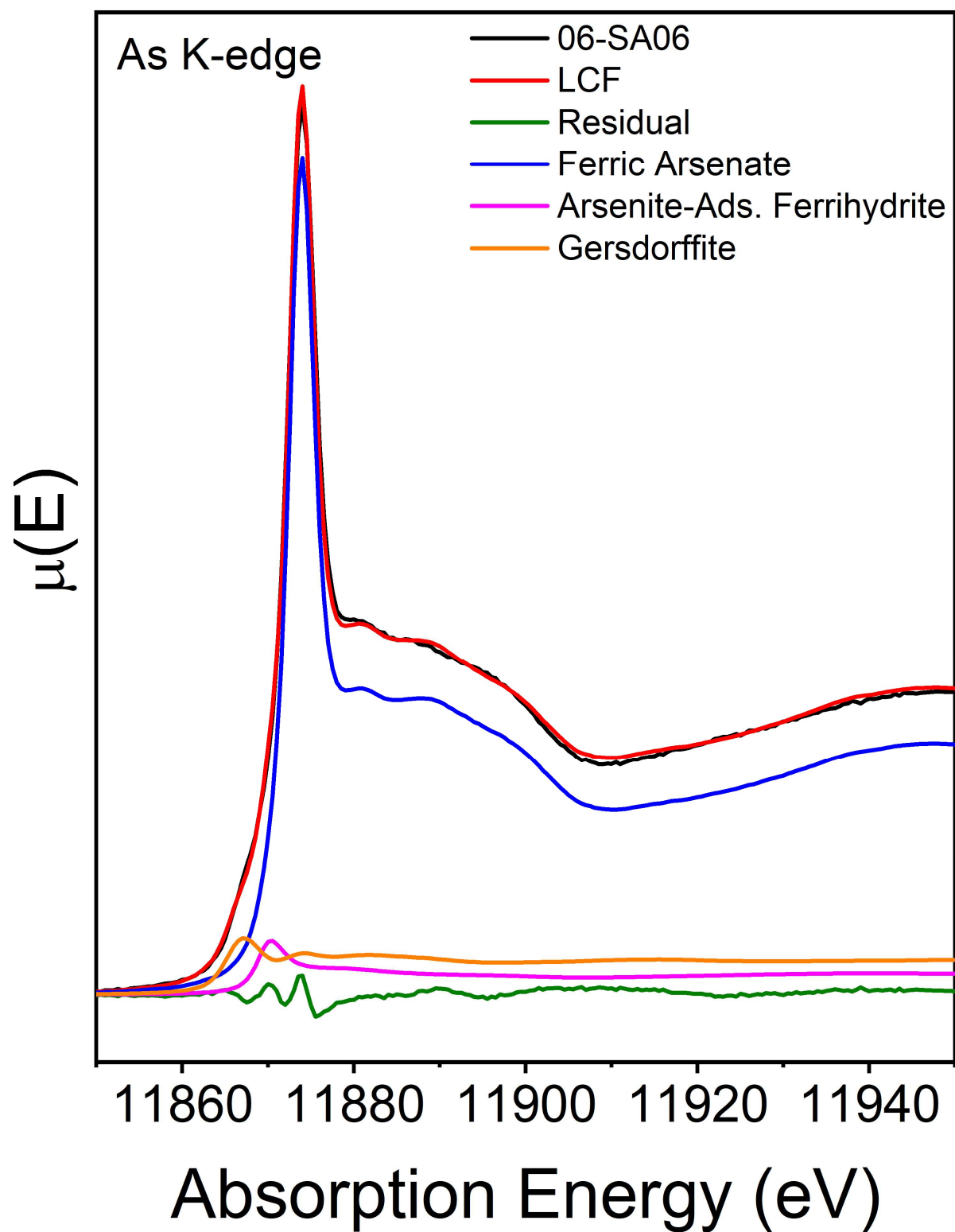


Figure 6.56. As K-edge XANES spectrum of **06-SA06** showing the component spectra and final fit with residual.

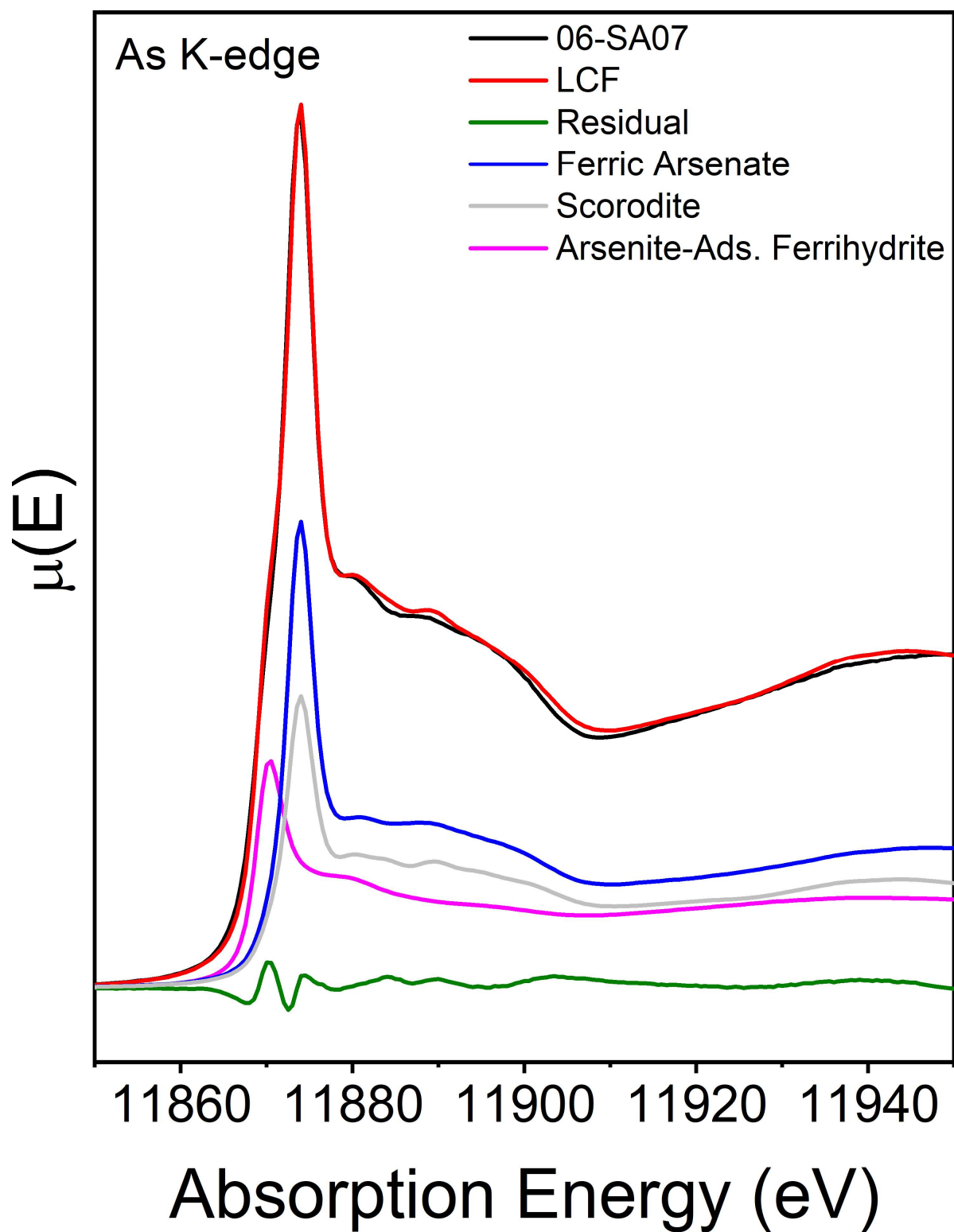


Figure 6.57. As K-edge XANES spectrum of **06-SA07** showing the component spectra and final fit with residual.

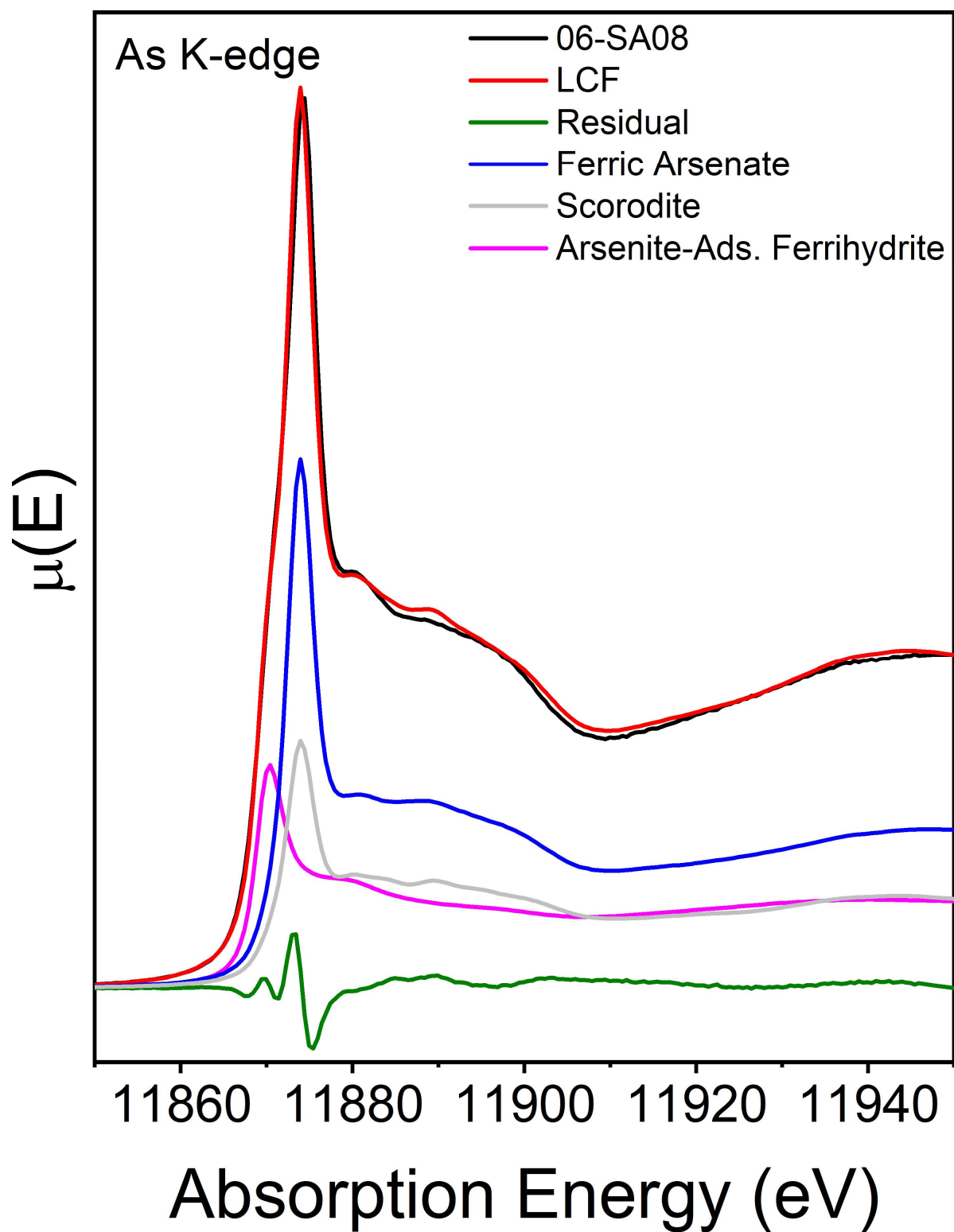


Figure 6.58. As K-edge XANES spectrum of **06-SA08** showing the component spectra and final fit with residual.

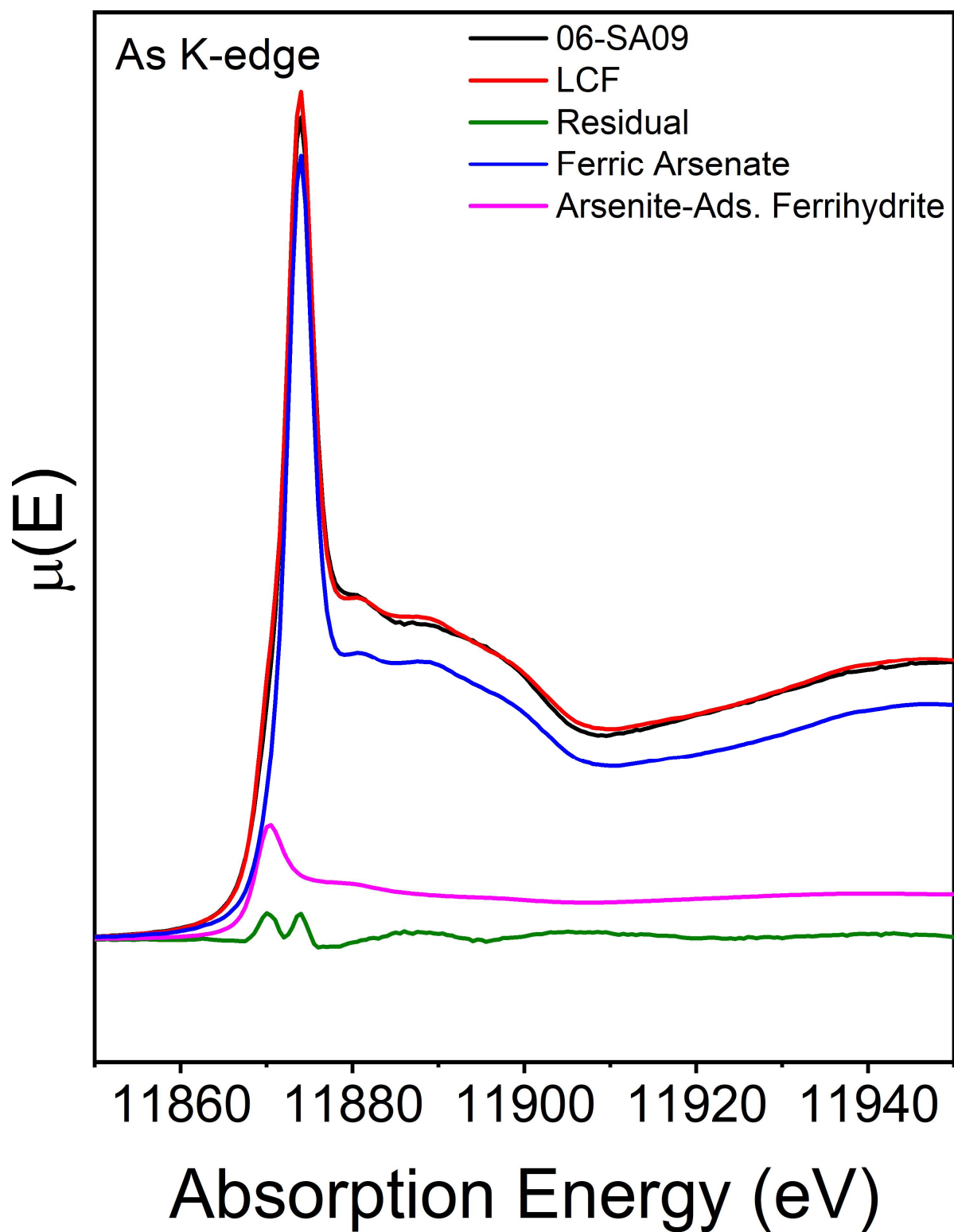


Figure 6.59. As K-edge XANES spectrum of **06-SA09** showing the component spectra and final fit with residual.

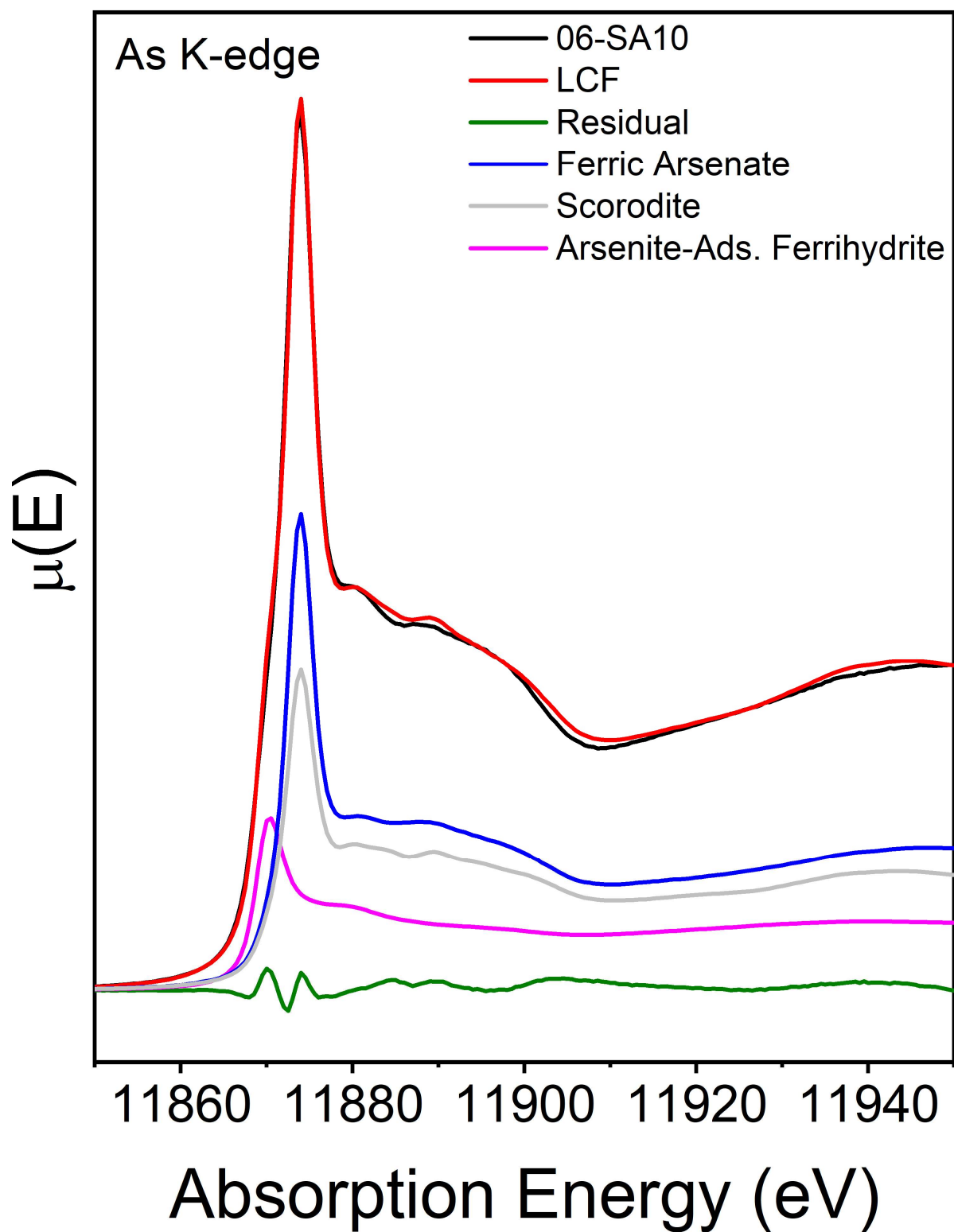


Figure 6.60. As K-edge XANES spectrum of **06-SA10** showing the component spectra and final fit with residual.

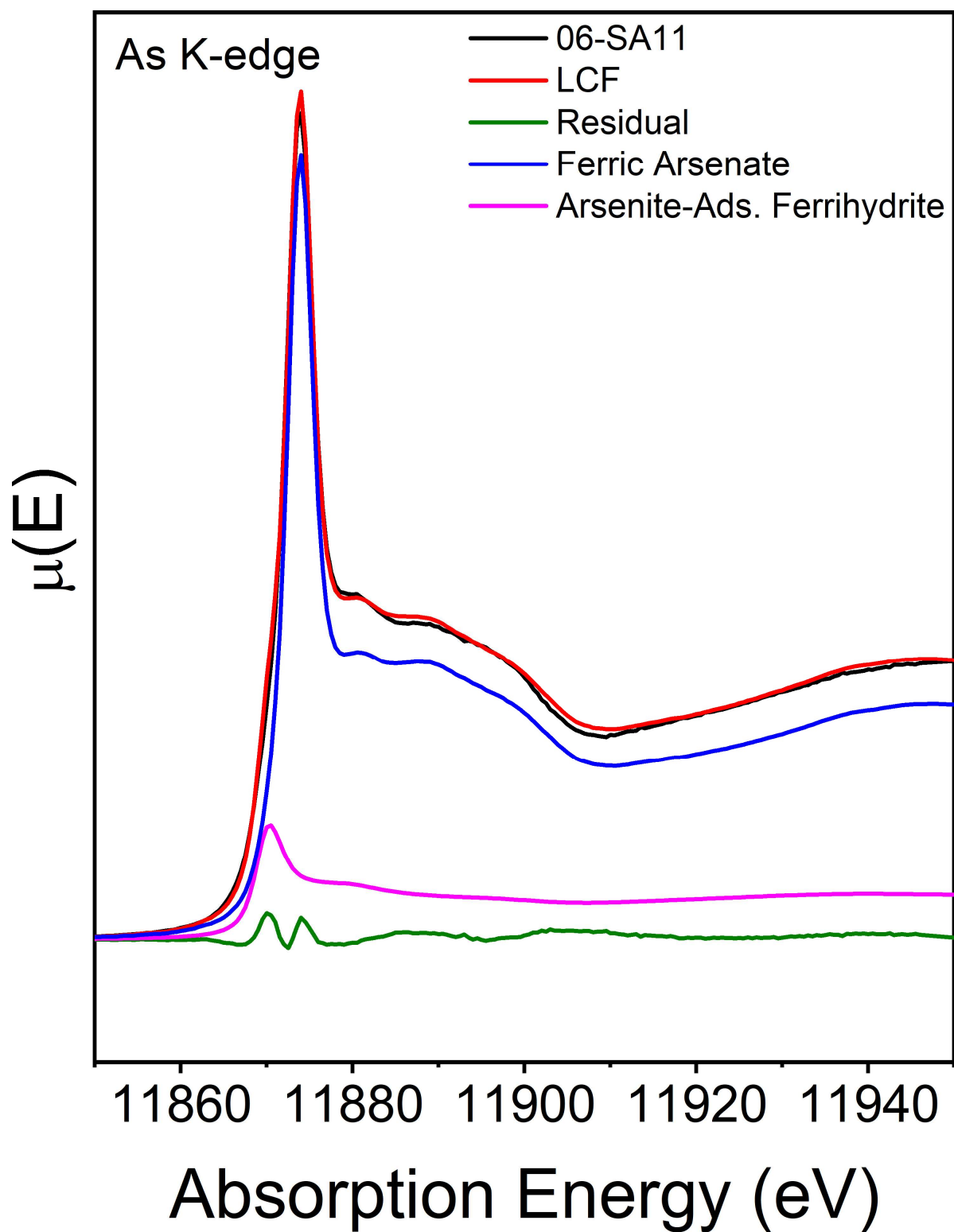


Figure 6.61. As K-edge XANES spectrum of **06-SA11** showing the component spectra and final fit with residual.

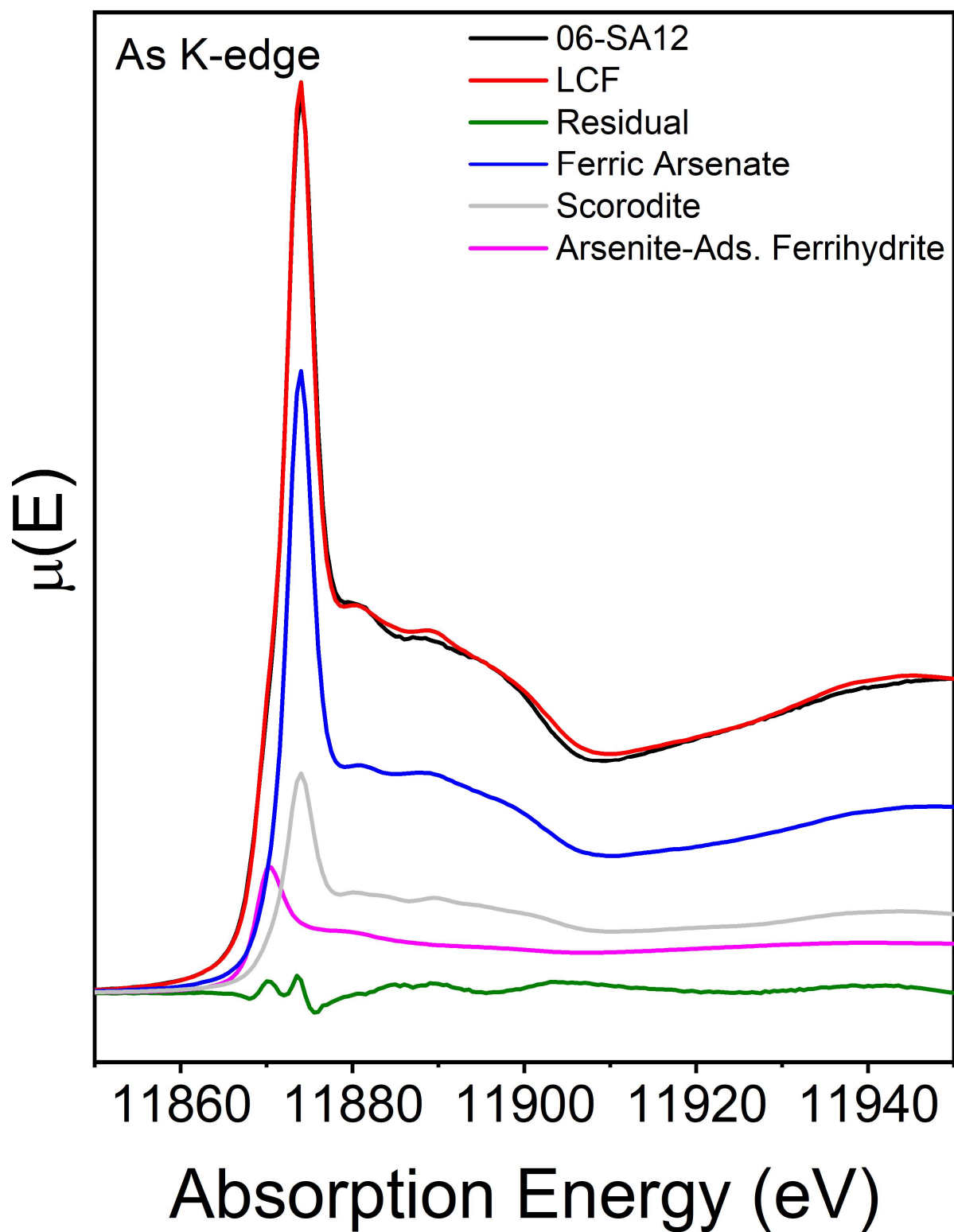


Figure 6.62. As K-edge XANES spectrum of **06-SA12** showing the component spectra and final fit with residual.

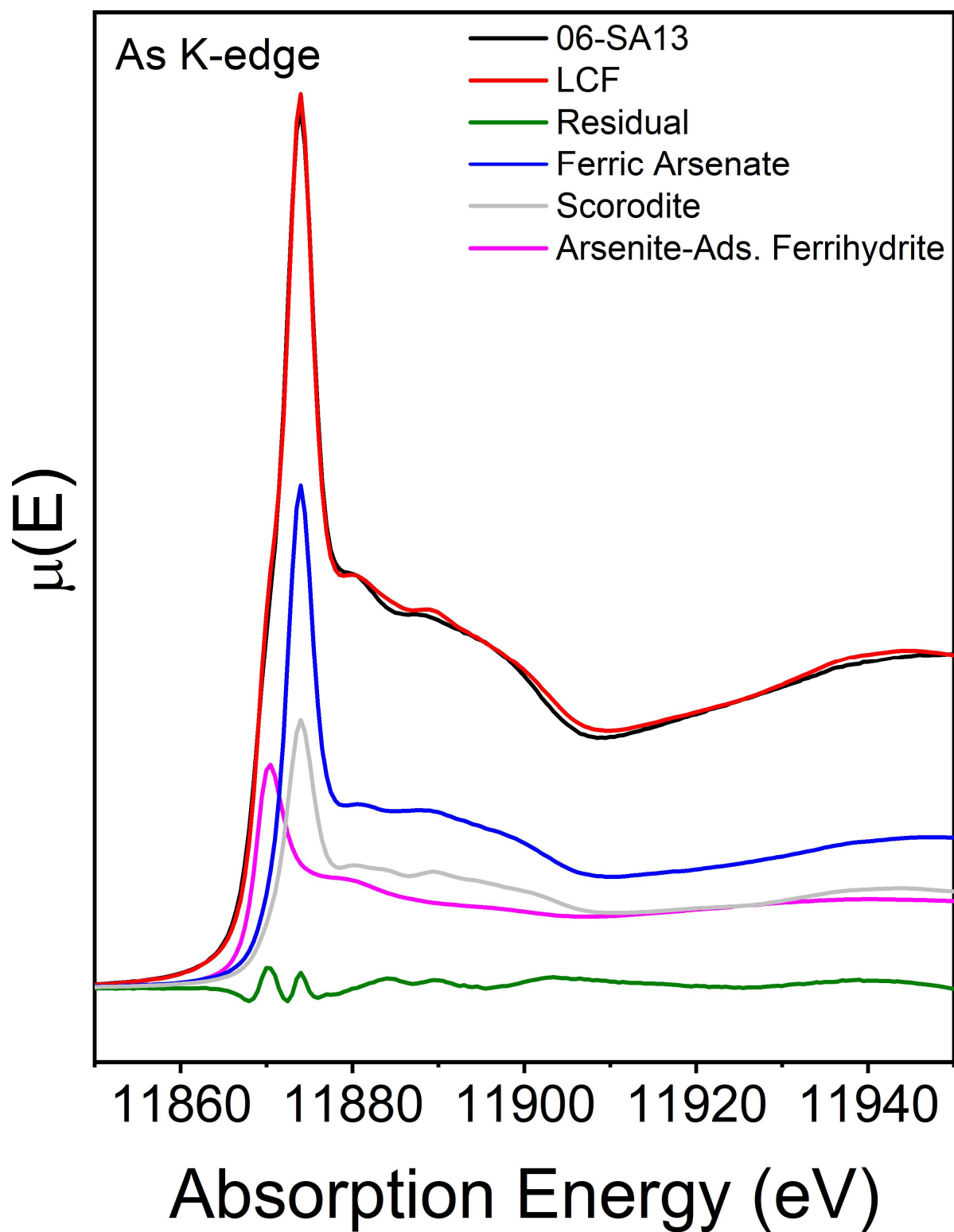


Figure 6.63. As K-edge XANES spectrum of **06-SA13** showing the component spectra and final fit with residual.

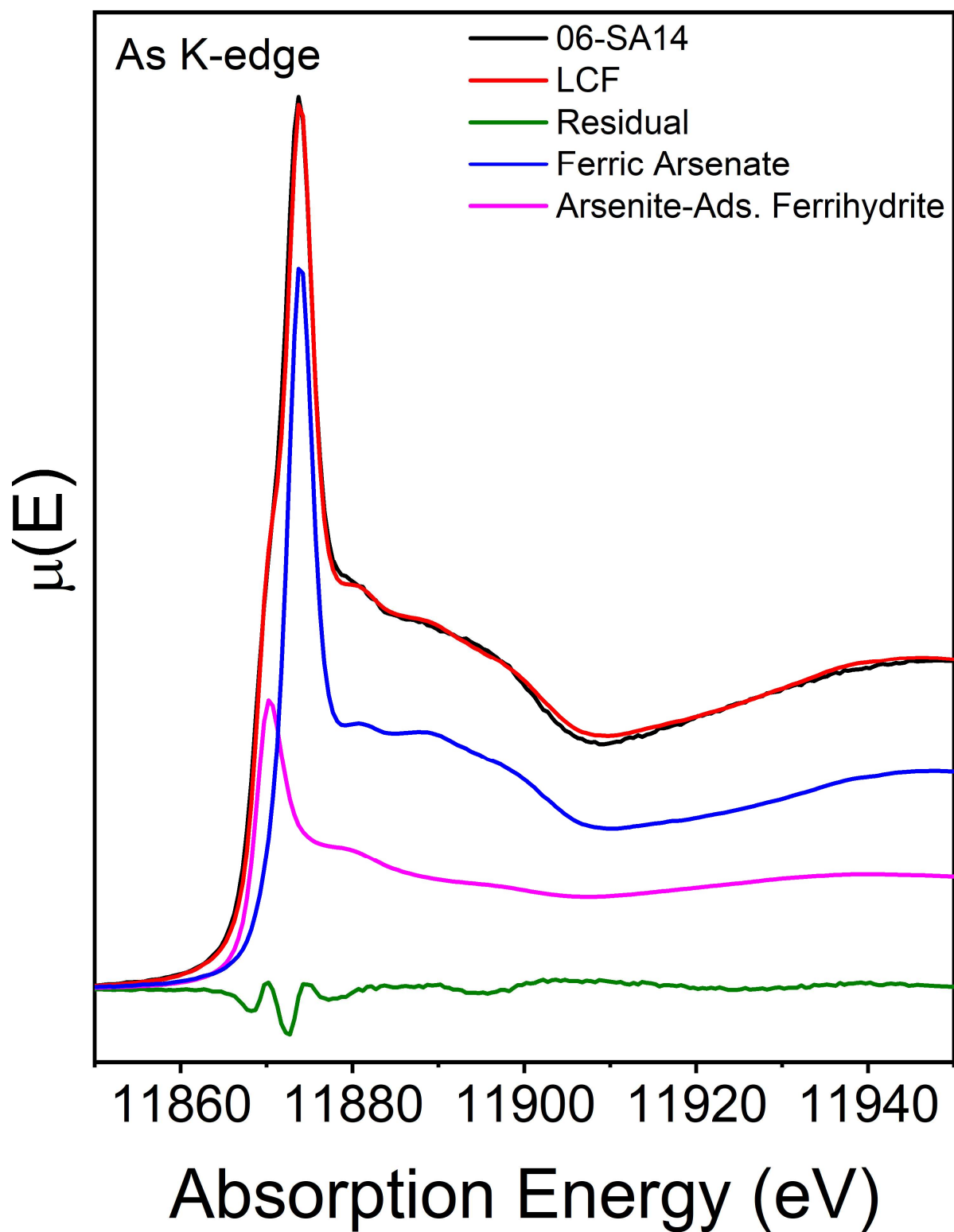


Figure 6.64. As K-edge XANES spectrum of **06-SA14** showing the component spectra and final fit with residual.

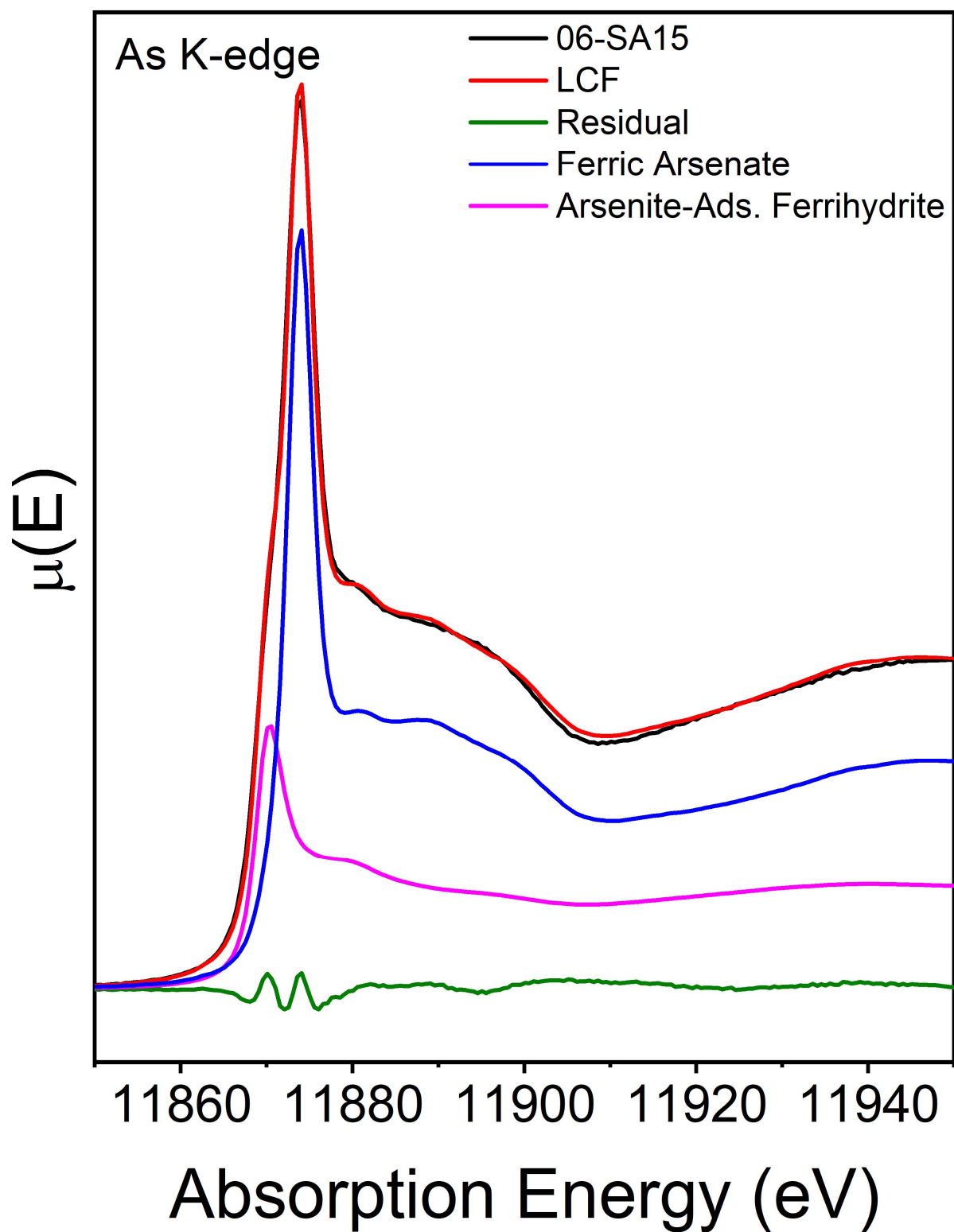


Figure 6.65. As K-edge XANES spectrum of **06-SA15** showing the component spectra and final fit with residual.

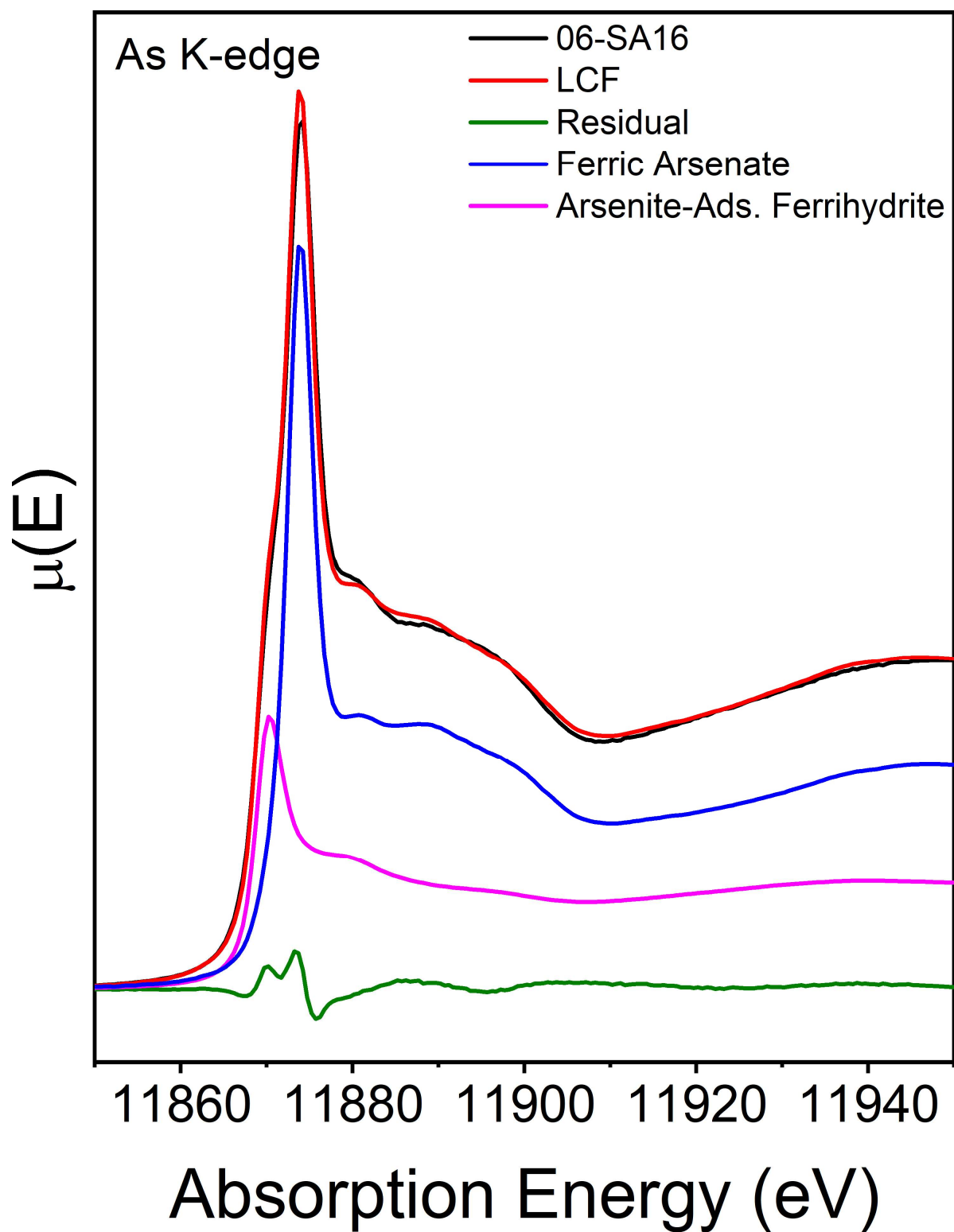


Figure 6.66. As K-edge XANES spectrum of **06-SA16** showing the component spectra and final fit with residual.

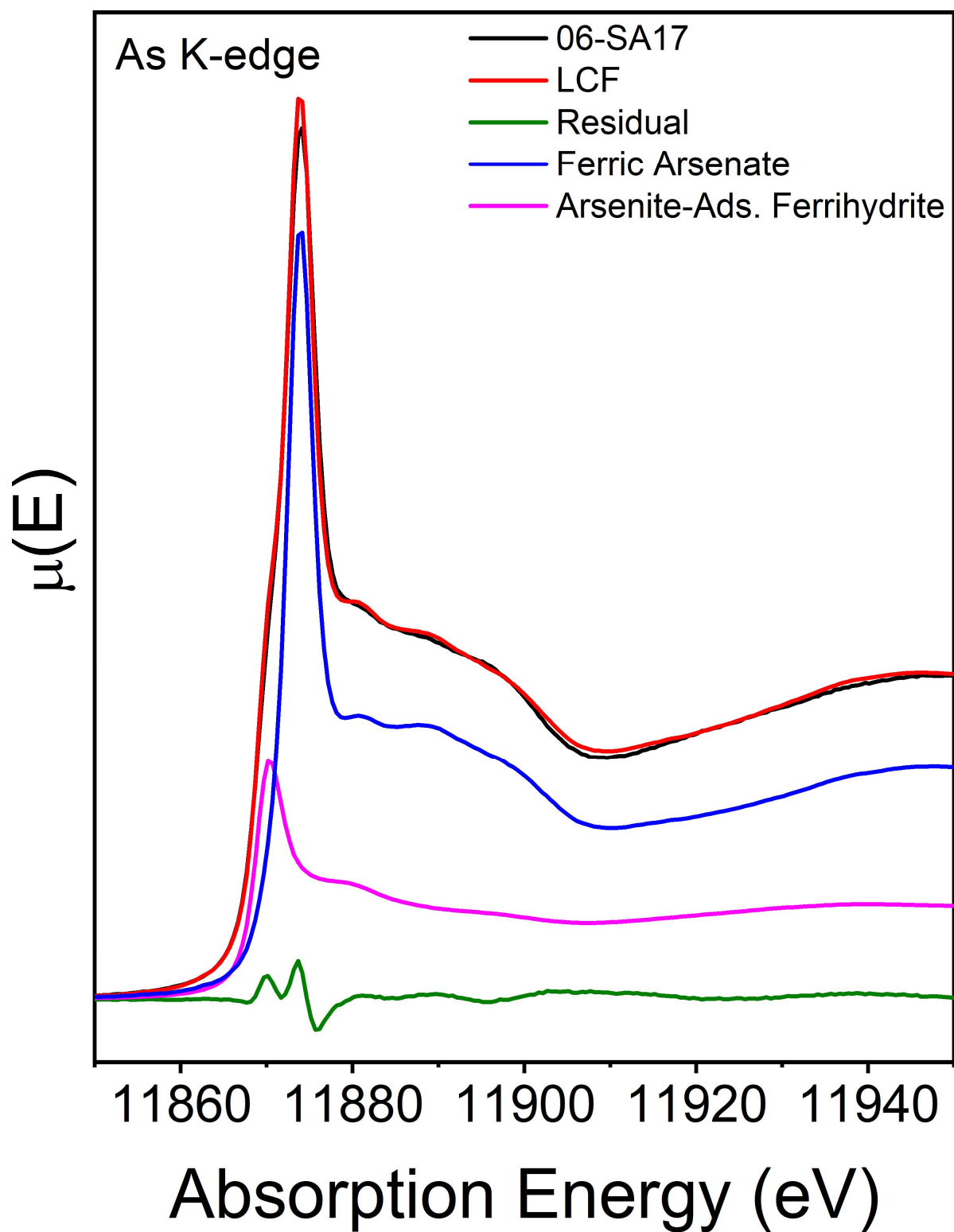


Figure 6.67. As K-edge XANES spectrum of **06-SA17** showing the component spectra and final fit with residual.

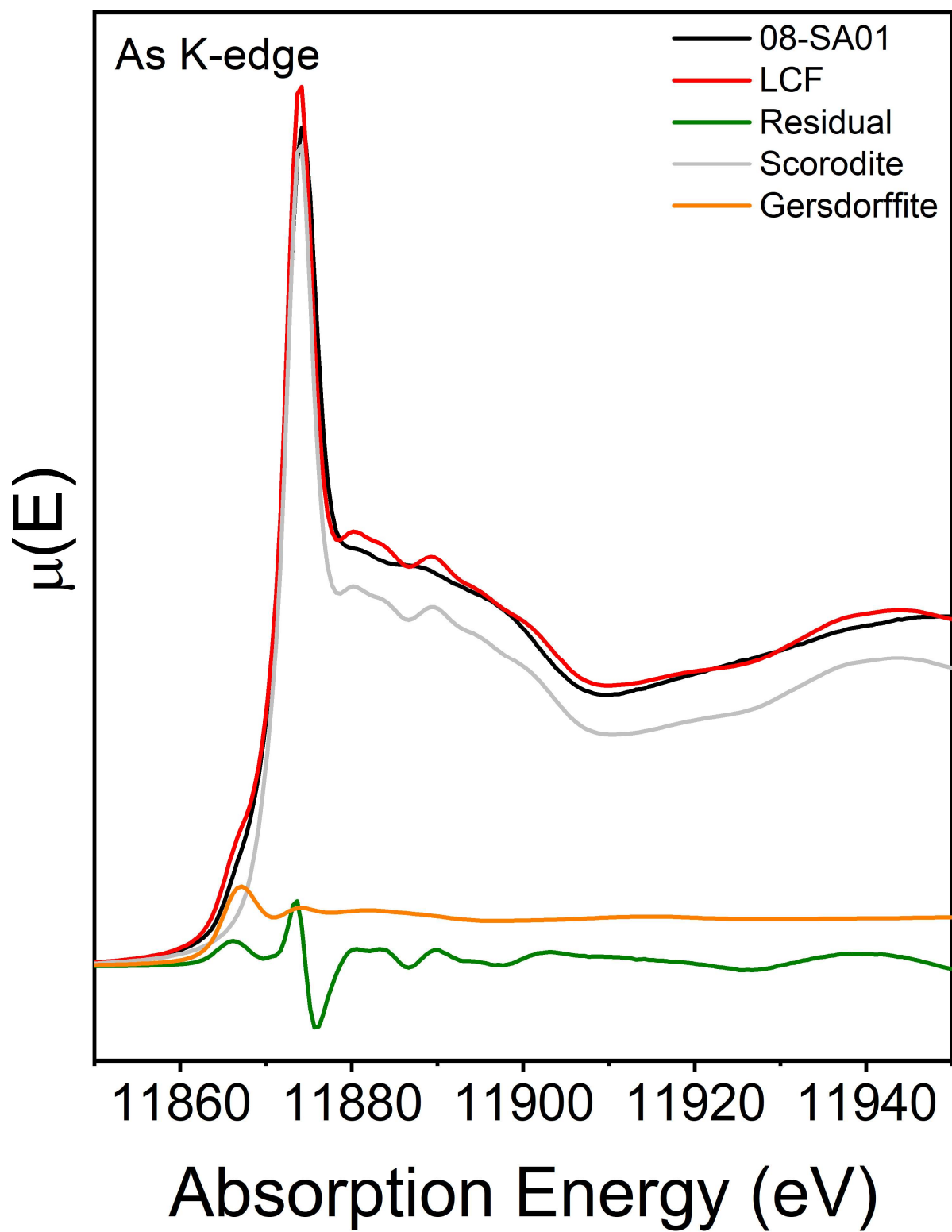


Figure 6.68. As K-edge XANES spectrum of **08-SA01** showing the component spectra and final fit with residual.

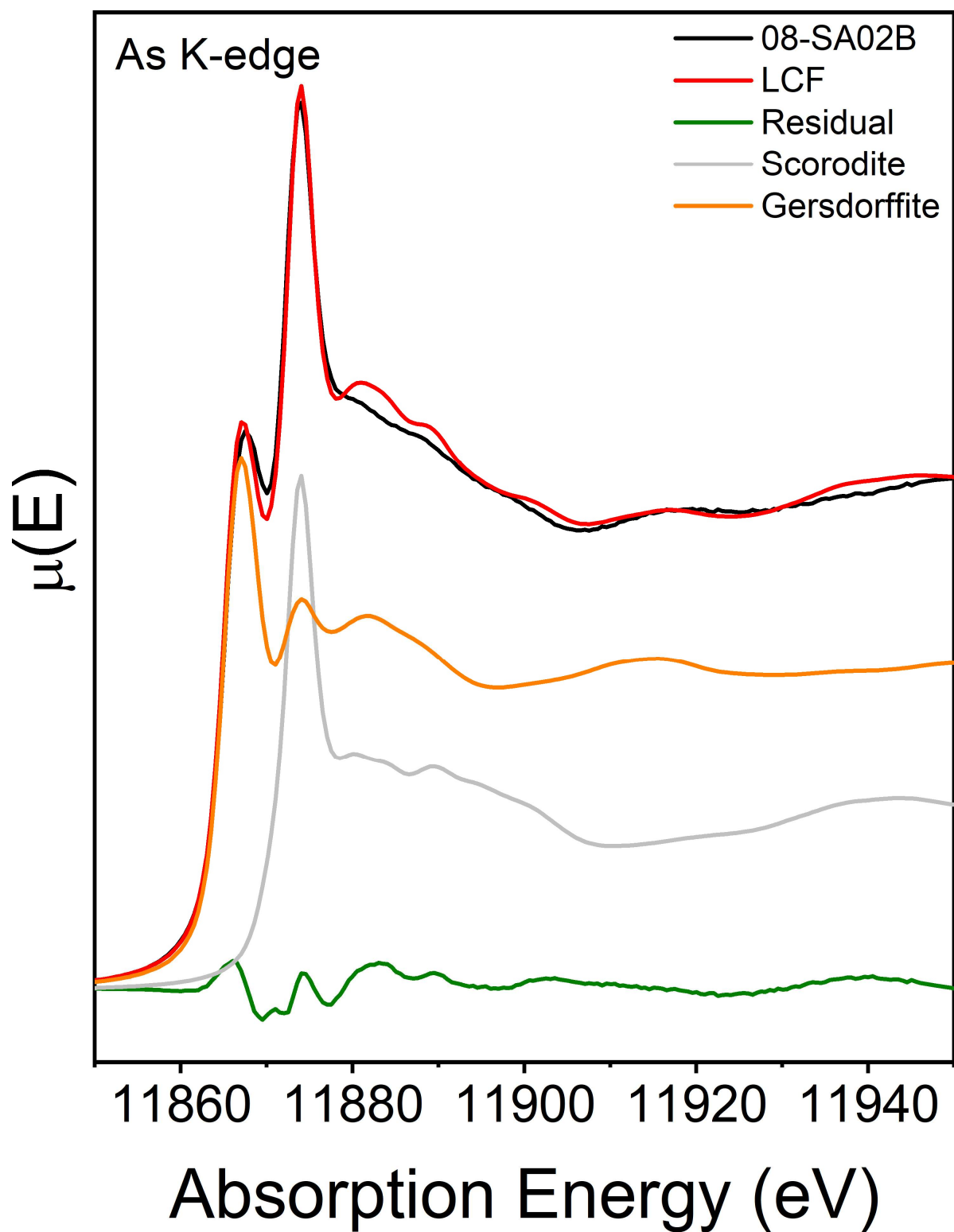


Figure 6.69. As K-edge XANES spectrum of **08-SA02B** showing the component spectra and final fit with residual.

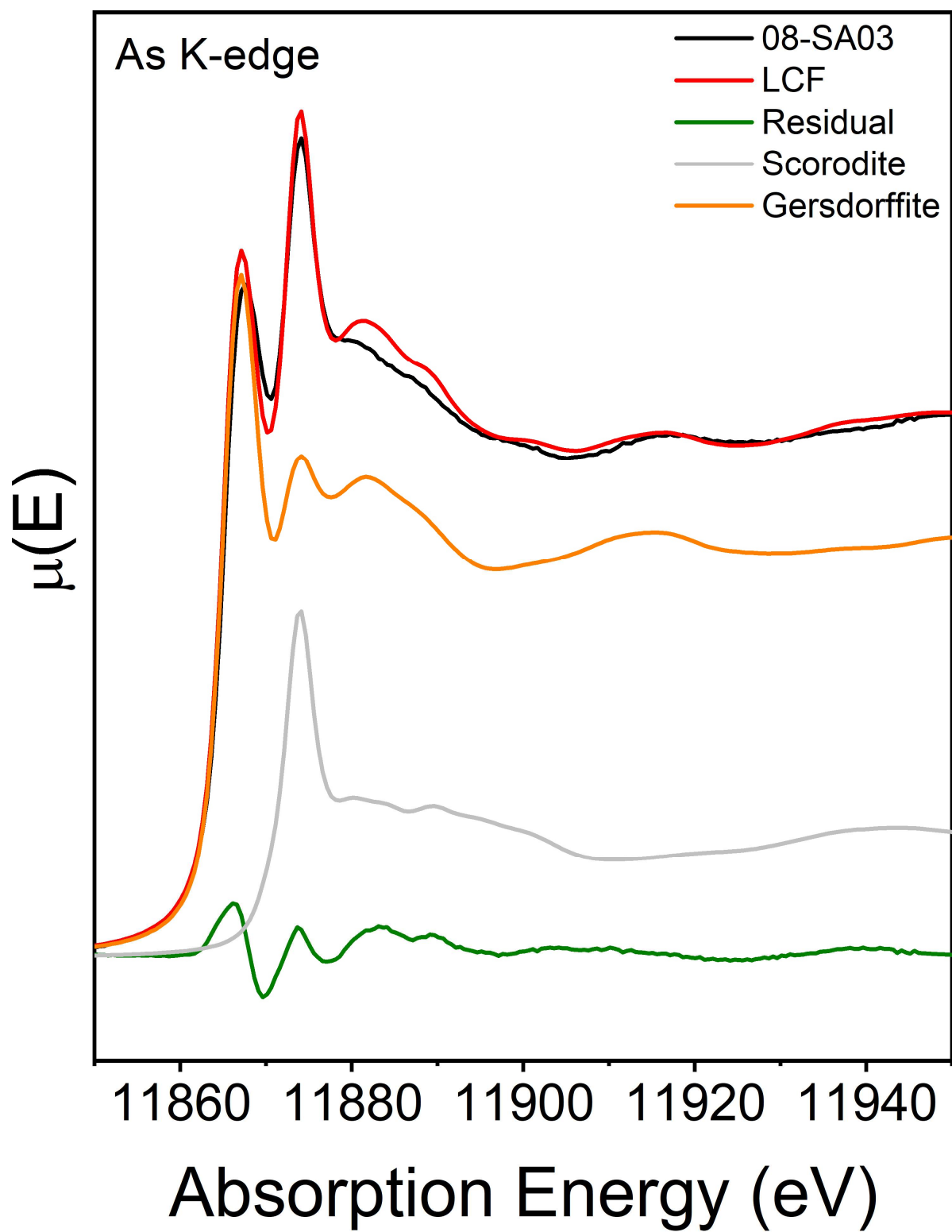


Figure 6.70. As K-edge XANES spectrum of **08-SA03** showing the component spectra and final fit with residual.

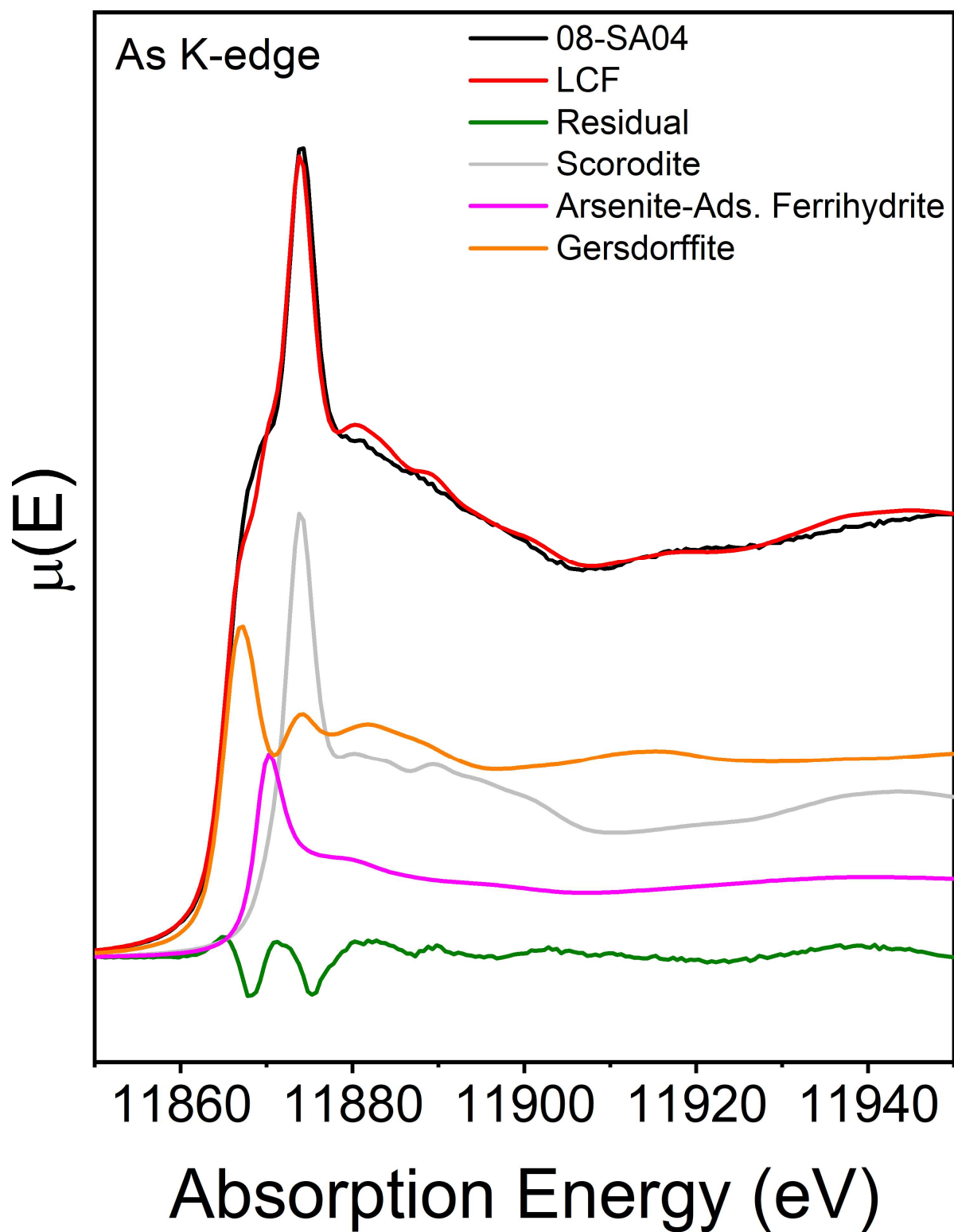


Figure 6.71. As K-edge XANES spectrum of **08-SA04** showing the component spectra and final fit with residual.

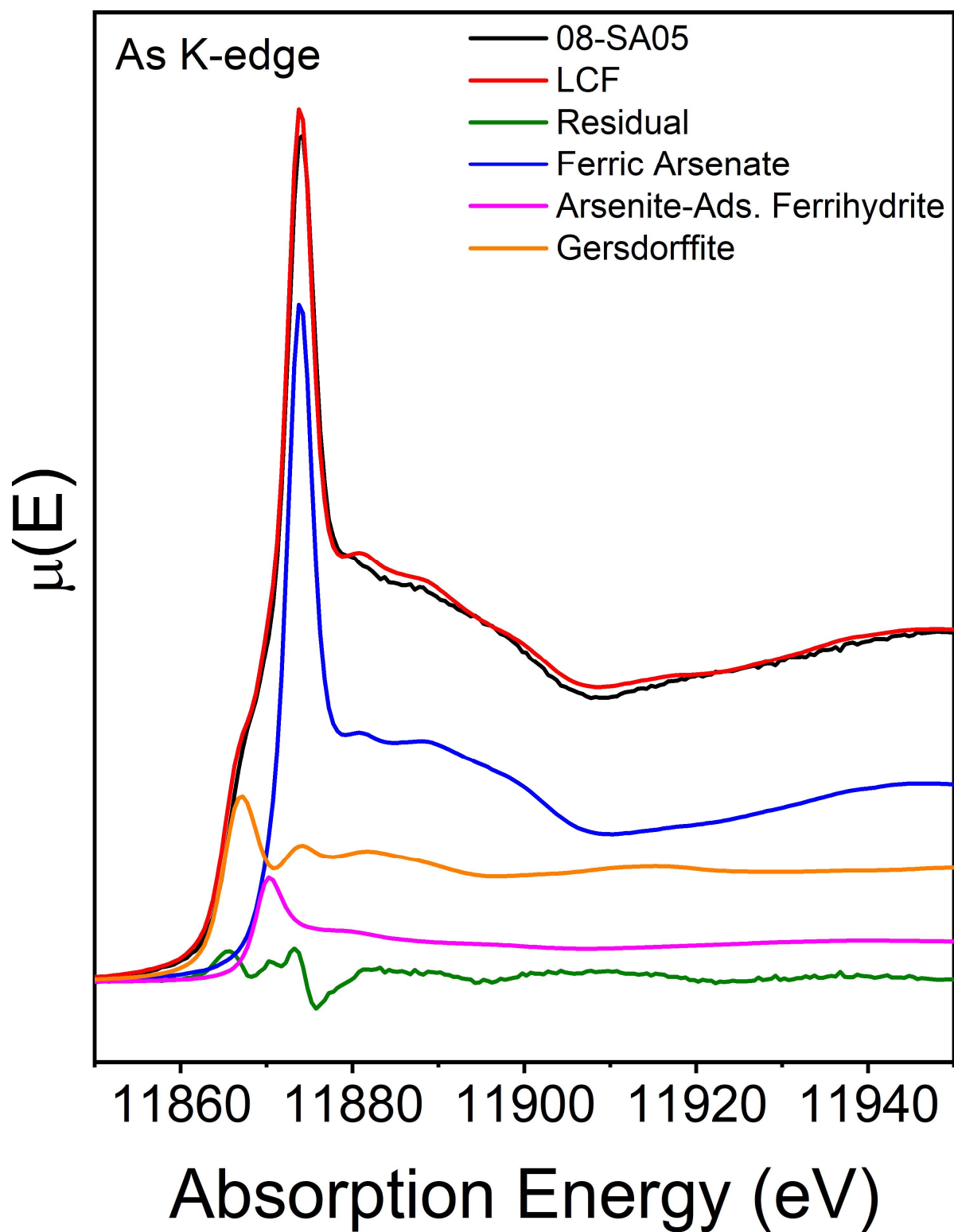


Figure 6.72. As K-edge XANES spectrum of **08-SA05** showing the component spectra and final fit with residual.

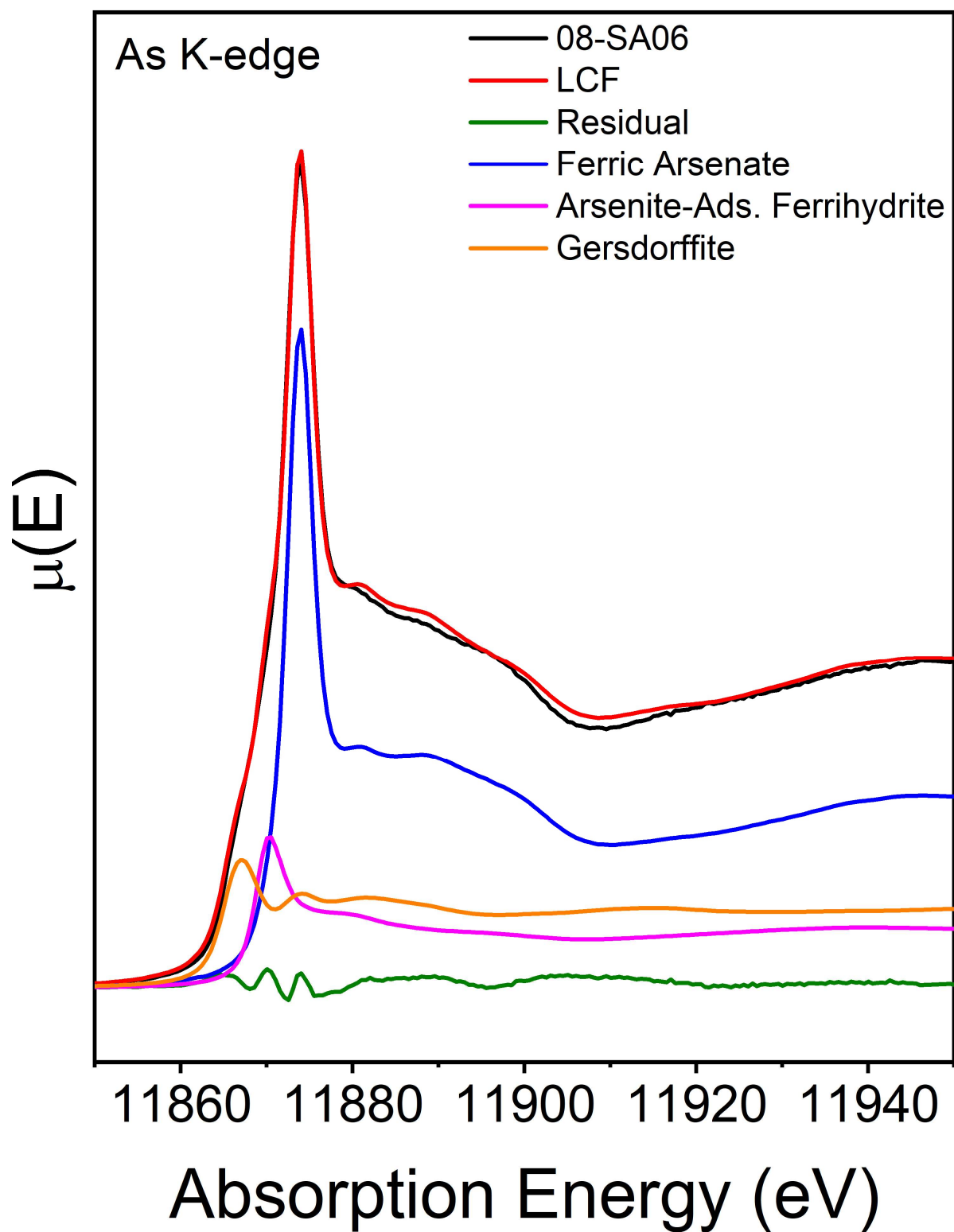


Figure 6.73. As K-edge XANES spectrum of **08-SA06** showing the component spectra and final fit with residual.

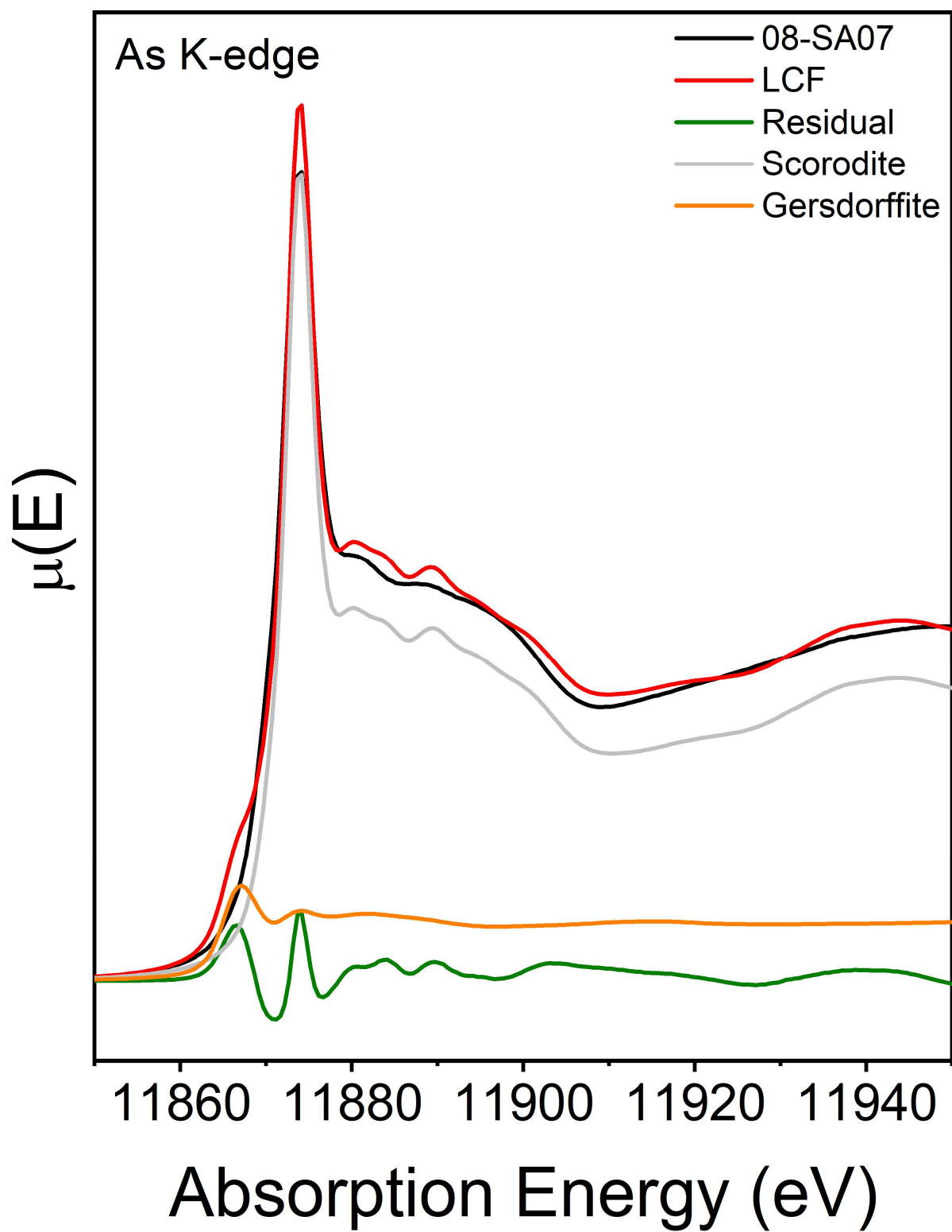


Figure 6.74. As K-edge XANES spectrum of **08-SA07** showing the component spectra and final fit with residual.

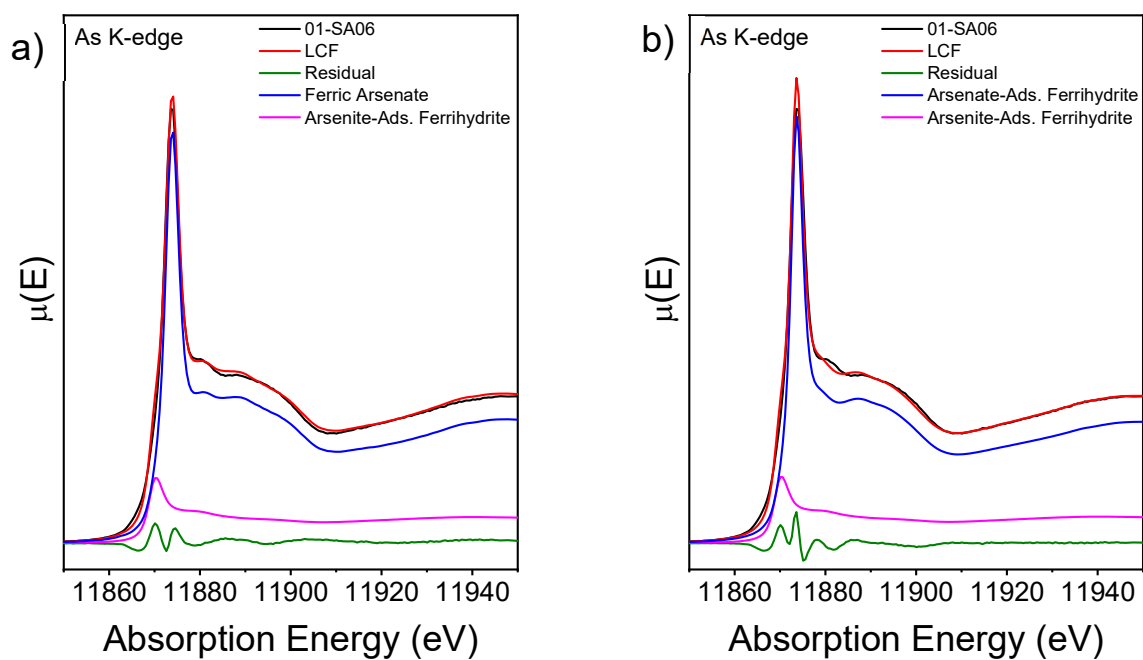


Figure 6.75. As K-edge XANES spectrum of **01-SA06** fitted with a) ferric arsenate and b) arsenate adsorbed on ferrihydrite.

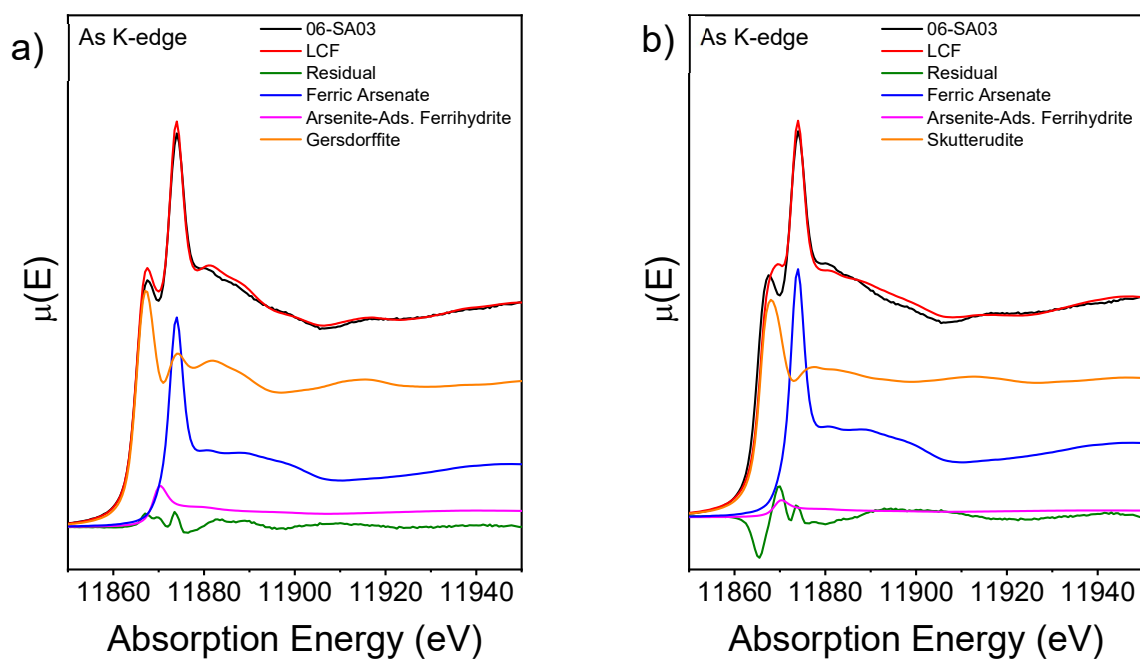


Figure 6.76. As K-edge XANES spectrum of **06-SA03** fitted with a) gersdorffite and b) skutterudite.

7.0 APPENDIX 3: ARSENIC K-EDGE EXAFS FIGURES

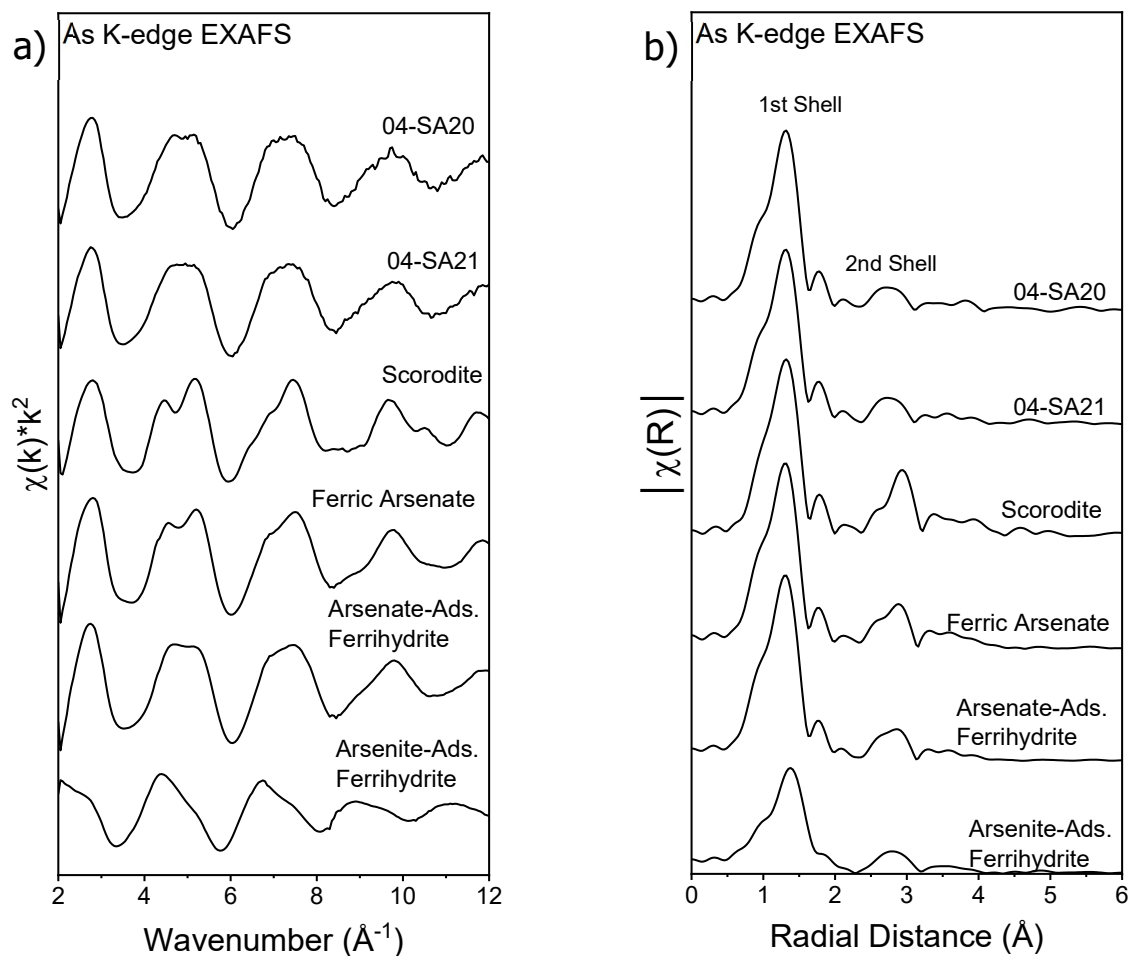


Figure 7.1. a) The normalized, background-subtracted k^2 -weighted As K-edge EXAFS spectra (k -space) and b) Fourier-transformed k^2 -weighted As K-edge EXAFS spectra (R -space) of the samples (**04-SA20** and **04-SA21**) and arsenate standards (scorodite, ferric arsenate, and arsenate adsorbed on ferrihydrite).

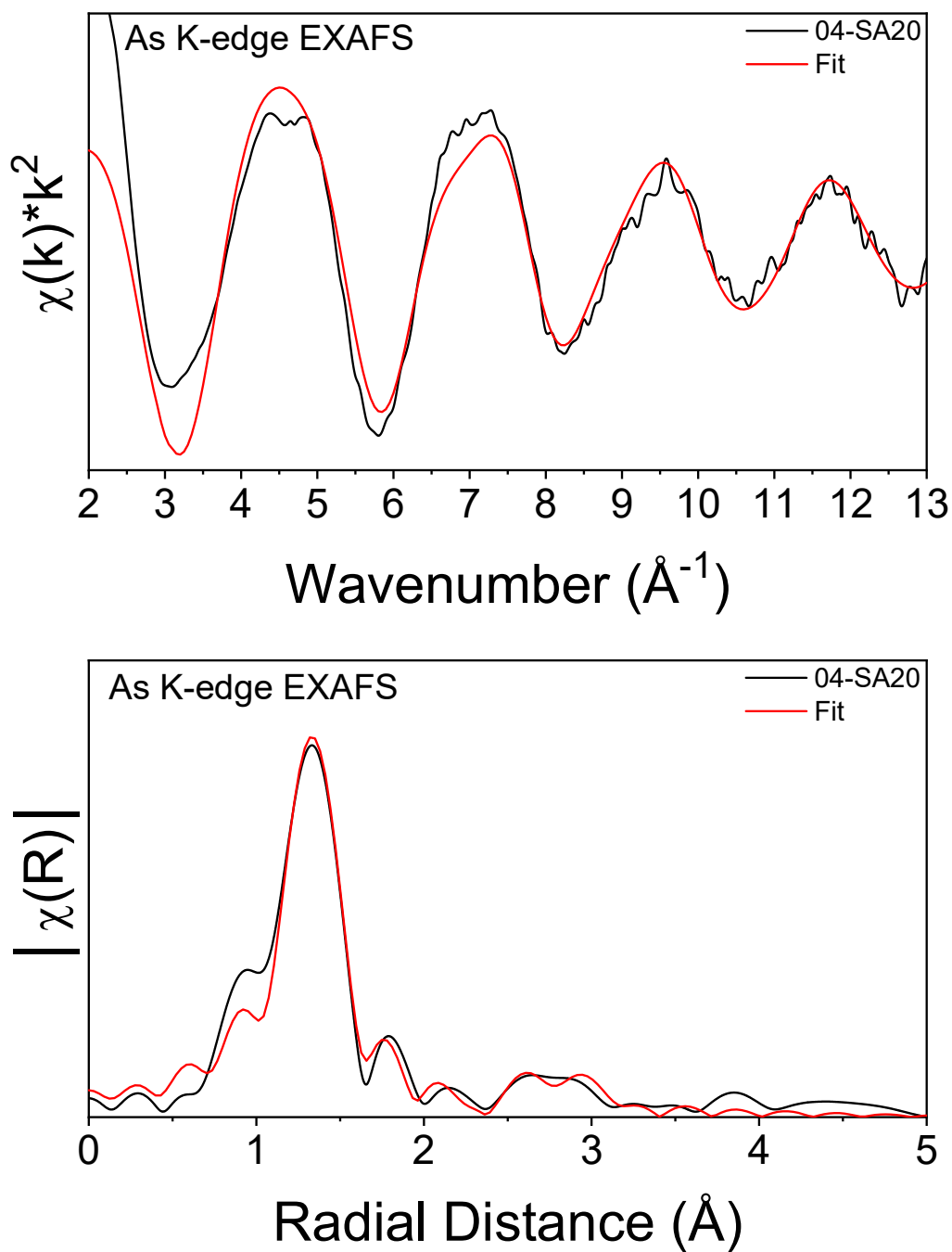


Figure 7.2. The fitted As K-edge EXAFS spectrum of **04-SA20** in k-space (top) and R-space (bottom).

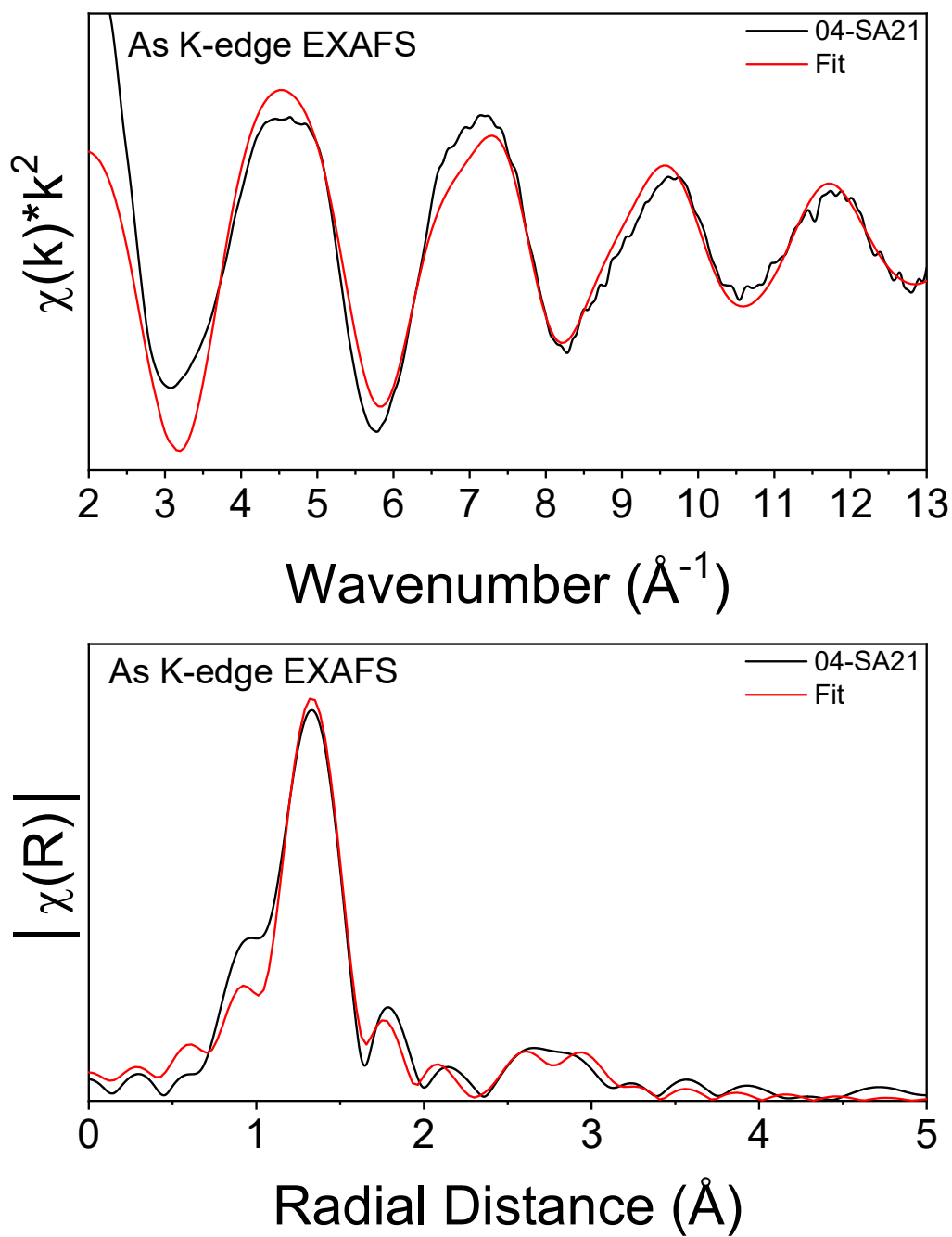


Figure 7.3. The fitted As K-edge EXAFS spectrum of **04-SA21** in k-space (top) and R-space (bottom).

Appendix D

Section D

Subsection B: Dr. Mahoney Reports

MEMORANDUM

To: John Rowson, Crystal Rinas - AREVA Resources, Inc.

From: John Mahoney, Ph.D. - Mahoney Geochemical Consulting LLC

Date: Sept. 24, 2010

Subject: Review of Molybdenum Geochemistry in the JEB TMF

INTRODUCTION

As part of an initial review of controls on molybdenum (Mo) in the JEB Tailings Management Facility (TMF) saturation index (SI) calculations were prepared using data collected in 2008. The primary purpose of the calculations was to identify possible phases that may control Mo concentrations in the TMF. Initial calculations were run using PHREEQC (Parkhurst and Appelo, 1999) using the MINTEQ.v4.dat database. This particular database was selected rather than one based upon the PHREEQC and WATEQ4F databases, which are also provided with the program, because the MINTEQ.v4.dat database includes reactions for molybdenum in solution. However, these calculations and a subsequent review of the solubility product constants (K_{sp}) and stability constants for ion pairs (K_{assoc} , or simply K) that include Mo indicate that additional work is required before these model calculations could provide reliable information about Mo in the TMF.

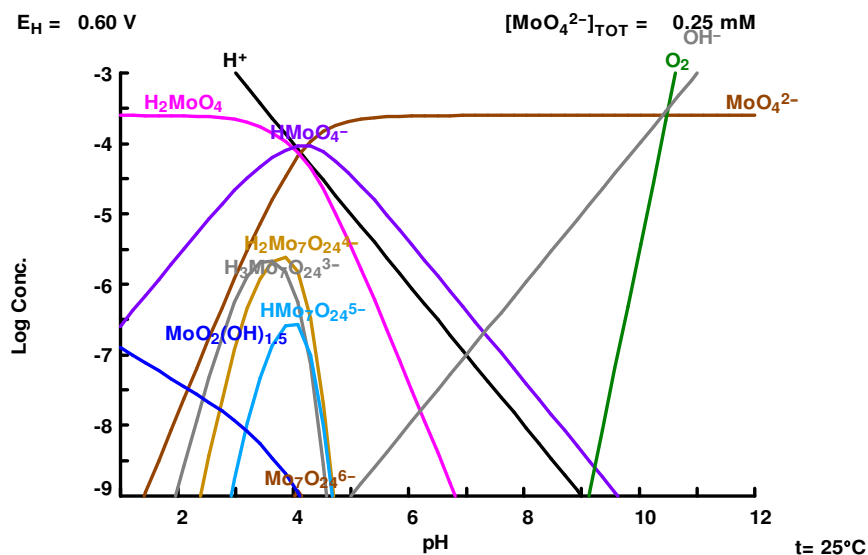
The calculations to evaluate molybdenum solubility were run separately from the calculations used to evaluate the saturation indices for iron, arsenic and uranium bearing phases. The MINTEQ.v4.dat database does not include the corrections and updates related to scorodite stability that were discussed in Langmuir et al. (2006). Therefore, results related to the arsenic bearing phases are not part of this discussion and any model run with the MINTEQ.v4.dat database should not be used to interpret arsenic geochemistry in the JEB TMF.

REVIEW OF MOLYBDATE THERMODYNAMICS

A review of the literature indicated that uncertainties exist about the K_{sp} values for some of phases that were considered. Table 1 (at end of this document) was prepared from various databases available to geochemical modeling programs including PHREEQC (Parkhurst and Appelo, 1999), MINTEQA2 (Allison et al., 1991), Visual MINTEQ (Gustafsson, 2010), The Geochemist's Workbench (Bethke, 2008, Bethke and Yeakel, 2010), HYDRA/MEDUSA (Puigdomenech, 2009) and EQ3NR/EQ6 (Wollery, 1992a, b, Wollery and Daveler, 1992). Also some values listed in publications were included in Table 1. The compilation in Table 1 exposes some significant issues with the databases that include molybdenum. At these low concentrations of molybdenum (c. 25 mg/L or 0.25 mM) and given the pH values in the TMF,

the various polymolybdate species (such as $\text{HMo}_7\text{O}_{24}^{5-}$) were not considered to be important (See Figure 1).

Figure 1. Log Concentrations of Molybdenum Species, plotted using HYDRA/MEDUSA



Based upon this review, additional complexes (solution species) were added to the database for these specific models. These complexes include: $\text{Ca}^{+2} + \text{MoO}_4^{-2} = \text{CaMoO}_4$, with a log K of 2.57, $\text{Na}^+ + \text{MoO}_4^{-2} = \text{NaMoO}_4^-$, with a log K of 1.1, and $\text{Mg}^{+2} + \text{MoO}_4^{-2} = \text{MgMoO}_4$, with a log K of 3.03 (Essington, 1990, 1992). A minor issue was also noted with the Visual MINTEQ database in that the $\text{H}_2\text{MoO}_4^\circ$ complex was not included in that compilation. The error with the Visual MINTEQ database has no bearing on the evaluation described in this memorandum.

In addition to the three complexation reactions that were added to the database, three additional solid phases were also included in the calculations. Two reactions were defined for ferrimolybdate, and an additional reaction was defined for NiMoO_4 . Several different solubility product constants (log K_{sp}) for ferrimolybdate were found in the database search. The first value of -35.29 was reported (Rai et al. 1987), as stated in Meima and Comans (1999). The other value of -38.52 was taken from the EQ3NR/EQ6 data0 database file for the Yucca Mountain Project, Release 5(Data0.YMP.r5); that value appears to have been taken from Lindsay (2001) and possibly support by data from Titley (1963). The Langmuir compilation provides an intermediate value of -37.74, which he attributes to Vlek and Lindsay (1977). It is possible that this range of values represents solids of different thermodynamic stability and most likely is related to different degrees of crystallinity. As will be demonstrated later, these values represent a fairly soluble mineral and given the conditions in the TMF it is unlikely that ferrimolybdate is actively controlling the concentrations of Mo in these waters.

Perhaps the most significant issue identified in the data compilation is the variation in the solubility product constants reported for NiMoO_4 . The MINTEQA2 derived databases included

Molybdenum Geochemistry in JEB TMF

a log K_{sp} value for $NiMoO_4$ of -11.14. This is based upon a Gibbs free energy (ΔG_f°) of -947.7 kJ/mol (-226.5 kcal/mol) that was reported by Bard et al. (1985) to be an estimate. A more recent evaluation by Morishita and Navrotsky (2003) reported a ΔG_f° of -921.2 kJ/mol (-220.17 kcal/mol), which produces a log K_{sp} of -6.50. This solubility product value had been included in the EQ3NR/EQ6 data0 database file for the Yucca Mountain Project, Release 5(Data0.YMP.r5). Both reported log K_{sp} values were checked by means of simple hand calculations and it appears that both K_{sp} values use the same Gibbs free energies of -10.9 kcal/mol for Ni^{+2} , and -200.4 kcal/mol for MoO_4^{-2} . These two free energies are cited in a compilation prepared by Dr. Donald Langmuir, and he indicates that the free energy for Ni^{+2} is from Wagman et al., (1969), and the free energy for MoO_4^{-2} is from Dellien et al. (1976). Because of the conflicting values reported in the databases, and based on the data review described above, a second log K_{sp} for $NiMoO_4$, with a value of -6.50, was also included in the models to improve our understanding of this phase.

There is another issue with the $NiMoO_4$ phase and that is whether a $NiMoO_4^\circ$ complex, analogous to the $CaMoO_4^\circ$ complex, exists in solution. If the solubility product for the $NiMoO_4$ phase is small, as suggested by the -11.14 value, then a corresponding ion pair (complex) could also have a large amount of stability and it would be expected to have a significant role in taking up Ni^{+2} and MoO_4^{-2} . The actual K_{sp} value could be even smaller if the complex were properly considered in the recalculation of the K_{sp} . If the solid has a K_{sp} of around -6.5, an order of magnitude less than powellite, then the importance of the corresponding $NiMoO_4^\circ$ complex is also likely to be diminished. If it is decided to further investigate the role of $NiMoO_4$ (solid) in the TMF, a series of bench scale measurements should be undertaken first to measure through direct solubility calculations the K_{sp} for $NiMoO_4$ and determine if a $NiMoO_4^\circ$ ion pair is important under these conditions.

MODELING

Figure 2 shows a simple Eh-pH diagram for molybdenum, and Figure 3 adds calcium to the diagram. Molybdenum and calcium concentrations in the figures are at concentrations typical of the values noted in the TMF pore waters. Figures 1 and 2 both indicate that the MoO_4^{-2} activity does not change if the pH is much above 5. This simplifies much of the modeling and discussion related to conditions in the TMF, most importantly is it reduces errors in the SI calculations due to inaccurate pH measurements, basically the activity of MoO_4^{-2} is insensitive to pH above a pH of approximately 5. Figure 3 indicates that at concentrations of Ca and Mo expected in the TMF that the $CaMoO_4$ phase has a large stability field, and so it is expected that it may play a role in controlling Mo concentrations.

Table 2 lists the results of the saturation index calculations for possible molybdate bearing phases for all samples. These phases include $CaMoO_4$ (sometimes called Powellite), $NiMoO_4$, ferrous molybdate ($FeMoO_4$), and ferrimolybdite [$Fe_2(MoO_4)_3$], as an anhydrous form. Some reports indicate that ferrimolybdate contains either 7 or 8 H_2O . Because of the somewhat

ambiguous solubility product constants for at least some of these phases, the table also includes the ion activity products (IAPs). Table 3 provides a brief summary of the results and it lists the maximum and minimum SI or IAP values. Average SI or IAP and standard deviations are also included in Table 3. Figure 4 plots these SI values as a function of pH.

Figure 2. Simple Eh – pH diagram for the system Mo - O - H.

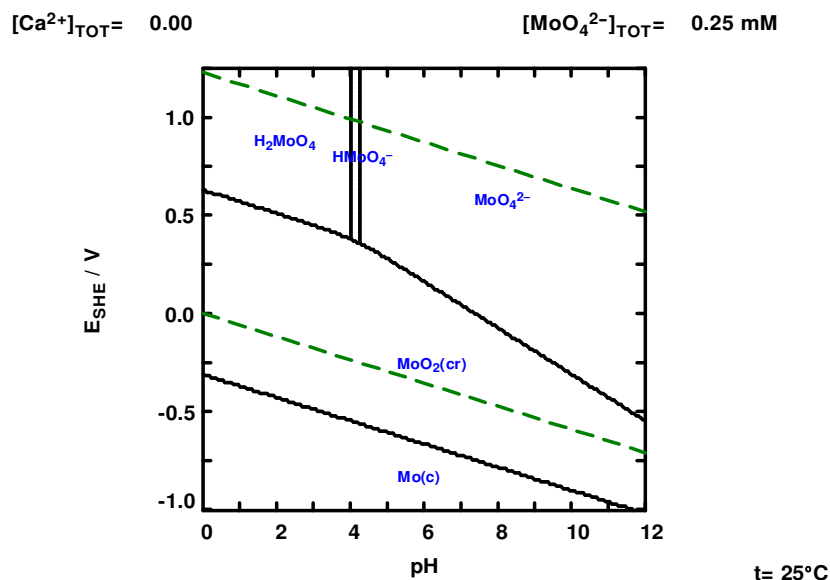
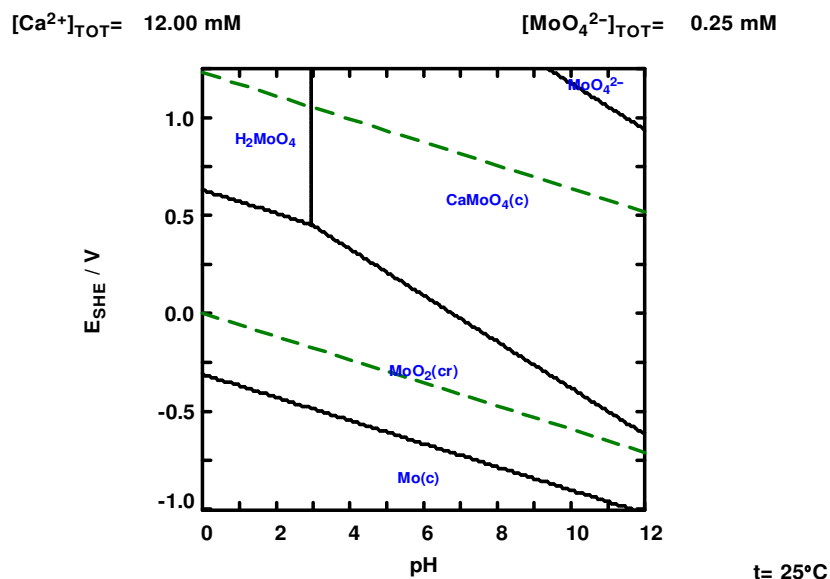


Figure 3. Eh - pH diagram for system Mo - Ca - O - H.



Consistent with the large stability field noted on Figure 3, CaMoO_4 is oversaturated in most samples. The average SI for CaMoO_4 is 0.72, assuming a $\log K_{sp}$ of about -7.94. Put another way, if CaMoO_4 were the controlling phase for Mo in The TMF the average $\log K_{sp}$ value for the

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solid in the TMF would be approximately -7.21. This is not too far off from the published value and it could indicate that a poorly crystalline powellite could be controlling the concentrations of molybdenum. The value of -7.21 is within the range of values discussed in Essington (1990) for CaMoO_4 . He indicated a range from -7.02 to -8.51, and he also indicates that Vlek and Lindsay reported a range of -7.19 to -8.50 for the $\log K_{\text{sp}}$ of CaMoO_4 . The rapid precipitation of mineral phases during raffinate neutralization would most likely form a less stable phase.

Because there are questions about the stability of the NiMoO_4 solid the resulting geochemical modeling results for the NiMoO_4 phase are not as straightforward. Assuming that the $\log K_{\text{sp}}$ value of -11.14 is correct then the samples appear to be oversaturated. With an average SI of 0.76 and an average IAP of -10.39 for this phase an argument similar to the argument for the CaMoO_4 phase could be raised; mainly that we are looking at a slightly less stable (more soluble) version of NiMoO_4 that is controlling the Mo concentrations. However, questions about the estimated ΔG_f° value provided in Bard et al. (1985) must be considered, particularly given the data provided in Morishita and Navrotsky (2003). When compared to that much less stable phase, the samples are all significantly undersaturated. At this time, I am inclined to accept the data of Morishita and Navrotsky (2003) and reject the much smaller K_{sp} value that was based upon an estimated Gibbs free energy reported in Bard et al. (1985).

The other possible simple divalent molybdate phase that was considered and also discussed in a brief conference call was ferrous molybdate (FeMoO_4). However, nearly all of the samples are undersaturated with respect to FeMoO_4 and the extent of this undersaturation is often very large. For the measured Eh conditions, the pe values used in the model represent a strong oxidizing condition and the activity of Fe^{+2} is simply too small to permit saturation with this phase. The sample that had the highest saturation index for this solid (SI value of +0.33) was TMF08-01_SA-15 at an elevation of 379.06 meters. This sample had the lowest Eh at 0.15 V, which was enough to increase the Fe^{+2} activity to permit an oversaturated condition. It should be noted that the average Eh for all samples was 0.33V. Also Gupta (1992) (see attached sheets) indicates that ferrous molybdate is made up of a reduced iron form and an oxidized molybdenum species and that the MoO_4^{-2} ion should undergo reduction in the presence of ferrous. Given the mixed redox states of iron, initially low pH conditions present during the relatively rapid neutralization of McLean Lake raffinates it may still be possible that this phase could precipitate and be stabilized within the mass of additional iron phases that precipitate with increasing pH.

Another phase that was considered was ferrimolybdite $\text{Fe}_2(\text{MoO}_4)_3$ (also identified as ferrimolybdate in some reports). As stated earlier, some reports indicate that it may contain up to 7 or 8 waters of hydration. These waters were not included in the formula, as the activity of water in these calculations is close to 1.0 the presence or absence of these waters has little impact on the SI or IAP calculations. Log IAP values for ferrimolybdite in the TMF ranged from -43.01 to -53.33 with an average of -47.53. These values are 9 orders of magnitude lower than the $\log K_{\text{sp}}$ for the most stable ferrimolybdite listed in Table 1. Simply stated, ferrimolybdite is too soluble to control molybdenum concentrations in these water samples. However, it should be

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mentioned that Follet and Barber (1966) indicated that they estimated a log Ksp value of 10^{-52} for ferrimolybdate in soils. This was reported in the abstract of that paper, but the completed paper was not readily available, and given the age of the work it was felt that it was superseded by more recent measurements. In contrast to the Follet and Barber proclamation, Sarafian and Furbish (1965) provided tabulated results for low pH solubility measurements of ferrimolybdate. A few of these analytical results were entered into a set of PHREEQC models and most of the

Table 2. Summary of Saturation Index and Ion Activity Product Calculations.

Description	Sample Elevation (mamsl)	pH	pe	Eh Volts	Mo (mg/L)	Activity Ca+2	Activity Ni+2	Activity MoO4-2	SI Gypsum	SI CaMoO4	SI NiMoO4 (Barc85)	SI NiMoO4 (mos/nay03)	SI FeMoO4	SI Fe2(MoO4)3 (Ra1)	SI Fe2(MoO4)3 (vmp.R5)	IAP CaMoO4	IAP NiMoO4	IAP FeMoO4	IAP Fe2(MoO4)3
								log K's =	-4.59	-7.94	-11.15	-6.5	-10.02	-35.29	-38.52	-7.94	-6.5 to -11.14	-10.02	-35.29 to -38.52
TMF08-01_SA-01_419.9	419.9	8.47	5.76	0.34	18.65	-2.40	-4.92	-4.32	-0.045	1.211	1.91	-2.74	-6.04	-16.28	-13.05	-6.73	-9.24	-16.06	-51.57
TMF08-01_SA-02_417.1568	417.16	7.54	6.37	0.38	26.88	-2.44	-6.72	-4.18	-0.040	1.315	0.26	-4.40	-4.66	-12.23	-9.00	-6.62	-10.90	-14.66	-47.52
TMF08-01_SA-03_414.1088	414.11	6.85	6.56	0.39	13.63	-2.39	-5.13	-4.47	-0.028	1.081	1.55	-3.10	-3.53	-9.90	-6.67	-6.85	-9.60	-13.52	-45.20
TMF08-01_SA-04_411.0608	411.06	7.09	5.93	0.35	22.45	-2.40	-5.51	-4.23	-0.062	1.302	1.42	-3.23	-3.23	-10.33	-7.10	-6.63	-9.73	-13.23	-45.62
TMF08-01_SA-05_408.0128	408.01	7.09	6.10	0.36	13.54	-2.40	-4.96	-4.53	-0.032	1.002	1.66	-2.99	-3.82	-11.47	-8.24	-6.93	-9.49	-13.82	-46.76
TMF08-01_SA-06_404.9648	404.96	8.23	4.59	0.27	16.54	-2.39	-5.82	-4.37	-0.053	1.177	0.97	-3.69	-4.32	-15.32	-12.09	-6.76	-10.19	-14.32	-50.61
TMF08-01_SA-07_401.9168	401.92	8.15	6.03	0.36	1.94	-2.43	-5.08	-5.42	-0.038	0.081	0.66	-4.00	-4.21	-13.27	-10.04	-7.85	-10.50	-14.21	-48.56
TMF08-01_SA-08_398.8688	398.87	7.23	5.36	0.32	4.78	-2.40	-5.32	-5.04	-0.009	0.499	0.80	-3.85	-1.13	-8.07	-4.84	-7.43	-10.35	-11.13	-43.36
TMF08-01_SA-09_398.2592	398.26	7.47	4.39	0.26	10.73	-2.38	-5.14	-4.64	-0.025	0.914	1.37	-3.28	-0.97	-9.29	-6.06	-7.02	-9.78	-10.96	-44.58
TMF08-01_SA-10_394.9064	394.91	7.03	6.75	0.40	5.08	-2.38	-5.56	-4.96	-0.001	0.589	0.64	-4.02	-4.58	-12.11	-8.88	-7.34	-10.52	-14.58	-47.40
TMF08-01_SA-11_391.2488	391.25	7.44	5.86	0.35	5.64	-2.45	-5.47	-4.92	-0.024	0.560	0.76	-3.89	-4.23	-13.14	-9.91	-7.37	-10.39	-14.23	-48.43
TMF08-01_SA-12_388.2008	388.20	7.20	4.78	0.28	7.79	-2.42	-5.63	-4.77	-0.048	0.750	0.76	-3.89	-1.31	-9.30	-6.07	-7.18	-10.39	-11.31	-44.59
TMF08-01_SA-13_386.0672	386.07	7.36	6.63	0.39	5.73	-2.40	-5.61	-4.95	-0.030	0.577	0.60	-4.06	-3.46	-10.11	-6.88	-7.36	-10.56	-13.46	-45.40
TMF08-01_SA-14_383.0192	383.02	7.00	5.76	0.34	3.93	-2.37	-5.15	-5.19	0.017	0.379	0.82	-3.83	-3.24	-11.68	-8.45	-7.55	-10.33	-13.24	-46.97
TMF08-01_SA-15_379.0568	379.06	6.90	2.47	0.15	11.03	-2.43	-5.46	-4.64	-0.026	0.861	1.05	-3.60	0.33	-10.54	-7.31	-7.07	-10.10	-9.66	-45.84
TMF08-01_SA-16_376.9232	376.92	7.29	4.76	0.28	10.33	-2.51	-5.90	-4.68	-0.056	0.750	0.58	-4.08	-1.86	-10.37	-7.14	-7.18	-10.58	-11.85	-45.66
TMF08-01_SA-17_373.8752	373.88	7.22	5.66	0.33	9.40	-2.44	-6.04	-4.80	-0.034	0.697	0.31	-4.34	-2.06	-9.11	-5.88	-7.24	-10.84	-12.06	-44.40
TMF08-01_SA-18_370.8272	370.83	6.85	4.69	0.28	4.80	-2.42	-5.47	-5.05	-0.025	0.467	0.64	-4.02	-0.83	-8.83	-5.60	-7.47	-10.52	-10.83	-44.12
TMF08-01_SA-19_366.8648	366.86	6.79	5.73	0.34	1.26	-2.41	-5.17	-5.67	0.015	-0.141	0.32	-4.34	-3.98	-13.69	-10.46	-8.07	-10.84	-13.97	-48.98
TMF08-02_SA-01_415.0232	415.02	7.96	5.78	0.34	0.83	-2.34	-6.41	-5.65	-0.050	-0.058	-0.91	-5.56	-6.21	-17.96	-14.73	-7.99	-12.06	-16.22	-53.25
TMF08-02_SA-02_411.9752	411.98	7.82	5.86	0.35	13.54	-2.39	-5.71	-4.55	-0.012	0.997	0.90	-3.76	-4.60	-13.55	-10.32	-6.94	-10.26	-14.60	-48.85
TMF08-02_SA-03_408.9272	408.93	7.83	5.58	0.33	14.24	-2.37	-5.72	-4.53	-0.005	1.027	0.90	-3.75	-4.51	-13.91	-10.68	-6.91	-10.26	-14.51	-49.20
TMF08-02_SA-04_405.8792	405.88	7.53	5.92	0.35	17.15	-2.37	-5.00	-4.44	0.002	1.119	1.71	-2.94	-3.52	-11.15	-7.92	-6.81	-9.44	-13.52	-46.44
TMF08-02_SA-05_403.136	403.14	7.58	5.88	0.35	8.81	-2.39	-4.98	-4.73	-0.011	0.817	1.45	-3.20	-4.99	-14.44	-11.21	-7.12	-9.70	-14.99	-49.73
TMF08-02_SA-06_400.088	400.09	7.61	5.08	0.30	14.65	-2.41	-6.07	-4.50	0.017	1.022	0.58	-4.07	-1.67	-9.16	-5.93	-6.91	-10.57	-11.67	-44.45
TMF08-02_SA-07_397.04	397.04	8.23	5.86	0.35	9.34	-2.39	-5.90	-4.69	-0.035	0.848	0.56	-4.09	-5.72	-15.89	-12.66	-7.09	-10.59	-15.72	-51.18
TMF08-02_SA-08_393.6872	393.69	7.61	5.78	0.34	2.95	-2.46	-5.55	-5.17	-0.023	0.307	0.43	-4.22	-4.98	-15.02	-11.79	-7.63	-10.72	-14.98	-50.31
TMF08-02_SA-10_388.8104	388.81	7.44	3.49	0.21	11.43	-2.42	-5.96	-4.60	-0.101	0.915	0.60	-4.05	-0.62	-10.31	-7.08	-7.02	-10.56	-10.62	-45.60
TMF08-02_SA-11_386.0672	386.07	7.35	6.27	0.37	4.27	-2.57	-5.65	-4.92	-0.285	0.442	0.58	-4.07	-4.92	-13.67	-10.44	-7.49	-10.57	-14.92	-48.96
TMF08-02_SA-12_381.8	381.80	7.34	4.93	0.29	3.39	-2.45	-5.64	-5.22	-0.068	0.260	0.29	-4.36	-2.55	-11.90	-8.67	-7.67	-10.86	-12.56	-47.19
TMF08-02_SA-13_379.0568	379.06	7.14	5.44	0.32	0.87	-2.38	-5.38	-5.82	0.042	-0.268	-0.05	-4.70	-2.20	-10.77	-7.54	-8.20	-11.20	-12.21	-46.06
TMF08-02_SA-14_376.0088	376.01	7.47	4.37	0.26	5.24	-2.55	-6.17	-4.91	-0.198	0.468	0.07	-4.58	-1.02	-9.72	-6.49	-7.47	-11.08	-11.01	-45.01
TMF08-02_SA-15_372.9608	372.96	7.71	5.58	0.33	4.88	-2.45	-5.30	-5.03	0.000	0.454	0.82	-3.83	-4.80	-14.95	-11.72	-7.48	-10.33	-14.79	-50.24
TMF08-03_SA-01_413.804	413.80	7.27	5.95	0.35	4.19	-2.34	-5.57	-4.96	0.001	0.633	0.62	-4.03	-3.36	-11.29	-8.06	-7.30	-10.53	-13.36	-46.58
TMF08-03_SA-02_411.9752	411.98	7.82	5.85	0.35	32.69	-2.40	-5.89	-4.11	0.020	1.425	1.15	-3.50	-4.26	-12.43	-9.20	-6.51	-10.00	-14.25	-47.72
TMF08-03_SA-03_410.756	410.76	7.04	6.07	0.36	24.67	-2.38	-5.16	-4.23	0.042	1.317	1.76	-2.89	-2.67	-9.05	-5.82	-6.61	-9.39	-12.65	-44.34
TMF08-03_SA-06_403.136	403.14	7.04	5.95	0.35	26.98	-2.42	-4.93	-4.26	-0.006	1.255	1.96	-2.69	-3.49	-10.78	-7.55	-6.68	-9.19	-13.50	-46.07
TMF08-03_SA-08_397.04	397.04	7.54	4.27	0.25	13.45	-2.39	-6.03	-4.61	0.003	0.941	0.51	-4.14	-0.36	-8.21	-4.98	-6.99	-10.64	-10.37	-43.50
TMF08-03_SA-09_391.5536	391.55	7.80	4.83	0.28	6.67	-2.39	-6.03	-4.87	-0.026	0.673	0.26	-4.40	-2.51	-11.64	-8.41	-7.26	-10.90	-12.52	-46.93
TMF08-03_SA-10_387.896	387.90	8.00	5.64	0.33	10.63	-2.39	-6.41	-4.68	-0.001	0.869	0.06	-4.59	-5.60	-16.02	-12.79	-7.07	-11.09	-15.61	-51.31
TMF08-03_SA-11_385.4576	385.46	7.79	5.59	0.33	7.46	-2.39	-6.39	-4.83	-0.036	0.716	-0.07	-4.72	-5.23	-15.54	-12.31	-7.22	-11.22	-15.24	-50.83
TMF08-03_SA-12_382.1048	382.10	7.54	5.93	0.35	7.35	-2.65	-6.16	-4.77	-0.054	0.516	0.22	-4.43	-4.74	-13.82	-10.59	-7.42	-10.93	-14.75	-49.11
TMF08-03_SA-13_378.752	378.75	8.26	5.80	0.34	6.98	-2.66	-6.12	-4.77	-0.091	0.501	0.26	-4.39	-6.38	-17.38	-14.15	-7.43	-10.89	-16.38	-52.67
TMF08-03_SA-14_376.0088	376.01	7.49	5.95	0.35	1.77	-2.53	-6.09	-5.44	-0.005	-0.044	-0.37	-5.03	-4.29	-13.62	-10.39	-7.98	-11.53	-14.29	-48.92
TMF08-03_SA-15_372.9608	372.96	7.66	6.27	0.37	3.31	-2.61	-5.99	-5.17	-0.015	0.159	0.00	-4.65	-3.91	-11.93	-8.70	-7.77	-11.16	-13.91	-47.22
TMF08-03_SA-16_370.5224	370.52	7.46	4.98	0.29	4.64	-2.48	-5.13	-5.03	0.003	0.429	0.99	-3.66	-1.97	-10.49	-7.26	-7.50	-10.16	-11.97	-45.78
TMF08-04_SA-01_411.9752	411.98	8.67	5.69	0.34	27.67	-2.40	-6.08	-4.15	-0.040	1.386	0.93	-3.73	-6.89	-18.04	-14.81	-6.55	-10.23	-16.88	-53.33
TMF08-04_SA-02_408.9272	408.93	7.28	6.68	0.39	41.20	-2.41	-5.40	-3.98	-0.049	1.544	1.77	-2.88	-4.13	-10.34	-7.11	-6.39	-9.38	-14.13	-45.63
TMF08-04_SA-03_405.8792	405.88	7.59	5.98	0.35	27.07	-2.40	-5.22	-4.19	-0.041	1.341	1.75	-2.90	-4.38	-12.57	-9.34	-6.59	-9.40	-14.35	-47.86
TMF08-04_SA-04_403.136	403.14	7.43	6.22	0.37	15.64	-2.35	-5.10	-4.46	0.012	1.120	1.59	-3.06	-4.19	-11.94	-8.71	-6.81	-9.56	-14.17	-47.23
TMF08-04_SA-05_400.088	400.09	7.80	5.66	0.33	14.84	-2.38	-5.13	-4.45	-0.007	1.113	1.58	-3.07	-4						

Table 3. Summary of Model Calculations

	SI Gypsum	SI CaMoO ₄	IAP CaMoO ₄	SI NiMoO ₄ (Bard85)	SI NiMoO ₄ (mos/nav03)	IAP NiMoO ₄	SI FeMoO ₄	IAP FeMoO ₄	SI Fe ₂ (MoO ₄) ₃ (Rai)	SI Fe ₂ (MoO ₄) ₃ (ymp.R5)	IAP Fe ₂ (MoO ₄) ₃
log K _{sp}	-4.59	-7.94		-11.15	-6.5		-10.02		-35.29	-38.52	
MAX	0.04	1.54	-6.39	1.96	-2.69	-9.19	0.33	-9.66	-7.72	-4.49	-43.01
MIN	-0.55	-0.37	-8.30	-0.91	-5.56	-12.06	-6.89	-16.88	-18.04	-14.81	-53.33
AVERAGE	-0.04	0.72	-7.21	0.76	-3.89	-10.39	-3.53	-13.53	-12.24	-9.01	-47.53
ST DEV	0.084	0.439	0.439	0.626	0.625	0.625	1.649	1.649	2.507	2.507	2.507

resulting IAP values were around 10^{-29} to 10^{-31} . It should be noted that these model calculations were of a cursory nature as only four of the approximately 15 data points were evaluated. It may be possible that additional remodeling efforts might demonstrate the presence of more stable ferrimolybdate, but the paper is lacking many experimental details, and for this initial assessment such an effort did not appear to be warranted.

A couple of other points are worth mentioning at this time, ferrimolybdate, behaves somewhat similarly to scorodite in that incongruent reactions, due to the formation of ferrihydrite, are expected at pH values greater than about 3. This is also mentioned in the page from Gupta (1992) attached to this memorandum. Consistent with this incongruent behavior, Sarafian and Furbish (1965) indicate that the lowest solubility of ferrimolybdate based upon their experiments is at a pH of 3.35. Therefore, it would be expected that ferrimolybdate could form during the raffinate neutralization process; and that it could be removed from further equilibrium processes as the pH stabilizes near 7 in the TMF.

Further examination of the CaMoO₄ model results was conducted to better understand the role of this phase in the TMF. Because of the variability in IAP values (Figure 5) a specific log K_{sp} value was not selected. It was felt that the IAP data in this case provided a better representation of the nature of the reactions in the TMF than use of saturation indices which are tied to a specific solubility product constant.

Figure 4. Summary of saturation index calculations for possible molybdate phases in the JEB TMF

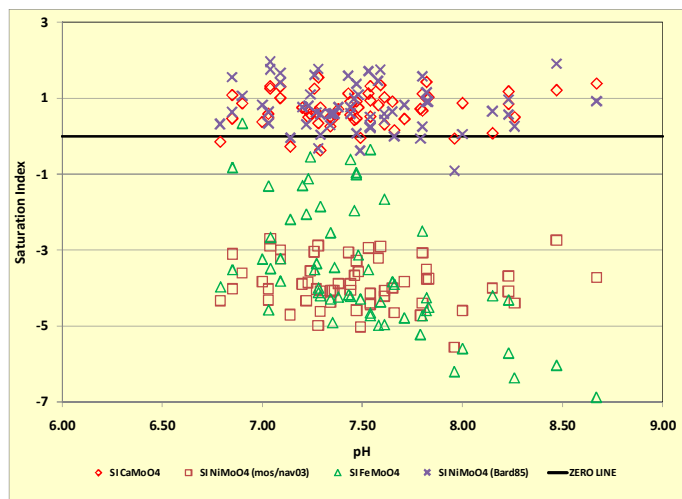
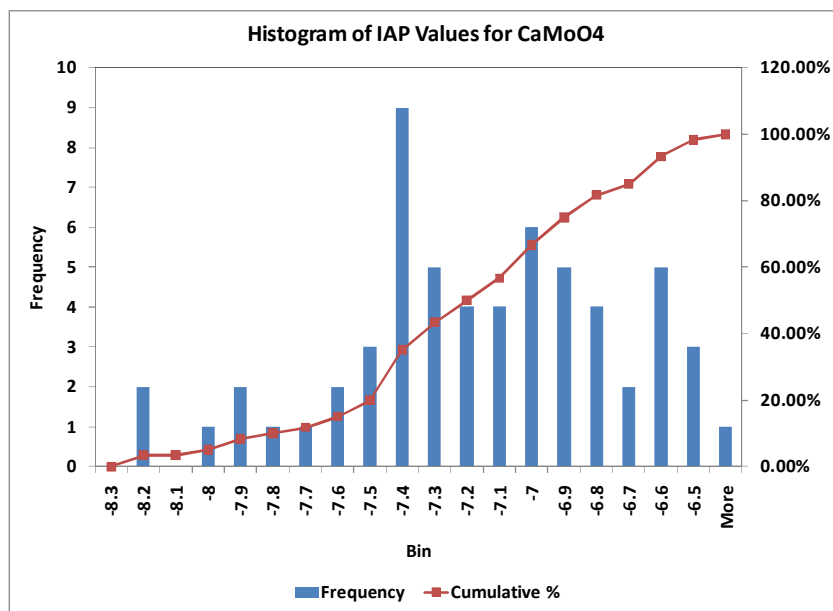


Figure 5. Histogram of IAP values for CaMoO₄ for samples collected in 2008



Since the IAP is the log sum of two parameters it was felt that the role of the two parameters should be examined simultaneously. Figure 6 plots the IAP of CaMoO₄ as a function of log activity of Ca⁺². Two points should be discussed. First the range of Ca⁺² activities is small compared to the overall range in IAP values for CaMoO₄. The range is about 0.35 log units for Ca⁺². This is because gypsum solubility, and the high sulfate concentrations, are controlling (buffering) the activity of the Ca⁺² component.

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The other point is related to the distribution of data on Figure 6, which suggests that there may be two different activity regions represented on the figure; one region where Ca^{+2} log activities exceed -2.5 that is characterized by a wide scatter in CaMoO_4 IAP values ranging up to approximately -6.4, and another regions with smaller Ca^{+2} log activities and less scatter in the CaMoO_4 IAP values. In this second region samples with Ca^{+2} log activities less than -2.50 appear to have IAP values less than approximately -7.25. Based upon this distribution, and taking the data related to the solubility product constants, the range of log K_{sp} values reported in the literature, and the lack of a trend between Ca^{+2} and IAP for CaMoO_4 , suggests we might attempt to define a region where solubility of CaMoO_4 probably is controlling the Mo concentration can be defined on Figure 6. Reasons for this behavior are not understood, at this time it is mainly an initial observation. It may be that in this region of lower Ca^{+2} activity, precipitation reactions are slower and a more crystalline CaMoO_4 forms.

Figure 6. IAP values of CaMoO_4 as a function of the log activity of Ca^{+2} .

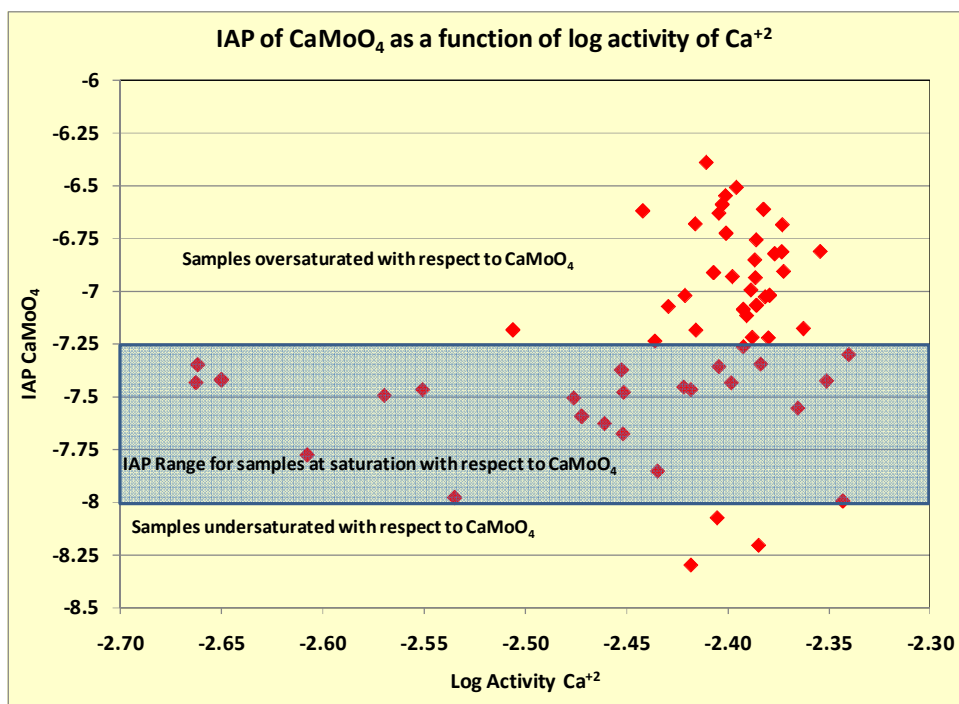


Figure 7 shows IAP data for the samples collected in 2008 as a function of elevation in the TMF. Several features are apparent. The samples at a higher elevation tend to have greater IAPs; moreover this pattern is consistent for all four sample locations. One possible explanation is that the younger samples eventually recrystallize (age) to form a more stable (smaller IAP) phase over time. This hypothesis was evaluated by comparing earlier results with the 2008 data set. Results from the 2001 and 2003 sampling programs were run under the same model conditions as the 2008 data. Figure 8 demonstrates that on average changes to IAP values in the older samples are not noted. Since IAP values remain constant, it is reasonable to state that the phase that is controlling molybdenum solubility in the TMF is stable and long term reactions that

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would cause further release are not in evidence. It is still possible that samples with higher IAPs may eventually recrystallize to something with the stability present in the lower portions of the JEB TMF. This would suggest that samples placed in the TMF initially were intrinsically more stable when placed; this may be related to a change in ore feed to the mill or to changes to the raffinate neutralization process.

Figure 7. IAP values for CaMoO_4 as a function of sample elevation for samples collected in 2008.

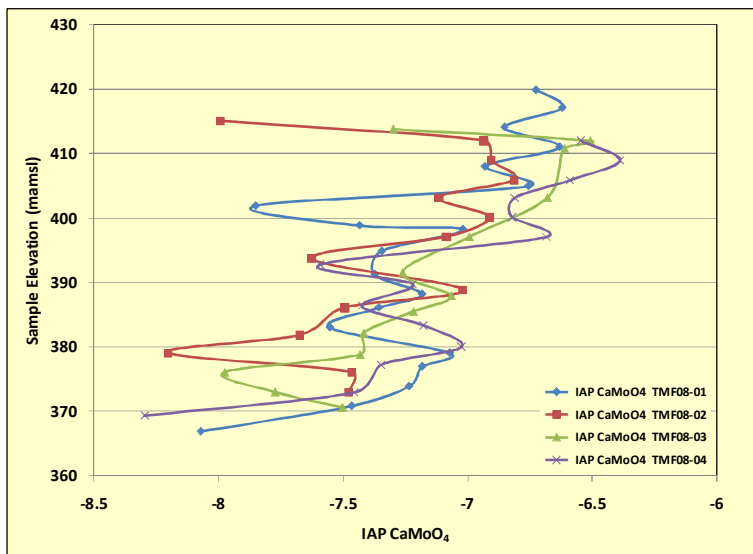
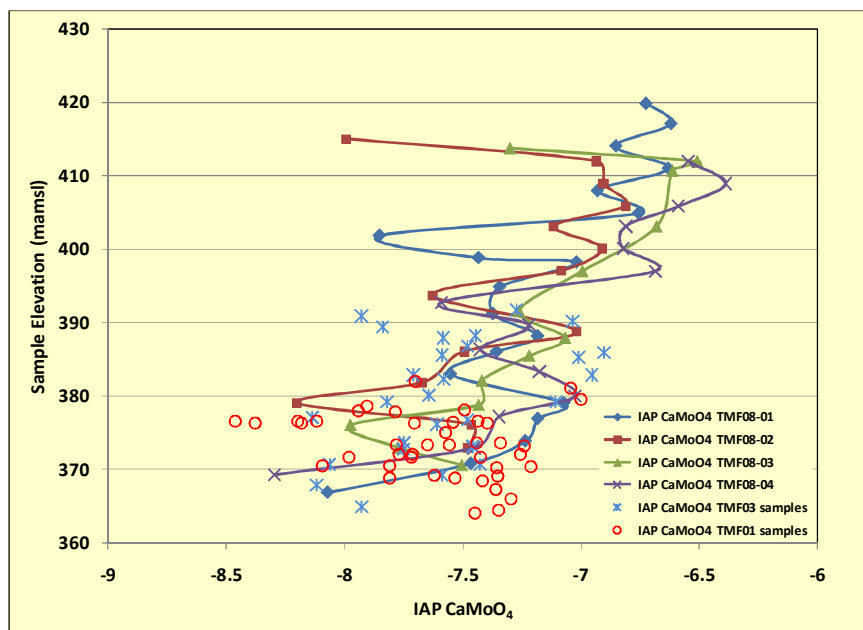


Figure 8. IAP values for CaMoO_4 as a function of sample elevation for samples collected in 2001, 2003 and 2008



CONCLUSIONS

This technical memorandum provides an initial evaluation of the geochemical conditions for molybdenum in the JEB TMF. At this time, one likely candidate for the long term control of molybdenum in the TMF appears to be powellite (CaMoO_4). The particular phase within the TMF may be slightly less stable than the phase reported to have a $\log K_{\text{sp}}$ of -7.95, and possible in the range of -7.5 to -7.25. The high oxidation conditions that help stabilize arsenic in the ferric arsenate phase scorodite, prevents the formation of ferrous molybdate (FeMoO_4), and ferrimolybdite appears to be far too soluble to control Mo in these waters. It may still be possible that during the raffinate neutralization process other phases such as ferrimolybdite may have precipitated, they are not stable under the conditions that exist in the TMF at this time. Recent data on the stability of NiMoO_4 suggests that it is too soluble to control Mo concentrations. The abundance of gypsum in the tailings means that calcium ion (Ca^{+2}) activities will remain at steady and relatively high levels over the long term. This has the advantage of stabilizing Mo concentrations at relatively low levels, which are expected to be similar to the levels presently observed in the TMF. The stability of CaMoO_4 in the TMF has been demonstrated in Figure 8.

This initial evaluation did not consider the influence of adsorption of Mo onto hydrous ferric oxide. At this time, I believe that mineral solubility reactions probably control the concentrations of Mo in these waters rather than surface complexation reactions.

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Table 1. Summary of thermodynamic data for Molybdenum (MoO₄⁻²).

	HYDRA/MEDUSA		EQ3NR/EQ6		Databases available with PHREEQC		Visual MINTEQ		GWB		OTHER REFERENCE SOURCES						
log K values			data0.ymp.R5		MINTEQ.v4.dat		LLNL.dat	Thermo.vdb		thermo.com.v8.r6+.dat	Meima & Comans		Langmuir thermodynamic compilation		Essington 1990 ES&T	Essington 1992 SSSAJ	
H2MoO4*	8.22	Smith/Martell	8.24	Mar/Smi	8.1636	NIST46.4	includes component but no other MoO4-2 species	?????!!		includes component but no other MoO4-2 species		8.24	Rai Zachara			8.23	
HMoO4-1	4.23	Smith/Martell	4.24	Mar/Smi	4.2988	NIST46.4		4.24				4.24	Rai Zachara			4.23	
CaMoO4*	-							2.57	Essington 92			2.57	Essington 92			3.09	2.57
MgMoO4*	-							3.03	Essington 92			3.03	Essington 92				3.03
NaMoO4-1	-															1.7	
KMoO4-1	-															1.29, 1.3	
PHASES																	
CaMoO4(s)	-7.95	Smith/Martell	-7.601	79rob/hem	-7.95			-7.95	NIST46.4							-8.05	
Powellite								-7.92	Felmy 92 paper states -7.93					-8.32 to -8.5	Langmuir cites Dellien 1976 for -8.32 value, and Vlek and Lindsay (1977) for -8.5 value	Essington cites numerous sources ranging from -8.51 to -7.02	
MgMoO4(s)	-1.85	Smith/Martell			-1.85			-1.85	NIST46.4								
H2MoO4(s)	-11.67	85bar/par			-12.8765			-12.8765	Bard85								
NiMoO4(s)	-		-6.5033	03mor/nav	-11.1421		-11.1421	Bard85				-6.52 or (-6.87)	Using ΔG° from 03Mor/Nav for NiMoO4 and ΔG° values from Langmuir compilation gets a value of -6.52, using Oelker et al. 1995 for ΔG°for Ni+2, MoO4-2 gets -6.87				
Fe2(MoO4)3	-		-38.52	63 tit, 01 lin							-35.29	Rai et al. EPRI EA-5176	-37.74	Langmuir cites Vlek and Lindsay equations 2 and 10 for value			
FeMoO4(s)	-				-10.091		-10.091	Bard85									
Although some programs use different sign conventions, we have assumed association reactions for dissolved species and dissociation reactions for solids. This is consistent with the approach used in PHREEQC.																	

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between 10 to 100°C, while the decahydrate is formed below about 10°C. The melting point of anhydrous Na_2MoO_4 is 627°C and its density is 3.28 g/cm³. The solubility of sodium molybdate at 15°C is 39.27% and at 100°C it is 45.27%.

2. Normal ammonium molybdate ($(\text{NH}_4)_2\text{MoO}_4$) — It is mainly used by chemical and catalyst manufacturers. It is chemically refined by dissolving technical MoO_3 (or pure MoO_3) in NH_4OH . The solution is filtered and then evaporated. The crystals obtained are subsequently filtered and dried ready to use. This is probably the purest commercially available molybdenum compound in the market today.

3. Calcium molybdate (CaMoO_4) — It occurs in nature as powellite, a mineral of molybdenum. The salt is white and is prepared from aqueous solutions of molybdates by the addition of calcium chloride. It can also be prepared by directly interacting calcium oxide and molybdic anhydrides at temperatures above about 450°C. The density of the salt is 4.28 g/cm³ and it melts at 1520°C.

4. Iron molybdates — There are two forms, one being the ferrimolybdate, $\text{Fe}_2(\text{MoO}_4)_3 \cdot n\text{H}_2\text{O}$ and the other the ferrous molybdate, FeMoO_4 . The ferrimolybdate separates out as a yellow precipitate when ferric chloride or sulfate is added to a solution of sodium molybdate. The precipitation of the ferrimolybdate corresponding to the indicated formula occurs at a pH value of approximately 3.5. The precipitate formed at higher pH values contains iron hydroxide and has a brown color, while the precipitate formed at lower pH values contains molybdic acid. The ferrimolybdate decomposes to its constituent oxides, Fe_2O_3 and MoO_3 , when heated above 600°C. Ferrous molybdate is not precipitated from molybdate solutions, since Fe^{2+} ions reduce MoO_4^{2-} , FeO and MoO_3 mixture is heated at 500 to 600°C in the absence of air to obtain ferrous molybdate.

5. Lead molybdate (PbMoO_4) — It is a white, sparingly soluble salt and occurs in nature as the mineral wulfenite. The salt may be prepared by precipitation from solutions of alkali metal molybdates or by heating a mixture of PbO and MoO_3 at 500 to 600°C. The density of lead molybdate is 6.92 and its melting point is 1065°C.

6. Copper molybdate (CuMoO_4) — The anhydrous copper molybdate, CuMoO_4 , is a green-yellow powder which is prepared by heating a mixture of CuO and MoO_3 at 500 to 700°C. The salt melts with decomposition at 820°C. The basic, bright-green copper molybdates are precipitated from aqueous solutions of sodium molybdate by the addition of copper salts. Depending on the conditions of precipitation, the composition of precipitates either corresponds to the formula $\text{CuO} \cdot 3\text{CuMoO}_4 \cdot 5\text{H}_2\text{O}$ or assumes the composition of the mineral lindgrenite, $2\text{CuMoO}_4 \cdot \text{Cu}(\text{OH})_2$.

7. Sodium paramolybdate ($5\text{Na}_2\text{O} \cdot 12\text{MoO}_3 \cdot 38\text{H}_2\text{O}$) — It crystallizes from solutions of the normal sodium molybdate when these are neutralized to a pH of about 5. The solubility of the crystalline hydrate at 30°C is 157 grams per 100 grams of water. The anhydrous salt is sparingly soluble in water.

8. Ammonium paramolybdate ($3(\text{NH}_4)_2\text{O} \cdot 7\text{MoO}_3 \cdot 4\text{H}_2\text{O}$) — It crystallizes from ammoniacal solutions in which the molecular ratio $\text{NH}_3:\text{MoO}_3$ is 6:7 or slightly higher. This ratio is obtained by evaporating the solution and thus expelling ammonia or by neutralizing part of the ammonia. It is stable in air and its solubility in water at 20°C is about 300 g/l

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Stability of Arsenite Surface Complexes in the JEB TMF

Surface complexation of arsenite species [As^{3+}] onto hydrous ferric oxide (HFO) is generally considered to be to less significant attenuation process than surface complexation of arsenate [As^{5+}] onto the same surface. However, there are conditions where arsenite surface complexation plays a significant role controlling the fate and mobility of arsenic. The primary purpose of this section is to demonstrate that arsenite surface complexes may form on iron hydroxide surfaces such as ferrihydrite [$\text{Fe}(\text{OH})_3$] and goethite (FeOOH), that they are stable over a wide pH range, and that these surface complexes can exist in the JEB TMF. The existence of these arsenite surface complexes helps to explain some of the observations made by the Canadian Light Source (Section 5.3.2.1)

A series of geochemical models were prepared to demonstrate the extent of arsenite surface complexation on ferrihydrite. The models were based upon diffuse layer model parameters (Dzombak and Morel, 1990). An Eh pH diagram was prepared that used diffuse layer model parameters on a hybrid ferrihydrite goethite surface to show the extent of sorption under a wide range of Eh and pH values. An additional diagram was also prepared based upon an alternative surface complexation model that included arsenite and arsenate surface complexation constants that were specific to the goethite surface.

Database Updates

The original diffuse layer model prepared by Dzombak and Morel (1990) provided a set of arsenate complexation constants onto the HFO (Ferrihydrite) surface. Three arsenate surface complexes were originally defined by Dzombak and Morel. Those authors also identified one reaction involving arsenite complexation onto HFO. In 2007, Gustafsson and Bhattacharya updated these reactions using various data sources from more recent literature. In general, they increased the arsenate surface complexation constants by one to two orders of magnitude and they also added a fourth reaction. This additional complex is the Hfo_wAsO_4^{-2} surface complex.

For arsenite surface complexation constants, Gustafsson and Bhattacharya reduced slightly the log K value from 5.41 to 5.27, but they also added another complex that is dominant at higher pH values. This added complex is the Hfo_wHAsO_3^- complex.

The following reactions from Gustafsson and Bhattacharya were used in the diffuse layer model calculations.

Arsenate



$\text{Hfo_wOH} + \text{AsO}_4^{-3} + \text{H}^+ = \text{Hfo_wAsO}_4^{-2} + \text{H}_2\text{O}$
log_k 19.5 # Added From Gustaffson Bhattacharya D&M did not include

$\text{Hfo_wOH} + \text{AsO}_4^{-3} = \text{Hfo_wOHAsO}_4^{-3}$
log_k 11.92 # From Gustaffson and Bhattacharya D&M value was 10.58

Arsenite

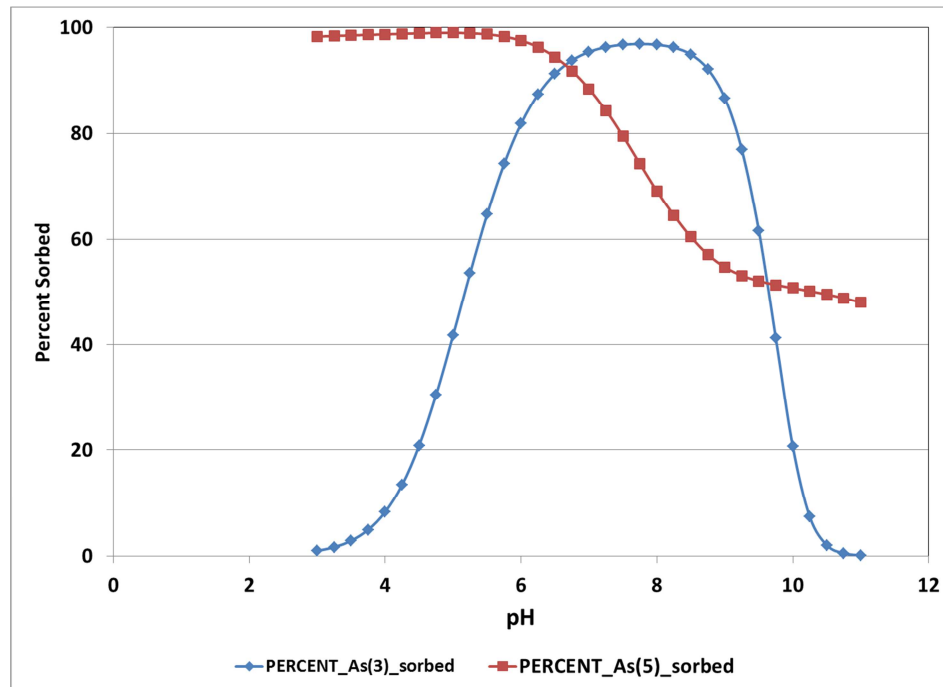
$\text{Hfo_wOH} + \text{H}_3\text{AsO}_3 = \text{Hfo_wH}_2\text{AsO}_3 + \text{H}_2\text{O}$
log_k 5.27 # changed based upon Gustaffson D&M value was 5.41

$\text{Hfo_wOH} + \text{H}_3\text{AsO}_3 = \text{Hfo_wHAsO}_3^- + \text{H}^+ + \text{H}_2\text{O}$
log_k -2.19 # added based upon Gustaffson D&M did not include

Surface Complexation Models

Figure 1 shows a series of PHREEQC (Parkhurst and Appelo, 2013) based calculations that compare As(3) and As(5) sorption onto HFO. To better show the slight difference between the As(3) and As(5) surface complexes the models were run at relatively low sorption capacities. The two valences, of As(3) and As(5) were defined in separate solutions and the surface complexation reactions used the same surface, but were modeled independently. At these low sorption capacities As(5) sorption is greater than As(3) under low pH conditions, but with increasing pH the proportion of As(3) sorption increases.

Figure 1. Extent of arsenite and arsenate surface complexation as a function of pH.



With increasing pH, the HFO surface develops a more negative surface charge that repels the more negative surface complexes. These negative surface complexes are generally associated with arsenate complexes. There are two related factors that explain the wider pH stability of the arsenite surface complex. The neutral arsenite solution complex H_3AsO_3 has a larger stability field than does H_3AsO_4 . H_3AsO_3 does not deprotonate to form H_2AsO_3^- until a pH of near 9.2 is reached (Figure 2). For H_3AsO_4 the first deprotonation reaction happens around a pH of 2.24, a further deprotonation reaction occurs at a pH of about 6.96 with the formation of HAsO_4^{2-} . Furthermore, the dominant Hfo_w H_2AsO_3 surface is a neutral surface complex so it is not affected by the negative surface charge. However with further increase in pH, the H_2AsO_3^- complex does start to dominant and some electrostatic repulsion takes place on the surface.

For these models the standard diffuse layer parameters were used. A weak site (Hfo_wOH) concentration of $2.5\text{e-}4$ moles/L was used to define the surface. The site concentration is based upon 0.122 grams/L of HFO at a proportion of 0.2 weak sites per mole HFO precipitated. The surface area was assumed to be $600\text{ m}^2/\text{gram}$. Strong sites were also included at $6.25\text{e-}6$ moles per liter, but these sites do not complex with anions. The initial arsenic concentration for either As(3) or As(5) was set at 10 mg/L.

Figure 2. Eh –pH diagram of arsenic soluble species only.

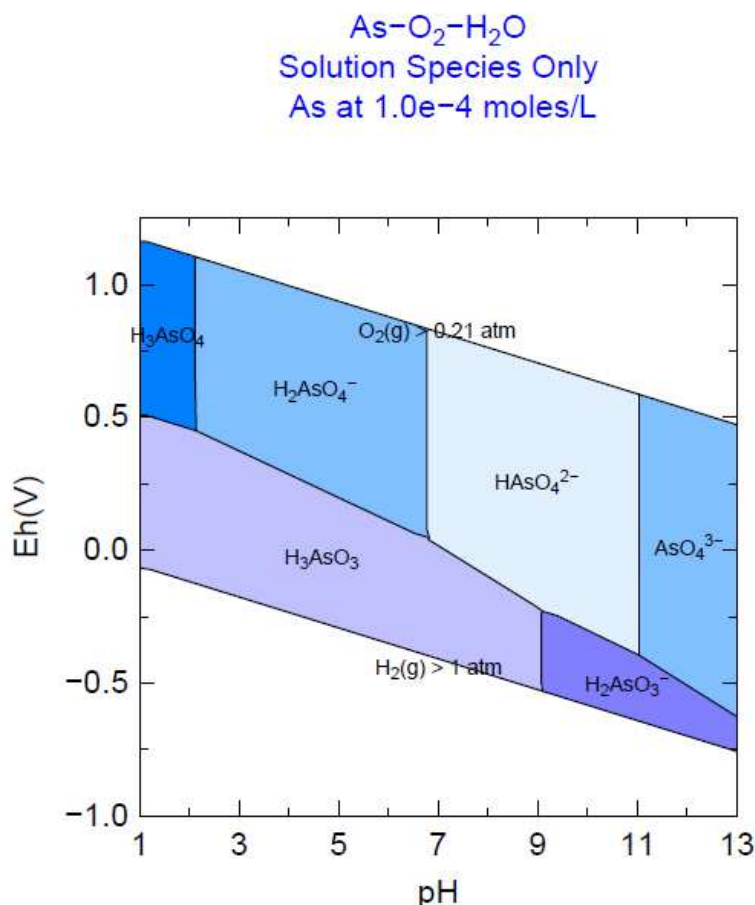


Figure 3 shows the distribution of As(3) surface complexes assuming a two surface complex model. Even a model that uses only one surface complex provides a fairly similar extent of adsorption (Figure 4), although the upper pH range is reduced compared to the two complex model. However, both models demonstrate a significant amount of arsenite surface complexation in the pH 6 to 8 range.

Figure 3. Distribution of arsenite surface complexes as a function of pH. This model used the two surface complexes as defined by Gustafsson and Bhattacharya (2007). The distribution of the two surface complexes and their cumulative percentage sorbed (green triangles) are shown.

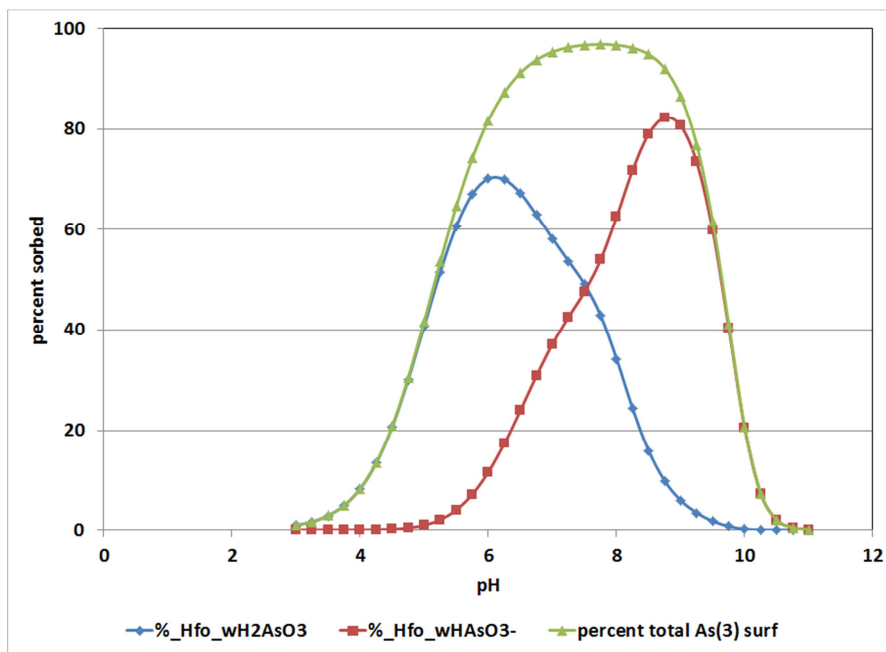
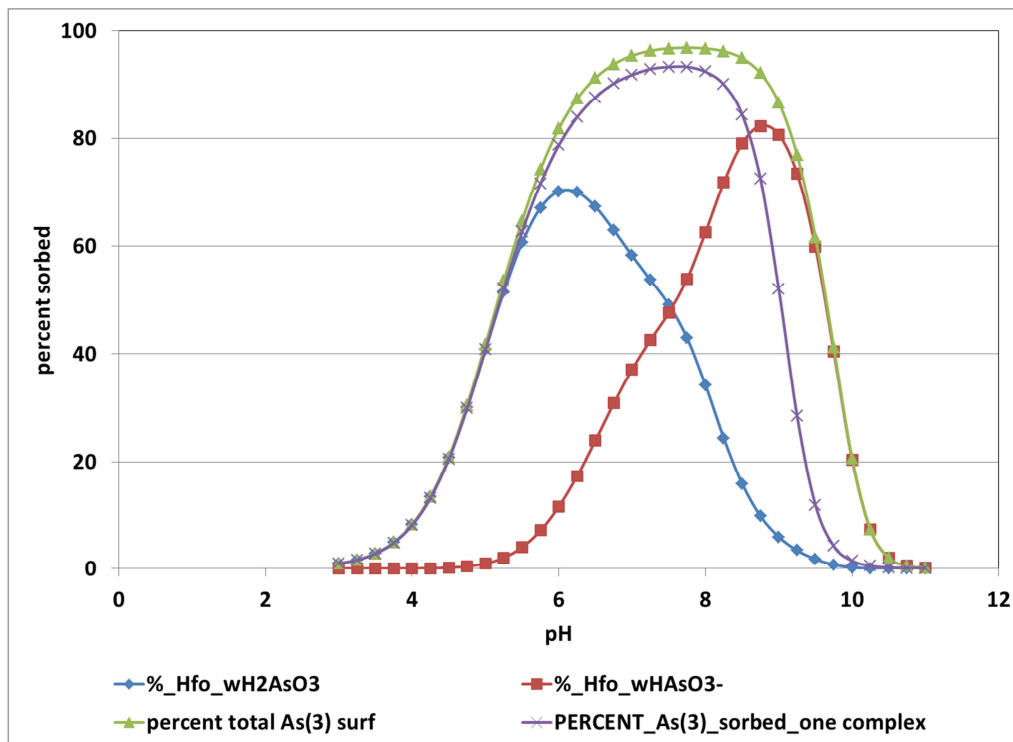


Figure 4. Comparison of arsenite sorption models. The two surface complexes model is compared to a model that only uses a single Hfo_wH₂AsO₃ surface complex (purple X's).



Eh – pH Diagrams

Figures 5(a,b) show Eh - pH diagrams for a ferrihydrite goethite hybrid surface. The figures were prepared using PhreePlot (Kinniburgh and Copper, 2011). This program uses the same types of input files and databases that the PHREEQC program uses. The figures present the dominant species, surface complexes or phase(s) for arsenic. The same surface complexation constants as defined above were used, but the surface site density was reduced from 0.2 moles of sites per mole of iron precipitate to 0.1 moles of weak sites, and the surface area was reduced to 60 m²/gram. This composite surface is an approximation of ferrihydrite converting to goethite. The goethite concentration was set at 0.05 moles/liter (Figure 5a). The figure demonstrates that the two surface complexes Hfo_wH₂AsO₃ and Hfo_wHAsO₃⁻ are present in the lower portion of the diagram. These complexation reactions are still defined in accordance with the diffuse layer model of Dzombak and Morel (1990). Some of the reduced arsenic solids have been suppressed in this plot to better show the distribution of the arsenite surface complexes. An additional figure (Figure 5b) was prepared that used a lower concentration of goethite (0.005 moles/L). Even at this lower goethite concentration the two arsenite surface complexation are present, although their distribution in the Eh - pH space have been reduced.

Figure 5a. Eh pH diagram for the system As-Fe-Ca-S-O₂-H₂O the underlying surface is based upon goethite stability but the surface complexation calculations use the Gustafsson and Bhattacharya (2007) surface complexes. Figure assumed a concentration of 0.05 moles/liter goethite.

Eh pH diagram for the system Fe-As-Ca-S-O₂-H₂O at 25°C showing dominant dissolved, or adsorbed species and solid phases
HFO – are hydrous ferric oxide surface complexes
As 50 mg/L, Ca 600 mg/L, Goethite 0.05m, SO₄-2 2000 mg/L

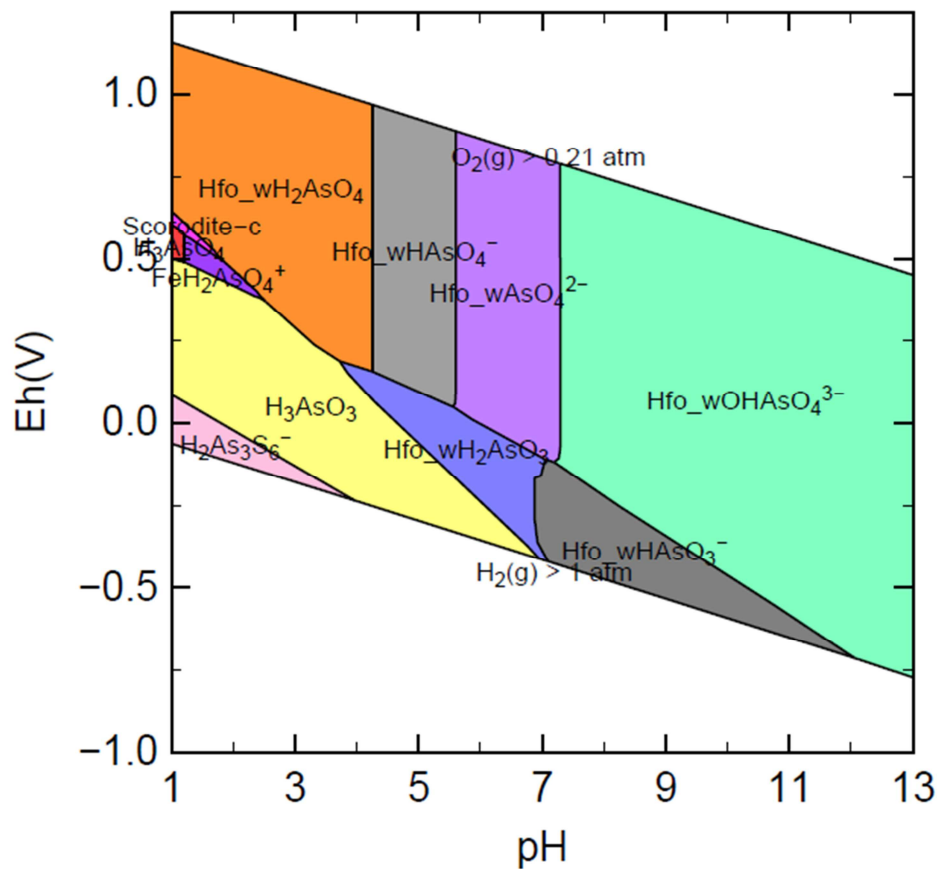
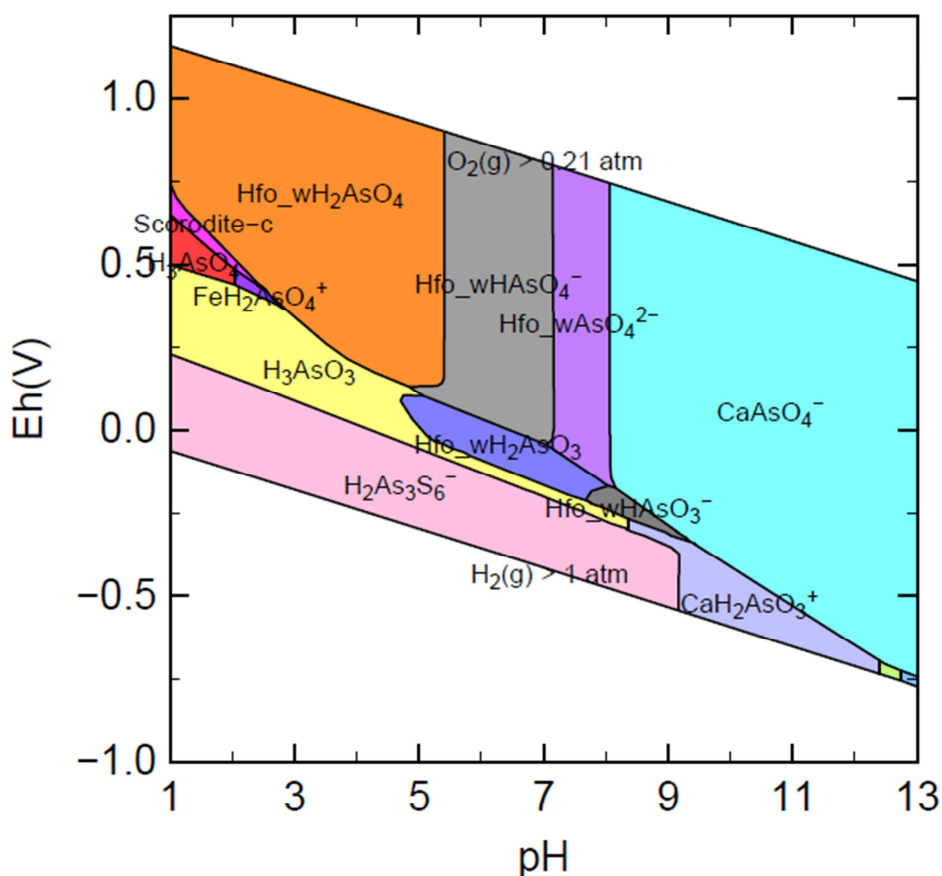


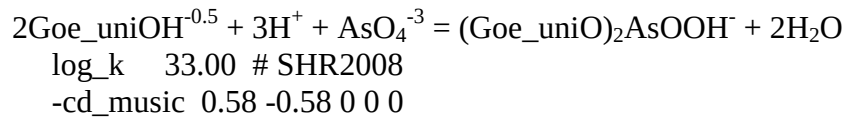
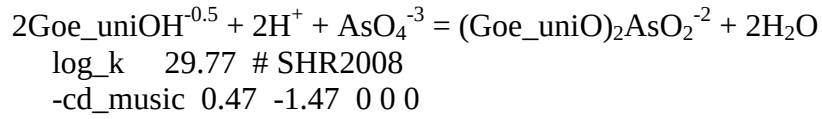
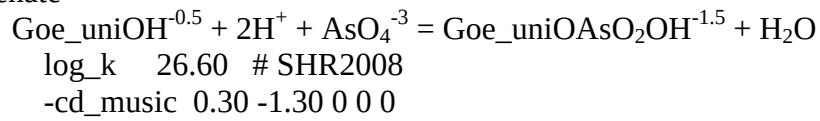
Figure 5b. Eh pH diagram for the system As-Fe-Ca-S-O₂-H₂O the underlying surface is based upon goethite stability but the surface complexation calculations use the Gustafsson and Bhattacharya (2007) surface complexes. Goethite at 0.005 m/L.

Eh pH diagram for the system Fe-As-Ca-S-O₂-H₂O at 25°C
 showing dominant dissolved, or adsorbed species and solid phases
 HFO – are hydrous ferric oxide surface complexes
 As 50 mg/L, Ca 600 mg/L, Goethite 0.005m, SO₄-2 2000 mg/L



An alternative surface complexation model database is also available for PHREEQC and PhreePlot. This model is called the Charge Distribution Multi Site Complexation model (CD_MUSIC) and in this case surface complexation reactions specific to goethite have been used to generate an alternative figure (Figure 6). These reactions are based upon work prepared by Stachowicz et al. (2006, 2008). The CD_MUSIC model for arsenic surface complexation reactions were run using the PHREEQC program onto a goethite surface. The surface complexation constants are listed below; data are from Stachowicz et al. (2008).

Arsenate



Arsenite

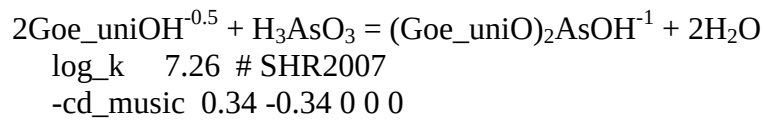
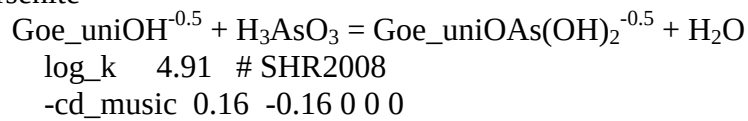
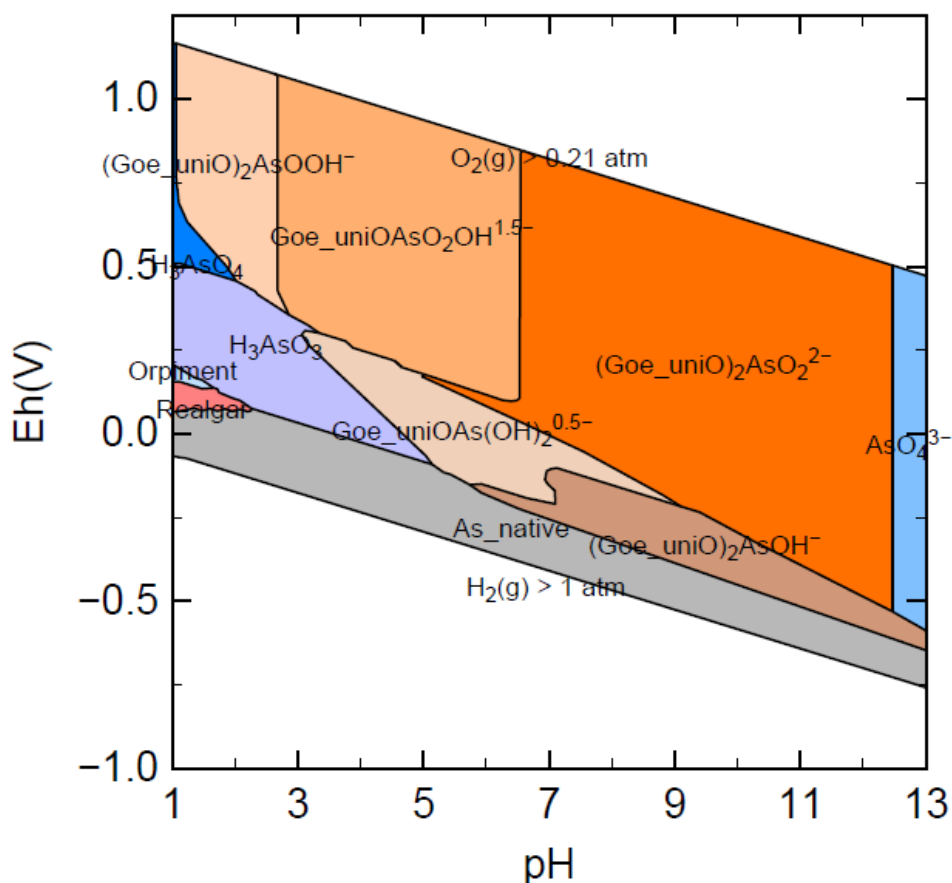


Figure 6. Eh pH diagram for the system As-Fe-Ca-S-O₂-H₂O, the underlying surface is based upon goethite stability and use a series of surface complexation constants based upon the CD_MUSIC model. Total Fe 3.5e-1 m/L, As 0.01 m/L, sulfate 0.01 m/L, NaOH used for pH adjustment.

Fe-As-S-H₂O (CD-MUSIC)



A version of Figure 6 was originally included as an example in the PhreePlot user's manual. Concentrations were defined in the original PhreePlot example input file. To maintain consistency with other figures in this report, the original PhreePlot figure has been converted from a log oxygen fugacity pH diagram to an Eh pH diagram. As shown on the figure, there are two goethite-arsenite surface complexes. They are $\text{Goe_uniOAs}(\text{OH})_2^{-0.5}$ and a bidendate surface complex $(\text{Goe_uniO})_2\text{AsOH}^-$. The figure demonstrates that arsenite surface complexes do exist and can even be dominant under a wide range of pH values and for moderate to low redox conditions.

CONCLUSIONS

These figures demonstrate that arsenite based surface complexes can be present for a considerable period of time within conditions consistent with the JEB TMF as the arsenic system progresses towards thermodynamic equilibrium with final oxidation to arsenate. Evidence discussed in other portions of this document have identified arsenite surface complexes onto goethite and these calculations demonstrate the geochemical literature are fully consistent with those observations.

REFERENCES

- Dzombak, D.A., and Morel, F.M.M., 1990. Surface complexation modeling - hydrous ferric oxide: New York, John Wiley and Sons, 393 p
- Gustafsson, J.P., and Bhattacharya, P., 2007. Geochemical modeling of arsenic adsorption to oxide surfaces. (Chapter 6). *in* Arsenic in Soil and Groundwater Environment, P. Bhattacharya, A. B. Mukherjee, J. Bundschuh, R. Zevenhoven, R. H. Loeppert (Editors) Trace Metals and other Contaminants in the Environment, Volume 9, p. 159–206 Elsevier B.V.
- Kinniburgh, D.G., and Cooper, D.M., 2011. PhreePlot – Creating graphical output with PHREEQC. Available at <http://www.phreeplot.org/>, last updated July 21, 2014, 606 p.
- Parkhurst, D.L., and Appelo, C.A.J., 2013. Description of input and examples for PHREEQC version 3 — A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Techniques and Methods, book 6, chap. A43, 497 p., available only at <http://pubs.usgs.gov/tm/06/a43>
- Stachowicz, M., Hiemstra, T., and van Riemsdijk, W. H., 2006. Surface speciation of As(III) and As(V) in relation to charge distribution. *J. Colloid Interface Sci.* **302**, 62–75.
- Stachowicz, M., Hiemstra, T., and van Riemsdijk, W.H., 2008. Multi-competitive interaction of As(III) and As(V) oxyanions with Ca²⁺, Mg²⁺, PO₄³⁻, and CO₃²⁻ ions on goethite. *J. Colloid Interface Sci.* **320**, 400-414.

Appendix D

Section D

Subsection C: Dr. Slaughter Reports

**A Scanning Electron Microscope,
Electron Microprobe, Chemical, and Mineral
Investigation of Select
TOVP Ageing Test,
TOVP Neutralization Test,
and 2001 TMF Samples**

Volume II - Data

**By
M. Slaughter
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Greeley, Colorado
970-330-5894**

**Appendix A - Log of Electron Microprobe
Images of
Samples 2001 TMF 4A and 8
and
TOVP Neutralization Test
6-Series Samples**

COLORADO SCHOOL OF MINES ELECTRON MICROPROBE LAB

SLAUGHTER IMAGING STUDY

SESSION 4 Sample 4A (block) (256x256)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u># PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
4-1SE	800x				15
	10355,22460,5269				
4-2BSE					
4-3Mg		3	2	0.2	
4-4Fe					
4-5S			4		
4-6Ni					
4-7Ca					
4-8As					
4-9Mg					
4-10Al			3		
4-11SE	4000x				15
	10046,22660,5279				
4-12BSE					
4-13Mg		3	3	0.2	
4-14Fe					
4-15S					
4-16As					
4-17Pb			4	5.0	
4-18Ni					
4-19BSE	8000x				15
	10061,22637,5282				
4-20SE					
4-22S		3	3	5.0	
4-23Ni					
4-24Ca					
4-25Fe					
4-26Mg					
4-27As					
4-28Al					
4-29Mn					
4-30Si		5	1	5.0	
4-31Ni					
4-32BSE	20000x				15
	10057,22636,5282				
4-33S		5	1	5.0	
4-34Ni					
4-35Ca					
4-36As					

SESSION 5 Sample 8 (pol. sec.)(256x256)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
5-1SE	2000x				15
	9679,21777,1385				

5-2BSE				
5-3Ca	5	2	5.0	
5-4As				
5-5SE				
5-6S				
5-7Ni				
5-8Mg				
5-9Fe				
5-10Al				
5-11Co				
5-11SE	2000x			15
	9146,22497,1381			
5-12BSE				
5-13Al	5	2	5.0	
5-14				
5-15Mg				
5-16As				
5-17S				
5-18Ni				
5-19Si				
5-20Fe				
5-21Fe				
5-22BSE	2000x			15
	9345,22454,1394			
5-23Ca	5	2	5.0	25
5-24Ni				
5-25S		3		30
5-26As				
5-27BSE	2000x			15
	9679,21777,1385			
5-28Ni	5	2	5.0	25
5-29Pb		3		30
5-30As				

SESSION 6 Sample 4A (pol. sec.)(256x256)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
6-1SE	2000x				15
	9693,20468,1391				
6-2BSE					
6-3Si	5	2	5.0		
6-4Ni					
6-5Al					
6-6Fe					
6-7As		3			30
6-8Mg		2			15
6-9As					
6-10S					25
6-11Ni					
6-12Ca					15

* note Images 6-7 to 6-12 were not focused properly

SESSION 7 Sample 8 (pol. sec.)(256x256)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
7-1SE	2000x				15
	9703,20077,1372				
7-2BSE					
7-3Ca	5		2	5.0	
7-4Fe					
7-5S					25
7-6Ni					
7-7Al					30
7-8As					

SESSION 8 Sample 4A (block)(256x256)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
8-1SE	400x				15
	10061,22637,5282				
8-2BSE					
8-3Al	5		2	5.0	
8-4Fe					
8-5SE	2000x				15
	10000,21766,5251				
8-6BSE					
8-7Al	5		2	5.0	
8-8Fe					
8-9Si					25
8-10Ni					
8-11BSE					25
8-12Si					
8-13Ni					
8-14Mg					30
8-15As					
8-16SE	4000x				15
	10318,21827,5235				
8-17BSE					
8-18Fe	5		2	5.0	
8-19Al					25
8-20Ni					

SESSION 9 Sample 4A (block)(256x256)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
9-1SE	4000x				15
	11964,21482,5260				
9-2BSE					
9-3Mg	5		2	5.0	
9-4Fe					
9-5Al					25
9-6Ni					
9-7Si			3		30

9-8As			
9-9Ca	2		15

SESSION 10 Sample 8 (pol. sec.)(256x256)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
10-1SE	2000x				15
	12484,20745,1394				
10-2BSE					
10-3Ca	5		2	5.0	
10-4Fe					
10-5Mg					
10-6Al					25
10-7Ni					
10-8Si			3		30
10-9As					

SESSION 11 Sample 4A (pol. sec.)(256x256)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
11-1SE	2000x				15
	10309,22881,1374				
11-2BSE					
11-3Ca	5		2	5.0	
11-4Fe					
11-5Mg					
11-6Al			3		25
11-7Ni					
11-8Si			3		30
11-9As					
11-10P					
11-11Ni					

SESSION 12 Sample 4A (block mount)(256x256)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
12-1BSE	4000x				15
	11961,21439,4283				
12-2As	5		2	0.2	15

SESSION 13 Sample 8 (pol. sec.)(512x512)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
<u>COORDINATES(xyz)</u>					
13-1SE	4000x				15
	15262,20832,1394				
13-2BSE					
13-3Al	3		2	0.2	15
13-4Si			1	5.0	

13-5Fe		2		
13-6Ni	3	2	5.0	25
13-7As	3	2	5.0	30

SESSION 14 Test Session- Try importing visilog image files

SESSION 15 Sample 8 (pol. sec.)(512x512)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
	<u>COORDINATES(xyz)</u>				
15-1SE	4000x				15
	13262,21303,1376				
15-2BSE					
15-3Fe	3		2	5.0	15
15-4Ni					25
15-5As					30

SESSION 16 Sample 4A (pol. sec.)(512x512)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
	<u>COORDINATES(xyz)</u>				
16-1SE	2000x				15
	10215,22788,463				
16-2BSE					
16-3Fe	5		1	5.0	15
16-4Ni					25
16-5As	10		1	5.0	30

SESSION 17 Sample 6-2 (pol. sec.)(512x512)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
	<u>COORDINATES(xyz)</u>				
17-1SE	2000x				15
	11737,21268,489				
17-2BSE					
17-3Al	3		2	5.0	15
17-4Si					
17-5Fe					
17-6Ca					
17-7S					
17-8Ni	3		2	5.0	25
17-9As					30

SESSION 18 Sample 6-3 (pol. sec.)(512x512)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>
	<u>COORDINATES(xyz)</u>				
18-1SE	2000x				15
	11645,17827,516				
18-2BSE					

18-3Ca	5	1	5.0	15	
18-4S		2			
18-5Al					
18-6Si					
18-7Fe					
18-8Ni	5	2	5.0	25	
18-2BSE2				30	better BSE
18-9As				30	

SESSION 19 Sample 6-4 (pol. sec.)(512x512)

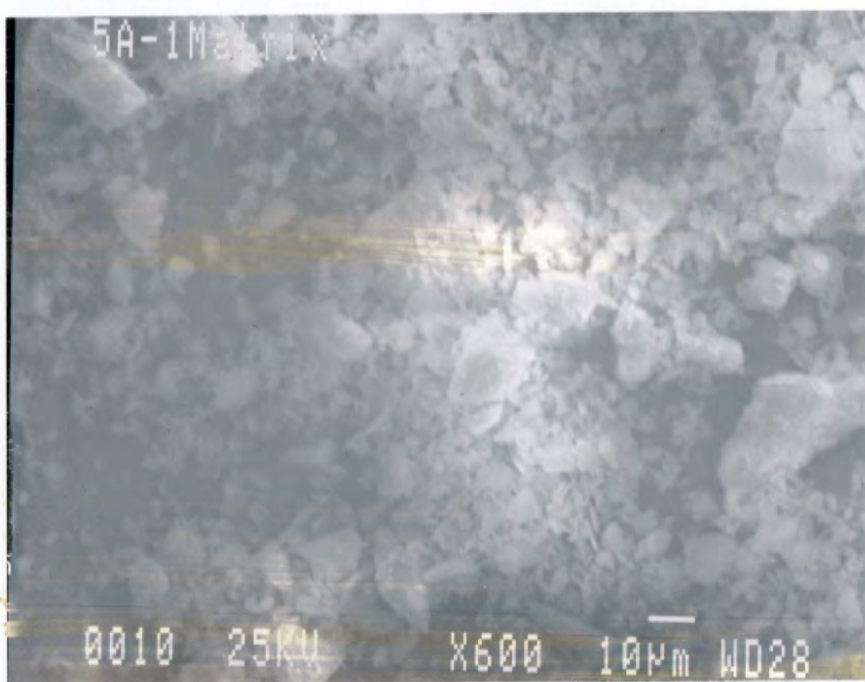
<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>	
<u>COORDINATES(xyz)</u>						
19-1SE	2000x				15	
	12206,18789,495					
19-2BSE						
19-3Ca	3	2	5.0	15		
19-4S						
19-5Mg						
19-6Al						
19-7Si						
19-8Fe						
19-2BSE2						better BSE
19-9Ni	3	2	5.0	25		
19-10As	5	2	5.0	30		

SESSION 20 Sample 6-5 (pol. sec.)(512x512)

<u>IMAGE</u>	<u>MAG.</u>	<u>TIME(mSec)</u>	<u>#PASSES</u>	<u>SPEED(sec/frame)</u>	<u>VOLTAGE(kV)</u>	
<u>COORDINATES(xyz)</u>						
20-1SE	2000x				15	
	12085,21628,518					
20-2BSE						
20-3Ca	3	2	0.2	15		
20-4S			5.0			
20-5Mg						low density
20-6Al						
20-7Si						
20-8Fe						low density-
background?						
20-9Mg2	3	2	5.0	25		rerun Mg higher
V						
20-10Ni						
20-11As	5	2	5.0	30		
20-8Fe2		3	2	5.0	15	change
bias/gain						

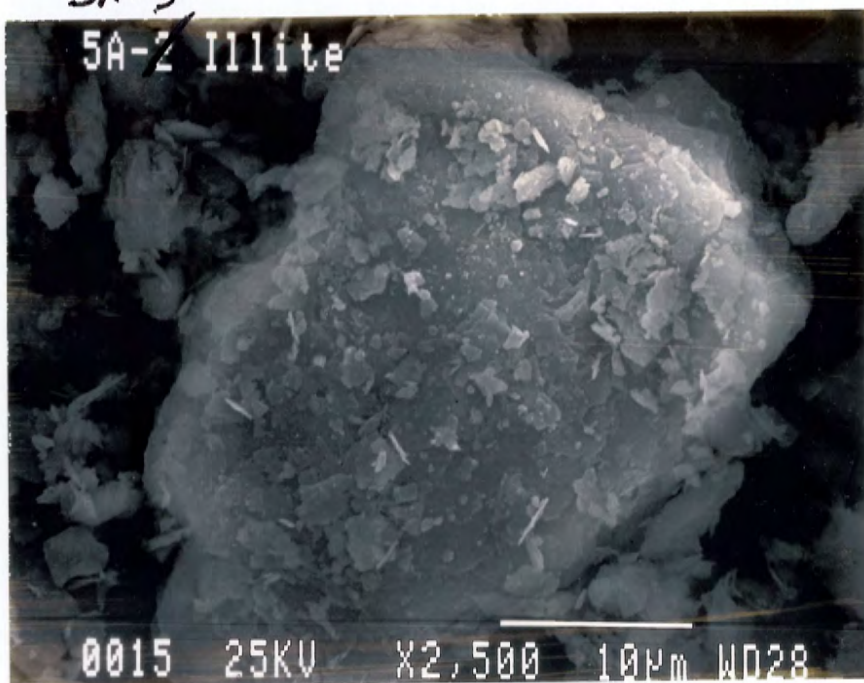
Number	Description	pH	Al	As	Ca	Fe	K	Mg	Na	Ni	Si	Cl	S(6)	Alkalinity
1	Raffinate	1.5	420	732	760	2400	210	260	48	560	260	14	14,100	0
2	1-1	2.00	380	170	700	1600	180	260	47	500	270	20	10,600	0.5
3	1-2	3.18	420	4.5	710	630	210	300	47	480	240	19	7,200	0.5
4	1-3	4.03	290	0.28	670	490	210	290	51	460	120	21	6,000	0.5
5	1-4	5.26	1.5	0.05	670	340	210	290	42	330	37	16	4,300	0.5
6	1-5	6.14	0.5	0.02	740	190	200	290	44	230	15	18	4,000	0.5
7	1-6	7.04	0.5	0.05	790	12.3	200	280	43	75	5.2	15	3,400	8
8	1-7	7.92	0.5	0.11	770	0.08	190	240	44	6	2	19	3,200	104
9	2-1	2.01	410	170	720	1600	230	260	1700	500	260	17	14,000	0.5
10	2-2	3.03	470	16	680	850	280	280	3300	500	270	19	13,300	0.5
11	2-3	4.06	380	0.35	640	570	300	290	4300	470	140	15	13,100	0.5
12	2-4	5.00	13	0.15	570	450	300	280	5400	430	54	17	13,000	0.5
13	2-5	6.37	0.5	0.08	540	300	310	280	6300	280	13	14	13,200	0.5
14	2-6	7.08	0.5	0.07	520	29	300	250	6800	48	5.8	18	13,400	0.5
15	2-7	8.01	0.5	0.21	570	0.07	300	220	7100	2	1.7	20	13,900	17
16	3-1	2.33	430	180	650	1500	220	280	78	470	290	20	10,600	0.5
17	3-2	3.11	530	22.8	690	910	240	330	61	480	290	22	8,000	0.5
18	3-3	4.15	320	1.1	510	610	160	260	46	440	170	13	6,500	0.5
19	3-4	6.03	2	0.16	510	380	150	250	35	320	31	15	3,900	0.5
20	3-5	7.52	0.5	0.06	550	57	140	220	37	56	6.6	17	2,700	0.5
21	4-1	2.08	420	160	730	1500	220	270	1600	490	260	14	14,000	0.5
22	4-2	3.06	420	9.7	650	770	230	260	2800	460	250	15	13,500	0.5
23	4-3	4.10	320	0.77	630	580	240	260	3600	460	140	18	13,600	0.5
24	4-4	5.89	0.5	0.1	550	340	240	250	5200	360	22	12	13,400	0.5
25	4-5	7.29	0.5	0.09	540	5.1	240	210	6200	14.8	5.3	18	14,000	10
26	Slurry 5A	7.57	0.5	0.09	650	0.1	190	220	49	7.5	1.6	16	2,900	9
27	Powder 5B	7.08	0.5	0.03	730	20.6	190	260	47	78	6.1	16	3,400	3
28	6-1	2.18	410	150	760	1600	200	270	62	500	280	13	10,200	0.5
29	6-2	3.15	460	6.7	680	730	210	290	52	460	270	17	7,400	0.5
30	6-3	4.04	290	0.54	620	570	200	280	50	450	140	11	6,100	0.5
31	6-4	6.09	0.5	0.08	610	340	200	270	42	250	17	16	3,800	0.5
32	6-5	7.38	0.5	0.06	650	2.2	200	240	42	5.3	3.2	18	2,800	4

**Appendix B - Scanning Electron Microscope
Images of
TOVP Ageing Test Samples ,
Samples 2001 TMF 4A and 8,
and
TOVP Neutralization Test
6-Series and 2-Series Samples**

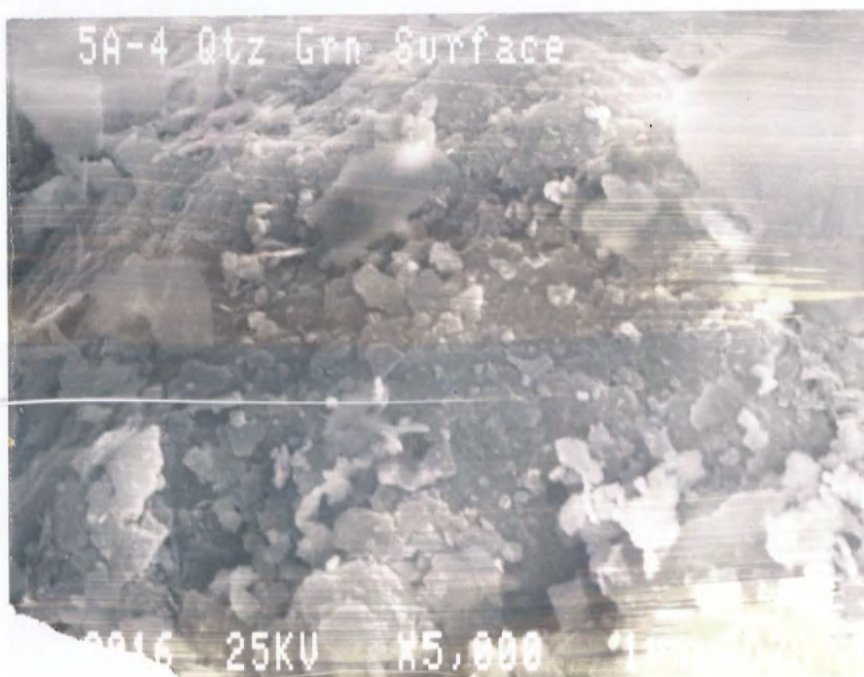


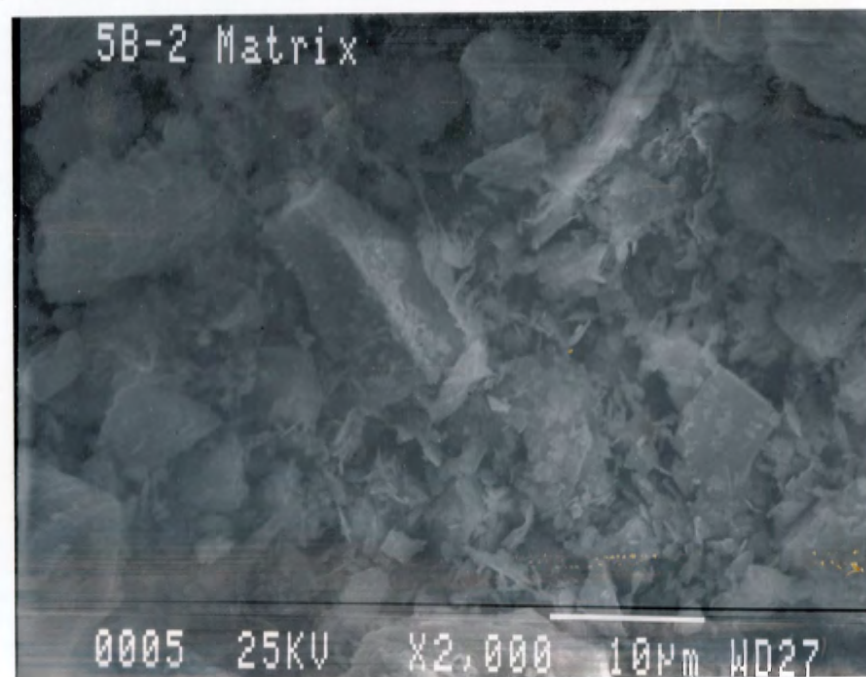
5A-3

5A-2 Illite

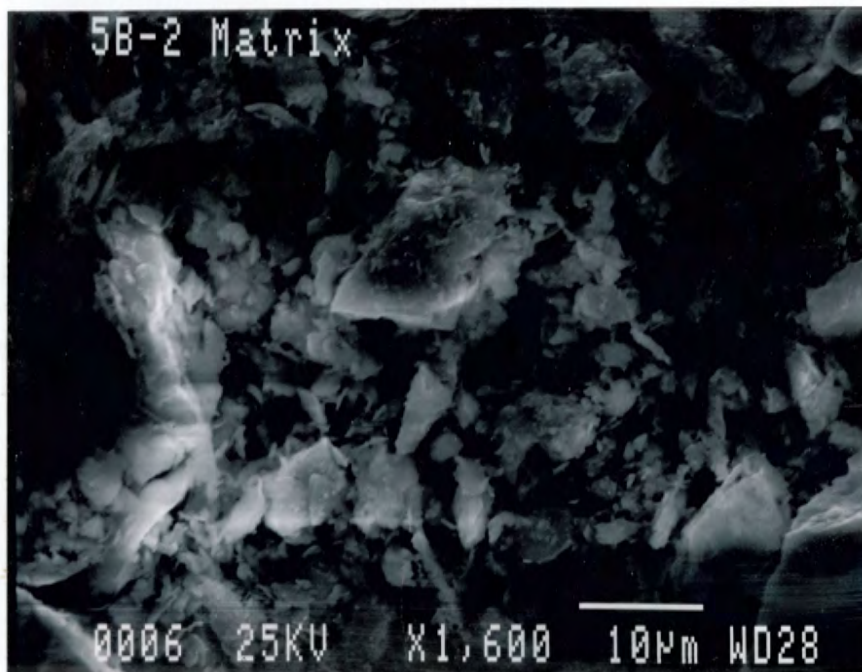


5A-4 Qtz Grn Surface

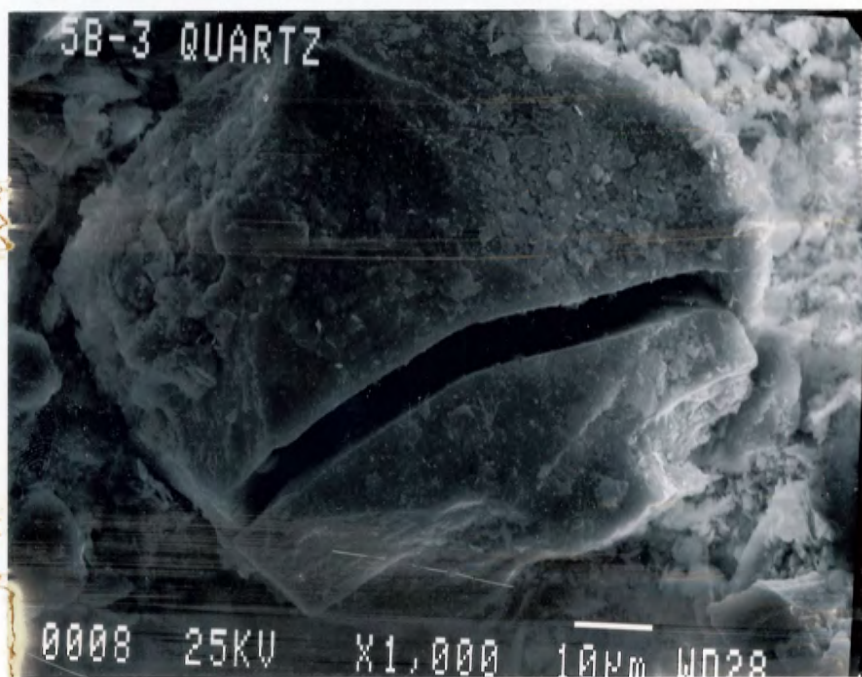


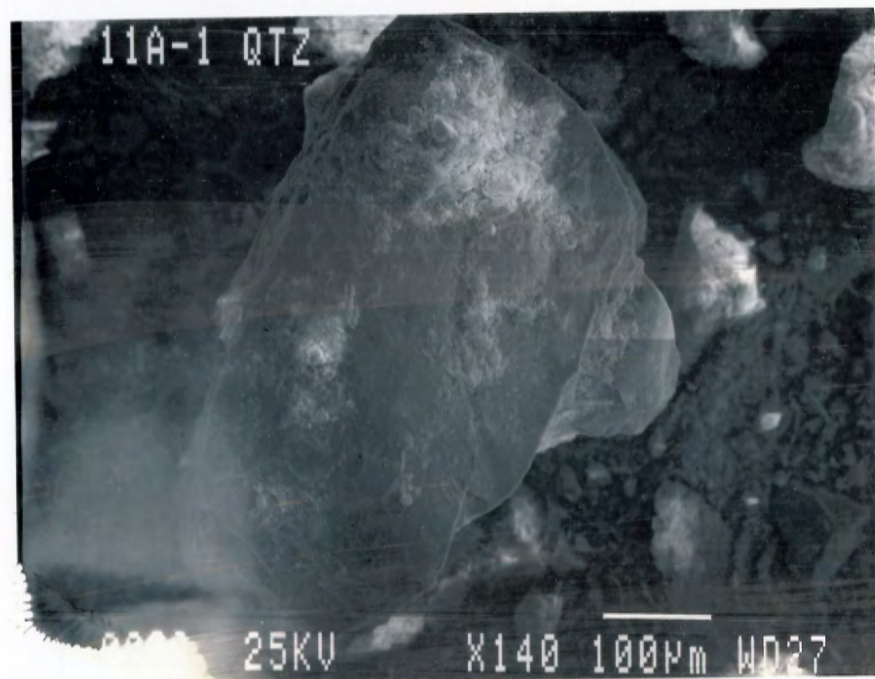
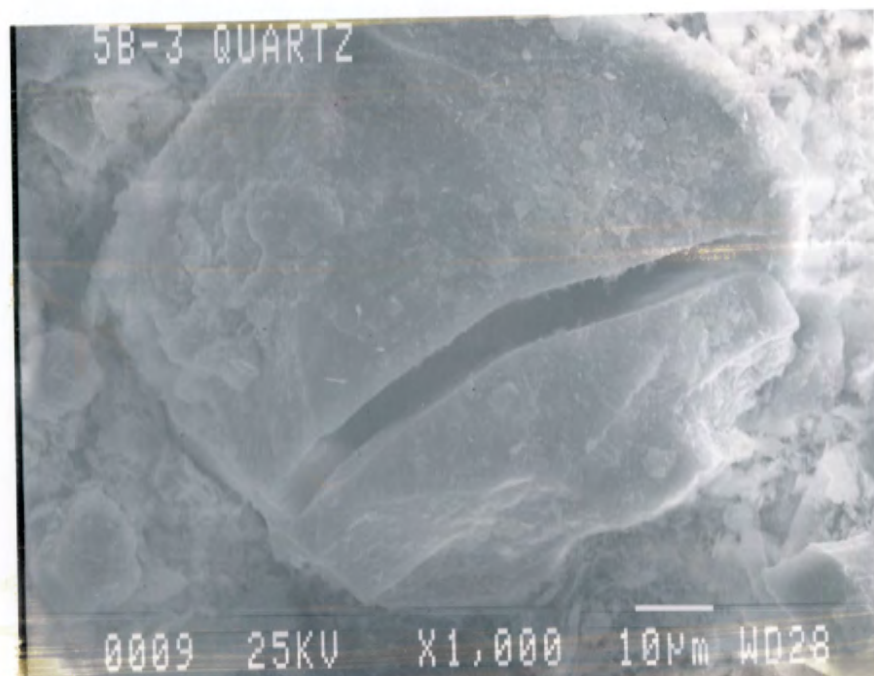


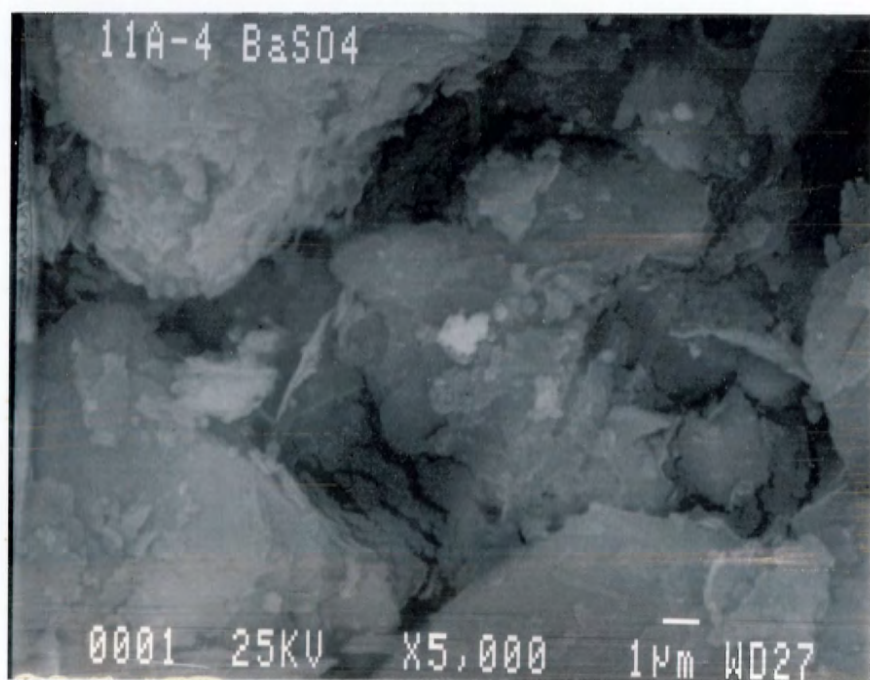
#1

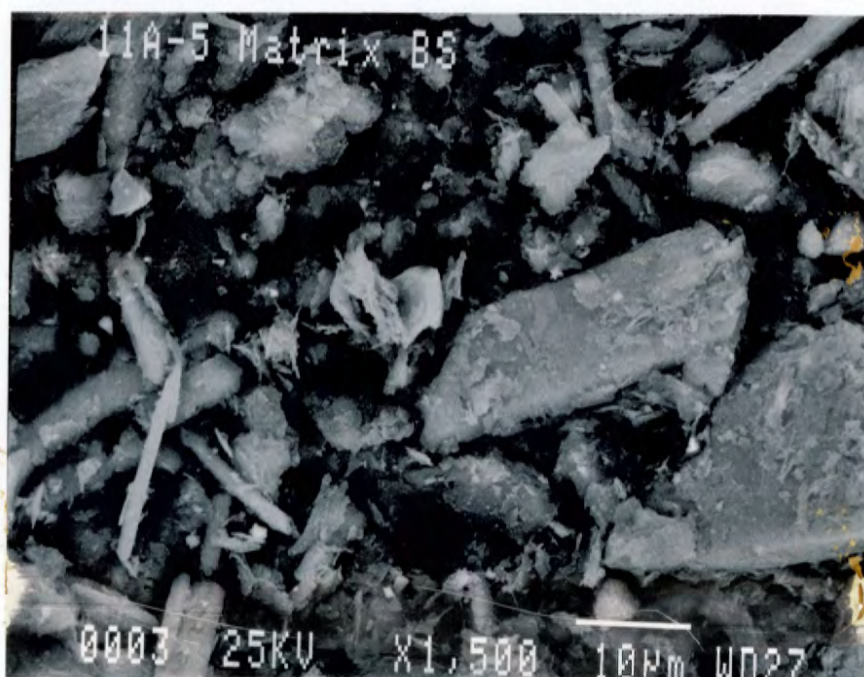
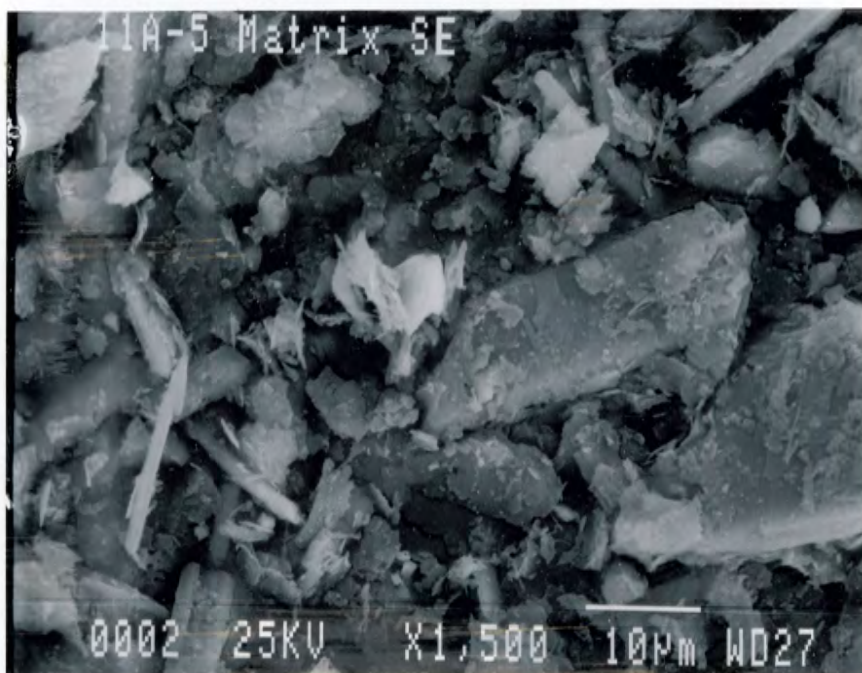


#2

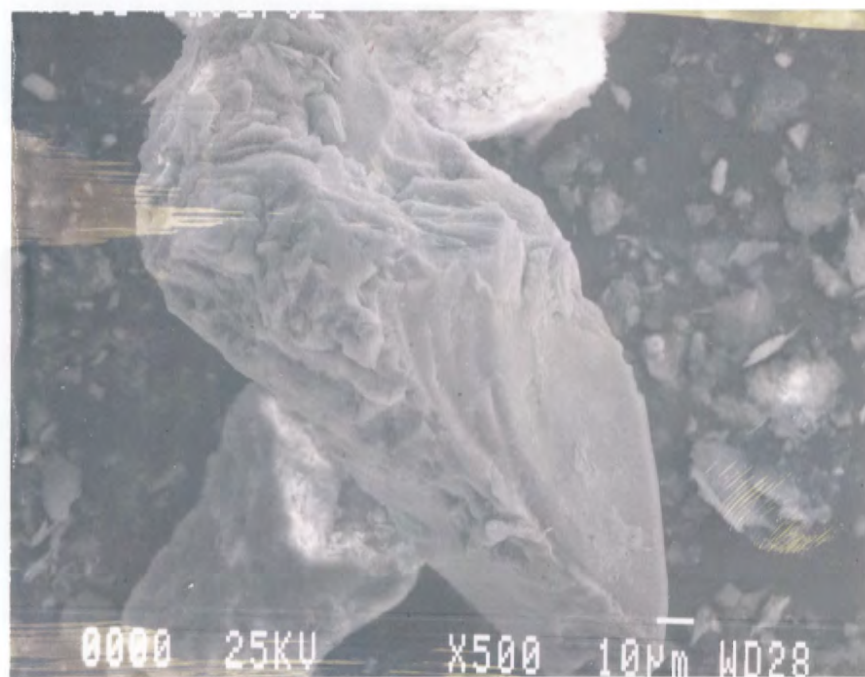
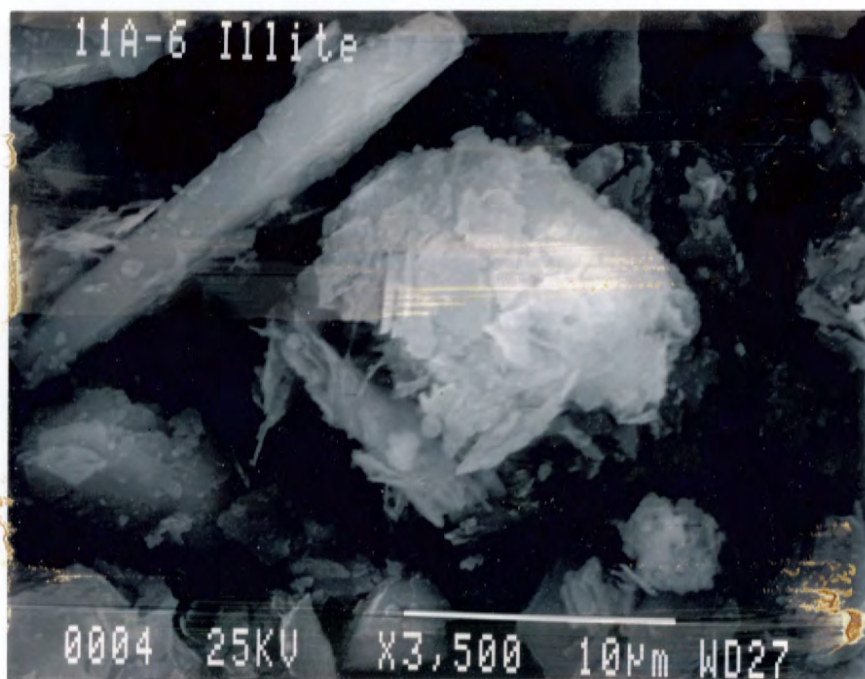








← 80µm →

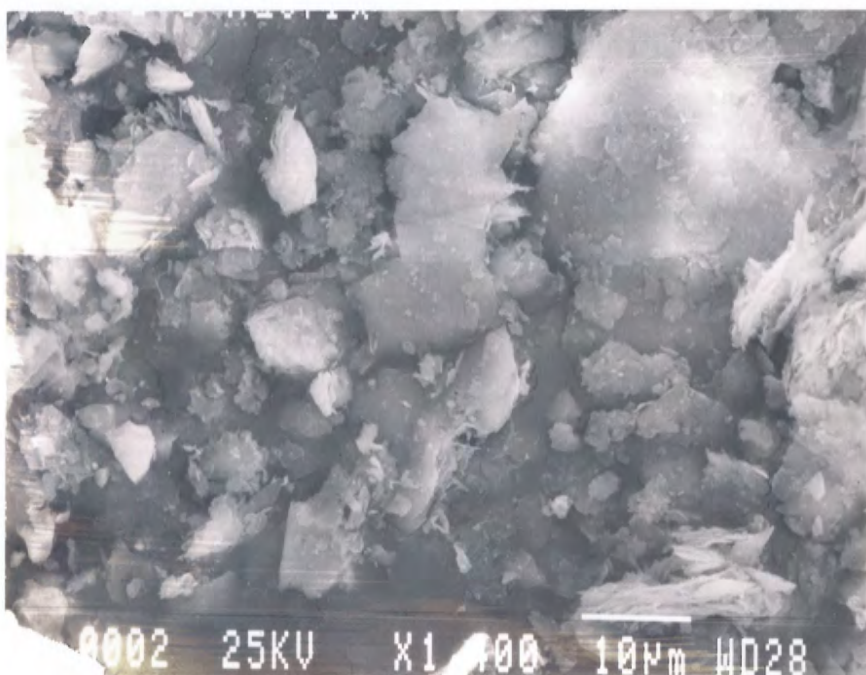


11B-1

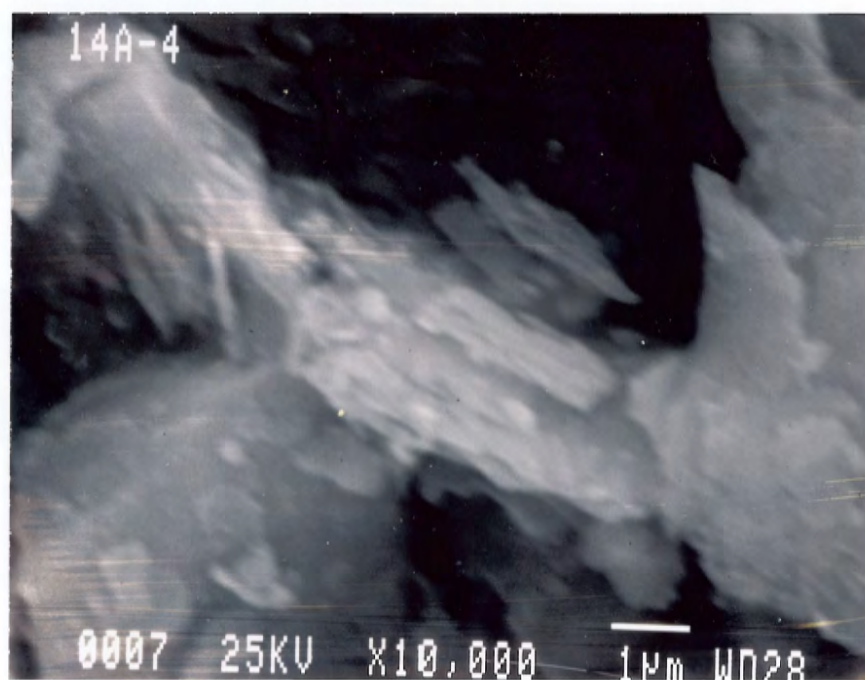
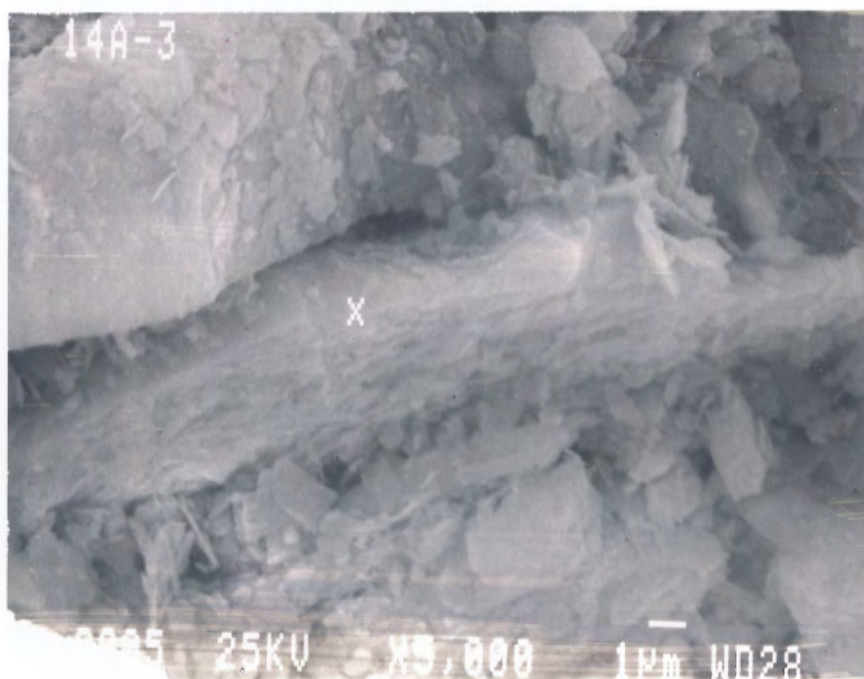
11B-2

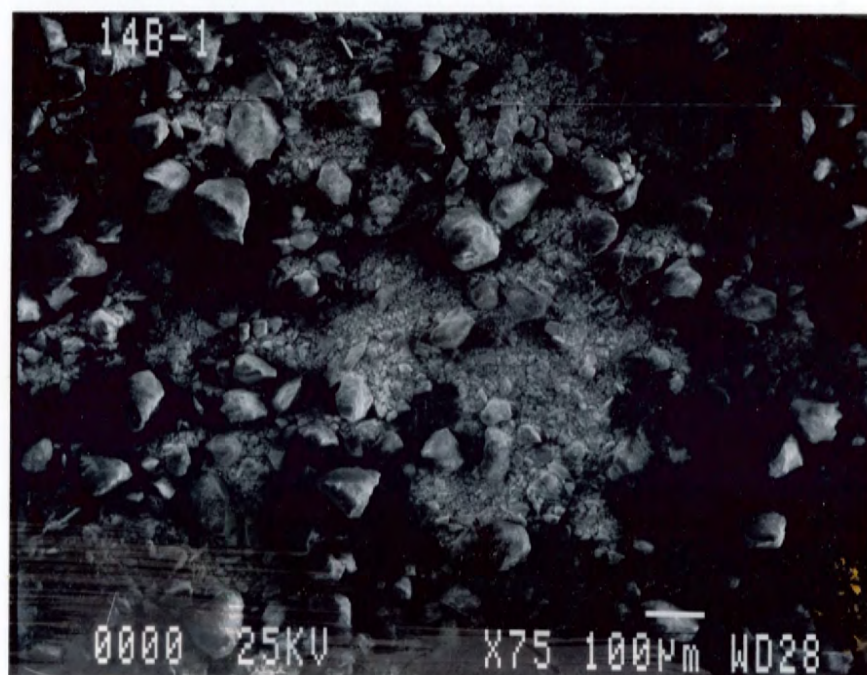
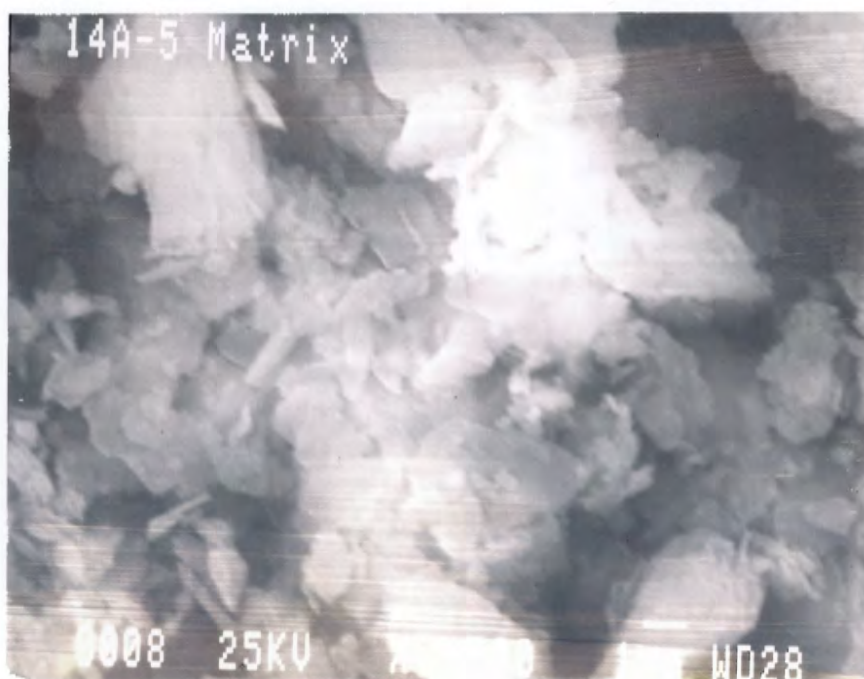


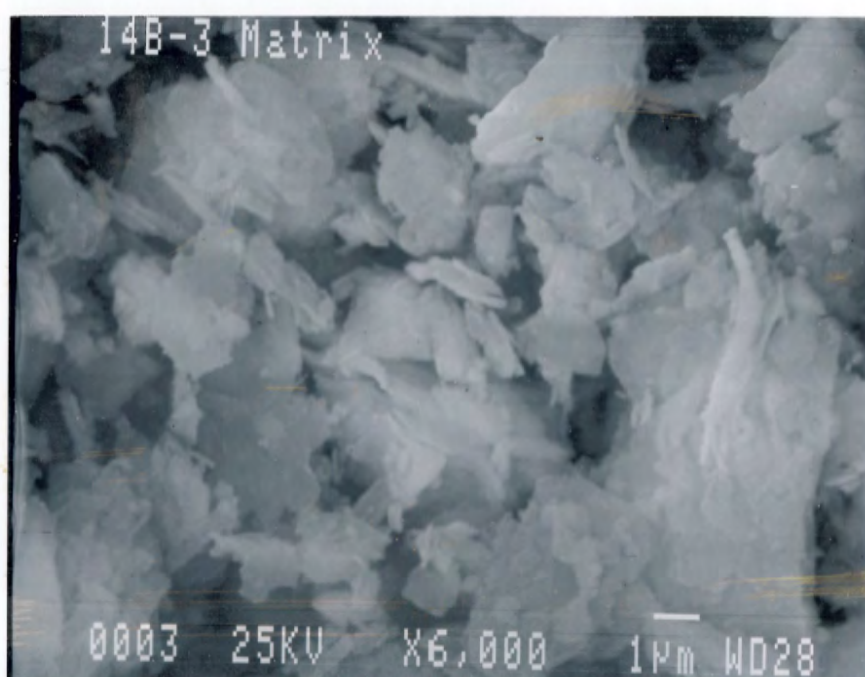
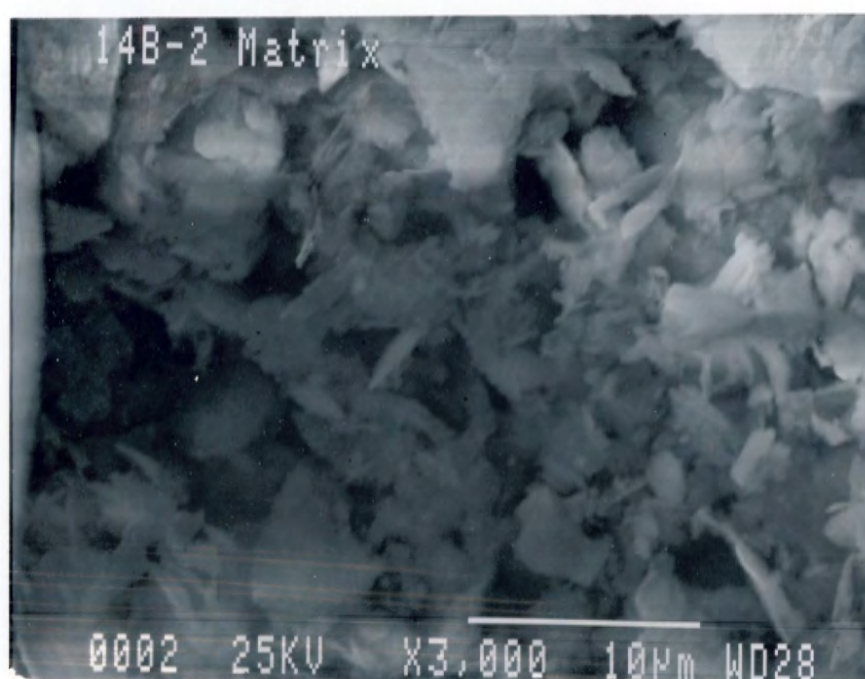
11B-3

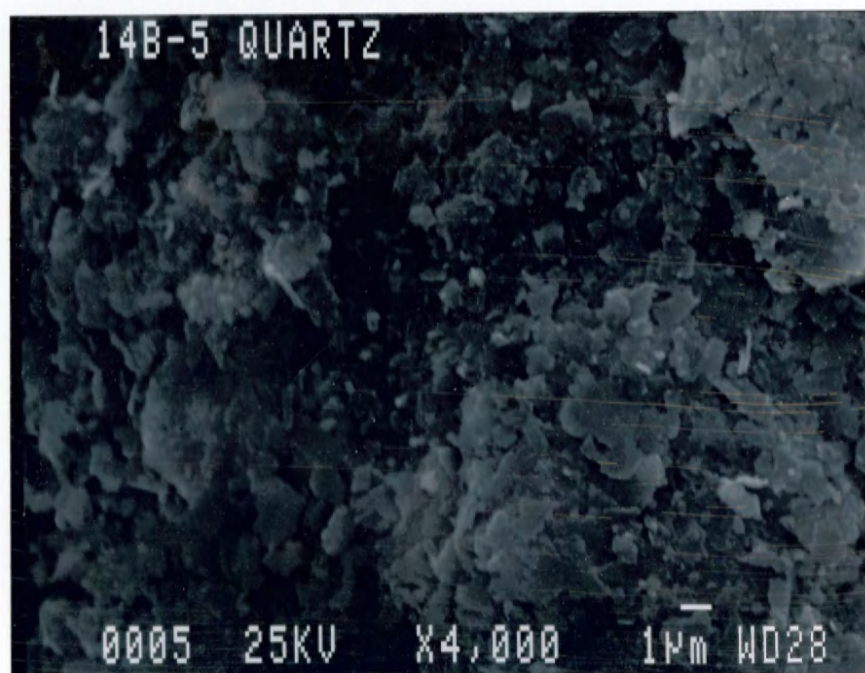


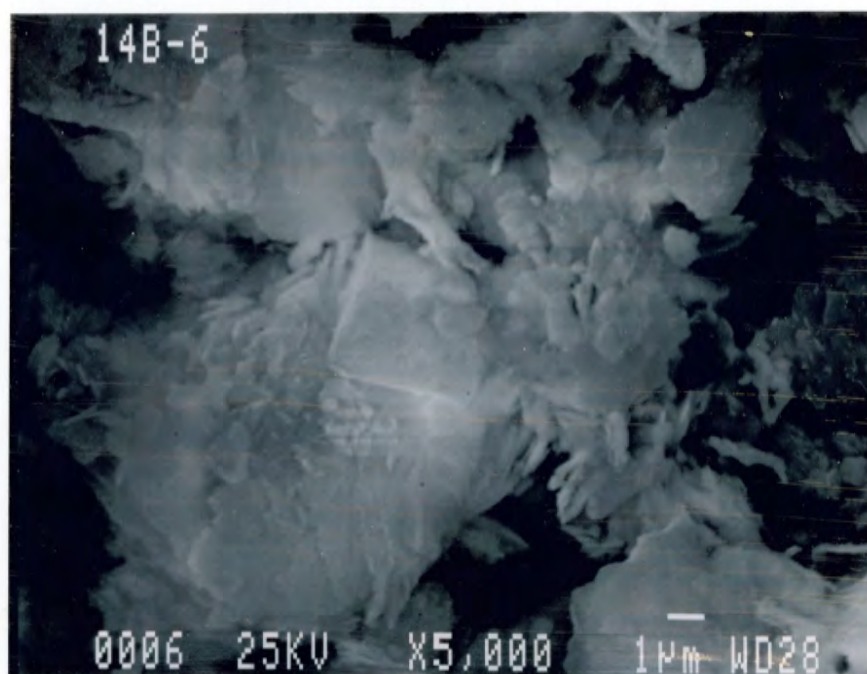


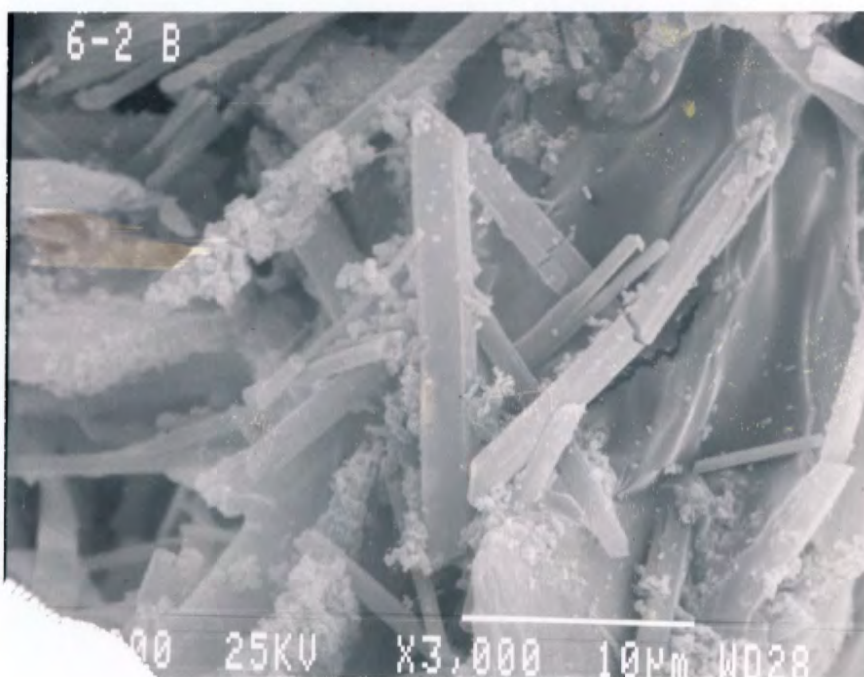
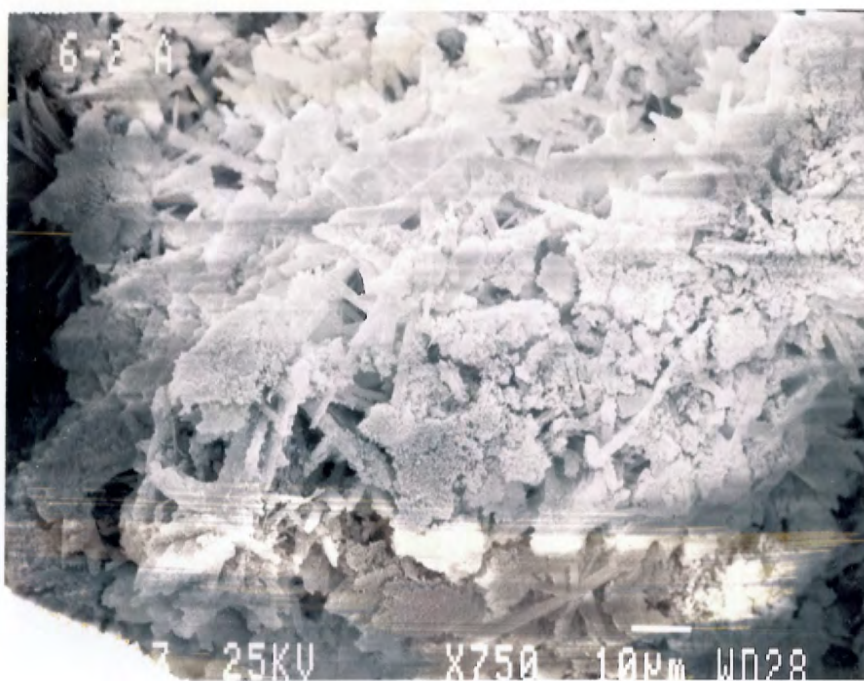




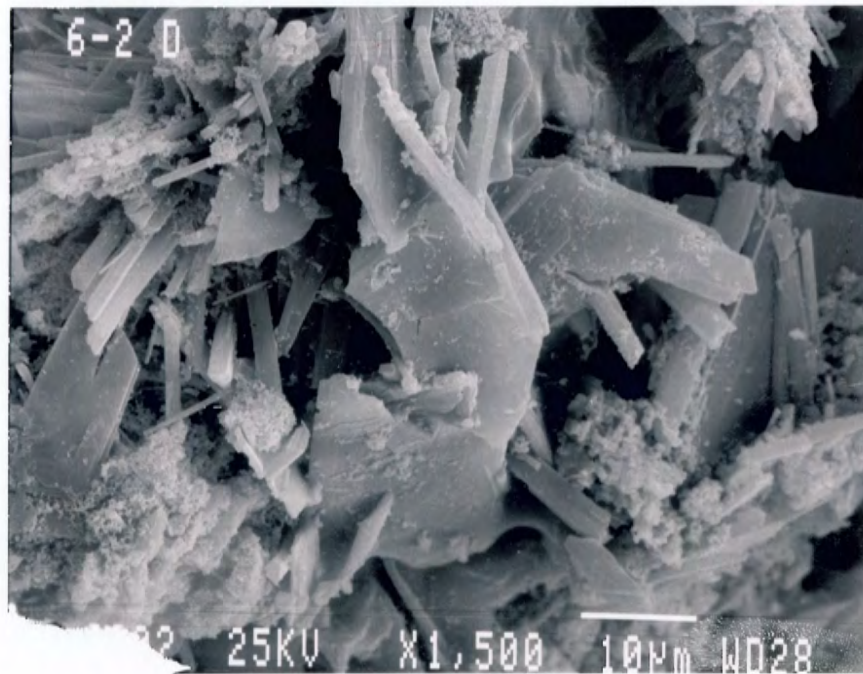
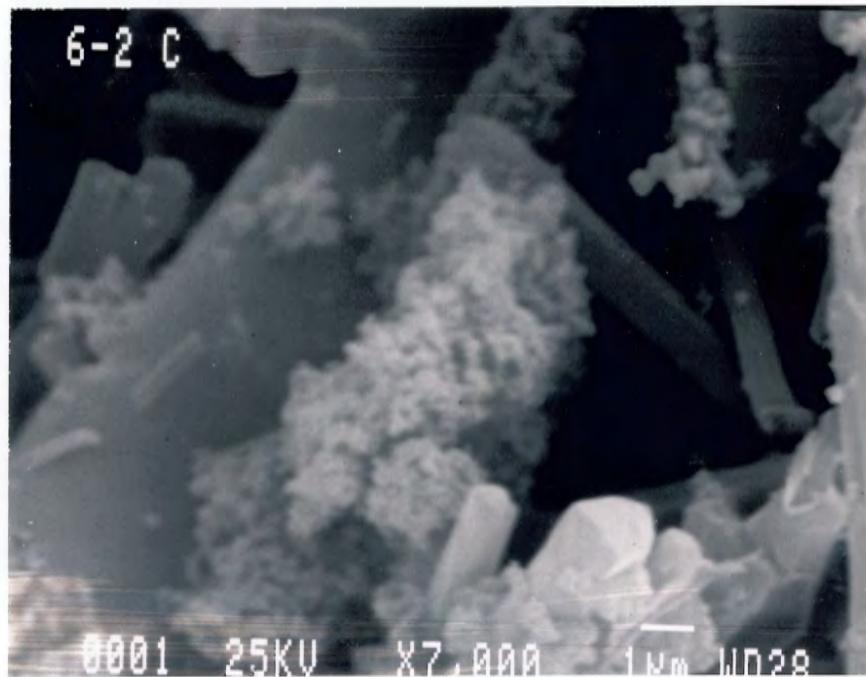


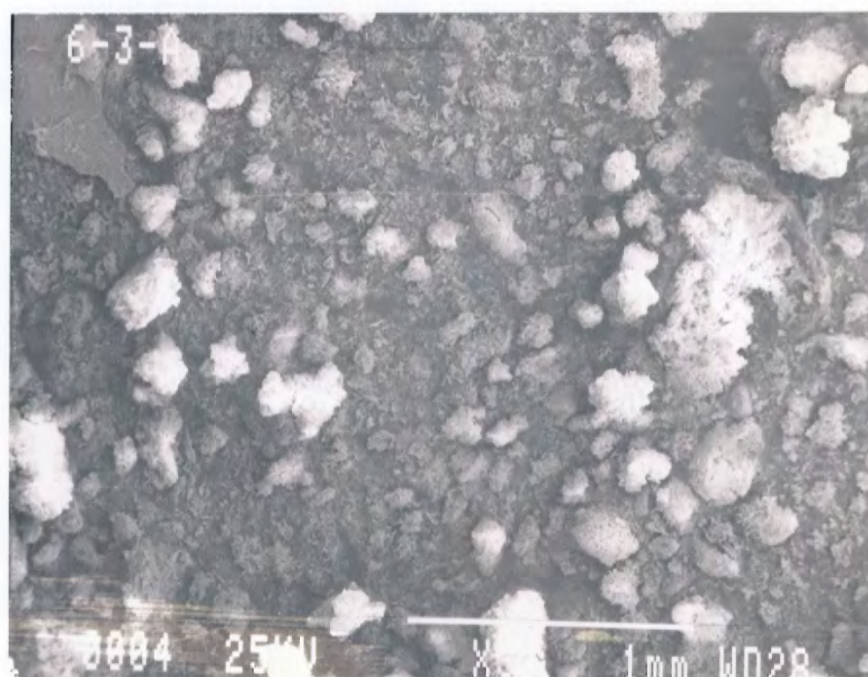
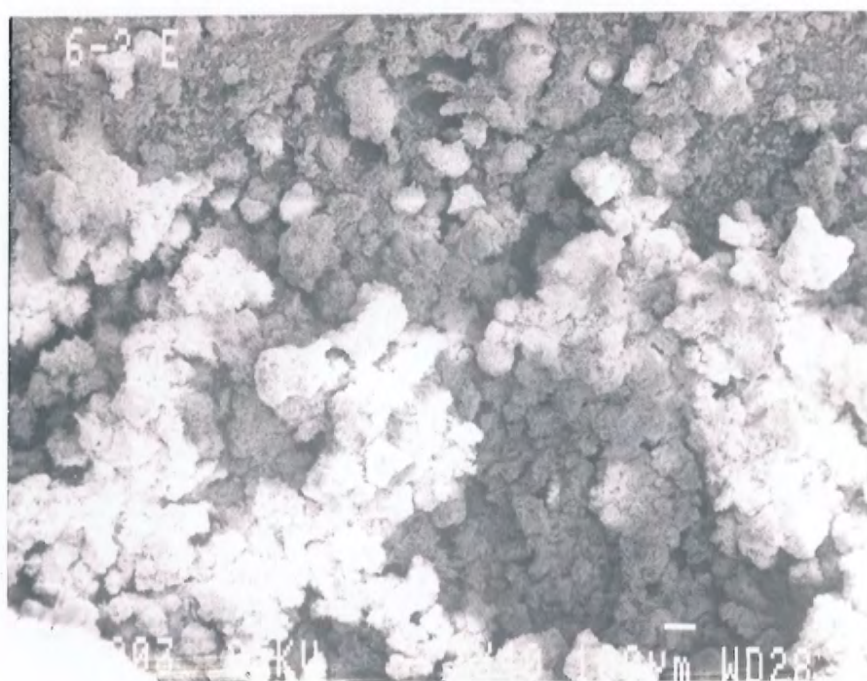






①
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↑





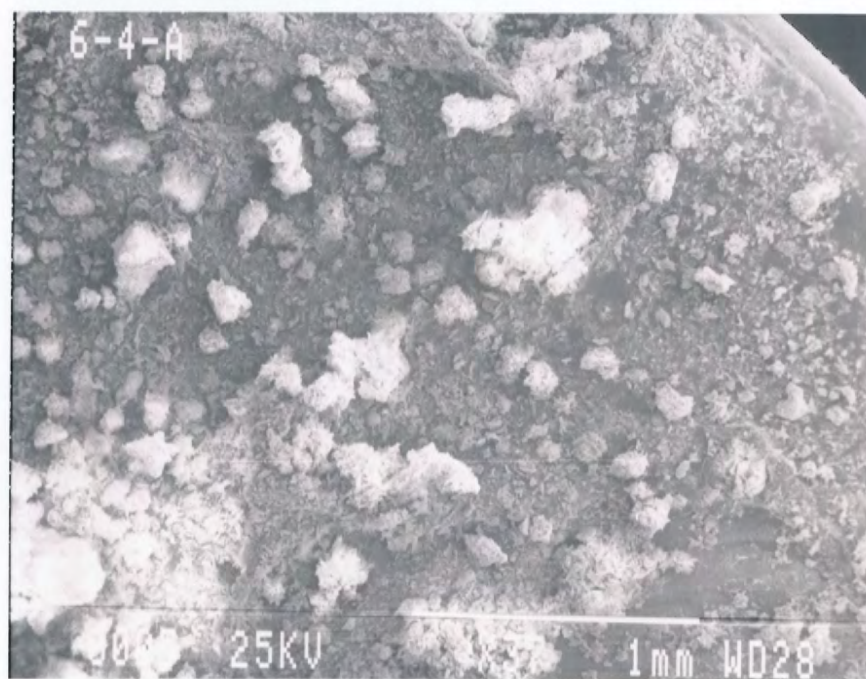
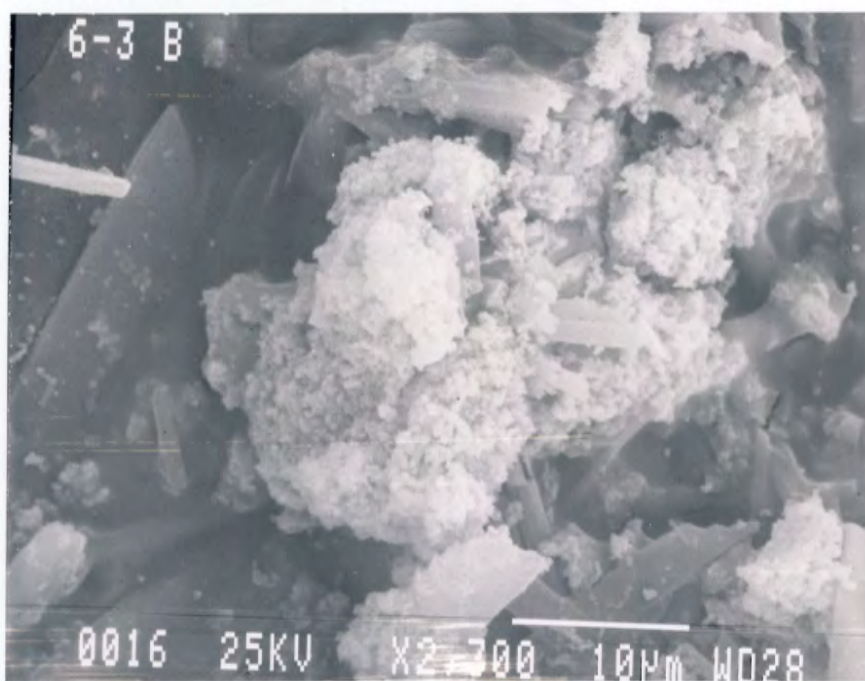
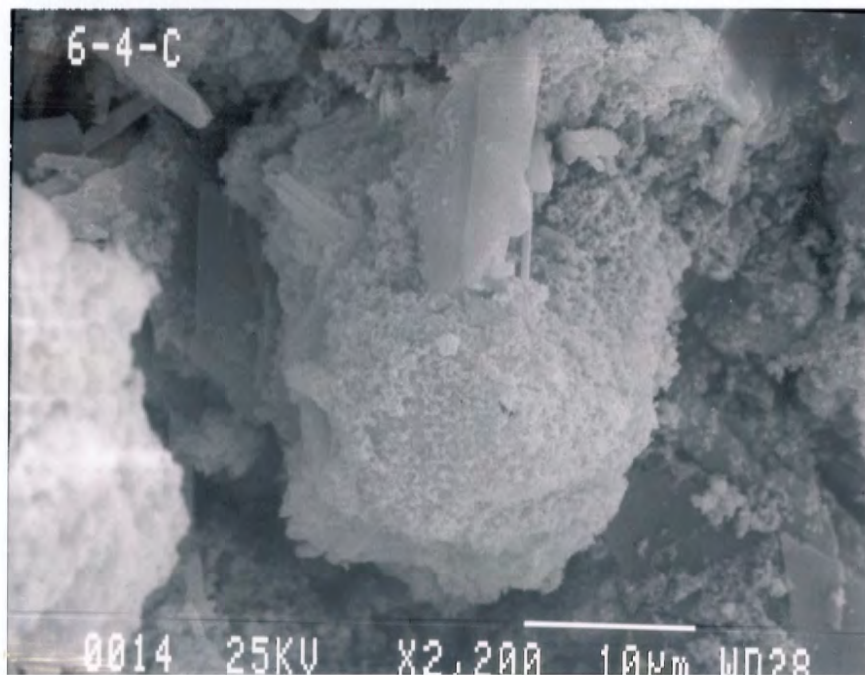
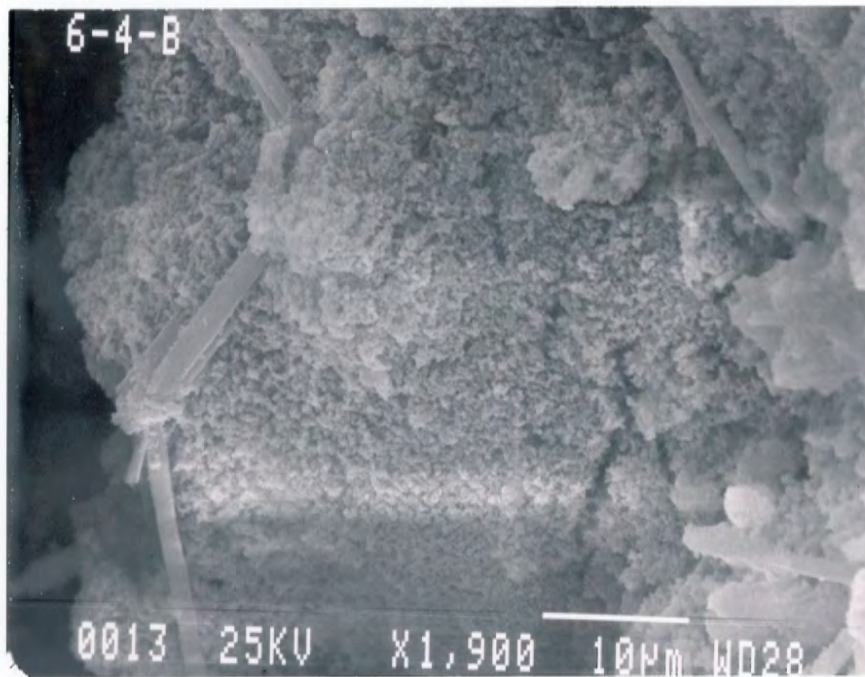
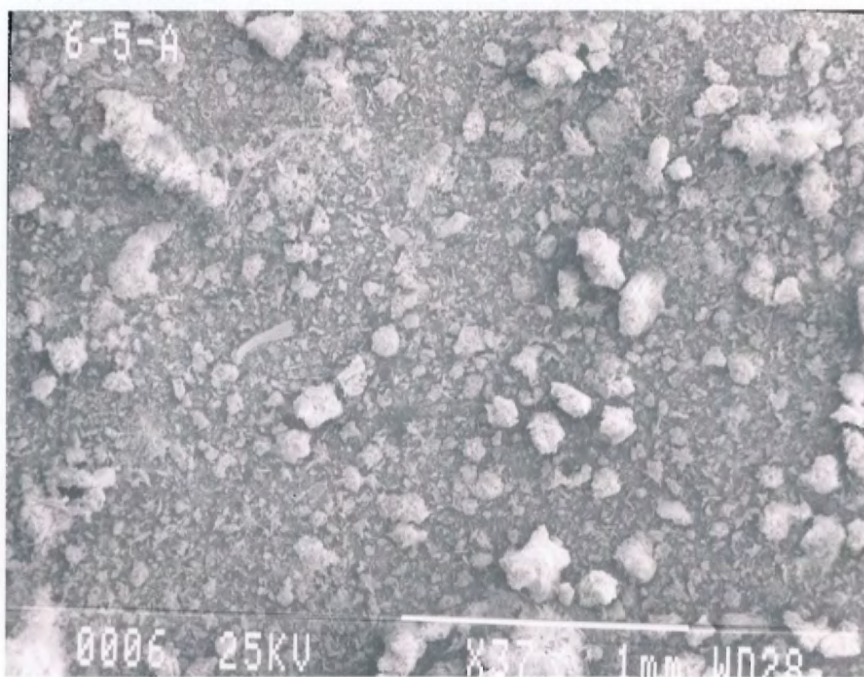
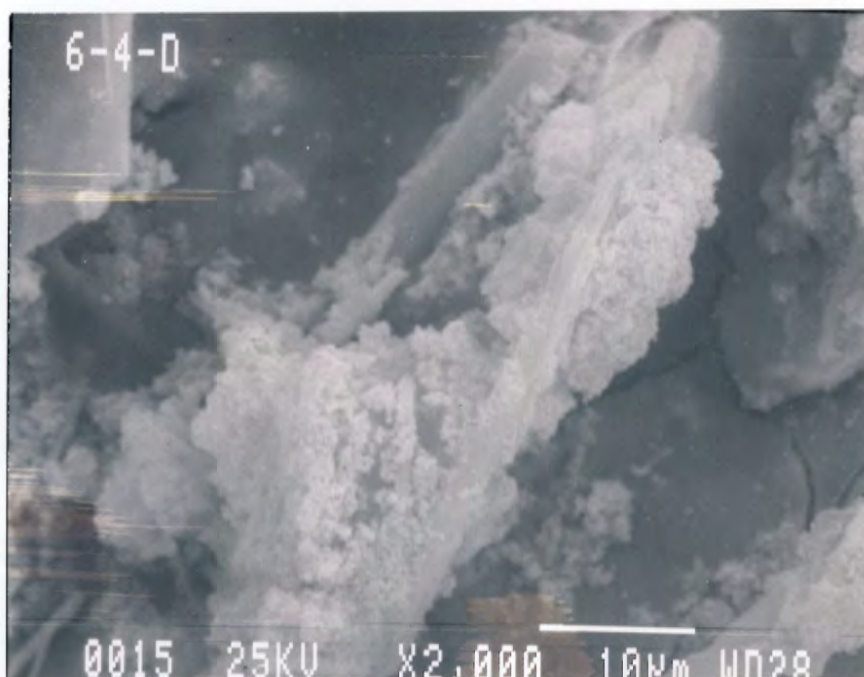


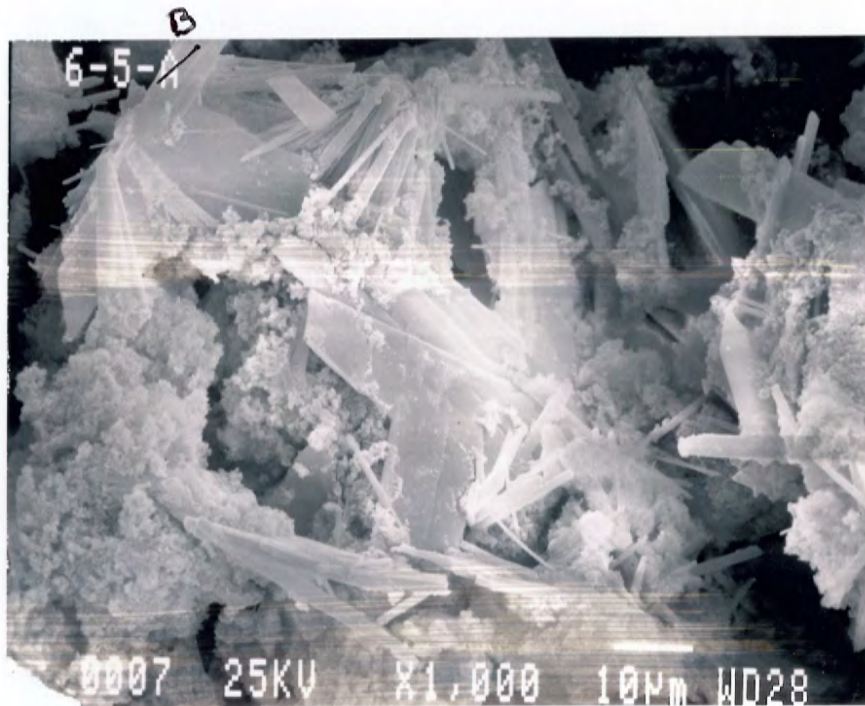
Figure 3.12

(2)

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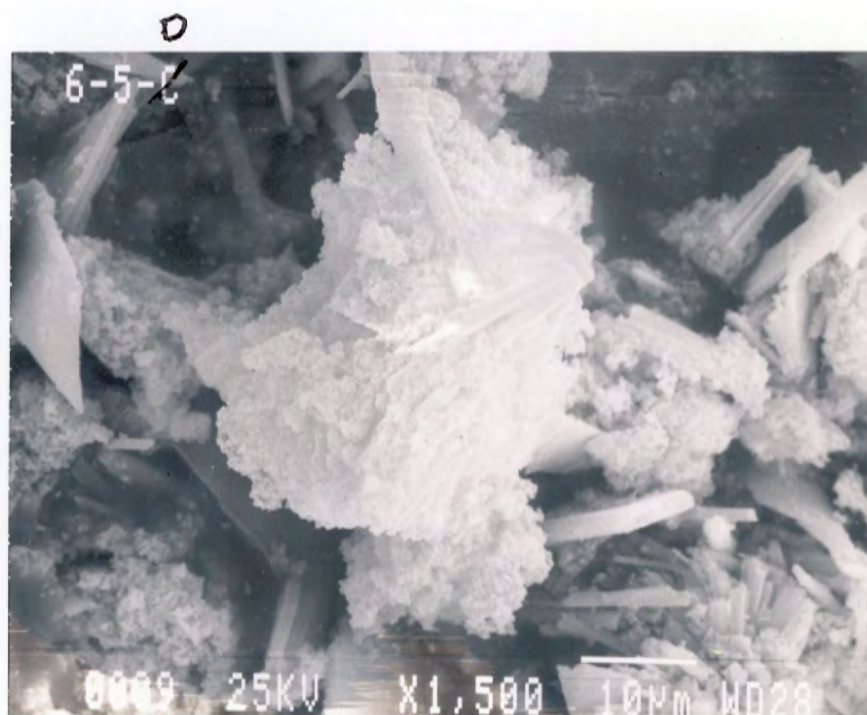
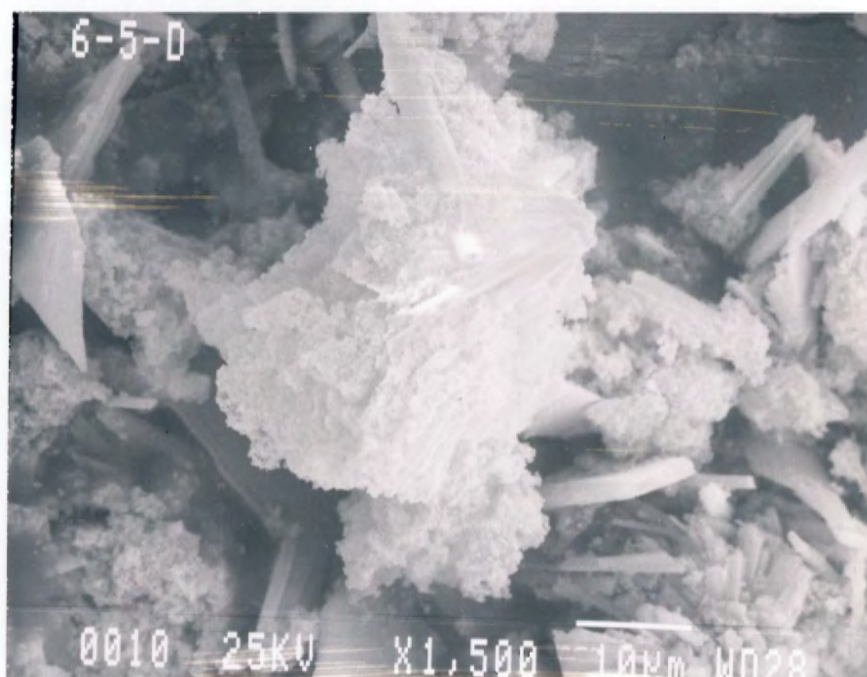






6-5B





6-5-D

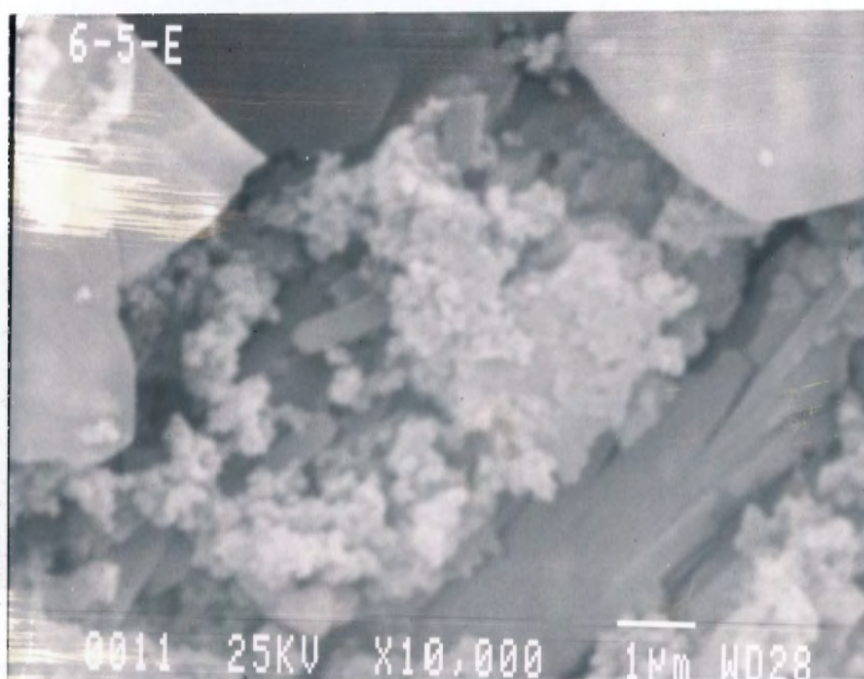
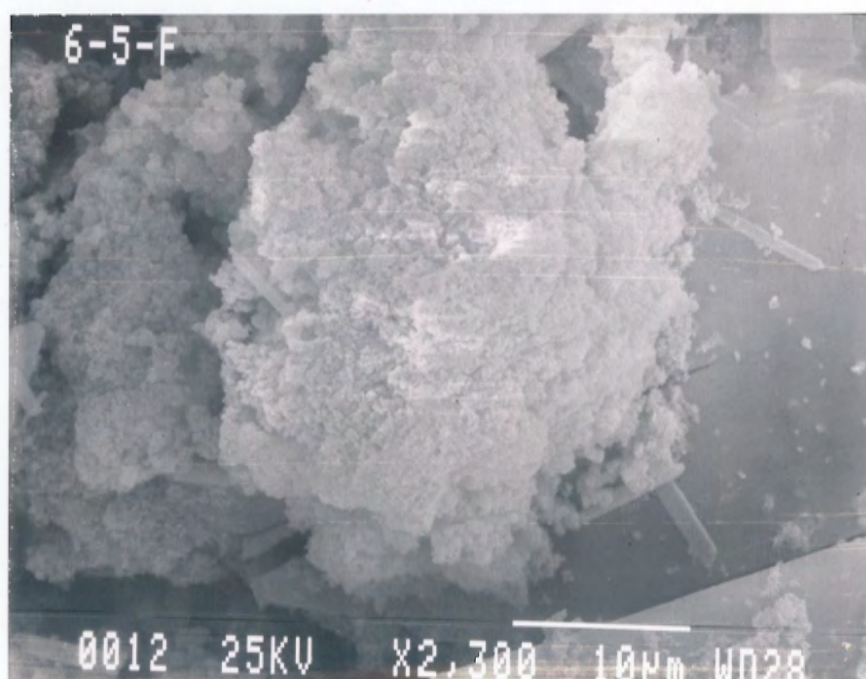
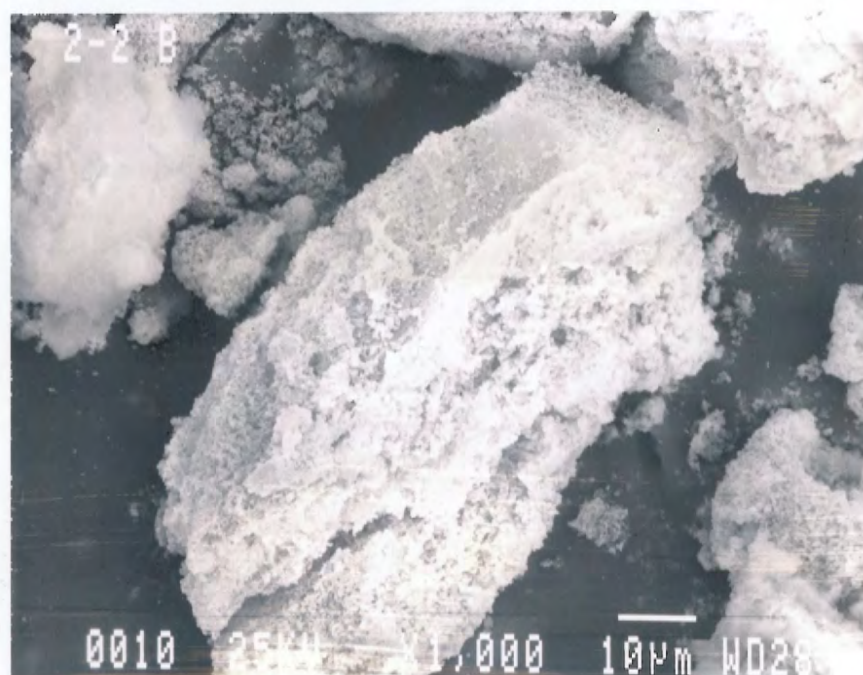
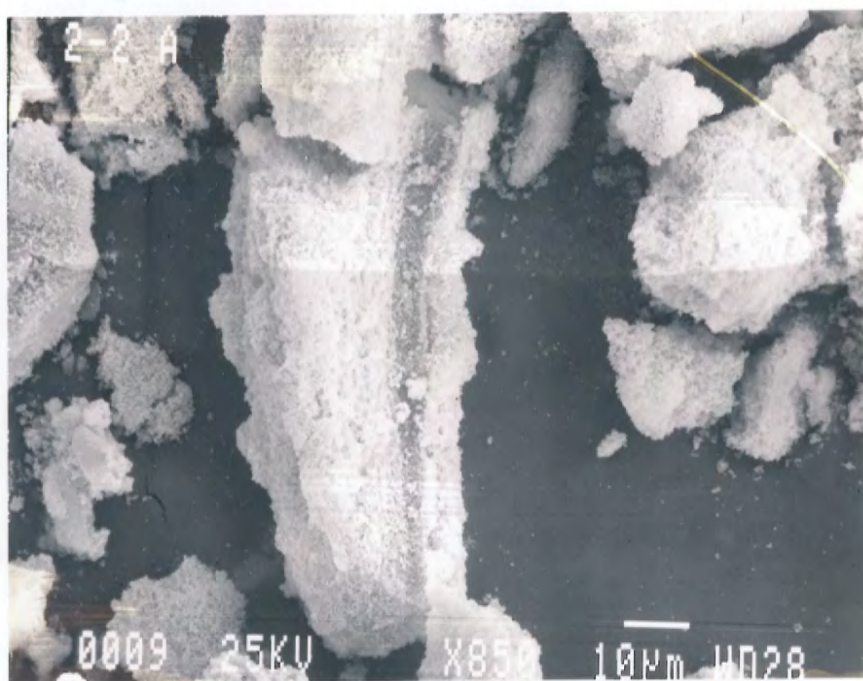
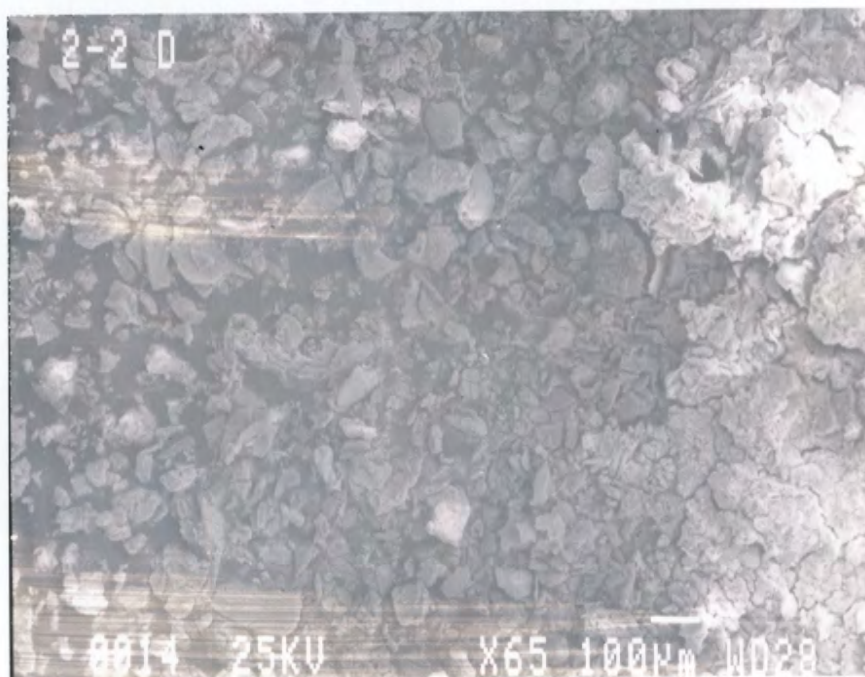


Figure 3.13

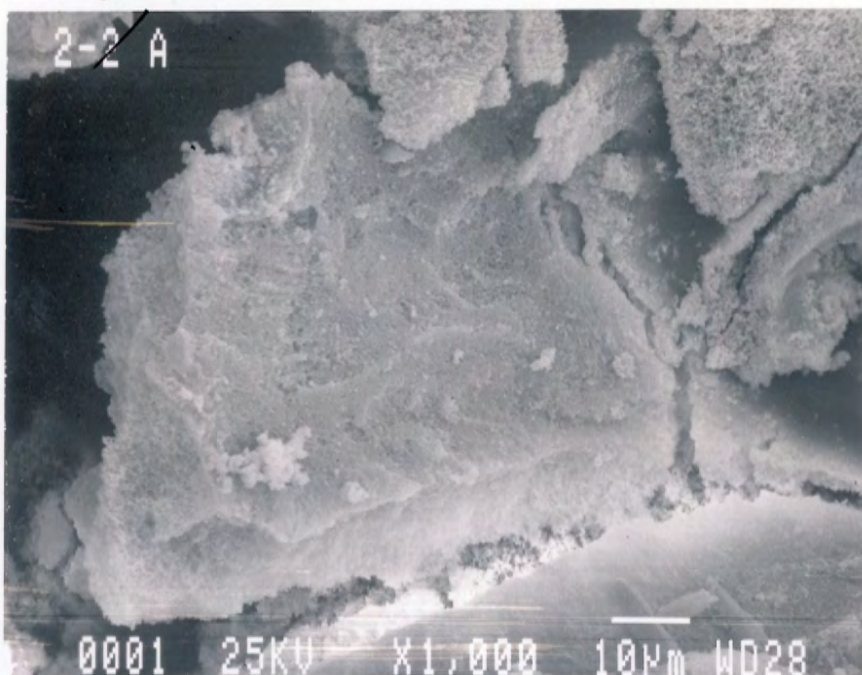


2-2A



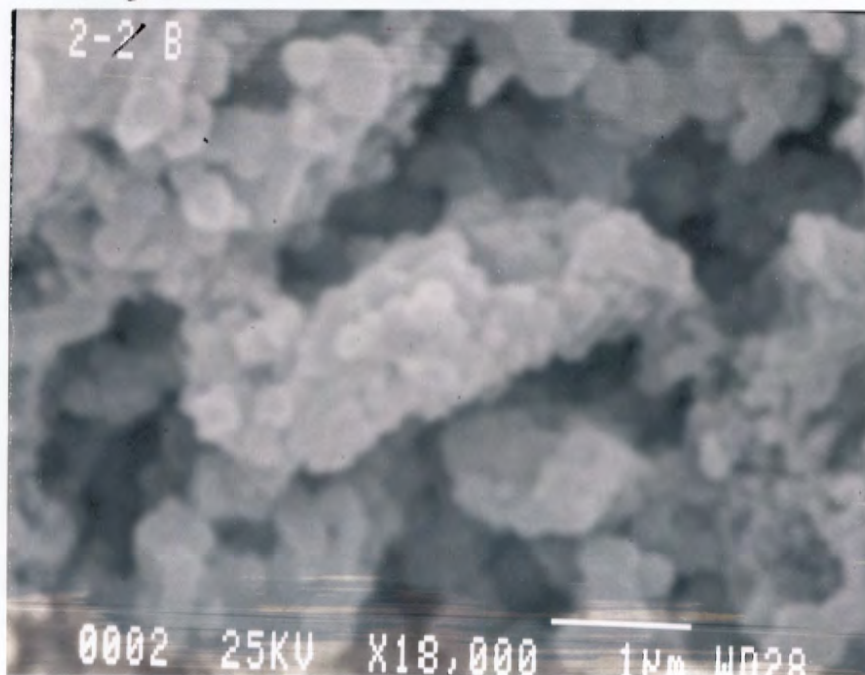


3



2-3A

3



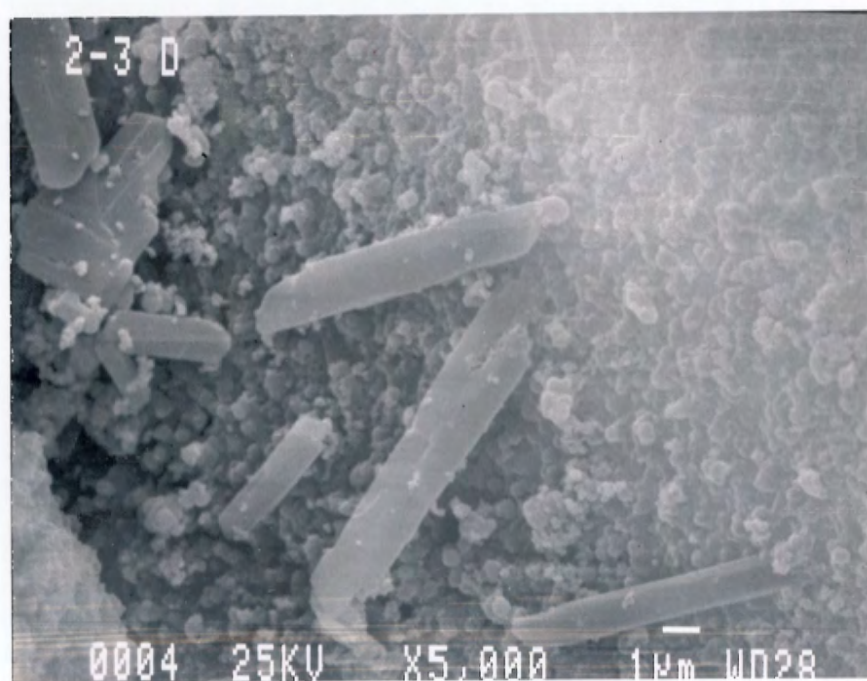
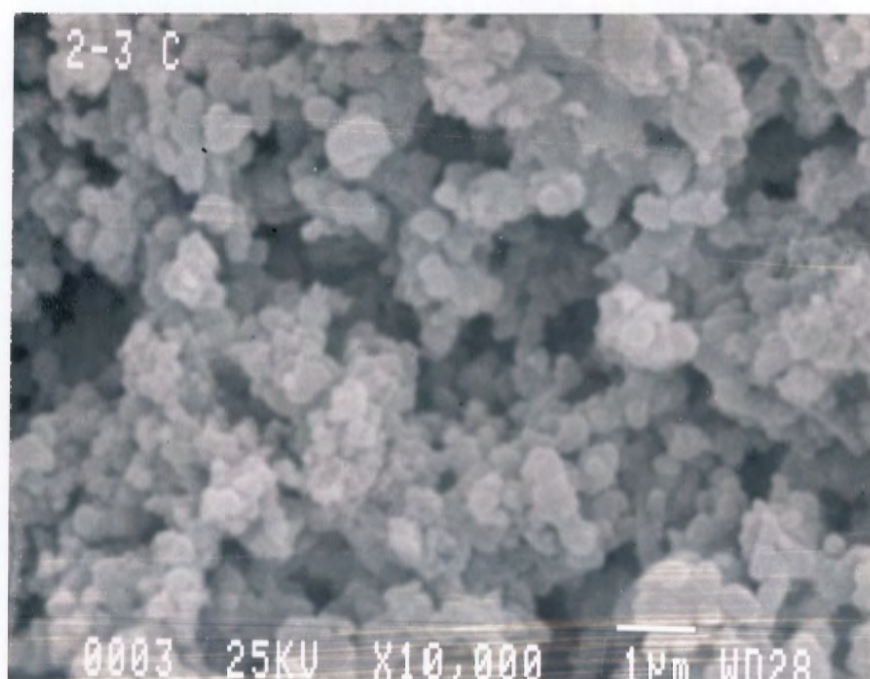
2-3B

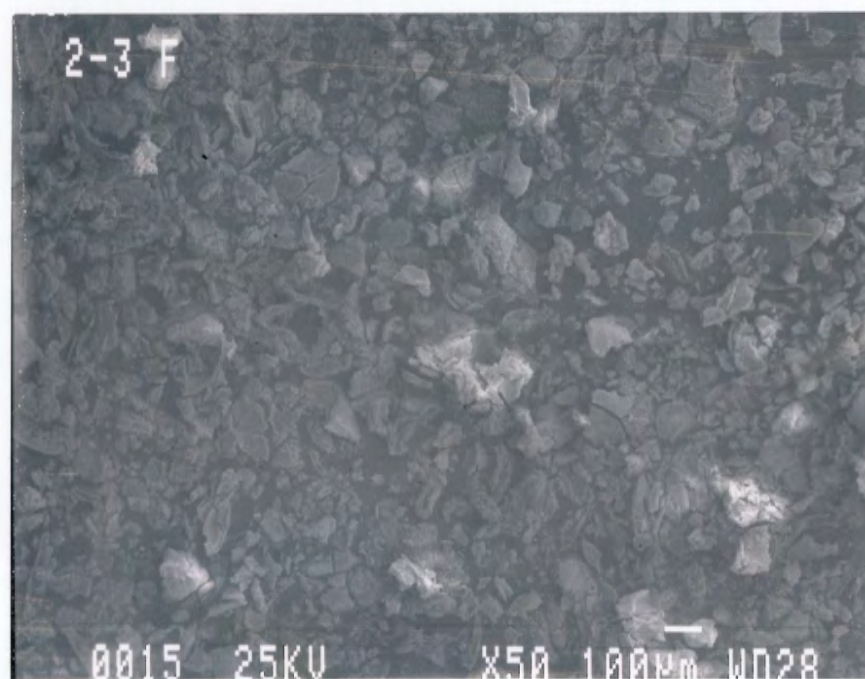
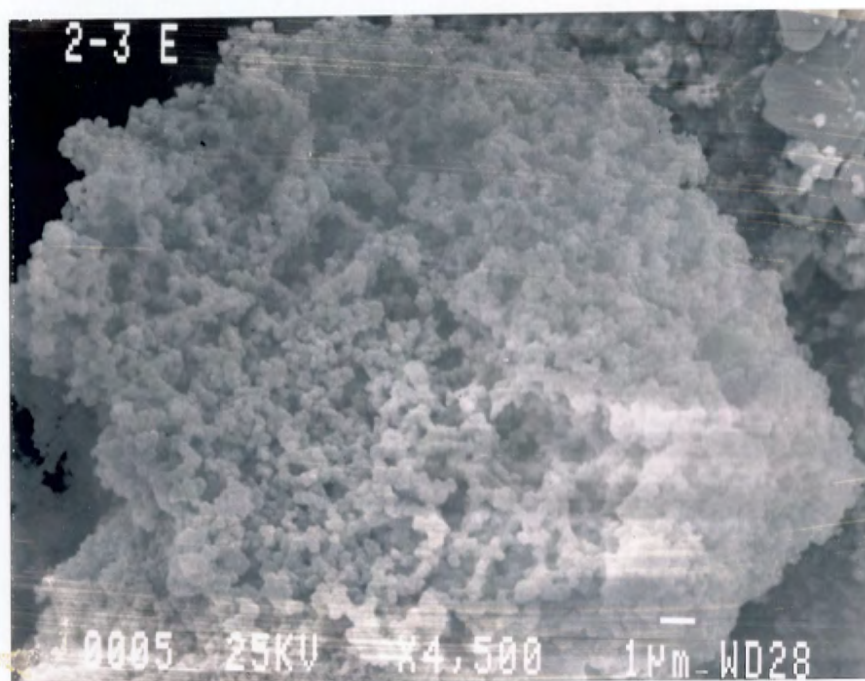
*
(A)
↑

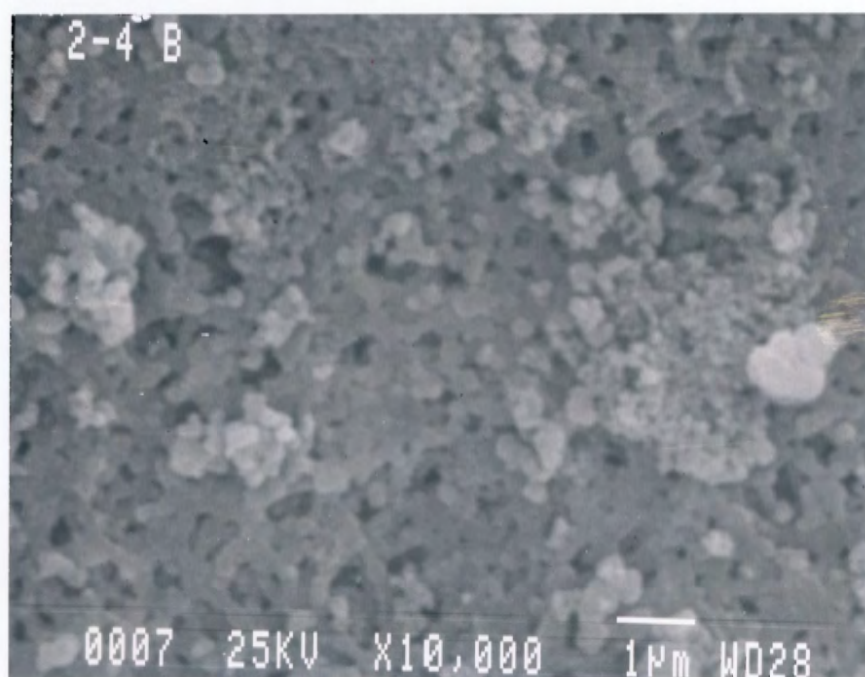
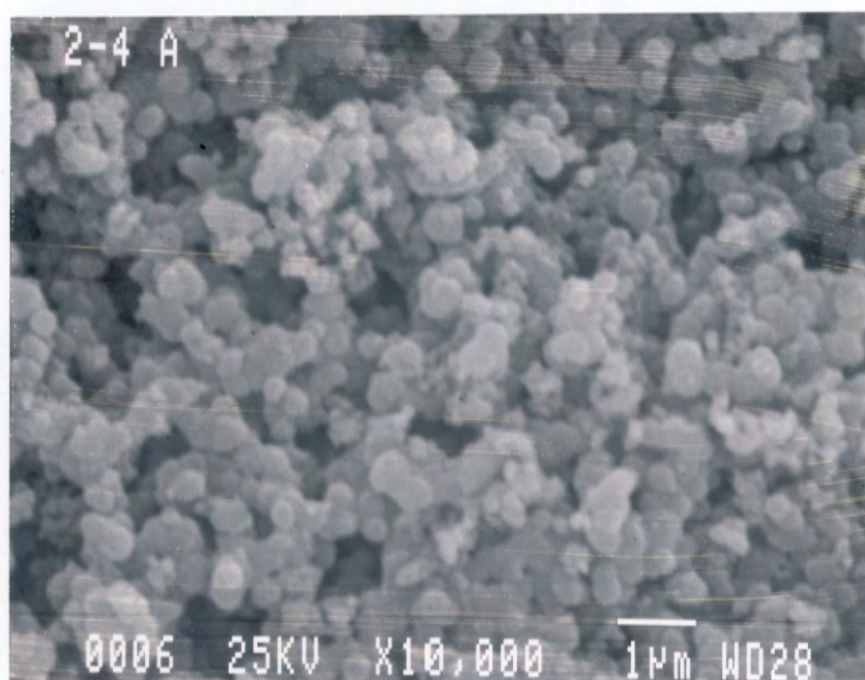
Figure 3.1.1-1

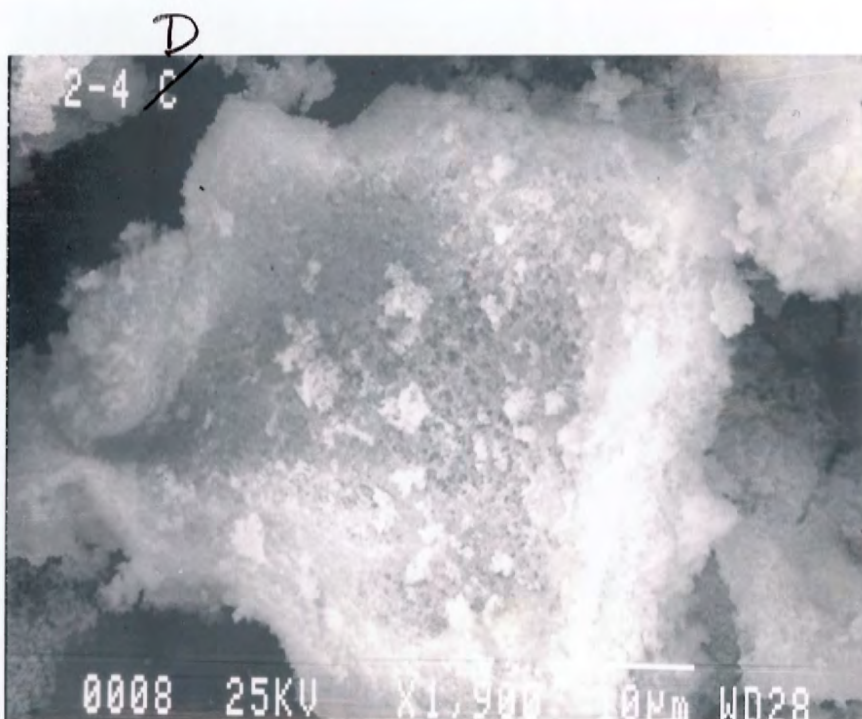
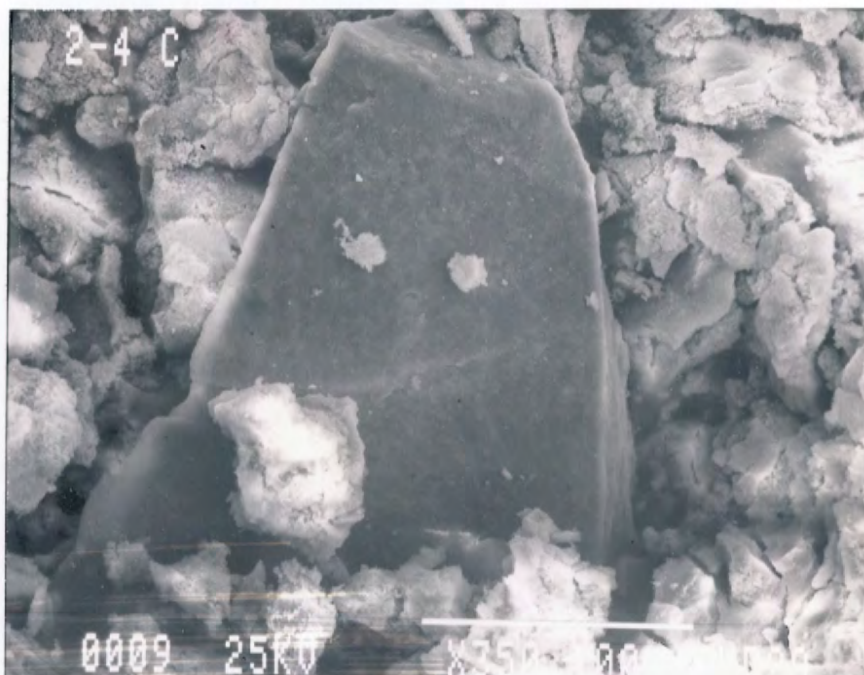
*

(B)

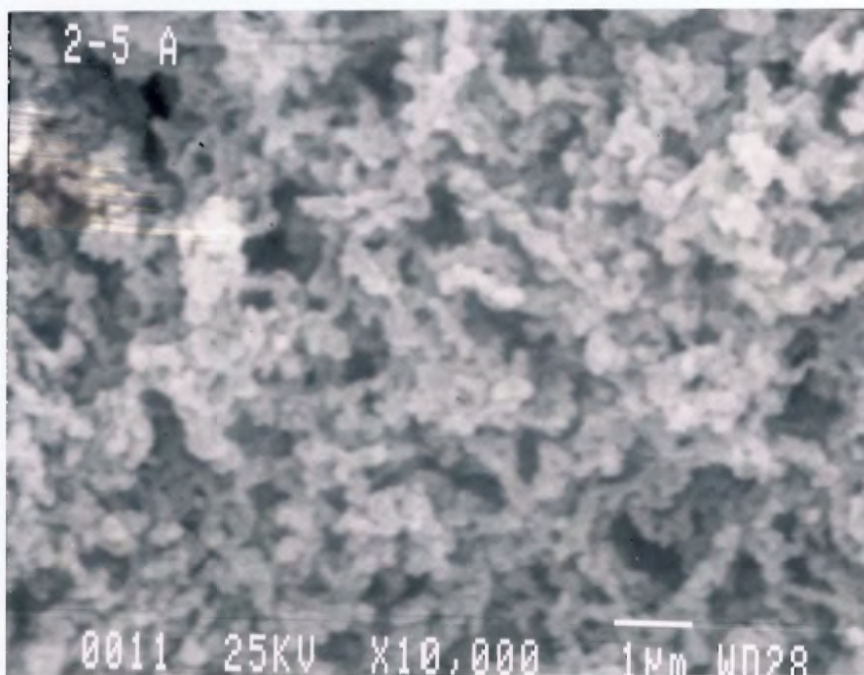
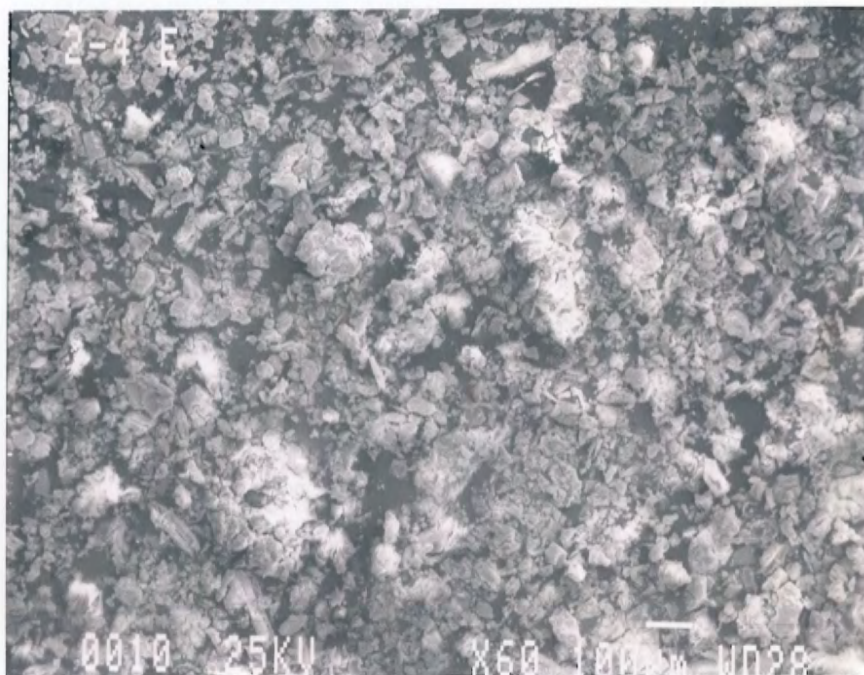


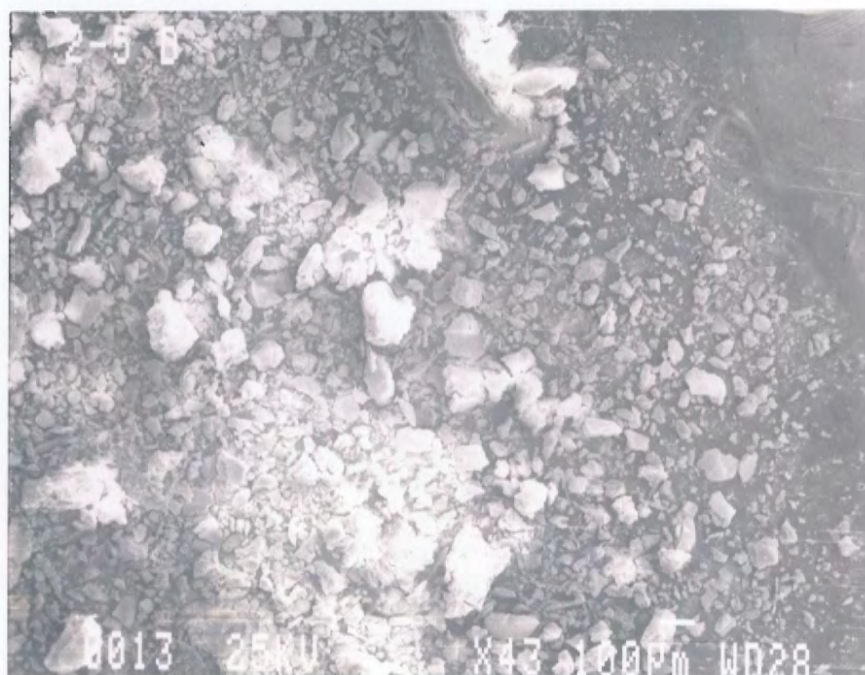
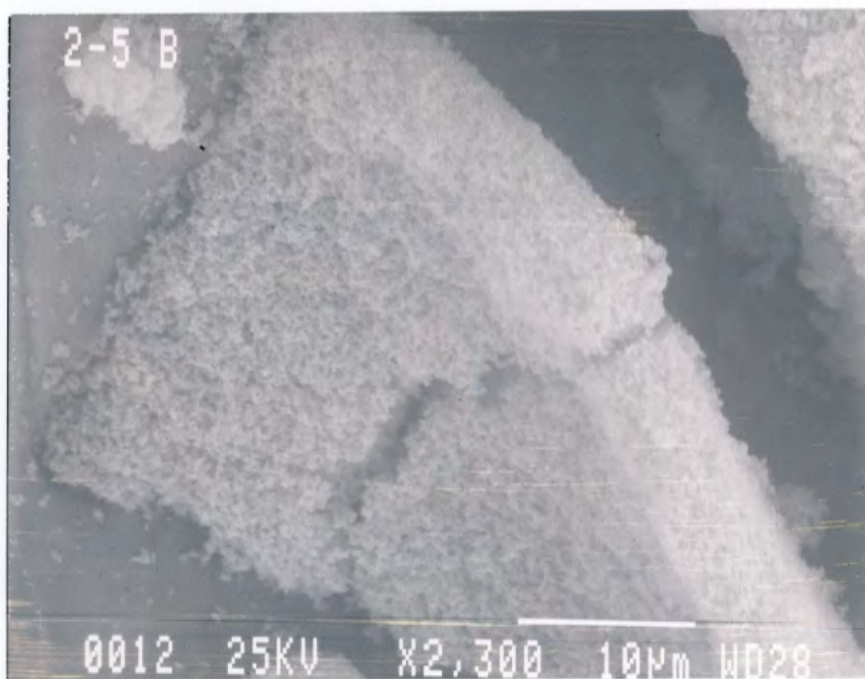


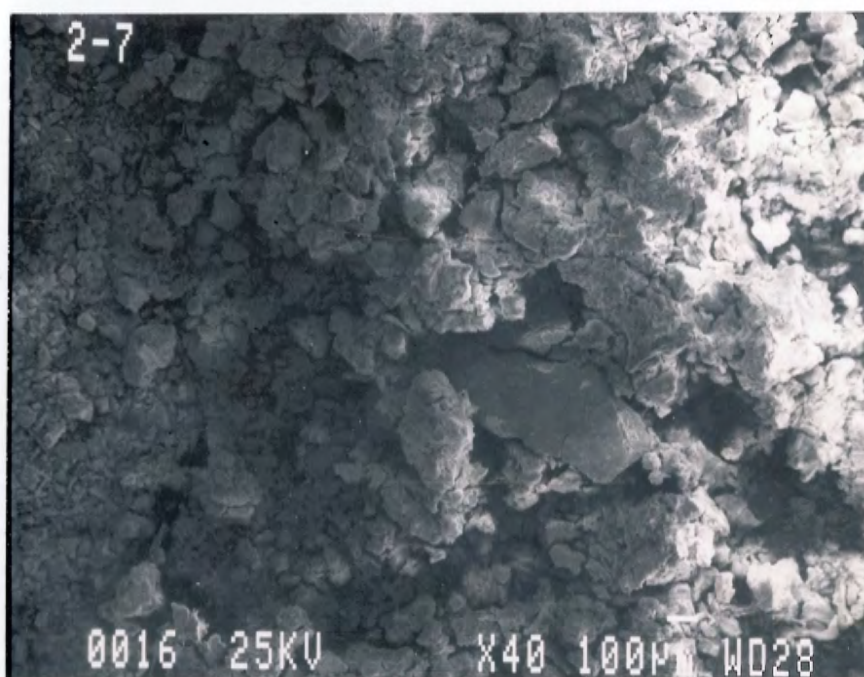




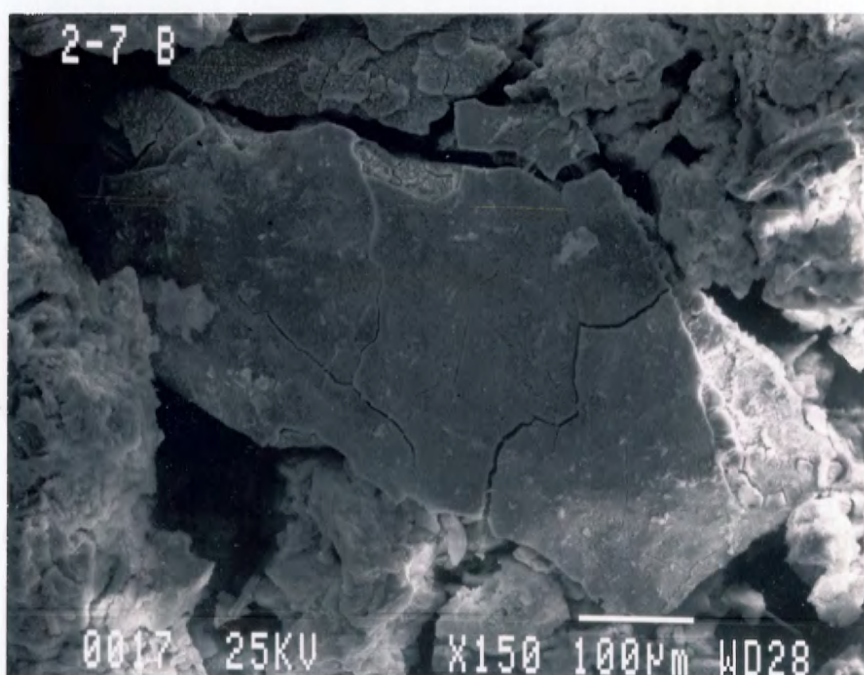
2-4-D

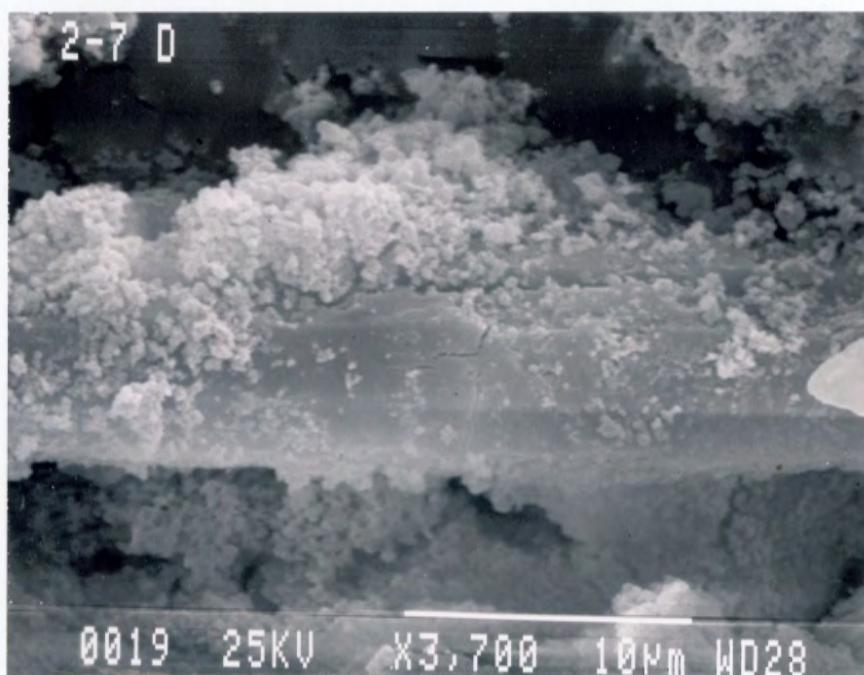
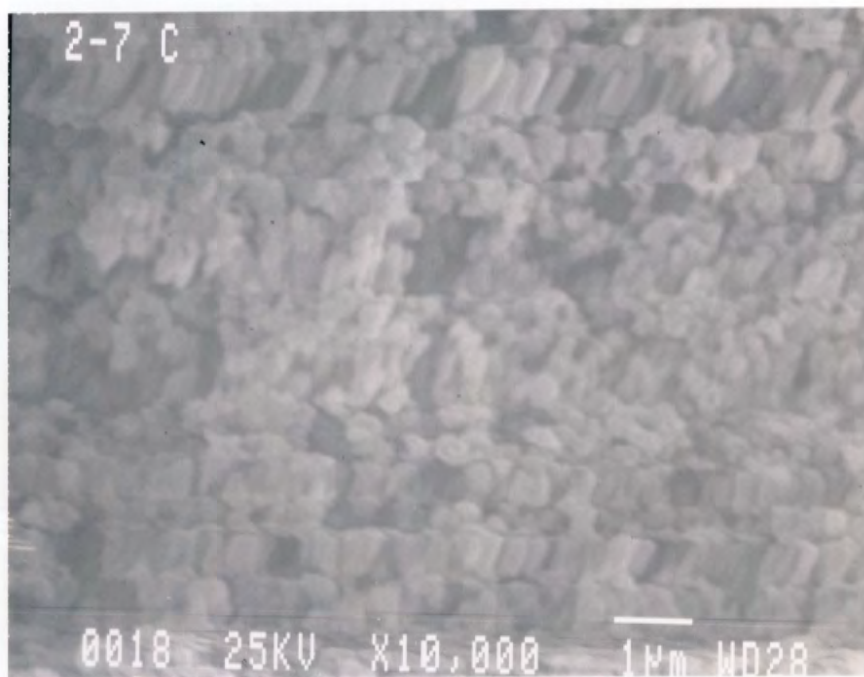




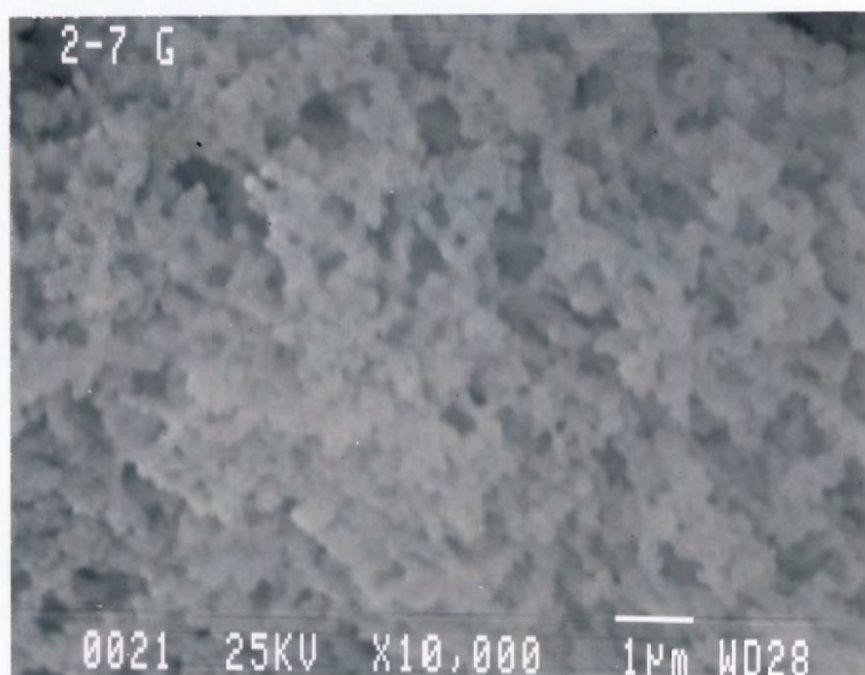
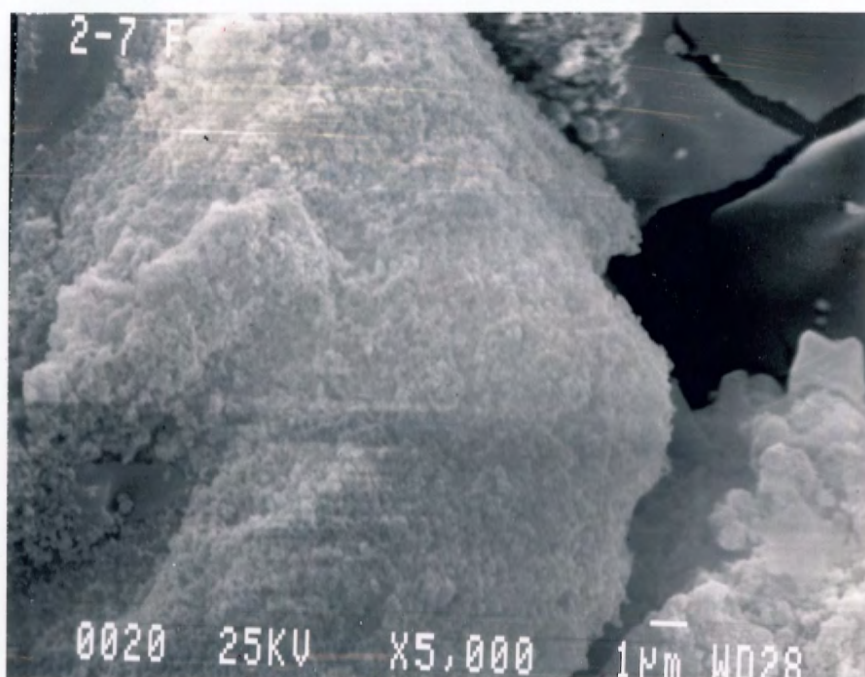


2-7A



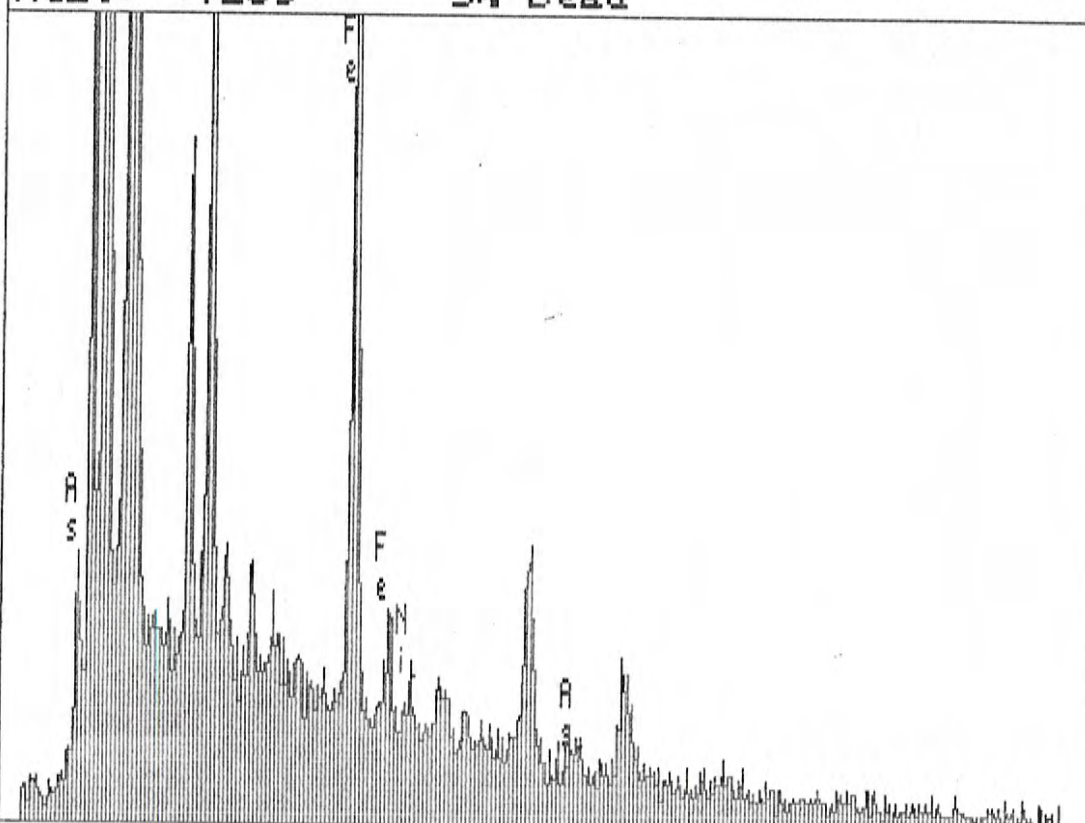


Also 2-7E



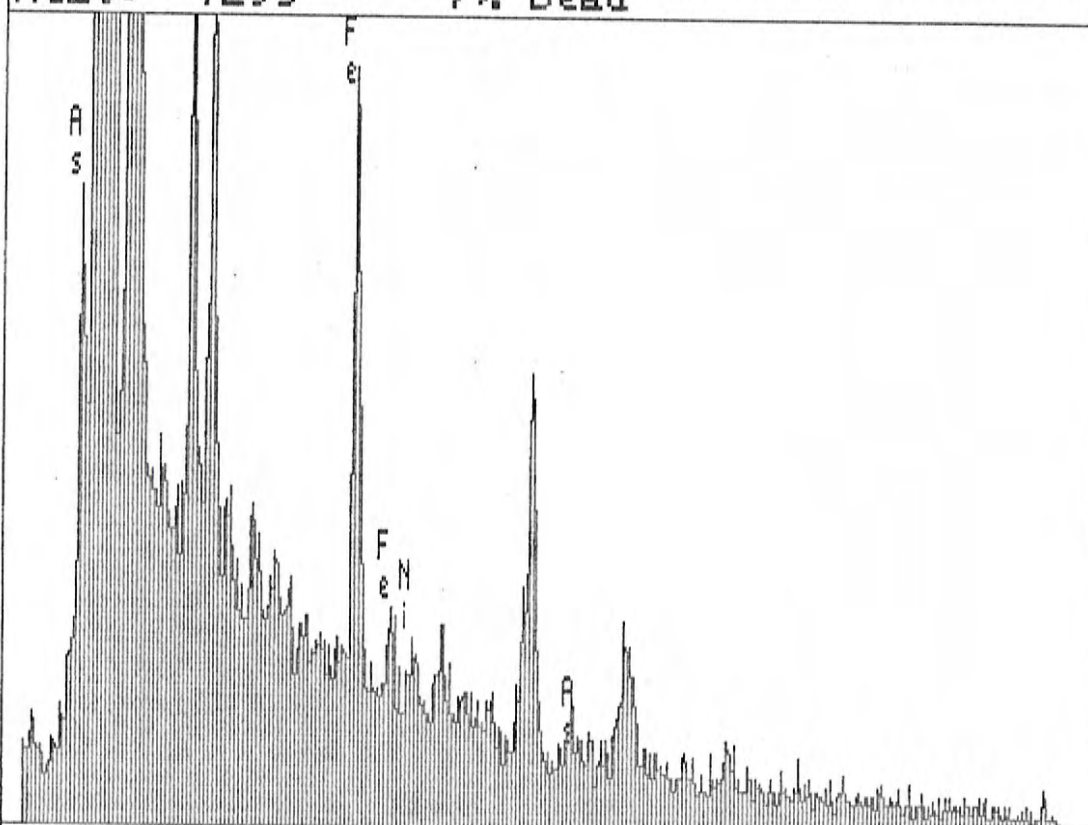
**Appendix C - Scanning Electron Microscope
X-Ray Spectra of
TOVP Ageing Test Samples ,
Samples 2001 TMF 4A and 8,
and
TOVP Neutralization Test
6-Series and 2-Series Samples**

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 126s 5% Dead



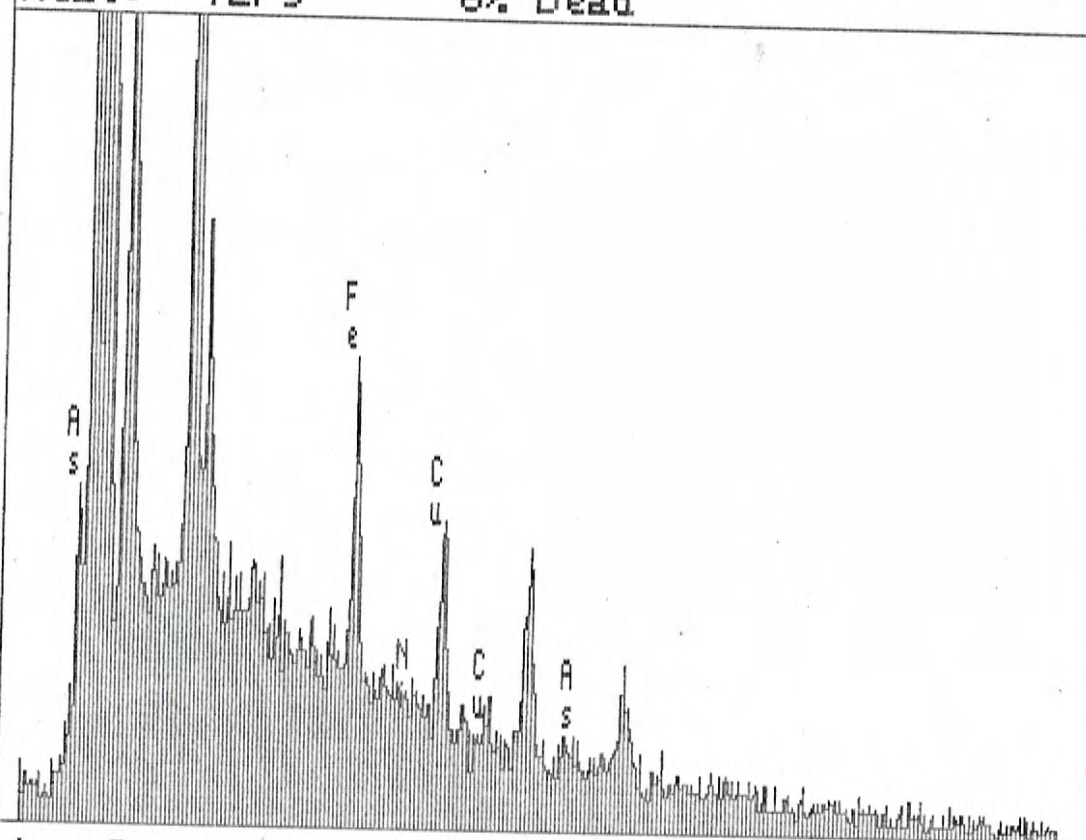
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 13 cts
MEM1:5a-1 Matrix

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 129s 7% Dead



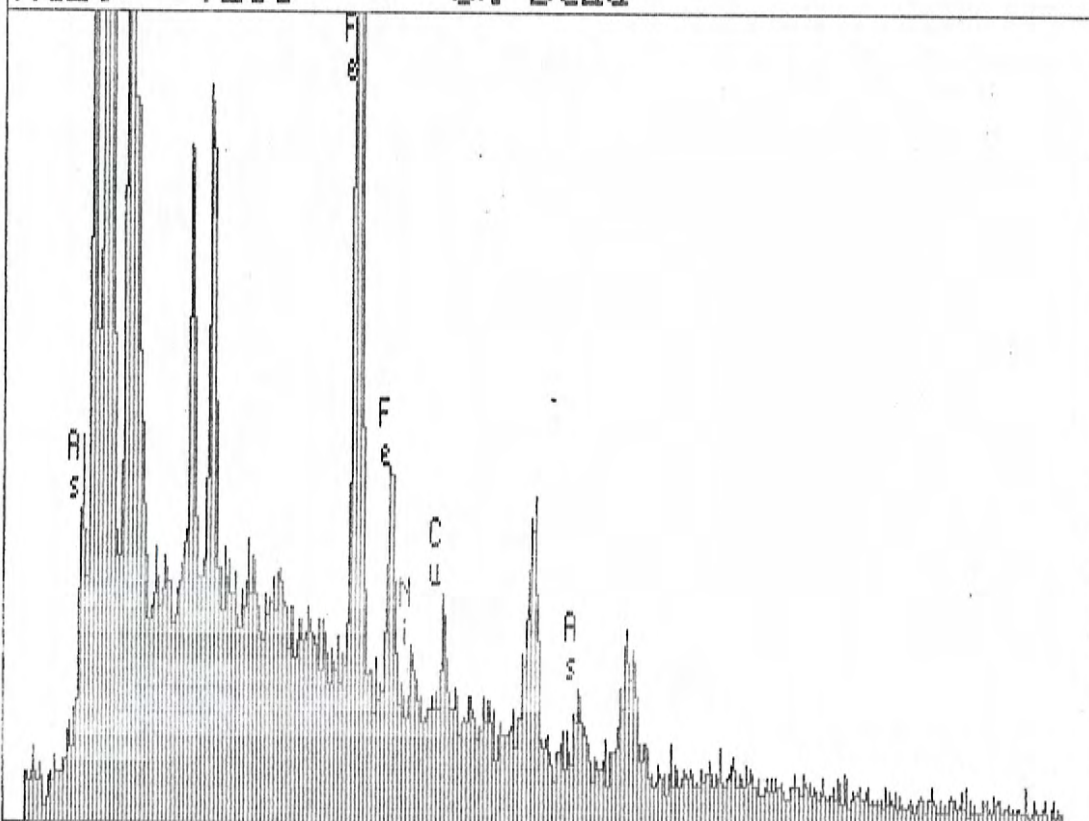
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 18 cts
MEM1:5A-2 Illite

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 127s 6% Dead



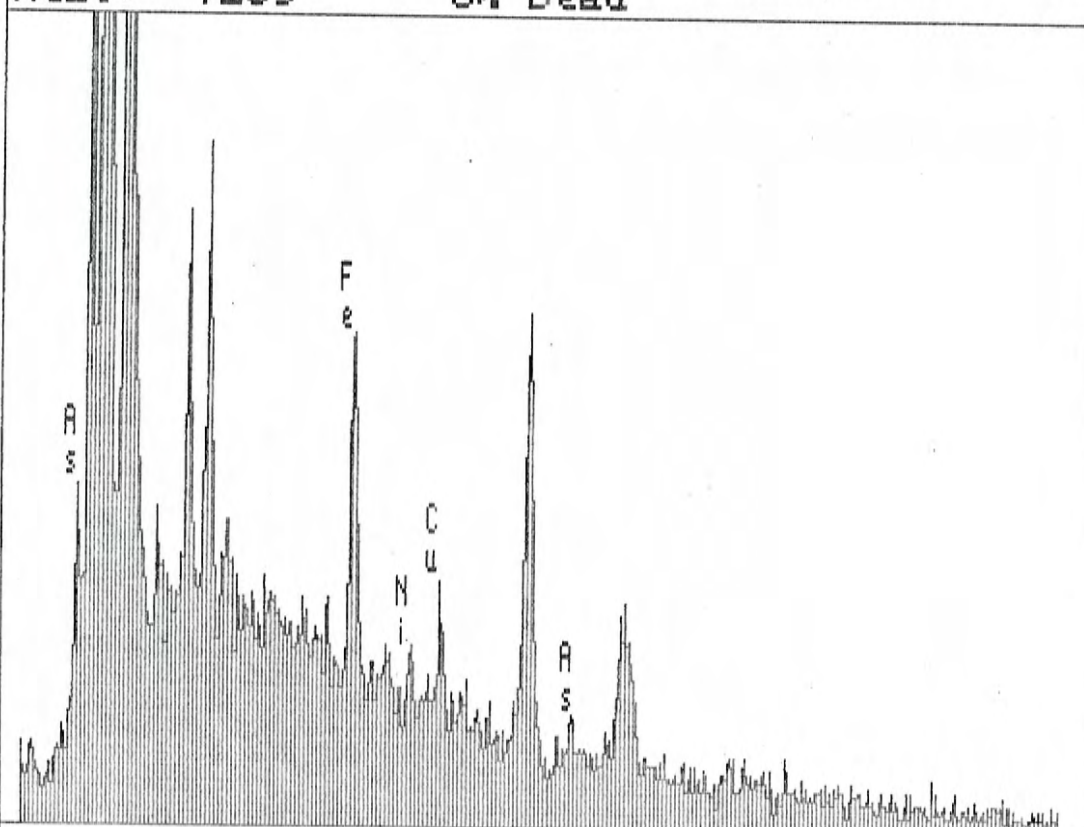
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 20 cts
MEM1:5A-3 Illite Grn

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 128s 6% Dead



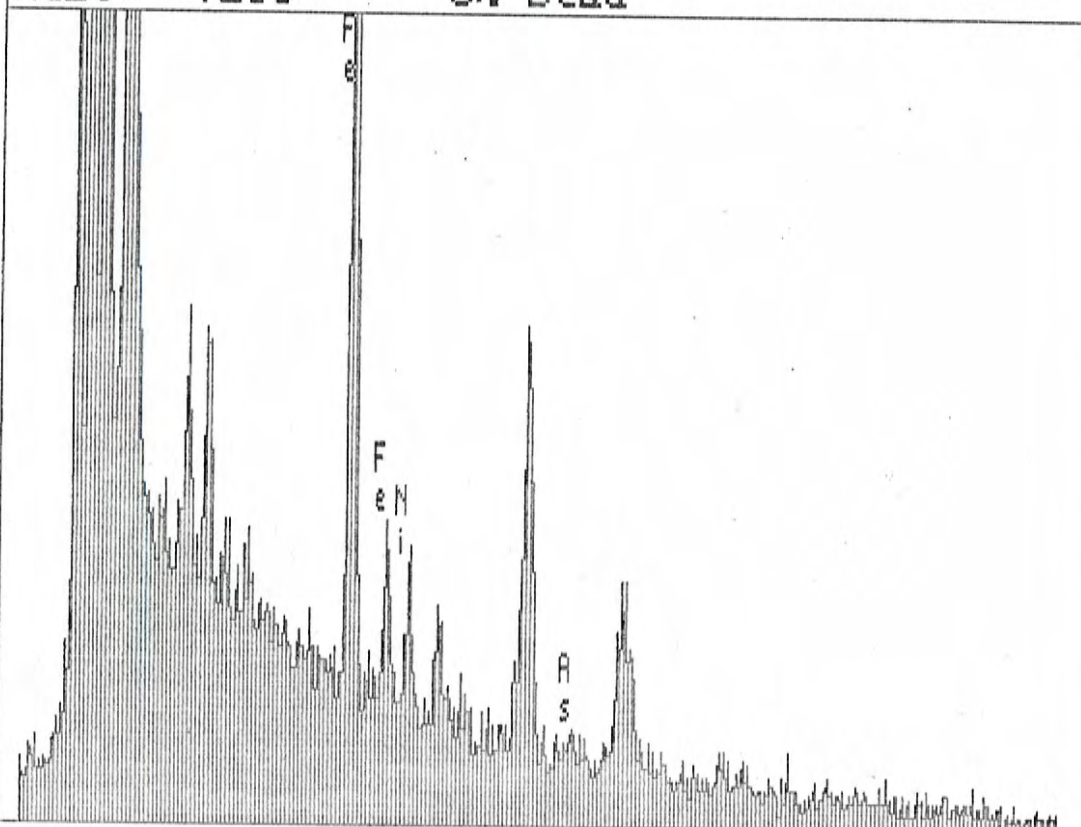
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 19 cts
MEM1:5A-4 Qtz Grn Surface

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 128s 6% Dead



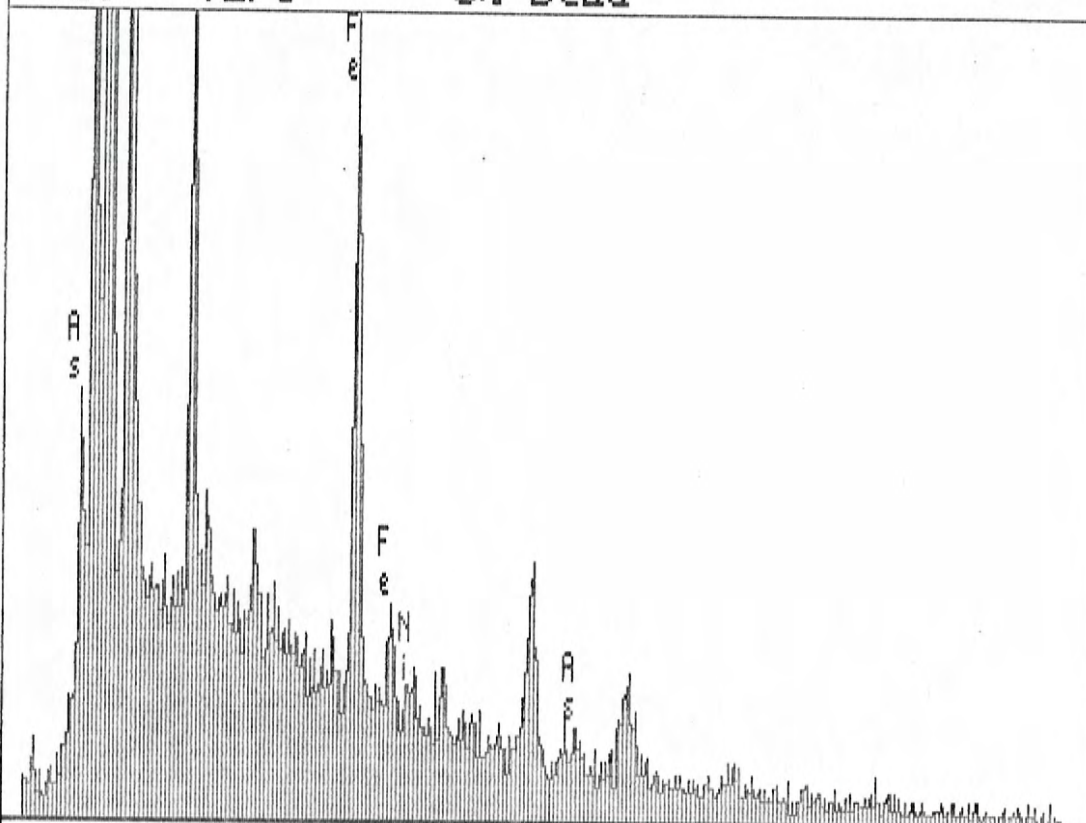
< - .2 10.043 keV 20.3 >
FS=255 ch 512= 12 cts
MEM1:5A-4 Spot

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 128s 6% Dead



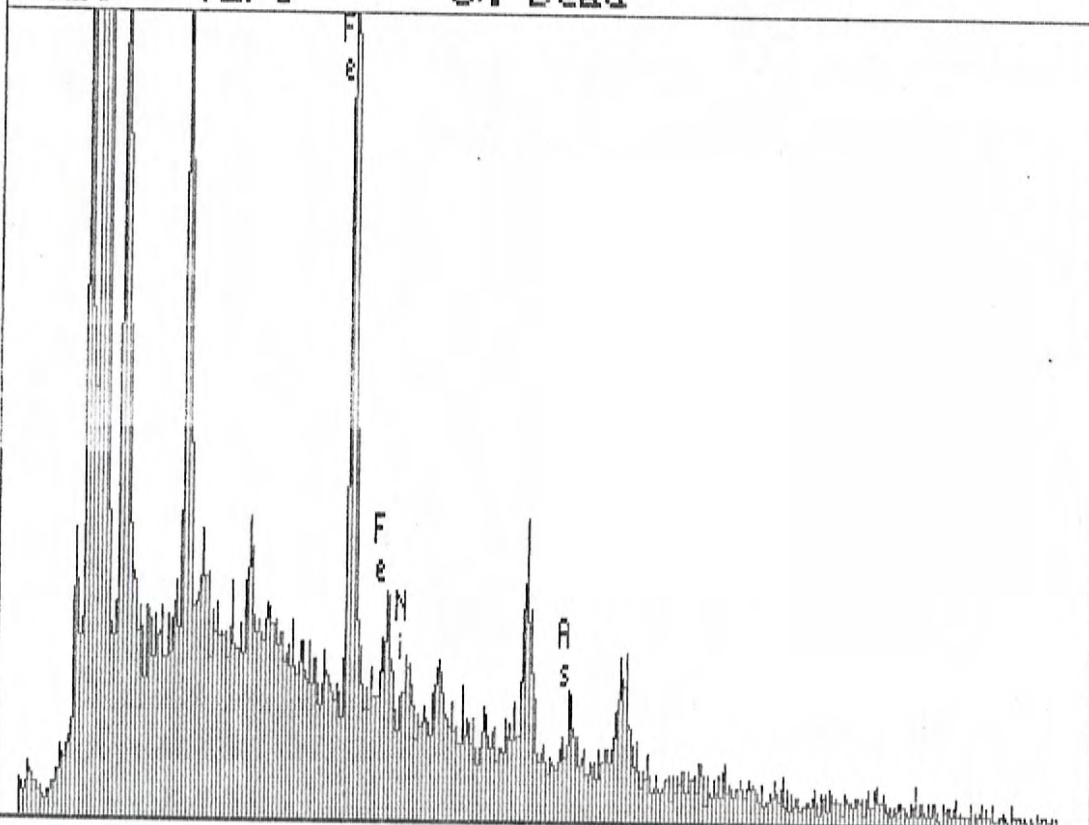
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 8 cts
MEM1:5A-5 Clorite

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 127s 6% Dead



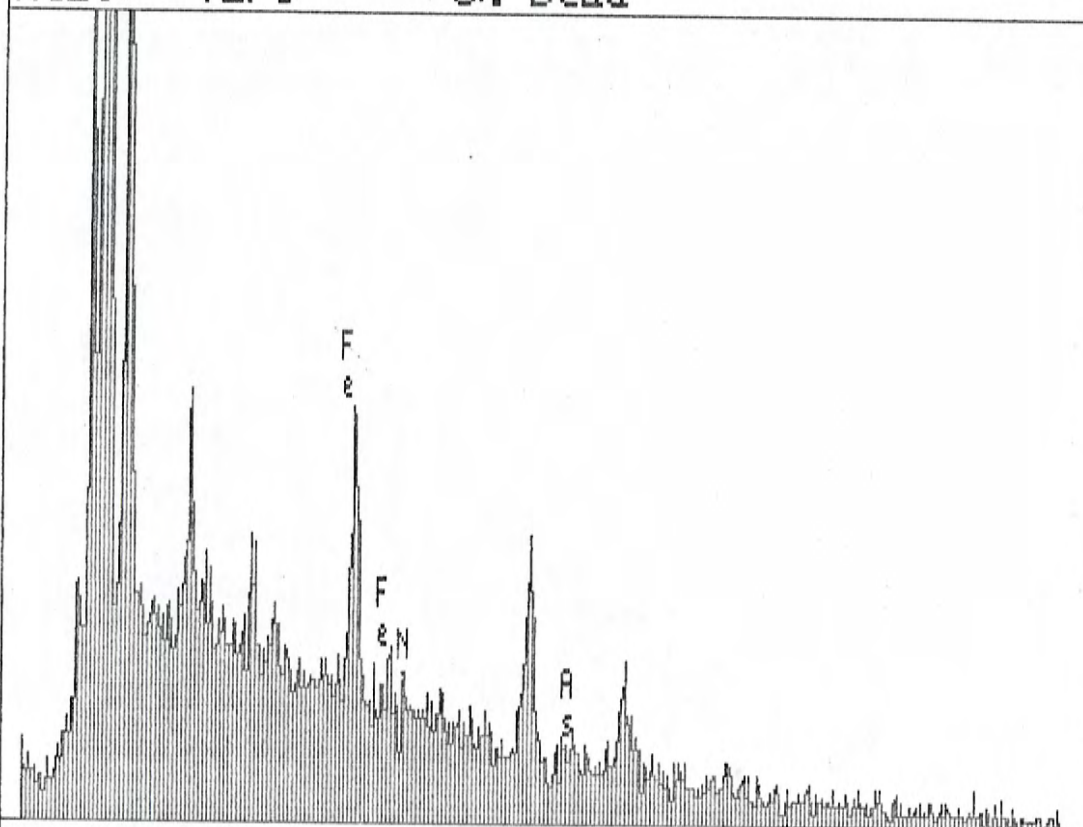
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 15 cts
MEM1:5B-2 Matrix #1 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 127s 6% Dead



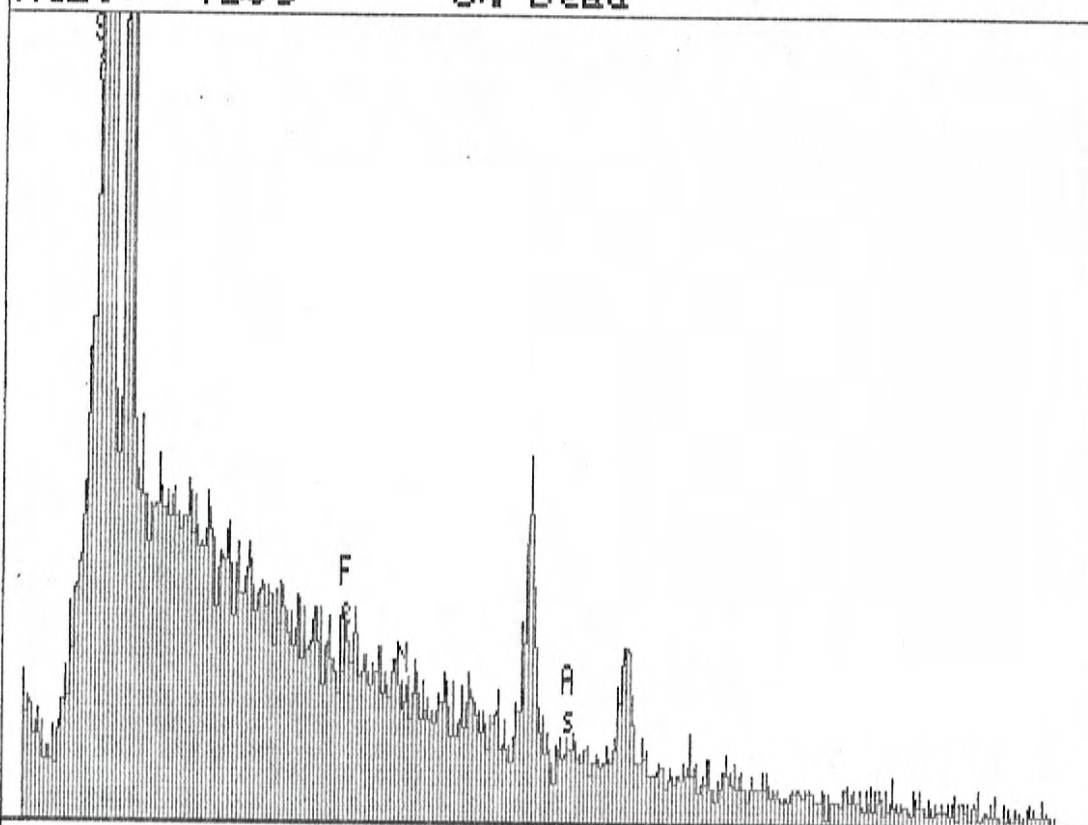
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 11 cts
MEM1: 5B-2 Matrix #2 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 127s 6% Dead



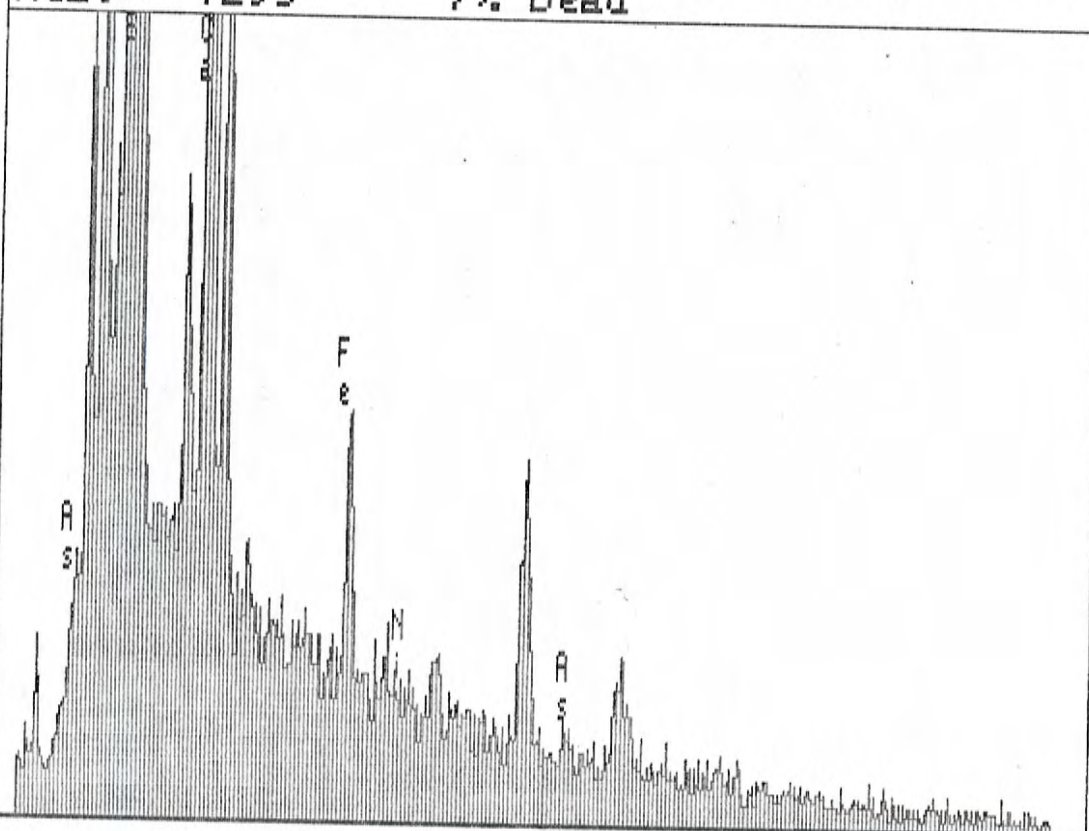
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 14 cts
MEM1:5B-3 QUARTZ

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 130s 8% Dead



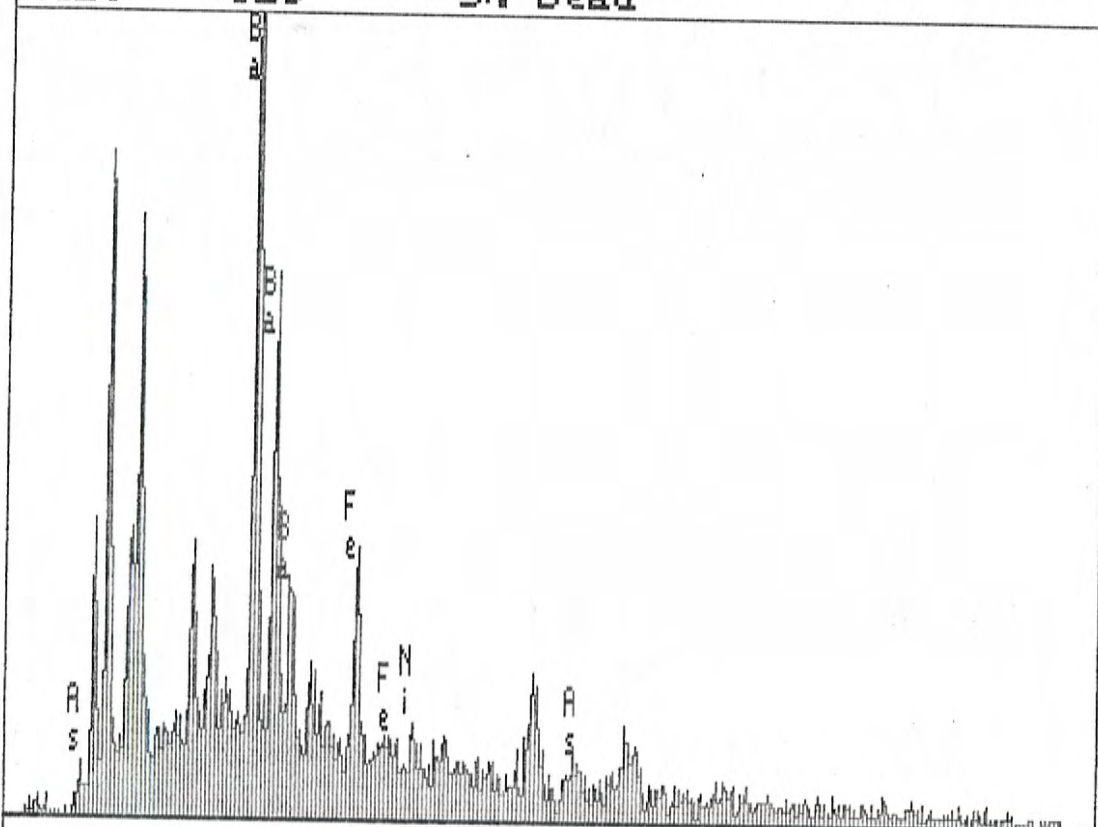
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 24 cts
MEM1:11A-1 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 129s 7% Dead



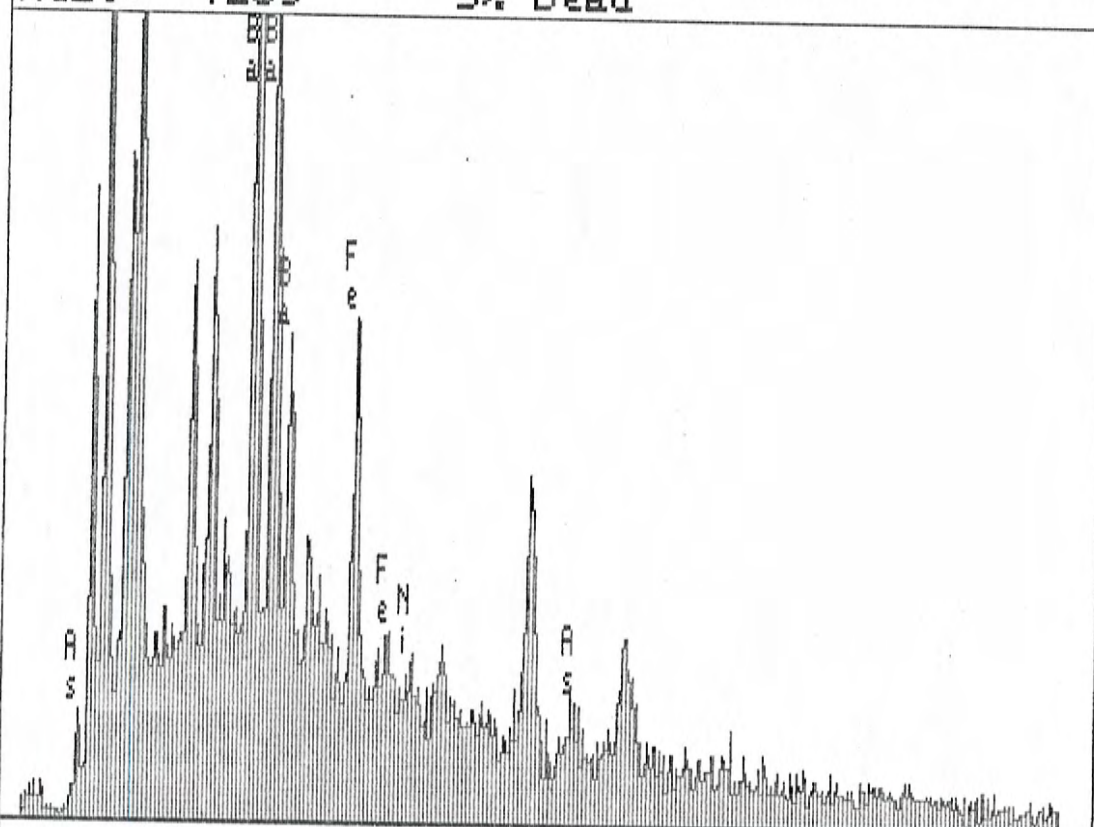
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 26 cts
MEM1:11A-3 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 59s Preset: 120s Remaining: 61s
Real: 62s 5% Dead



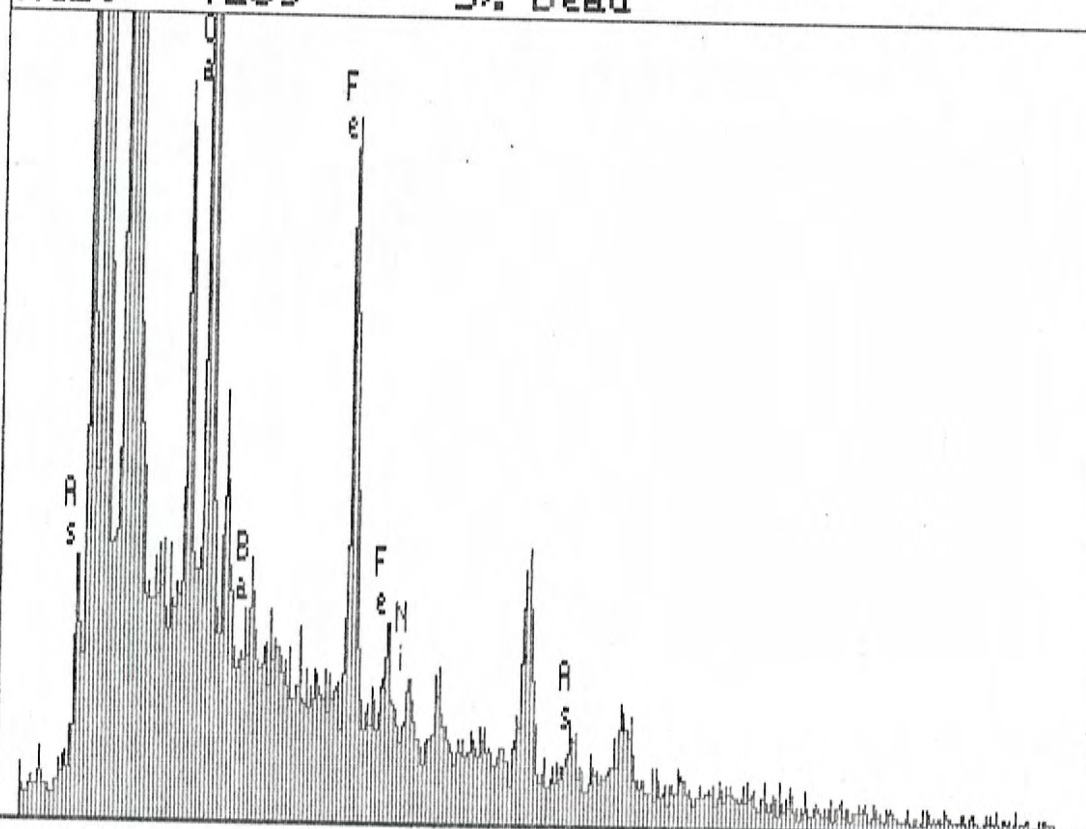
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 12 cts
MEM1: 11A-4 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 126s 5% Dead



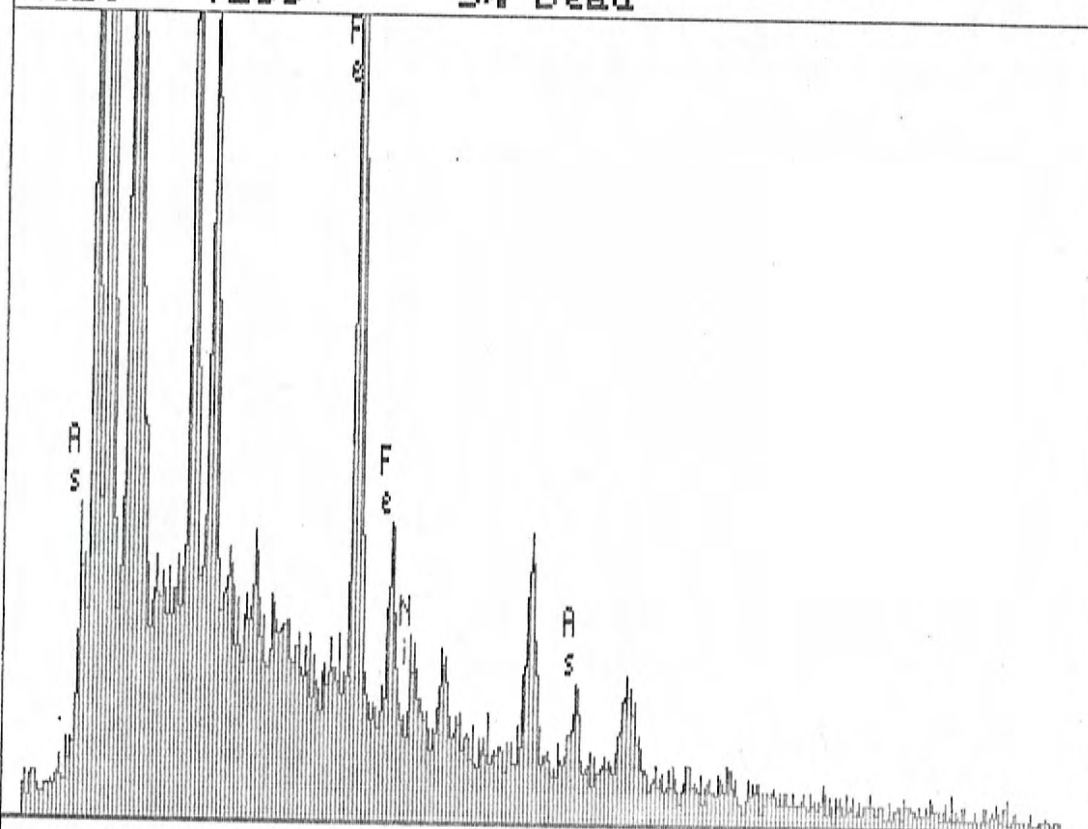
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 22 cts
MEM1:11A-4 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 126s 5% Dead



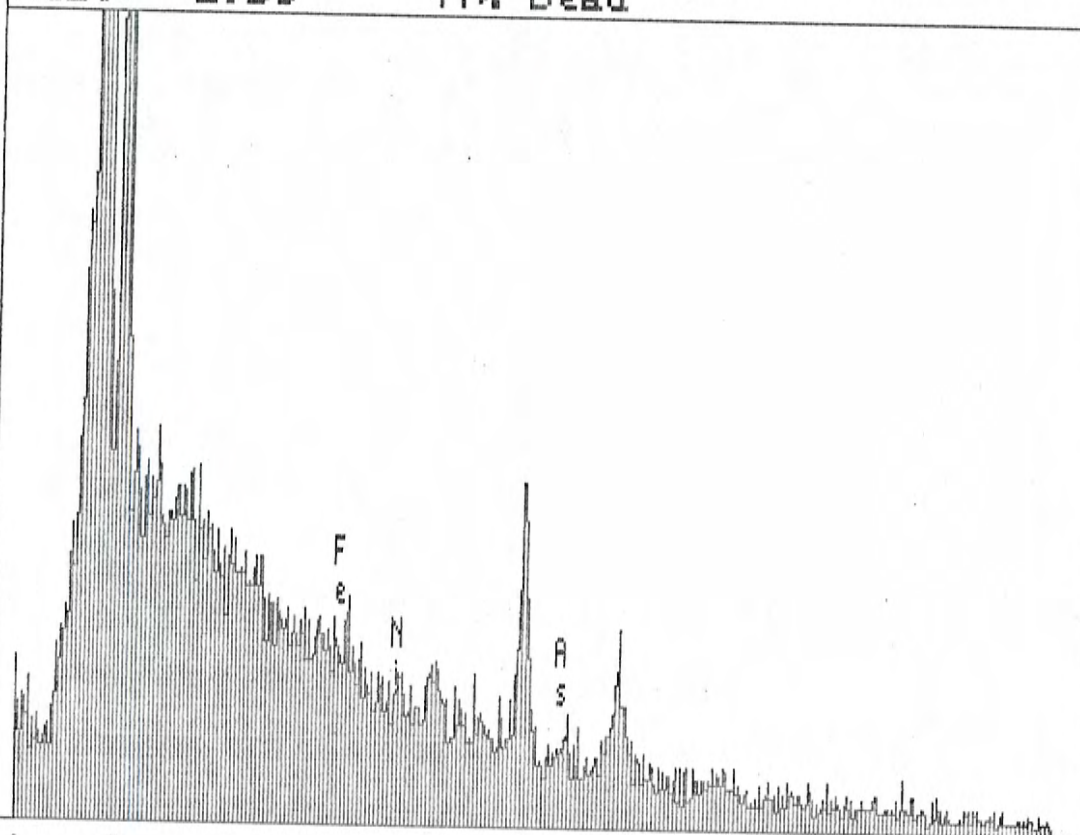
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 10 cts
MEM1:11A-5 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 126s 5% Dead



< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 17 cts
MEM1:11A-6 Illite /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 205s 41% Dead

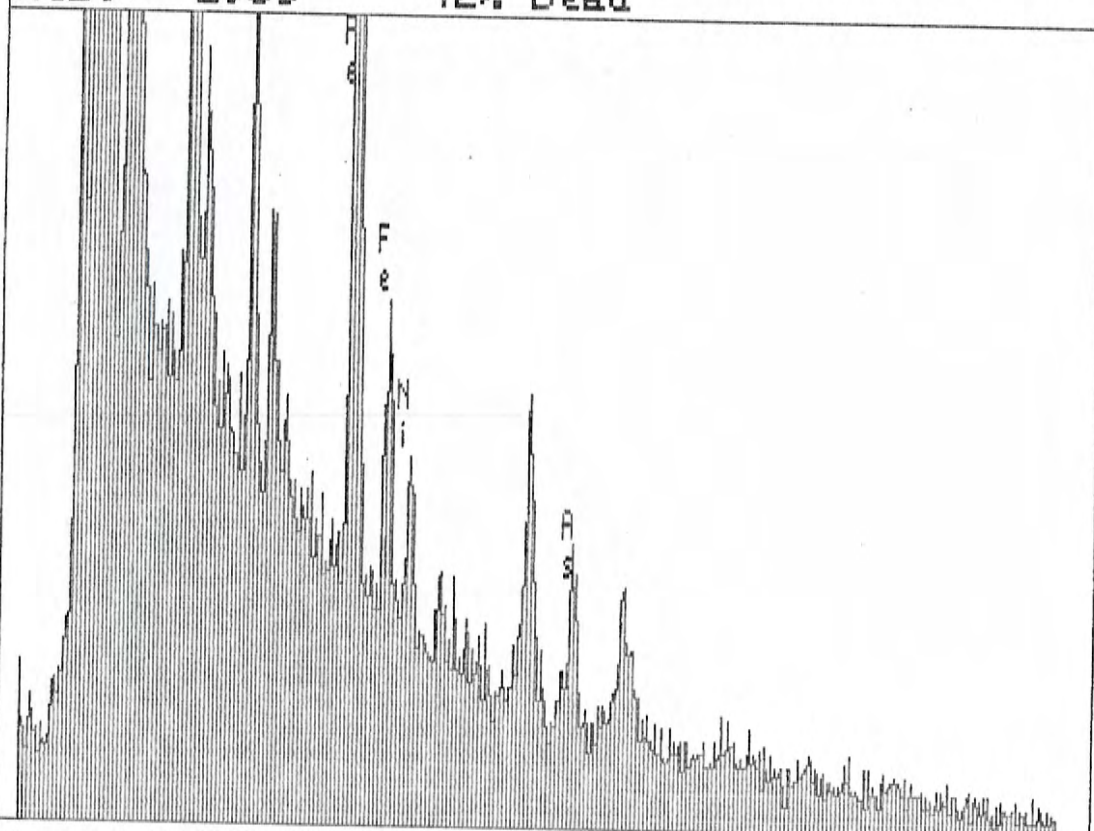


< -0.2
FS=255
MEM1:11B-1

10.043 keV
ch 512=

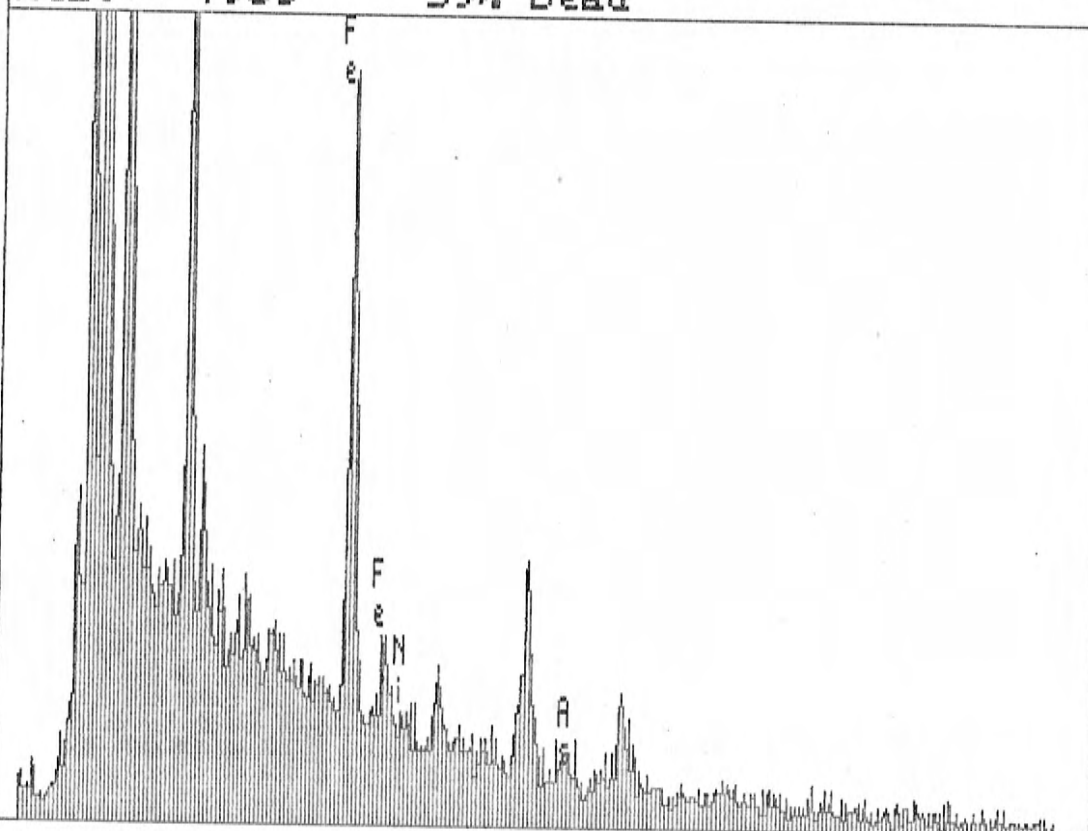
20.3 >
17 cts

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 206s 42% Dead



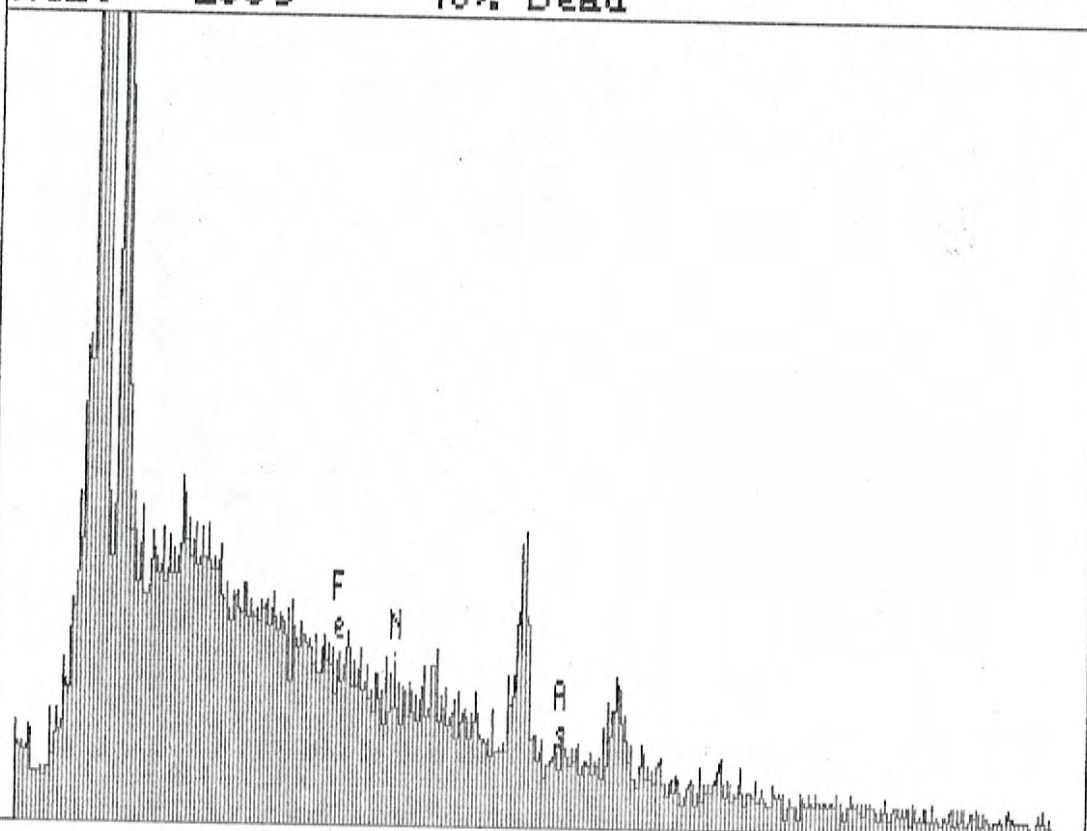
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 32 cts
MEM1:11B-2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 198s 39% Dead



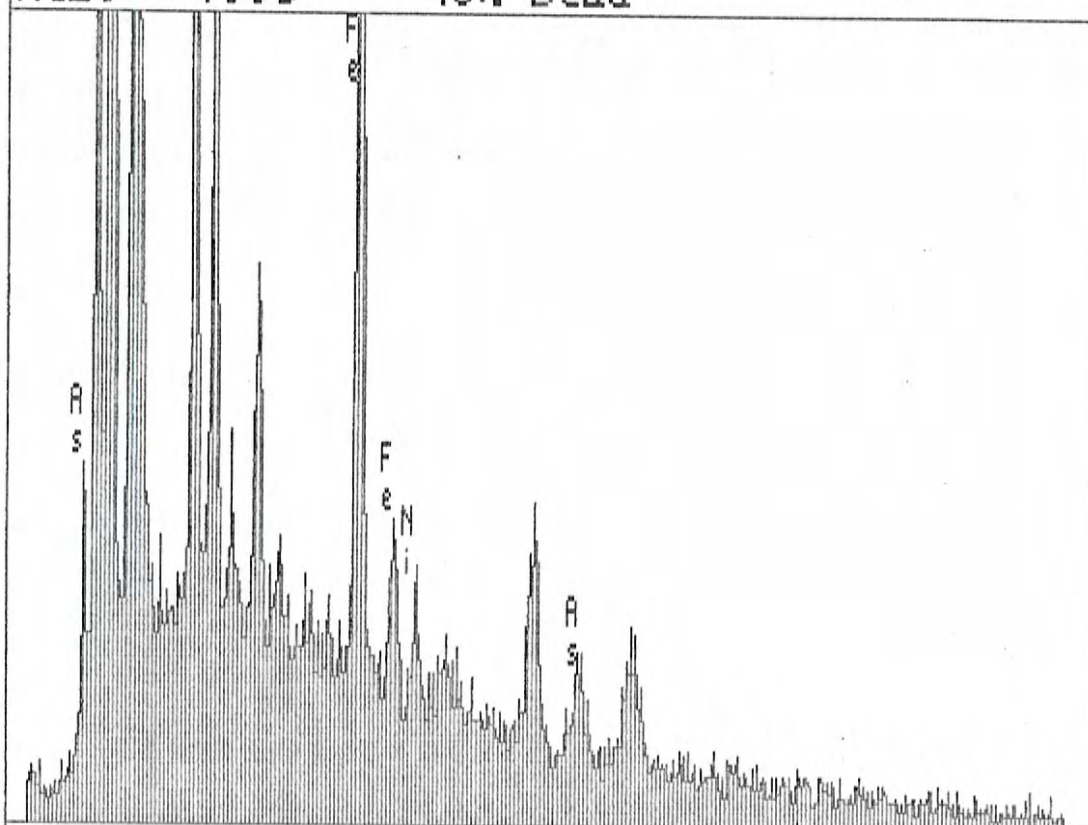
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 15 cts
MEM1:11B-3 Matrix

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 200s 40% Dead



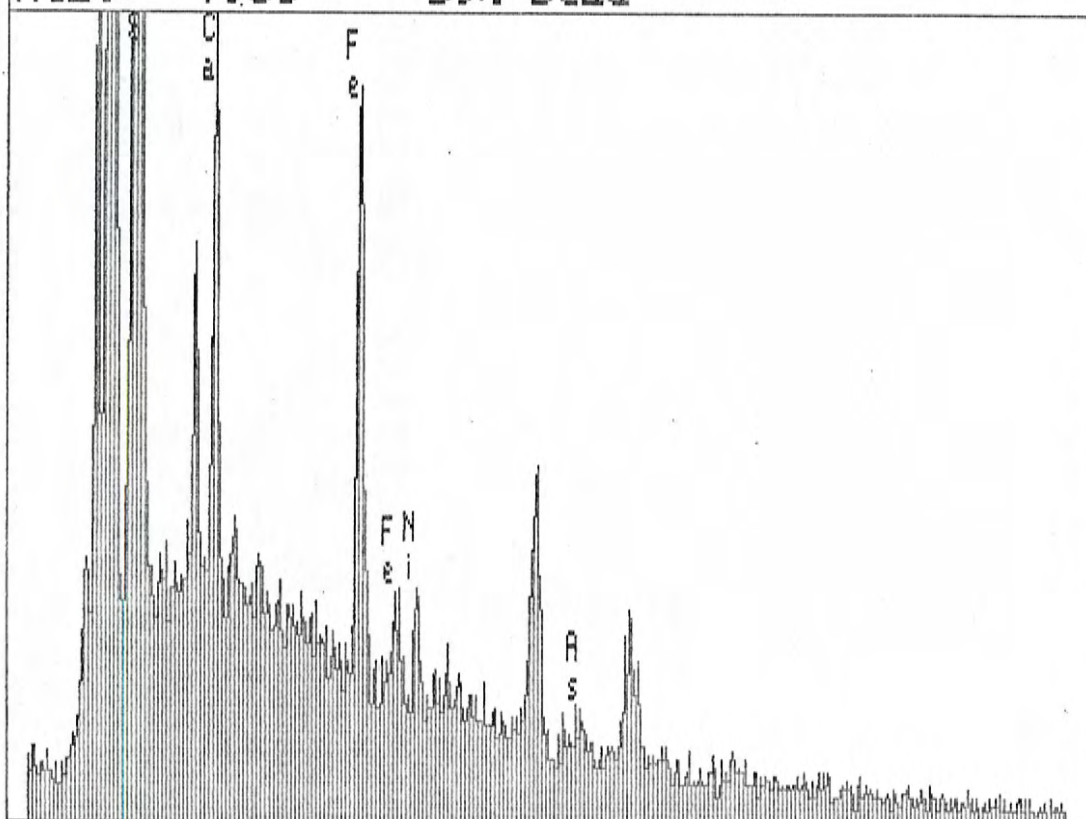
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 19 cts
MEM1:14A-1 Quartz

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 199s 40% Dead



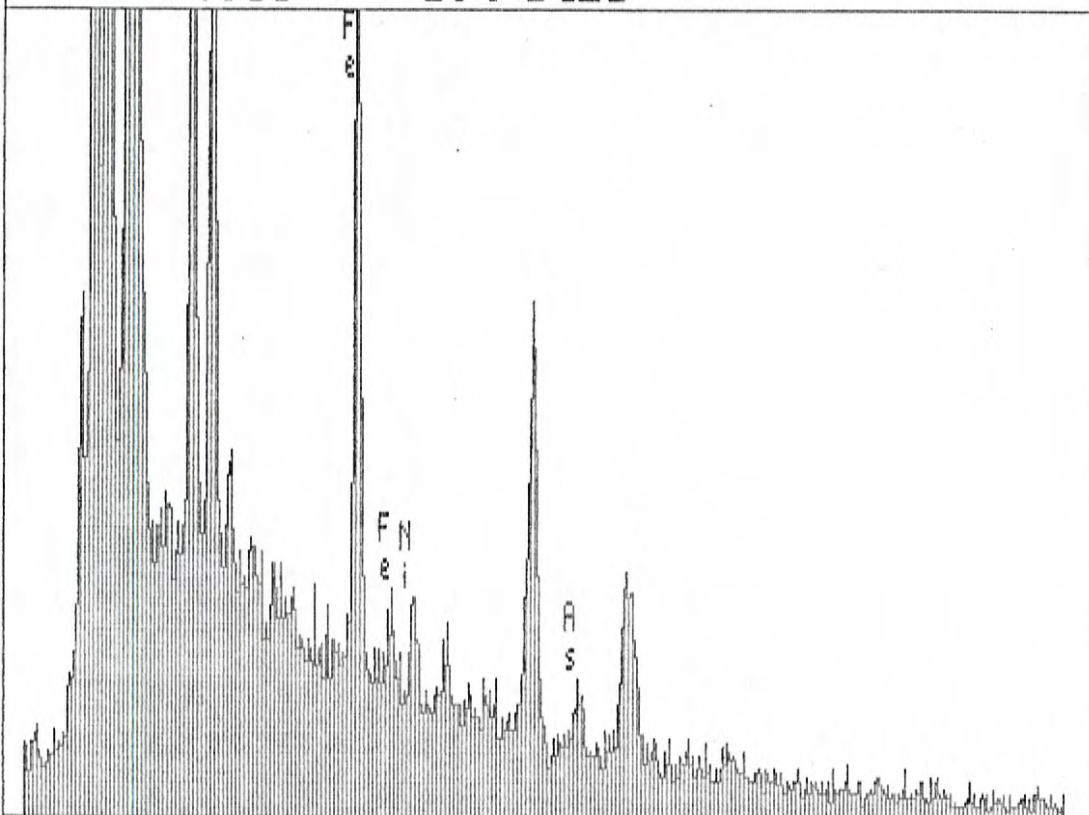
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 18 cts
MEM1:14A-2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 198s 39% Dead



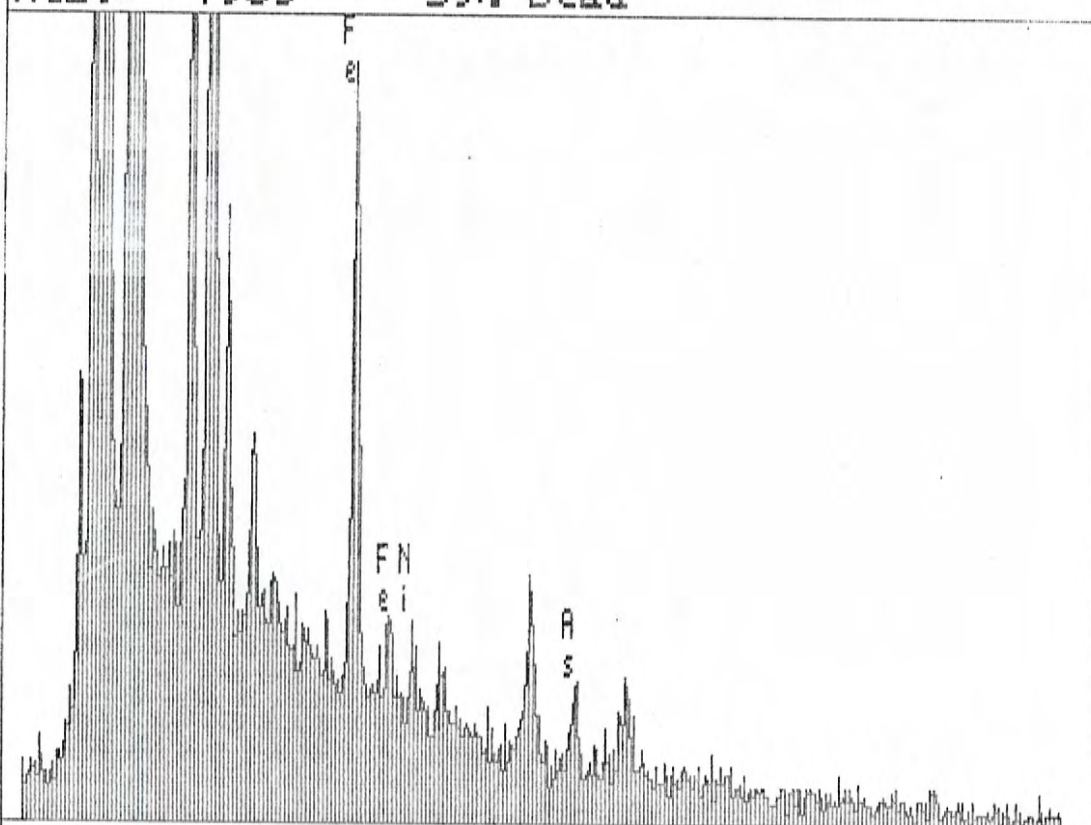
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 21 cts
MEM1:14A-3

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 198s 39% Dead

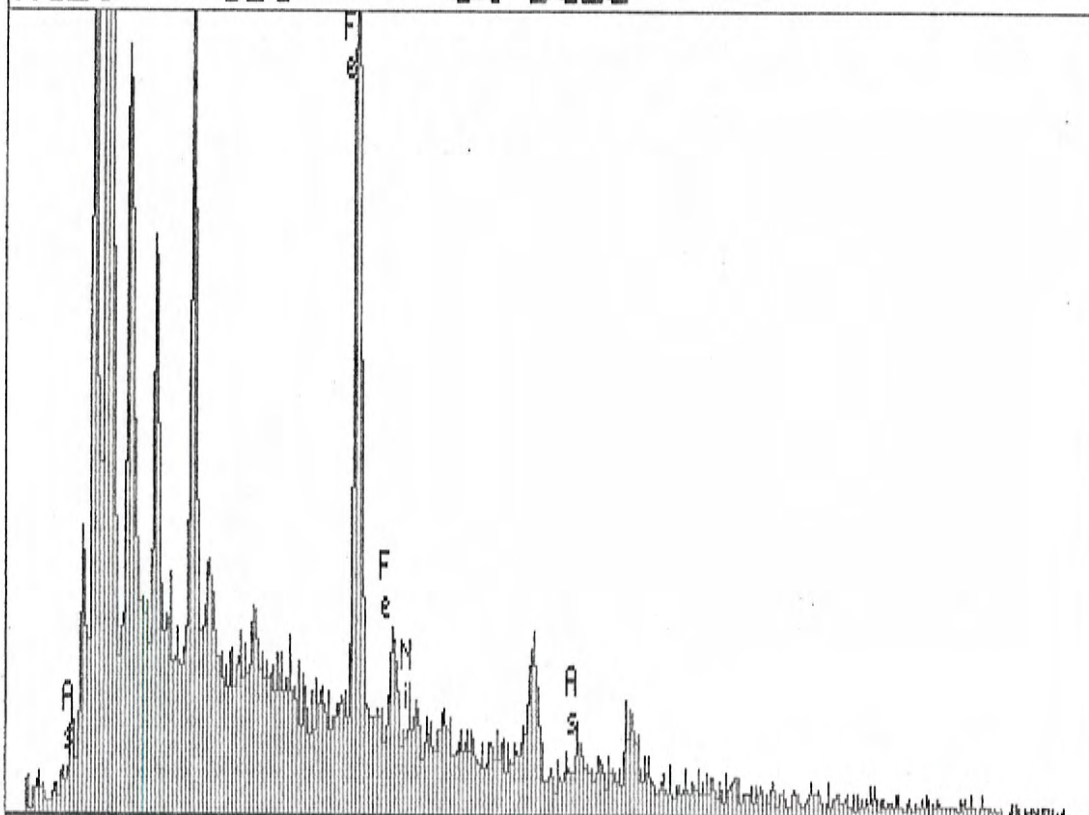


< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 10 cts
MEM1:14A-4

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 198s 39% Dead

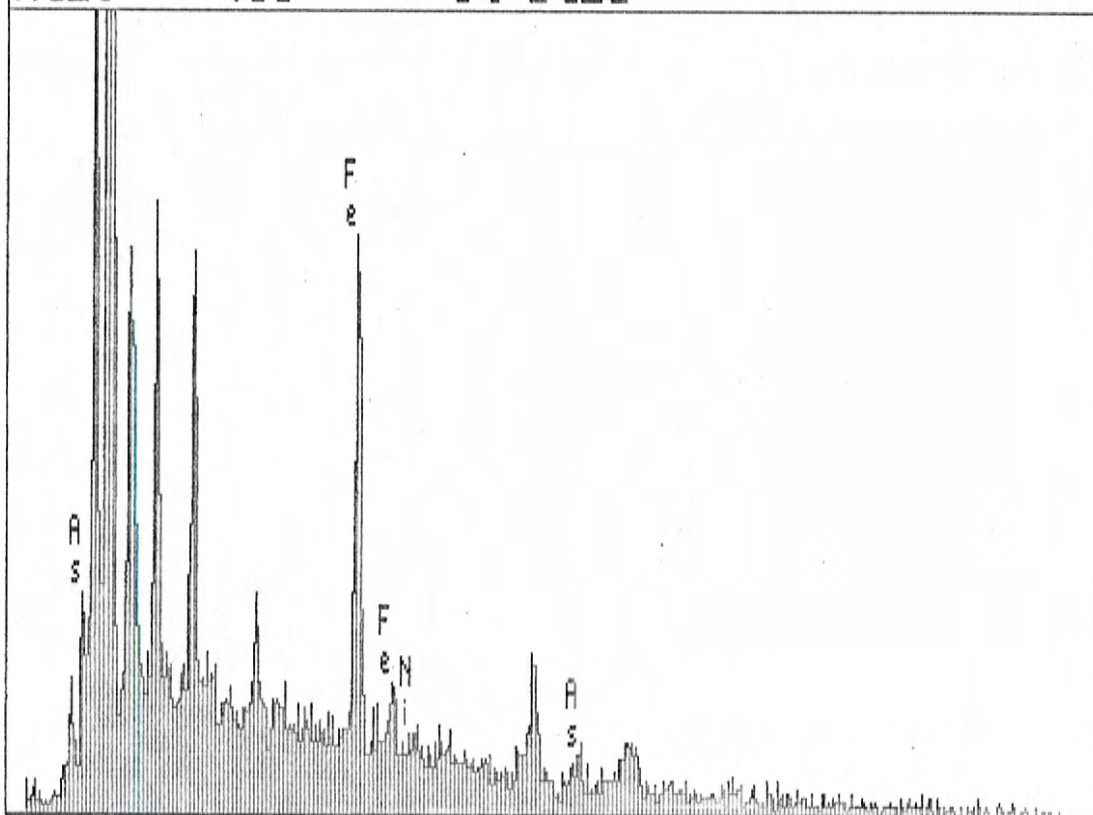


X-RAY(1): 0 - 20 keV Window : None
Live: 61s Preset: 61s Remaining: 0s
Real: 65s 6% Dead



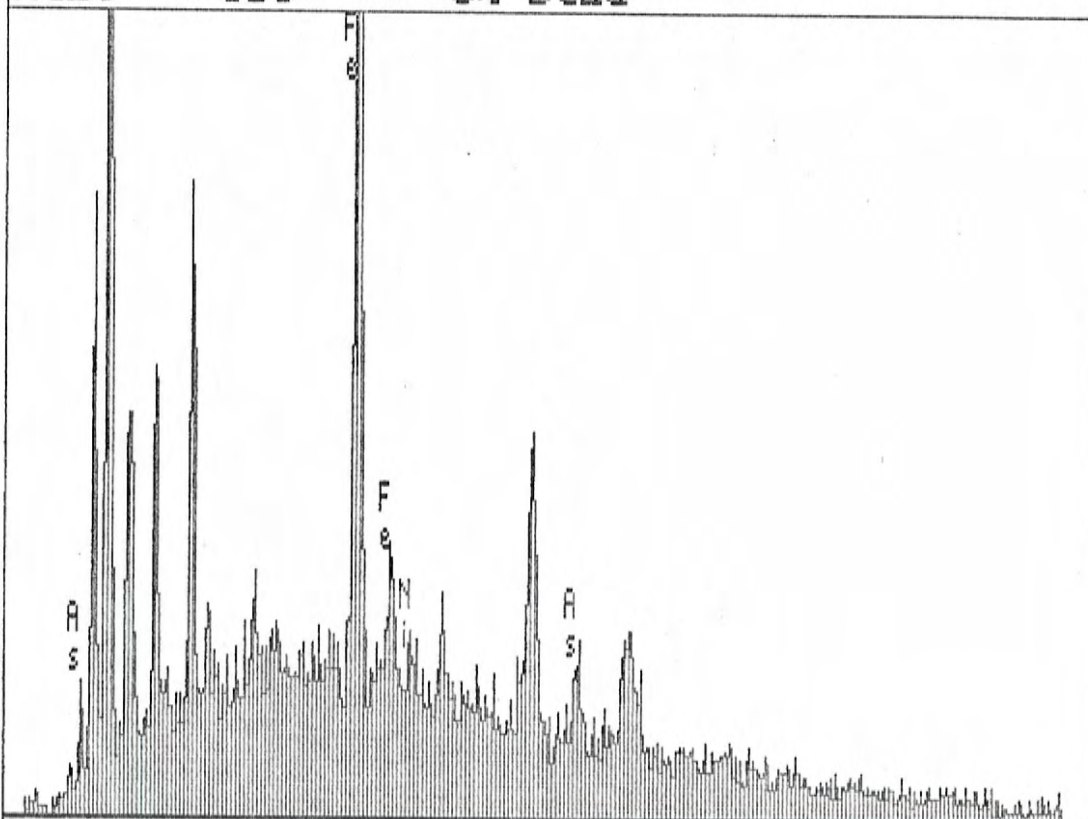
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 14 cts
MEM1:14B MATRIX /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 45s Preset: 45s Remaining: 0s
Real: 48s 6% Dead



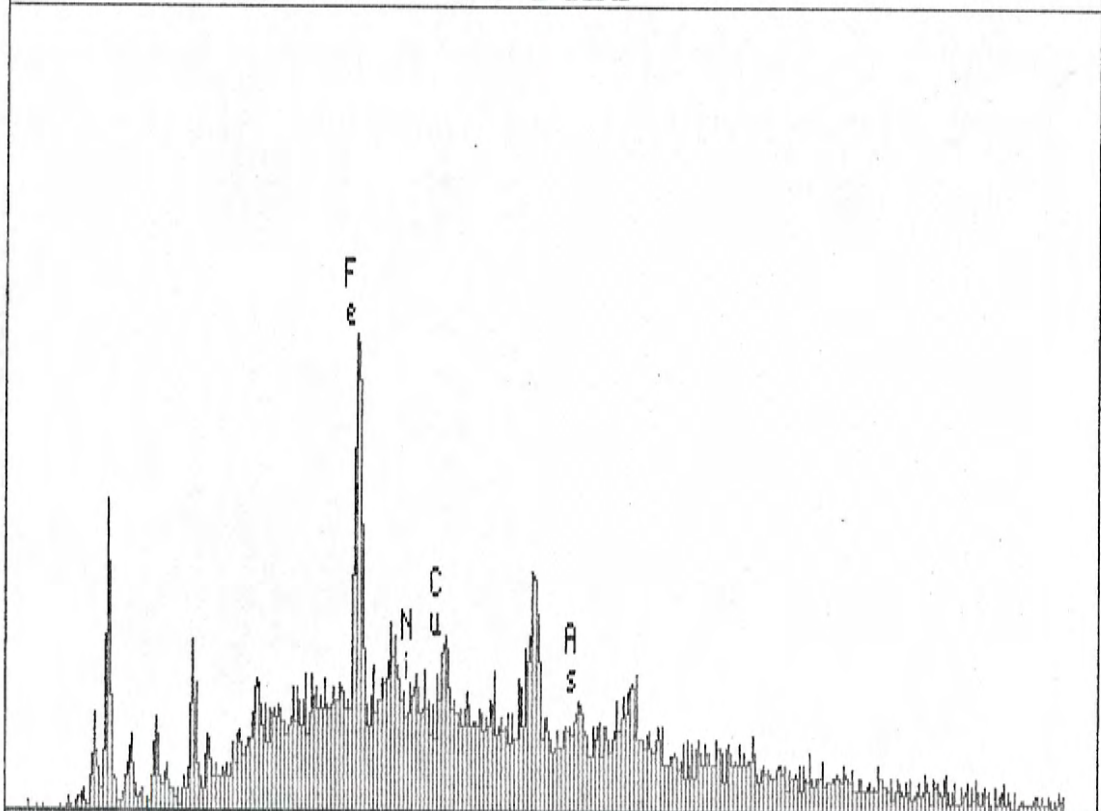
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 8 cts
MEM1:14B-2 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 61s Preset: 61s Remaining: 0s
Real: 65s 6% Dead



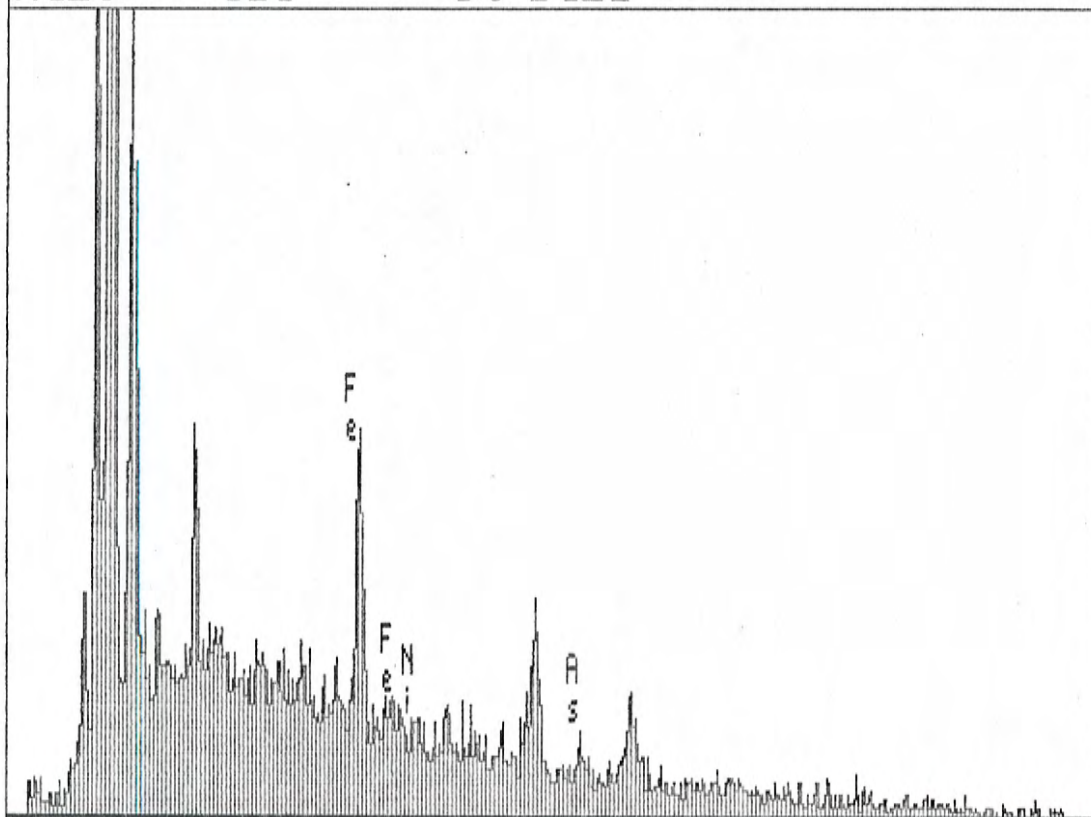
< - .2 10.043 keV 20.3 >
FS=255 ch 512= 19 cts
MEM1:14B-3 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 122s Preset: 61s Remaining: 0s
Real: 126s 3% Dead



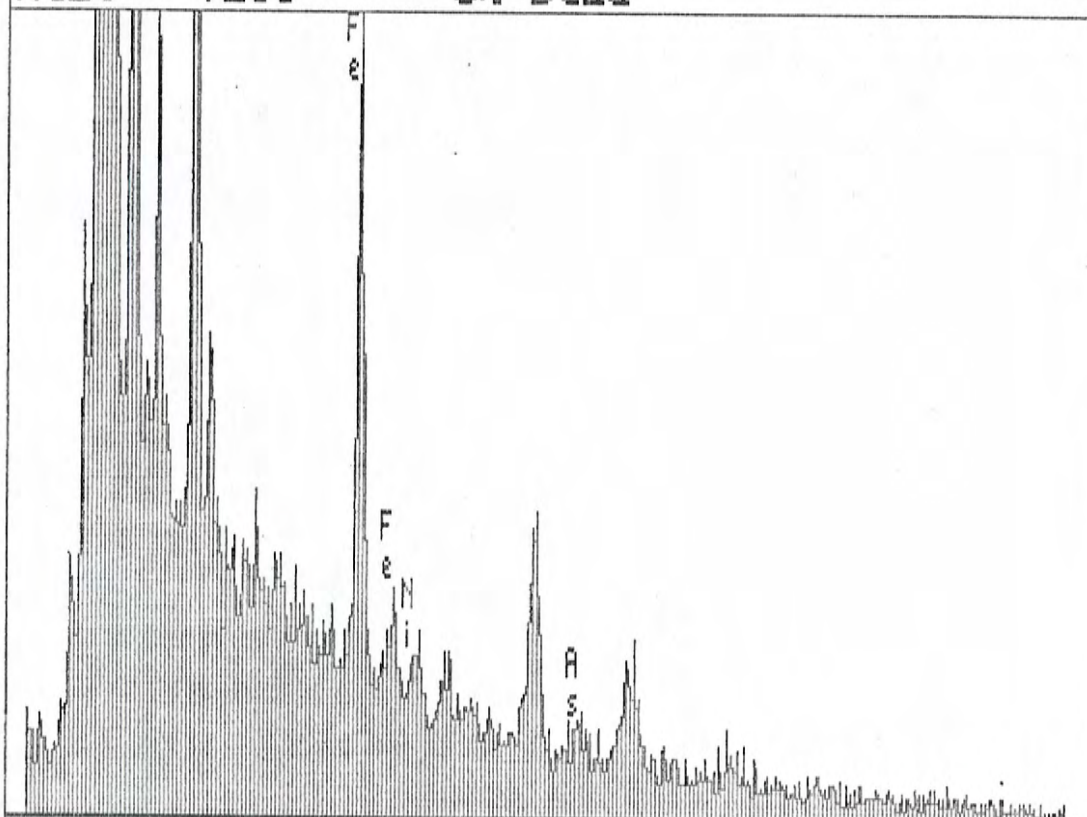
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 15 cts
MEM1:14B-4 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 61s Preset: 61s Remaining: 0s
Real: 65s 6% Dead



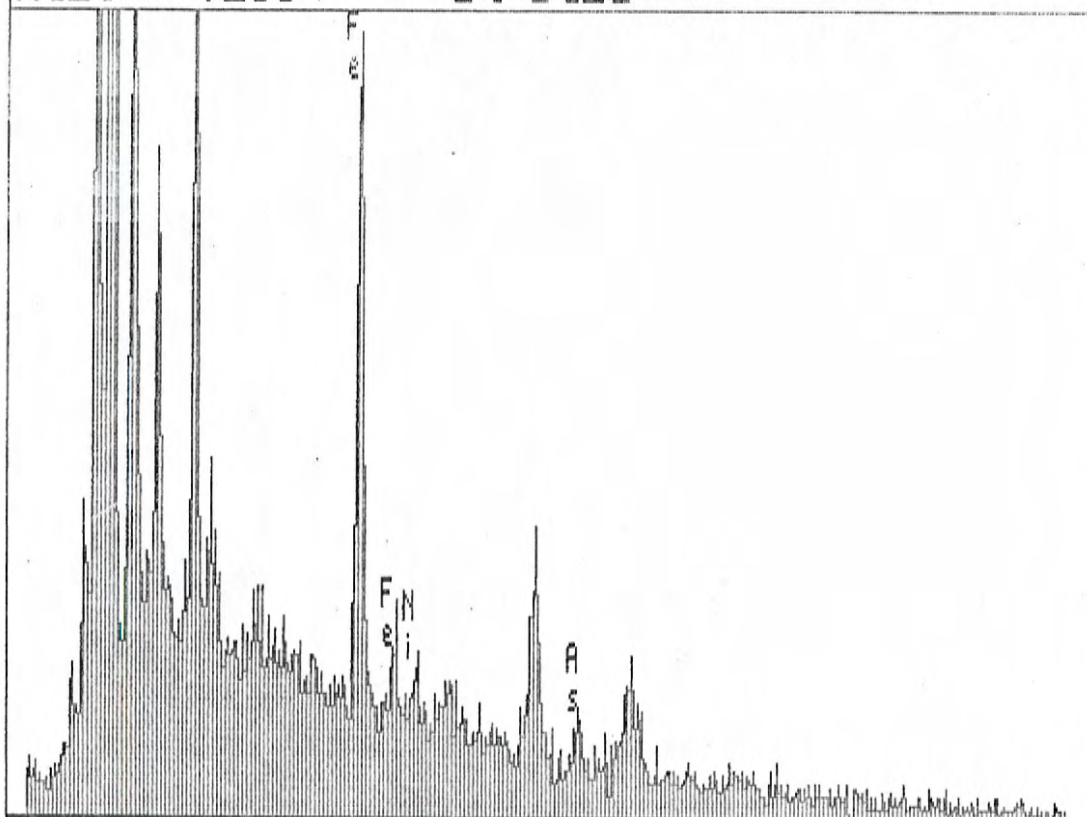
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 12 cts
MEM1:14B-5 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 128s 6% Dead



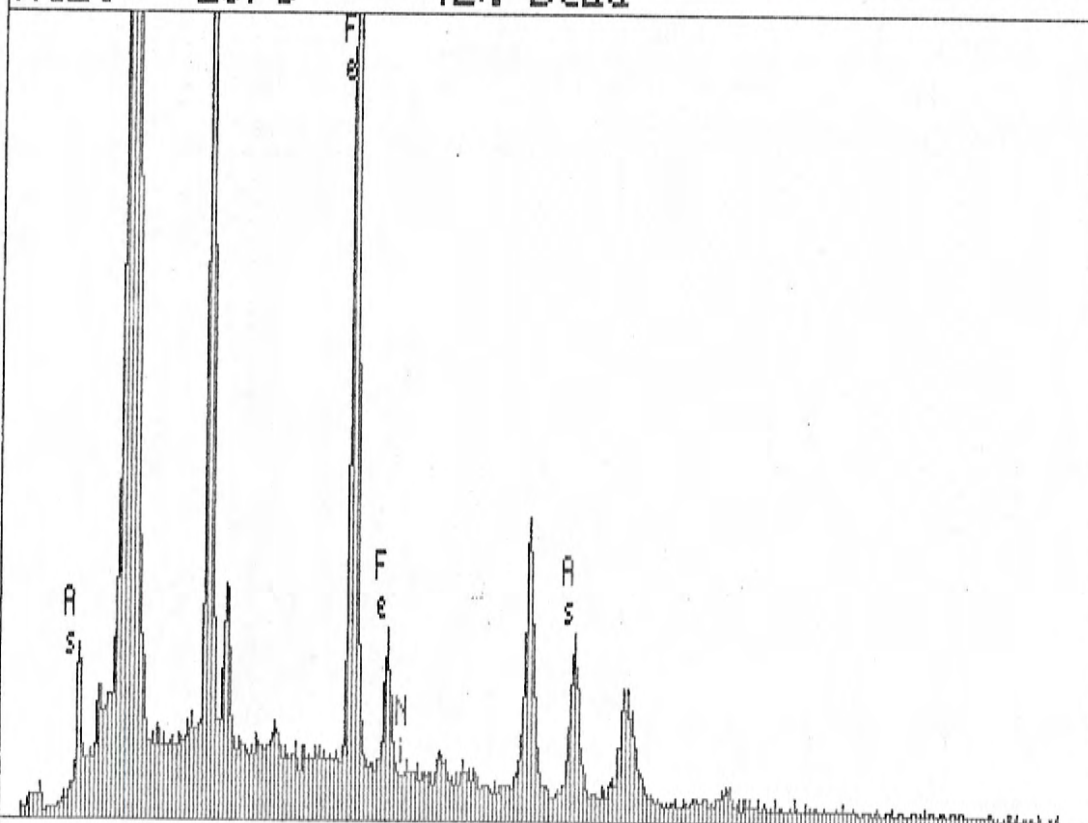
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 16 cts
MEM1:14B-6 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 126s 5% Dead



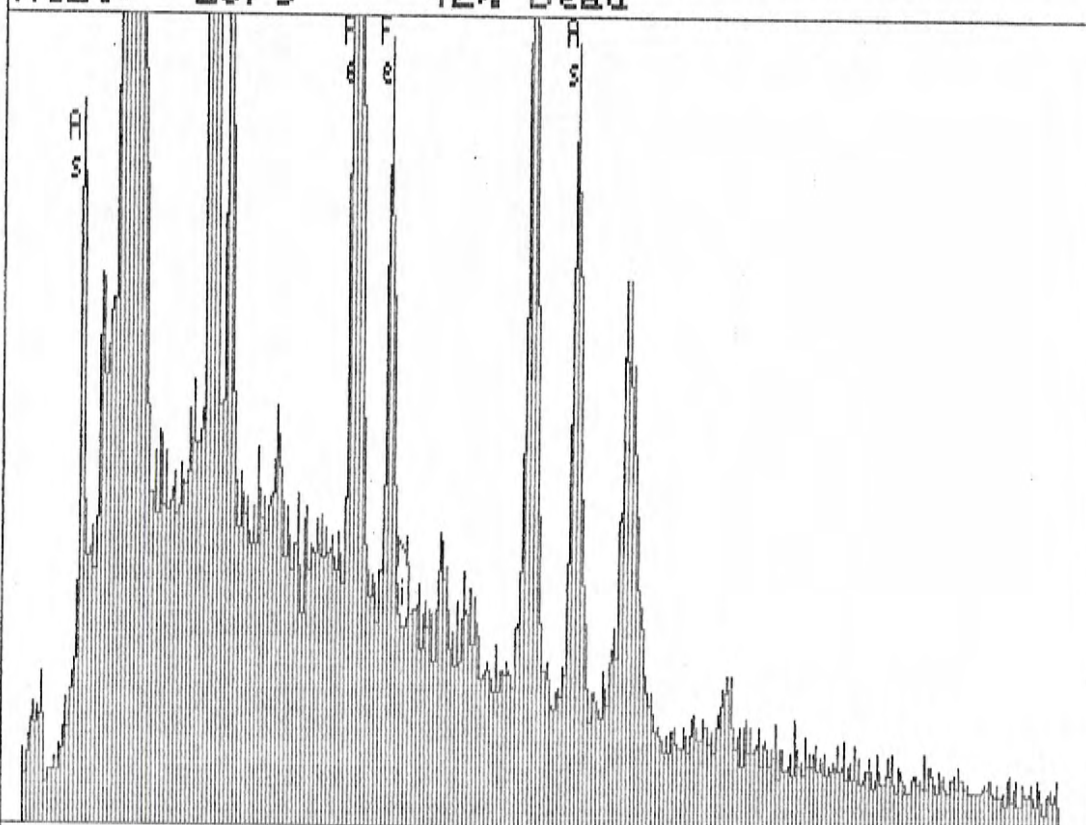
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 9 cts
MEM1:14B-7 /MEM2

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 207s 42% Dead



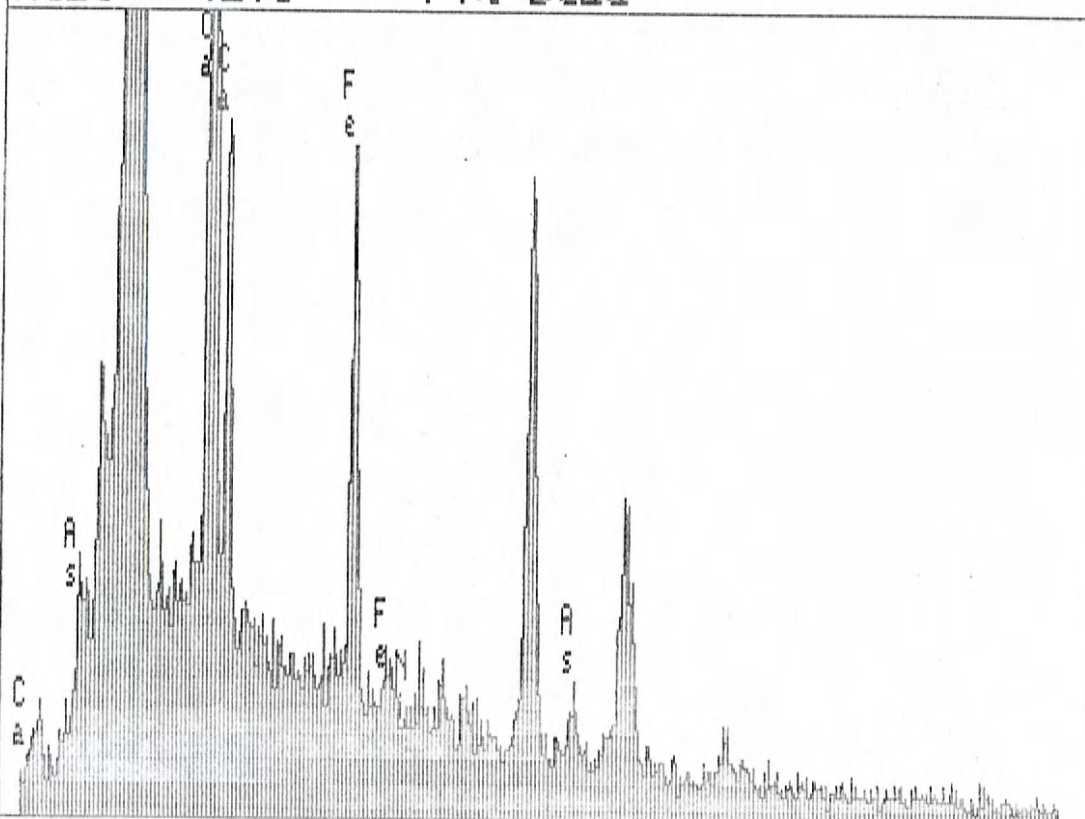
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 28 cts
MEM1:6-2 A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 207s 42% Dead



< -.2 10.043 keV 20.3 >
FS=255 ch 512= 28 cts
MEM1:6-2 A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 421s 71% Dead

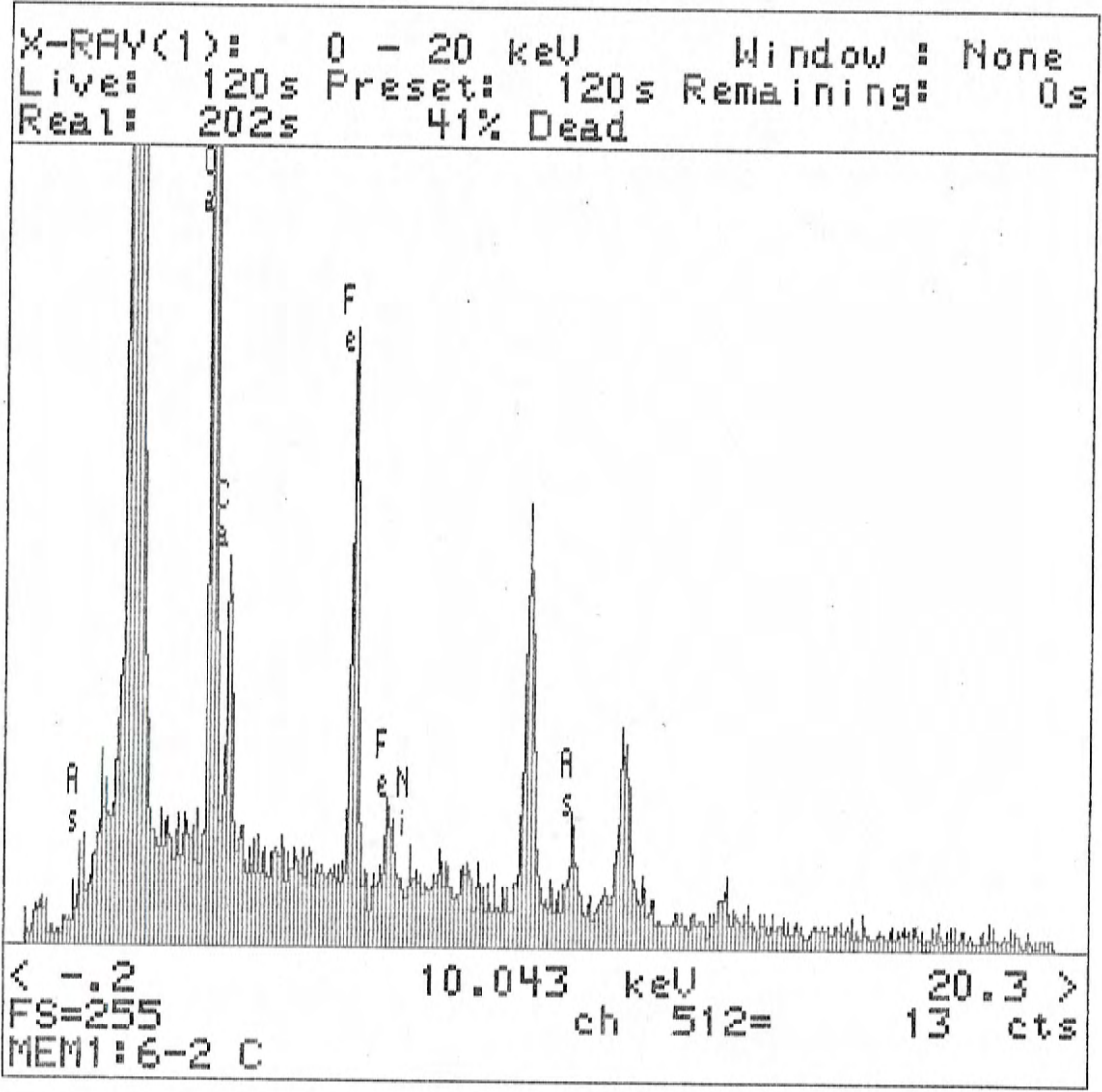


< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 17 cts
MEM1:6-2B

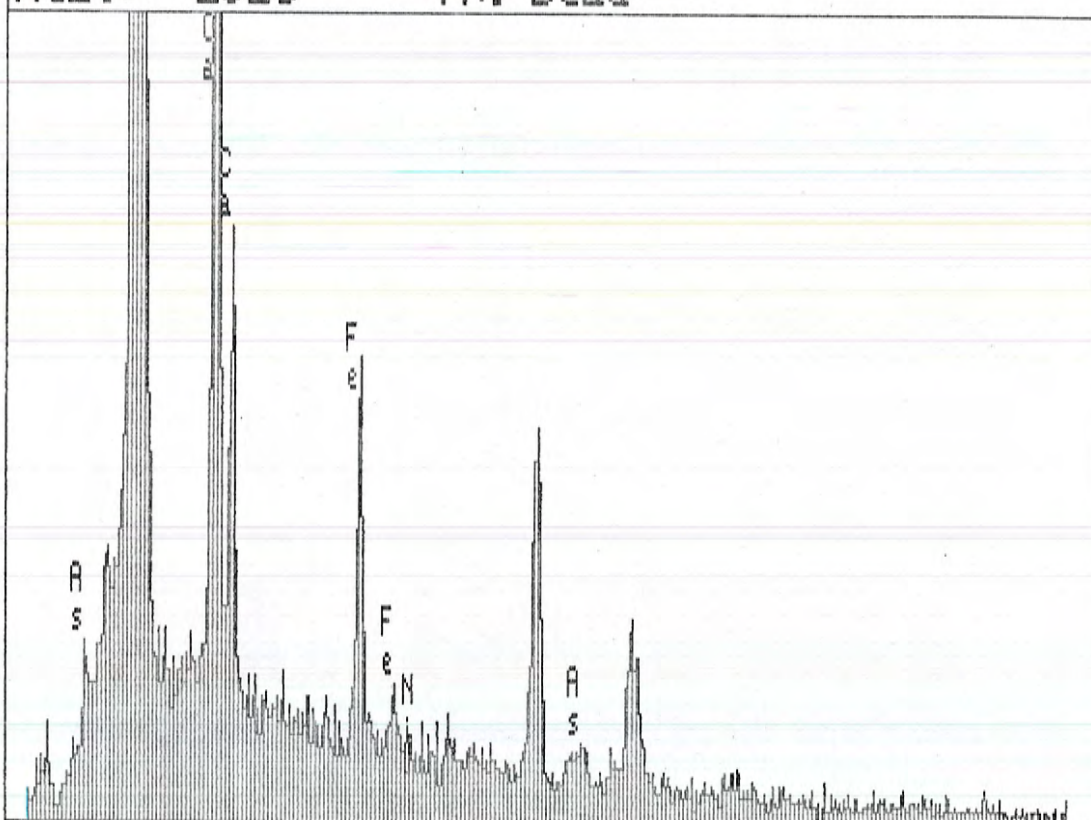
Figure 3.11

①

* sample

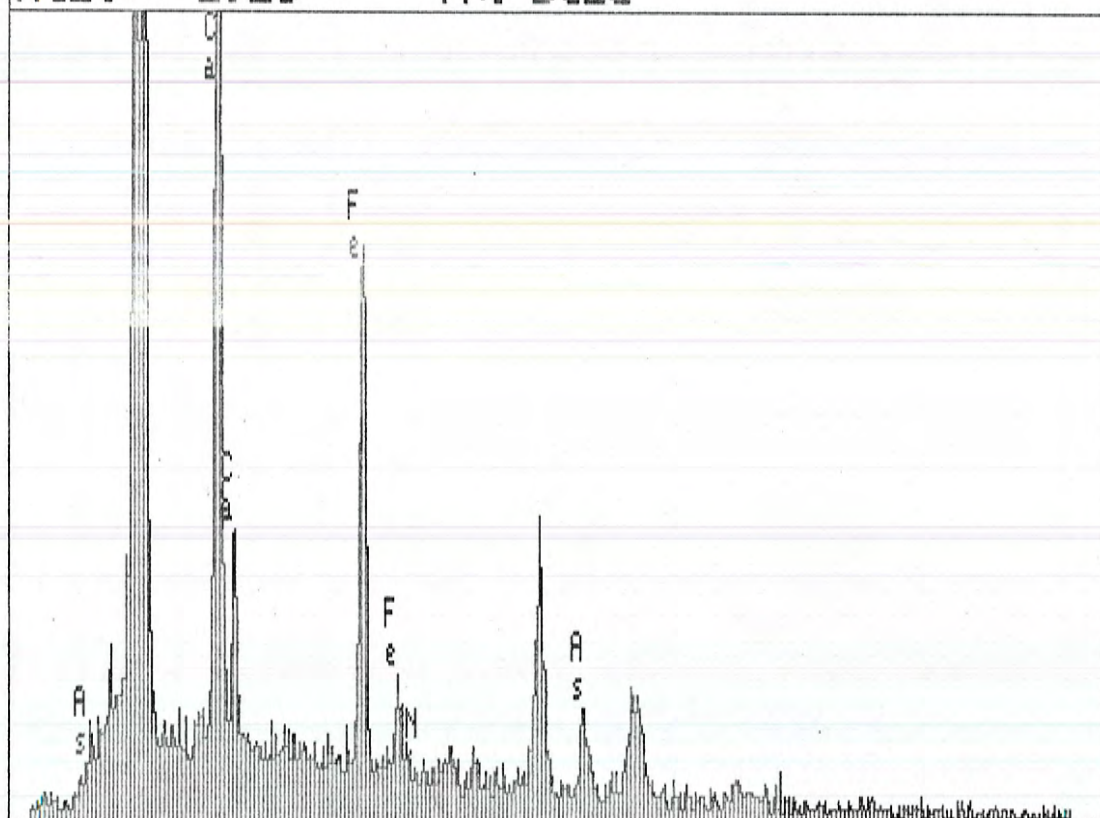


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



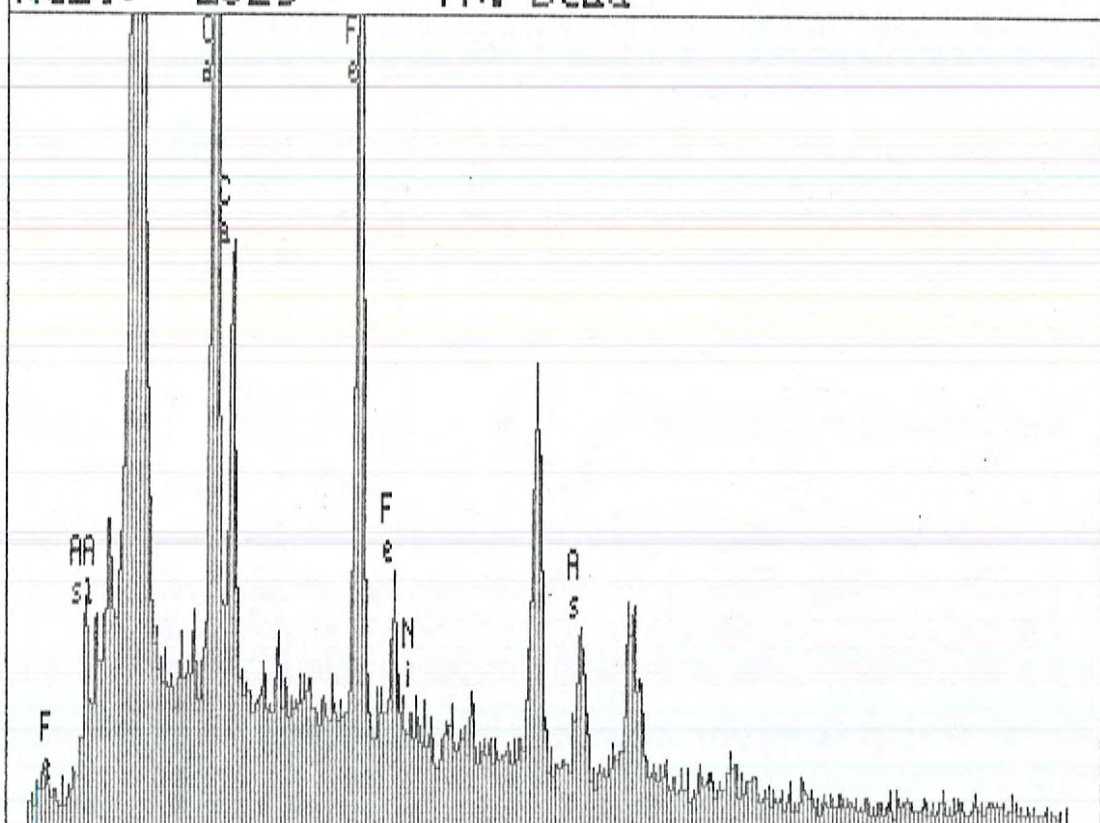
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 11 cts
MEM1:6-2 D

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



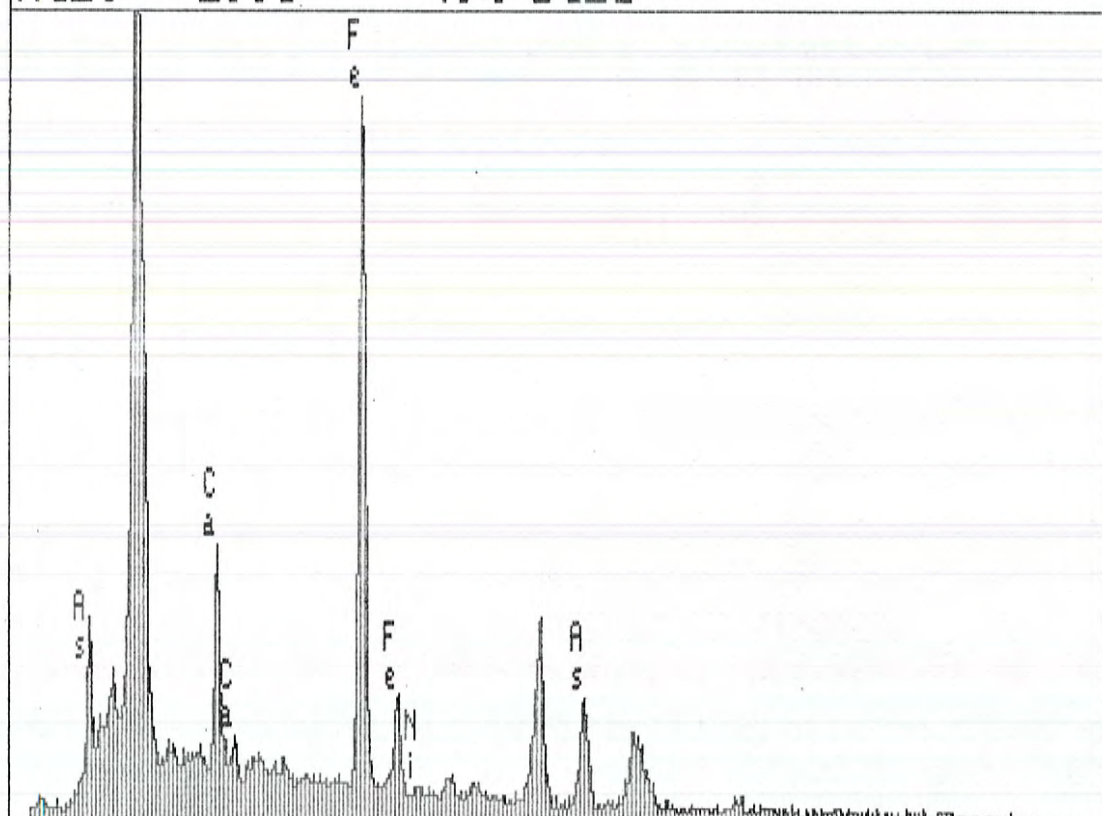
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 8 cts
MEM1:6-2 E

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



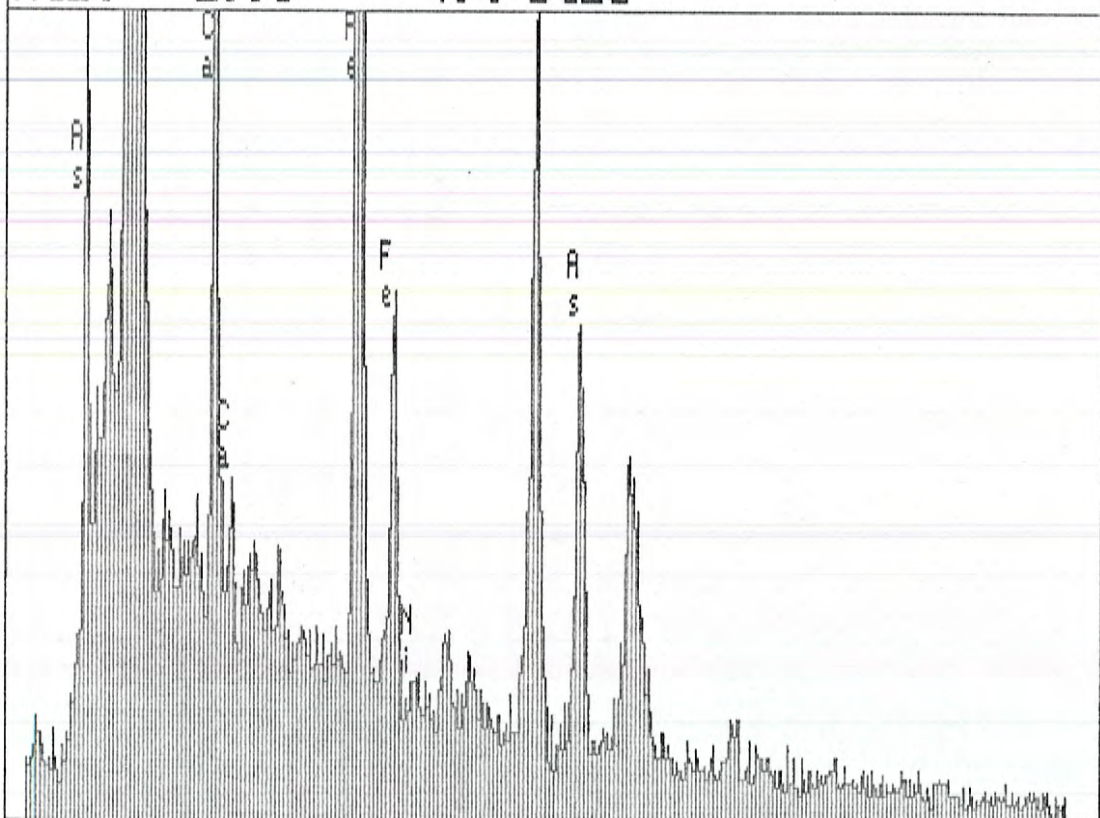
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 21 cts
MEM1:6-3 A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 200s 40% Dead



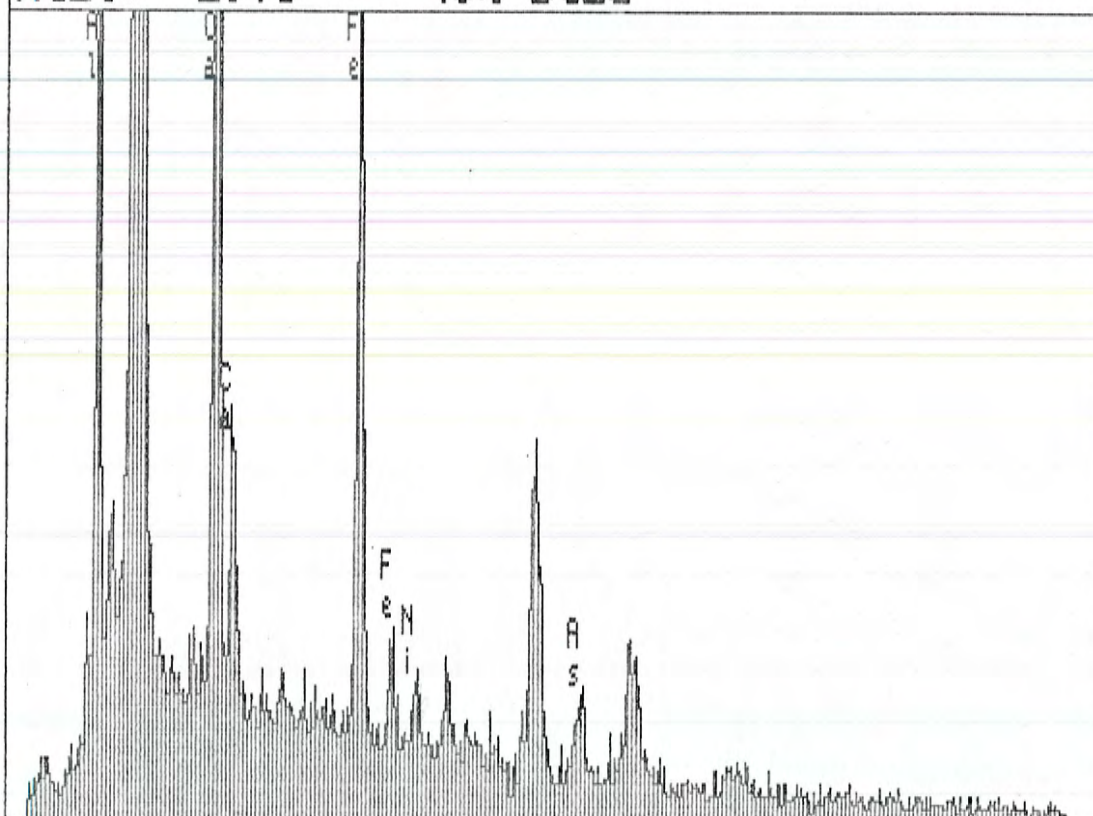
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 17 cts
MEM1:6-3 B

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 200s 40% Dead

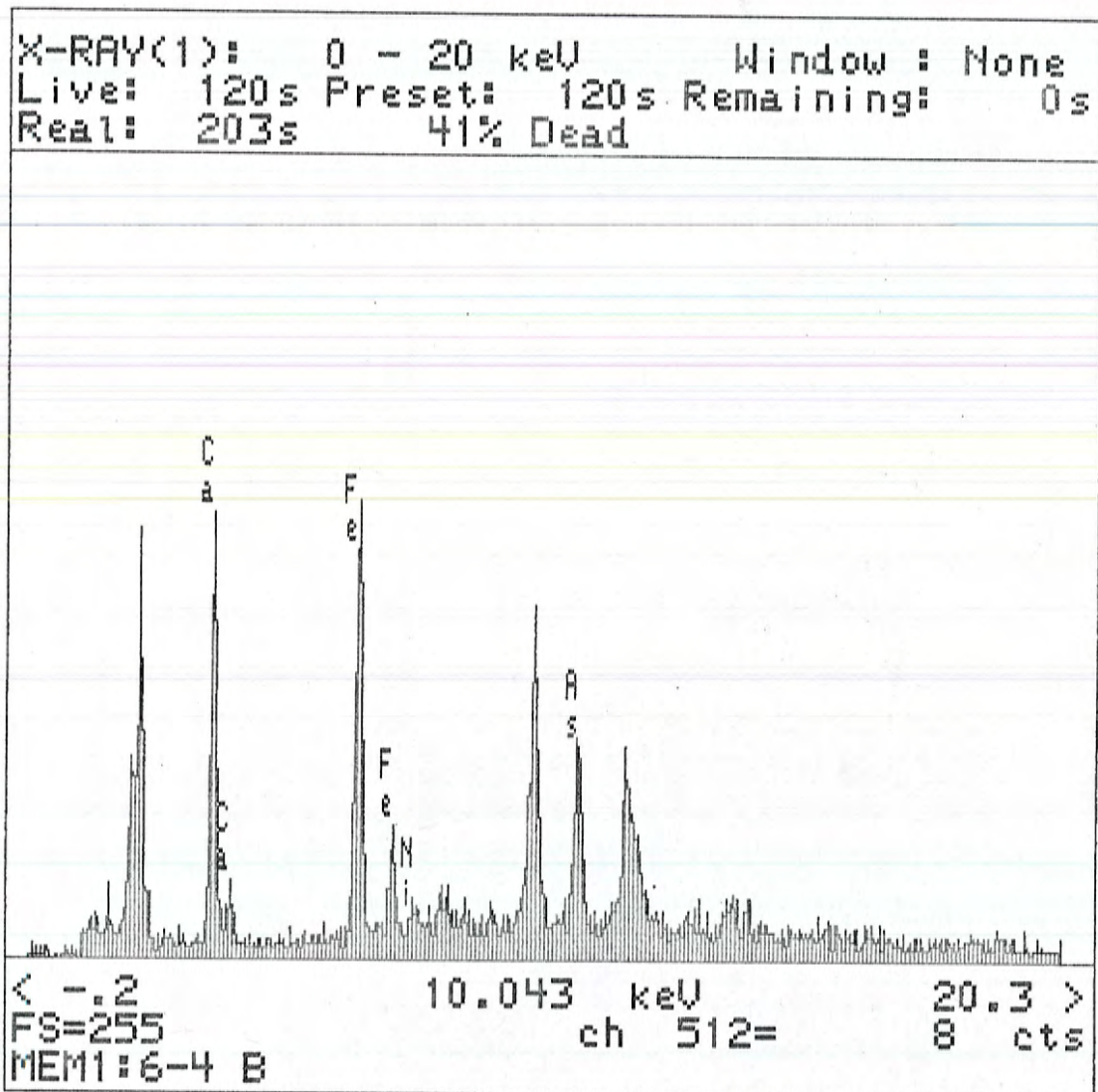


< -.2 10.043 keV 20.3 >
FS=255 ch 512= 17 cts
MEM1:6-3 B

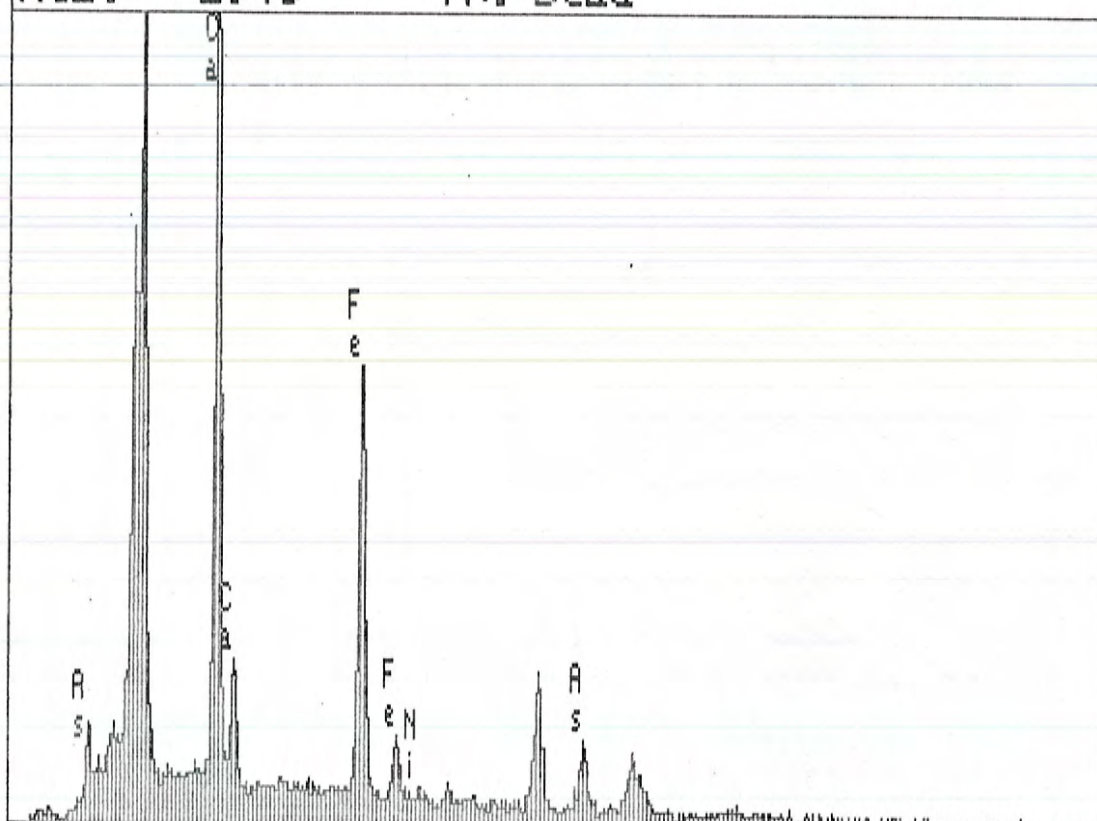
X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 201s 40% Dead



< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 11 cts
MEM1:6-4A

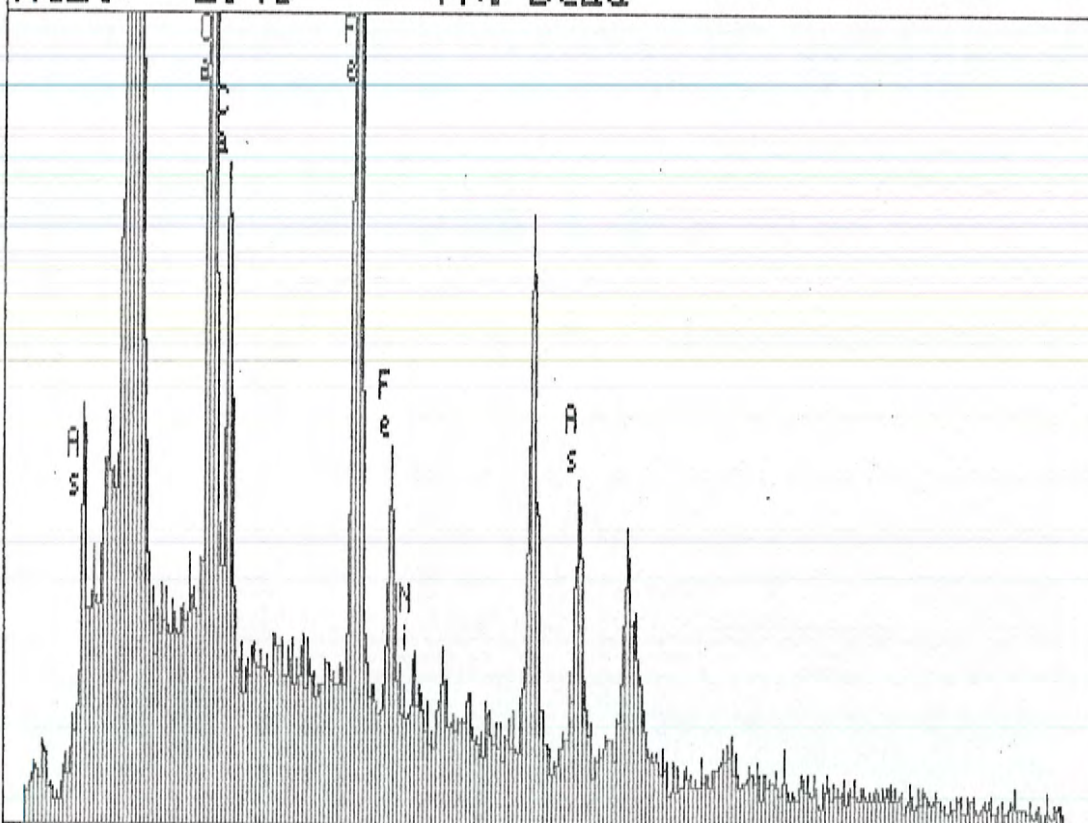


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 204s 41% Dead



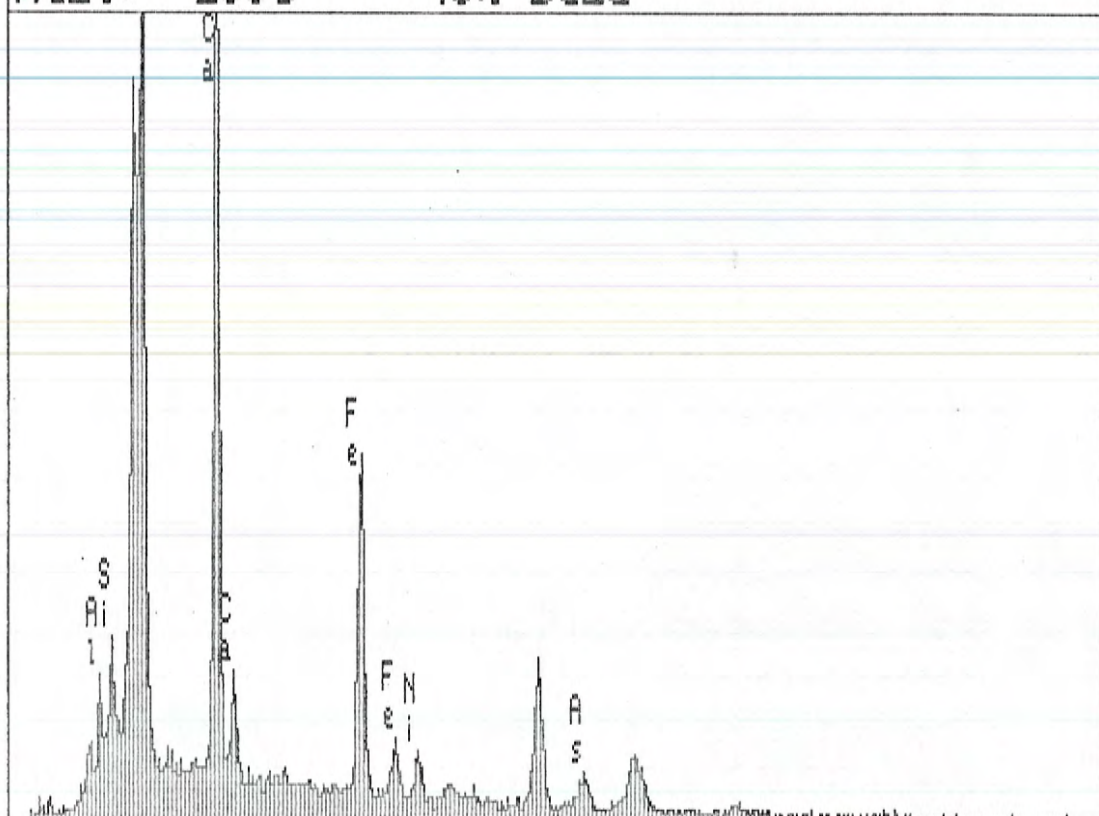
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 11 cts
MEM1:6-4 C

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 204s 41% Dead



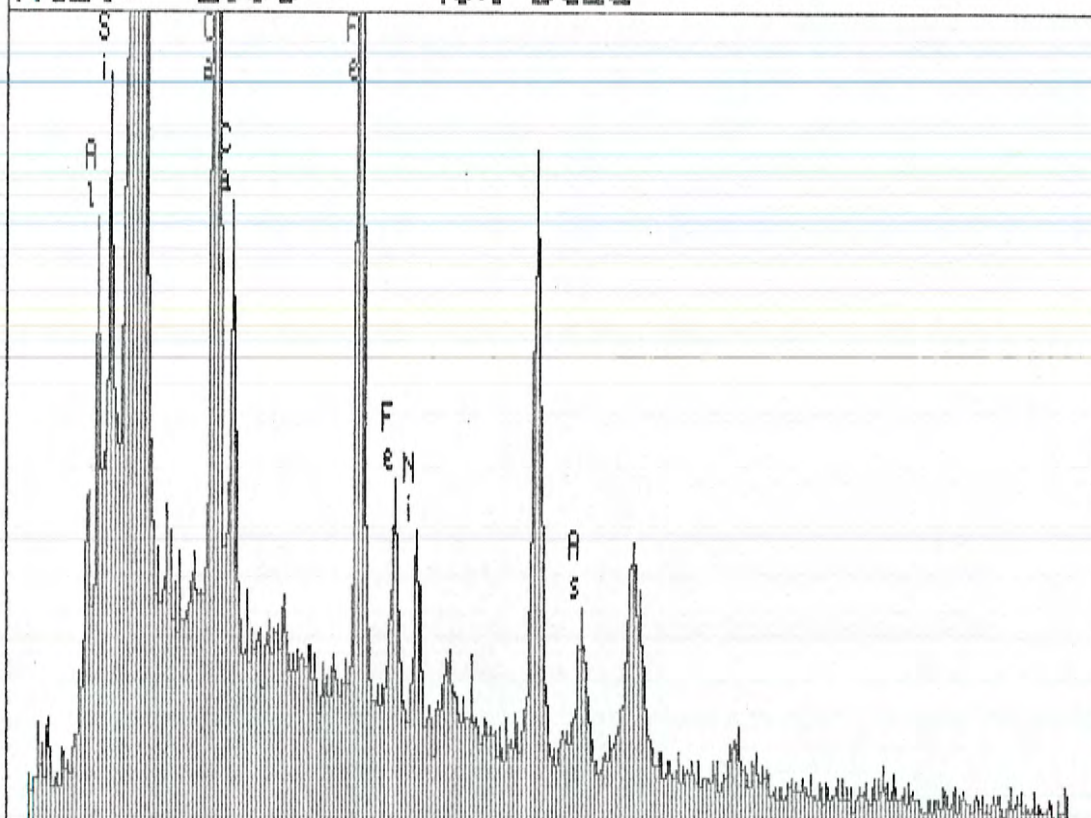
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 11 cts
MEM1: 6-4-C

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 200s 40% Dead



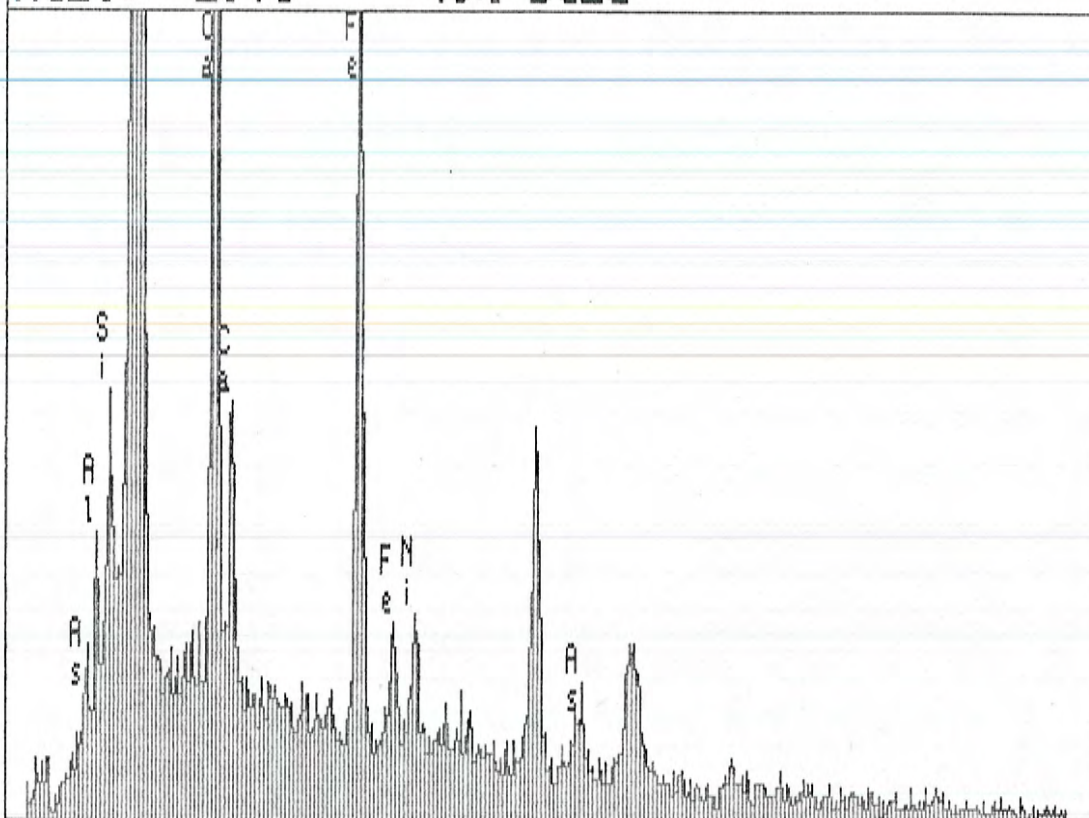
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 13 cts
MEM1:6-4D

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 200s 40% Dead



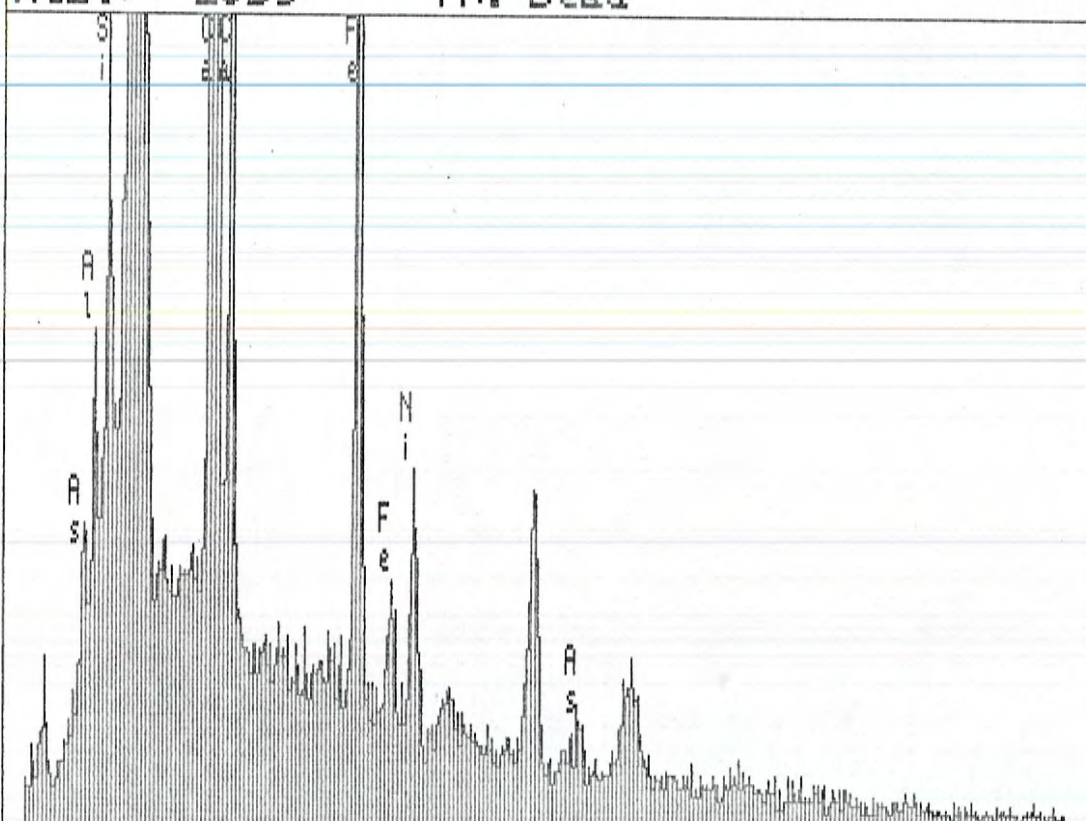
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 13 cts
MEM1:6-4D

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 201s 40% Dead



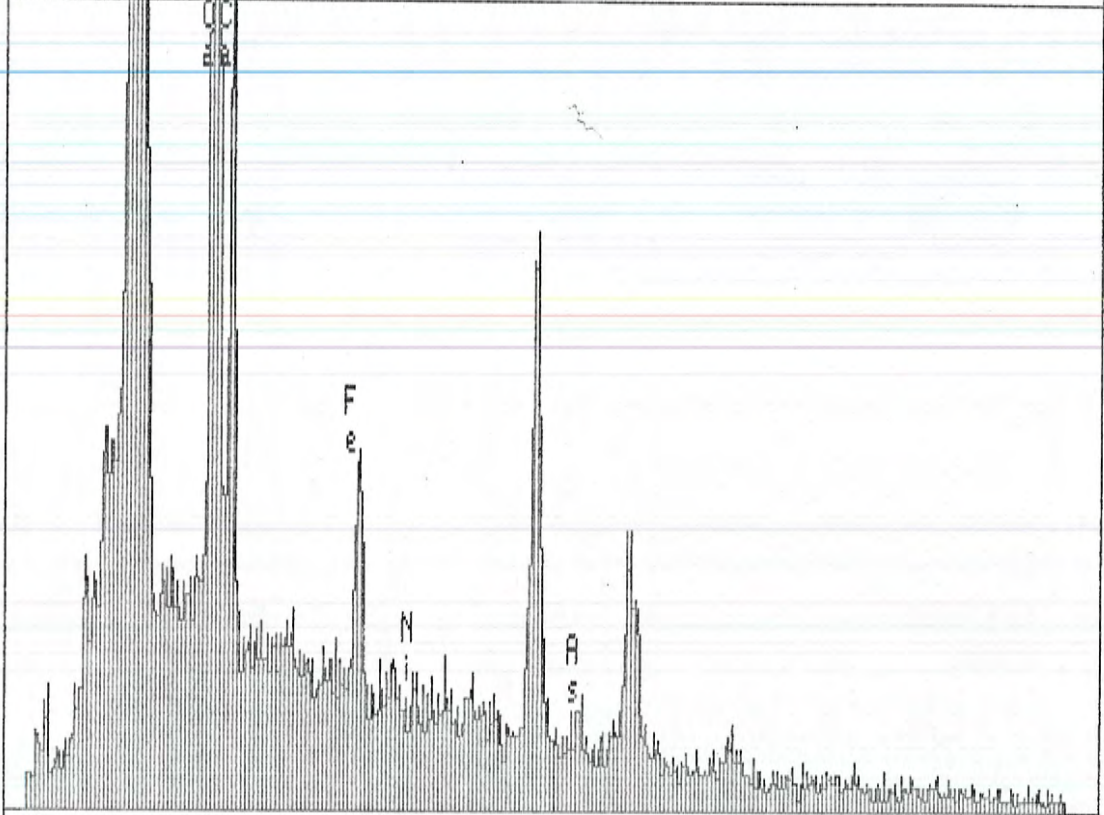
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 10 cts
MEM1:6-5A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 203s 41% Dead



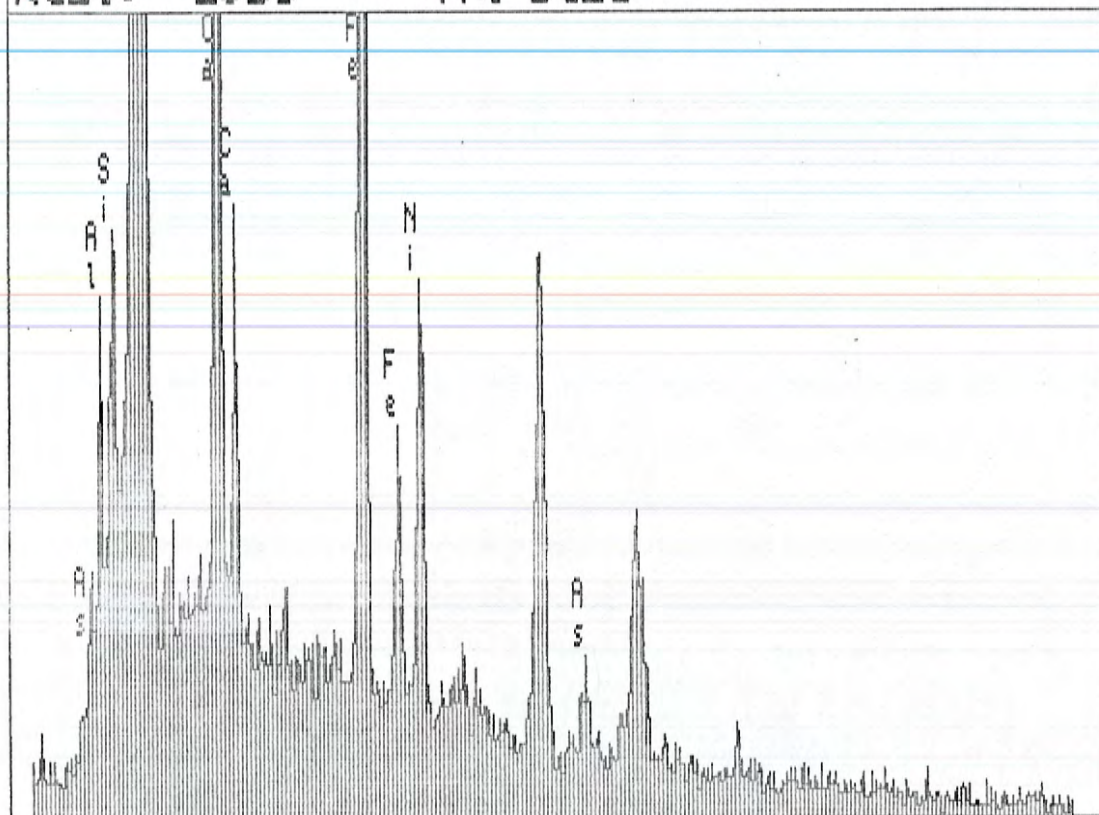
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 14 cts
MEM1:6-5B

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



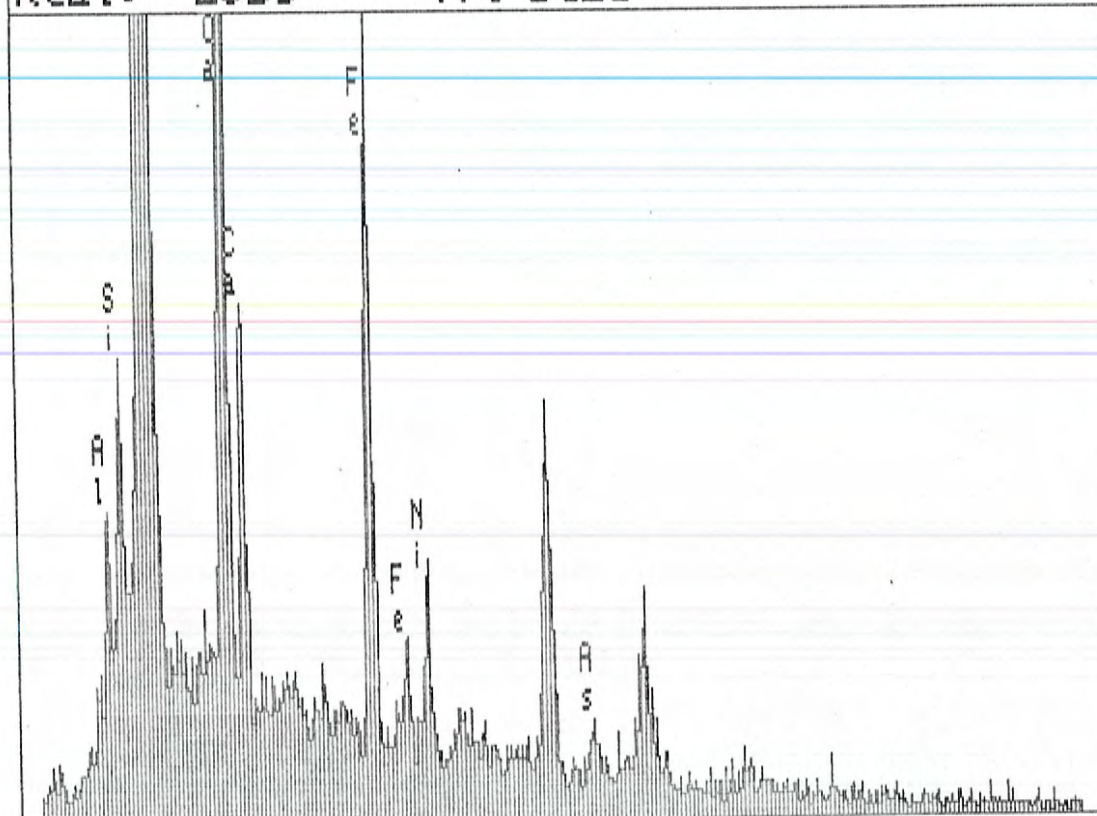
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 17 cts
MEM1:6-5C

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 203s 41% Dead



< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 15 cts
MEM1:6-5-D

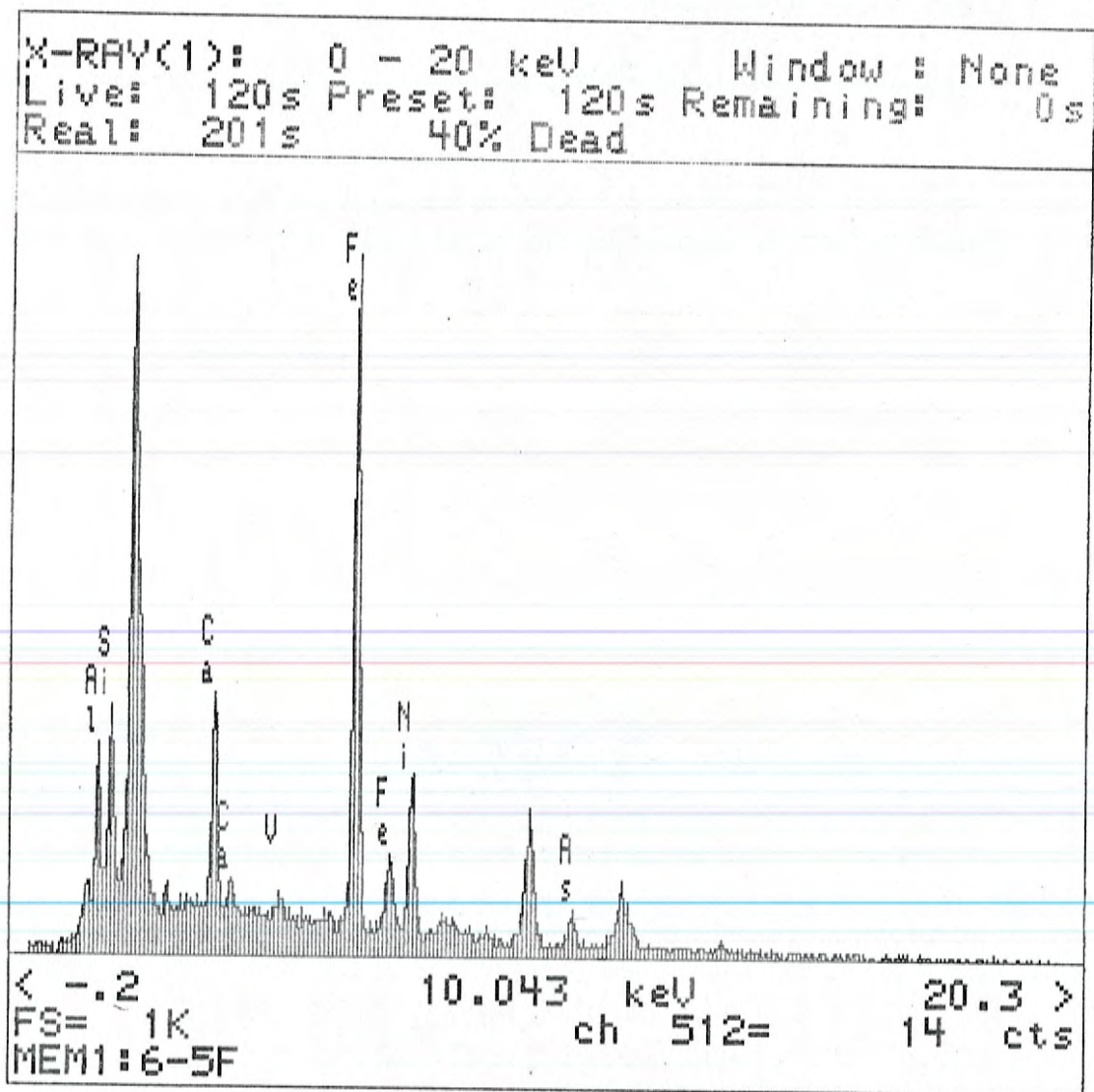
X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 203s 41% Dead



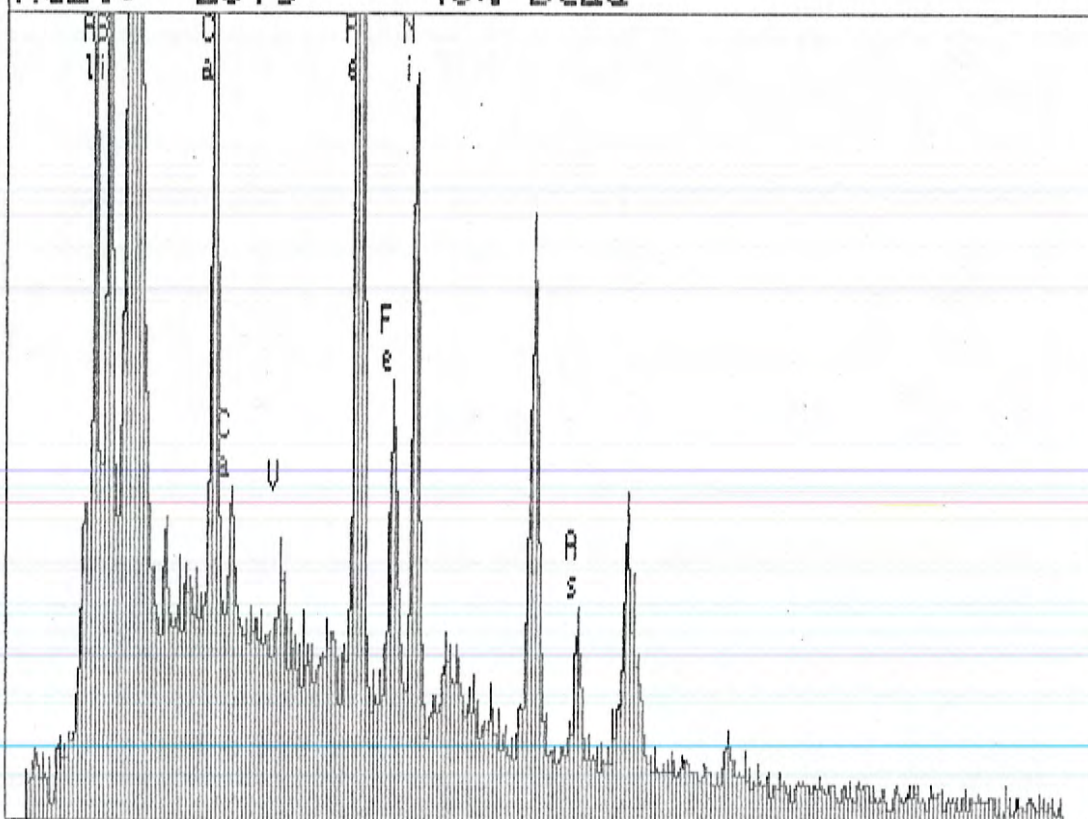
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 12 cts
MEM1:6-5 E

Figure 3.13

3

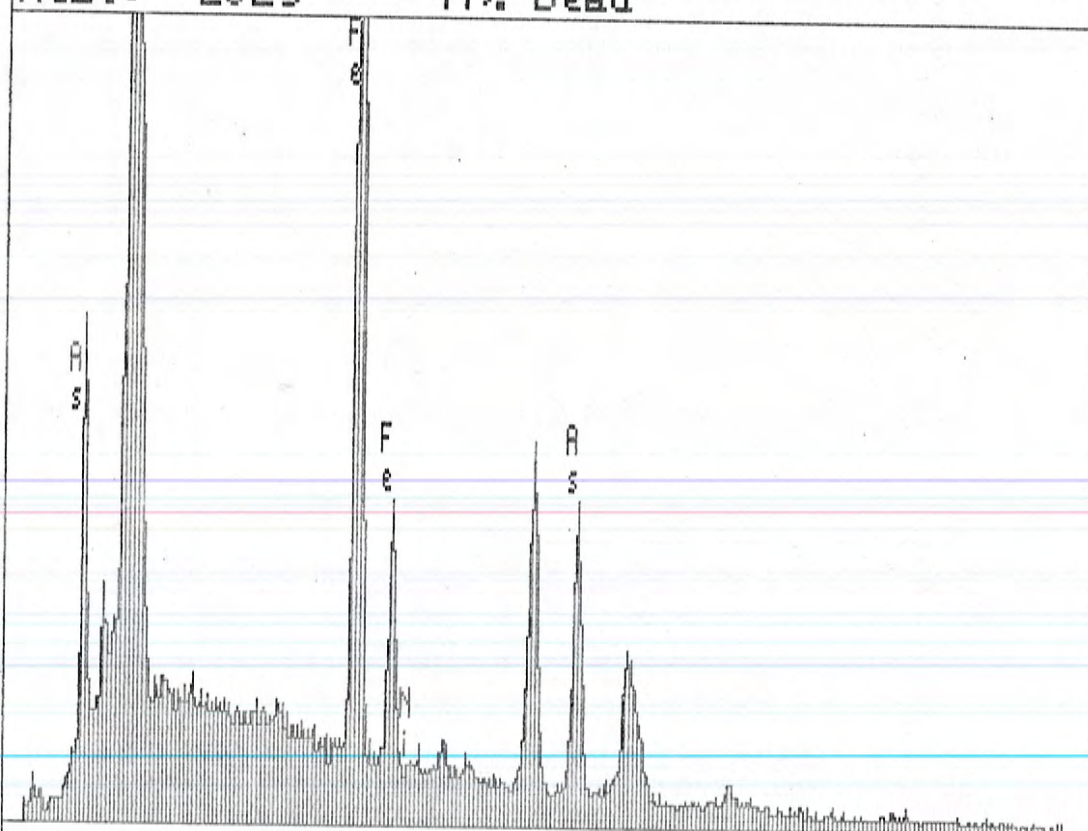


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 201s 40% Dead



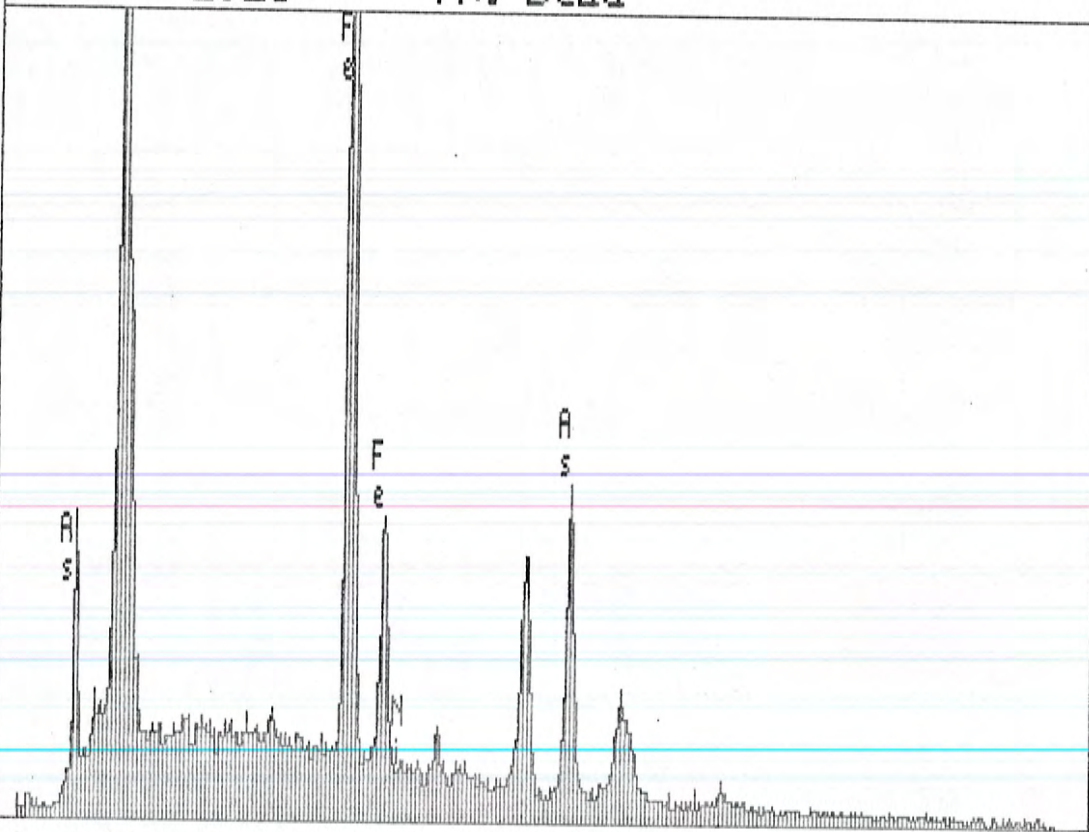
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 14 cts
MEM1:6-5F

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



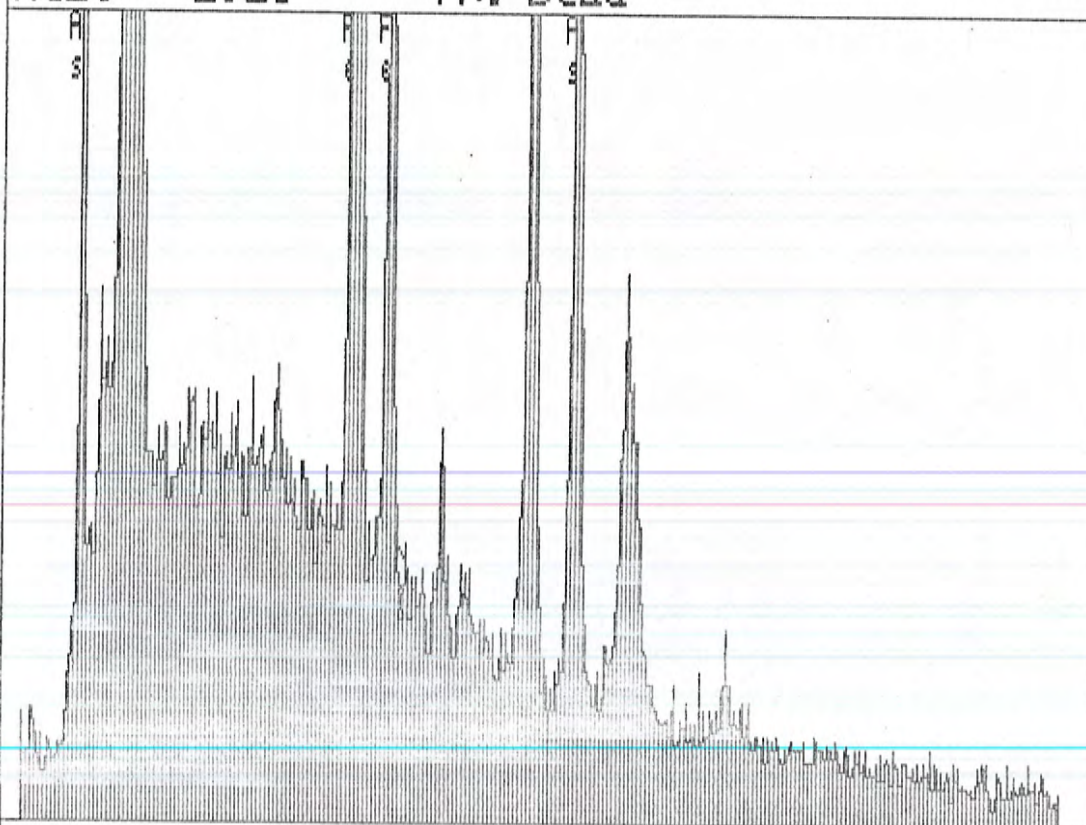
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 39 cts
MEM1:2-2 A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



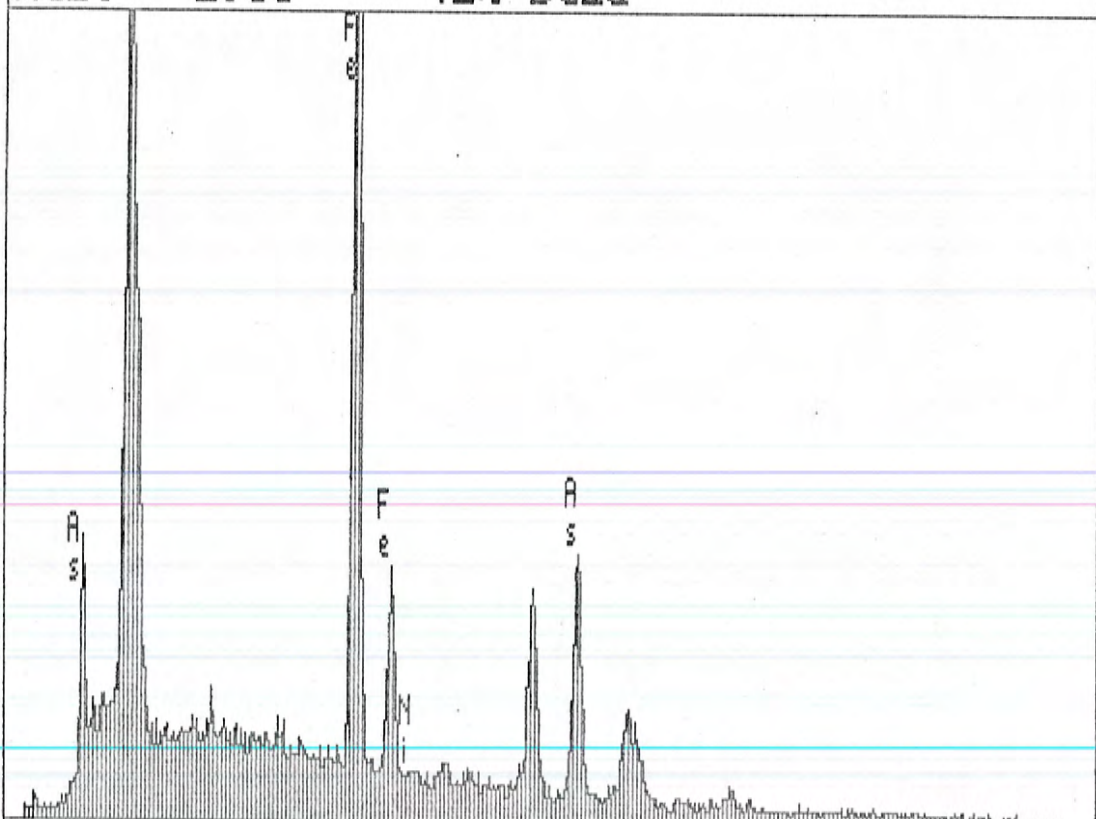
< -.2 10.043 keV 20.3 >
FS= 1K ch 512= 28 cts
MEM1: 2-2 B

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



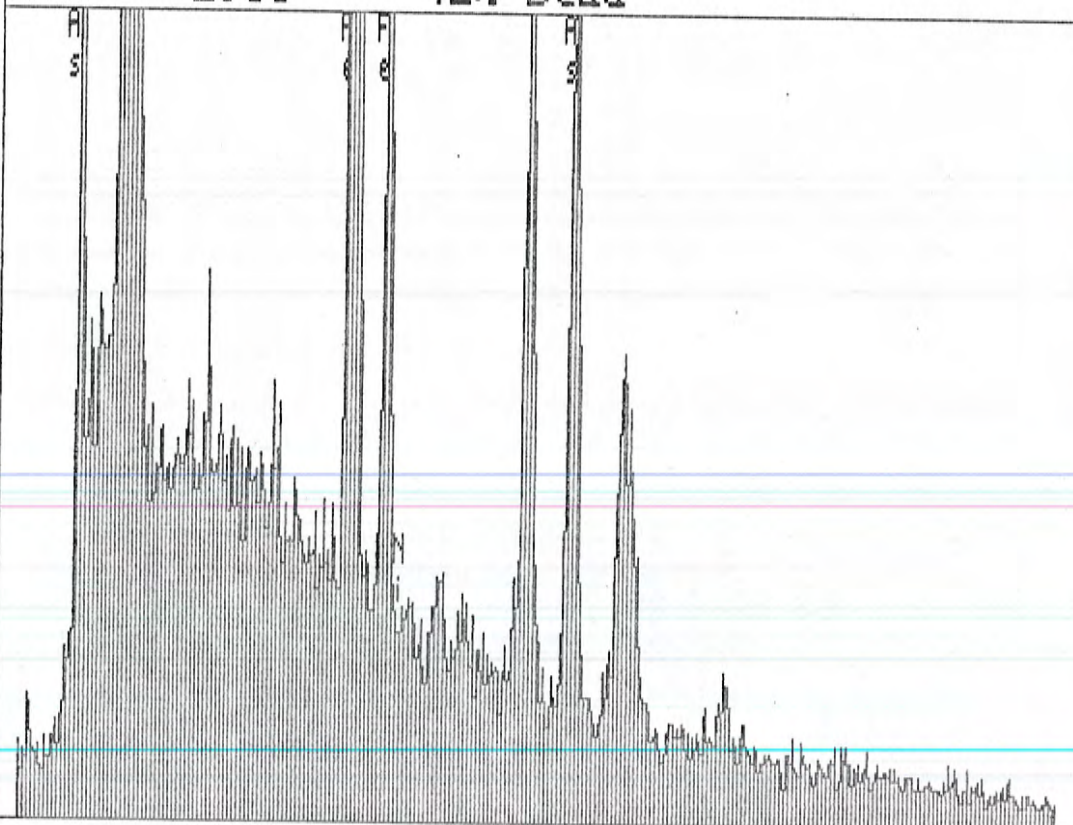
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 28 cts
MEM1: 2-2 B

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 206s 42% Dead



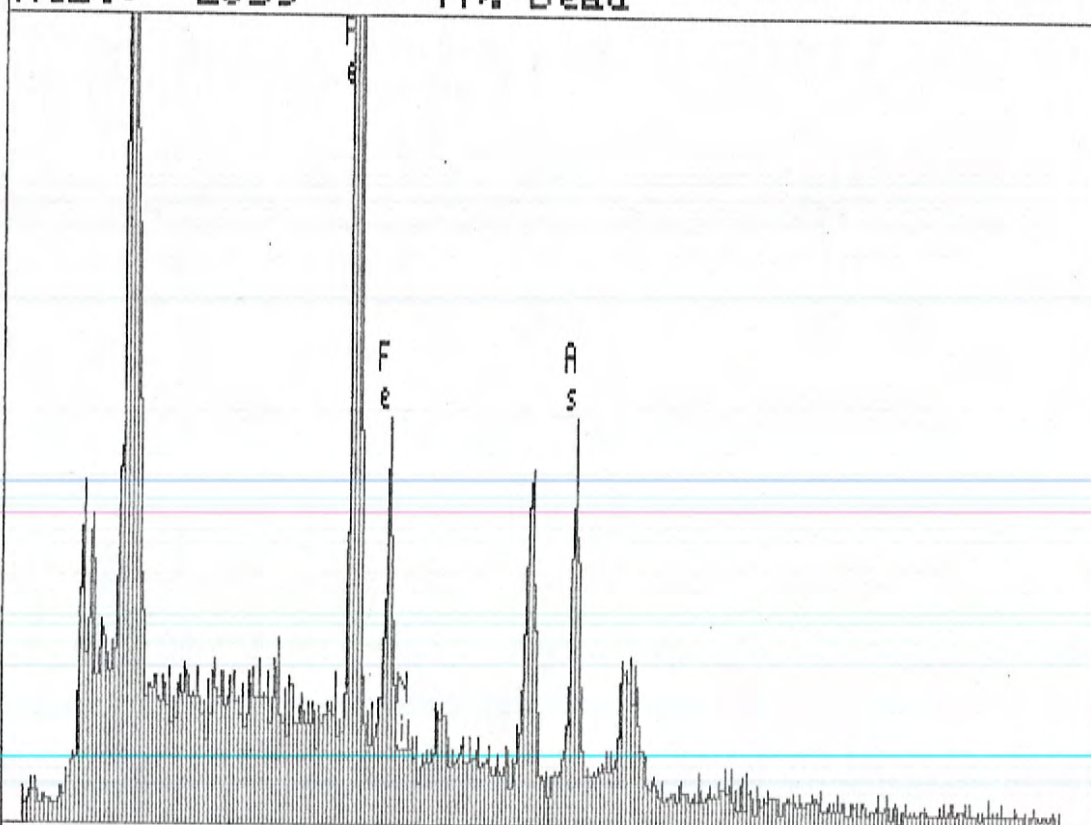
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 39 cts
MEM1:2-2C

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 206s 42% Dead



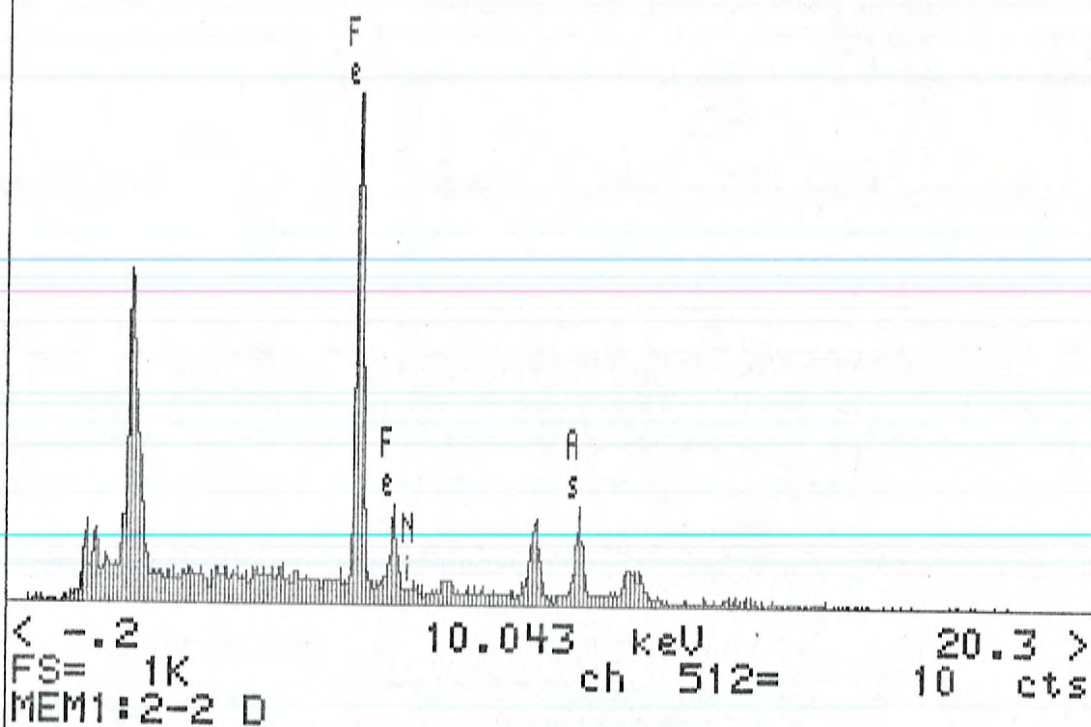
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 39 cts
MEM1:2-2C

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 203s 41% Dead

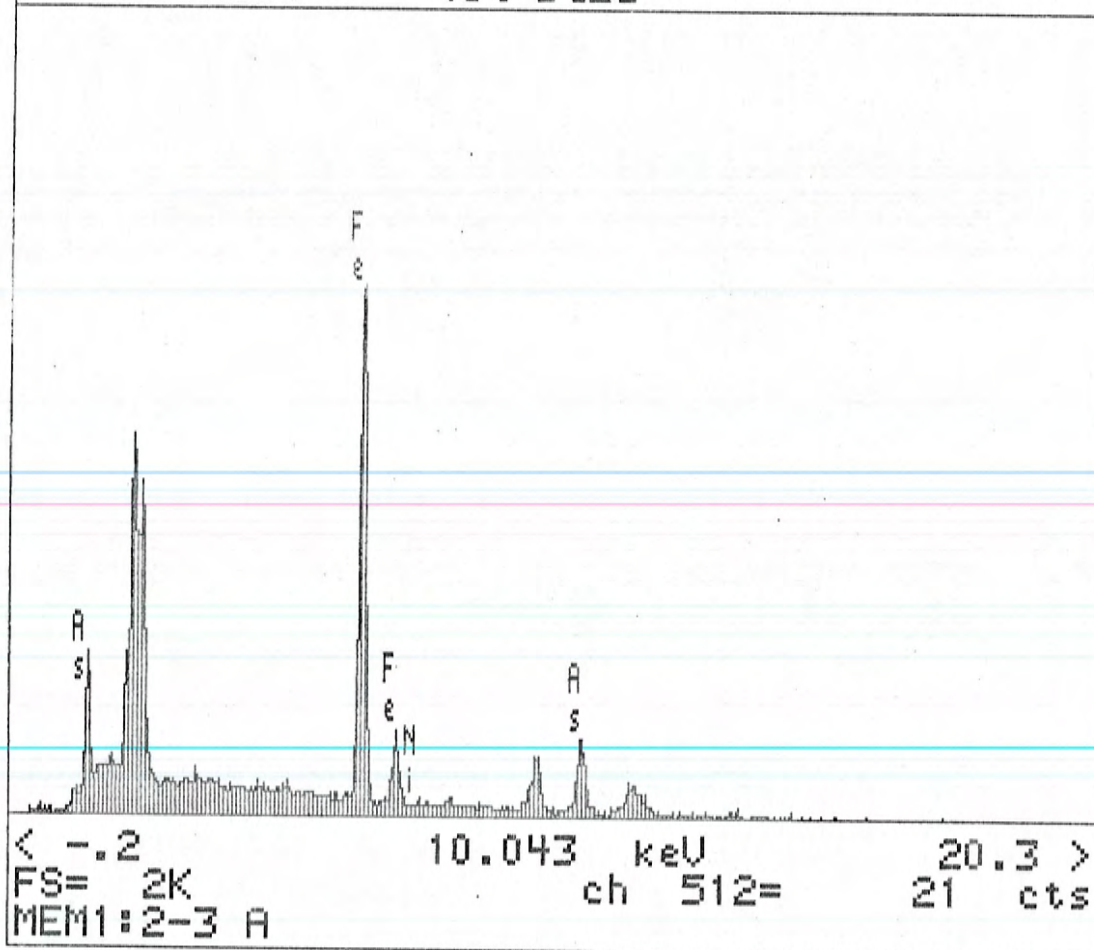


< -.2 10.043 keV 20.3 >
FS=255 ch 512= 10 cts
MEM1:2-2 D

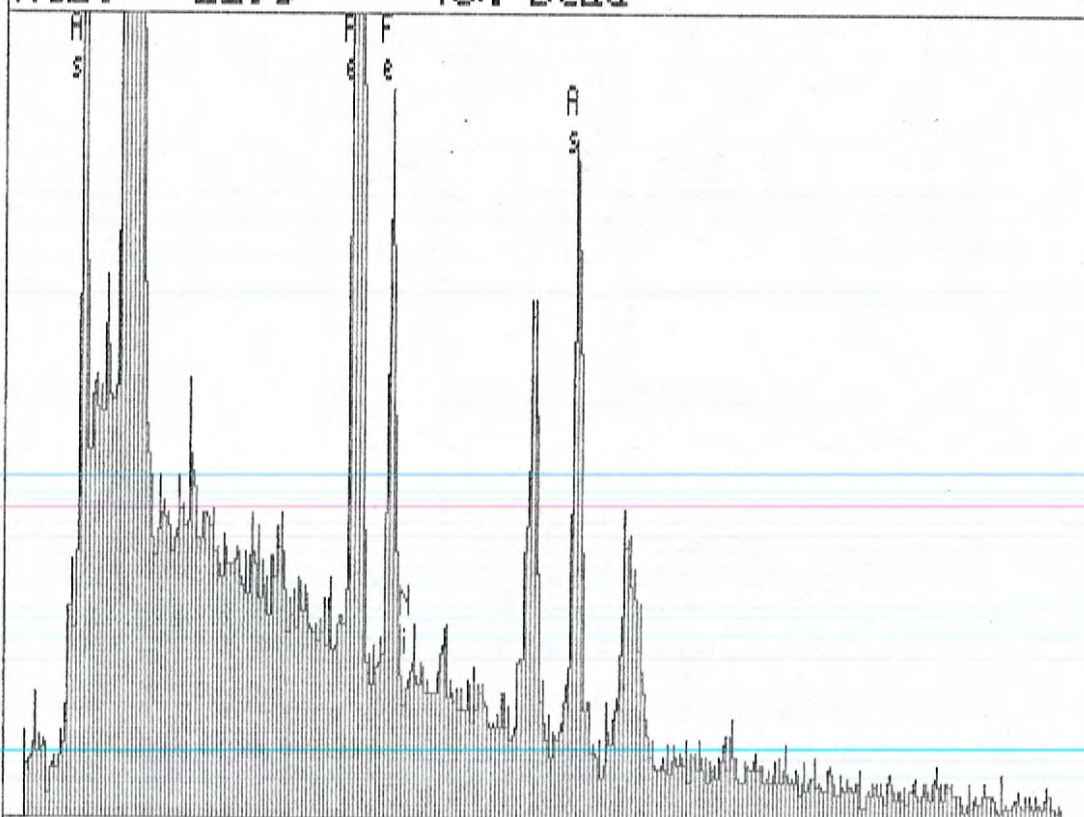
X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 203s 41% Dead



X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 60s
Real: 229s 48% Dead

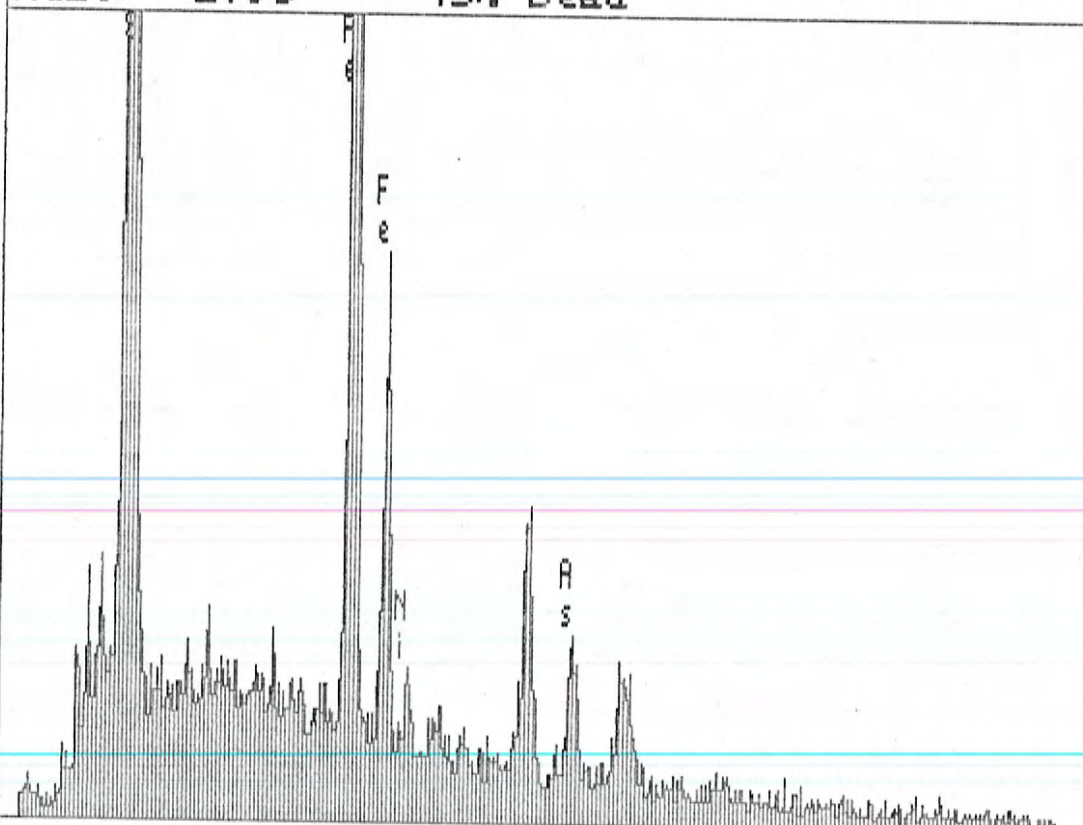


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 60s
Real: 229s 48% Dead



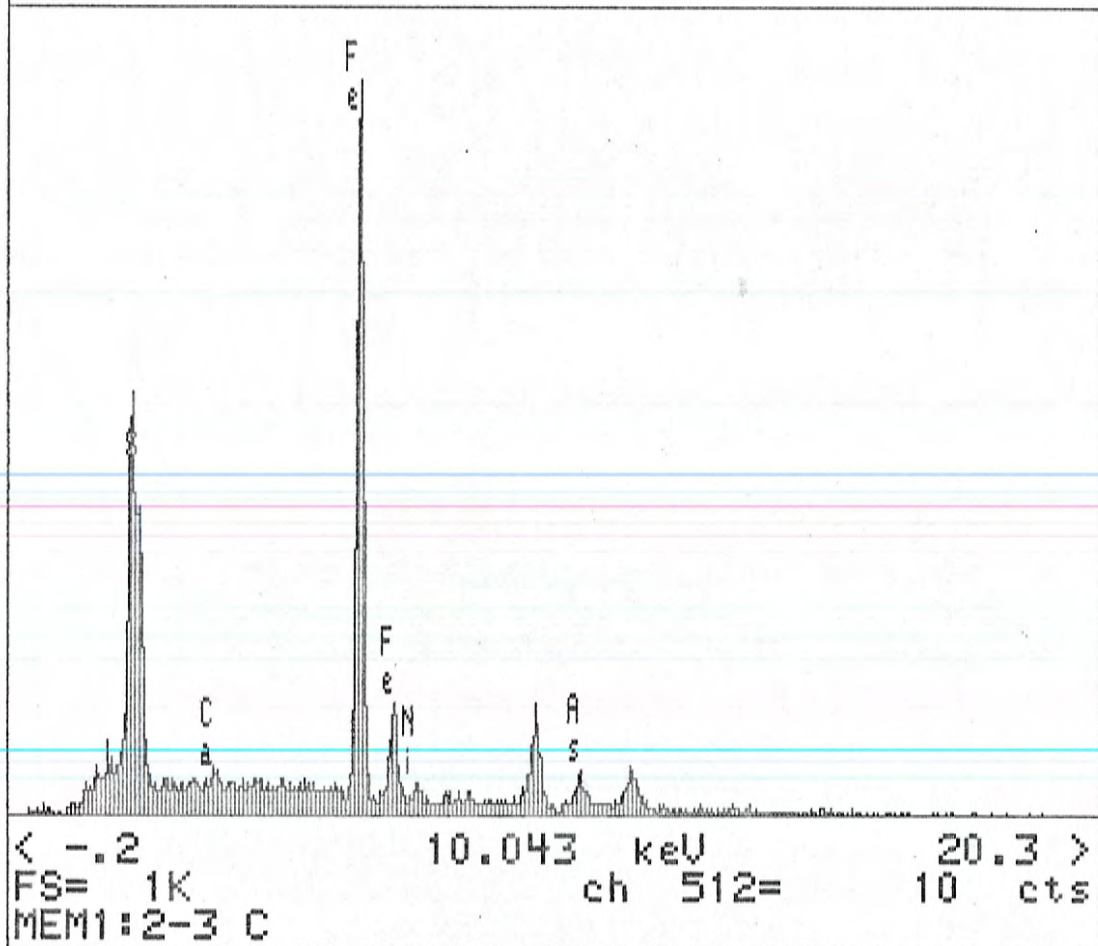
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 21 cts
MEM1:2-3 A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 210s 43% Dead

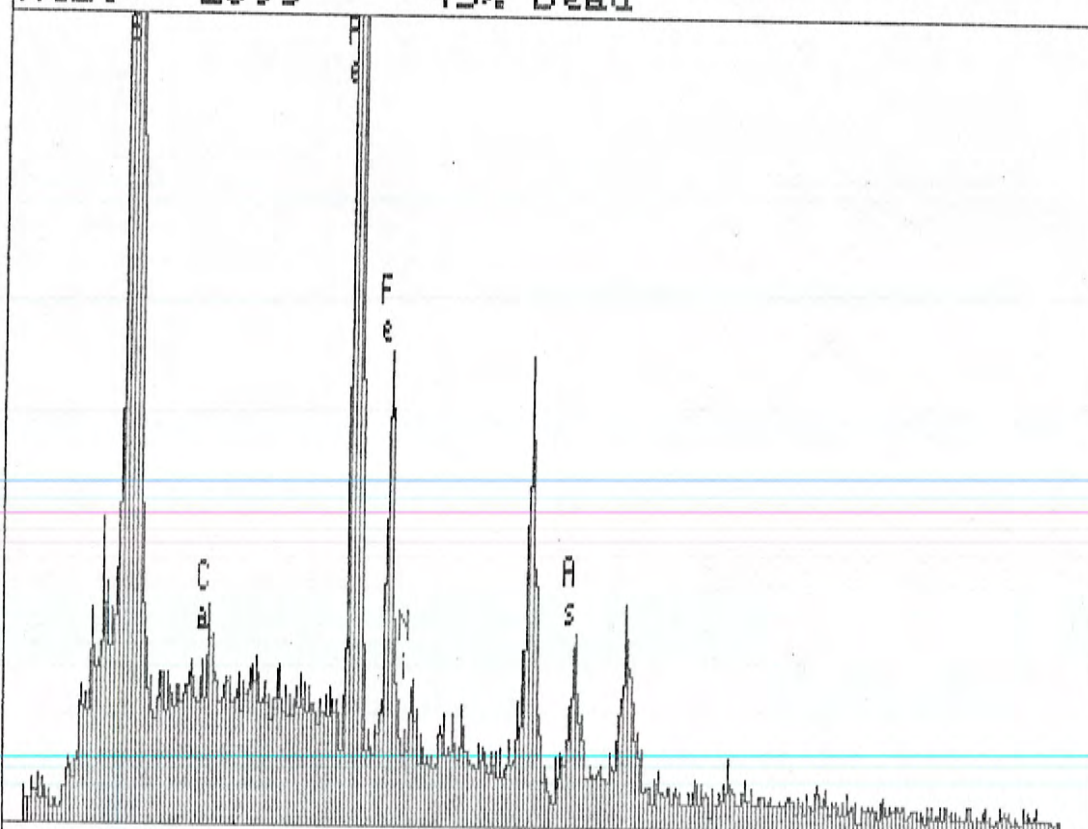


< -.2 10.043 keV 20.3 >
FS=255 ch 512= 12 cts
MEM1:2-3 B

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 209s 43% Dead

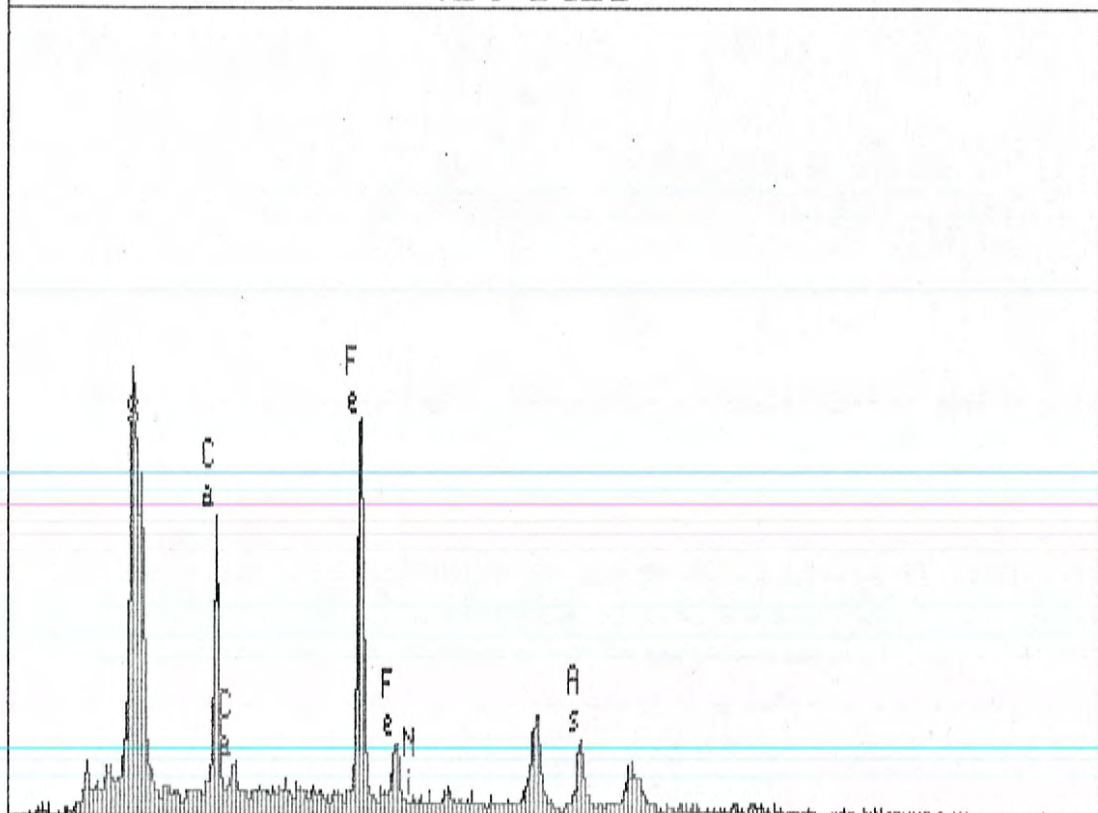


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 209s 43% Dead



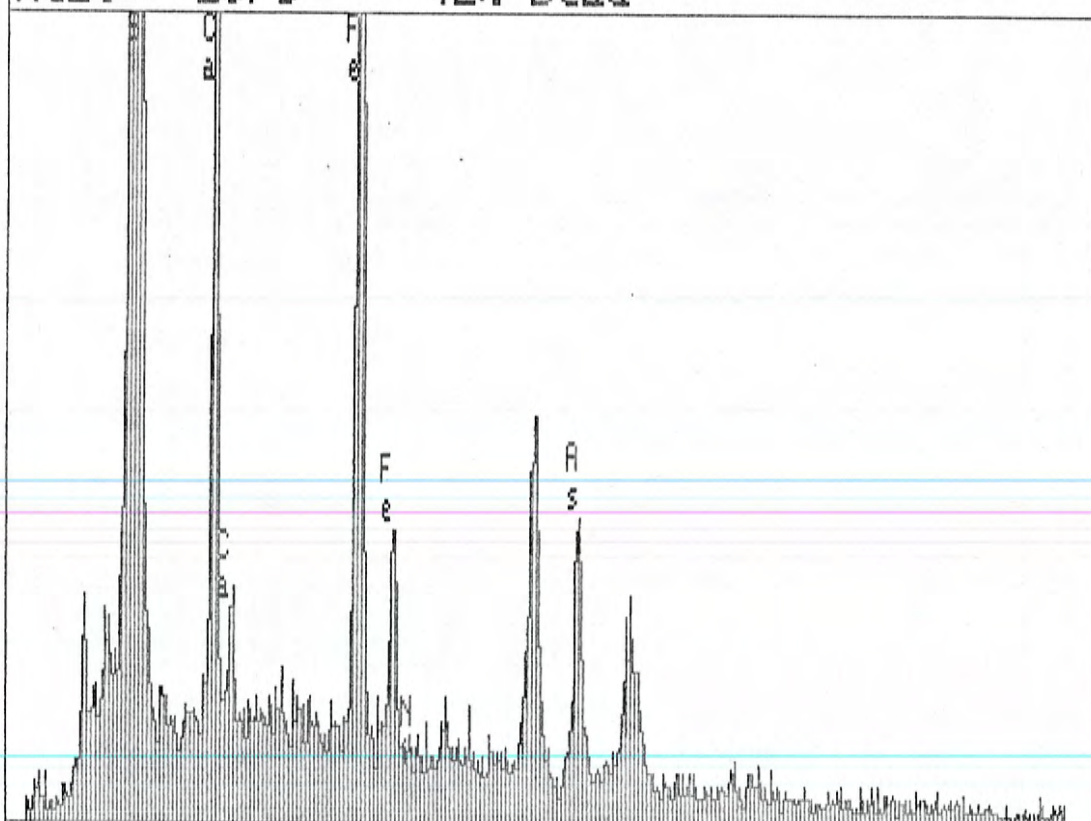
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 10 cts
MEM1:2-3 C

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 207s 42% Dead



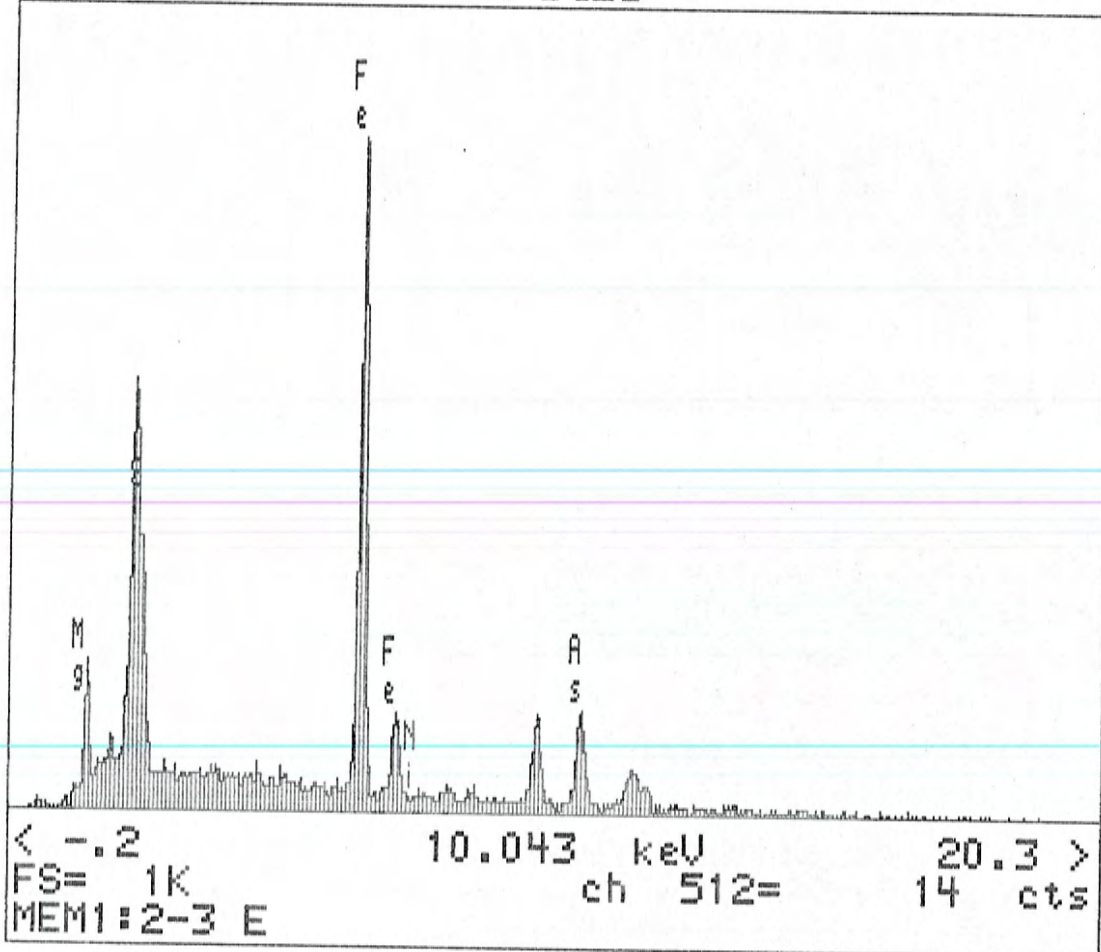
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 8 cts
MEM1:2=3 D

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 207s 42% Dead

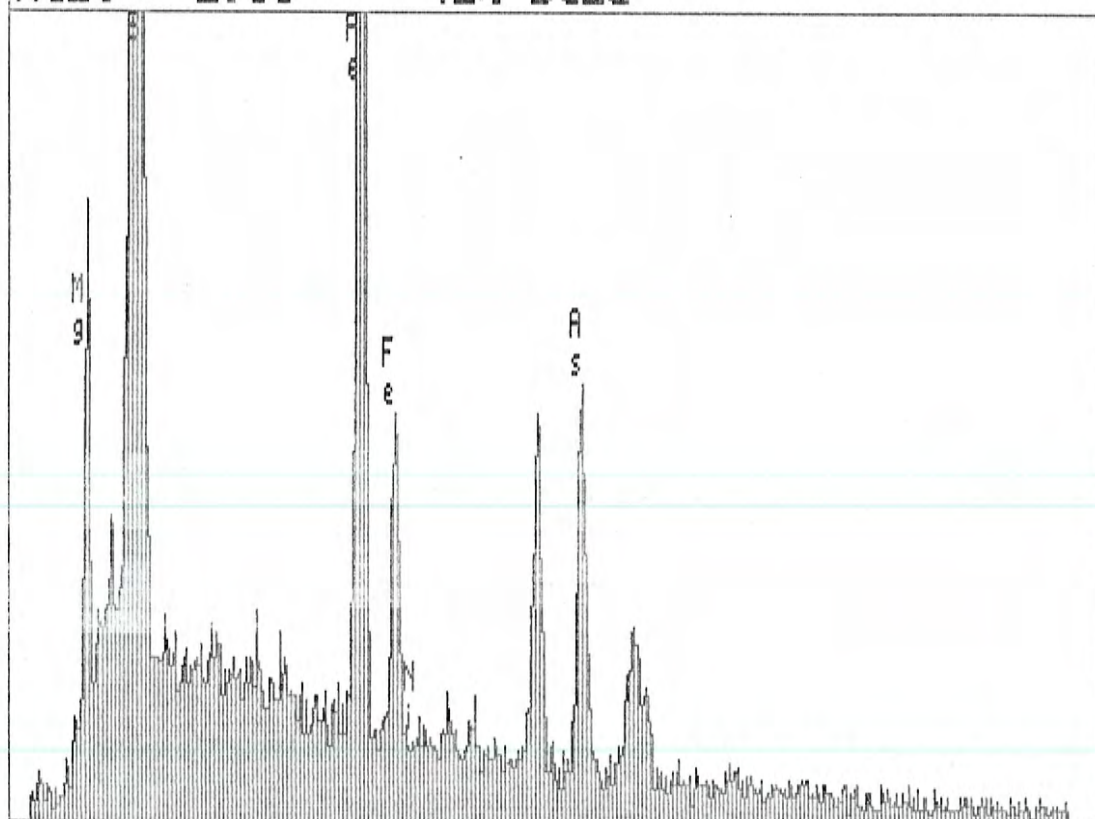


< -.2 10.043 keV 20.3 >
FS=255 ch 512= 8 cts
MEM1:2=3 D

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 208s 42% Dead

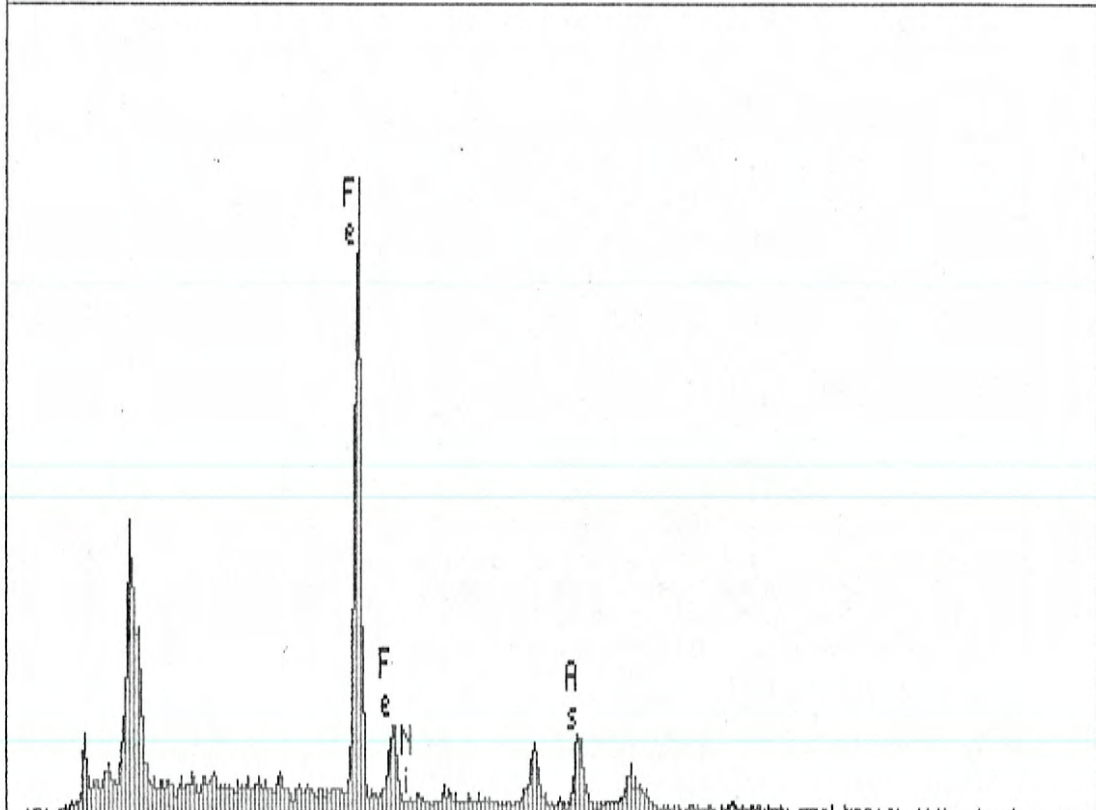


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 208s 42% Dead



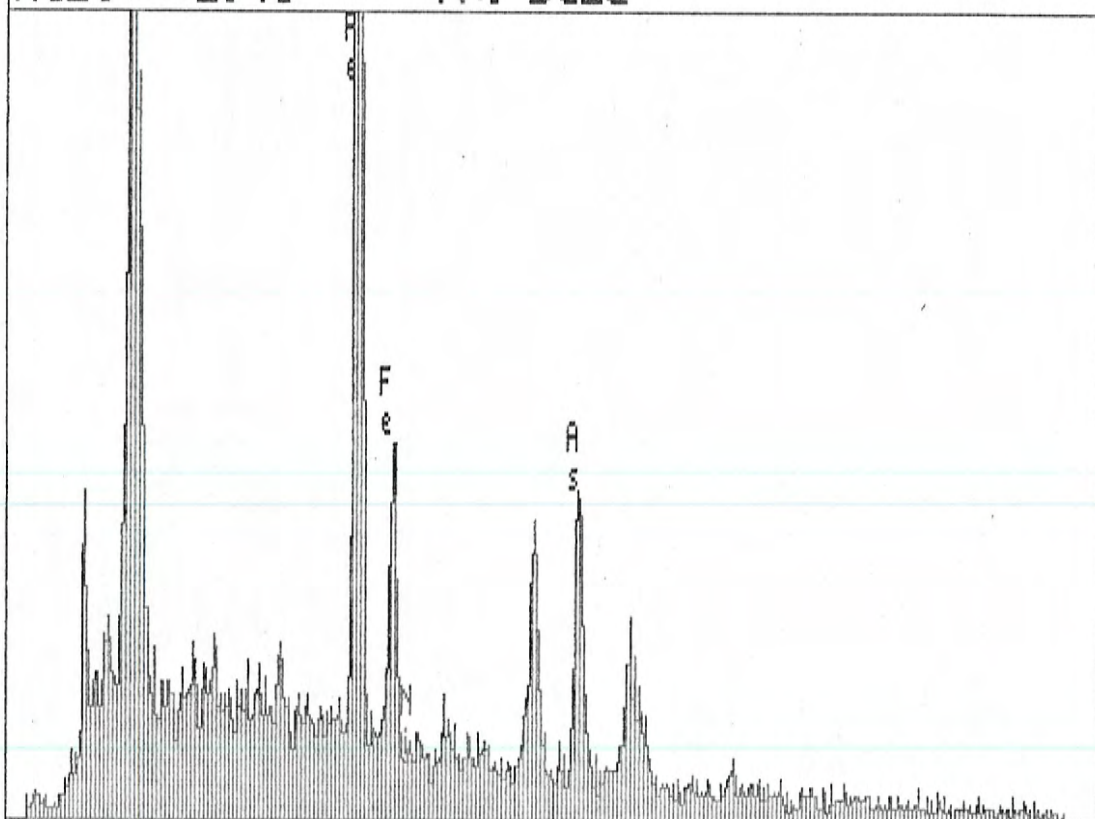
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 14 cts
MEM1:2-3 E

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 204s 41% Dead



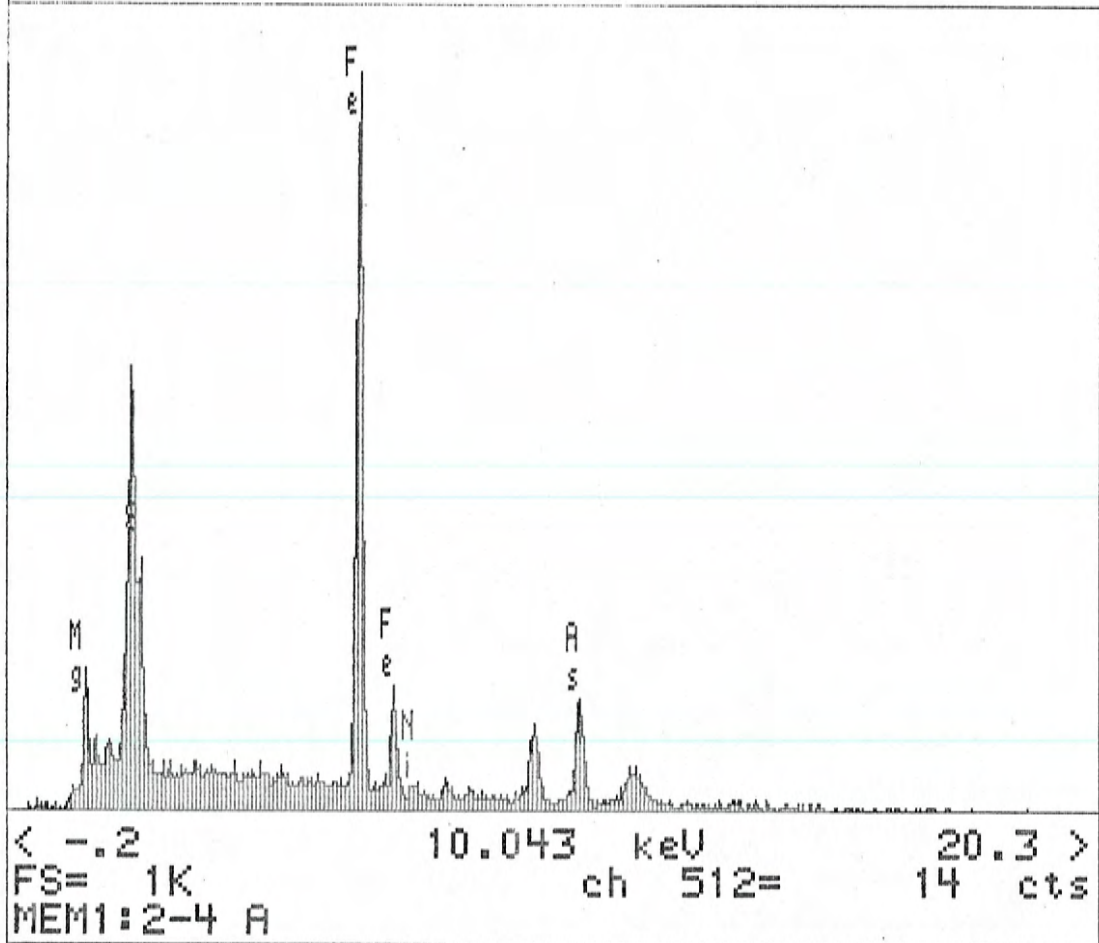
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 10 cts
MEM1:2-3 F

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 204s 41% Dead

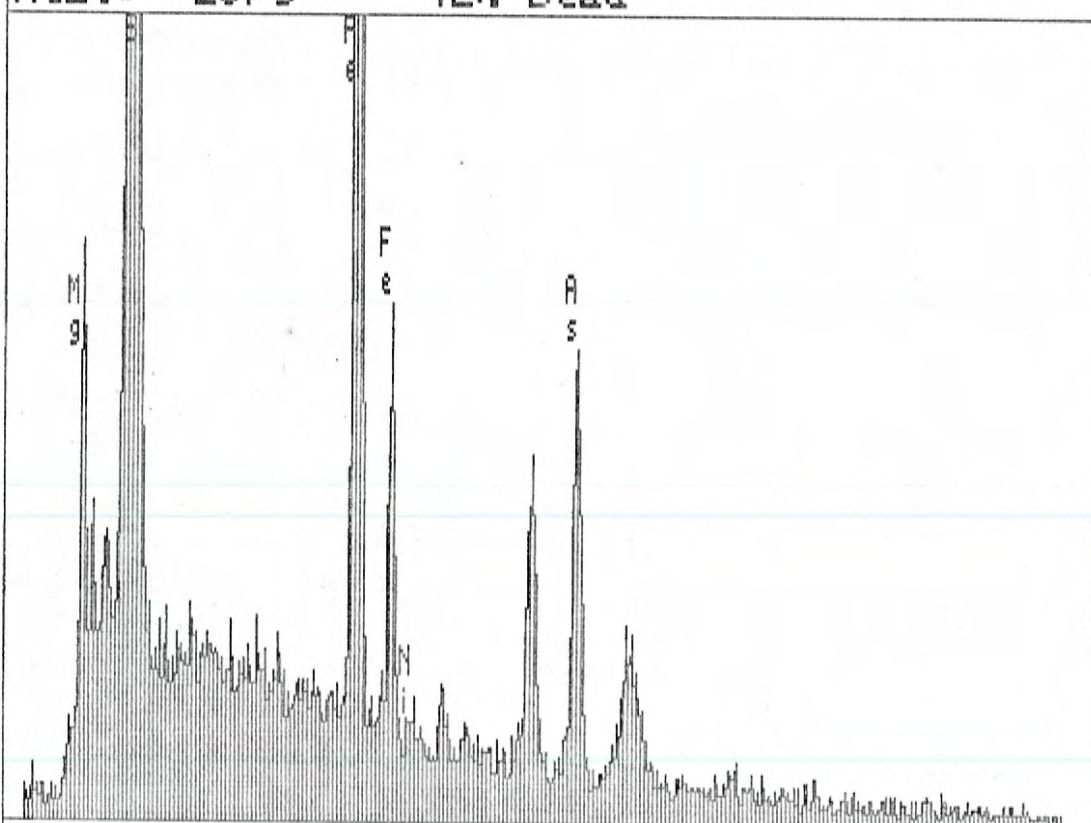


< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 10 cts
MEM1:2-3 F

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 207s 42% Dead

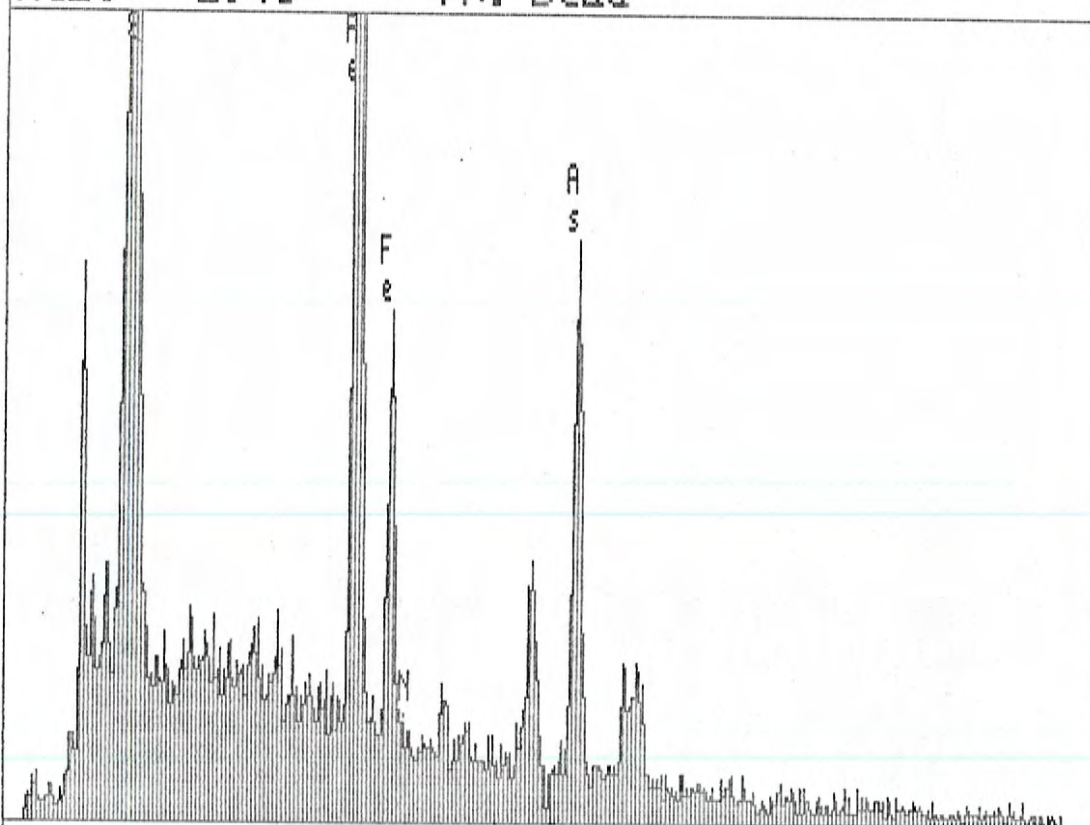


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 207s 42% Dead



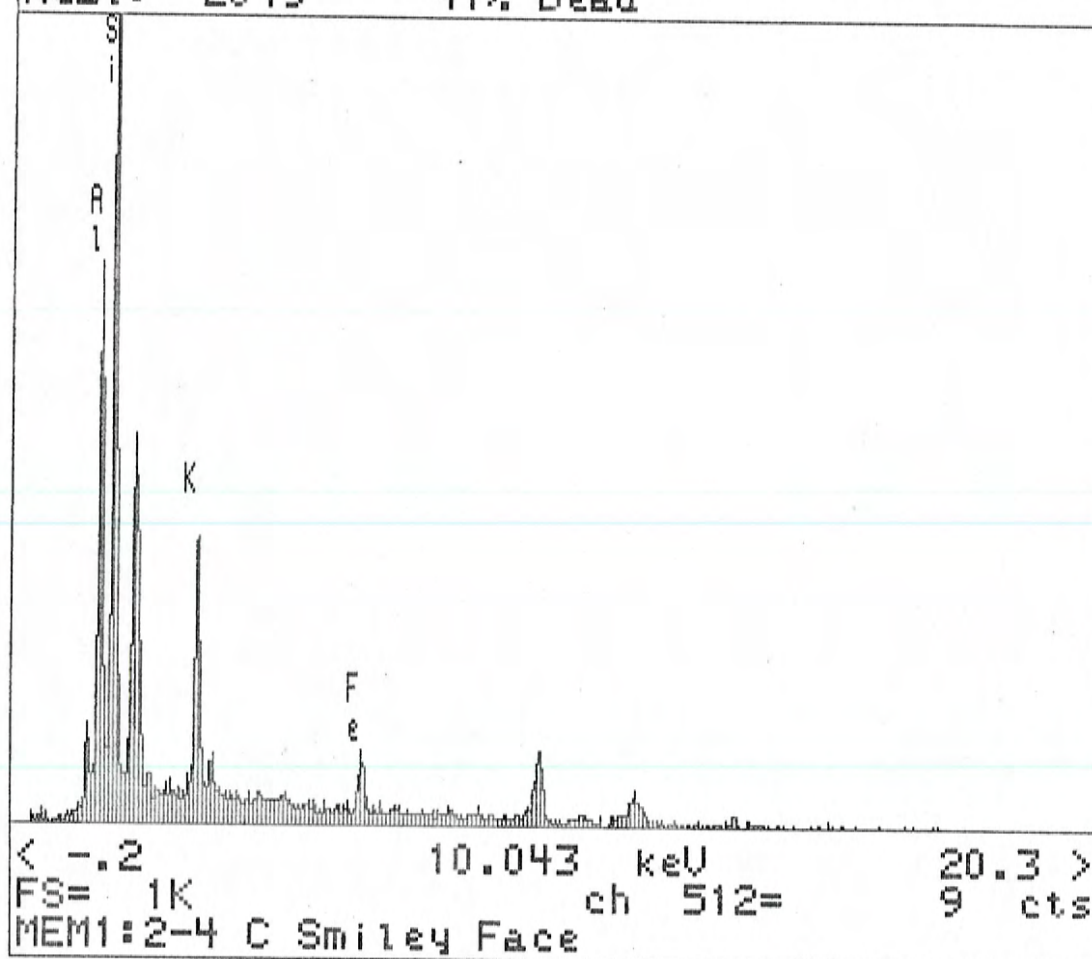
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 14 cts
MEM1:2-4 A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 204s 41% Dead

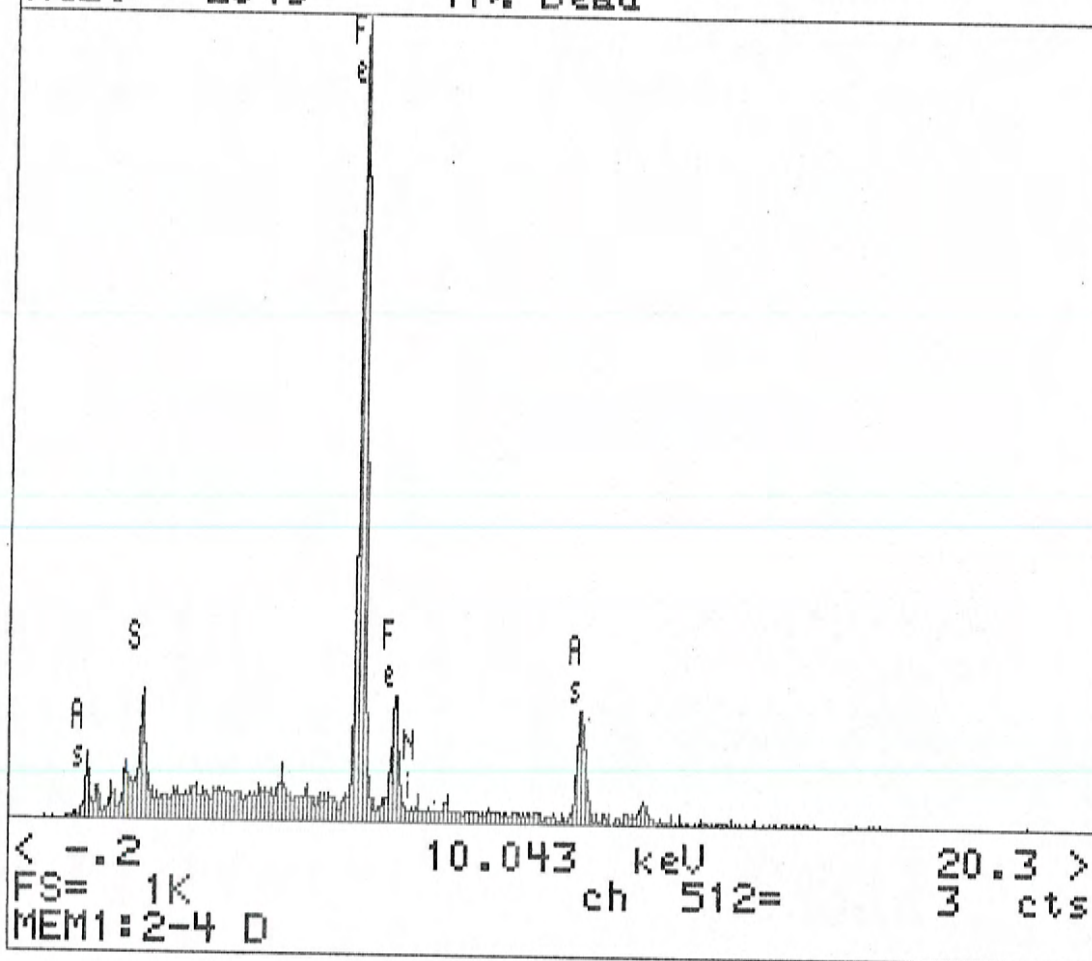


< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 16 cts
MEM1:2-4 B

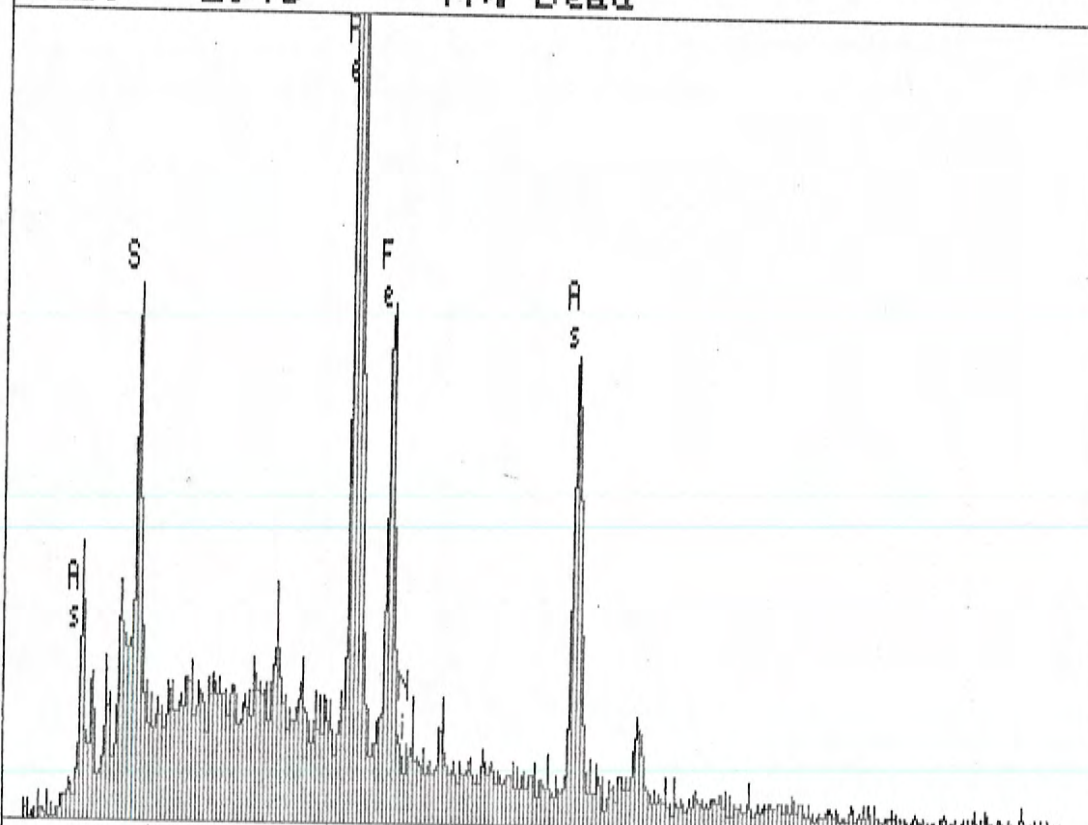
X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 204s 41% Dead



X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 204s 41% Dead

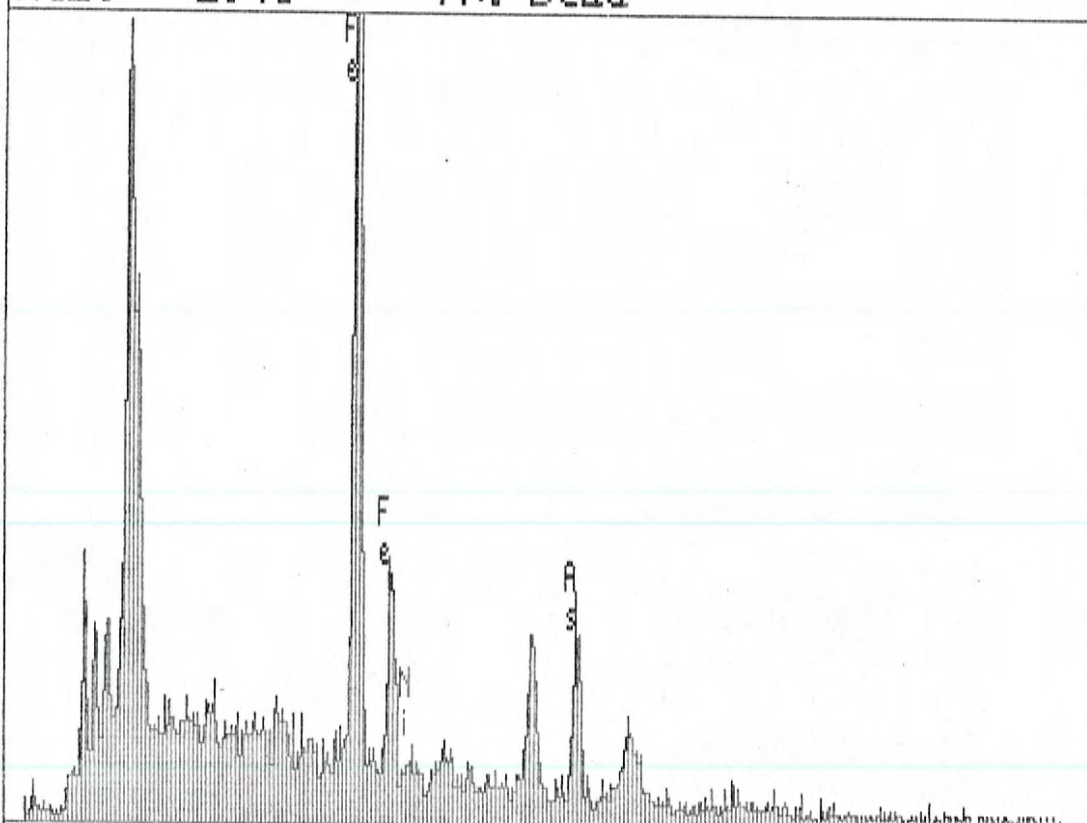


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 204s 41% Dead



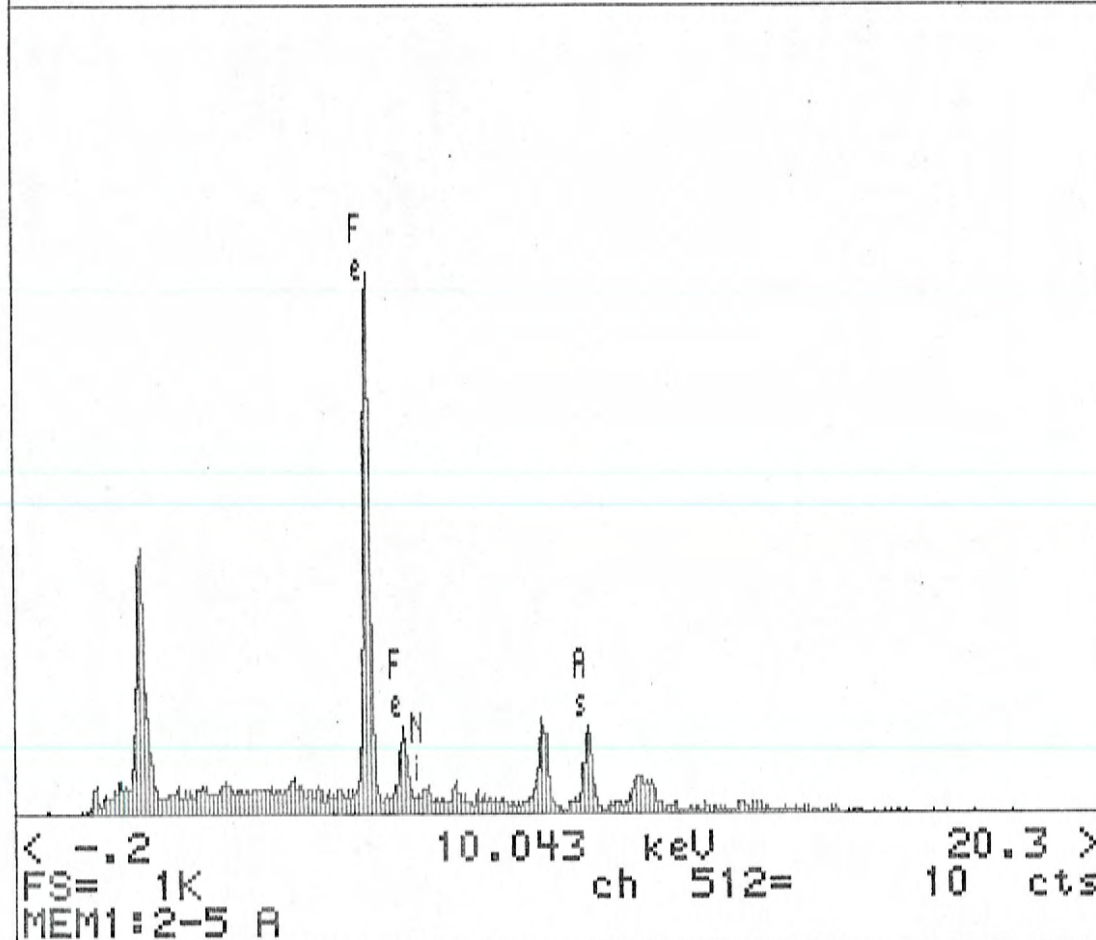
< - .2 10.043 keV 20.3 >
FS=255 ch 512= 3 cts
MEM1:2-4 D

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 204s 41% Dead

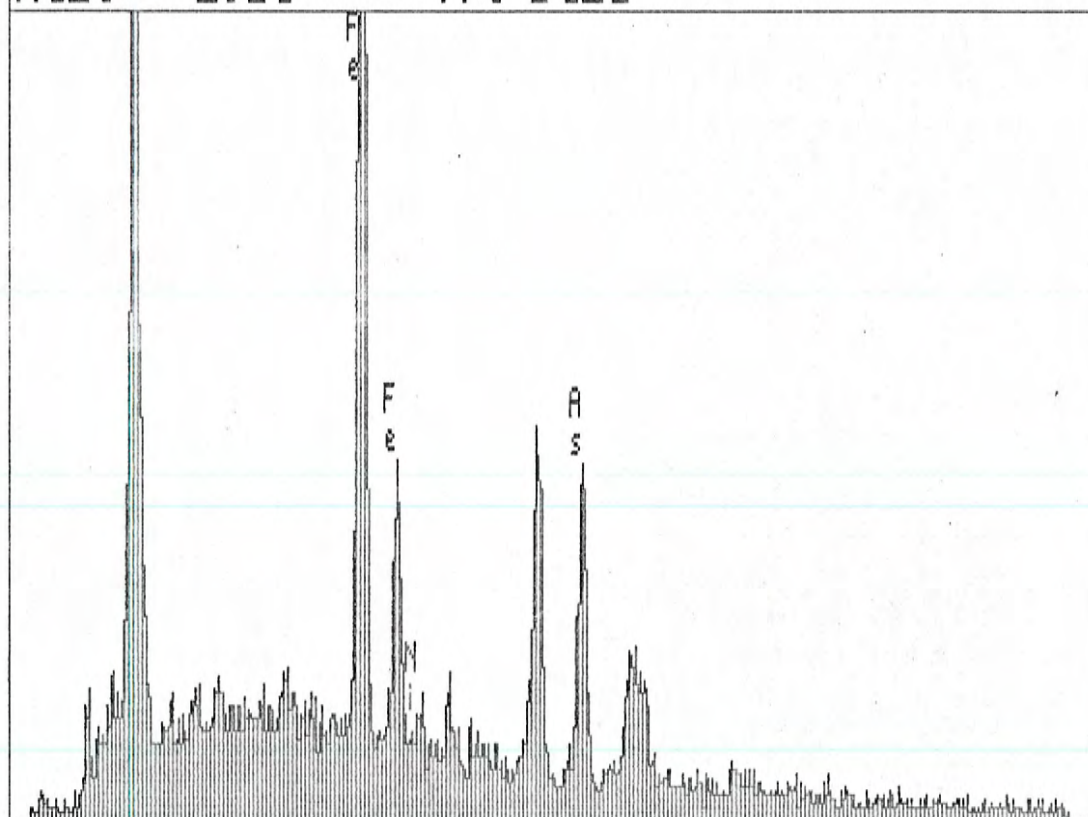


< -.2 10.043 keV 20.3 >
FS=255 ch 512= 6 cts
MEM1:2-4 E

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 205s 41% Dead

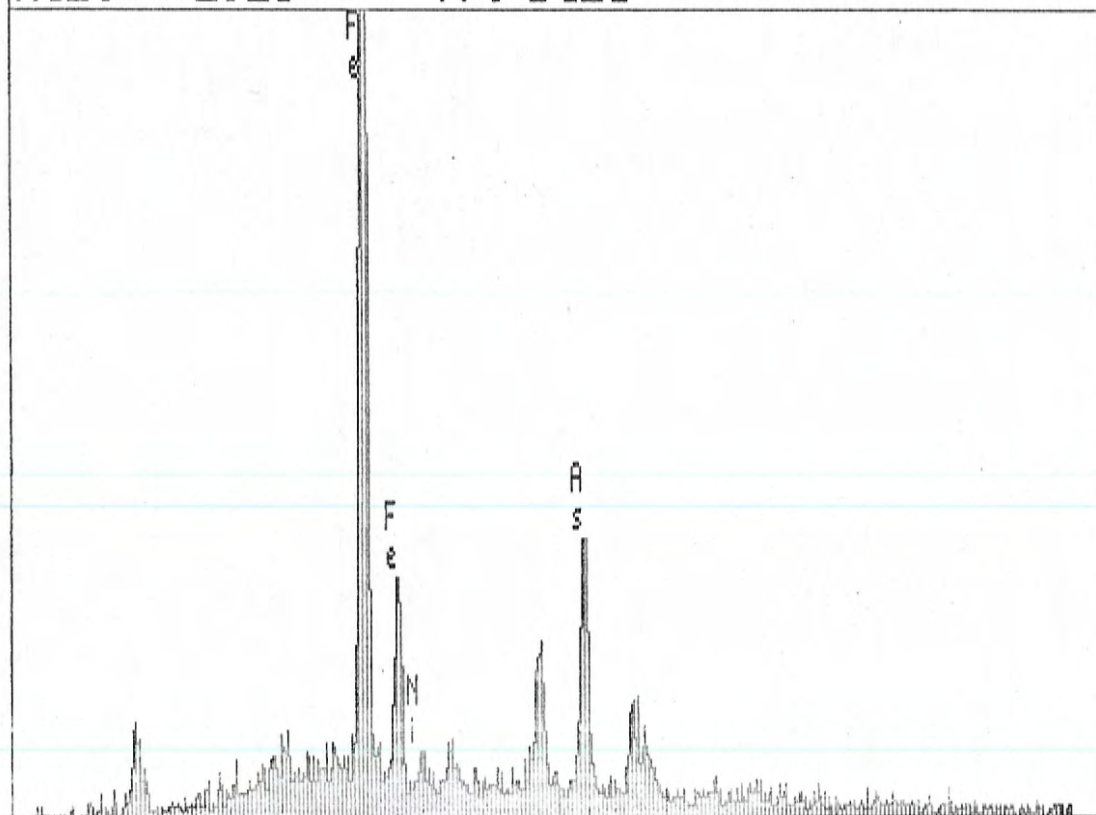


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 205s 41% Dead



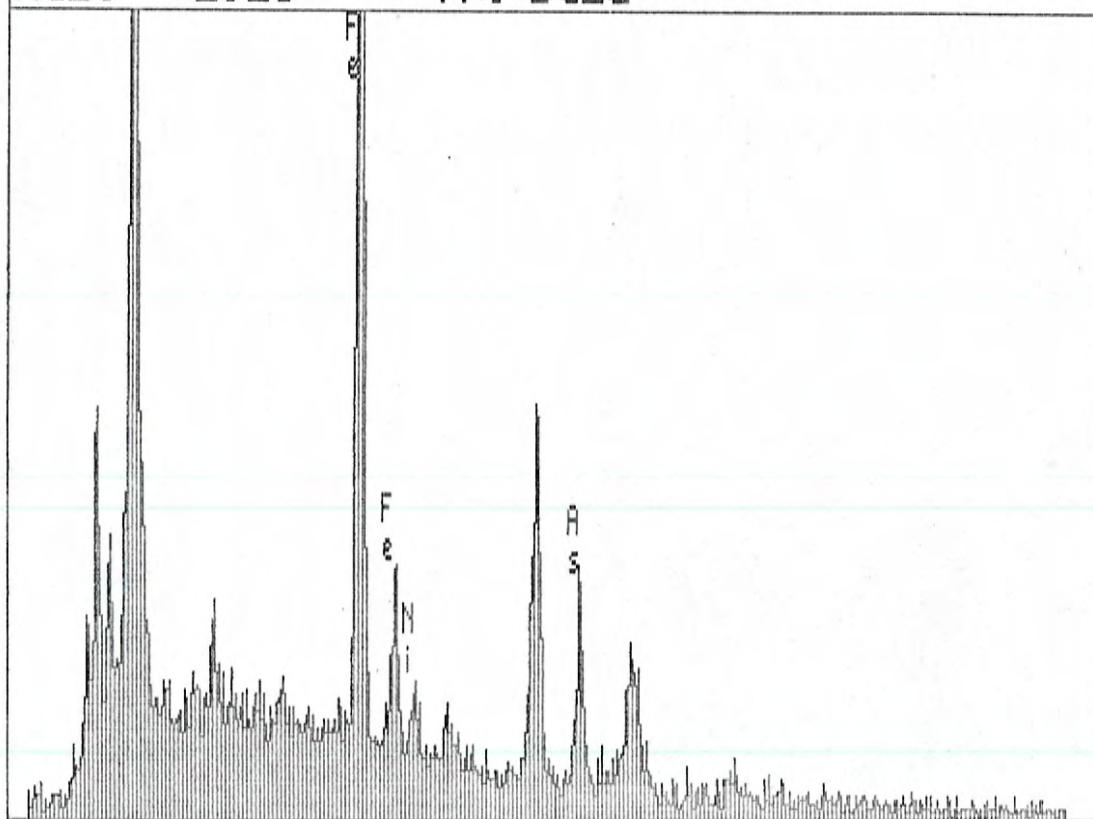
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 10 cts
MEM1:2-5 A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



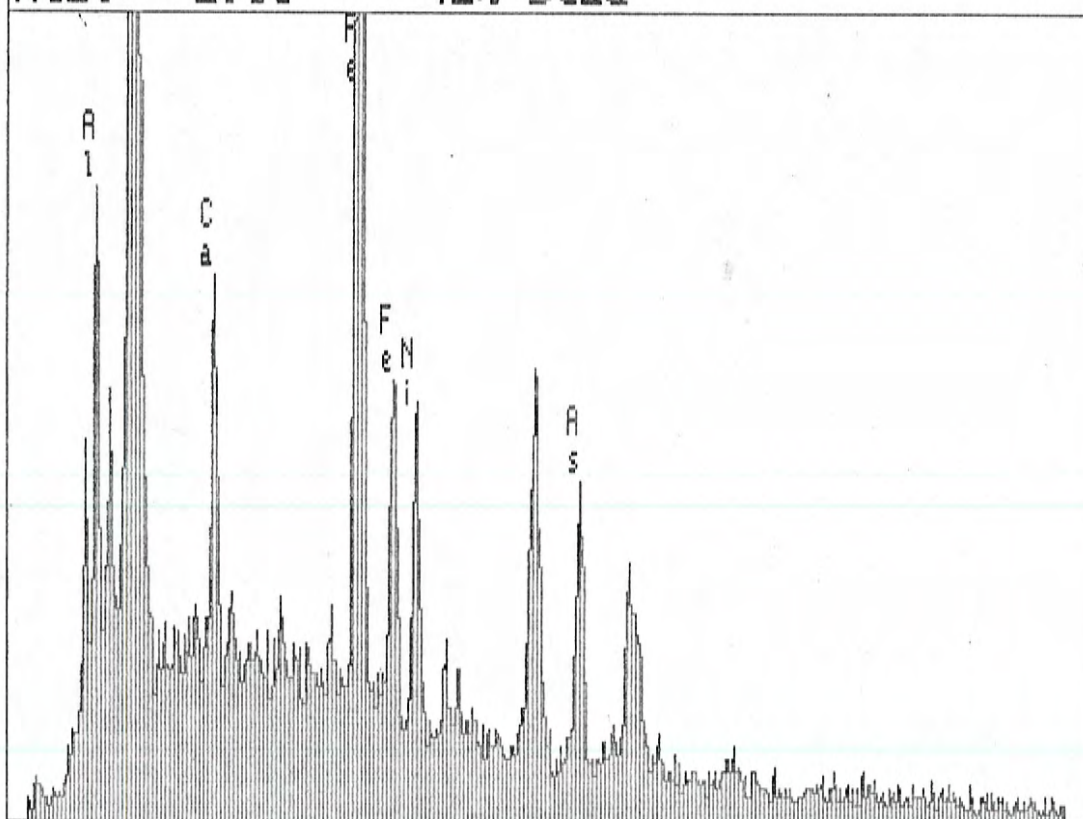
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 6 cts
MEM1:2-5 B

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



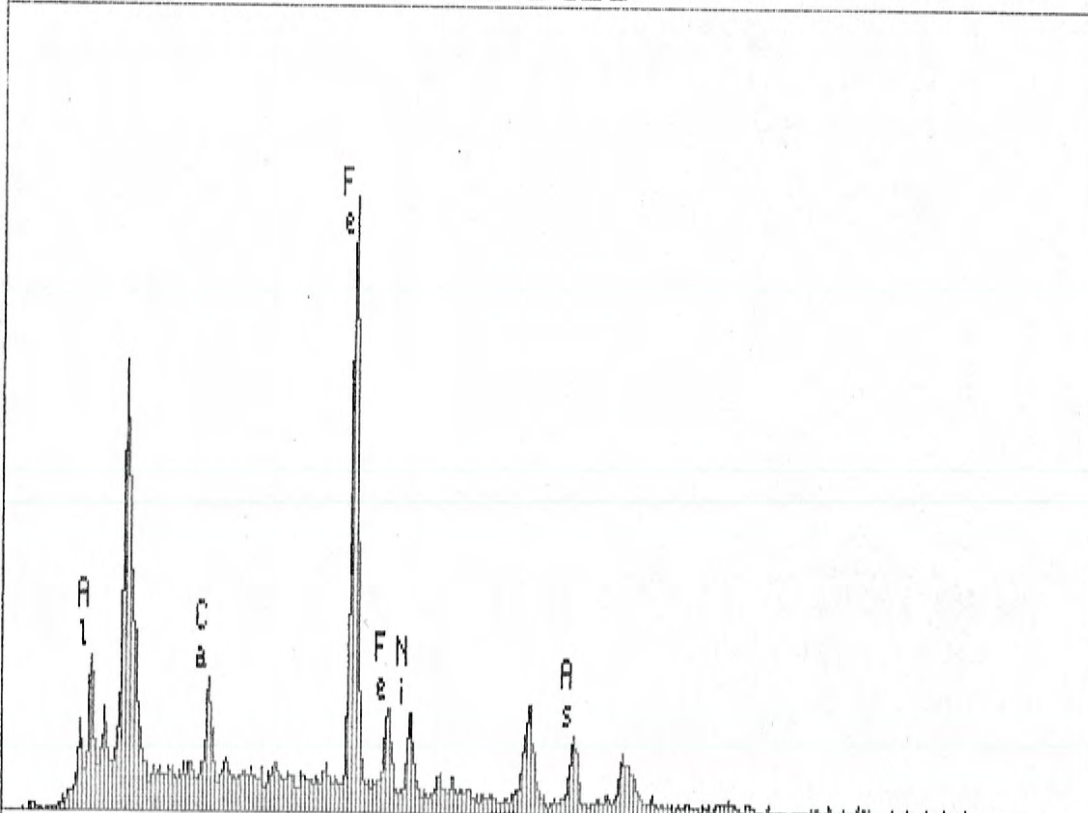
< -.2 10.043 keV 20.3 >
FS=255 ch 512= 12 cts
MEM1:2-5 D

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 206s 42% Dead



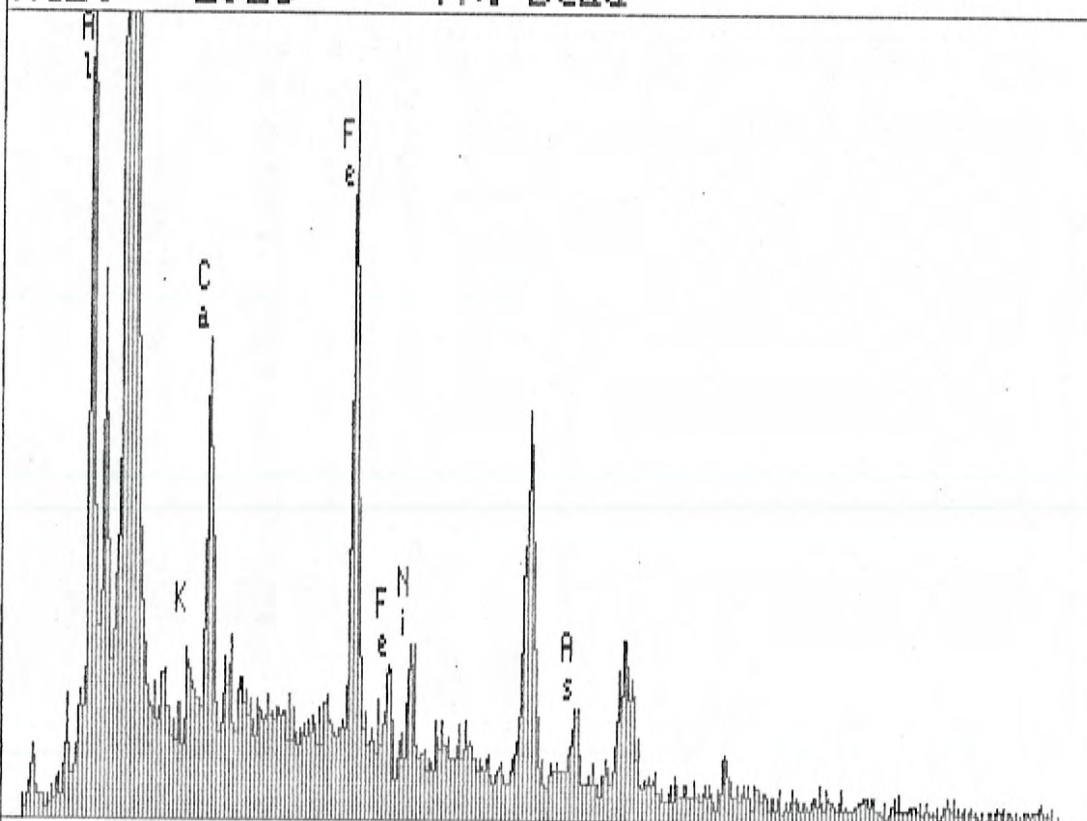
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 15 cts
MEM1: 2-7A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 206s 42% Dead



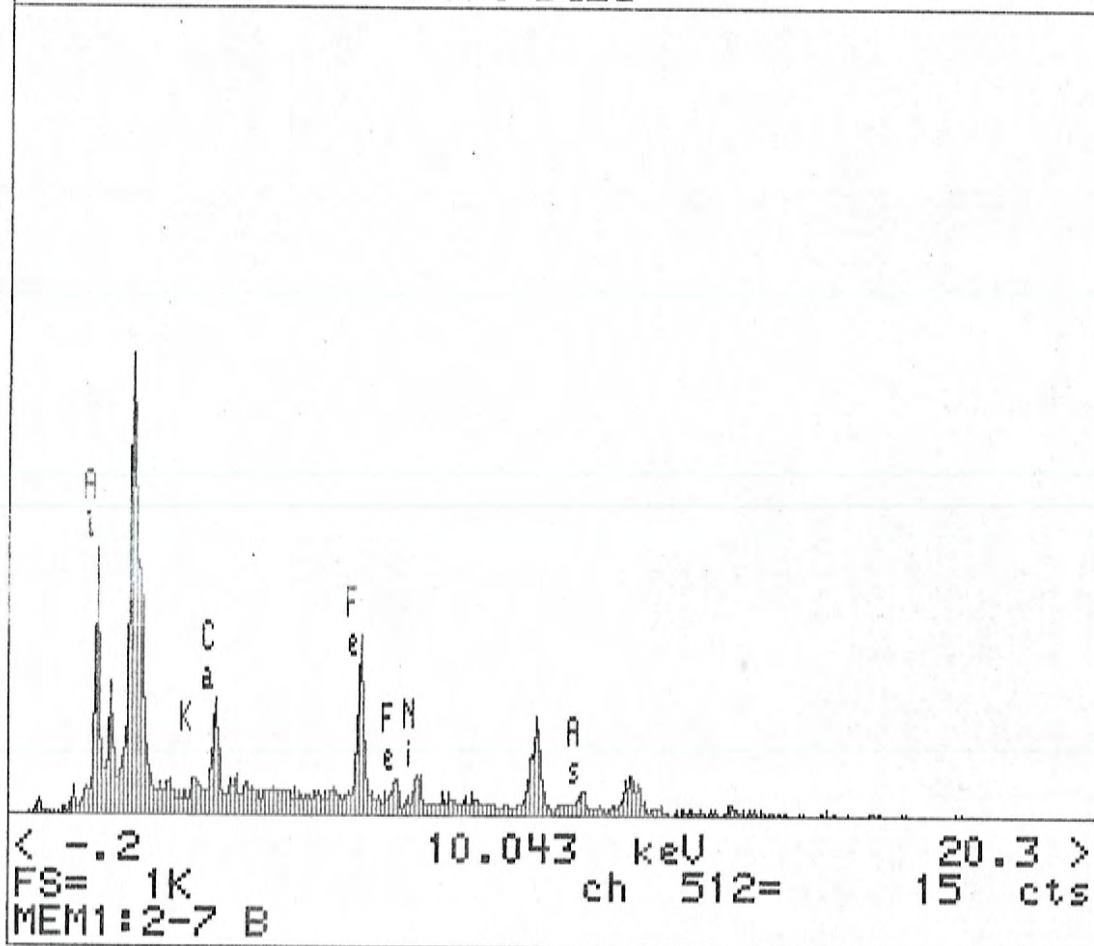
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 15 cts
MEM1: 2-7A

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead

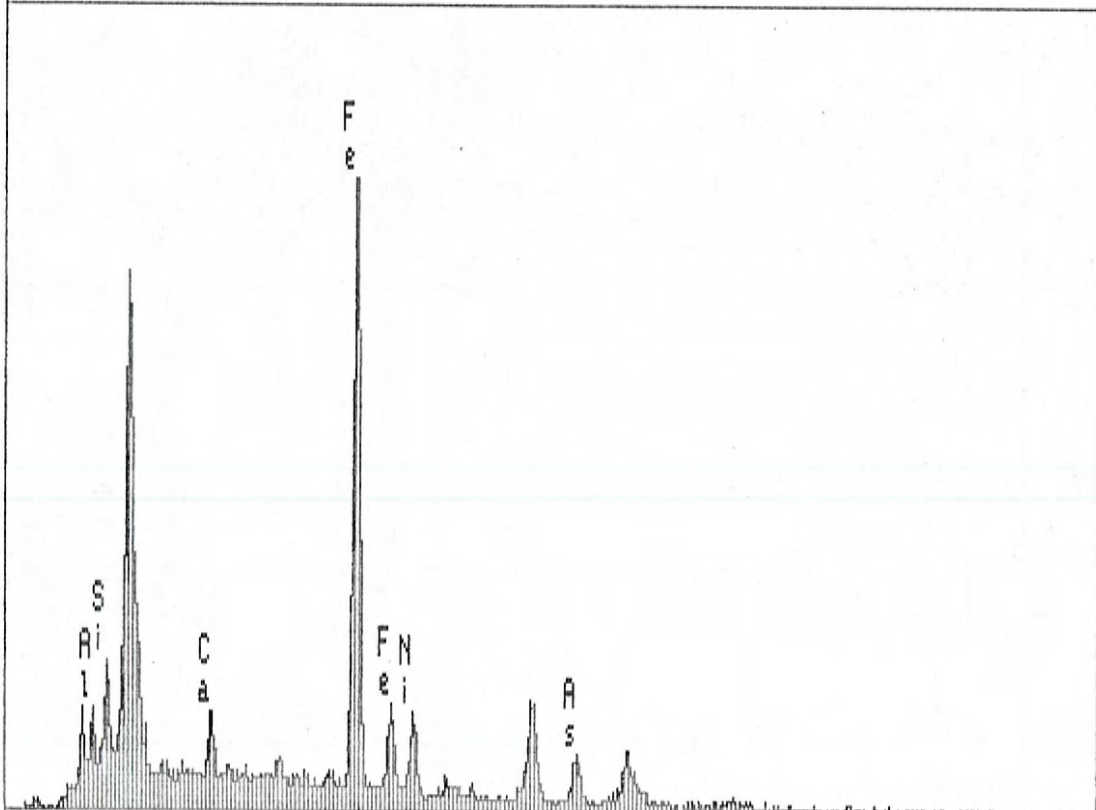


< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 15 cts
MEM1:2-7 B

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead

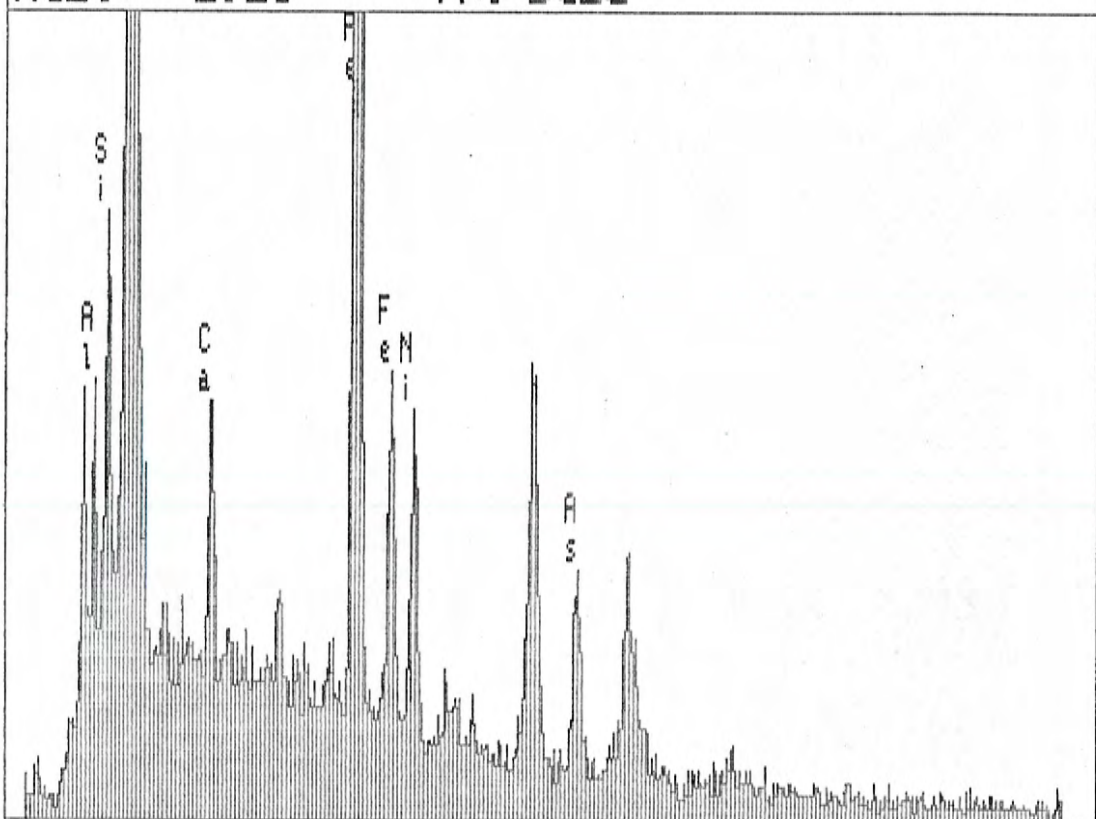


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



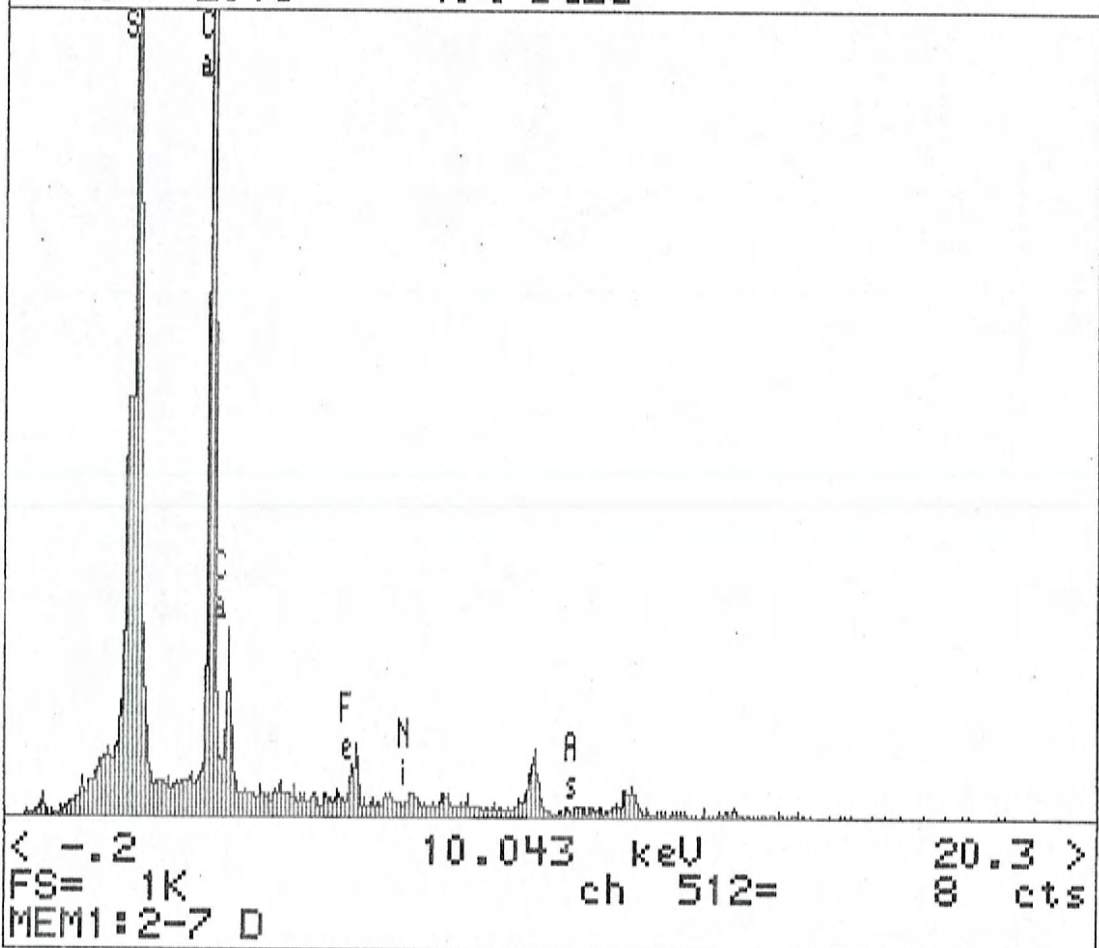
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 18 cts
MEM1:2-7 C

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead

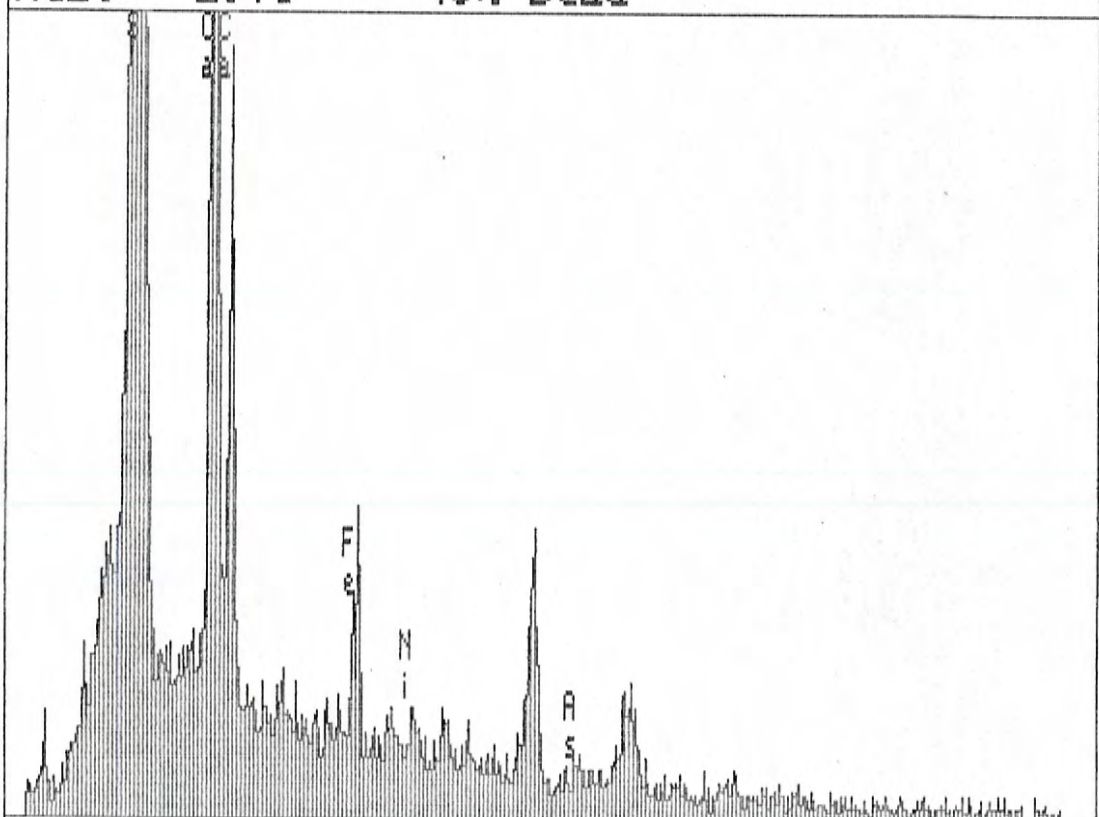


< -.2 10.043 keV 20.3 >
FS=255 ch 512= 18 cts
MEM1:2-7 C

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 201s 40% Dead

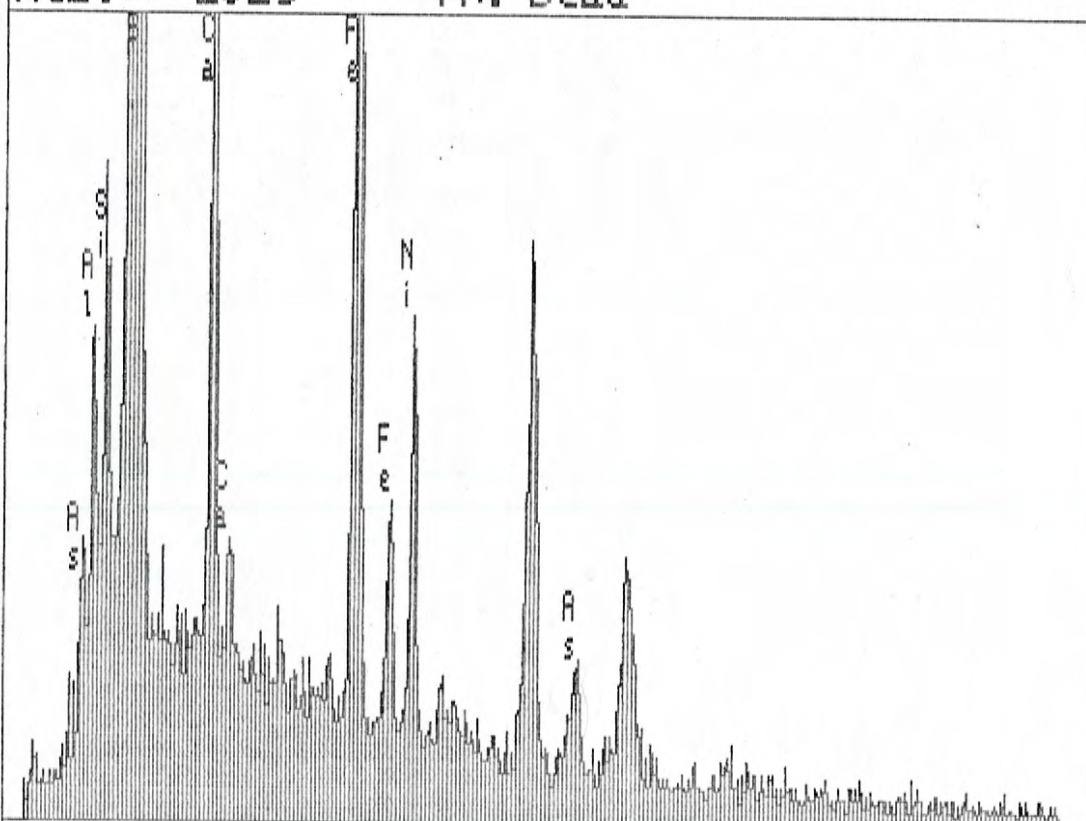


X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 201s 40% Dead



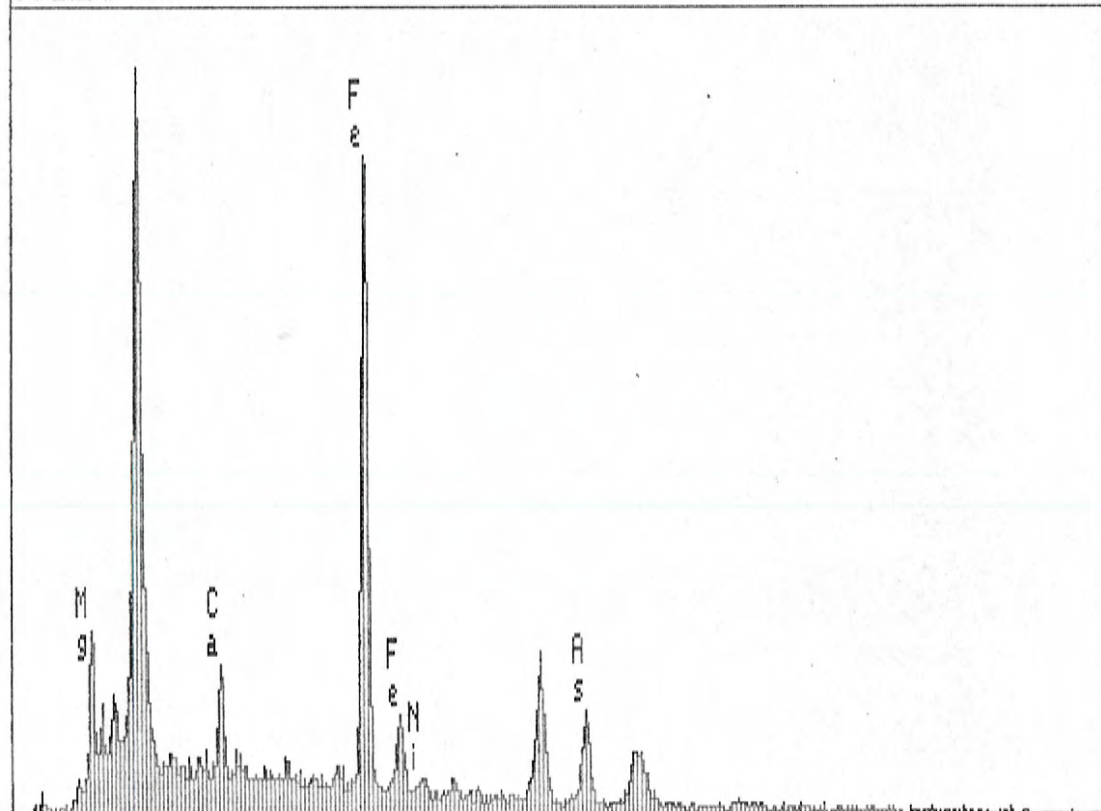
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 8 cts
MEM1:2-7 D

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 202s 41% Dead



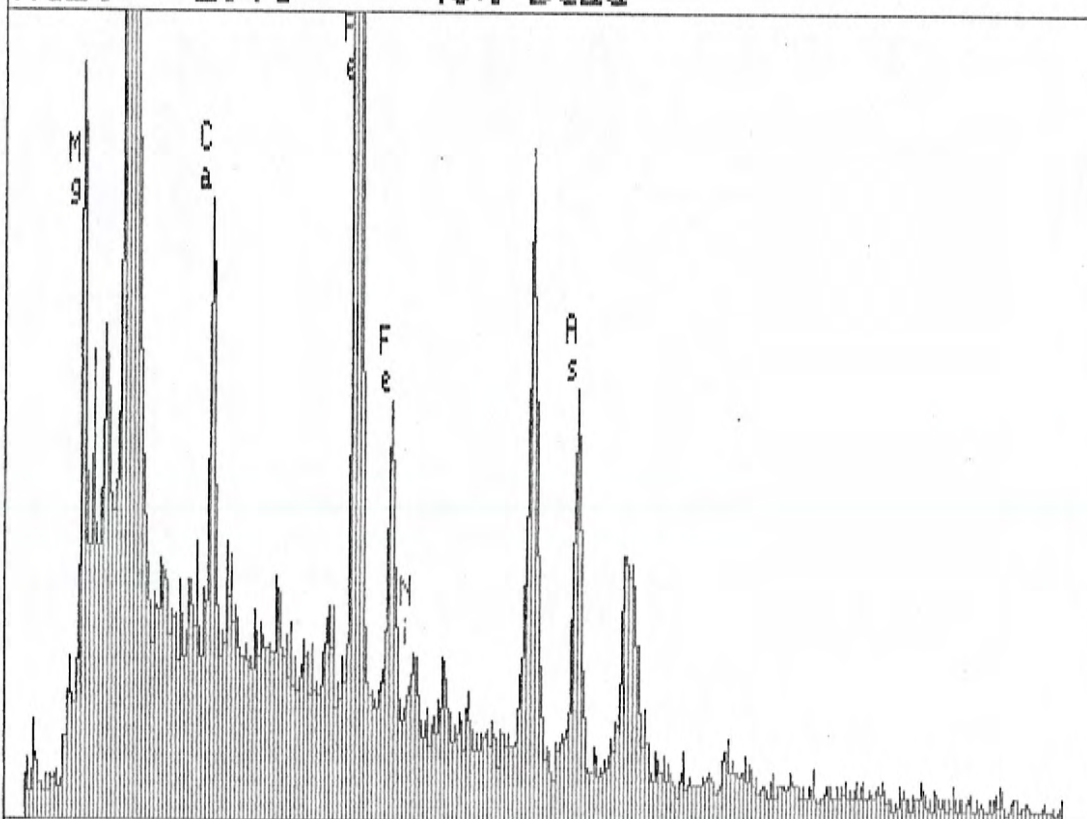
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 17 cts
MEM1:2-7 E

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 201s 40% Dead



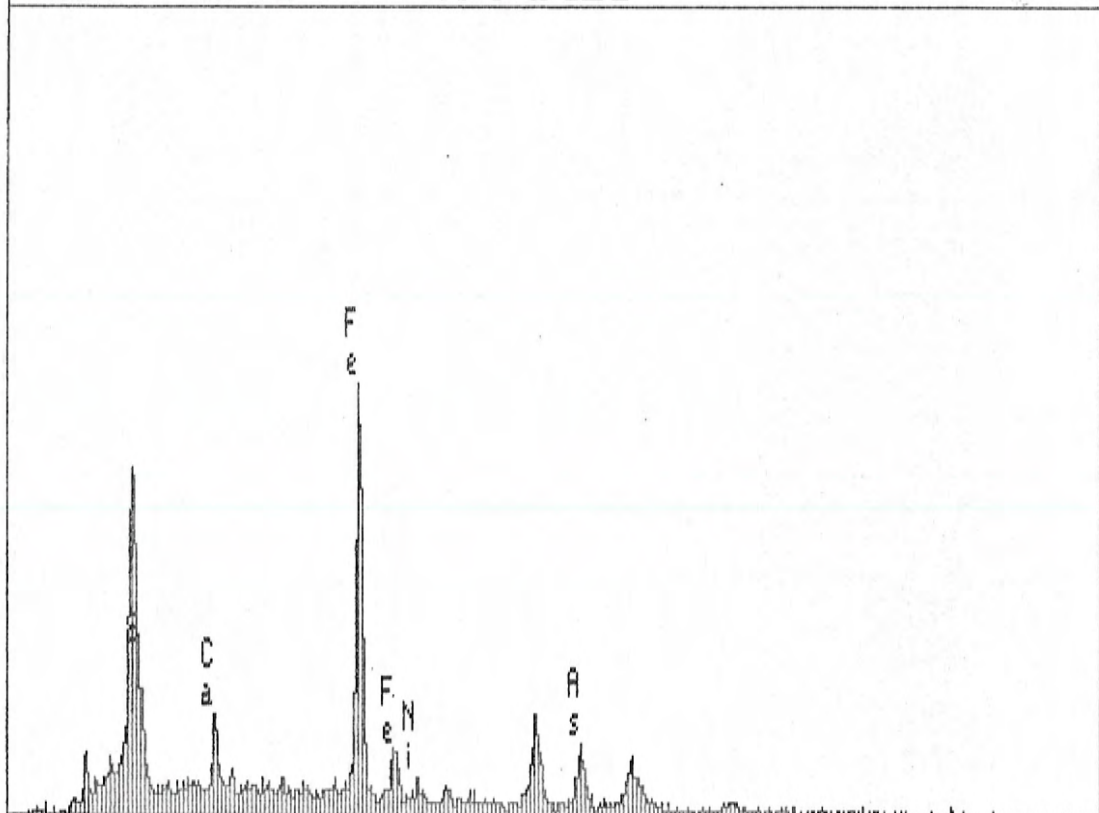
< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 10 cts
MEM1:2-7 F

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 201s 40% Dead



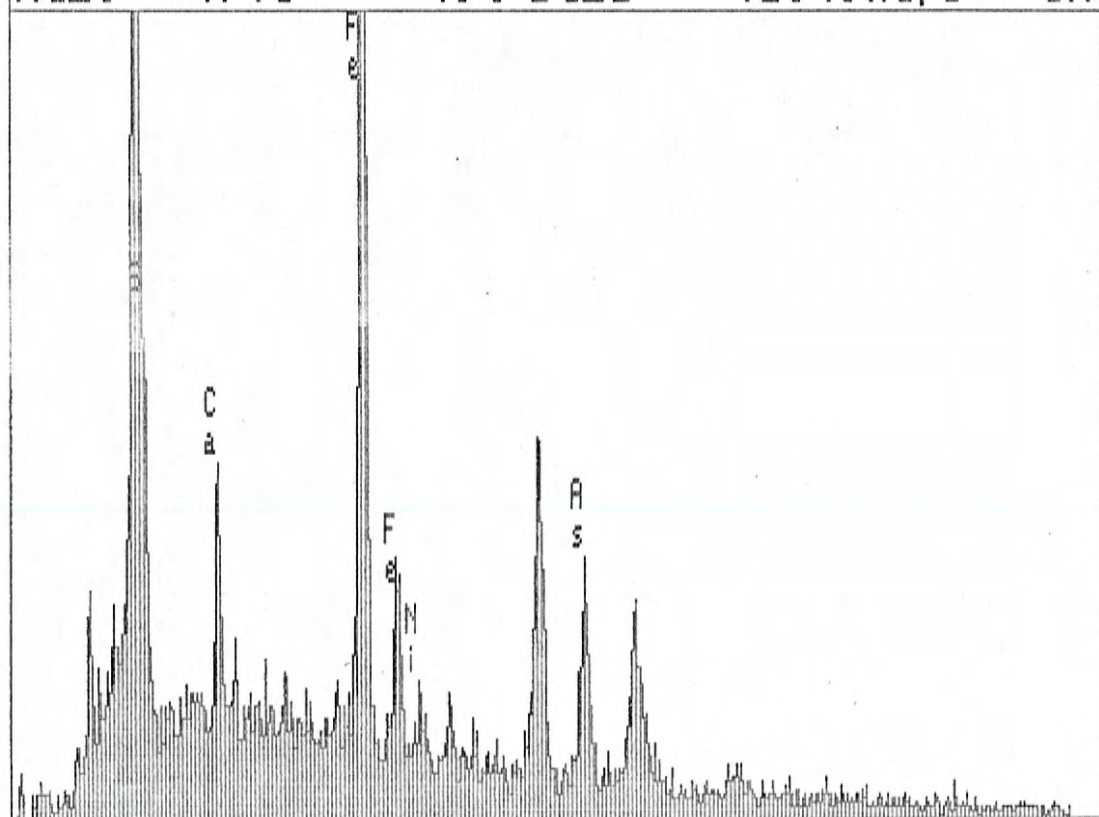
< -0.2 10.043 keV 20.3 >
FS=255 ch 512= 10 cts
MEM1:2-7 F

X-RAY(1): 0 - 20 keV Window : None
Live: 120s Preset: 120s Remaining: 0s
Real: 201s 40% Dead



< -0.2 10.043 keV 20.3 >
FS= 1K ch 512= 7 cts
MEM1:2-7 G

X-RAY(1): 0 - 20 keV Window : None
Live: 102s Preset: 120s Remaining: 18s
Real: 171s 40% Dead 13.49kcps IN



< -.2 10.043 keV 20.3 >
FS=255 ch 512= 7 cts
MEM1:2-7 G

**Appendix D - Scanning Electron Microscope
X-Ray Spectra Peak
Heights and Ratios of
 $K\beta$ and $K\alpha$ Lines of Fe, Ni, and As
of the
TOVP Neutralization Test
6-Series and 2-Series Samples**

**By John Mahoney
from data of Appendix C**

Figure 3 - Energy Dispersive X-ray Peak Heights for Samples from Set 2 1K scale

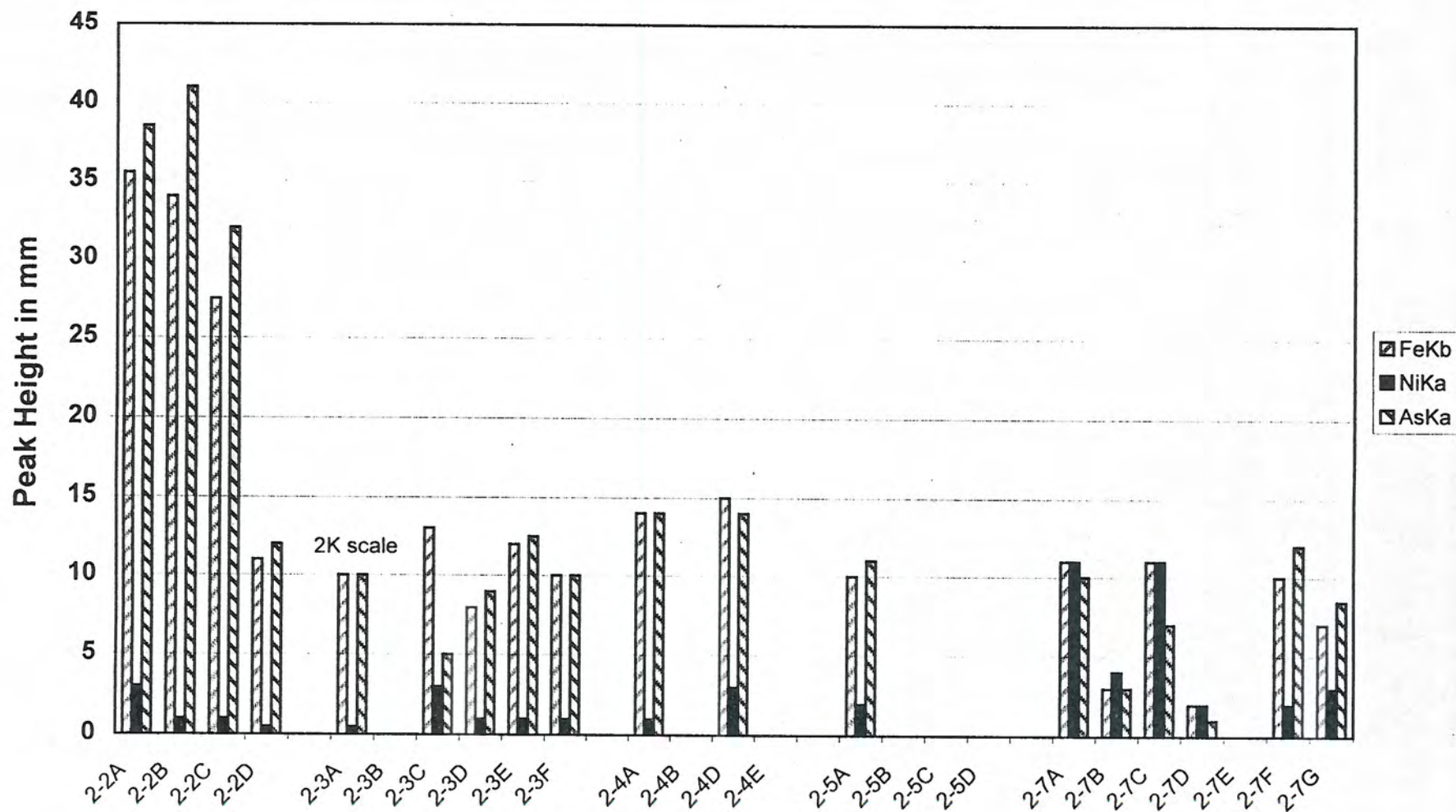


Figure 4 - Energy Dispersive X-ray Peak Heights for Samples from Set 6 255-scale

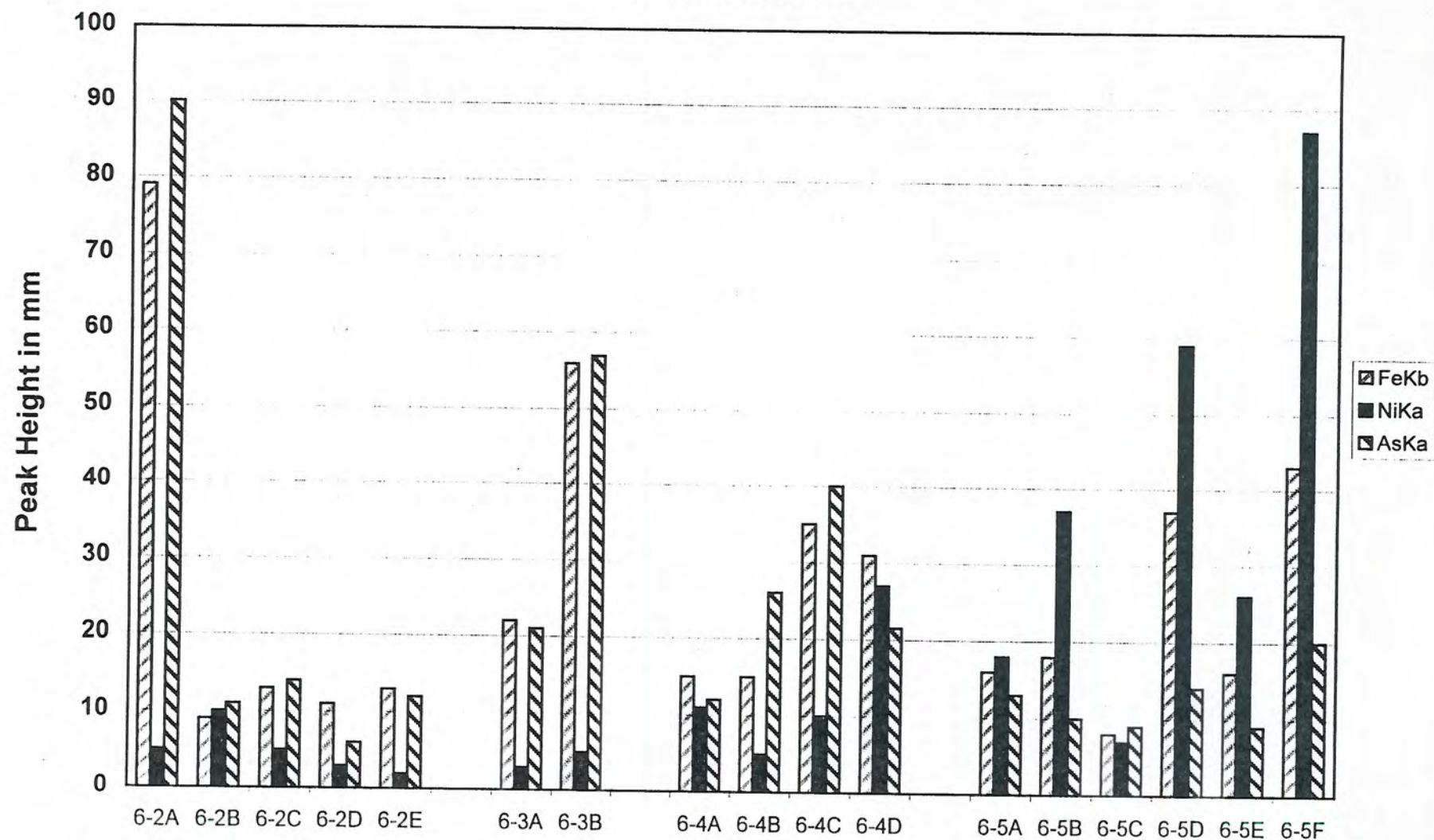


Figure 5 - Ni/As Peak Height Ratios for Samples from Set 2

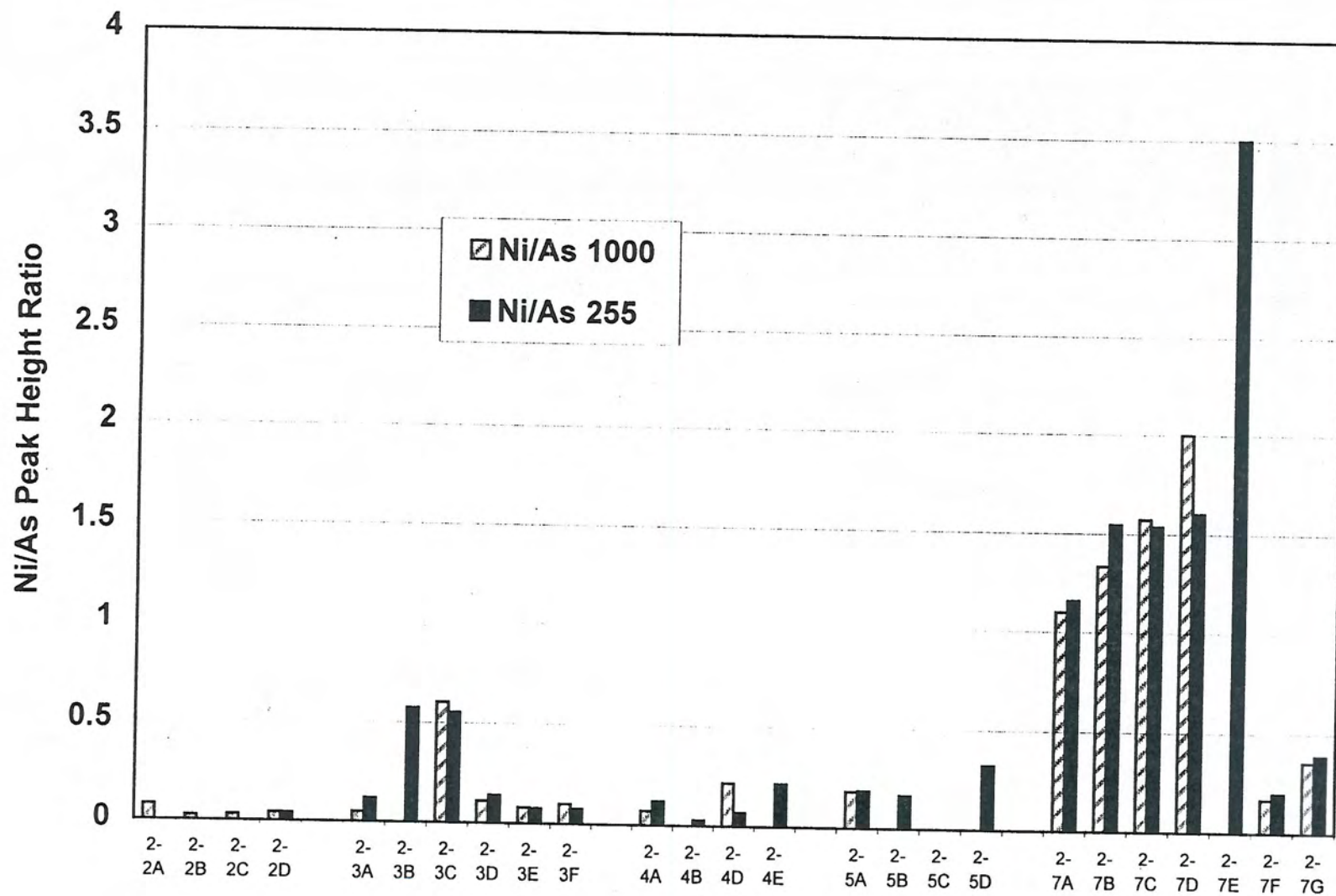


Figure 6 - Ni/As Peak Height Ratios for Samples from Set 6

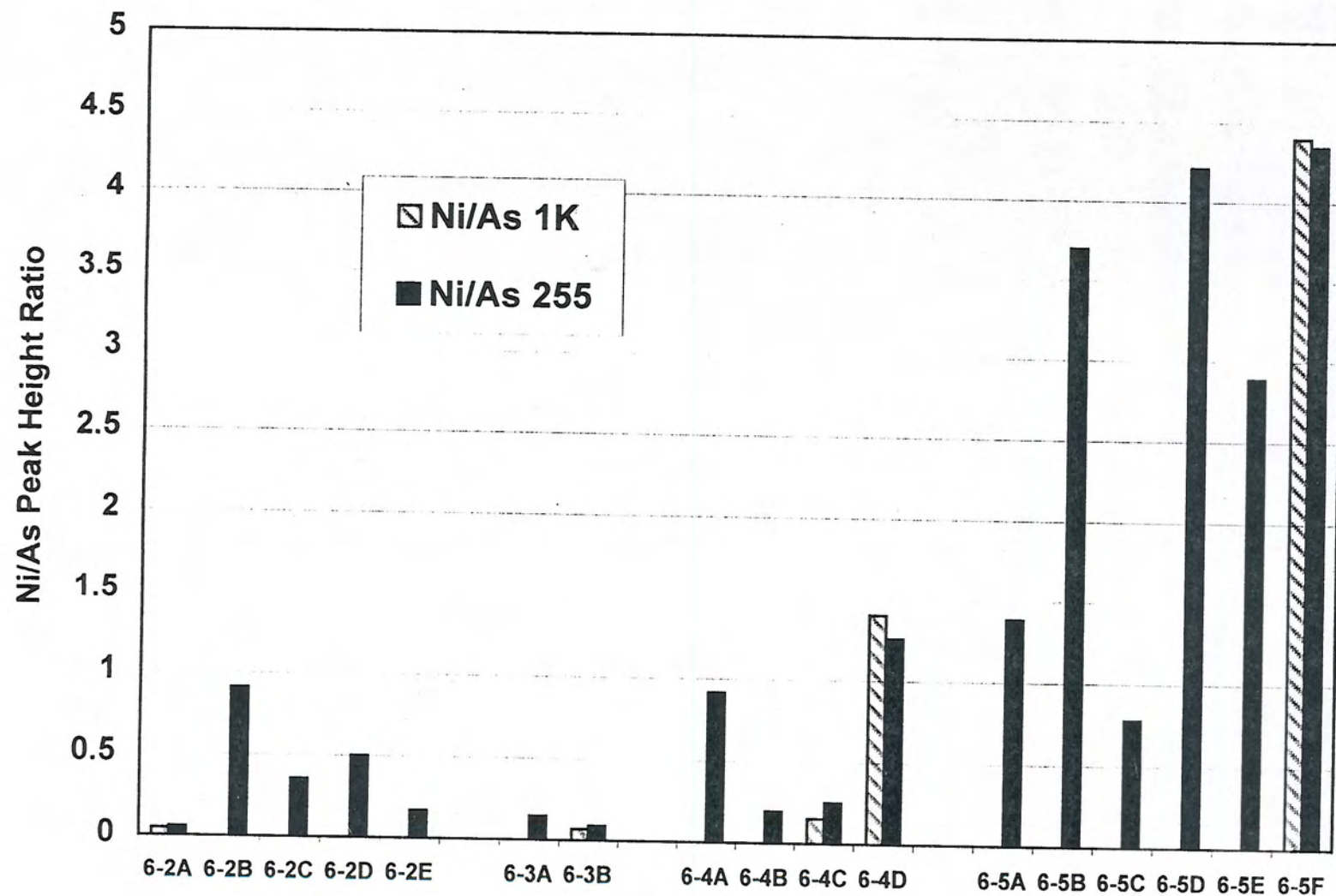


Figure 7 - Fe/As Peak Height Ratios for Samples from Set 2

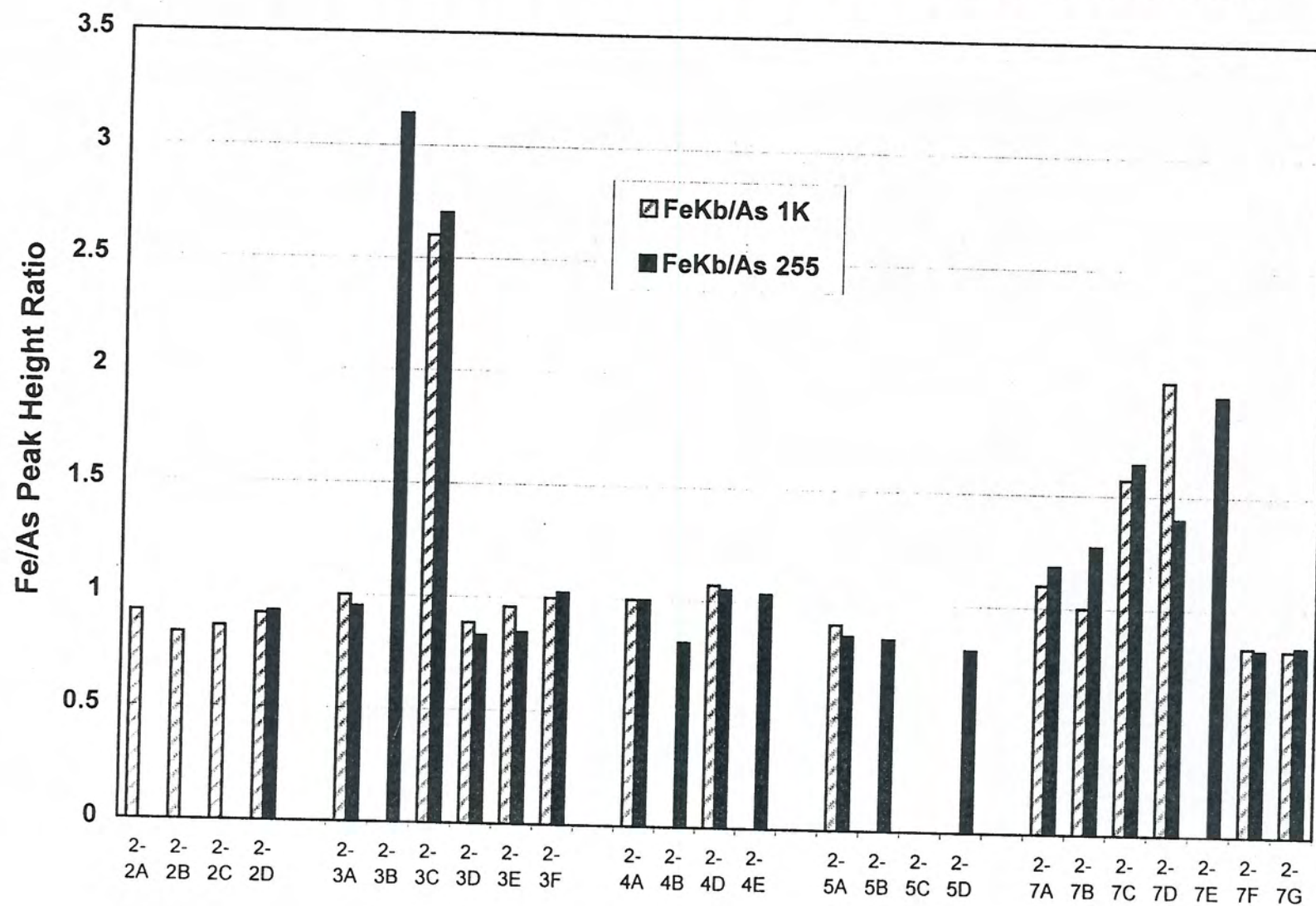


Figure 8 - Fe/As Peak Height Ratios for Samples from Set 6

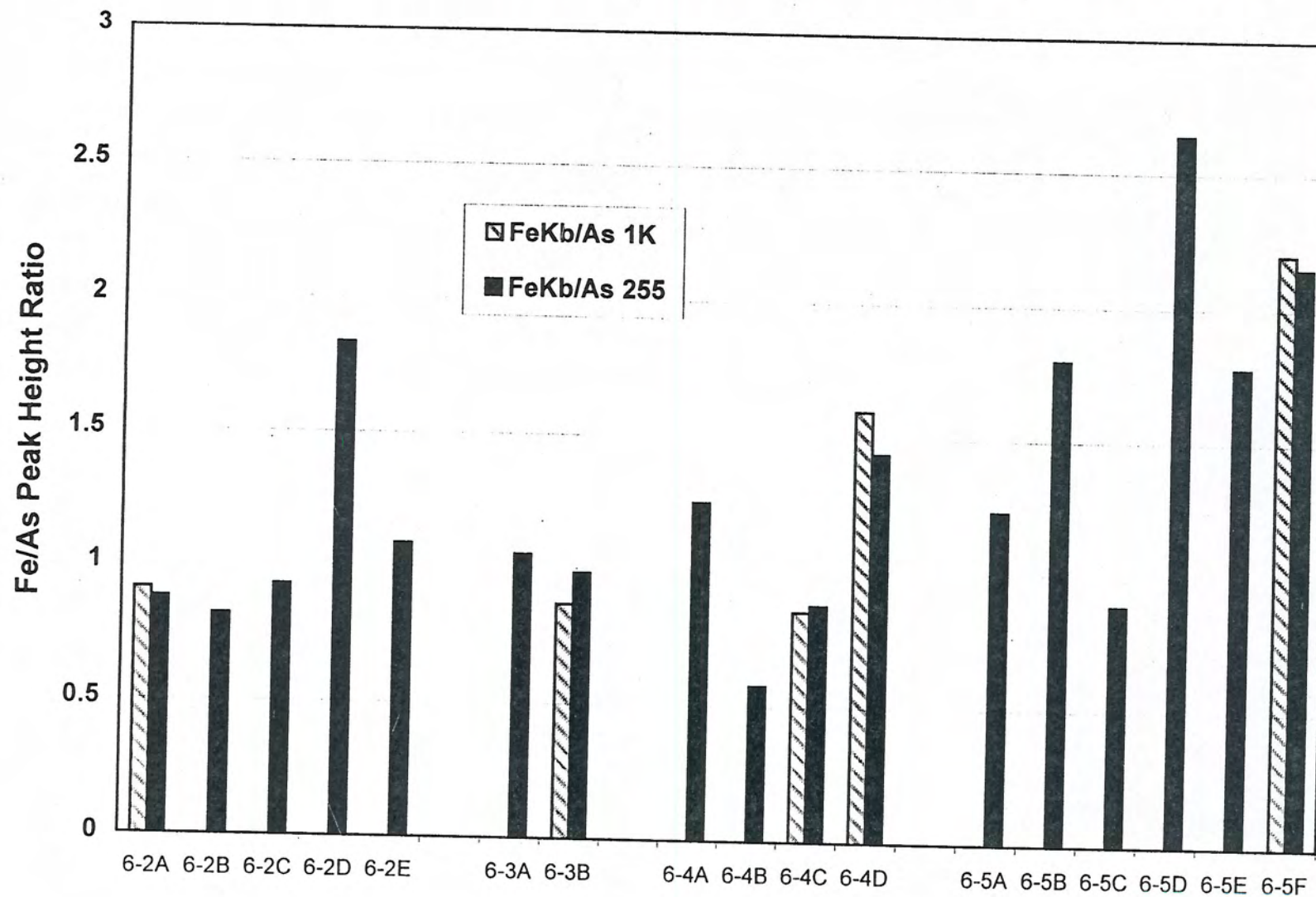


Figure 9 - Fe/Ni Peak Height Ratios for Samples from Set 2

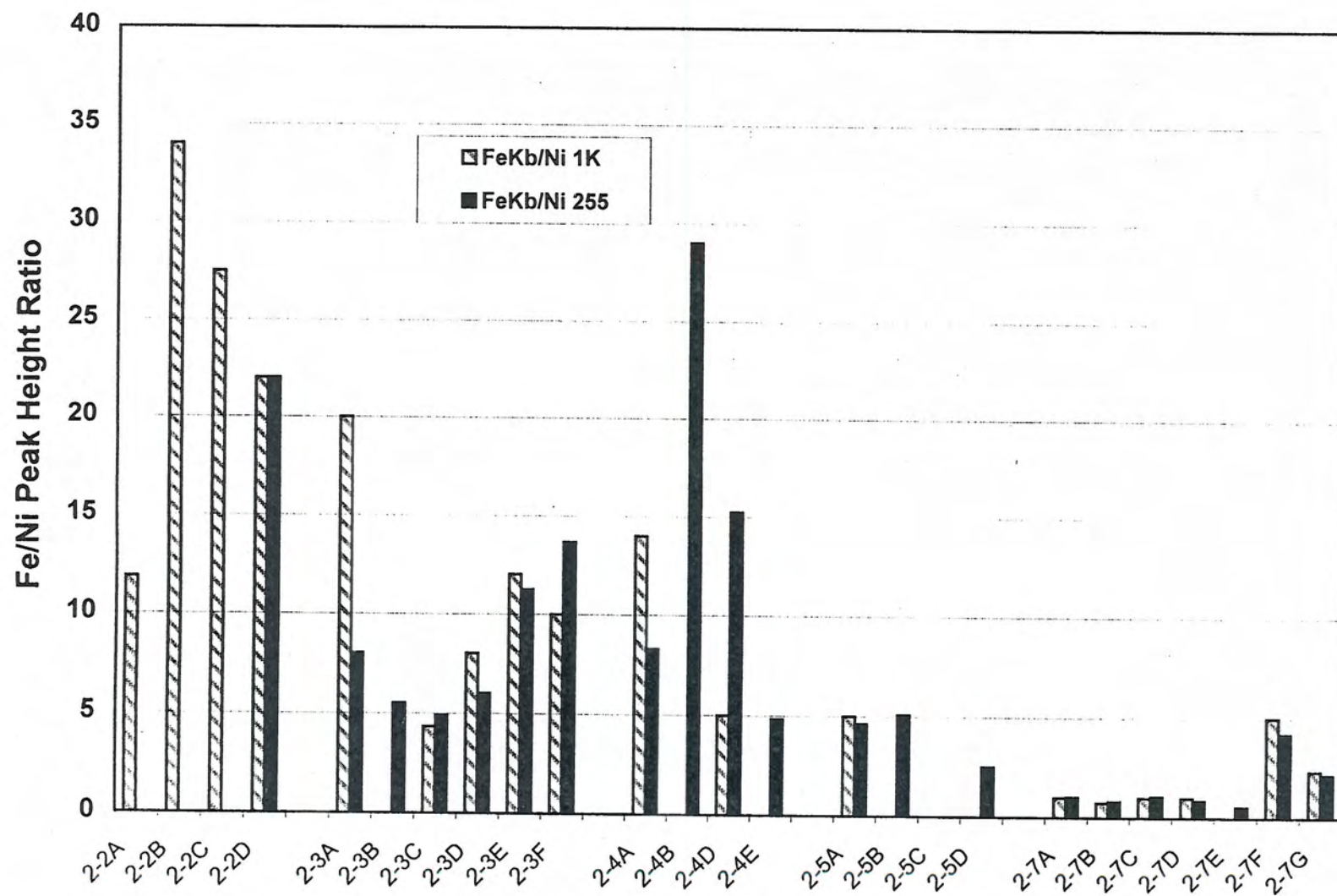
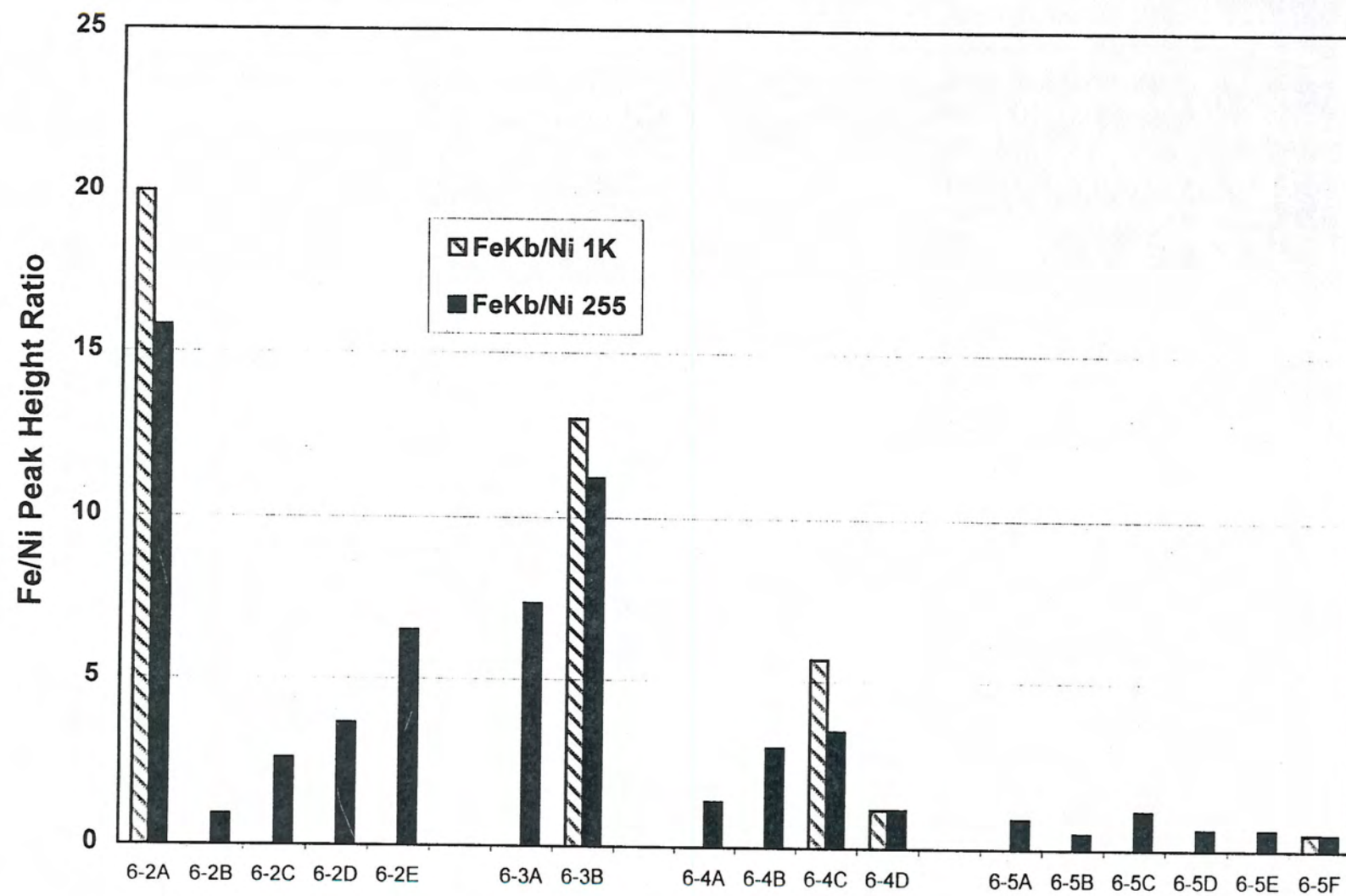


Figure 10 - Fe/Ni Peak Height Ratios for Samples from Set 6



**Appendix E - Chemical Analyses of the TOVP
Neutralization Test 6-Series and 2-Series Samples**

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SAMPLE NO. - TOVP 6-2

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	.193	.194
TI	O2 -	.0619	.0621
AL2	O3 -	2.89	2.90
FE2	O3 -	13.50	13.55
FE	O -	.216	.217
CA	O -	23.52	23.60
MG	O -	.00	.00
K2	O -	.0542	.0544
NA2	O -	.00	.00
V2	O5 -	.503	.505
MN	O -	.00	.00
CR2	O3 -	.00	.00
NI	O -	.224	.225
CU	O -	.00	.00
AS2	O5 -	6.75	6.77
P2	O5 -	1.82	1.83
PB	O -	.0232	.0233
U	O3 -	.00	.00
S	O3 -	27.59	27.69
H2	O- -	16.77	16.77 *
H2	O+ -	22.38	22.38
C	O2 -	.00	.00
ORG	-	.0700	.0700 *
TOTAL		99.72	

* - not included in normalization

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SAMPLE NO. - TOVP 6-3

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	2.42	2.43
TI	O2 -	.0552	.0554
AL2	O3 -	1.85	1.86
FE2	O3 -	12.95	12.99
FE	O -	.207	.207
CA	O -	24.58	24.67
MG	O -	.0631	.0633
K2	O -	.0710	.0713
NA2	O -	.00	.00
V2	O5 -	.458	.459
MN	O -	.0079	.0079
CR2	O3 -	.0158	.0158
NI	O -	.387	.388
CU	O -	.0158	.0158
AS2	O5 -	5.79	5.81
P2	O5 -	1.60	1.61
PB	O -	.0237	.0238
U	O3 -	.00	.00
S	O3 -	28.38	28.47
H2	O- -	12.77	12.77 *
H2	O+ -	20.85	20.85
C	O2 -	.00	.00
ORG	-	.0700	.0700 *
TOTAL		99.73	

* - not included in normalization

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SAMPLE NO. - TOVP 6-4

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	2.96	2.97
TI	O2 -	.0315	.0316
AL2	O3 -	5.14	5.15
FE2	O3 -	9.90	9.93
FE	O -	.190	.191
CA	O -	23.03	23.10
MG	O -	.236	.237
K2	O -	.0629	.0631
NA2	O -	.00	.00
V2	O5 -	.307	.308
MN	O -	.0472	.0473
CR2	O3 -	.00	.00
NI	O -	1.20	1.20
CU	O -	.0708	.0710
AS2	O5 -	3.87	3.88
P2	O5 -	1.07	1.07
PB	O -	.0157	.0158
U	O3 -	.00	.00
S	O3 -	30.52	30.62
H2	O- -	5.35	5.35 *
H2	O+ -	21.11	21.11
C	O2 -	.00	.00
ORG	-	.0700	.0700 *
TOTAL		99.76	

* - not included in normalization

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SAMPLE NO. - TOVP 6-5

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	2.96	2.96
TI	O2 -	.0310	.0310
AL2	O3 -	4.07	4.05
FE2	O3 -	10.44	10.41
FE	O -	.291	.290
CA	O -	23.50	23.44
MG	O -	.489	.488
K2	O -	.0621	.0619
NA2	O -	.00	.00
V2	O5 -	.295	.294
MN	O -	.217	.217
CR2	O3 -	.00	.00
NI	O -	2.07	2.07
CU	O -	.0543	.0542
AS2	O5 -	3.50	3.49
P2	O5 -	.978	.975
PB	O -	.0155	.0155
U	O3 -	.00	.00
S	O3 -	29.05	28.97
H2	O- -	7.04	7.04 *
H2	O+ -	22.19	22.19
C	O2 -	.00	.00
ORG	-	.150	.150 *
TOTAL		100.20	

* - not included in normalization

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SAMPLE NO. - TOVP 2-2

WEIGHT PERCENT COMPOUNDS

	ABSOLUTE	NORMALIZED
SI O2 -	3.98	3.99
TI O2 -	.194	.195
AL2 O3 -	1.90	1.91
FE2 O3 -	39.36	39.51
FE O -	.154	.155
CA O -	.215	.216
MG O -	.00	.00
K2 O -	.280	.281
NA2 O -	.417	.418
V2 O5 -	.618	.620
MN O -	.0144	.0144
CR2 O3 -	.302	.303
NI O -	.488	.490
CU O -	.0287	.0288
AS2 O5 -	8.43	8.47
P2 O5 -	2.04	2.05
PB O -	.165	.166
U O3 -	.0072	.0072
S O3 -	13.16	13.21
H2 O- -	9.20	9.20 *
H2 O+ -	27.96	27.96
C O2 -	.00	.00
ORG -	.180	.180 *
TOTAL	99.71	

* - not included in normalization

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SAMPLE NO. - TOVP 2-3

WEIGHT PERCENT COMPOUNDS

	ABSOLUTE	NORMALIZED
SI O2 -	3.00	3.01
TI O2 -	.201	.201
AL2 O3 -	.911	.913
FE2 O3 -	38.92	39.04
FE O -	.156	.157
CA O -	.165	.165
MG O -	.00	.00
K2 O -	.194	.194
NA2 O -	.158	.158
V2 O5 -	.925	.928
MN O -	.0143	.0144
CR2 O3 -	.0789	.0791
NI O -	.459	.460
CU O -	.0287	.0288
AS2 O5 -	12.81	12.85
P2 O5 -	1.56	1.56
PB O -	.165	.165
U O3 -	.0072	.0072
S O3 -	11.95	11.99
H2 O- -	10.24	10.24 *
H2 O+ -	28.08	28.08
C O2 -	.00	.00
ORG -	.240	.240 *
TOTAL	99.78	

* - not included in normalization

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SAMPLE NO. - TOVP 2-4

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	10.73	10.75
TI	O2 -	.123	.123
AL2	O3 -	5.27	5.28
FE2	O3 -	24.61	24.64
FE	O -	.157	.157
CA	O -	.692	.693
MG	O -	.00	.00
K2	O -	.555	.556
NA2	O -	.670	.671
V2	O5 -	.749	.751
MN	O -	.0216	.0217
CR2	O3 -	.0721	.0722
NI	O -	.922	.924
CU	O -	.101	.101
AS2	O5 -	13.58	13.60
P2	O5 -	1.75	1.75
PB	O -	.166	.166
U	O3 -	.0072	.0072
S	O3 -	11.49	11.51
H2	O- -	10.46	10.46 *
H2	O+ -	28.23	28.23
C	O2 -	.00	.00
ORG	-	.230	.230 *
TOTAL		99.89	

* - not included in normalization

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SAMPLE NO. - TOVP 2-5

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	11.27	11.31
TI	O2 -	.149	.150
AL2	O3 -	6.58	6.60
FE2	O3 -	26.58	26.67
FE	O -	.655	.657
CA	O -	1.75	1.76
MG	O -	.0785	.0787
K2	O -	.479	.480
NA2	O -	.942	.945
V2	O5 -	.871	.874
MN	O -	.0157	.0157
CR2	O3 -	.0785	.0787
NI	O -	3.23	3.24
CU	O -	.220	.220
AS2	O5 -	14.38	14.42
P2	O5 -	1.43	1.43
PB	O -	.141	.142
U	O3 -	.0078	.0079
S	O3 -	9.06	9.09
H2	O- -	17.27	17.27 *
H2	O+ -	21.83	21.83
C	O2 -	.00	.00
ORG	-	.240	.240 *
TOTAL		99.75	

* - not included in normalization

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SAMPLE NO. - TOVP 2-7

WEIGHT PERCENT COMPOUNDS

		ABSOLUTE	NORMALIZED
SI	O2 -	3.84	3.84
TI	O2 -	.0804	.0805
AL2	O3 -	3.11	3.12
FE2	O3 -	33.89	33.94
FE	O -	.538	.539
CA	O -	3.52	3.53
MG	O -	.322	.322
K2	O -	.233	.234
NA2	O -	1.02	1.02
V2	O5 -	.868	.870
MN	O -	.748	.749
CR2	O3 -	.0563	.0564
NI	O -	6.65	6.66
CU	O -	.137	.137
AS2	O5 -	14.49	14.51
P2	O5 -	1.44	1.44
PB	O -	.105	.105
U	O3 -	.0080	.0081
S	O3 -	9.23	9.24
H2	O- -	16.16	16.16 *
H2	O+ -	19.12	19.12
C	O2 -	.478	.478
ORG	-	.200	.200 *
TOTAL		99.87	

* - not included in normalization

**Appendix F - Mineral Analyses and Approximate
Mineral Compositions of the TOVP
Neutralization Test
6-Series and 2-Series Samples**

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ANALYZED MINERAL CONTENT

SAMPLE NO. - TOVP 6-2

MINERAL	WT. PERCENT	VOL. PERCENT
AMORPHOUS SILICA	.20	.19
RUTILE	.06	.04
HYDROBASALUMINITE	6.60	7.74
GOETHITE	7.03	4.00
CALCIUM HYDROXIDE	8.82	9.79
JAROSITE	.44	.35
Ni, Fe ARSENATE	.99	.76
SCORODITE	12.58	9.78
STRENGITE	4.83	4.18
GYPSUM	52.36	56.11
QUENSTEDTITE	6.08	7.06
OBJECTIVE FUNCTION =	99.989	

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ANALYZED MINERAL CONTENT

SAMPLE NO. - TOVP 6-3

MINERAL	WT. PERCENT	VOL. PERCENT
AMORPHOUS SILICA	2.48	2.33
RUTILE	.06	.03
HYDROBASALUMINITE	2.92	3.42
GOETHITE	7.33	4.18
CALCIUM HYDROXIDE	9.43	10.48
JAROSITE	.43	.34
Ni, Fe ARSENATE	1.89	1.46
SCORODITE	10.10	7.86
STRENGITE	4.25	3.69
GYPSUM	54.21	58.18
QUENSTEDTITE	6.89	8.02
OBJECTIVE FUNCTION =	99.990	

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ANALYZED MINERAL CONTENT

SAMPLE NO. - TOVP 6-4

MINERAL	WT. PERCENT	VOL. PERCENT
AMORPHOUS SILICA	3.03	2.80
RUTILE	.03	.02
HYDROBASALUMINITE	10.10	11.68
FERRIHYDRITE	7.67	4.95
THEOPHRASITE	.91	.56
CALCIUM HYDROXIDE	4.92	5.38
JAROSITE	.33	.26
ANNABERGITE	2.75	2.09
SCORODITE	5.59	4.29
STRENGITE	2.84	2.42
GYPSUM	59.76	63.17
QUENSTEDTITE	2.08	2.38
OBJECTIVE FUNCTION =	99.995	

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ANALYZED MINERAL CONTENT

SAMPLE NO. - TOVP 6-5

MINERAL	WT. PERCENT	VOL. PERCENT
AMORPHOUS SILICA	3.02	2.82
RUTILE	.03	.02
HYDROBASALUMINITE	9.69	11.32
FERRIHYDRITE	9.09	5.93
CALCIUM HYDROXIDE	6.16	6.81
JAROSITE	.32	.25
ANNABERGITE	3.11	2.38
THEOPHRASITE	2.27	1.40
SCORODITE	4.56	3.53
STRENGITE	2.58	2.23
GYPSUM	58.03	61.98
QUENSTEDTITE	1.13	1.31
OBJECTIVE FUNCTION =	99.987	

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ANALYZED MINERAL CONTENT

SAMPLE NO. - TOVP 2-2

MINERAL	WT. PERCENT	VOL. PERCENT
AMORPHOUS SILICA	4.11	3.39
RUTILE	.20	.10
HYDROBASALUMINITE	5.66	5.84
GREEN RUST II	31.75	34.73
GYPSUM	.67	.63
JAROSITE	2.09	1.44
SODIUM HYDROXIDE	.55	.56
Ni,Fe ARSENATE	1.51	.61
KANKITE	19.48	19.37
STRENGITE	5.45	4.16
QUENSTEDTITE	28.49	29.12
OBJECTIVE FUNCTION =	99.946	

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ANALYZED MINERAL CONTENT

SAMPLE NO. - TOVP 2-3

MINERAL	WT. PERCENT	VOL. PERCENT
AMORPHOUS SILICA	3.09	2.55
RUTILE	.20	.11
HYDROBASALUMINITE	2.68	2.76
GREEN RUST II	28.40	30.99
GYPSUM	.51	.48
JAROSITE	1.43	.98
SODIUM HYDROXIDE	.21	.21
Ni,Fe ARSENATE	1.45	.59
KANKITE	30.57	30.32
STRENGITE	4.16	3.16
QUENSTEDTITE	27.28	27.82
OBJECTIVE FUNCTION =	99.977	

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ANALYZED MINERAL CONTENT

SAMPLE NO. - TOVP 2-4

MINERAL	WT. PERCENT	VOL. PERCENT
AMORPHOUS SILICA	11.00	10.01
RUTILE	.12	.07
HYDROBASALUMINITE	15.62	17.77
FERRIHYDRITE	10.61	6.73
GYPSUM	2.15	2.23
JAROSITE	4.64	3.54
SODIUM HYDROXIDE	.88	.99
Ni,Fe ARSENATE	2.63	1.96
KANKITE	31.03	34.01
STRENGITE	4.66	3.92
QUENSTEDTITE	16.60	18.70
OBJECTIVE FUNCTION =	99.934	

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ANALYZED MINERAL CONTENT

SAMPLE NO. - TOVP 2-5

MINERAL	WT. PERCENT	VOL. PERCENT
AMORPHOUS SILICA	11.58	12.22
RUTILE	.15	.10
HYDROBASALUMINITE	17.60	23.22
FERRIHYDRITE	19.05	14.01
Ni,Fe ARSENATE	7.50	6.49
GYPSUM	5.45	6.57
JAROSITE	4.01	3.55
SODIUM HYDROXIDE	1.23	1.62
THEOPHRASTITE	1.06	.74
SCORODITE	22.00	19.22
STRENGITE	3.81	3.72
QUENSTEDTITE	6.53	8.53
OBJECTIVE FUNCTION =	99.988	

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ANALYZED MINERAL CONTENT

SAMPLE NO. - TOVP 2-7

MINERAL	WT. PERCENT	VOL. PERCENT
AMORPHOUS SILICA	3.96	4.45
RUTILE	.08	.06
HYDROBASALUMINITE	6.81	9.55
FERRIHYDRITE	27.96	21.88
THEOPHRASTITE	5.52	4.10
GYP SUM	9.12	11.69
JAROSITE	1.96	1.85
SODIUM HYDROXIDE	1.34	1.88
ANNABERGITE	7.51	6.91
SCORODITE	22.36	20.78
STRENGITE	3.86	4.00
QUENSTEDTITE	8.28	11.51
CALCIUM CARBONATE	1.11	1.22
OBJECTIVE FUNCTION =	99.885	

MINERAL ANALYZER MINERAL DENSITY AND COMPOSITION FILE
COGEMA Mineral File

GYPSUM.....2.32	All samples
CA1.00 S1.00 O6.00 H+4.00	
HYDROBASALUMINITE....2.12	TOVP 6-2, 2-3
AL4.00 S1.00 O27.0 H+36.0	
HYDROBASALUMINITE....2.12	TOVP 6-4
AL4.00 S1.00 O16.0 H+14.0	
HYDROBASALUMINITE....2.12	TOVP 6-5
AL4.00 S1.00 O21.0 H+24.0	
HYDROBASALUMINITE....2.12	TOVP 2-2,2-3,
AL4.00 S1.00 O27.0 H+36.0	2-4
HYDROBASALUMINITE....2.12	TOVP 2-5
AL4.00 S1.00 O26.0 H+34.0	
HYDROBASALUMINITE....2.12	TOVP 2-7
AL4.00 S1.00 O23.0 H+18.0	
AMORPHOUS SCORODITE..3.10	All samples
FE .90 AL .10 AS1.00 O6.00 H+4.0	
SCORODITE.....3.20	All samples
FE .90 AL .10 AS1.00 O6.00 H+4.00	
KANKITE.....2.20	TOVP 2-2,2-3,2-4
FE1.00 AS1.00 O9.00 H+10.	
SODIUM HYDROXIDE.....2.13	All samples
NA1.00 O1.00 H+1.00	
THEOPHRASITE.....4.00	TOVP 6-4
NI .59 O2.00 H+2.00 MG .39 Fe .02	
THEOPHRASITE.....4.00	TOVP 6-5
NI.615 O2.00 H+2.00 MG .38 Fe.015	
THEOPHRASITE.....4.00	TOVP 2-5
NI .84 O2.00 H+2.00 MG .16 Fe .01	
THEOPHRASITE.....4.00	TOVP 2-7
NI .86 O2.00 H+2.00 MG .13 Fe .01	
ANNABERGITE.....3.23	TOVP 6-3
NI1.60 AS2.00 O16.0 H+16.0 MG .45 CU .06 Fe .89	
ANNABERGITE.....3.23	TOVP 6-4
NI1.99 AS2.00 O16.0 H+16.0 MG .30 CU .19 Fe .52	
ANNABERGITE.....3.23	TOVP 6-5
NI1.98 AS2.00 O16.0 H+16.0 MG .24 CU .13 Fe .67	
ANNABERGITE.....3.23	TOVP 2-7
NI2.47 Fe .46 AS2.00 O10.0 H+8.00 CU .19	
JAROSITE.....3.16	All samples
K1.00 FE1.00 S2.00 O14.0 H+6.00	
STRENGITE.....2.87	All samples
FE1.00 P1.00 O6.00 H+4.00	
CALCIUM CARBONATE....2.71	
CA1.00 C1.00 O3.00	
AMORPHOUS SILICA.....2.65	TOVP 6-2,6-3,
SI .99 AL .01 O2.00 K .01	6-4,6-5
AMORPHOUS SILICA.....2.65	TOVP 2-2,2-3,2-4,
SI .99 AL .01 O2.01 H+ .03	2-4,2-5,2-7
GREEN RUST II.....2.00	TOVP 2-2,2-3
FE2.00 O4.00 H+2.00	
QUENSTEDITE.....2.14	All samples
FE2.00 S3.00 O23.0 H+22.0	
GOETHITE.....4.37	All samples
FE0.90 AL .10 O2.00 H+1.00	
RUTILE.....4.22	All samples
TI1.00 O2.00	
CALCIUM HYDROXIDE....2.24	TOVP 6-2,6-3,

CA1.00	O2.00	H+2.00							6-4,6-5
FERRIHYDRITE.....			3.80					TOVP	6-4,6-5,
FE5.00	AL .00	O12.0	H+9.00						2-5,2-7
Ni,Fe ARSENATE.....			3.23					TOVP	6-2
NI1.50	Fe1.50	AS2.00	O10.0	H+8.00					
Ni,Fe ARSENATE.....			3.23					TOVP	6-3
NI1.60	Fe .88	AS2.00	O16.0	H+16.0	MG .46			CU	.06
Ni,Fe ARSENATE.....			3.23					TOVP	2-2
NI2.17	Fe .71	AS2.00	O10.0	H+8.00	CU .12				
Ni,Fe ARSENATE.....			3.23					TOVP	2-3
NI2.12	Fe .75	AS2.00	O10.0	H+8.00	CU .12				
Ni,Cu,Fe ARSENATE....			3.23					TOVP	2-4
NI2.34	Fe .40	AS2.00	O10.0	H+8.00	CU .24				
Ni,Fe,Cu ARSENATE....			3.23					TOVP	2-5
NI2.22	Fe .60	AS2.00	O10.0	H+8.00	CU .18				

**Appendix G - Mineral Analyses
Tables, Graphs, and Charts of the TOVP
Neutralization Test
6-Series and 2-Series Samples**

**By Don Langmuir and John Mahoney
From the Data of Appendix F**

Note: The formula as presented for nickel hydroxide, $\text{Ni}(\text{OH})_2$, is actually $\text{Ni, Mg}(\text{OH})_2$, with a Mg content of about 1/3, and Ni about 2/3.

Mineralogy of the 6 Series 2002 TOVP Neutralization Tests

	6-2	6-3	6-4	6-5
pH	3.15	4.04	6.09	7.38
Amorphous Silica	0.2	2.48	3.03	3.02
Rutile	0.06	0.06	0.03	0.03
Hydrobasaluminite	6.6	2.92	10.1	9.69
Ferrihydrite	0	0	7.67	9.09
Goethite	7.03	7.33	0	0
Green rust II	0	0	0	0
Gypsum	52.36	54.21	59.76	58.03
Ca(OH) ₂	8.82	9.43	4.92	6.16
Theophrastite	0	0	0.91	2.27
Jarosite	0.44	0.43	0.33	0.32
Ni,Fe Arsenate	0.99	1.89	0	0
Annabergite	0	0	2.75	3.11
Scorodite	12.58	10.1	5.57	4.56
Kankite	0	0	0	0
Strengite	4.83	4.25	2.84	2.58
Quenstedtite	6.08	6.89	2.08	1.13
NaOH	0	0	0	0
Calcium Carbonate	0	0	0	0
	99.99	99.99	99.99	99.99
	0.4764	0.4579	0.4024	0.4197

Mineralogy of the 6 Series 2002 TOVP Neutralization Tests After Adjusting for Gypsum

	6-2	6-3	6-4	6-5
Amorphous Silica	0.42	5.42	7.53	7.20
Rutile	0.13	0.13	0.07	0.07
Hydrobasaluminite	13.85	6.38	25.10	23.09
Ferrihydrite	0.00	0.00	19.06	21.66
Goethite	14.76	16.01	0.00	0.00
Green rust II	0.00	0.00	0.00	0.00
Ca(OH) ₂	18.51	20.59	12.23	14.68
Theophrastite	0.00	0.00	2.26	5.41
Jarosite	0.92	0.94	0.82	0.76
Ni,Fe Arsenate	2.08	4.13	0.00	0.00
Annabergite	0.00	0.00	6.83	7.41
Scorodite	26.41	22.06	13.84	10.86
Kankite	0.00	0.00	0.00	0.00
Strengite	10.14	9.28	7.06	6.15
Quenstedtite	12.76	15.05	5.17	2.69
NaOH	0.00	0.00	0.00	0.00
Calcium Carbonate	0.00	0.00	0.00	0.00

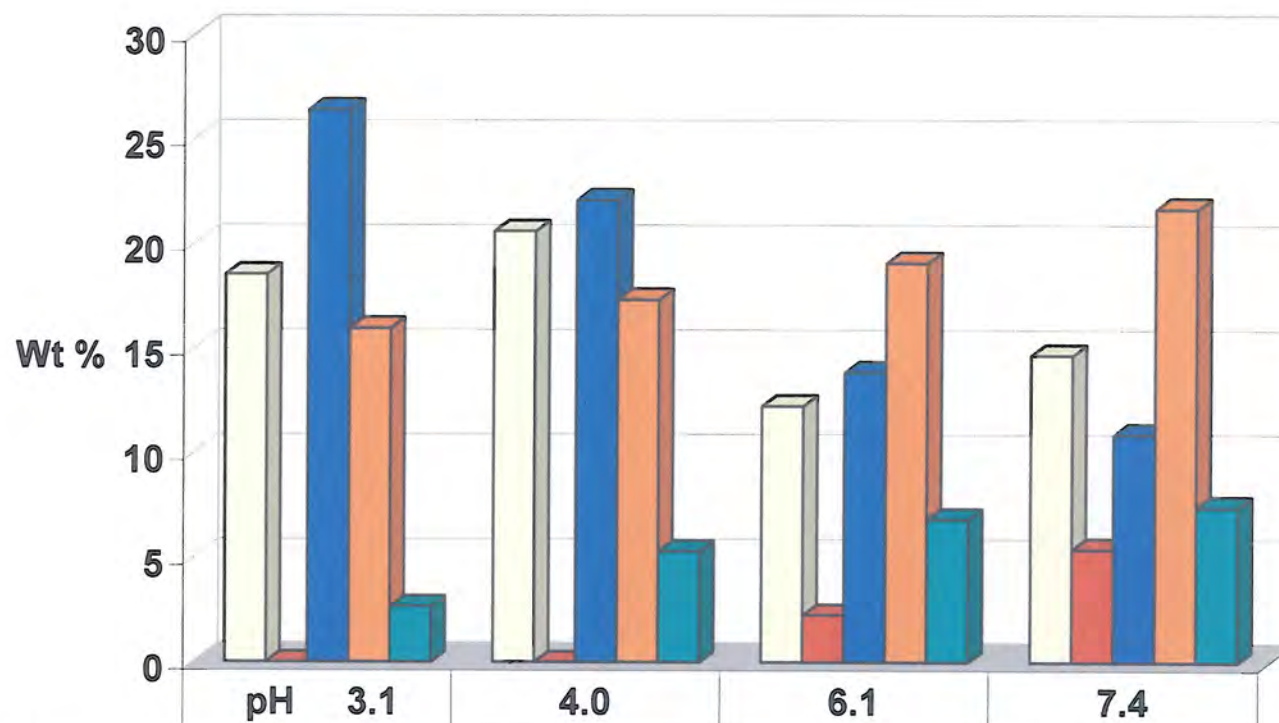
Mineralogy of the 2 Series 2002 TOVP Neutralization Tests

	2-2	2-3	2-4	2-5	2-7
pH	3.03	4.06	5	6.37	8.01
Amorphous Silica	4.11	3.09	11	11.58	3.96
Rutile	0.2	0.2	0.12	0.15	0.08
Hydrobasaluminite	5.66	2.68	15.62	17.6	6.81
Ferrihydrite	0	0	10.61	19.05	27.96
Goethite	0	0	0	0	0
Green rust II	31.75	28.4	0	0	0
Gypsum	0.67	0.51	2.15	5.45	9.12
Ca(OH) ₂	0	0	0	0	0
Theophrastite	0	0	0	1.06	5.52
Jarosite	2.09	1.43	4.64	4.01	1.96
Ni,Fe Arsenate	1.51	1.45	2.63	7.5	0
Annabergite	0	0	0	0	7.51
Scorodite	0	0	0	22	22.36
Kankite	19.48	30.57	31.03	0	0
Strengite	5.45	4.16	4.66	3.81	3.86
Quenstedtite	28.49	27.28	16.6	6.53	8.28
NaOH	0.55	0.21	0.86	1.23	1.34
Calcium Carbonate	0	0	0	0	1.11
0	99.96	99.98	99.92	99.97	99.87
Without Gypsum	99.33	99.49	97.85	94.55	90.88

Mineralogy of the 2 Series 2002 TOVP Neutralization Tests After Adjusting for Gypsum

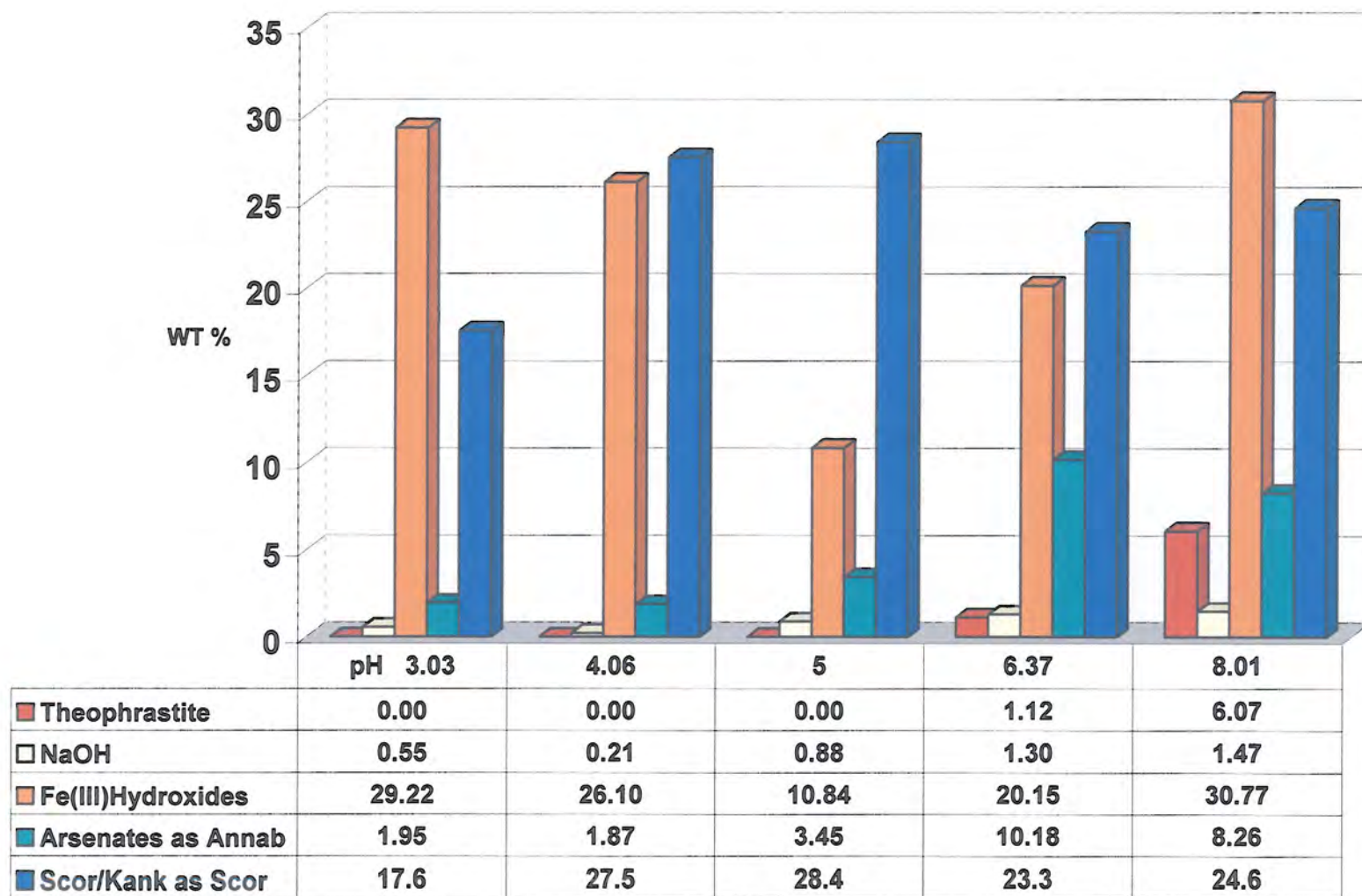
	2-2	2-3	2-4	2-5	2-7
Amorphous Silica	4.14	3.11	11.24	12.25	4.36
Rutile	0.20	0.20	0.12	0.16	0.09
Hydrobasaluminite	5.70	2.69	15.96	18.61	7.49
Ferrihydrite	0.00	0.00	10.84	20.15	30.77
Goethite	0.00	0.00	0.00	0.00	0.00
Green rust II	31.96	28.55	0.00	0.00	0.00
Gypsum	0.67	0.51	2.20	5.76	10.04
Ca(OH) ₂	0.00	0.00	0.00	0.00	0.00
Theophrastite	0.00	0.00	0.00	1.12	6.07
Jarosite	2.10	1.44	4.74	4.24	2.16
Ni,Fe Arsenate	1.52	1.46	2.69	7.93	0.00
Annabergite	0.00	0.00	0.00	0.00	8.26
Scorodite	0.00	0.00	0.00	23.27	24.60
Kankite	19.61	30.73	31.71	0.00	0.00
Strengite	5.49	4.18	4.76	4.03	4.25
Quenstedtite	28.68	27.42	16.96	6.91	9.11
NaOH	0.55	0.21	0.88	1.30	1.47
Calcium Carbonate	0.00	0.00	0.00	0.00	1.22

Weight % of Phases Precipitated by Liming of Acid Raffinate Solutions to Select pH Values

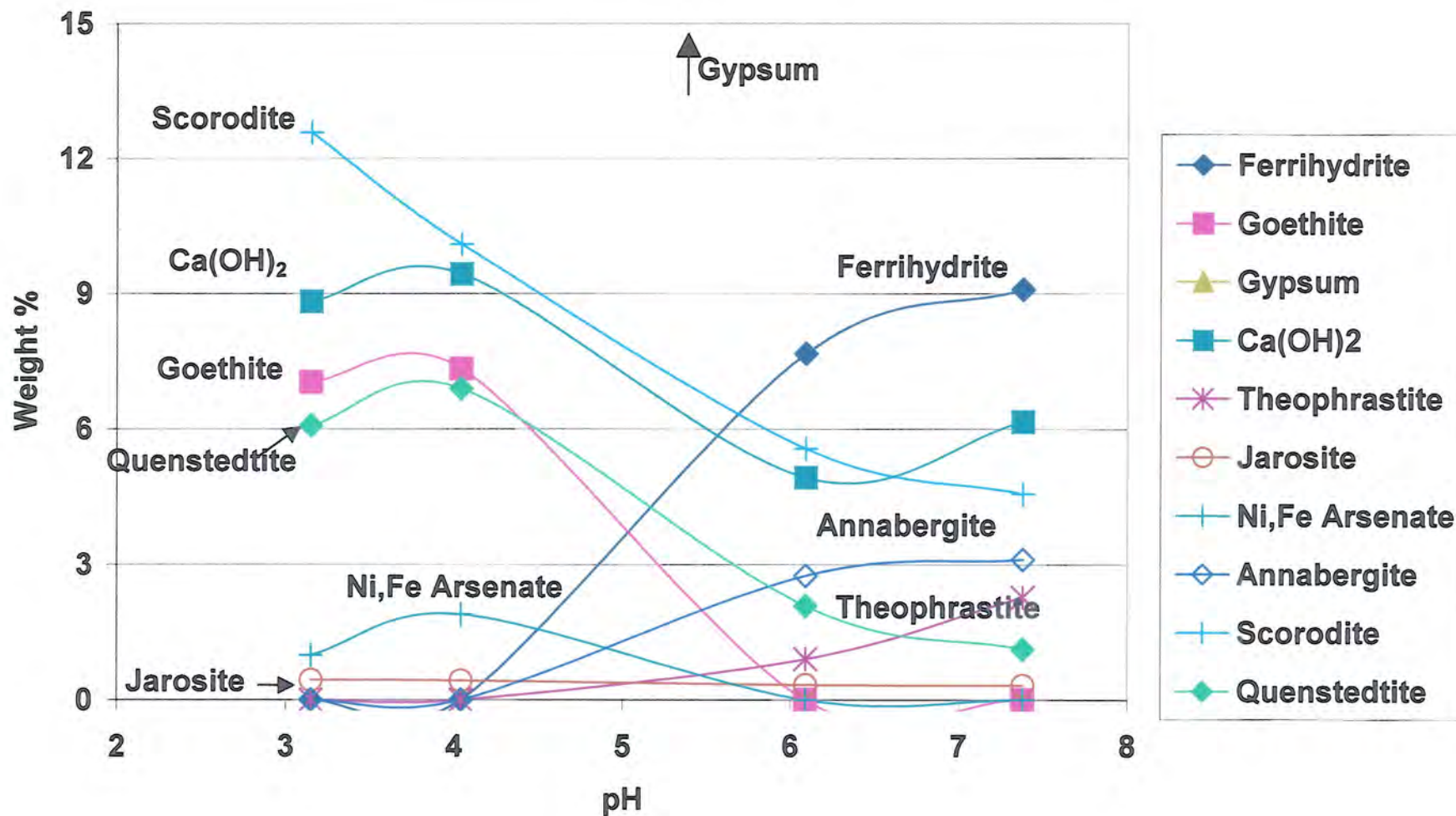


□ Ca(OH) ₂	18.5	20.6	12.2	14.7
■ Theophrastite	0.0	0.0	2.3	5.4
■ Scorodite	26.4	22.1	13.8	10.9
■ Fe(III) Hydroxides	16.0	17.3	19.1	21.7
■ TOT Arsenates as Annab	2.7	5.3	6.8	7.4

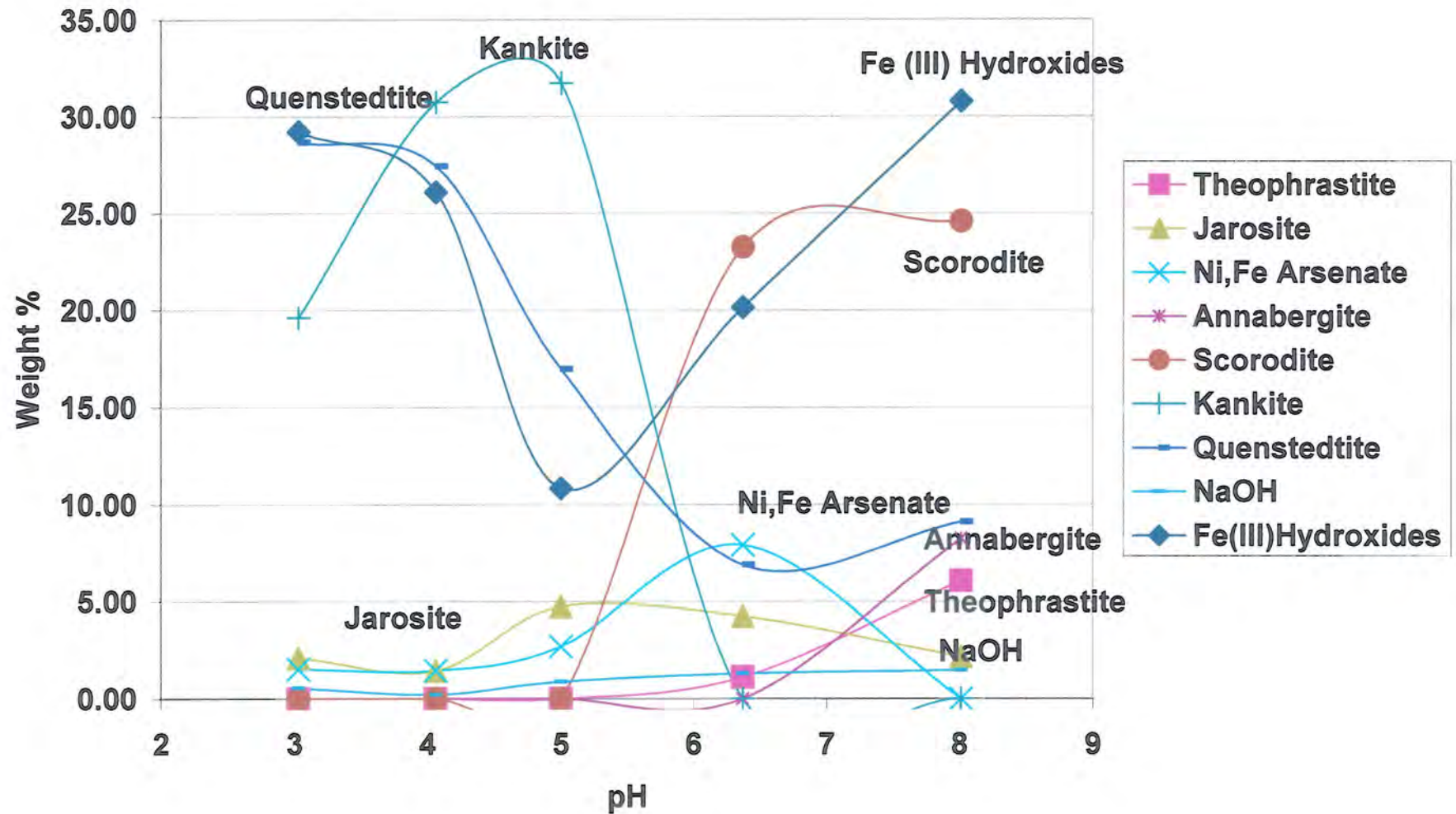
Weight % of Phases Precipitated by Neutralizing Acid Raffinate Solutions to Select pH Values



Mineralogy of Secondary Solids In Ca(OH)_2 Neutralized Raffinates (Series 6)



Mineralogy of Secondary Solids in NaOH Neutralized Raffinates (Series 2) adjusted by removing gypsum



**Appendix H - X-Ray Diffraction
Patterns of the TOVP
Neutralization Test
6-Series and 2-Series Samples**

FN: tovp6-2.rd

ID:

SCINTAG/USA

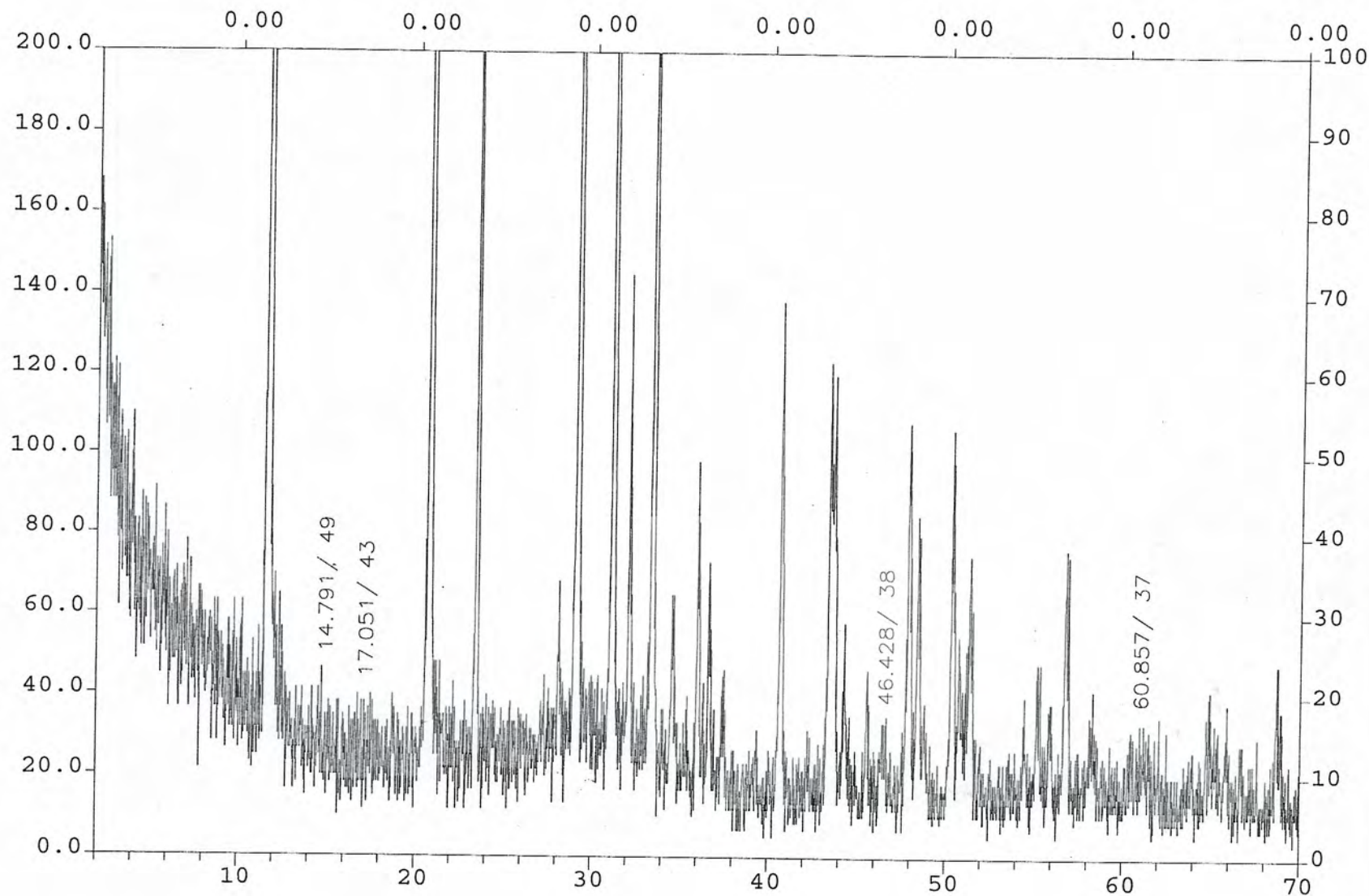
DATE: 6/22/102

TIME: 15:31

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: tovp6-2.rd

ID:

SCINTAG/USA

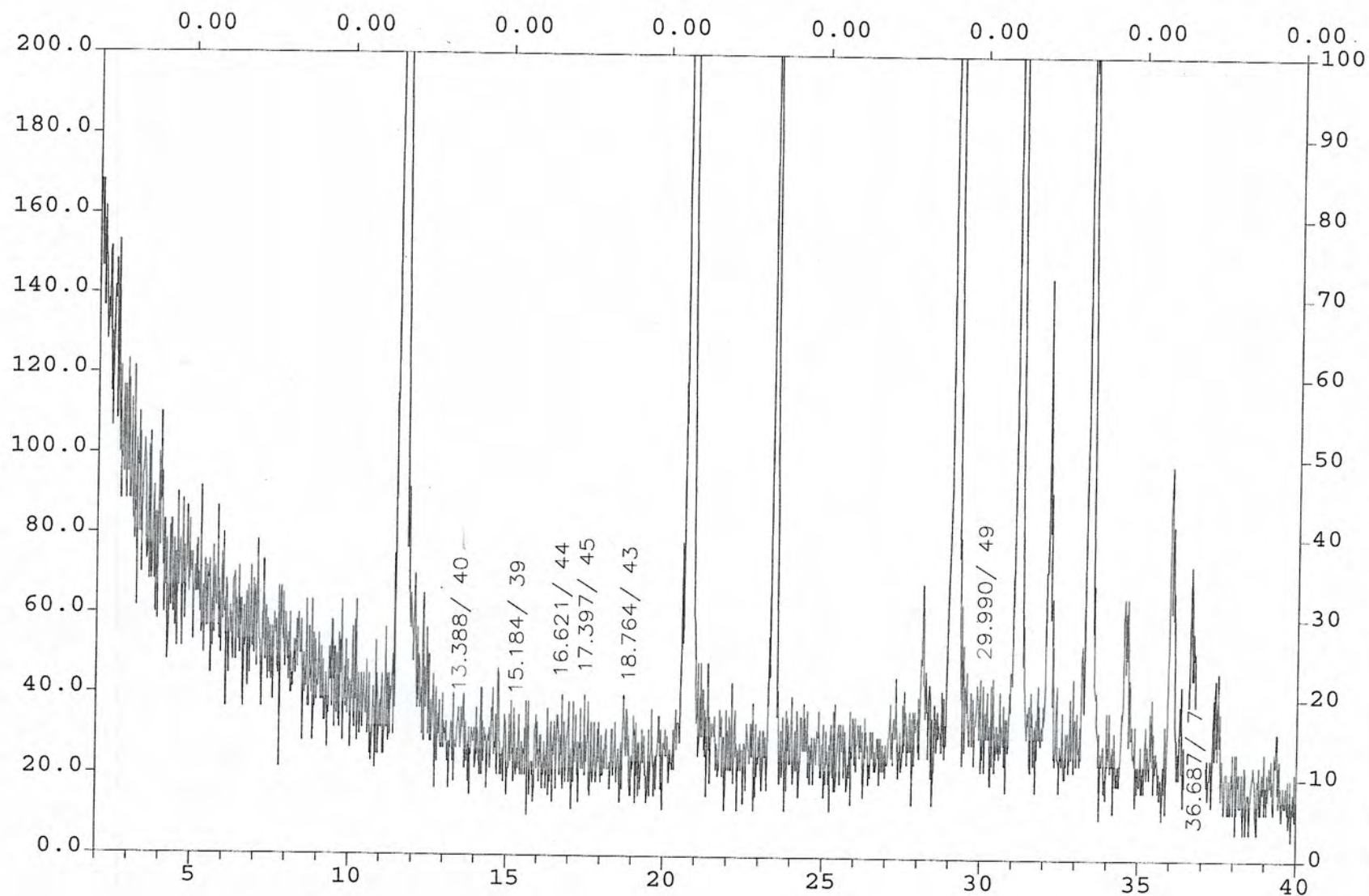
DATE: 6/22/102

TIME: 15:31

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: tovp6-3.rd

ID:

SCINTAG/USA

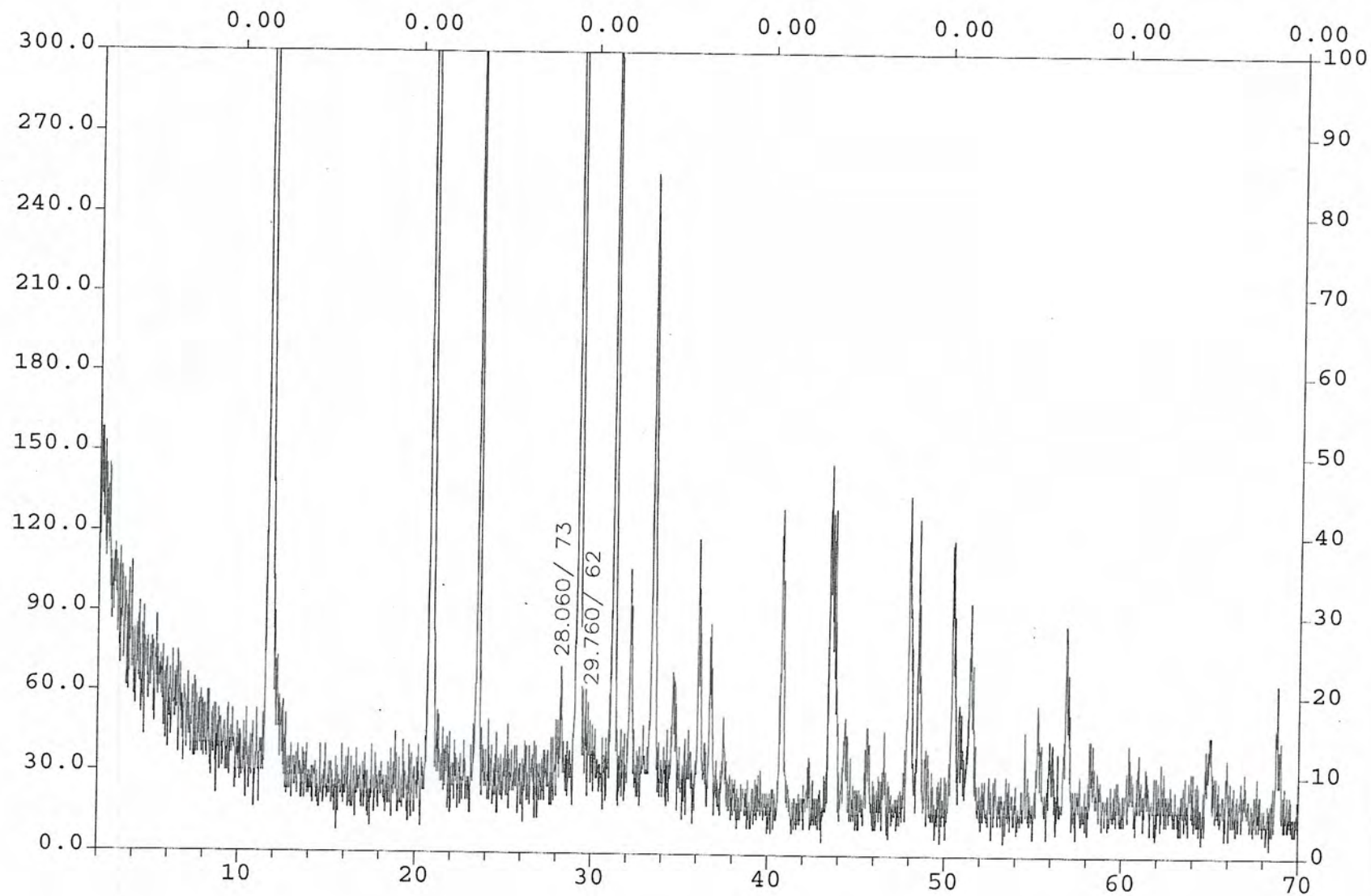
DATE: 6/22/102

TIME: 16:08

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: tovp6-3.rd

ID:

SCINTAG/USA

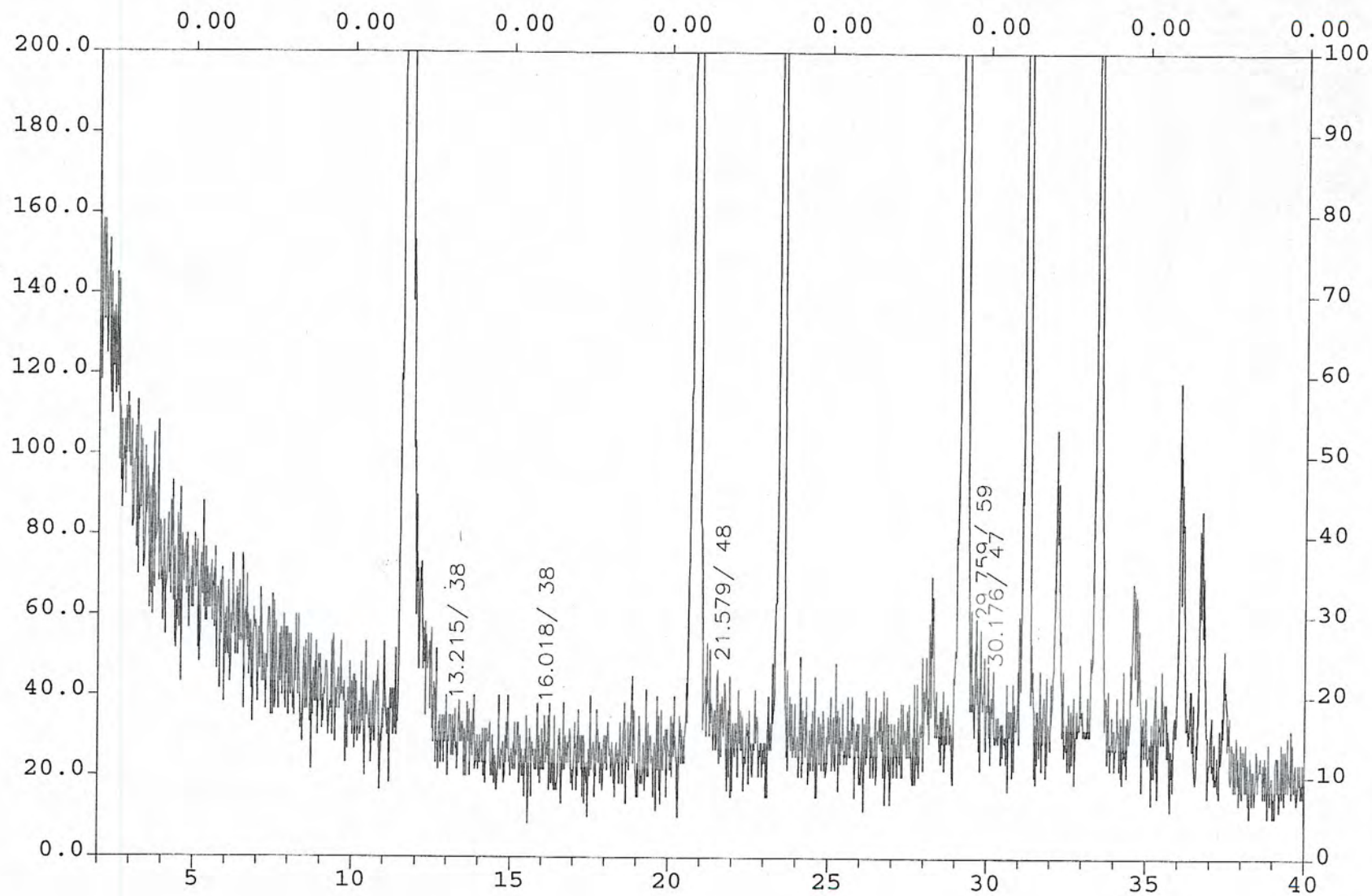
DATE: 6/22/102

TIME: 16:08

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: tovp6-4.rd

ID:

SCINTAG/USA

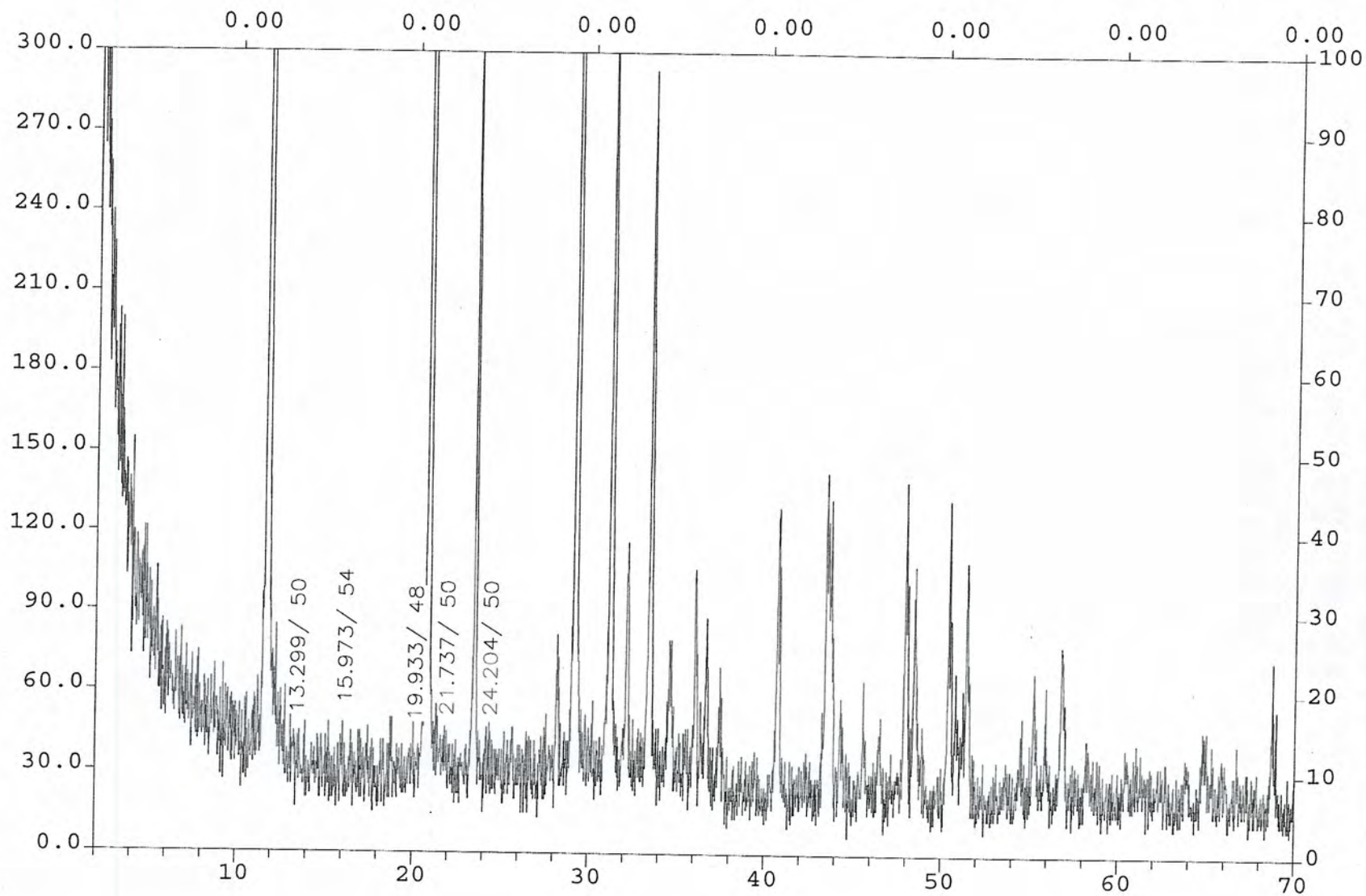
DATE: 6/22/102

TIME: 16:46

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: tovp6-4.rd

ID:

SCINTAG/USA

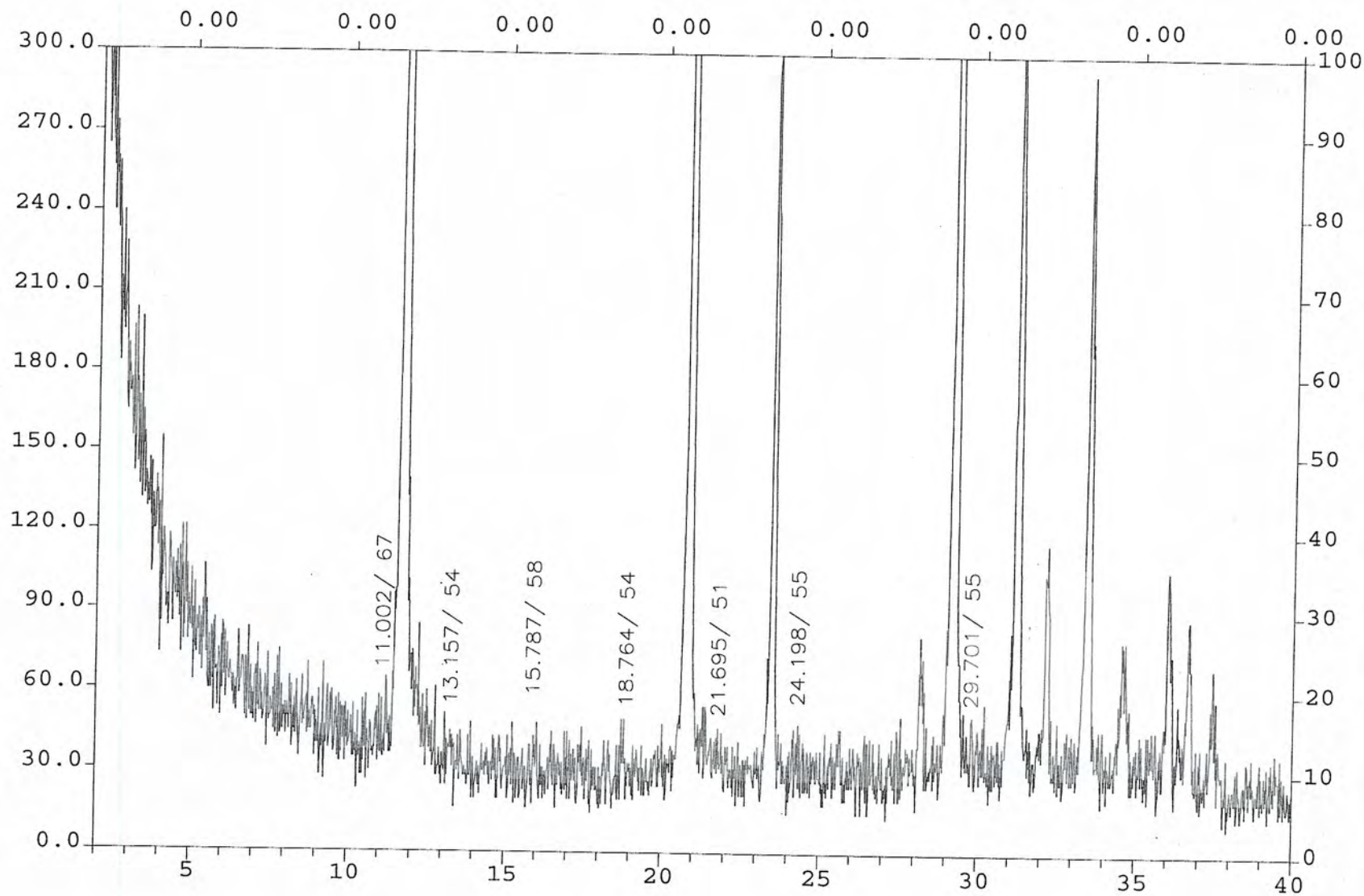
DATE: 6/22/102

TIME: 16:46

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: tovp6-4.rd

ID:

SCINTAG/USA

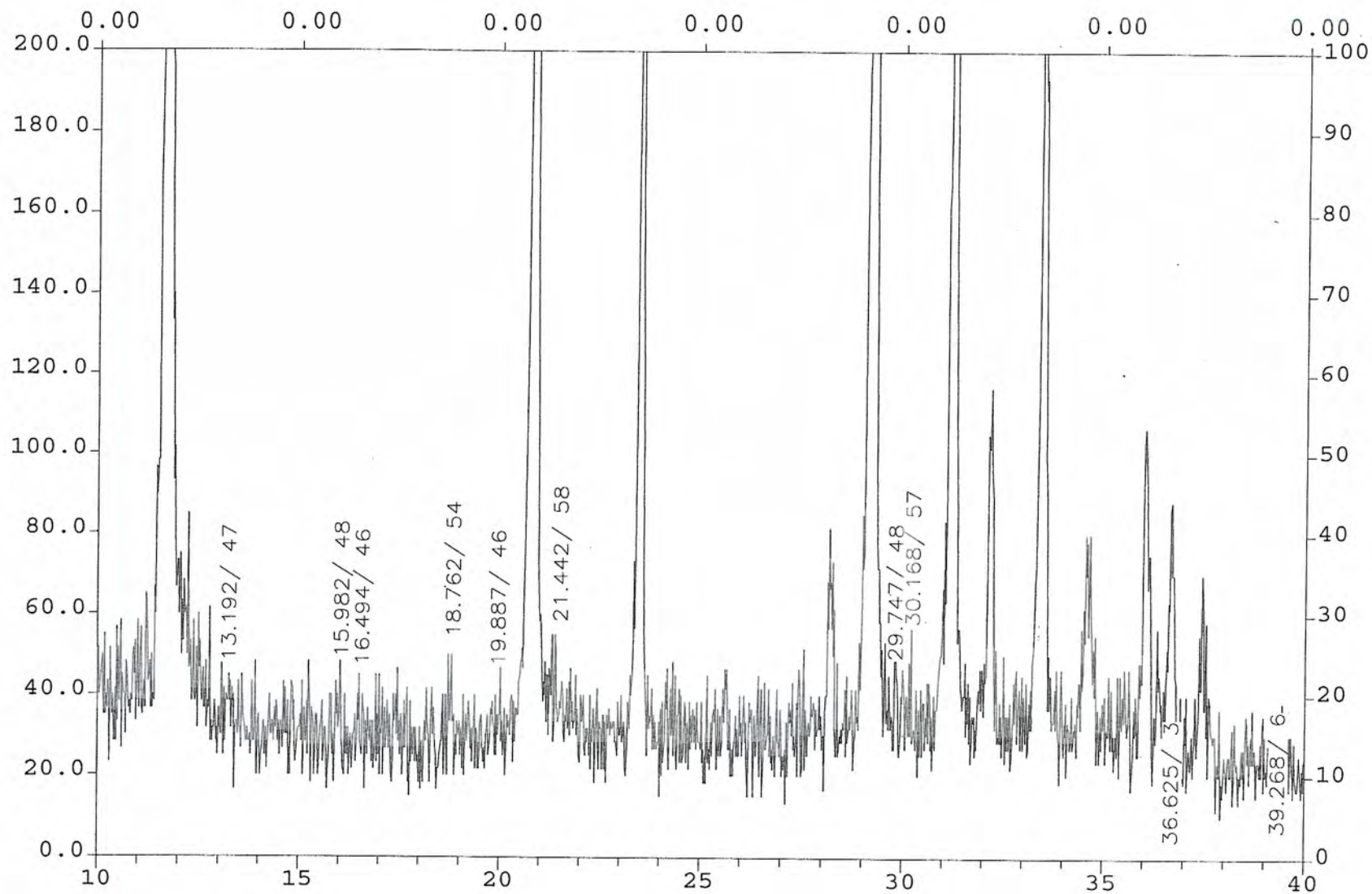
DATE: 6/22/102

TIME: 16:46

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: tovp6-5.rd

ID:

SCINTAG/USA

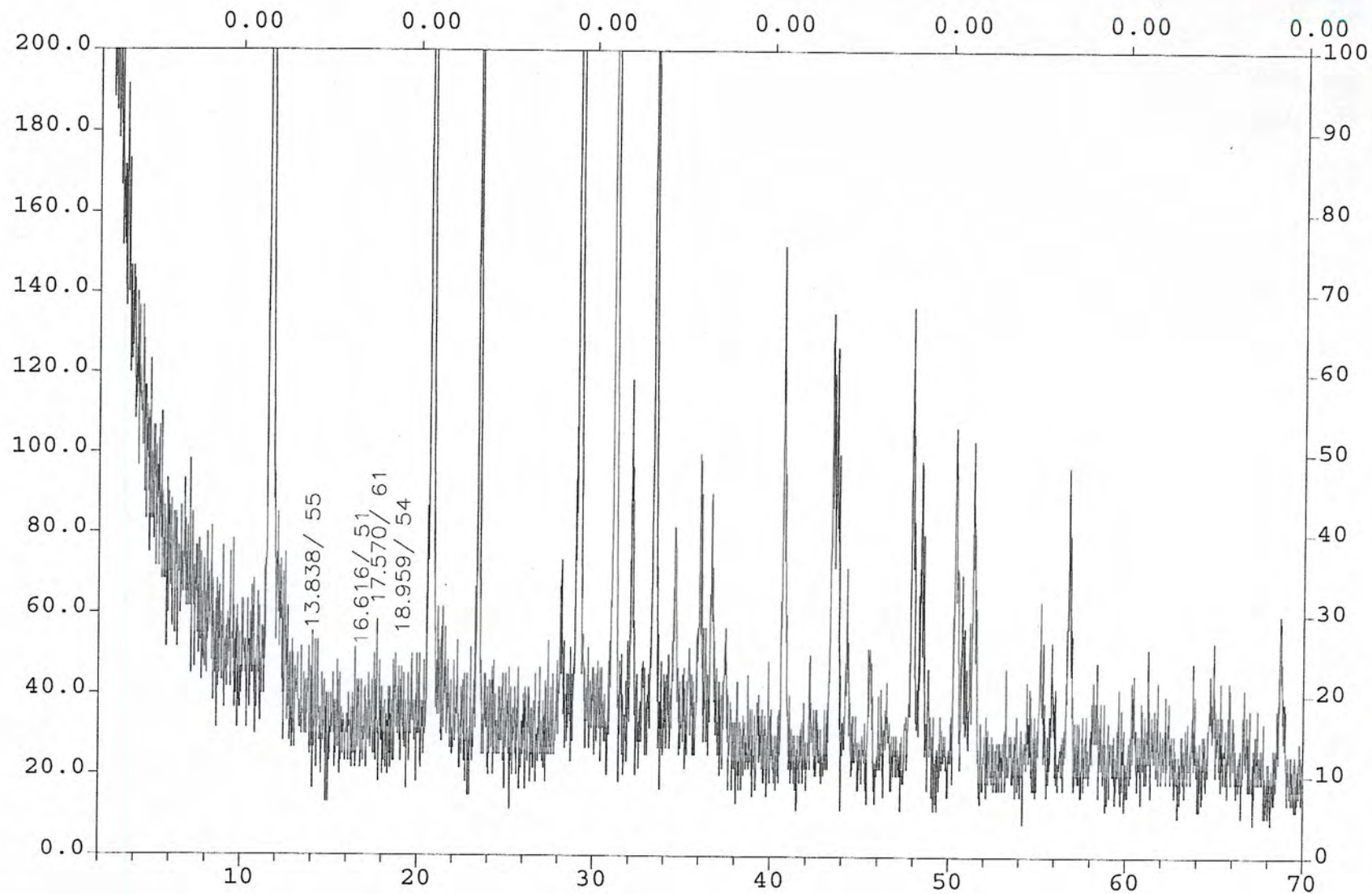
DATE: 6/22/102

TIME: 17:25

PT: -0.000

STEP: 0.020

WL: 0.00000



FN: tovp6-5.rd

ID:

SCINTAG/USA

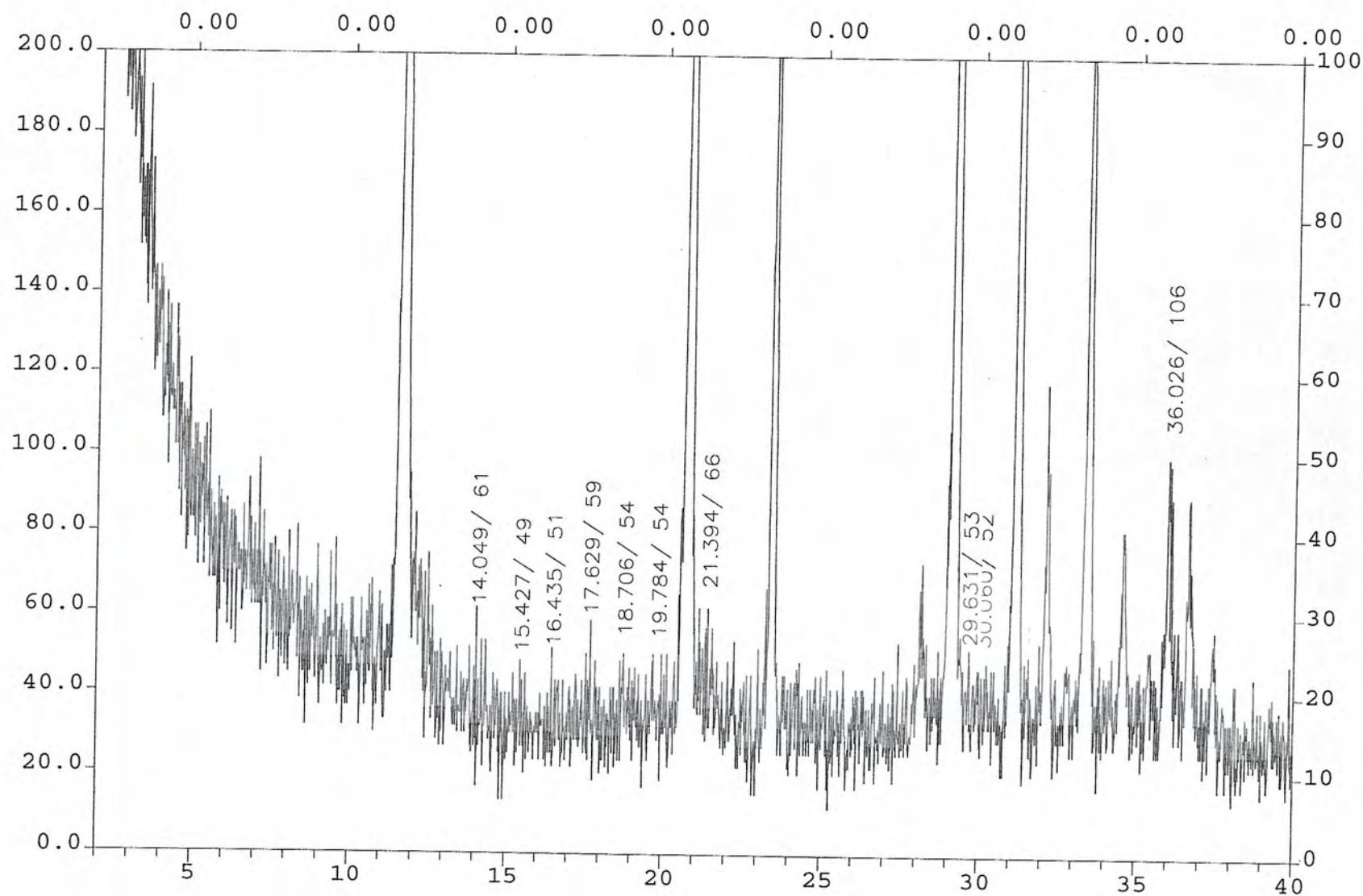
DATE: 6/22/102

TIME: 17:25

PT: -0.000

STEP: 0.020

WL: 0.00000



PK 400

FN: tovp2-3.rd

ID:

SCINTAG/USA

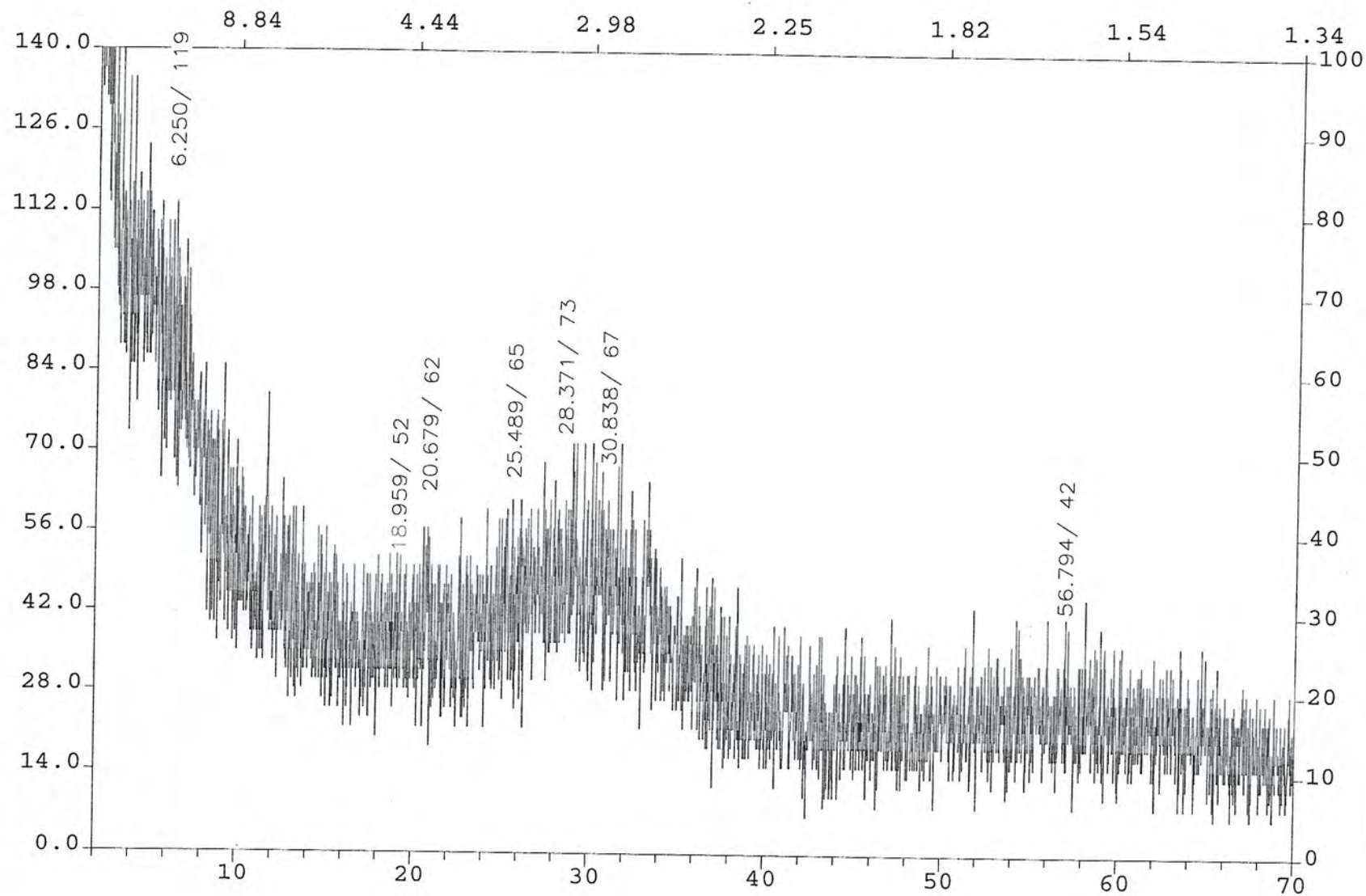
DATE: 6/22/102

TIME: 12:51

PT: 0.600

STEP: 0.020

WL: 1.54056



4303
FN: tovp2-2.rd

ID:

SCINTAG/USA

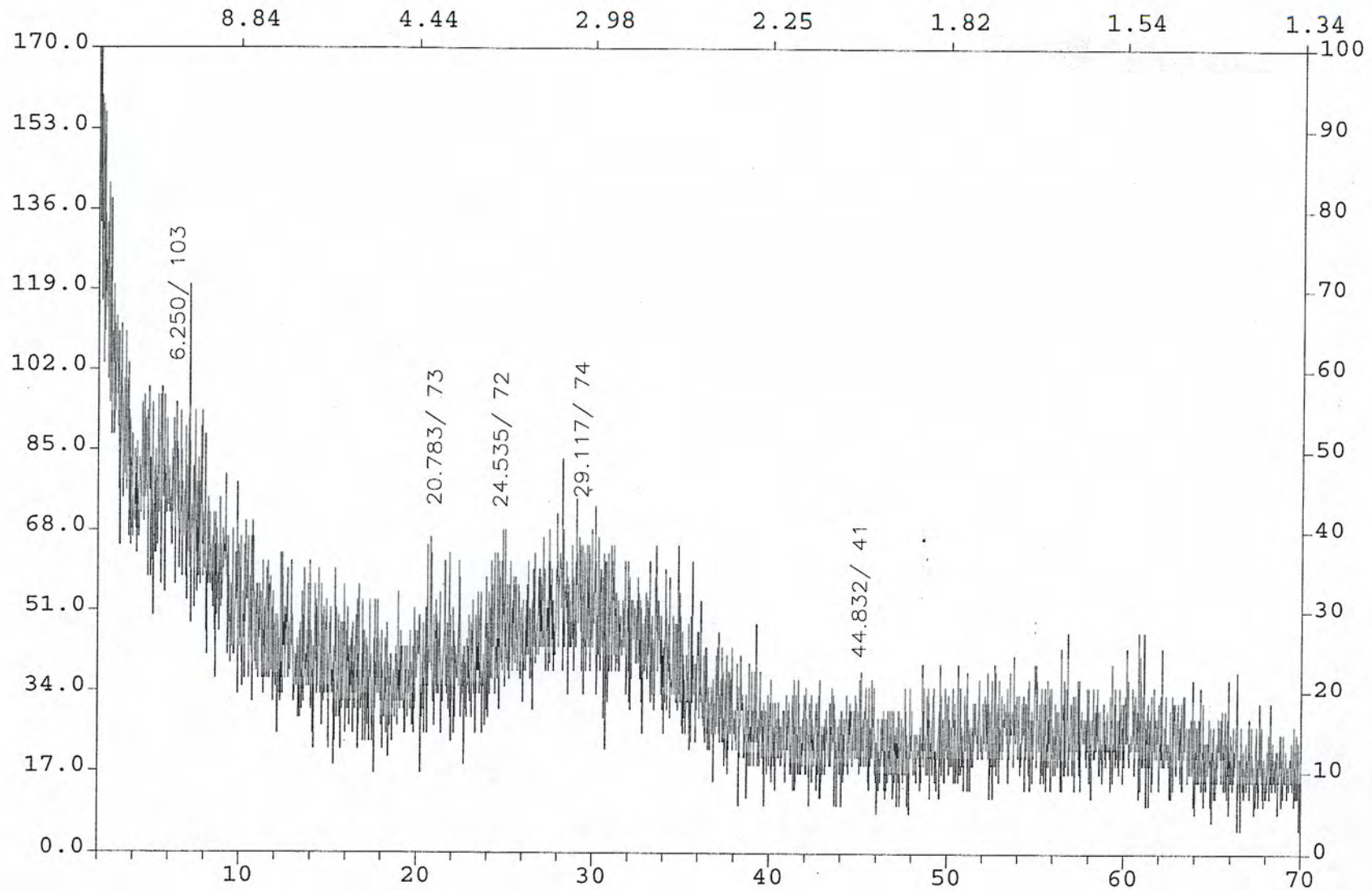
DATE: 6/22/102

TIME: 12:12

PT: 0.600

STEP: 0.020

WL: 1.54056



FN: tovp2-5.rd

ID:

SCINTAG/USA

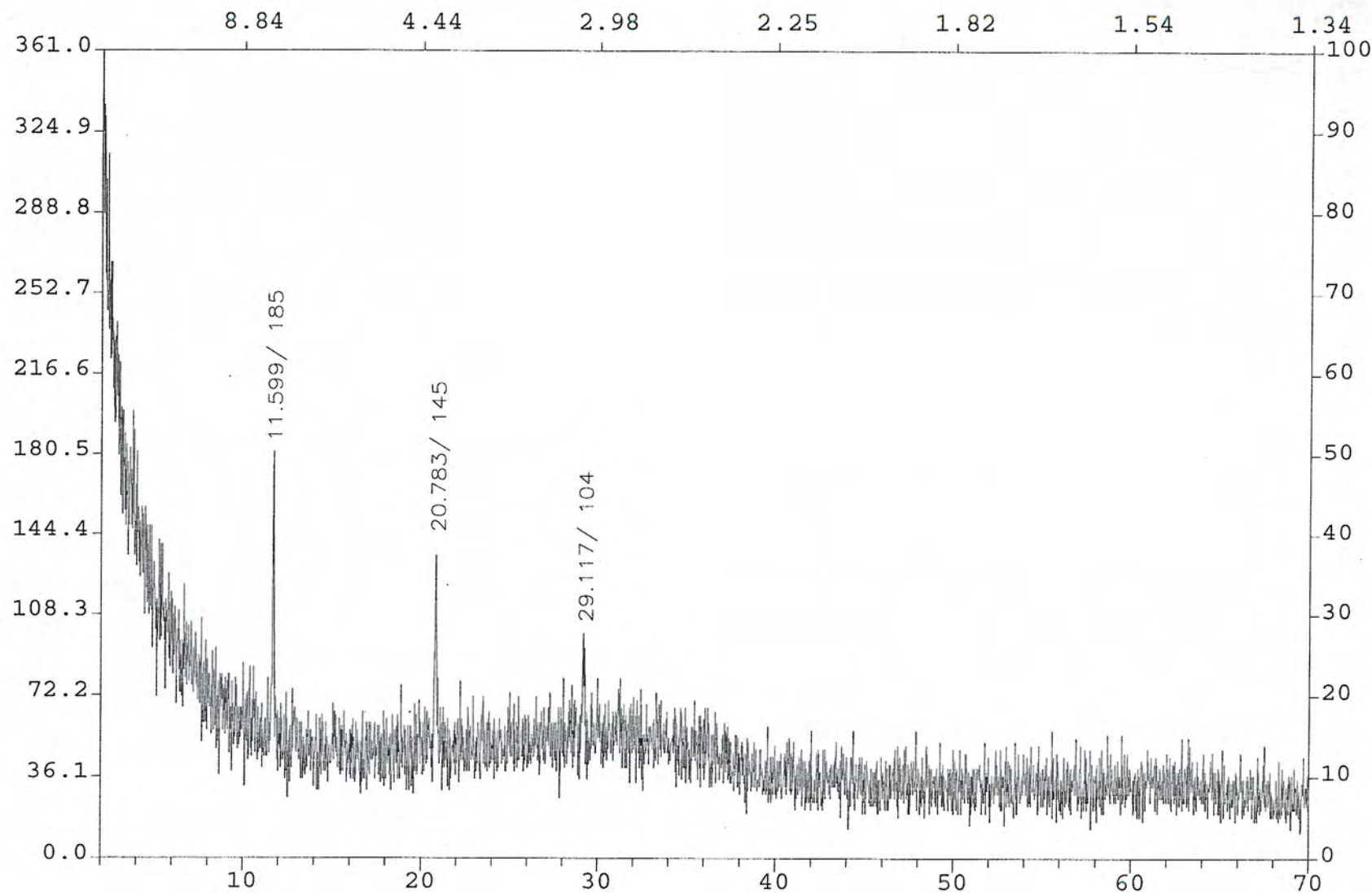
DATE: 6/22/102

TIME: 14:07

PT: 0.600

STEP: 0.020

WL: 1.54056



FN: tovp2-7.rd

ID:

SCINTAG/USA

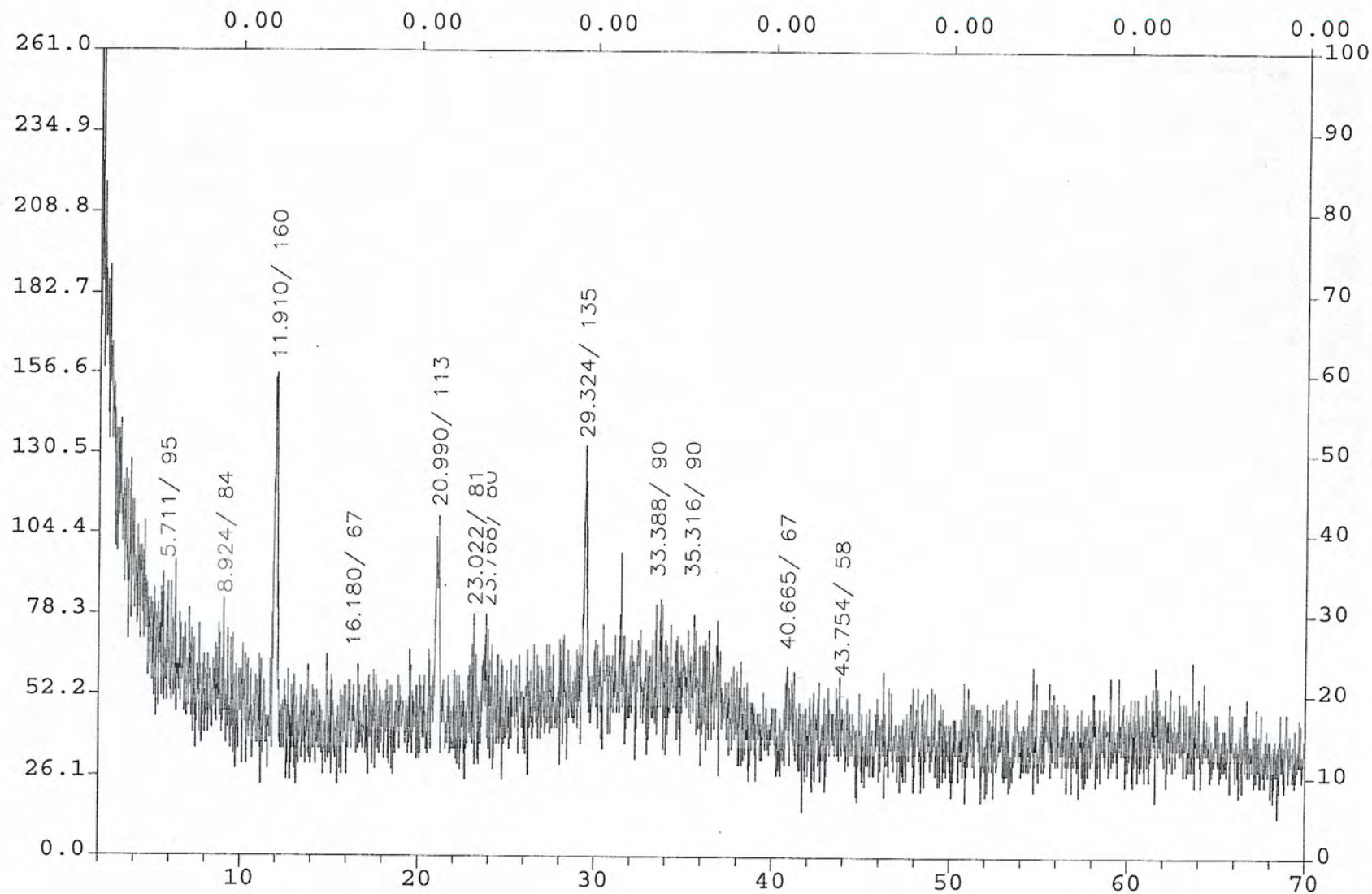
DATE: 6/22/102

TIME: 18:04

PT: -0.000

STEP: 0.020

WL: 0.00000



**Appendix I - JCPDS X-Ray Diffractions
for New and Related Minerals
in the TOVP Neutralization Test
6-Series and 2-Series,
TOVP Ageing Test, and
2001 TMF Samples**

Fe O (OH)14H O
5 7 2

Iron Oxide Hydroxide Hydrate

Ferrihydrite, syn

Rad: MoKa Lambda: 0.7107 Filter: Beta d-sp:
Cutoff: Int: Visual I/Icor:
Ref: Chukhrov, F. et al., Izv. Akad. Nauk SSSR, 23 (1973)

Sys: Hexagonal S.G.: P
a: 5.08 b: c: 9.4 A: C: 1.8504
A: B: C: Z: 1 mp:
Ref: Van der Giessen, J. Inorg. Nucl. Chem., 28 2155 (1966)

Dx: 3.80 Dm: 3.80 SS/FOM: F6=2(.109,27)

ea: nwB: ey: Sign: 2V:
Ref:

Color: Yellow, dark brown

Prepared by slow hydrolysis of ferric salts at pH>3, and below 9.5. Measured density and color from Am. Mineral., 60 485 (1975). PSC: hP26. To replace 22-1117. Mwt: 480.30. Volume[CD]: 210.08.

2-theta	Int.	h k l		
35.892	100	1	1	0
40.798	80	2	0	0
46.284	80	1	1	3
53.212	50	1	1	4
61.345	70	1	1	5
62.728	80	1	0	6

Strong lines: 2.50/X 2.21/8 1.96/8 1.48/8 1.51/7 1.72/5 0.00/1 0.00/1

				2-theta	Int.	h k l		
FeO(OH)				17.796	10	0	2	0
Iron Oxide Hydroxide				21.239	100	1	1	0
Goethite				26.347	10	1	2	0
				33.280	30	1	3	0
				34.743	8	0	2	1
Rad: Co	Lambda: 1.78897	Filter:	d-sp:	35.598	4	1	0	1
Cutoff:	Int:	1/Icor:		36.041	16	0	4	0
Ref: For original reference see PDF card set prior to 1980.				36.619	25	1	1	1
				40.004	10	1	2	1
				41.148	20	1	4	0
Sys: Orthorhombic	S.G.: Pbnm (62)			45.092	2	1	3	1
a: 4.596	b: 9.957	c: 3.021	A: 0.4616	47.306	6	0	4	1
A:	B:	C:	Z: 4	50.705	8	2	1	1
Ref: Ibid.			mp:	51.596	2	1	4	1
Dx: 4.27	Dm:	SS/FOM: F29=7(.075,57)		53.178	20	2	2	1
ea:	nwb:	ey:	Sign:	54.094	10	2	4	0
Ref:			2V:	55.260	4	0	6	0
				57.324	6	2	3	1
PSC: oP16. To replace 1-0401. Deleted by 29-713. Mwt: 88.85. Volume [CD]:				59.013	16	1	5	1
138.25.				61.390	10	0	0	2
				63.348	4	3	2	0
				64.030	10	0	6	1
				65.808	2	1	1	2
				67.198	8	3	3	0
				69.173	8	1	7	0

theta	Int.	h k l		2-theta	Int.	h k l		2-theta	Int.	h k l	
71.590	8	1	3	2							
75.094	2	3	3	1							
76.736	2	1	7	1							
80.030	2	3	4	1							

Strong lines: 4.18/X 2.69/3 2.45/3 2.19/2 1.72/2 2.49/2 1.56/2 4.98/1

O I H O 2 3 2 Iron Oxide Hydrate <i>Green Rust II</i>					2-theta	Int.	h k l		
Rad: CoKa					8.105	100	0	0	1
Lambda: 1.7902					16.161	80	0	0	2
Filter:					24.367	80	0	0	3
d-sp:					32.570	40	1	0	0
Cutoff: Int: Visual					33.666	60	1	0	1
I/Icor:					36.511	60	1	0	2
Ref: Bernal, Dasgupta, Mackay, Clay Miner. Bull., 4 15 (1959)					41.089	60	1	0	3
Sys: Hexagonal					46.840	60	1	0	4
S.G.:					53.480	20	1	0	5
a: 3.17					58.075	20	1	1	0
b:					58.765	20	1	1	1
c: 10.9					60.678	20	1	1	2
A:									
B:									
C:									
A:									
C: 3.4385									
Ref: Ibid.									
mp:									
DX:									
Dm:									
SS/FOM: F12=8(.100,15)									
ea:									
nwB:									
ey:									
Sign:									
2V:									
Ref:									
Color: Dark green									
O assigned because composition is doubtful. Prepared from ferrous sulfate and sodium hydroxide mixed in 1:1 proportions and oxidation of the precipitate.									
Also called: Green Rust II. Mwt: 177.71. Volume[CD]: 94.86.									

Strong lines: 10.9/X 5.48/8 3.65/8 2.66/6 2.46/6 2.20/6 1.94/6 2.75/4

				2-theta	Int.	h k l
(SO) 111H 0						
2 4 3 2						
Iron Sulfate Hydrate				7.681	10	0 2 0
Quenstedtite				14.159	10	0 -1 1
				14.877	20	1 0 0
				15.317	80	0 -2 1
				15.898	30	1 1 0
Rad: CuK α	Lambda: 1.5418	Filter: Mono.	d-sp: Guin. -57.4	16.588	30	0 2 1
Cutoff:	Int:	I/Icor:		17.238	10	-1 3 0
Ref: Cesbron, B., Bull. Soc. Fr. Mineral. Cristallogr., 87 125 (1964)				17.618	40	1 2 0
				18.469	5	-1 -1 1
				18.666	10	0 3 1
Sys: Triclinic	S.G.: P-1 (2)			19.982	30	1 3 0
a: 6.15	b: 23.77	c: 6.56	A:	21.187	80	-1 3 1
A: 94.17	B: 101.7	C: 96.31	Z: 2	21.765	100	-1 -3 1
Ref: Ibid.			mp:	22.319	5	0 -5 1
				22.665	10	0 6 0
Dx: 2.14	Dm: 2.15	SS/FOM: F30=3(.124,82)		22.962	30	-1 4 1
ea: 1.547	nwB: 1.566	ey: 1.594	Sign: +	23.391	60	1 1 1
Ref: Dana's System of Mineralogy, 7th Ed., II 535 (1951)				23.772	20	1 -3 1
				24.099	5	-1 -4 1
				24.851	5	1 2 1
Color: Light violet				25.354	30	0 -6 1
Specimen from Tierra Amarilla, Chile. C.D. Cell: a=6.560, b=23.770, c=6.150,				25.727	30	-1 5 1
alpha=96.31, beta=101.70, gamma=94.17, a/b=0.2760, c/b=0.2587. PSC: aP100.				26.832	20	1 3 1
Structure reference: Thomas, J., Robinson, P., Fang, J., Am. Mineral., 59 582				27.421	30	1 -5 1
(1974). Mwt: 598.03. Volume[CD]: 928.91.				28.127	30	0 -2 2

2-theta	Int.	h k l	2-theta	Int.	h k l	2-theta	Int.	h k l
28.401	20	0 1 2	33.369	5	-2 5 0			
29.063	20	-1 1 2	34.715	40	0 8 1			
29.858	5	-2 2 0	35.279	5	1 -8 1			
30.179	10	-2 0 1	35.598	5	-1 9 0			
30.797	20	-2 -1 1	36.146	10	-1 -8 1			
31.635	20	1 5 1	36.743	10	2 -4 1			
31.913	30	2 2 0	37.313	5	-1 6 2			
32.137	5	-1 8 0	37.867	5	1 3 2			
32.582	5	-1 -7 1						
33.103	20	0 4 2						

Strong lines: 4.08/X 5.78/8 4.19/8 3.80/6 5.03/4 2.58/4 5.57/3 5.34/3

					2-theta	Int.	h k l		
$\text{Ni,Mg}(\text{OH})_2$									
Nickel Hydroxide					19.005	90	0 0 1		
Theophrastite, magnesian					33.002	60	1 0 0		
					38.303	100	1 0 1		
					51.658	70	1 0 2		
					59.013	70	1 1 0		
Rad: CuK α	Lambda: 1.5418	Filter: Ni	d-sp: D.S.		62.634	50	1 1 1		
Cutoff:	Int: Visual	I/Icor:			69.524	30	1 0 3		
Ref: Livingstone, A., Bish, Mineral. Mag., 46 1 (1982)					72.675	30	1 1 2		
					82.267	20	2 0 2		
					88.592	5	1 1 3		
Sys: Hexagonal	S.G.: P-3m1 (164)				91.762	5	1 0 4		
a: 3.131	b:	c: 4.666	A:	C: 1.4903	97.699	10	2 0 3		
A:	B:	C:	Z: 1	mp:	101.039	15	2 1 1		
Ref: Ibid.					110.589	15	2 1 2		
Dx: 3.31	Dm: 3.60	SS/FOM: F15=5(.121,23)			117.297	10	3 0 0		
ea:	nwB:	ey:	sign:	2V:					
Ref:									
Color: Blue-green									
Specimen from the Hagdale quarry, Unst, Shetland, Scotland. Microprobe analysis, average of two theophrastite-zaratite grains (wt.%): NiO 63.1, MgO 7.6, CuO 0.9, SO ₃ 1.1, minor SiO ₂ , FeO: (Ni _{0.628} Mg _{0.372})(OH) ₂ , with Dx = [3.350]. n=1.66, for blue-green; n=1.613, for emerald-green. Brucite group, brucite subgroup. PSC: hP5. Deleted by 14-117, higher FN; Bayliss 6/92. Mwt: 78.96. Volume[CD]: 39.61.									

Strong lines: 2.35/X 4.67/9 1.77/7 1.56/7 2.71/6 1.48/5 1.35/3 1.30/3