CHAPTER V

RESULTS

This chapter describes the analytical results of geological materials particularly those of rock and soil samples collected from the study area by X-Ray fluorescence (XRF), atomic absorption spectrophotometry (AAS) techniques, and spectrophotometry. Samples were analyzed for aluminium, iron, manganese, zinc, copper, and lead.

XRF Analysis

Fifteen international standard reference rocks were employed in the XRF analysis for the purpose of quality control. Certified value for both major and minor elements are shown in Table 5.1 and the analytical results of those reference materials obtained in this study are shown in Table 5.2.

Comparing the results with the certified values, it is obvious that the XRF results should be resonably reliable and can be viewed with a strong confidence. The results are shown in Table 5.3.

Table 5.1 Certified values of reference rocks used in XRF technique.

Ref.	Type	Al$_2$O$_3$ (%)	Fe$_2$O$_3$ (%)	MnO (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)
mica-Fe	Biotite	19.50	25.65	0.35	130	0.4	1.3
BEN	Basalt	10.07	12.84	0.20	12	7.2	0.4
MRG-1	Gabbro	8.50	17.82	0.17	19	13.5	0.1
JGB-1*	Gabbro	17.66	15.16	0.17	10	8.5	0.2
ANG	Anorthosite	29.80	3.36	0.04	2	1.9	0.2
BHVO1	Basalt	13.85	12.23	0.17	18	14	NA
NIM-L	Lujavrite	13.64	10.00	0.77	40	1.3	4.3
AGV-1	Andesite	17.19	6.78	0.1	8.6	5.9	6.6
SY-3	Syenite	11.80	6.42	0.32	24	1.6	13
FKN	K-Feldspar	18.61	0.09	0.01	10	0.2	24
GSP-1	Granodiorite	15.16	4.32	0.04	10.3	3.4	5.4
G-2	Granite	15.40	2.68	0.03	1.1	3.1	8.5
JR-2*	Rhyolite	12.86	0.86	0.11	2.7	0.2	2.1
BCS267	Silica Brick	0.85	0.79	0.15	NA	NA	NA
SO-4	Soil	10.32	3.39	0.08	9.4	2.2	1.4

NA = No Data

Standard rock of USGS (United State Geological Survey)

* = GSJ (Geological Survey of Japan).

Table 5.2 Analytical results of reference rocks by XRF technique.

Ref.	Type	Al_2O_3 (%)	Fe_2O_3 (%)	MnO (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)
mica-Fe	Biotite	19.00	24.15	0.29	125	0.3	1.3
BEN	Basalt	10.01	12.80	0.19	11	7	0.3
MRG-1	Gabbro	8.49	17.7	0.11	18	13.5	0.1
JGB-1*	Gabbro	17.16	14.96	0.16	9.5	8.1	0.2
ANG	Anorthosite	29.5	3.34	0.04	2	1.9	0.2
BHVO1	Basalt	13.74	12.13	0.15	17	13	NA
NIM-L	Lujavrite	13.00	9.5	0.77	39	1.3	4
AGV-1	Andesite	17.10	6.66	0.1	8.4	5.5	6.3
SY-3	Syenite	11.74	6.2	0.82	22	1.4	12
FKN	K-Feldspar	17.61	0.09	0.01	8	0.2	22
GSP-1	Granodiorite	15.16	4.22	0.03	9.3	3.4	5.4
G-2	Granite	15.4	2.64	0.03	1.1	3.1	8.5
JR-2*	Rhyolite	12.6	0.86	0.11	2.7	0.2	2.1
BCS267	Silica Brick	0.79	0.65	0.15	NA	NA	NA
SO-4	Soil	10.2	3.37	0.07	8.9	2.2	1.4

NA = No Data

Standard rock of USGS (United State Geological Survey)

* = GSJ (Geological Survey of Japan).

Table 5.3   Analytical results of samples by XRF technique

sample code	type	Al_2O_3 (%)	Fe_2O_3 (%)	MnO (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)
KN-1	sandstone	2.11	1.88	0.06	20	11	<5
KN-2	limestone	<0.01	<0.01	<0.01	<10	<10	<5
KN-3	metamorphic	2.16	0.77	<0.01	<10	<10	<5
KN-4	sandstone	0.07	<0.01	<0.01	<10	<10	<5
KN-5	shale	17.16	5.96	0.01	30	43	20
KN-6	shale	19.39	7.93	0.08	40	30	<5
KN-7	shale	8.76	2.66	0.04	<10	16	<5
KN-8	shale	11.4	4.33	0.04	15	46	8
KN-9	limestone	<0.01	<0.01	<0.01	<10	<10	<5
KN-10	limestone	0.97	0.4	0.02	<10	<10	<5
KN-11	limestone	<0.01	<0.01	<0.01	<10	<10	<5
KN-12	limestone	<0.01	<0.01	<0.01	<10	<10	<5
KN-13	limestone	<0.01	<0.01	<0.01	14	<10	<5
KN-14	limestone	<0.01	0.03	<0.01	26	<10	<5
KN-15	shale	15.85	10.06	0.01	21	47	<5
KN-16	metamorphic	14.44	0.76	0.03	40	25	14
KN-17	metamorphic	2.92	0.67	<0.01	20	20	16
KN-18	limestone	3.11	0.65	<0.01	10	<10	<5
KN-19	limestone	2.5	0.4	<0.01	25	<10	9
KN-20	shale	11.32	4.68	0.22	40	65	30
KN-21	limestone	0.03	0.07	0.01	<10	<10	<5
KN-22	shale	16.01	7.6	0.02	40	27	14
KN-23	shale	5.02	2.04	<0.01	<10	<10	27
KN-24	shale	3.91	1.41	0.06	27	<10	44
KN-25	sandstone	1.36	0.6	0.09	16	<10	<5
KN-26	limestone	0.99	2.34	0.27	36	<10	14

sample code	type	Al_2O_3 (%)	Fe_2O_3 (%)	MnO (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)
KN-27	metamorphic	5.71	2.45	0.05	<10	<10	33
KN-28	limestone	<0.01	<0.01	<0.01	<10	<10	<5
KN-29	limestone	0.05	<0.01	<0.01	<10	<10	<5
KN-30	limestone	0.07	0.01	<0.01	<10	<10	<5
KN-31	sandstone	1.27	0.71	<0.01	<10	<10	12
KN-32	sandstone	0.23	0.36	0.02	<10	<10	<5
KN-33	shale	3.47	2.12	0.02	34	<10	22
KN-34	shale	3.22	2.72	0.01	45	<10	25
KN-35	limestone	0.02	0.02	<0.01	24	<10	<5
KN-36	limestone	1.09	0.21	<0.01	<10	<10	<5
KN-37	shale	1.81	0.38	<0.01	50	30	28
R-1	limestone	0.06	0.03	<0.01	14	<10	<5
R-2	limestone	0.1	0.04	<0.01	<10	<10	<5
R-3	limestone	0.28	0.03	<0.01	<10	<10	<5
R-4	limestone	0.11	0.01	<0.01	<10	<10	<5
R-5	shale	16.76	8.04	0.01	30	28	10
R-6	shale	14.38	5.94	0.06	31	25	11
R-7	limestone	1.77	1.09	0.05	36	<10	10
R-8	sandstone	0.02	0.22	0.01	<10	<10	<5
R-9	limestone	<0.01	0.05	<0.01	<10	<10	<5
R-10	limestone	0.09	0.03	<0.01	<10	<10	<5
R-11	shale	16.88	5.01	4.07	55	24	15
R-12	shale	13.38	1.11	<0.01	40	21	14
R-13	shale	14.64	7.06	0.03	44	64	26
R-14	shale	11.48	0.64	<0.01	21	<10	<5
R-15	limestone	0.05	0.02	<0.01	<10	<10	<5
R-16	limestone	0.03	0.03	<0.01	<10	<10	<5

sample code	type	Al$_2$O$_3$ (%)	Fe$_2$O$_3$ (%)	MnO (%)	Zn (ppm)	Cu (ppm)	Pb (ppm)
R-17	limestone	0.01	0.05	<0.01	11	<10	<5
G-1	granite	12.69	1.72	0.03	33	<10	64
B-1	basalt	14.57	10.66	0.18	35	85	<5
ST-1	soil	10.98	2.66	0.1	36	25	10
ST-3	soil	11.91	3.81	0.11	39	69	15
ST-6	soil	16.73	6.71	0.24	29	82	20

However, the high detection limit of the XRF technique, especially those for the trace metals, makes the technique unsuitable for the purpose of this study. In addition, some results are not shown as exact number but by range, thus, making the calculation and assumption test of statistical procedure impossible.

For more precise data, the AAS technique which yields lower detection limit is employed. And for the purpose of quality control a standard reference rock (JDO-1), dolomite, from Geological Survey of Japan was analyzed with every batch of samples. The certified values of JDO-1 is shown in Table 5.4

Table 5.4 Certified values of standard reference rock (JDO-1).

	Mean	Standard deviation	Maximum	Minimum
Al (ppm)	85.76	37.06	158.82	42.35
Fe (ppm)	143.35	39.16	209.77	48.95
Mn (ppm)	48.00	7.201	54.20	30.97
Zn (ppm)	34.45	4.83	39.8	23.5

Unfortunately, the values of copper and lead of the JDO-1 are not certified because the number of laboratories participation in the intercalibration exercise of JDO-1 is not large enough to make the analytical results of copper and lead statistically acceptable. In addition, the results of each laboratory vary considerably (as shown in Table 5.5).

Table 5.5 Uncertified values for trace metals of the JDO-1.

Cu conc. (ppm)	tech.	lab code	Pb conc. (ppm)	tech.	lab code
1.3	AA	B-213	2.1	AA	B-239
1.3	AA	B-272	<6	XRF	B-304
<5	XRF	B-239	<10	XRF	B-226
5.5	AA	B-266			

Cu conc. : concentration of copper in ppm.
Pb conc. : concentration of lead in ppm.
tech. : Analytical technique.
lab code : Laboratory

In order to establish reliable values for trace elements of the JDO-1. Two replicates of JDO-1 were analyzed with every batch of sample making a total of 20 replicates. All replicates of JDO-1 were analyzed with GFAAS for Zn, Cu, and Pb. Average values of the 20 replicates are shown in Table 5.6 and analytical results in this study are shown in Table 5.7.

Table 5.6 Average values for trace metals in the JDO-1.

Laboratory	Zn (ppm)	Cu (ppm)	Pb (ppm)
EMDEC [1]	38.45	2.84	1.92
Marine sciences [2]	39.50	3.00	2.00
STREC [3]	40.25	9.84	6.00
PERKIN [4]	37.14	2.68	1.80

[1] Eastern Marine Fisheries Development Center, GFAAS Hitachi series Z-8100

[2] Marine Sciences Laboratory, Chulalongkorn University, GFAAS Perkin-Elmer series 4100 ZL

[3] Scientific And Technological Research Equipment Centre, GFAAS Variance series Spectr AA-300 GTA 96 graphite tube.

[4] Laboratory of Perkin-Elmer(Thailand) Ltd., GFAAS Perkin-Elmer series SIMAA 6000

Table 5.7 Analytical results of samples by AAS technique (in ppm).

sample code	type	Al	Fe	Mn	Zn	Cu	Pb
KN-1	sandstone	23441	3417.40	741.74	19.97	14.39	9.62
KN-2	limestone	8100	696.13	118.45	13.66	7.17	4.52
KN-3	metamorphic	45366	19396.33	358.65	30.54	20.56	8.95
KN-4	sandstone	25750	3578.76	887.61	12.50	15.53	5.63
KN-5	shale	79930	45248.59	807.42	51.17	30.85	26.91
KN-6	shale	87800	51190.78	685.89	64.39	29.75	21.52
KN-7	shale	55111	13621.67	834.94	33.09	21.57	17.61
KN-8	shale	38866	11269.20	695.03	21.45	15.53	9.12
KN-9	limestone	2900	1361.46	242.23	10.05	4.34	1.93
KN-10	limestone	7916	2060.90	451.27	22.01	4.38	4.89
KN-11	limestone	1756	117.21	108.02	7.03	2.50	2.04
KN-12	limestone	2723	1108.90	252.76	9.92	2.61	1.96
KN-13	limestone	5666	1020.44	249.66	12.33	4.38	4.26
KN-14	limestone	3960	1821.50	244.50	15.91	2.97	3.35
KN-15	shale	76300	51998.30	654.32	61.39	24.67	24.23
KN-16	metamorphic	81333	40487.26	683.85	51.48	30.02	23.87
KN-17	metamorphic	31053	12332.35	448.88	24.73	20.50	13.92
KN-18	limestone	3006	1676.29	15.72	9.91	12.43	2.66
KN-19	limestone	17533	11771.00	907.54	33.19	15.02	15.89
KN-20	shale	51466	13145.94	469.16	34.64	17.24	20.54
KN-21	limestone	5916	1436.94	339.93	19.05	7.13	5.79
KN-22	shale	62366	24832.84	520.01	30.77	27.37	19.7
KN-23	shale	67800	14514.22	469.07	39.86	20.04	20.05
KN-24	shale	84733	39357.81	685.48	53.2	36.7	29.07
KN-25	sandstone	14033	11518.27	933.19	33.53	10.22	8.65
KN-26	limestone	9700	2678.45	313.43	31.41	7.58	19.73
KN-27	metamorphic	78140	27303.95	484.68	54.88	26.98	20.15

sample code	type	Al	Fe	Mn	Zn	Cu	Pb
KN-28	limestone	2533	1448.51	289.18	12.78	5.12	4.07
KN-29	limestone	2446	1025.72	134.46	9.3	10.91	6.21
KN-30	limestone	5710	1245.13	331.72	9.78	3.21	9.63
KN-31	sandstone	15166	4658.07	99.64	17.26	10.77	11.43
KN-32	sandstone	11366	924.54	125.25	20.77	12.86	5.55
KN-33	shale	52033	14455.77	586.63	47.00	28.74	18.21
KN-34	shale	48166	16433.73	636.14	35.01	29.61	21.05
KN-35	limestone	2980	2019.16	366.7	12.62	6.15	4.29
KN-36	limestone	10283	7598.13	994.89	32.46	14.59	13.50
KN-37	shale	97900	51066.83	963.51	66.44	30.36	29.51
R-1	limestone	4756	2413.19	628	24.39	4.49	6.62
R-2	limestone	3233	2887.11	350.8	22.89	7.3	5.26
R-3	limestone	6340	2683.12	344.08	24.73	4.36	6.46
R-4	limestone	2283	1795.66	286.21	30.39	4.79	5.2
R-5	shale	57533	22454.33	473.61	29.39	25.68	13.47
R-6	shale	56800	18692.95	988.09	32.72	23.24	12.47
R-7	limestone	15500	6124.45	515.34	36.62	12.65	13.43
R-8	sandstone	17976	9799.17	71.18	39.35	10.37	14.83
R-9	limestone	7516	3670.84	547.39	18.62	4.35	6.30
R-10	limestone	5500	2527.14	1008.1	20.23	2.59	6.07
R-11	shale	56766	28632.05	669.74	35.06	30.86	28.09
R-12	shale	66600	34829.23	410.6	40.68	25.76	18.07
R-13	shale	89433	43580.96	779.6	55.52	39.86	26.53
R-14	shale	87500	40589.31	947.18	59.35	32.82	27.59
R-15	limestone	4046	1749.14	435.34	19.84	4.40	5.75
R-16	limestone	3633	2188.41	358.8	17.38	6.72	5.36
R-17	limestone	3023	1154.18	256.13	20.51	7.25	6.21

sample code	type	Al	Fe	Mn	Zn	Cu	Pb
G-1	granite	82066	31575.76	544.06	62.97	31.94	19.84
B-1	basalt	73266	66962.62	1049.5	64.15	42.52	16.24
ST-1	soil	58413	19866.96	1097.4	53.09	25.89	21.53
ST-2	soil	76591	30678.07	1094.8	51.21	27.55	21.87
ST-3	soil	63256	34743.94	1027.1	50.12	20.21	20.49
ST-4	soil	74153	32740.37	1145.0	56.32	26.34	22.63
ST-5	soil	87463	44525.52	1052	55.32	39.19	25.53
ST-6	soil	88536	42513.02	1122.3	63.62	40.81	26.3
	Mean	37313.3	16761.06	569.90	33.06	17.52	13.74
	SD	32985.1	17522.49	316.48	17.61	11.75	8.48