Factor 3

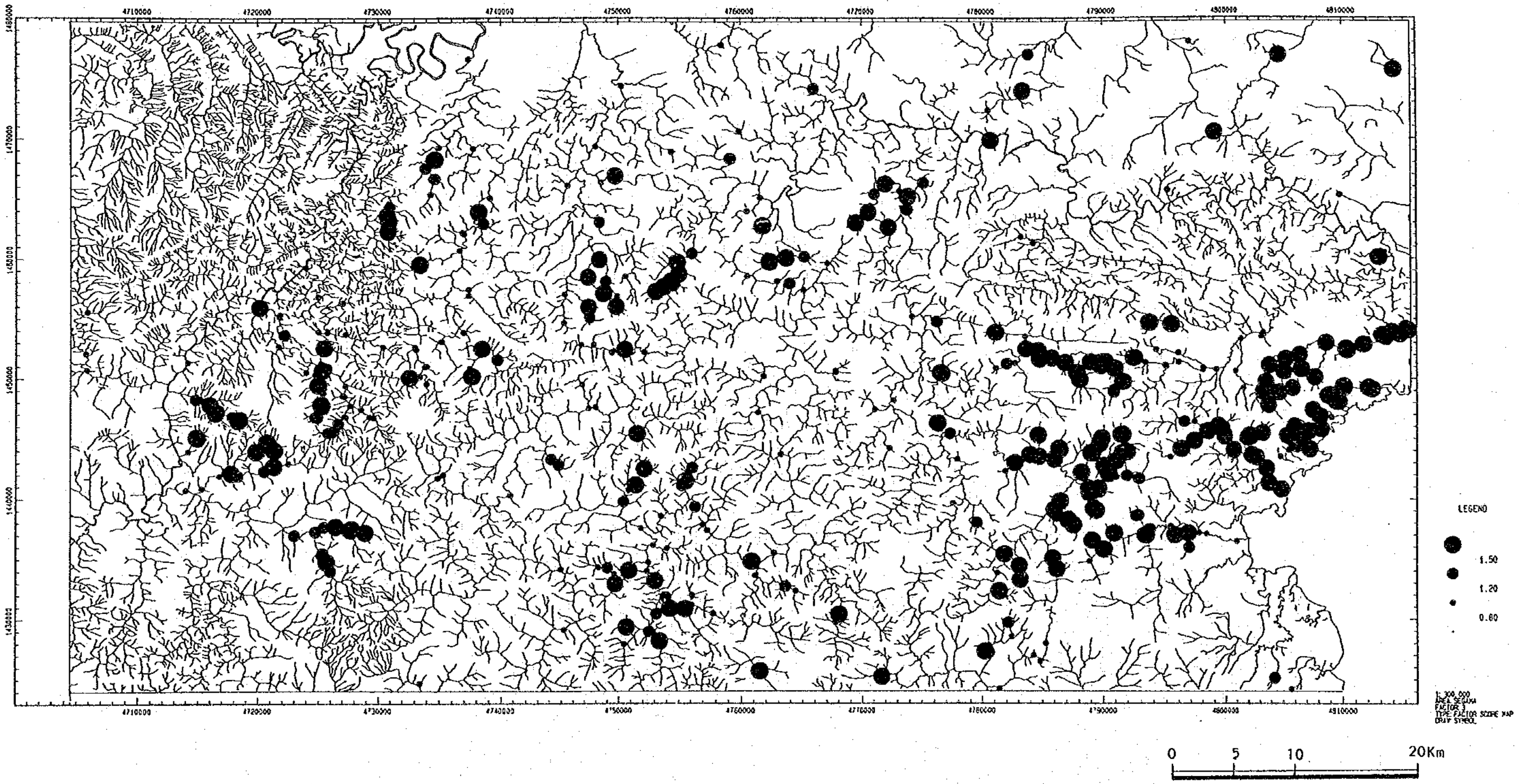


Fig. II-1-7 Distribution map of factor 3 factor scores for stream sediment samples in the Segama area

1-2-4 Pan concentrate survey

(1) Sampling

Pan concentrates of 175 samples were collected in this area. Descriptions of the samples are shown in Appendix 6. The maximum weight of the pan concentrate sample is 393 grams. The weight of the samples collected in the area of the sedimentary rocks are extreamely light.

(2) QME analyses

Results of the qualitative mineral examination (QEM) analyses of pan concentrate samples are shown in Appendix 7. According to the examination, magnetite, chromite, ilmenite, goethite and pyrite were observed as the main minerals. Small amounts of zircon were also observed. Some pan concentrate samples contain a large amount of pyroxene and hornblende. The samples with a small amount of pan concentrates are mainly composed of quartz and feldspar. Minor amounts of native gold were recognized in a few pan concentrate samples. The results of the qualitative mineral examination are shown in Fig. II-1-8. Relationship between main minerals and geology is as follows;

Magnetite	Magnetite was observed in the most of the samples. Large amount of magnetite was collected in the zone of basement rocks around Sungai Kawag, Sungai Taliwas and the upper stream of Sungai Segama, in the zone of the ultra-basic to basic rocks and Chert-Spilite formation around the lower stream of Sungai Bole and the upper stream of the Sungai Dewata.
Chromite	A large amount of chromite was collected in the upper stream of Sungai Taliwas and Sungai Kawag, the lower stream of Sungai Bole, the upper stream of Sungai Segama and the upper stream of Sungai Danum where are occupied by ultra-basic rocks. The sample with the maximum amount of chromite is found in the upper stream of Sungai Kawag which is originated from the ultra-basic rocks in the western part of village of Silam where is presumed to be a potentiality of chromium deposits.
Ilmenite	Ilmenite was observed in the samples collected in the zone of basement rocks and ultra-basic to basic rocks.
Goethite	Goethite was recognized in the most of the samples and the amounts of goethite increase in the zone of the sedimentary rocks.
Pyrite	A small amount of pyrite was observed in the samples collected in the area of sedimentary rocks and the Chert-Spilite formation.

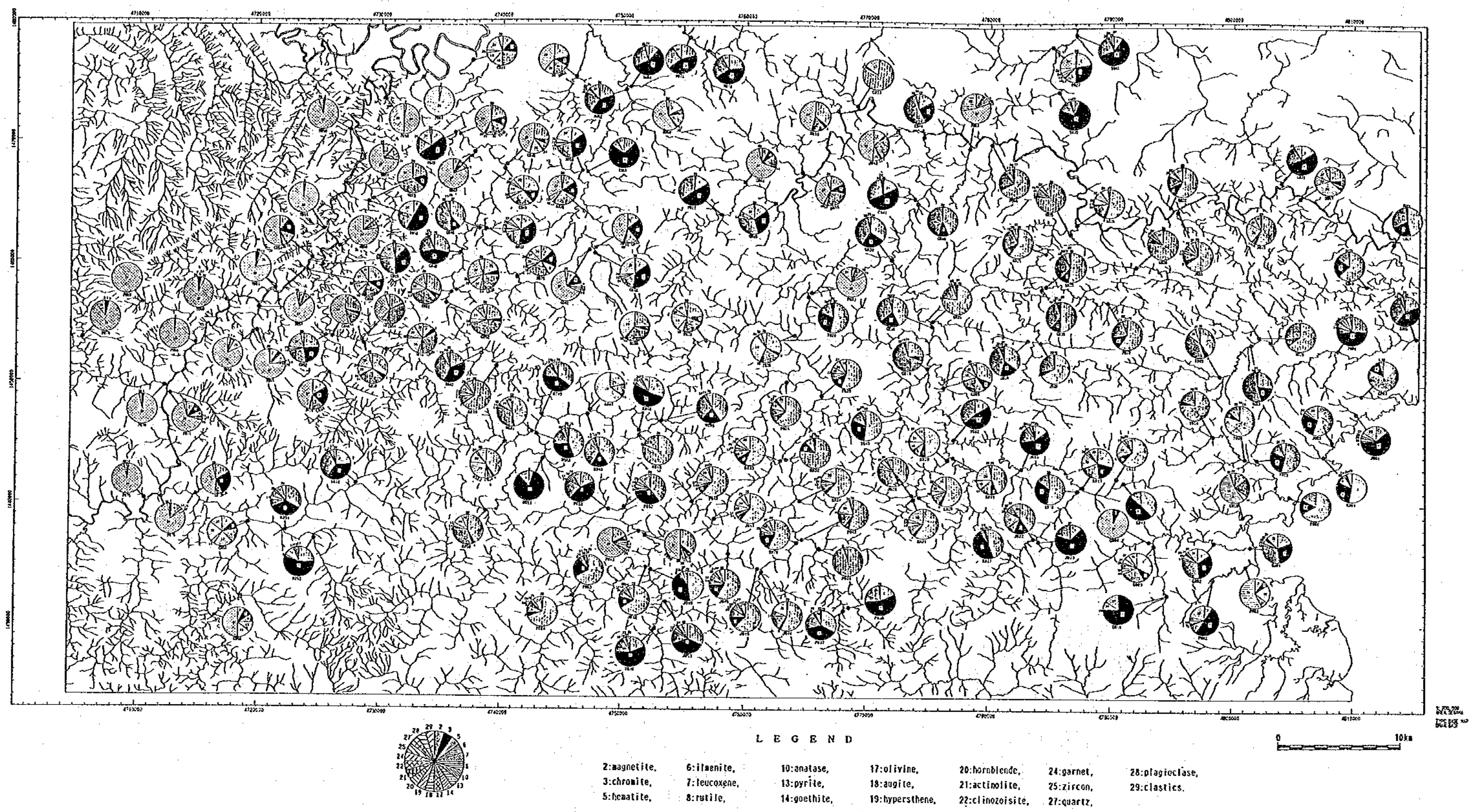


Fig. II-1-8 Interpretation map of pan concentrate samples in the Segama area

Native gold A minor native gold is observed in a sample collected in Sungai Malog, a sample collected in the middle stream of Sungai Segama, a sample collected in the upper stream of Sungai Danum and two samples in the small rivers around Silam. The samples collected in Sungai Malog, the upper stream of Sungai Segama and the small river around Silam are situated in the Chert-Spilite formation. The sample collected in the upper stream of Sungai Danum is found in the zone of sandstone. Native gold was not recognized in the samples collected in the zone of the basement rocks where show the high concentration of Au in the stream sediment geochemical survey.

1-2-5 Rock geochemical survey

Fifty one typical rock samples were analyzed for 21 elements. The list of samples is shown on Table II-1-4. Location of samples is shown in Fig. II-1-3. Analytical results are shown in Appendix 8.

According to the analytical results, more than 80 % of samples show the content less than detection limit in Au, Hg and Mo. Relationship between each element and rocks is as follows;

As : The maximum value of 21 ppm is detected in shale. High values are detected in the sedimentary rocks such as shale and sandstone.

Au : More than 80 % of samples show the value less than the detection limit. The maximum value of 3 ppb is detected in gneiss ans chert. High values are detected in gneiss.

Ba : The maximum value of 483 ppm is detected in volcanic breccia. High values are detected in volcanic breccia, sandstone, mudstone and granite.

Co : The maximum value of 130 ppm is detected in harzburgite. High values more than 100 ppm are restricted in the ultra-basic rocks.

Cr : The maximum value of 2,795 ppm is detected in peridotite. High values more than 2,000 ppm are restricted in the ultra-basic rocks.

Cu : The maximum value of 173 ppm is detected in volcanic breccia. High values are detected in volcanic breccia, amphibolite, gabbro and dolerite.

Hg : The samples of 82 % are less than the detection limit. The maximum value of of 47 ppb is detected in sandstone. High values are detected in sandstone, shale, mudstone and dolerite.

K : The maximum value of 2.04 % is detected in sandstone. A distinct relationship between K and the rock type was not obtained.

Mg : The maximum value of 23.95 % is detected in peridotite. High values are restricted in the ultra-basic rocks.

Mn : The maximum value of 3,234 ppm is detected in sandstone. A distinct relationship between Mn and rocks was not obtained.

Table II-1-4 List of rock geochemical samples in the Segama area

Ser. No.	Sample No.	Coordinates N	Coordinates E	1/50,000 Topo. Sheet	Name of Stream	Descriptions	Geol. Unit
1	K037	1467.60	4747.10	Sungai Malua	S. Malua	sandstone	P_4Km
2	N101	1452.70	4747.75	Sungai Malua	S. Berseh	siliceous shale	KPCs
3	N097	1452.40	4750.50	Sungai Malua	S. Berseh	gabbro	Ub
4	G054	1468.55	4756.55	Sungai Malua	S. Bilong	sandstone	KPCs
5	N074	1475.85	4756.65	Sungai Malua	S. Latangah	sandstone	P_4Km
6	N079	1469.15	4764.45	Sungai Bole	S. Kling Kawang	basalt	KPCs
7	J040	1453.55	4783.80	Sungai Bole	S. Kawag	volcanic breccia	KPCs
8	N011	1469.25	4795.65	Mansuli	—	chert	KPCs
9	N015	1459.20	4796.10	Mansuli	S. Kawang Gibong	tonalite	Cb
10	J034	1461.65	4796.50	Mansuli	S. Dapalak	granite	Cb
11	N068	1463.00	4802.80	Mansuli	S. Upak	gneiss	Cb
12	J009	1456.30	4804.60	Mansuli	S. Taliwas	gneiss	Cb
13	J010	1457.40	4806.65	Mansuli	S. Taliwas	gneiss	Cb
14	C032	1461.20	4808.35	Mansuli	S. May May	gneiss	Cb
15	C030	1466.30	4809.00	Mansuli	—	mudstone	P_4Ay
16	N044	1466.90	4812.10	Mansuli	—	sandstone	P_4Ay
17	N089	1446.40	4737.30	Ulu Segama	S. Karangan	dolerite	Ub
18	K043	1451.30	4737.70	Ulu Segama	S. Malubuk	basalt	KPCs
19	N091	1445.40	4737.90	Ulu Segama	S. Karangan	gabbro	Ub
20	N088	1445.25	4737.90	Ulu Segama	S. Karangan	shale	P_4Km
21	N086	1445.20	4738.65	Ulu Segama	S. Karangan	sandstone	P_4Km
22	N084	1445.70	4739.40	Ulu Segama	S. Karangan	dolerite	Ub
23	K040	1451.25	4739.60	Ulu Segama	S. Malubuk	gabbro	Ub
24	N095	1442.70	4744.65	Ulu Segama	S. Danum	sandstone	P_4Km
25	P031	1447.00	4761.55	Sungai Ulu Bole	S. Purut	sandstone	KPCs
26	P030	1446.20	4765.40	Sungai Ulu Bole	S. Segama	tuff	P_4Km
27	P041	1434.40	4766.95	Sungai Ulu Bole	S. Beruang	gneiss	Cb
28	K031	1432.90	4767.75	Sungai Ulu Bole	S. Beruang	gabbro	Cb
29	Y033	1449.90	4768.10	Sungai Ulu Bole	S. Segama	sandstone	P_4Km
30	N022	1439.40	4773.00	Sungai Ulu Bole	S. Ulu Bole	amphibolite	Cb
31	N020	1442.30	4774.55	Sungai Ulu Bole	S. Ulu Bole	sandstone	KPCs
32	J014	1435.45	4776.75	Sungai Ulu Bole	S. Ulu Bole	amphibolite	Cb
33	J012	1438.00	4777.30	Sungai Ulu Bole	S. Ulu Bole	gneiss	Cb
34	J013	1437.35	4777.35	Sungai Ulu Bole	S. Ulu Bole	gabbro	Ub
35	J027	1435.10	4782.25	Sungai Ulu Bole	S. Ulu Bole	gabbro	Ub
36	N012	1437.05	4783.30	Sungai Ulu Bole	S. Juak	sandstone	KPCs
37	J024	1445.10	4784.65	Sungai Ulu Bole	S. Juak	peridotite	Ub
38	J020	1438.40	4785.00	Sungai Ulu Bole	S. Juak	volcanic breccia	KPCs
39	C033	1436.25	4785.55	Sungai Ulu Bole	S. Juak	sandstone	KPCs
40	N004	1451.80	4787.75	Sungai Ulu Bole	—	peridotite	Ub
41	C035	1432.85	4785.85	Sungai Ulu Bole	S. Juak	chert	KPCs
42	N013	1434.85	4786.65	Sungai Ulu Bole	—	chert	KPCs
43	G013	1436.75	4793.50	Silam	S. Takun	basalt	KPCs
44	G014	1435.00	4793.80	Silam	S. Takun	tuff	P_4Km
45	G015	1434.30	4794.00	Silam	S. Takun	sandstone	P_4Km
46	C008	1439.10	4797.50	Silam	S. Diwata	basalt	KPCs
47	Y017	1445.80	4799.70	Silam	S. Diwata	peridotite	Ub
48	Y002	1441.50	4801.00	Silam	S. Diwata	dolerite	KPCs
49	Y004	1445.70	4803.30	Silam	S. Diwata	dunite	Ub
50	N052	1447.40	4808.40	Silam	—	haezburgite	Ub
51	N053	1450.60	4811.80	Silam	—	peridotite	Ub

Mo : The samples of 94 % show the value less than the detection limit. A distinct relationship between Mo and rocks was not obtained.

Na : A distinct relationship between Na and rocks was not obtained.

Ni : The maximum value of 2,391 ppm is detected in peridotite. High values are restricted in the ultra-basic rocks.

Pb : The maximum value of 15 ppm is detected in sandstone. The samples of 68 % show the value less than the detection limit. High values are detected in sandstone.

S : The maximum value of 0.557 % is detected in shale. A distinct relationship between the contents of S and the kinds of rock was not obtained.

Sb : The maximum value of 18.4 ppm is detected in basalt. High values are detecyed in the basic rocks such as basalt and gabbro.

Sr : The maximum value of 1,216 ppm is detected in gneiss. High values are detected in the basement rocks of gneiss and granite.

Ti : The maximum value of 2.24 % is detected in volcanic breccia. High values are detected in basalt, volcanic breccia, amphibolite and gneiss. The contents of Ti is presumed to be related with the basic rocks.

U : The maximum value of 8.8 ppm is detected in volcanic breccia. High valuea are detected in sandstone and shale.

W : The maximum value of 1,044 ppm is detected in chert. High values are detected in chert and sandstone.

Zn : The maximum value of 220 ppm is detected in harzburgite. High values are detected in the ultra-basic rocks. The basic rocks such as basalt, dolerite and gabbro contain the relatively higher values of Zn.

Judging from the relationship between elements and rocks, high values of Co, Cr, Mg, Ni and Zn are detected in the ultrabasic rocks. High values of Cu, Sb, Zn and Ti are detected in the basic rocks. The elements including As, Hg, Pb and U have the close relationship with the sedimentary rocks such as sandstone and shale. The relationship between elements and rocks in the area indicates the same characteristics as the general feature obtained in the typical rocks.

1-2-6 Soil geochemical survey

Seventy four soil samples were analyzed for 6 elements of Al, Co, Cr, Fe, Ni and Pt. Lateritic soil samples were collected from the B horizon in the area of the ultra-basic and basic rocks. List of samples is shown in Appendix 10. Analytical results are shown in Appendix 9. As the results of data treatment for the analytical results, the following statistics were obtained.

Element	Mean value	Minimum value	Maximum value
Al	1.10 %	0.31 %	3.07 %
Co	113 ppm	13 ppm	718 ppm
Cr	1,327 ppm	78 ppm	17,305 ppm
Fe	2.20 %	0.68 %	8.03 %
Ni	645 ppm	36 ppm	5,313 ppm
Pt	7 ppb	5>ppb	35 ppb

The maximum values of Cr (17,305 ppm) and Ni (5,313 ppm) are relatively high. The sample with the maximum value of Cr was collected from the north of the ultra-basic bodies in the northwest of Silam. A sample collected nearby the maximum value sample shows about 9,000 ppm of Cr. The samples with contents of more than 5,000 ppm are ten samples. All these samples are found in the northwest of Silam where ultra-basi rocks occurs. The sample with the maximum value of Ni is found at the western margin of ultra-basic rock body in the northwest of Silam. The sample with more than 3,000 ppm of Ni are eleven samples and all these samples are found in the ultra-basic rocks around Silam. High value sample of Cr and Ni were not detected in the area of ultra-basic rocks from the cenral to western part of the survey area. The maximum value of Co is 718 ppm and the most of the samples show the value less than 500 ppm of Co. The maximum value of Pt is 35 ppb.

1-2-7 Results of laboratorial studies

(1) Observation of thin sections

Thin section observation was carried out for 12 samples collected from the basement rocks, ultra-basic rocks, basic rocks and Chert-Spilite formation. Results of the observation are shown in Table II-1-5.

As the results of the observation, cumulate texture was observed in the sample of peridotite, dunite and gabbro. These rocks are thought to form a part of ophiolite. Dunite (No.Y004) and peridotite (No.N052) collected in the eastern part of the area are serpentinized. Basalt (No.K043) collected in the Chert-Spilite formation is chloritized. Altered rock (No.Y066) collected from the mineralized zone with massive and disseminations of pyrite is strongly silicified.

(2) Observation of polished sections

Mineral showings confirmed in this survey are disseminations of chromite in dunite located near Darvel bay, massive and dissemination of pyrite in the upper stream of Sungai Segama and floats containing the disseminations of pyrite collected in the upper stream of Sungai Danum. Five polished section were prepared for the samples collected from the mineral showings. Observation results for these sections are shown in Table II-1-6. As the result of the observation, disseminated chromite (No.N042) is recognized in dunite. Disseminated pyrite with minor chalcopyrite were detected in the sample (No.J050) collected in the upper stream of Sungai Segama. Disseminated pyrite with minor amounts of chalcopyrite, covelline, sphalerite and pyrrhotite were detected in the sample (No.Y069). Among the float samples collected in the upper stream of Sungai Danum, a sample (No.J055) contains ore minerals including disseminated pyrite and sphalerite with minor amounts of covelline and bornite. Identified mineral in the sample No.N090 is only disseminated pyrite.

(3) X-ray diffraction analyses

The x-ray diffraction analyses were carried out for five samples. Results of X-ray diffraction analyses are shown on Table II-1-7. The samples with massive and disseminated pyrite were collected in the upper stream of Sungai Segama. Among these samples, sericite was identified in the sample No.J050 and chlorite, quartz and prehnite were identified in the sample No.Y069. In the sample No.J055, quartz, sericite and montmorillonite were identified. Main alteration minerals identified

Table II-1-5 Observation results of thin sections collected in the Segama area

Ser. No.	Sample No.	Location Coordinates		Geologic Units	Rock Name	Texture	Phenocryst and main minerals									Groundmass and accessory minerals							Metamorphic and altered minerals													
		N	E				quartz	plagioclase	biotite	hornblende	actinolite	clinopyroxene	orthopyroxene	olivine	opaque minerals	plagioclase	clinopyroxene	glass	allanite	apatite	zircon	opaque minerals	quartz	albite	actinolite	tremolite	anthophyllite	prehnite	pumpellyite	epidote	chlorite	serpentine	sericite	montmorillonite	calcite	opaque minerals
1	J014	1435.45	4776.75	Cb	Amphibolite	Nematoblastic	◯	◎		◎					●								●							●						
2	J027	1435.10	4782.25	Ub	Gabbro	Sutured		◎		◎		○			●								●		◎					●	○		●			
3	J051	1434.75	2750.85	Cb	Schist	Nematoblastic																	◯		◎	◯		◯	○	○	○					●
4	K031	1432.85	4767.75	Ub	Gabbro	Cumulus	○	◎		◎	○	◯			●																○					
5	K040	1451.25	4739.60	Ub	Gabbro	Orthocumulus		◎				◯		◯	●																○	○			○	●
6	K043	1451.30	4737.70	KPCs	Basalt	Intergranular and amygdaloidal		●								◎	◎	○				●		◎							◎			○	○	●
7	N015	1459.20	4796.10	Cb	Tonalite	hypidiomorphic granular	◯	◎	○	○					○				●	●	●	●								●	○					
8	N052	1447.40	4808.40	Ub	Harzburgite	Adcumulus						○	◯	◎	●																	◎				○
9	N089	1446.40	4737.30	Ub	Dolerite	Ophitic		◎				◎			○														○	●	◯	●		●	●	
10	Y002	1441.50	4801.00	Ub	Dolerite	Ophitic		◎				◎			○								○					○	○	●	○					
11	Y004	1445.70	4803.30	Ub	Dunite	Adcumulus						○		◎	●												◯					◎				○
12	Y066	1431.00	4746.10	KPCs	Altered rock	Lepidoblastic																	◎	○	○		◯									○

◎ :abundant, ◯ :common, ○ :a little, ● :rare.

Table II-1-6 Observation results of polished sections collected in the Segama area

Ser. No.	Sample No.	Location Coordinates		Descriptions	chalcopyrite	covellite	bornite	sphalerite	pyrite	pyrrhotite	magnetite	hematite	goethite	chromite	pyrolusite	gangue minerals	Remarks
		N	E														
1	J050	1434.75	4750.85	Dissemination of pyrite in sericitized, silicified schist	○				◎		●	○				◯	Pyrite:fractured, subhedral-euhedral.
2	J055	1447.40	4746.80	Dissemination of pyrite in silicified tuff breccia.		○	○	◯	◯							◎	Pyrite:framboidal, euhedral.
3	N042	1445.80	4808.60	Dissemination of chromite in dunite.							●	●		○		◎	
4	N090	1445.95	4737.65	Dissemination of pyrite in silicified, chloritized rock					◎							◎	
5	Y069	1430.85	4746.20	Dissemination of pyrite in chloritized rock	●	●		●	◎	●		●				◎	

◎ :abundant, ◯ :common, ○ :a little, ● :rare.

Table II-1-7 Results of X-ray diffraction analyses for samples in the Segama area

Ser. No.	Sample No.	Location Coordinates		Descriptions	Detected minerals								Remarks
		N	E		montmorillonite	chlorite	sericite	quartz	plagioclase	prehnite	pyrite	chalcopyrite	
1	J050	1434.75	4750.85	Dissemination of pyrite in sericitized and silicified schist.			○	◎	●		◎		
2	J055	1447.40	4746.80	Dissemination of pyrite and bornite in strongly silicified tuff breccia.	●		●	◎			◯		
3	N087	1445.35	4738.15	Dissemination of pyrite and quartz vein with pyrite and chalcopyrite in chloritized rock.		◯		◎			●	○	size of float 10×10×3cm
4	N090	1445.95	4737.65	Dissemination of pyrite in silicified, chloritized rock.		●		◎	○		◎		size of float 20×10×10cm
5	Y069	1430.85	4746.20	Dissemination of pyrite in chloritized rock.		◎		◯	◎	○	●		

◎ :abundant, ◯ :common, ○ :a little, ● :rare.

Table II-1-8 List of ore samples and their assay results in the Segama area

Ser. No.	Sample No.	Location Coordinates		Descriptions	Analytical Elements							Remarks
		N	E		Au (g/t)	Ag (g/t)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	S (%)	
1	J050	1434.75	4750.85	Dissemination of pyrite in sericitized, silicified schist	0.1>	0.1>	642	1>	55	14	26.37	sampling width:2m
2	J055	1447.40	4746.80	Dissemination of pyrite and in silicified tuff breccia, bornite	1.2	42.6	9320	358	39900	42	9.96	size of float: 3 × 3× 3m
3	N087	1445.35	4738.15	Dissemination of pyrite and quartz vein with pyrite and chalcopyrite in altered rock	0.4	15.0	51100	1>	300	1>	5.45	size of float: 10×10×3cm
4	N090	1445.95	4737.65	Dissemination of pyrite in silicified, chloritized rock	0.1>	0.1>	87	3	81	1>	12.78	size of float: 20×10×10cm
5	Y069	1430.85	4746.20	Dissemination of pyrite in chloritized rock	0.1>	0.9	439	6	506	1>	4.48	sampling width:2.5m

in the sample No.N087 and No.N090 are quartz and chlorite. Based on these identified minerals, different alteration is presumed in the each mineralized zone.

(4) Ore assaying

Five samples collected in the mineral showings were assayed for the elements of Au, Ag, Cu, Pb, Zn, Mo and S. The assay results are shown in Table II-1-8. Sample No.J050 and sample No.Y069 collected in the mineral occurrence with massive and disseminated pyrite in the upper stream of Sungai Segama show low grades of Cu and Zn. Among the float samples collected in Sungai Danum, the float with 3 m in diameter (sample No.J055) contains 1.2 g/t Au, 42.6 g/t Ag, 0.9 % Cu and 3.9 % Zn. The float with 10 cm in diameter (sample No.N087) contains 0.4 g/t Au, 15.0 g/t Ag and 5.1 % Cu. These float samples indicate the highest contents among the assayed samples.

1-3 Survey results of the Semporna area

1-3-1 Geology and mineralization

Geology of the Semporna area consists of pre-Triassic crystalline basement rocks, ultra-basic rock and sedimentary rocks with basic effusives of Cretaceous to Eocene, and sedimentary rocks after Eocene. The southern part of the area is widely covered with Pliocene to Holocene volcanic rocks with pyroclastics. During this survey, reconnaissance geologic survey was also carried out. Geologic map(Fig.II-1-9) of this area was prepared using existing data(H.J.C. Kirk; 1961, S.K. Chung; 1971, P.S. Lim; 1981, Y.E. Heng; 1985 and D.T.C. Lee; 1988) and the results of this survey.

The crystalline basements (Cb) of pre-Triassic are found at the boundary between Segama and Semporna areas and consist of gneiss and schist. Pre-Cretaceous limestone (KMb) occures in the limited area of the northeastern part of this area.

Ultra-basic rock(Ub) bodies are scattered in the northern part of the area with a direction of E-W. Width of the body is up to several kilometers. The ultra-basic rocks consist of serpentinite, serpentinized peridotite and gabbros. These rocks occur with close relationship each other. The Chert-Spilite formation (KPCs) mainly consisting of basaltic pillow lavas occurs in the surroundings of the ultra-basic rock bodies. These two units may form a part of ophiolite.

The central part of this area is widely covered with sedimentary rocks from Eocene to Middle Miocene. These sedimentary rocks are divided into three formations including Kalabakan formation (P_4Kl) in the west, Kuamut formation (P_4Km) in the center and Kalumpang formation (P_4Kg) in the east. The Kalabakan formation consists of sandstone, siltstone, mudstone and shale. The Kuamut formation is characterized with slump breccia and consists of conglomerate, sandstone and siltstone. The Kalumpang formation is characterized with tuffaceous sediments and consists of tuff, tuffaceous sandstone, shale and mudstone.

Sedimentary rocks from Middle to Late Miocene occures at the western end of this area. These sedimentary rocks are divided into Tanjong formation (N_2Tj) and Kapilit formation (N_2Kp). The Tanjong formation consists of sandstone and siltstone. The Kapilit formation mainly consists of mudstone and siltstone. Umas Umas formation (N_4Um) from Middle Miocene to Pliocene occurs in the small area along the down stream of Sungai Merotai Besar in the central part of the area. This formation consists of sandstone, shale and mudstone. In the eastern part, Balung formation (N_4Bl) which is same age of the Umas Umas formation, occurs in the

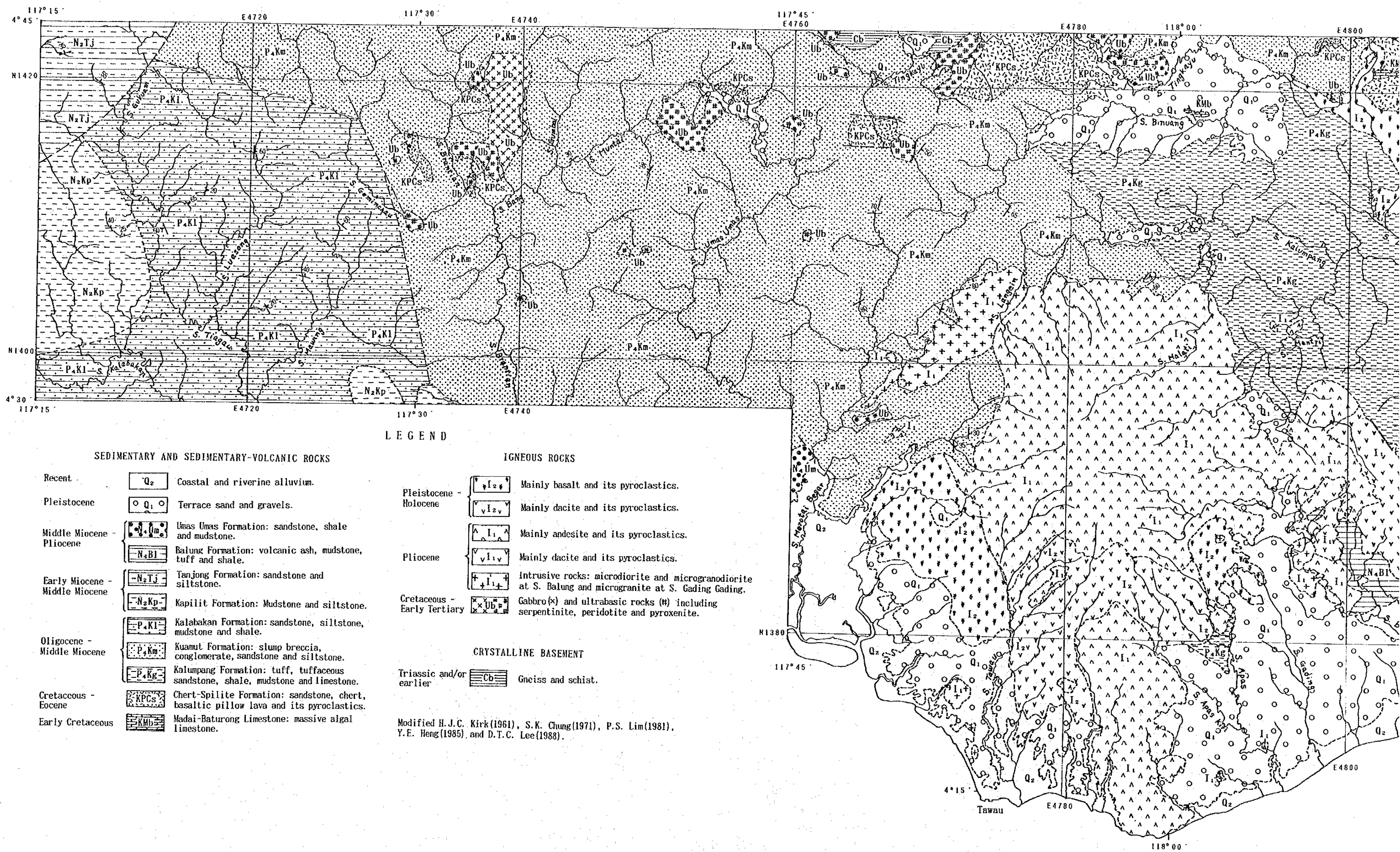


Fig. II-1-9 Geologic map of the Semporna area

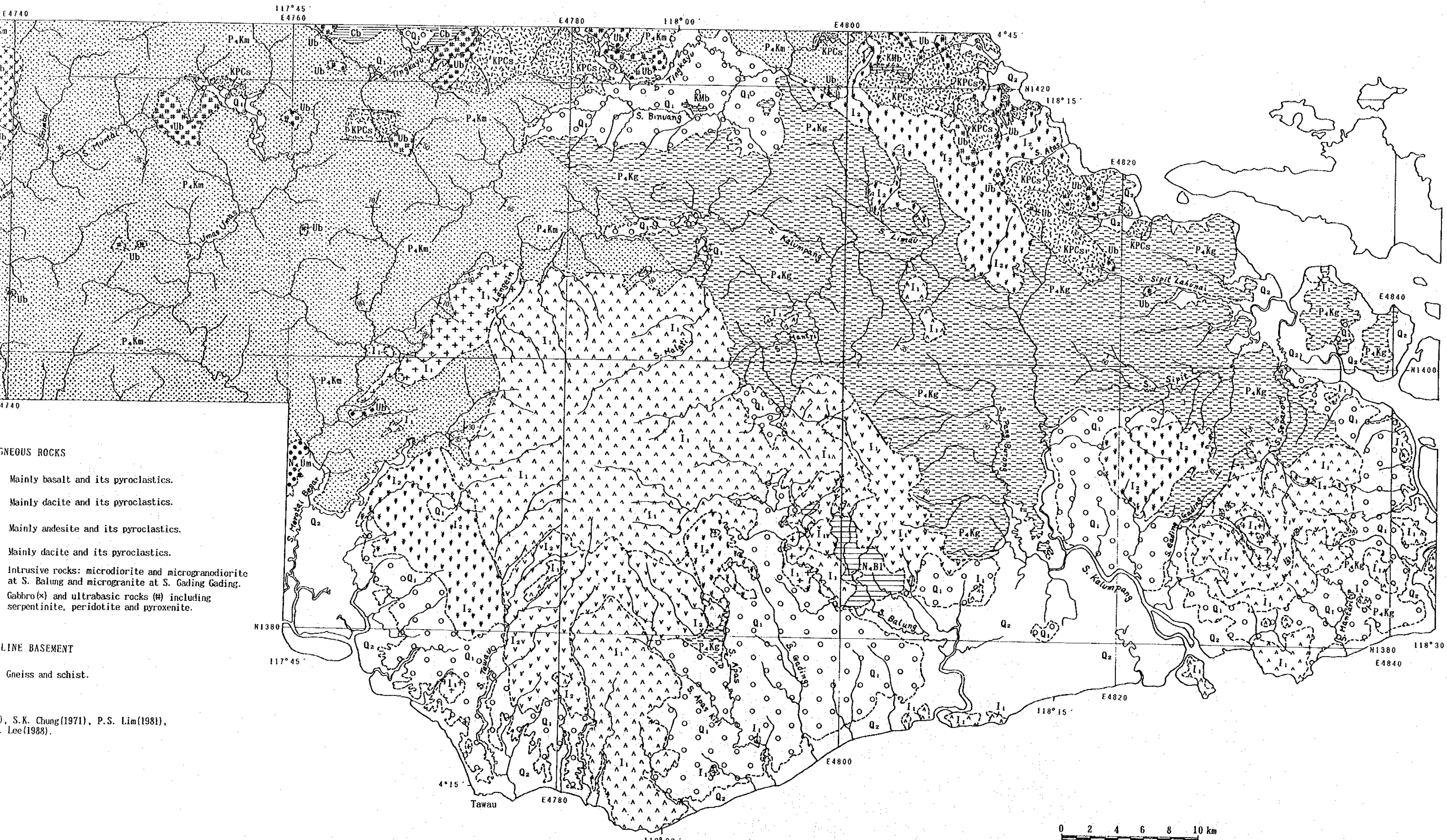


Fig. II-1-9 Geologic map of the Semporna area

limited area at the middle stream of Sungai Balung. This formation consists of volcanic ash, mudstone, tuff and shale.

Terrace deposits (Q_1) of Pleistocene is found from southern central part to southeastern part of the area. Alluvium gravels (Q_2) are found along river and coastal line.

The southern central part of the area is widely covered with volcanics of Pliocene (I_1) and volcanics from Pleistocene to Holocene (I_2). The Pliocene volcanics consist of andesite dominated faces and dacite dominated faces. Small bodies of micro-diorite and micro-granodiorite intruded within these volcanics in the southeastern part of this area. The Pleistocene to Holocene volcanics consist of dacite and basalt flows and their pyroclastics, and are found in the small areas in the of southern and northeastern parts of this area.

Geologic structure of this area is characterized with ENE-WSW trending volcanic zone. Fault systems of NNW-SSE and NNE-SSW are found in ths area. The geologic structure of the basement rocks is not clear.

Mineralization in this area is represented by hydrothermal mineralization within the volcanic rocks. Significant mineralized zones are known between northern bank of Sungai Balung and Mt. Mantri, and Nagos area of the southeastern part of this area. Exploration work has benn carried out by Zamia SDN BHD for these mineralized zones.

1-3-2 Sampling

The sampling work was carried out along streams using road network in the southern and eastern parts of this area where plantation is widely distributed. Due to limited road system in the northern and western parts of this area, camps were established lower sream of Sungai Tiagau, Sungai Brantian and upper stream of Sungai Kalumpang. Using these cample, sampling was conducted by flighing camp along the streams.

At the sampling site of each stream sediment sample, geology nearby, color, grain size, order of stream etc, were described and sample list (Appendix 11) was prepared. The sample location of the stream sediment samples are shown in Fig.II-1-10 and Plate II-1-2.

Pan concentrate samples were collected in the main stream. The sampling site was described as the same manner of the stream sediment samples and the sample list (Appendix 16) was prepared for each sampling site. The location of the sample points are shown in Fig.II- 1-11.

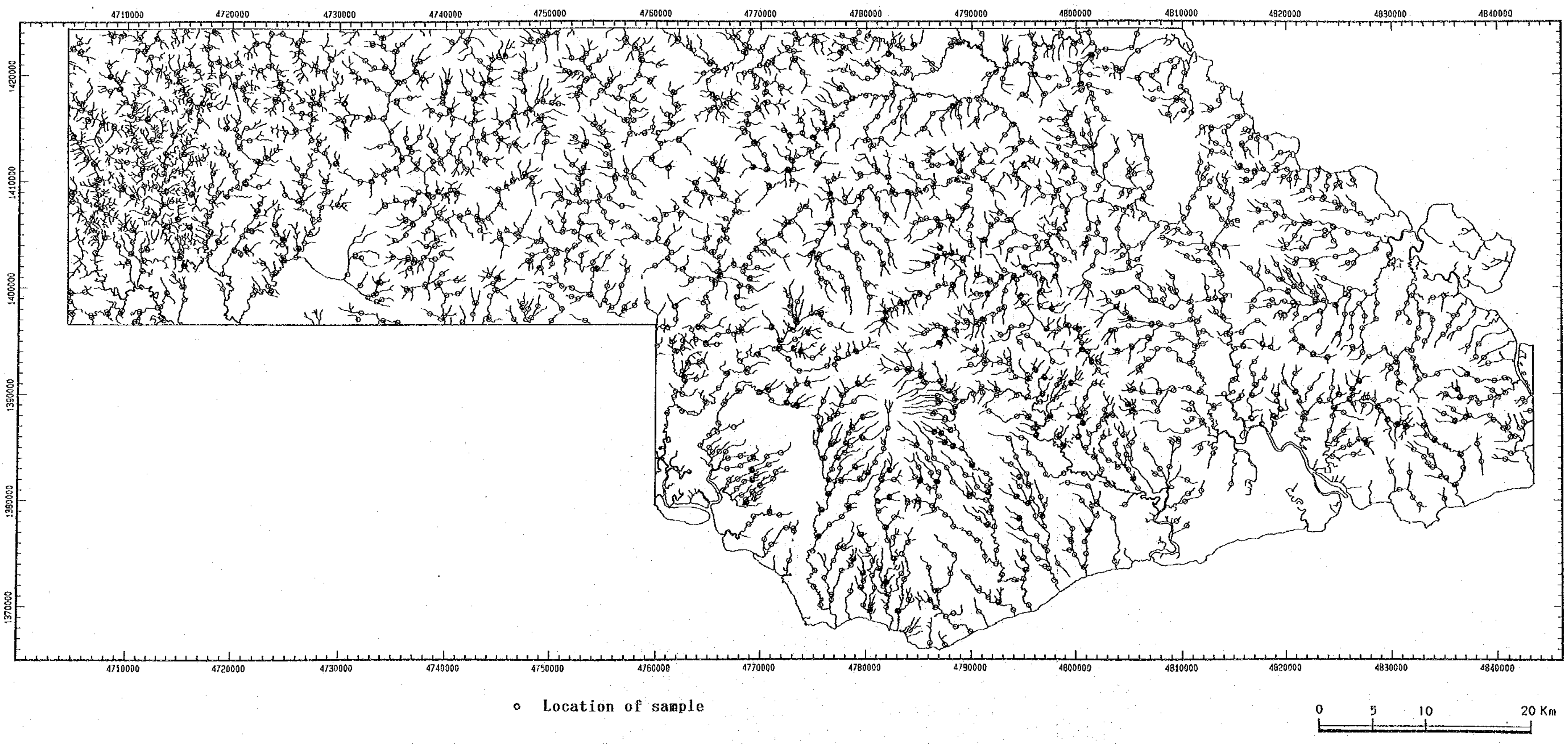


Fig. II-1-10 Location map of stream sediment samples in the Semporna area

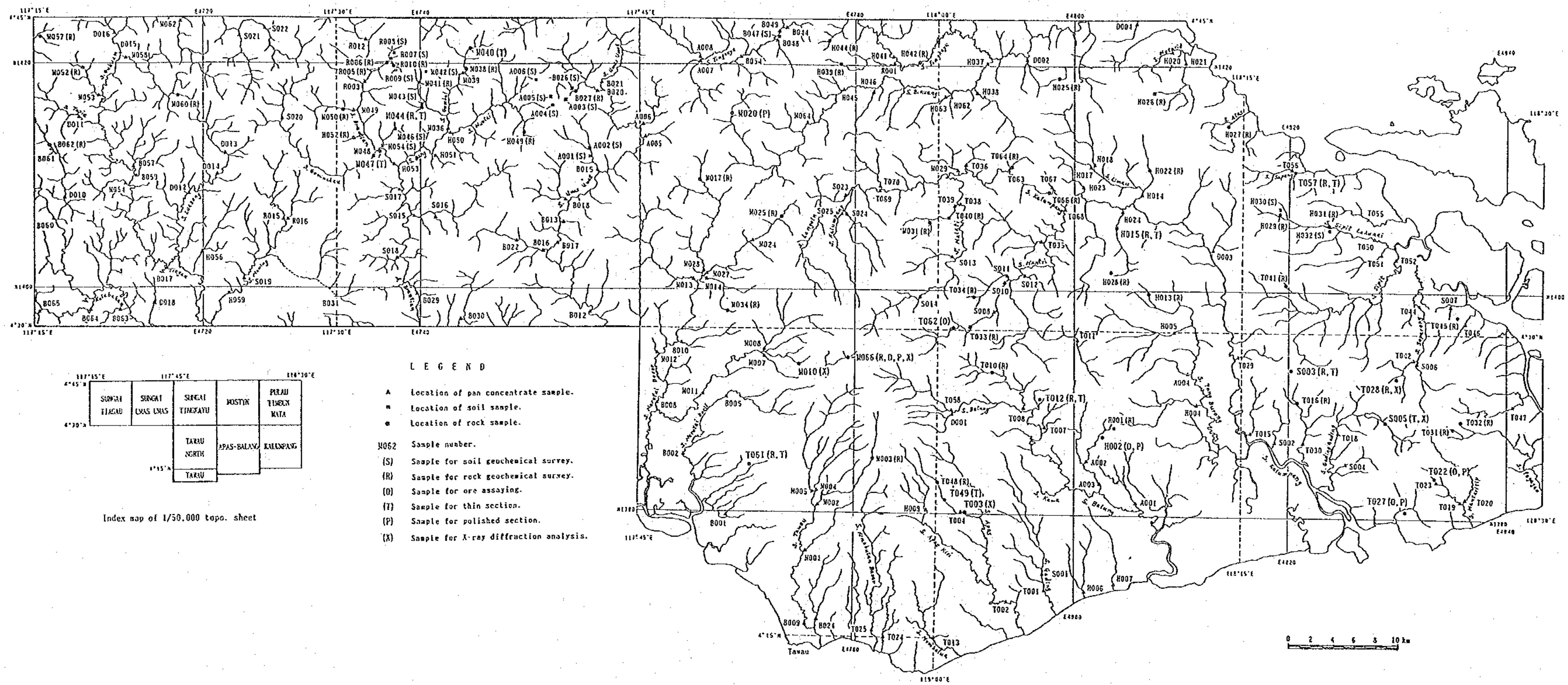


Fig. II-1-11 Location map of samples for geochemical and laboratorial studies in the Semporna area

Rock samples which representing the geology of this area were collected. The location of these rock samples are shown in Fig.II-1-10.

Soil samples were collected in the area of ultra-basic rocks where lateritic soil is developed. At the each sampling site, color, grain size, topography etc. were described. The location of these soil samples are shown in Fig.II-1-11.

During the sampling work, preliminary geologic survey was conducted and samples for laboratorial studies were collected. The laboratorial studies includes thin sections, polished sections, x-ray diffraction analyses and ore assaying. The sample locations of these laboratorial studies are shown in Fig.II-1-11.

1-3-3 Stream sediment geochemical survey

List of the stream sediment samples in this survey are shown in Appendix 11 and the analytical results are in Appendix 12.

(1) Pathfinder element

Twenty one elements were analyzed for each sample and the analytical results were statistically treated by computer. Statistics obtained by this data treatment are given in Table II-1-9. As shown in this table, analytical values of Au, Mo and W indicates less than their detection limit for most the samples. The maximum values of Au (9,320 ppb), S (5.526 %), Pb (789 ppm) and Ba (1,230 ppm) indicate comparatively higher values. In order to clarify the distribution pattern for each elemement, histograms and cumulative frequency graphs (Appendix 13) were prepared. The cumulative frequency curves for Hg, Ni and U bend rightward. This indicate overlapping distribution of the element consisting of higher and lower groups.

Correlation coefficients among the elements were calculated in order to examine the relation between each element. Correlation matrix is shown in Table II-1-10. Among the elements, the following elements indicate good correlation (correlation coefficient; more than 0.600) between them.

Ba-Cu, Ba-K, Ba-Sr, Co-Cu, Co-Mg, Co-Mn, Co-Sr, Co-Ti, Co-Zn, Cr-Ni, Cu-Mg, Cu-Sr, Cu-Zn, Mg-Na, Mg-Sr, Mn-Ti, Mn-Zn, Na-Sr, Sr-Zn, Ti-Zn

These relations clearly reflect the geology in this area. Au is has characteristically good relation with Pb (correlation coefficient; 0.325).

(2) Single element analysis

Based on the results of statistic data treatment, distribution map of each element was prepared using four ranks mentioned in the palagraph of 1-1-3.

Table II-1-9 Statistics of stream sediment geochemical survey in the Semporna area

Element	Statistics						EDA method*3		
	Below detection limit (%)	Maximum value	Minimum value	Mean*1 value (b)	Standard deviation	b + 2S.D. *2	Median	Upper Wisker	Upper Fence
As (ppm)	53.1	227	< 1	1.8	0.652	36.4	0.5	10	512
Au (ppb)	92.3	9,320	< 1	0.7	0.597	10.7	0.5	0.5	0.5
Ba (ppm)	—	1,230	10	105.1	0.283	387.1	107	180	623
Co (ppm)	2.3	233	< 1	12.0	0.443	92.3	13	31	169
Cr (ppm)	—	19,479	43	194.7	0.336	915.2	166	316	832
Cu (ppm)	0.4	604	< 1	15.5	0.331	71.2	16	31	140
Hg (ppb)	15.9	1,250	< 10	22.2	0.403	141.5	23	44	190
K (%)	4.4	2.45	< 0.01	0.259	0.545	3.182	0.32	0.71	3.82
Mg (%)	—	17.13	0.01	0.465	0.432	3.406	0.49	1.07	5.02
Mn (ppm)	5.1	6,970	< 5	276.9	0.756	8,994.9	449.5	1,212	33,283
Mo (ppm)	80.9	22	< 1	0.6	0.239	1.9	0.5	1	0.5
Na (%)	1.6	2.32	< 0.01	0.168	0.515	1.799	0.20	0.46	3.52
Ni (ppm)	0.04	1,692	< 1	34.3	0.350	171.5	33	58	184
Pb (ppm)	35.5	789	< 2	3.8	0.531	43.7	4	10	243
S (%)	—	5.526	0.003	0.033	0.363	0.175	0.029	0.060	0.231
Sb (ppm)	10.5	247.7	< 0.2	2.89	0.638	54.57	3.9	9.2	61.7
Sr (ppm)	—	350	3	40.0	0.325	178.4	41	78	333
Ti (%)	—	8.84	0.06	0.563	0.461	4.696	0.52	1.72	21.4
U (ppm)	0.6	34.4	< 0.2	1.32	0.276	4.70	1.4	2.0	4.3
W (ppm)	91.7	12	< 2	1.1	0.137	2.1	1	1	1
Zn (ppm)	—	710	6	57.0	0.342	274.9	61	116	502

*1: geometric mean *2: background value + 2 x standard deviation *3: Exploratory Data Analysis (Kurzl H., 1988)

Table II-1-10 Coorelation matrix of elements for stream sediment in the Semporna area

	As	Au	Ba	Co	Cr	Cu	Hg	K	Mg	Mn	Mo	Na	Ni	Pb	S	Sb	Sr	Ti	U	W	Zn
As	1.000																				
Au	.136	1.000																			
Ba	.135	.099	1.000																		
Co	-.354	-.010	.344	1.000																	
Cr	-.177	-.007	-.362	.150	1.000																
Cu	-.041	.069	.606	.658	-.106	1.000															
Hg	.096	.093	.415	.286	-.271	.387	1.000														
K	.222	.004	.696	.135	-.303	.492	.340	1.000													
Mg	-.275	-.067	.427	.809	.204	.705	.228	.357	1.000												
Mn	-.370	.125	.203	.697	.128	.420	.134	-.125	.547	1.000											
Mo	-.007	.000	.175	.093	-.089	.197	.137	.137	.102	.080	1.000										
Na	-.059	-.124	.565	.467	-.020	.575	.199	.698	.713	.194	.064	1.000									
Ni	-.118	-.048	.056	.424	.603	.337	.005	.102	.577	.195	-.070	.388	1.000								
Pb	.278	.325	.045	-.158	-.033	-.049	.112	-.078	-.276	-.030	.008	-.314	-.058	1.000							
S	.138	.092	.504	.320	-.160	.563	.428	.345	.360	.179	.166	.348	.116	.113	1.000						
Sb	-.188	.041	.116	.386	.246	.248	.004	.029	.407	.394	.226	.224	.203	-.081	.090	1.000					
Sr	-.133	-.064	.671	.615	-.164	.704	.347	.578	.743	.380	.183	.811	.239	-.259	.475	.306	1.000				
Ti	-.365	.128	.176	.702	.068	.382	.238	-.217	.469	.759	.139	.035	.042	.003	.266	.362	.360	1.000			
U	.103	.009	.087	-.055	-.272	-.025	.145	-.049	-.227	-.058	.001	-.261	-.276	.252	.141	-.183	-.119	.178	1.000		
W	.021	.043	.069	.100	.001	.100	.087	.063	.080	.054	.131	.003	.046	.092	.072	.129	.039	.108	.008	1.000	
Zn	-.193	.126	.545	.830	-.038	.751	.376	.288	.732	.662	.154	.442	.254	-.004	.470	.347	.645	.740	.122	.143	1.000

Threshold value of each element was deliniated using EDA method which is the same method applied to the Segama area. Results of the EDA method are shown in Appendix 14 and Table II-1-9. The distribution maps of each element are shown in Appendix 15. The distribution of high value zone and anomalous zone for each element is summarized as follow;

As : Significant high value samples are found at the north of Sungai Balung and the Nagos area in the souteast where known mineralized zones occures. Some high value samples are also found in the upper most stream of Sungai Kalumpang. Comparatively higher value samples are widely distributed in the west of the area. Anomalous value of As is 10 ppm and tend to show similar distribution tendency of the high value samples.

Au : High value and anomalous samples mostly are found at the north of Sungai Balung where known mineralized zones occurs. Extremely high value (maximum: 9,320 ppb) samples are found at the upper stream of Sungai Mantri in the center.

Ba : High value and anomalous (more than 180 ppm) samples are found near ultra-basic bodies in the upper stream of Sungai Brantian, area between Sungai Balung and Sungai Kalumpang and northeastern corner of this area. Because known mineralized zones are situated in the area between Sungai Balung and Sungai Kalumpang, this element deliniates mineralized zone and the area of ultra-basic rocks.

Co : High value and anomalous samples of this element show similar distribution tendency of Ba and are distributed in the area of volcanics and Chert-Spilite formation. Relationship between mineralization and this element is not clear due to their low absolute values.

Cr : High value and anomalous samples are well corespond to the distribution of ultra-basic rocks, Chert-Spilite formation and basalt flows. Because of the lower absolute values compare to the Segama area, potentiality of chromite deposit is low in this area. The area of sedimentary rocks, andesite and dacite show lower value samples.

Cu : High value samples are well correspond to the distribution of volcanics, ultra-basic rocks and Chert-Spilite formation. The anomalous samples are concentrated in the Mantri area, but the absolute values are comparatively low.

Hg : High value samples are distributed the area between Sungai Balung and Sungai Kalumpang, the east of Tawau and along Sungai Tiagau. Anomalous samples (more than 190 ppb) are concentrated in the upper most stream of Sungai Kalumpang and southern margin of the central part. These anomalous zones are correspond to the altered zone of volcanics and hot springs are also found in these areas.

K : Distribution of the high value sample is well correspond to the distribution of the Tanjong and Kapilit formations. The high value samples are also scattered in the area between Sungai Balung and Sungai Kalumpang. Distribution of the anomalous samples (more than 0.71 %) are same as the distribution of the high value zones. The anomalous sample in the area between Sungai Balung and Sungai Kalumpang may have relation with mineralization because the mineral showings occur in this area.

Mg : High value samples are well correspond to the distribution of ultra-basic rocks. Comparative high value samples are also found in the upper stream of Sungai Kalumpang. This area is occupied with andesite and tuffaceous sedimentary rocks. Anomalous zones (more than 5.02 %) are limited in the area of ultra-basic rocks.

Mn : High value and anomalous samples are concentrated in the central to eastern part of the survey area. These areas are occupied with volcanics or vicinity of volcanic zones. No anomalous samples are found in the area of sedimentary rocks.

Mo : High value samples are distributed in the central to eastern part of the area. The absolute value of Mo is low and no relationship between the contents and mineralization are recognized.

Na : High value samples tend to distribute in the area of ultra-basic rocks and volcanic rocks. But no clear tendencies are observed for this element.

Ni : Hig and anomalous value samples are concentrated in the area of ultra-basic rocks and show similar distribution tendency of Cr. Potentiality of nickel ore deposits is limited in the area of the ultra-basic rocks.

Pb : Distribution of the high value samples are well correspond to the distribution of the high value samples of Au and are concentrated in the area of Sungai Balung and Sungai Kalumpang. The high value samples are also found in the upper most stream of Sungai Kalumpang. Anomalous samples (more than 243 ppm) are concentrated at the upper stream of Sungai Mantri where known mineral showingsare distributed.

S : High value samples are concentrated in the area of volcanic rocks and the northwestern margin of the area where sedimentary rocks occures. Because pyrite disseminations are recognized in the altered volcanic rocks, the contents of S may have close relationship with alteration. Several hot spring are found in the altered zones, and therefore the relationship between the alteration and mineralization is not clear.

Sb : High value zones are mainly situated in the central to eastern part of this area. Higher value samples are found in the area of volcanic rocks and basement rocks. Anomalous samples (more than 61.7 ppm) are found at the northern bank of the middle stream of Sungai Balung and northeastern end of this area.

Sr : High value samples are found in the area of volcanic rocks and ultra-basic rocks and the surroundings. This element shows similar distribution tendency of Na. The anomalous samples (more than 333 ppm) are scattered in the high value zones and show no clear distribution tendencies.

Ti : High value samples are well corrspond to the distribution of volcanic rocks and have similar distribution tendency of Mn.

U : High and anomalous samples are characteristically concentrated in the southern central part of this area. Because acidic rocks contain more uranium in general, this high value zones may have relationship with dacite in this area.

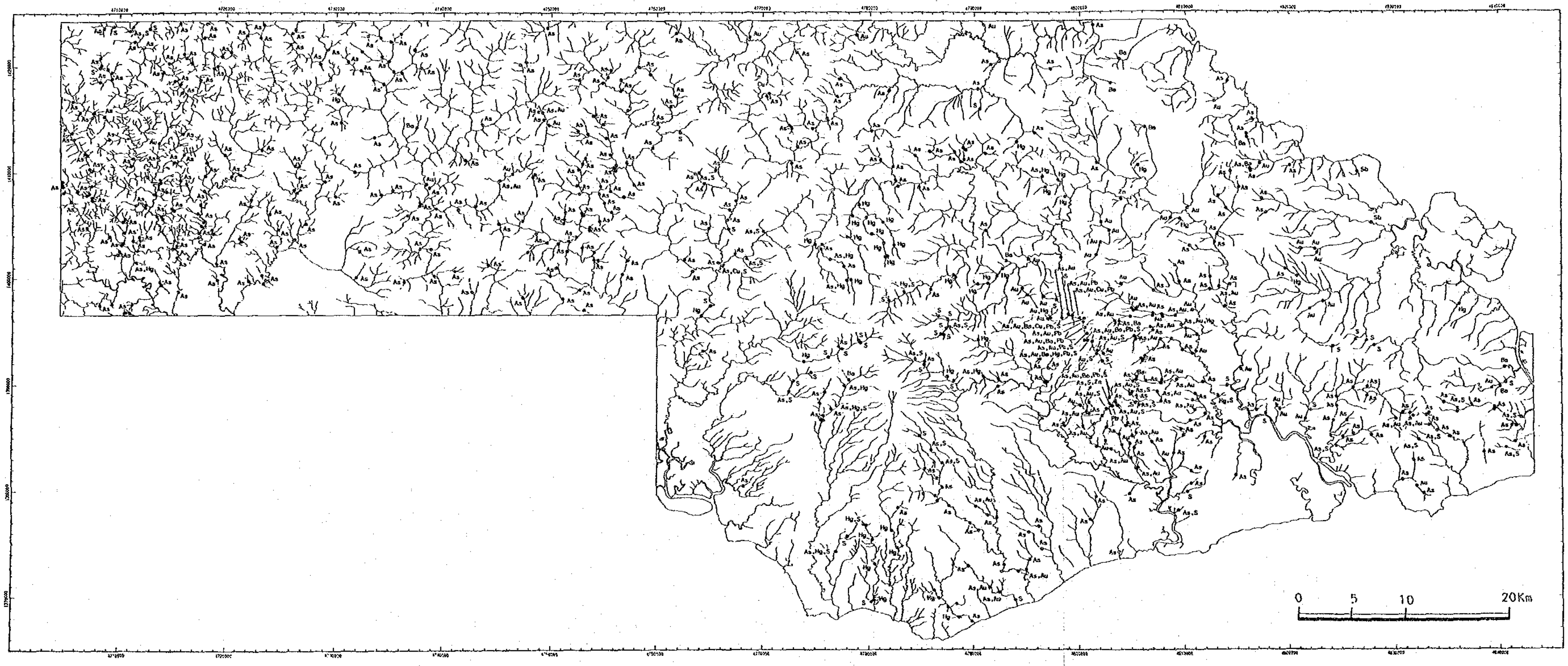


Fig. II-1-12 Distibution map of anomalous stream sediment samples for major elements in the semporna area

W : High and anomalous zones are scattered in the western to central part of this area. No clear distribution tendencies are observed. Because of low contents of W, no potentiality of tangusten deposits are expected in this area.

Zn : Distribution tendency of high value samples are similar to that of Co, and are observed in the area of volcanics in the central part of this area. Anomalous samples (more than 502 ppm) are found in the middle stream of Sungai Kalumpang and Sungai Balung. The anomalous samples in the middle stream of Sungai Kalumpang is isolated and no high value samples are observed in the surroundings of this zone.

Judging from the distribution tendencies of the elements, the elements are classified into two groups. One is closely related with geology and the other is related with mineralization in this area. Nine elements including As, Au, Ba, Cu, Hg, Pb, S, Sb and Zn are thought to have relationship with mineralization. Distribution of anomalous samples for these nine elements are shown in Fig.II-1-12.

(3) Multi element analysis

In order to clarify the relationship among the pathfinder elements, cluster analysis was made in this survey. Dendrogram calculated is shown in Fig.II-1-13. As shown in this figure, following groups of element form cluster.

Mn - Ti   Na - Sr   Mg - Co - Zn   Cr - Ni   Au - Pb

These related elements each other show similar distribution tendencies.

In addition to the cluster analyses, factor analyses of varimax rotation method were applied in this survey. Results of the factor analyses are shown in Table II-1-11. Five factors are deliniated in this survey. The elements which have close relationship with these factors are as follows:

Factor 1 Ba-Cu-Na-S-Sr

Factor 2 Co-Mg-Mn-Ti

Factor 3 Cr-Ni

Factor 4 Au-Pb

Factor 5 Sb

Among these facters factor 1, 2, 4 and 5 have negative relationship with these elements. Judging from the relationship between the factor and the related elements, the foctor 1 has some relation with copper mineralization. The factor 2 may relates to volcanics, the factor 3 may relates to ultra-basic rocks and the factor 4 possibly indicates gold-silver mineralization. Consequently, factor 1 and factor 4 have possibility to be the factors of mineralization. Distribution maps of factor 1 and factor 4 factor scores are shown in Fig.II-1-14 and Fig. II-1-15

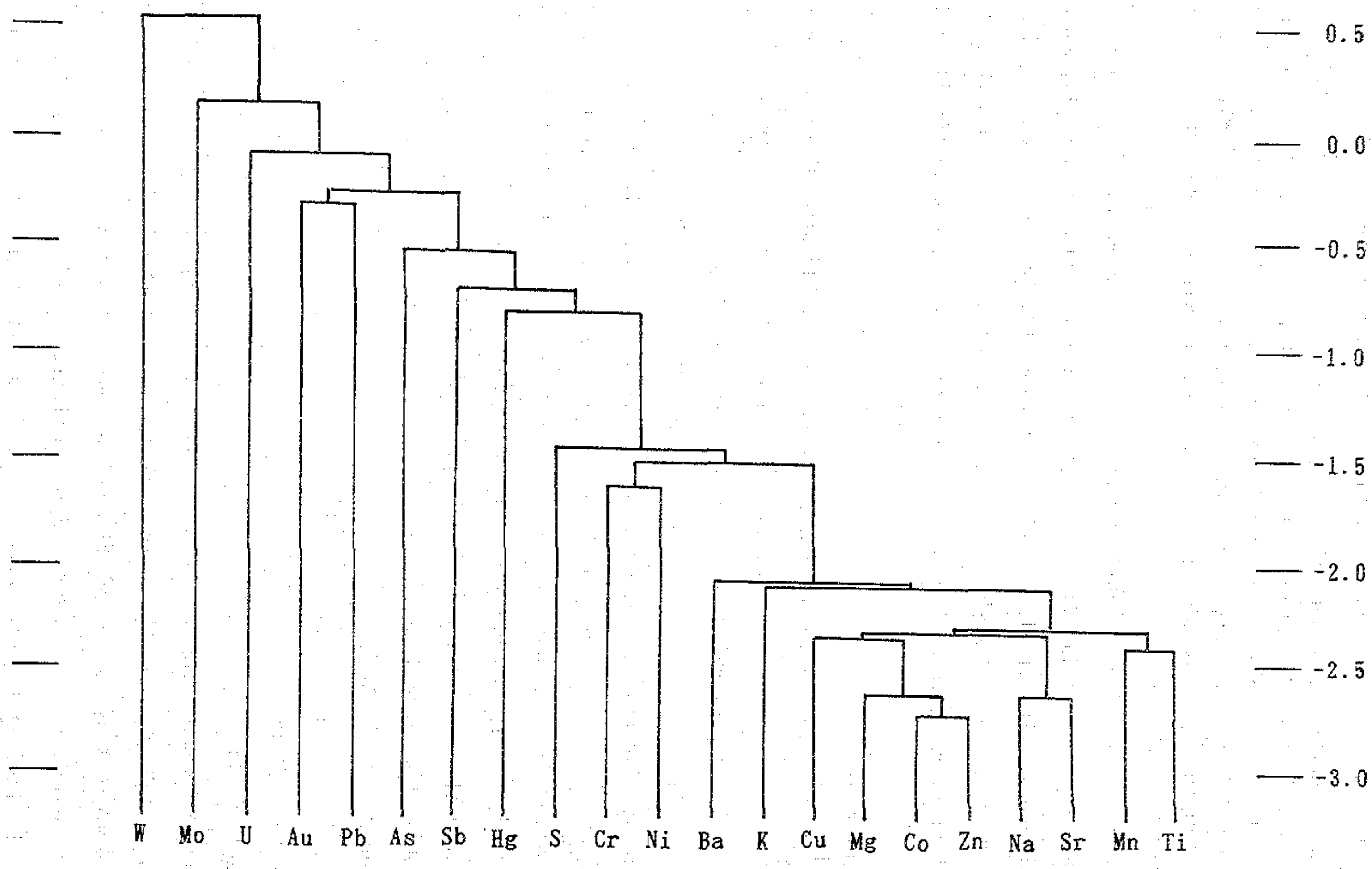


Fig. II-1-13 Dendrogram of elements for stream sediments in the Semporna area

Table II-1-11 Results of factor analyses for stream sediments in the Semporna area

Element	Factor loadings (Varimax rotation)					Communality
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	
As	-0.167	0.468	-0.089	-0.357	0.029	0.3830
Au	-0.012	-0.036	0.002	-0.458	-0.170	0.2396
Ba	-0.802	-0.071	-0.157	-0.084	-0.176	0.7110
Co	-0.423	-0.779	0.254	0.088	-0.043	0.8598
Cr	0.306	-0.139	0.739	-0.025	0.010	0.6593
Cu	-0.746	-0.383	0.137	-0.073	-0.103	0.7384
Hg	-0.490	-0.156	-0.190	-0.234	0.026	0.3559
K	-0.801	0.282	-0.015	0.098	-0.151	0.7546
Mg	-0.582	-0.528	0.443	0.238	-0.117	0.8841
Mn	-0.103	-0.806	0.103	-0.019	-0.213	0.7168
Mo	-0.138	-0.065	-0.101	-0.049	-0.379	0.1793
Na	-0.763	-0.042	0.294	0.402	-0.136	0.8509
Ni	-0.218	-0.156	0.777	0.010	0.101	0.6853
Pb	0.053	0.076	-0.075	-0.618	0.011	0.3964
S	-0.607	-0.178	-0.048	-0.281	0.002	0.4817
Sb	-0.065	-0.342	0.257	0.049	-0.487	0.4271
Sr	-0.780	-0.320	0.056	0.290	-0.217	0.8451
Ti	-0.077	-0.890	-0.090	-0.133	-0.135	0.8412
U	-0.019	-0.094	-0.406	-0.289	0.214	0.3040
W	-0.058	-0.061	0.031	-0.153	-0.202	0.0720
Zn	-0.569	-0.720	0.044	-0.135	-0.113	0.8747
F.C.*1	38.3 %	29.7 %	15.2 %	10.9 %	6.0 %	—

*1: Factor contribution

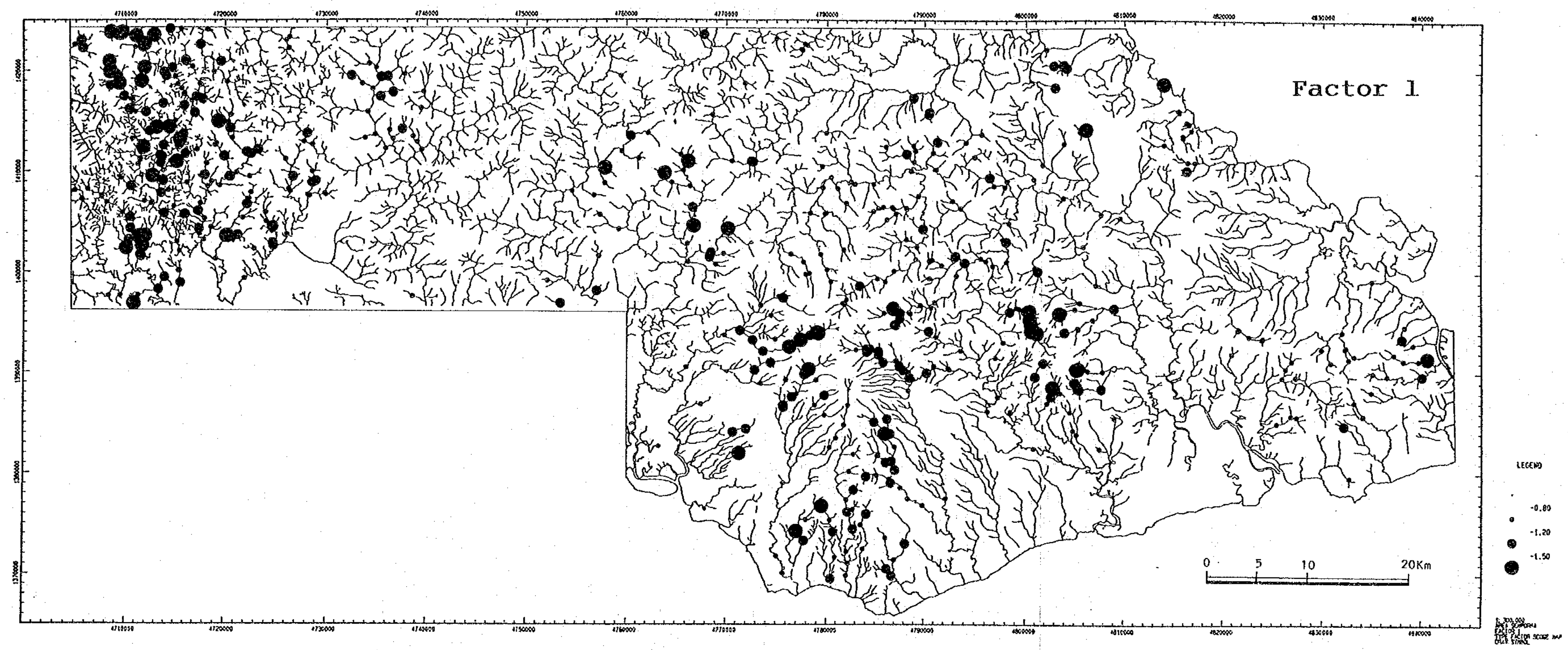


Fig. II-1-14 Distribution map of factor 1 factor scores for stream sediment samples in the Semporna area

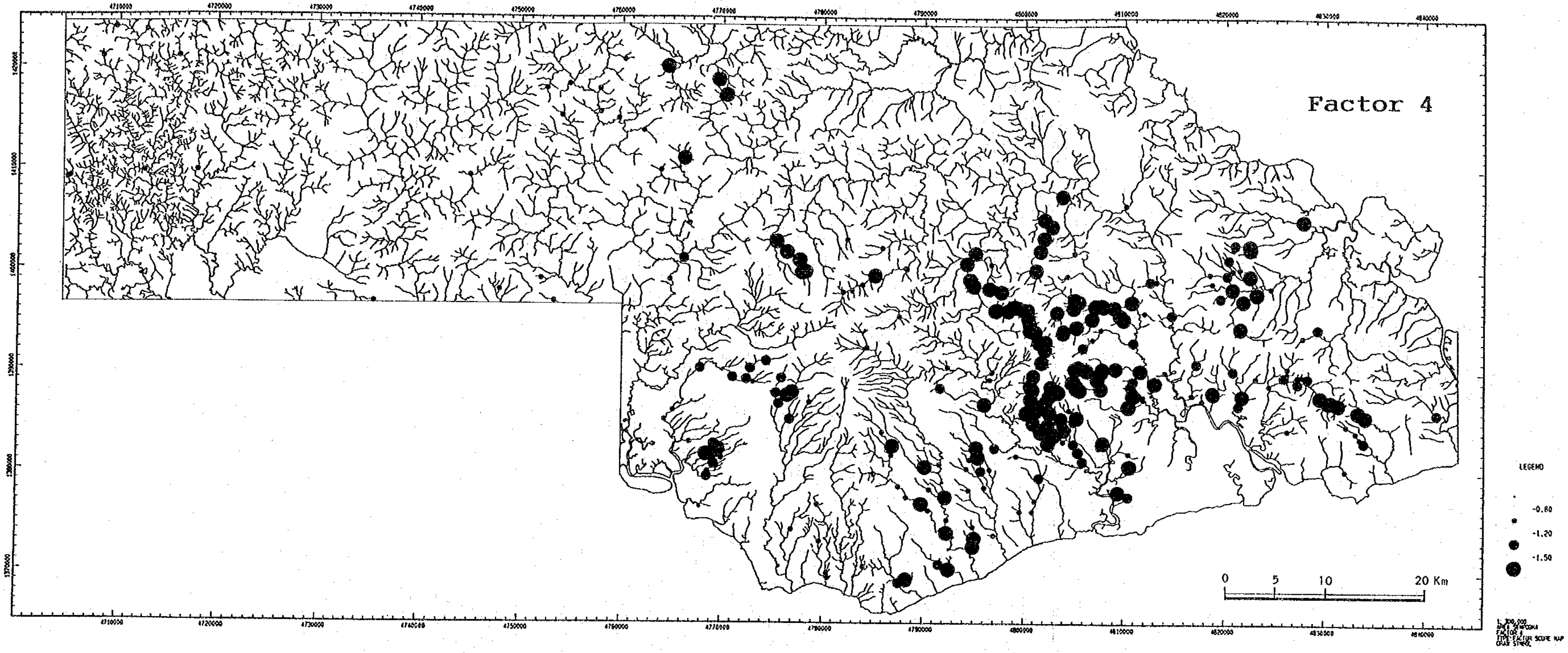


Fig. II-1-15 Distribution map of factor 4 factor scores for stream sediment samples in the Semporna area

respectively. Distribution of these factor scores are summarized as follows:

Factor 1 : High factor score (negative figure) zones are concentrated in the area of Tanjong and Kapilit formations and are scattered in the area of volcanic rocks. Cyprus type sulfide deposits in the Chert-Spilite formation is the expecting copper deposits in this area. But no high score zones are found in the area of the Chert-Spilite formation. This fact may suggest low potentiality of copper deposits in this area.

Factor 4 : The high factor score (negative figure) zones are found in the area between Sungai Balung and Sungai Kalumpang, upper stream of Sungai Sipit, upper most stream of Sungai Kalumpang, down stream of Sungai Merotai Kecil and upper most stream of Sungai Tawau. Among these zones, many known showings are situated in the area between Sungai Balung and Sungai Kalumpang.

The results show that the factor 4 deliniates known gold-silver showings in this survey.

1-3-4 Pan concentrate survey

(1) Sampling

During the survey 160 pan concentrate samples were collected from main streams in this area. The sample was collected by five times panning (approximately 25 liters of gravels). Maximum weight among the samples is 774 grams but some samples collected in the area of sedimentary rocks are less than one gram. Locations of these samples are shown in Fig. II-1-11 and the list of sample are shown in Appendix 16.

(2) QME analysis

Results of the QME analyses are shown in Appendix 17. As the results of the QME analyses, magnetite, chromite, ilmenite, goethite, pyrite and zircon were recognized as the heavy minerals. Minor amounts of leucoxene, rutile, monazite, tourmaline, marcasite and hematite were also observed. Some samples contain comparatively large amounts of pyroxenes and hornblende. Native gold were confirmed in four samples. The minerals detected in this survey are almost same as the minerals in the Segama area. The small amount samples contain many quartz and plagioclase. Illustration of the results of QME analyses are shown in Fig. II-1-16. The relationship between heavy minerals and geology is summarized as follows:

Magnetite : Magnetite was detected from the most of the samples. Significant amounts of magnetite were confirmed in the samples collected in

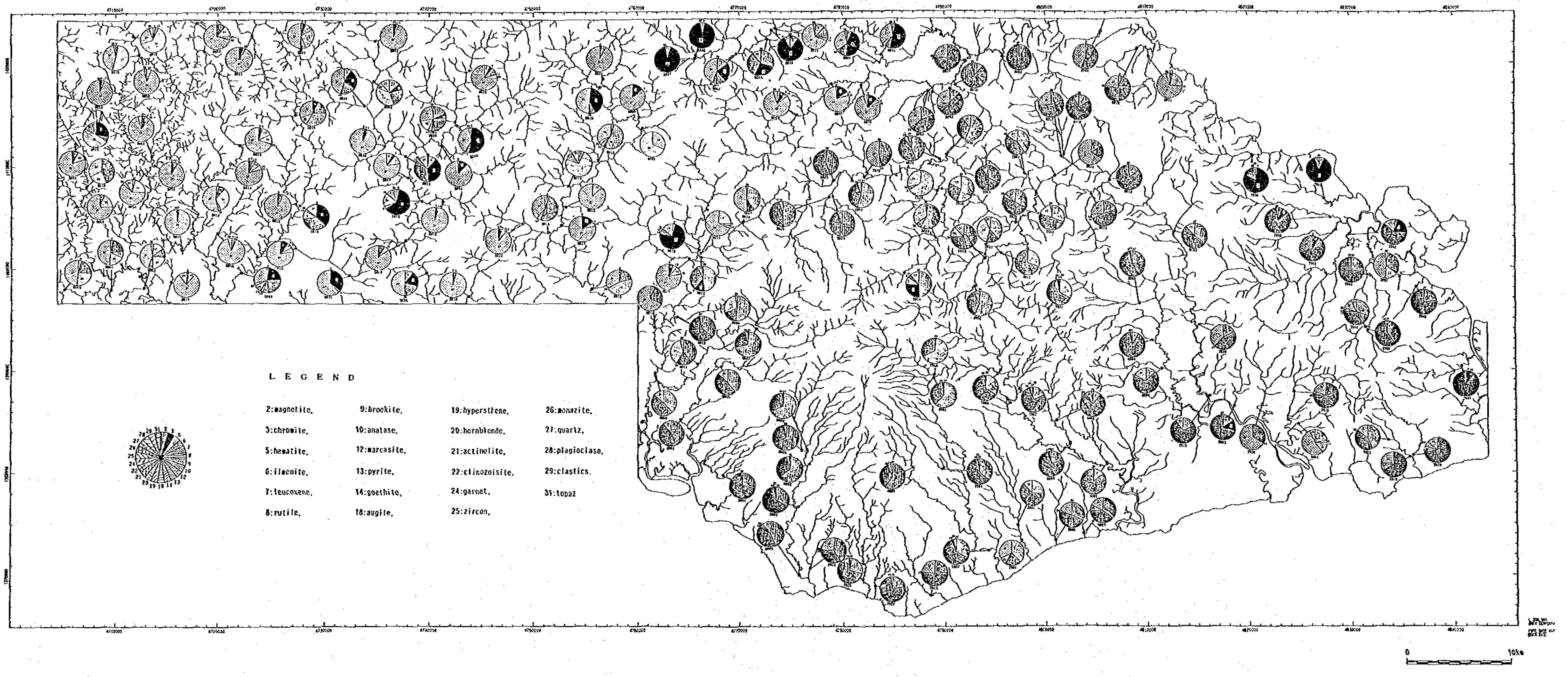


Fig. II-1-16 Interpretation map of pan concentrate samples in the Semporna area

the central part of the area where volcanics are widely distributed.

Chromite : Chromite was also detected in many samples. Significant amounts of chromite was confirmed for the samples collected in the eastern, northern and western parts in this area. Ultra-basic to basic rocks occur at the upper stream of these parts.

Ilmenite : Ilmenite was observed in the most of the samples. The samples with large amounts of ilmenite are distributed in the central to eastern part of this area where volcanic rocks are widely distributed.

Goethite : Goethite tends to occur in the western part of this area where sedimentary rocks are distributed.

Pyrite : A small amount of pyrite was confirmed in the western part of this area where sedimentary rocks occur. A large amounts of pyrite was detected in the samples collected at the upper stream of Sungai Geminchau.

Native gold : Native gold was detected in four samples collected at the tributary of Sungai Pang Burong, upper stream of Sungai Pang Burong, Sungai Balung and Sungai Mantri. These areas were also detected as the high value zones of gold in the stream sediment geochmical survey.

Zircon : Zircon tend to occur in the samples collected in the western part of this area where sedimentary rocks are distributed.

1-3-5 Rock geochemical survey

Fifty (50) representative rock samples were collected in this survey and chemically analyzed for 21 elements same as the stream sediment samples. Locations of the sample are shown in Fig. II-1-11. The sample list is shown Table II-1-12 and the analytical results are shown in Appendix 18. As the results of the chemical analyses, more than 60 % samples give less than the detection limit for the elements of As, Au, Mo and Pb.

The relationship between the rock and contents of each element are summarized as follows:

As : About 70 % samples give the value less than the detection limit. The maximum value was obtained from altered volcanic rocks. Sandstone and mudstone tend to give comparatively higher values (3 ppm to 6 ppm).

Au : 94 % samples give the value less than the detection limit. Altered volcanic rocks give higher values. The maximum value is 23 ppb.

Ba : Micro-granodiorite give the maximum value of 1,636 ppm. Diorite, andesite, basalt and tuff give comparatively higher value in a range of 200 ppm to 600 ppm.

Co : Serpentinite give the maximum value (110 ppm). High values (more than 100 ppm) were obtained only from the ultra-basic rocks. Altered rock, basalt

Table II-1-12 List of rock geochemical samples in the Semporna area

Ser. No.	Sample No.	Coordinates N	Coordinates E	1/50,000 Topo. Sheet	Name of Stream	Descriptions	Geol. Unit
1	M057	1422.58	4705.07	Sungai Tiagau	—	siltstone (muddy)	N_2Tj
2	M052	1419.75	4708.66	Sungai Tiagau	S. Tiagau	siltstone	N_2Tj
3	B062	1412.23	4706.19	Sungai Tiagau	S. Kalabakan	mudstone	N_2Kp
4	M060	1417.24	4717.72	Sungai Tiagau	S. Gukuam	shale	N_2Kp
5	R006	1420.16	4737.02	Sungai Umas Umas	S. Brantian	meta-gabbro	P_4Km
6	R005	1419.58	4736.15	Sungai Umas Umas	S. Brantian	green rock, basalt?	KPCs
7	R010	1419.68	4737.57	Sungai Umas Umas	S. Brantian	meta-gabbro	Ub
8	M041	1418.30	4739.87	Sungai Umas Umas	S. Gumbal	meta-gabbro	Ub
9	M050	1416.05	4733.00	Sungai Umas Umas	S. Brantian	tuffaceous sandstone	P_4Km
10	H052	1413.35	4733.82	Sungai Umas Umas	S. Brantian	pillow lava	KPCs
11	M038	1419.35	4744.15	Sungai Umas Umas	S. Gumbal	sandstone	P_4Km
12	M044	1416.24	4740.22	Sungai Umas Umas	S. Gumbal	meta-gabbro	Ub
13	H049	1413.80	4749.55	Sungai Umas Umas	S. Muntai	sandstone	P_4Km
14	B027	1417.95	4753.93	Sungai Umas Umas	S. Umas Umas	serpentinite	Ub
15	M034	1398.06	4768.32	Sungai Tingkayu	S. Merotai B.	andesite	I_1
16	H044	1422.01	4777.50	Sungai Tingkayu	S. Tingkayu	pillow breccia	KPCs
17	H039	1420.02	4778.70	Sungai TingKayu	S. Tingkayu	sandstone	P_4Km
18	M017	1409.65	4765.85	Sungai Tingkayu	S. Merotai B.	silicified sandstone	P_4Km
19	M025	1406.82	4773.22	Sungai Tingkayu	S. Merotai B.	mudstone	P_4Km
20	H042	1420.38	4786.39	Sungai Tingkayu	S. Tingkayu	pillow breccia	KPCs
21	M031	1405.89	4787.05	Sungai Tingkayu	S. Malati	siltstone	P_4Km
22	M066	1393.80	4778.55	Tawau North	S. Merotai	altered rock w/py	I_1
23	T061	1384.20	4770.45	Tawau North	S. Merotai K.	basalt	I_2
24	M003	1384.75	4781.73	Tawau North	S. Tawau	andesite	I_2
25	T048	1382.85	4787.75	Tawau North	S. Apas	andesitic lapill.tf.	I_2
26	T040	1406.42	4788.50	Mostyn	S. Malati	lapilli tuff	P_4Kg
27	H025	1418.90	4798.55	Mostyn	S. Tingkayu	basalt	I_2
28	T064	1410.75	4794.23	Mostyn	S. Kalumpang	tuffaceous sandstone	P_4Kg
29	T066	1408.63	4797.80	Mostyn	S. Kalumpang	coarse sandstone	P_4Kg
30	T034	1399.35	4790.95	Mostyn	S. Mantri	andesite w/py	I_1
31	T033	1396.65	4790.55	Mostyn	S. Mantri	altered rock w/py	I_1
32	H026	1417.62	4807.30	Mostyn	—	basalt	I_2
33	H022	1410.70	4806.87	Mostyn	S. Limau	coarse tuff	P_4Kg
34	H015	1405.62	4803.94	Mostyn	—	micro-diorite	I_1
35	H028	1401.64	4803.36	Mostyn	—	tuffaceous sandstone	P_4Kg
36	H013	1399.88	4806.94	Mostyn	S. Tundong	sandstone	P_4Kg
37	H027	1414.67	4814.16	Mostyn	S. Atas	red chert	KPCs
38	T010	1392.95	4792.46	Apas-Balang	S. Balung	medium tuff	I_1
39	T012	1390.44	4796.70	Apas-Balang	S. Balung	dacite	I_1
40	H001	1387.94	4803.56	Apas-Balang	—	altered An. w/py	I_1
41	H029	1407.52	4819.20	Pulau Timbun Mata	S. Sipit Lahu.	serpentinite	Ub
42	T041	1400.95	4819.75	Pulau Timbun Mata	S. Sipit	co-tuff, argillized	P_4Kg
43	T057	1510.96	4820.10	Pulau Timbun Mata	S. Sapang	green rock, basalt?	KPCs
44	H031	1405.98	4823.41	Pulau Timbun Mata	S. Sipit Lahu.	serpentinite	Ub
45	T045	1397.92	4835.27	Pulau Timbun Mata	—	micro-diorite	I_1
46	S003	1393.04	4820.15	Kalumpang	—	basalt	I_2
47	T016	1390.05	4821.02	Kalumpang	S. Pinang B.	andesite	I_2
48	T028	1392.35	4829.75	Kalumpang	S. Separong	sili. andesite w/py	I_1
49	T032	1388.74	4835.56	Kalumpang	—	fine tuff	I_1
50	T031	1388.05	4834.88	Kalumpang	—	andesite	I_1

and gabbro give comparatively higher value (approximately 50 ppm).

Cr : Serpentinite give the maximum value of 1,611 ppm. Ultra-basic rocks tend to give higher values. Gabbros and basalt have also higher values in a range of 200 ppm to 500 ppm.

Cu : Altered volcanic rock gives the maximum value (150 ppm). Basalt, gabbro and chert give comparatively higher values in a range of 60 ppm to 80 ppm.

Hg : Altered rock gives significant high values (maximum 2,905 ppb). Other kind of rocks give lower values except tuff. Contents of Hg in tuff is in a range of 100 ppb to 300 ppb.

K : Altered rock indicate the maximum value of 5.23 %. Mudstone, tuff, basalt and andesite have comparatively higher values. Ultra-basic rocks give the values of less than the detection limit.

Mg : Serpentinite gives the maximum value (21.33 %). Ultra-basic rocks give more than 20 % of Mg. Gabbro and basalt show in a range of 3 % to 6 % Mg contents.

Mn : Sandstone give the maximum value of 4,960 ppm. No tendencies are recognized.

Mo : 66 % of the samples give less than the detection limit. Altered rock give the maximum value of 3 ppm. Altered rock and tuff give slightly higher values.

Na : Basalt gives the maximum value of 4.65 %. Gabbro and basalt show comparatively higher values of more than 2 %. Altered rock and ultra-basic rocks give lower values less thann 0.2 %.

Ni : Serpentinite gives the maximum value (2,181 ppm). Ultra-basic rocks indicate more than 2,000 ppm. Basalt and gabbro indicate comparatively higher value in a range of 100 ppm to 200 ppm.

Pb : The maximum value (10 ppm) was obtained from sandstone. 80 % of the sample show less than the detection limit. Altered rock give comparatively higher value of 6 ppm.

S : The maxmum value of 7.944 % was obtained from altered rock. Altered rocks give more than 3 % but other kinds of rocks give low values.

Sb : Basalt gives the maximum value (14.0 ppm). Basalt and tuff tend to give higher values.

Sr : Tuff gives the maximum value of 824 ppm. Sandstone, diorite and andesite tend to give higher values.

Ti : Basalt gives the maximum value (2.03 %). Basalt gives more than 1 % contents.

U : The maximum value (2.8 ppm) was obtained from altered rock and andesite. Sandstone and altered rock give comparatively higher values.

W : The maximum value (339 ppm) was obtained from sandstone. Sandstone tends to give higher values.

Zn : Serpentinite gives the maximum value of 180 ppm. Ultra-basic rocks tends to give higher values. Serpentinite, basalt and diorite give more than 100 ppm.

1-3-6 Soil geochemical survey

Seventeen soil samples were collected in this area and six elements (Al, Co, Cr, Fe, Ni and Pt) were chemically analyzed. Sample location of these samples are shown in Fig.II-1-11. List of the sample and the analytical results are shown in Appendix 19.

The statistics for these samples are as follows:

Element	Mean value	Minimum value	Maximum value
Al	0.82 %	0.16 %	2.32 %
Co	108 ppm	31 ppm	433 ppm
Cr	1,158 ppm	340 ppm	4,176 ppm
Fe	1.85 %	0.81 %	3.63 %
Ni	775 ppm	117 ppm	3,506 ppm
Pt	7 ppb	5>ppb	25 ppb

The analytical results give comparatively low values. The sample collected at the upper stream of Sungai Umas Umas gives the maximum value of Co (433 ppm), and most samples give less than 250 ppm of Co. The sample indicating the maximum value of Cr (4,176 ppm) was collected at the middle stream of Sungai Sipit Lahunai in the eastern part of the area. The sample indicating the maximum value of Ni (3,506 ppm) was collected at the upper stream of Sungai Mantri. Ni contents for the most sample are less than 2,000 ppm. Ultra-basic rocks are scattered from the eastern part to the western part in this area. But, potentiality of nickel ore deposits is thought to be low, because of the low contents of Ni in the lateritic soil.

1-3-7 Results of laboratorial studies

(1) Observation of thin sections

Ten samples including basic rocks, Chert-Spilite formation, Kuamut formation, Pliocene volcanic rocks and Pleistocene to Holocene volcanic rocks were collected and observation of thin sections was made for these rocks. Results of the observation are shown in Table II-1-13. As the results of this observation, gabbro sample shows cumulus texture. This gabbro may form a part of ophiolite. The sample of tuff (T057) collected from Chert-Spilite formation indicates weak chloritization. Tuff (M040) sample collected from Kuamut formation is affected by strong epidotization and weak silicification. Andesite (S003, T049) and basalt (T061) samples contain chlorite, montmorillonite and zeolites as the alteration minerals.

Table II-1-13 Observation results of thin sections collected in the Semporna area

Ser. No.	Sample No.	Location Coordinates N	Location Coordinates E	Geologic Units	Rock Name	Texture
1	H015	1405.62	4803.94	I_1	Gabbro	Equigranular
2	M040	1421.05	4744.37	P_4 Km	Coarse tuff	Pyroclastic
3	M044	1416.24	4740.22	Ub	Gabbro	Cumulus
4	M047	1412.31	4736.45	Ub	Gabbro	Cumulus
5	S003	1393.04	4820.15	I_2	Andesite	Porphyritic and intersertal
6	S005	1388.84	4828.62	I_1	Tonalite	Hypidiomorphic granular
7	T012	1390.44	4796.70	I_1	Pumiceous tuff	Pyloclastic
8	T049	1381.58	4788.37	I_2	Andesite	Porphyritic
9	T057	1410.96	4820.10	KPCs	Andesitic coarse tuff	Pyloclastic
10	T061	1384.20	4770.45	I_2	Basalt	Porphyritic and intergranular

Fragments, grains and minerals

Ser. No.	basalt	andesite	scoria	quartz	plagioclase	biotite	hornblende	clinopyroxene	orthopyroxene	olivine	opaque minerals
1					◎			○	o		o
2		○	o		○			○	◎		●
3					◎			◎			
4					◎		○	◎			●
5					◎			o	o		●
6				◎	◎	o					●
7											
8					○	o	○				
9	○	○									
10					○			o		o	●

Matrix, groundmass and accessory minerals

Ser. No.	tuff	pumice	quartz	plagioclase	biotite	clinopyroxene	orthopyroxene	glass	apatite	opaque minerals
1										
2	◎			○		○				
3										
4										
5				○		o	o	◎		●
6									●	
7	o	◎	◎					○		●
8			○	◎	o					
9	◎		○	○						
10				◎		○	o			●

Altered minerals

Ser. No.	quartz	actinolite	prehnite	pumpellyite	epidote	chlorite	zeolite	illite	sericite	montmorillonite	calcite	opaque minerals
1		●				●						
2	o		o	o	◎							
3			o		o	○				o		●
4		○				o		○		o		
5												
6					o	○			●			
7	o									o		o
8						◎				o		
9				○		o					o	
10						o	o			o		

◎ :abundant, ○ :common, o :a little, ● :rare.

(2) Observation of polished sections

Five samples were collected from the mineralized and altered zones of Pliocene volcanic rocks and this study was carried out for these samples. The observation results are shown in Table 1-14. Pyrite, goethite and pyrolusite was confirmed in these samples. Pyrolusite was confirmed in the gossanized sample collected ar the northern bank of Sungai Balung.

(3) X-ray diffraction analyses

Results of this analyses are shown in Table II-1-15. The alteration minerals detected in this analyses are montmorillonite, kaolinite, halloysite, chlorite, sericite, cristobalite, quartz and K-feldspar. Other than these minerals, plagioclase and pyrite were also detected. The alteration mineral assemblage indicates acidic to intermediate hydrothermal alteration in this area.

(4) Ore assaying

Five samples were collected from mineralized and altered zones in this area. Seven elements including Au, Ag, Cu, Pb, Zn, Mo and S were assayed in this survey. Results of this assaying are given in Table II-1-16. All samples give Au and Ag values of less than the detection limit. Sample number T027 give the maximum Cu value of 0.02 %. Sample number H002 give the maximum Pb value of 0.05 %. No significant assay values were obtained in this survey.

Table II-1-14 Observation results of polished sections collected in the Semporna area

Ser. No.	Sample No.	Location Coordinates		Descriptions	pyrite	goethite	pyrolusite	gangue minerals	Remarks
		N	E						
1	H002	1387.37	4802.60	Gossan with quartz veinlets			◎	○	Pyrolusite: zonal.
2	M020	1415.55	4768.75	Reddish brown strongly silicified rock with quartz stringer and weak dissemination of pyrite.			●	◎	
3	M066	1393.83	4778.55	Dark gray strongly silicified and argillized rock with dissemination of pyrite.	○			◎	Pyrite: subhedral-euhedral.
4	T022	1383.70	4833.30	Dissemination of pyrite in silicified rock.	○			◎	Pyrite: anhedral-euhedral.
5	T027	1380.65	4831.42	Gossan with quartz veinlets.		●		◎	

◎ :abundant, ○ :common, ∘ :a little, ● :rare.

Table II-1-15 Results of X-ray diffraction analyses for samples in the Semporna area

Ser. No.	Sample No.	Location Coordinates		Descriptions	Detected minerals										Remarks
		N	E		montmorillonite	kaolinite	halloysite	chlorite	sericite	cristobalite	quartz	plagioclase	k-feldspar	pyrite	
1	M010	1393.40	4774.70	Whitish gray bleached altered rock with dissemination of pyrite.	●		○		●		◎	○		o	
2	M066	1393.83	4778.55	Dark gray strongly silicified and argillized rock with dissemination of pyrite.		◎					◎			○	
3	S005	1388.84	4828.62	Whitish gray weakly chloritized Tonalite.	o			○			◎	◎			
4	T003	1380.42	4790.11	Light yellow strongly argillized rock.	o		○			◎	◎		○		
5	T028	1392.35	4829.75	Whitish gray strongly silicified rock with pyrite.	●						◎	◎	○	●	

◎ :abundant, ○ :common, o :a little, ● :rare.

Table II-1-16 List of ore samples and their assay results in the Semporna area

Ser. No.	Sample No.	Location Coordinates		Descriptions	Analytical Elements							Remarks
		N	E		Au (g/t)	Ag (g/t)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	S (%)	
1	H002	1387.37	4802.60	Gossan with quartz vein	0.1>	0.1>	18	508	132	1>	0.066	float
2	M066	1393.83	4778.55	Dark gray strongly silicified and argillized rock with dissemination of pyrite.	0.1>	0.1>	58	14	9	1>	3.37	
3	T022	1383.70	4833.30	Gossan in silicified rock.	0.1>	0.1>	86	139	30	50	2.37	
4	T027	1380.65	4831.42	Gossan with quartz vein	0.1>	0.1>	215	268	5	1>	0.038	
5	T062	1396.12	4787.90	Dark gray strongly silicified and argillized rock with dissemination of pyrite.	0.1>	0.1>	87	13	25	1>	5.22	

1-4 Kinabalu/Labuk area

1-4-1 Geology and mineralization

Geology of this area consists of ultra-basic rocks (Ub), Chert-spilite formation (KPCs) and overlying younger sedimentary rocks. Geologic map in this area is shown in Fig. II-1-17.

The ultra-basic rocks (Ub) consist mainly of harzburgite, dunite and pyroxenite and are widely distributed in the center of this area. These ultra-basic rocks are generally affected by serpentinization. Gabbro bodies which show close relation with the ultra-basic rocks, occurs in the southwestern margin of this area. These rocks are from Cretaceous to early Tertiary (Y.E. Heng, 1985) in age.

Volcanic rocks mainly consisting of spilite are found overlying and/or nearby the ultra-basic rocks with close relationship each other. This volcanic rocks form a part of the Chert-Spilite formation (KPCs)(Y.E. Heng, 1985). This formation deposited during Cretaceous to Eocene in age (Y.E. Heng, 1985).

The northern part of this area is widely occupied by sandstone formation covering the ultra-basic rocks and Chert-Spilite formation. This sandstone forms a part of Crocker formation (P_2Cr) (Y.E. Heng, 1985) and is Eocene to Oligocene in age. Kulapis formation (P_2Ks) which is same age of the Crocker formation, is found in a limited area at the eastern part of this area. This formation consists of sandostone with subordinate siltstone and shale.

Kudat formation (P_3Kd) of Oligocene in age (Y.E. Heng, 1985) is distributed along Sungai Tungud in the north central part of this area. This formation consists of alternation of sandstone, shale, mudstone and siltstone.

Garinono formation (P_4Gr) of Oligocene to Middle Miocene in age (Y.E. Heng, 1985) is distributed in the southeastern part of this area covering the Crocker and Kulapis formations. This formation is characterized with slump breccia, but this formation mainly consists of sandstone in this area.

The northeastern margin of this area is occupied with Bongaya formation (N_4By) (Y.E. Heng, 1985) which is Middle Miocene to Pliocene in age. This formation consists of sandstone with subordinate mudstone and siltstone.

The eastern part of this area is widely covered with gravels, and terrace deposits are also observed along the main rivers.

Fault systems recognized in this area are NNW-SSE and NNE-SSW systems. These systems cut the ultra-basic rocks and Chert-Spilite formation. Geologic structure

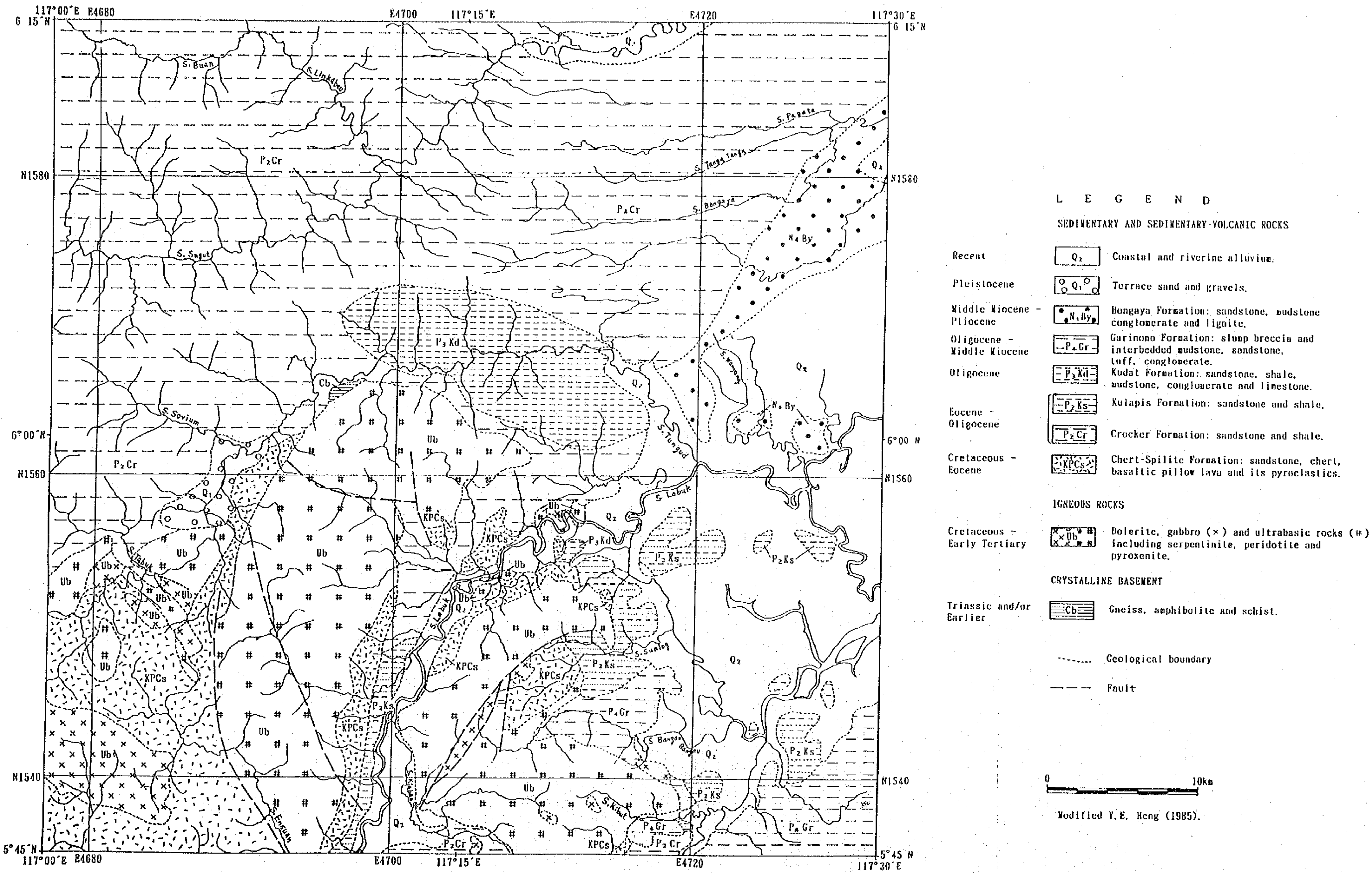


Fig. II-1-17 Geologic map of the Kinabalu/Labuk area

in the area of sedimentary rocks is obscure.

The most significant known mineralized zone is Bidu Bidu Hill ore deposits situated in the middle stream of Sungai Sualog. This ore deposit is classified to be Cyprus type massive sulfide deposits and is situated in the Chert-Spilite formation. Mineral showings of copper and chromium are also known in the ultra-basic rocks and Chert-Spilite formation.

1-4-2 Sampling

This suvery area is situated from the eastern part of the Kinabalu area to the northern part of the Labuk area covering four topographic map sheets (Linkabau, Kiabau, Sungai Sungai and Terusan Sapi) of 1:50,000 in scale. The base camp for this survey was established in the down stream of Sungai Meliau. The sampling work was carried out using log transportation road and flighing camp along streams. Two boats with engine were used for the survey along sungai Sugut in the northern part of the survey area. Swamp area in the east was excluded for the sampling due to difficult accessibility. The northeastern corner of this area is also excluded in this sampling work because of difficulty of flighing camp.

Sampling method of stream sediments is same to the sampling in the Segama and Semporna areas. List of stream sediment samples is shown in Appendix 20 and the locations of the each sampling site are shown in Plate II-1-3.

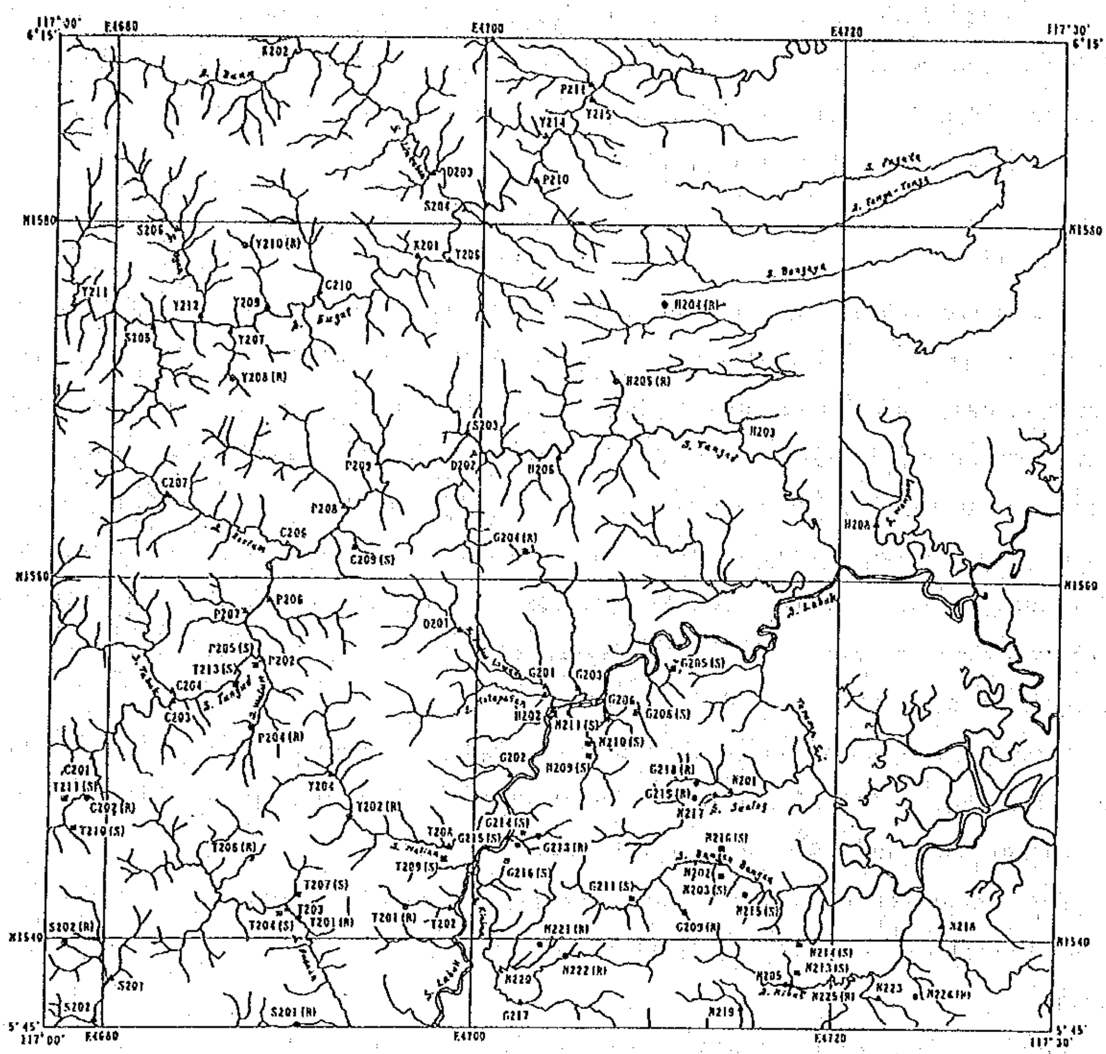
Pan concentrate samples was collected from main tributaries in this area. List of the sample is shown in Appendix 22 and the sampling sites are shown in Fig. II-1-18.

Representative rock samples in this area are collected and chemically analyzed. List of these sample is shown in Appendix 24 and the sampling sites are shown in Fig. II-1-18.

Lateritic soil samples were collected in the area of ultra-basic rocks. List and location of these samples are shown in Appendix 25 and Fig. II-1-18, respectively.

1-4-3 Survey results

Sampling and chemical analyses for the stream sediments, rock and soil were completed in this survey. Qualitative Mineral Examination (QME) was also conducted for the pan concentrate samples. The chemical analyses for three elements such as Au, Pt and U were completed by Chemex Labs Ltd., Canada and other remaining elements were analysed in the Technical Laboratory of Bishimetal Exploration CVo.,



LEGEND

▲ Location of pan concentrate sample.
■ Location of soil sample.
● Location of rock sample.

N209 Sample number.
(S) Sample for soil geochemical survey.
(R) Sample for rock geochemical survey.

0 2 4 6 8 10km

Fig. II-1-18 Location map of pan concentrate, rock and soil samples in the Kinabalu/Labuk area

Ltd. in japan.

Analytical results of the stream sediment samples are shown in Appendix 21. Results of QME are shown in Appendix 25. Analytical results of rock and soil samples are given in Appendix 24 and 25 respectively.

Data processing and analyses will be carried out in the next phase together with the data of the Kinakalu and Labuk areas which are planned in the next phase.

Chapter 2 Heliborne geophysical survey

2-1 Outline of survey

Heliborne geophysical surveys, consisting of magnetics and gamma-ray radiometrics, were carried out in six areas of Sabah State, Malaysia, in 1990 and 1991 fiscal years, in order to clarify the distribution of magnetic and radiometric rocks and to observe magnetic anomalies caused by massive sulfide ore deposits and mineralizations.

In the phase I, the data acquisition work for three areas, Kinabalu(old), Segama and Southern Semporna, have been carried out from November 13th, 1990 to March 20th, 1991, and in 1991 fiscal year the data acquisition for four areas, Northern and Southern Kinabalu, Labuk and Northern Semporna, were done from September 24th, 1991 to January 20th, 1992. Those locations are shown in Fig.II-2-1.

The surveyed areas in the phase I and phase II occupy about 5,650 km^2 and 7,700 km^2, respectively, and the total surveyed area is about 12,250 km^2 in total. Line lengths flown in the phase I and phase II are 10,919 line-km and 16,659.4 line-km, respectively, and the total line length flown is 27,578.4 line-km.

Moreover, in 1990 fiscal year, the in-situ measurements of magnetic susceptibilities and radiometric activities were made at 106 points for the typical 24 kinds of rocks and ores distributed within the survey area, and in 1991 fiscal year, the laboratorial measurements of magnetic susceptibilities and radiometric activities were made also for 102 rock samples collected at the locations in the Segama and Semporna areas, where magnetic and radiometric anomalies were observed.

In this report, the results of the data analysis and interpretation for the five areas(10,650 km^2 and 21,923.4 line-km in total), Southern Kinabalu(including Kinabalu area in 1990 fiscal year), Labuk, Segama, and Northern and Southern Semporna, are described.

2-2 Coverage of work

Field operations of the heliborne geophysical surveys in the phase I and phase II were done by Aerodat Ltd., Canada. The survey in the phase I took twice as long as initially proposed due to unexpected long periods of poor weather conditions. And the survey in the phase II also took twice as long as initially proposed due to unexpected long periods of poor weather conditions so that one additional survey system was applied from early December, 1991.

Specifications of the survey are as follows:

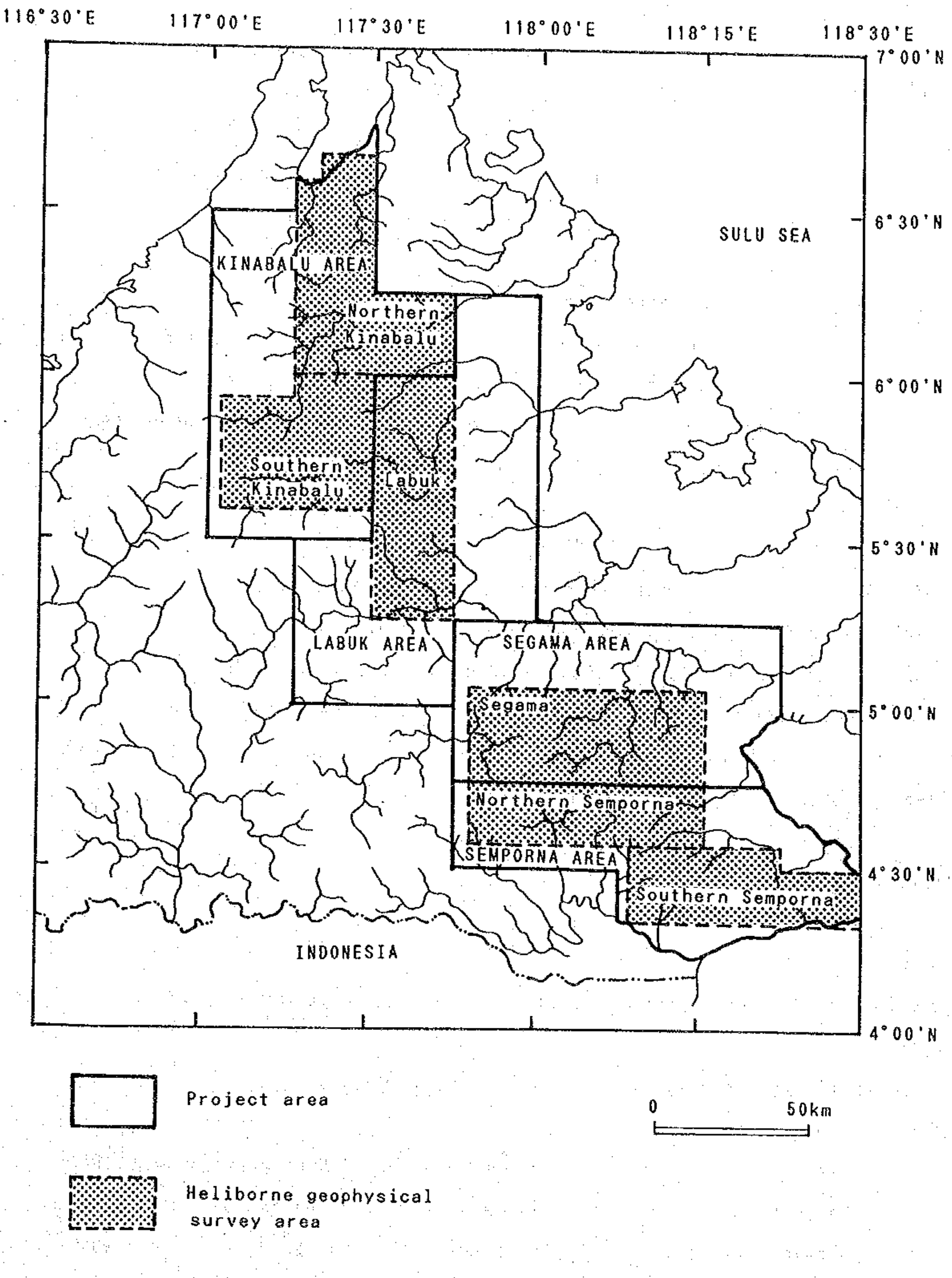


Fig. II-2-1 Location map of the heliborne geophysical survey area

(1) **Method** Heliborne geophysical survey

(2) **Items** Total intensity of geomagnetic field

Gamma-ray radiometrics(U, Th, K, and Total count)

(3) **Flight level** 150 ± 30 metres terrain clearance

Magnetometer Sensor 150 m terrain clearance

Spectrometer Sensor 180 m terrain clearance

(4) **Line spacing** Traverse line 500 m

Tie line 10 km

(5) **Direction of traverse line**

E-W; Kinabalu(Old), Northern Kinabalu, Southern Kinabalu and Labuk areas

N-S; Segama, Northern Semporna and Southern Semporna areas

(6) **Total line length** 10,919 km in the phase I

16,659.4 km in the phase II

27,578.4 km in total

(7) **Equipment** Equipment used are shown in Table II-2-1.

(8) **Navigation** GPS (Global Positioning System)

(9) **Traverse ground speed** Approximately 75 knots(135 km/h)

The geomagnetic field in the general area has a total intensity of about 36,000 nT, an inclination of 6° to 8° south and a declination of 1° east of south.

Flight records are shown in Appendix 19.

2-3 Methodology

2-3-1 Heliborne survey

The helicopter-borne geophysical survey was carried out on the following conditions:

(1) **Data aquisition/processing** Aerodat Limited (Canada)

(2) **Survey period**

Kinabalu(Old) area	December 13th, 1990 to January 6th, 1991
Southern Semporna area	January 11th, 1991 to February 8th, 1991
Segama area	February 12th, 1991 to March 20th, 1991
Labuk area	September 24th, 1991 to November 17th, 1991
Southern Kinabalu area	September 24th, 1991 to January 20th, 1992
Northern Semporna area	January 6th, 1992 to January 10th, 1992
Northern Kinabalu area	November 20th,1991 to January 18th, 1992

(3) Operation base	Kinabalu(Old) area	Ranau
	Segama area	Danum Valley Camp
	Southern Semporna area	Tawau
	Labuk area	Kundasang
	Southern Kinabalu area	Kundasang
	Norhtern Semporna area	Luasong Forestry Centre
	Norhtern Kinabalu area	Kundasang and Kota Marudu

(4) Navigation

The primary navigation system was one based on GPS(Global Positioning System) position determinations. The GPS receiver (Trimble TANS 12017-10) provides updated position coordinates (latitude/logitude or UTMs) every second. These data fed into a navigation computer system (Picodas PNAV 2001) which provides guidance to the pilot. Set-up for any survey area involves entering the area corners, flight line direction and spacing into the navigation system. The system then guides the pilot over a programmed grid of survey lines.

The navigator/operator is responsible to maintain and operate the geophysical equipment and keeps a record of the flight path by marking prominent topographic features on a 1:50,000 scale topographic map as the aircraft moves along the survey line. For those of short intervals when GPS navigation was unavailable, the operator and pilot used traditional visual navigation. The navigator/operator map shows the flight path as a series of manual fiducial markers.

(5) Equipment

1) Aircraft

An Aerospatiale AS355F1 Twinstar(Malaysian Registration No.9M-DPK) was used in 1990 fiscal year. And two same helicopters(Malaysian Registration No.9M-TAN and 9M-AZK) were used in 1991 fiscal year. The installation of the geophysical equipment in the helicopter were carried out by Aerodat at the Sabah Air hanger in Kota Kinabalu in both years.

2) Airborne-Magnetometer

A sensor of the magnetometer(IFG/Aerodat AS355F1) employed was a Scintrex H8 cesium, optically pumped magnetometer sensor. The sensitivity of this instrument is 0.001 nT(nano Tesla) at a 0.2 second sampling rate. The sensor was towed in a bird 30 meters below the helicopter.

The sensor must be oriented to intercept the geomagnetic field within certain angular limits. Normally the sensor operates in only one hemisphere and operations near the magnetic equator such as this survey area require re-

Table II-2-1 Specifications of heliborne geophysical survey instruments

Name	Model	Manufacturer	Specifications
Airborne Magnetometer Cesium Magnetometer Sensor	HSM2 V1W2321 H8	IFG/Aerodat (Canada) Scintrex (Canada)	Resolution; 0.001 nT Sensitivity; 0.005 nT, Range;20,000 - 100,000 nT
Spectrometer	Pgam6000 Pgam6100 Pgam6500	Picodas (Canada)	Crystal volume; 32.7ℓ (downward), 4.1ℓ (upward), Crystal resolution; >12 %, Range; 0.1 - 3.0 MeV/256 ch, 0.1 photopeak resolution
Data Acquisition System /Graphic Recorder	DGR33	RMS Instr. (Canada)	Analog Inputs; 32, Analog Input Range; ±10V, Chart Resolution; 4x4dots/mm, Chart Sensitivity; 10 mV/cm - 10 V/cm, Interface; RS-232-C x 4ports, Data Sample Rate; 10/sec: Event Markers, Manual Fiducial Mark, 5/sec: Magnetometer, Navigation, 1/sec: Spectrometer
Cartridge Tape Recorder	TCR12	RMS Instr. (Canada)	Recording Density; 6400 BPI, Capacity; 11.7 MBytes
Station Magnetometer	M234	Barringer Research (Canada)	Sampling Rate; 1 sec, Resolution; 0.1 nT, Accuracy; 0.5 nT, Range; 20,000 - 90,000 nT
Radar Navigator	PNAV2001	Picodas (Canada)	Resolution; 0.5 m
GPS Receiver	TANS 12017-10	Trimble (U.S.A.)	Accuracy; ±10 m
Barometric Altimeter	1241M	Rosemount (U.S.A.)	Relative Accuracy; ±7 ft, Resolution; ±10 ft
Radar Altimeter	KRA-10A	King (U.S.A.)	Range; 40 - 2,500 ft, Resolution; 5 ft, Accuracy; 5 %
Flight Path Recorder	AG2400	Panasonic (Japan)	VHS style Video-Recorder in NTS format
Helicopter	TwinStar AS355F2	Aerospatial (France)	Type; Twin-engine turbine (Allison 250-C20F), Size; 10.3 ft (H) x 42.5 ft (L) x 8.3 ft (W), Main Rotor Diameter; 35.1 ft, Useful Load; 2,928 lb (1,212 Kg)

Spectrometer windows:

Window;	Lower	Higher	Window;	Lower	Higher
Bi (upward)	1138	1154	Bi214 (downward)	138	154
Total (upward)	1034	1233	K40 (downward)	113	129
T1208 (downward)	201	233	Total (downward)	034	233

orientation of the sensor at the end of every survey line. This was avoided by remote swithing of the sensor electronics at the end of every survey line.

3) Gamma-ray spectrometer

Gamma-ray spectrometer consists of a Picodas PGAM 6000 spectrometer and PGAM 6100 calibrator coupled to two crystal packs with a crystal volume of 2048 $inch^3$ [33,500 cm^3] (downward looking) plus 256 $inch^3$ [4,200 cm^3] (upward looking). Crystal packs were a Picodas DXTL 6500(1,024 $inch^3$ [16,800 cm^3] dwonward looking plus 256 $inch^3$ [4,200 cm^3] upward looking) and a Geometrics GAX 1000(1,024 $inch^3$ [16,800 cm^3] downward looking). The two crystal packs were mounted in the passenger cabin immediately behind the pilot and operator. The crystal sensors were maintained at a temperature of 45°C.

The system features automatic gain stabilization using the pottasium peak at 1.46 MeV), a cosmic radiation monitor(3.0 to 6.0 MeV) and real time anti-coincidence correction.

The spectrometer channels recorded and their energy windows were as follows;

channel	Window(MeV)	channel	Window(MeV)
Total count(TC) - downward	0.41 - 2.81	Uranium(U) - downward	1.66 - 1.86
Total count(TC) - upward	0.41 - 2.81	Uranium(U) - upward	1.66 - 1.86
Potassium(K) - dowward	1.36 - 1.56	Thorium(Th) - downward	2.41 - 2.81
		Cosmic	3.0 - 6.0

The radiometric data were recorded at a 1 second update rate (counts per second - cps). Digital recording is 1 cps.

The system was subject to careful calibration and performance monitoring in the field. This involved system calibration using a secium source and performance checks using pottasium, uranium and thorium samples. These checks were done at the beginning of every survey flight. Gain stabilization was maintained by tracking the K^{40} photo-peak. High altitude radioactive background levels determined above sea or lakes for every flight.

4) Radar altimeter

A King KRA-10 radar altimeter was used to record terrain clearance. The output from the instrument is a linear function of altitude.

A quoted accuracy of this instrument is 5%. In areas of heavy forest cover, the altimeter gives the height of the aircraft above the top of the forest. The radar altimeter determines the distance to the nearest point within a 45° solid angle centered on the axes of the transmitter antenna. In area of extreme terrain, this distance may not be the distance to a point directly below the helicopter.

5) Barometric altimeter   A Rosemount M1241 barometric altimeter.

6) Tracking camera

A Panasonic colour video camera was used to record flight path on VHS video tape. The camera was operated in continuous mode. The flight number, 24 hour clock time(to 0.01 second), and manual fiducial number are encoded on the video tape.

7) GPS navigation system

A Trimble TANS GPS receiver coupled to a Picodas PNAV navigation system was used to direct the pilot over a programmed grid and to generate flight path position coordinates every second. The Trimble GPS receiver provides raw coordinates to the PNAV system. The PNAV system manipulates these data for course direction and deviation.

The Global Positioning System(GPS) is a U.S. Department of Defence program which will provide world-wide, 24-hour, all weather position determination capability. The GPS receiver takes in coded data form satellites in view and thereafter works out the range to each satellite. A further calculation using these ranges gives the position of the receiver in some earth-fixed coordinate system(latitude/longitude, UTMs). The elevation of the receiver is given with respect to a model ellipsoidal earth.

The final satellite constellation will consist of 21 satellites(18 active, 3 spare) in 12 hour orbits. Currently there are 16 satellites in place and some gaps in coverage can be expected. The accuracy of any autonomous position determination can be as good as ±5 m in the local horizontal plane. The U.S. Department of Defence may degrade the signals available to commercial users which reduce this figure to something like ±100 m. This degraded condition is called selective availability. On the most of this survey, selective availability was not activated and the better accuracy was available.

The GPS receiver antenna was mounted on a small platform fixed on the magnetometer bird tow cable some 5 meters below the helicopter. The update rate was 1 second. Coordinates were recorded with a resolution of 1 metre.

8) Analog recorder

A RMS dot matrix recorder was used to display the data during the survey. Record contents are as follows;

Label	Contents			Scale
Geophysical Sensor Data				
MAGF	Total Magnetic Field(Fine)			2.5 nT/mm
MAGC	Total Magnetic Field(Course)			25 nT/mm
TCDN	Radiometrics;	Total Count	Downward	100 cps/mm
K-40		Potassium	Downward	10 cps/mm
URDN		Uranium	Downward	5 cps/mm
URUP		Uranium	Upward	2.5 cps/mm
TH		Thorium	Dwonward	5 cps/mm
COSM		Cosmic Ray		10 cps/mm
Ancillary Data				
RALT	Radar Altimeter			10 ft/mm
BALT	Barometric Altimeter			20 ft/mm

Chart speed was 2 mm/second. The 24 hour clock time is printed every 20 seconds. The total magnetic field value is printed every 30 seconds. The UTM coordinates form GPS/PNAV system are printed every minute.

Vertical lines crossing the record are operator activated manual fiducial markers. The start of any survey line is identified by two closely spaced manual fiducials, and the end of any survey line by three closely spaced manual fiducials. Manual fiducials are numbered in order. Every tenth manual fiducial is indicated by its number, printed at the bottom of the record.

9) Digital recorder

A RMS DGR-33 data system are located at the start and the end of each flight and at intermediate times needed. Contents and update rates were as follows;

Data Type	Recording Interval	Recording Resolution
Magnetometer	0.2 sec	0.001 nT
Spectrometer(7 channels)	1 sec	1 cps
Position(2 channels)	1 sec	1 m
Altimeter(2 channels)	0.2 sec	1 ft

10) Base station magnetometer

An IFG-2 proton precession magnetometer was operated at the base of operations to record diurnal variations of the earth's magnetic field. The clock of the base station was synchronized with that of the airborne system to facilitate later correction. Recording resolution was 1 nT. The update rate was 4 seconds.

External magnetic field variations are recorded on a 3"wide paper chart and in digital form. The analog record shows the magnetic field trace plotted on a grid. Each division of the grid(0.25") is equivalent to 1 minute(chart speed) or 5 nT(vertical sensitivity). The date, time and current total field magnetic value are printed every 10 minutes.

2-3-2 Ground survey and laboratorial measurement

In 1990 fiscal year, in-situ measurements of magnetic susceptibilities and radiometric intensities were made at 106 points for the typical 24 kinds of rocks and ores distributed in in the four areas, Kinabalu, Labuk, Segama and Semporna. Instruments used for this survey are listed in Table II-2-2, and the measuring points, and magnetic susceptibility and radiometric intensity at each measuring point are shown in Fig.II-2-2 and Appendix 20, respectively.

In 1991 fiscal year, 52 and 50 rock samples were collected for the laboratorial measurements of magnetic susceptibilities and radiometric activities at at the locations in the Segama and Southern Semporna areas, where magnetic and radiometric anomalies were observed. Instruments used for laboratorial measurements are listed in Table II-3-3, and the sampling locations, and the results of the both areas are shown in Fig.II-2-3, and Appendix 21, respectively.

2-4 Data processing

2-4-1 Flight path

The flight path is drawn using linear interpolation between x,y positions from the navigation system. These positions are updated every second(or about 0.8mm at a scale of 1:50,000), and expressed as UTM eastings(x) and UTM northings(y).

The manual fiducials are shown as a small circle and labelled by fiducial number. The 24 hour clock time is shown as a small square, plotted every minute and labelled every 2 minutes. Small tick marks are plotted every 2 seconds. Larger tick marks are plotted every 10 seconds.

The flight path map is merged with the base map by matching fiducial locations with prominent topographic features as seen on 1:50,000 scale topographic maps. The Latitude/Longitude coordinates and UTM grid were taken from these topographic maps and their accuracy is based upon this registration process.