about the Magondi Mobile Belt of the southern part of Mhangura and the Zambezi Mobile Belt of the northern part of the survey area.

The initial event of geological structure with relationship to the Magondi mobile belt was the extension of rift valley which formed the Magondi basin. The rift valley is considered to be formed along the left lateral fracture zone by the activity of Great Dyke in the eastern part out of the survey area. The eastern margin of sedimentary basin in the eastern part of the area is limited by the direction of the NNE–SSW with generally parallel to the Great Dyke. The margin is bent to the direction of the NNW–SSW in northern part of Mhangura of the centre of this area.

The Deweras Group is consisted of alluvial fan sediments, stream sediments and playa sediments. During the period of sedimentation, several mafic igneous activities occurred. The Lomagundi Group is considered to be formed in sedimentary environment of coast. Piriwiri Group is Black Sea type underwater sediments, It is presumed to be formed in the environment of continental slope or seabed fan (Master, 1991).

Most of the survey area is located within the Magondi mobile belt, and was affected by metamorphism of several times. The main geological structure shows different characteristics in the southern and the northern part of the survey area.

The main geological structure of the southern part of the survey area is characterized by isoclined fold with the direction of the NNE to the NE and thrust along the eastern margin of Magondi sedimentary basin. These structures are cut by right lateral fault of the direction of the NE–SW. Fault of the direction of the NW–SE also develops within Lomagundi Group and Piriwiri Group in the western part out of the survey area.

As regards the relationship between the Archaean younger granite and the Deweras Group near Mhangura in the central part of the area, the contact of the granite and the Deweras Group by thrust is observed in underground of mine and unconformity is observed at the surface.

The direction of the NNE–SSW to the N–S direction, fold structure of the direction of the NE–SW and lateral fault of the NE–SW direction are recognized in the northern part, however no structure of the NW–SE direction is recognized (Thole, 1974).

2–4 Mineralization

2–4–1 Survey of the Mines and Mineralization Areas

Survey was carried out in 5 mineralization areas which are combined and summed from 9 mineralization zones. Geological maps and sketches of each zone are shown in Fig.II–2–6 to Fig.II–2–14. Microscopic observation of polished ore samples, chemical analyses of ore minerals, and survey results of mineralization zones are shown in Table II–2–2 to Table II–2–4. Photomicrograph of polished ore samples are shown in appendix A–2.

Table II-2-2 Result of the microscopic observations of polished section.

No.	Rock names	Locality	Coordinate		sulphides									Oxide minerals					Others			Remarks
			Latitude	Longitude	Py	Mc	Po	Cub	Cp	Bo	Cc	Cv	Sph	Mt	Il	Hem	Fh	Mal	Qtz	Ca	Ot	
KR 44A	quartz vein	Shamrocke East	16°26.16'S	30° 1.73'E	△				·		·		·						◎		△	
KR 44C	Fe oxide quartz rock	Shamrocke East	16°25.99'S	30° 1.76'E										○			△		◎			
KR 48A	quartz vein in amphibolitic rock	Shamrocke Mine	16°25.78'S	30° 0.33'E		(·)	○		·						△						◎	1)
KR 48C	amphibole calc-silicate? rock	Shamrocke Mine	16°25.78'S	30° 0.33'E		(·)	·		△				·		·						◎	1)
KR 48D	dolomitic rock	Shamrocke Mine	16°25.78'S	30° 0.33'E			·	△	△						·				○	◎		
KR 49B	amphibole calc-silicate? rock	Shamrocke Mine	16°25.78'S	30° 0.33'E		(·)	△		○				·		·						◎	1)
KR 49C	sandstone / amphibolite	Shamrocke Mine	16°25.78'S	30° 0.33'E		(·)	△		△						·						◎	1)
KR 52	siliceous rock	Shamrocke West	16°25.91'S	29°58.41'E	△	·					·	·	·						◎		○	
KR 54	dolomite, impure	Old Alaska Mine	17°23.99'S	30° 0.17'E					·	◎	◎										△	
KR 60	arkose	Mangula, Underground	16°53.31'S	30° 9.58'E					·	△	△								◎			
KR 61	quartz-magnetite vein	Chirombozi	16°50.63'S	30°10.57'E										○		·			◎			
NR 72	amhibolitic rock	Norah Mine	16°52.20'S	30° 9.52'E					○	·		·		·		△					◎	
NR 73	arkose	Norah Mine	16°52.20'S	30° 9.52'E									·			△			◎		△	
NR 75	quartz vein in doleritic rock	Norah Mine	16°52.20'S	30° 9.52'E					◎	△	·	·		·		·			◎		◎	
NR 78	arkose	Norah Mine	16°52.20'S	30° 9.52'E						◎	·	·		·		·					◎	
NR 79	doleritic basalt with sulphides	Norah South	16°57.21'S	30° 9.52'E					△	△	·	·									◎	
NR 80	arkose	Mangula, Underground	16°52.31'S	30° 9.59'E					△	·				·		·			◎		·	
NR 82	arkose-conglomerate	Mangula, Underground	16°52.31'S	30° 9.59'E					·	△	△					△			◎		△	2)
NR 83	arkose	Mangula, Underground	16°52.31'S	30° 9.59'E					△				·			·			◎		△	
NR 84	quartz-feldspar vein in arkose	Mangula, Underground	16°52.31'S	30° 9.59'E						△	·			·		△					◎	2)
NR103	arkose	Angwa Mine	17°32.96'S	30° 3.37'E						·	·					·					◎	
NR104	quartz-bornite vein in arkose	Angwa Mine	17°32.96'S	30° 3.37'E					·	·	·			·		·			◎		○	2)
NR106	arkose	Angwa Mine	17°32.96'S	30° 3.37'E					·	△	·			△							◎	2)
NR107	quartz vein in doleritic rock	Angwa Mine	17°32.96'S	30° 3.37'E					○					△							◎	
NR113	qz vein	United Kingdom Mine	17° 4.67'S	30°11.24'E							○	·						△	◎			
NR123	dolomite	Old Alaska Mine	17°23.99'S	30° 0.17'E							△	·						△			◎	
NR124	dolomite	Old Alaska Mine	17°23.99'S	30° 0.17'E							△	·						△			◎	
NR126	dolomite	Old Alaska Mine	17°23.99'S	30° 0.17'E							·	·						△			◎	
NR136	arkose	Avondale Mine	17°17.86'S	30° 4.11'E					·							·			○	○	◎	
NR137	arkose	Avondale	17°17.86'S	30° 4.11'E					·	·	△								◎		○	
YR 60	banded ironstone	Riversdale	17° 0.40'S	30° 4.82'E										◎		·					◎	

◎:abundant ○:commom △:minor ·:rare

Abbreviations

Py:pyrite Mc:marcasite Po:pyrrhotite Cub:cubanite Cp:chalcopyrite Bo:bornite Cc:chalcocite Cv:covelline Sph:sphalerite
Mt:magnetite Il:ilmenite Hem:hematite Fh:Fe-hydroxides Mal:malachite Qtz:quartz Ca:carbonates Ot:other gangue minerals

Remarks

1) Pyrrhotite is partly replaced by marcasite.
2) graphic texture between bornite and covelline.

Table II-2-3 Assay of ores.

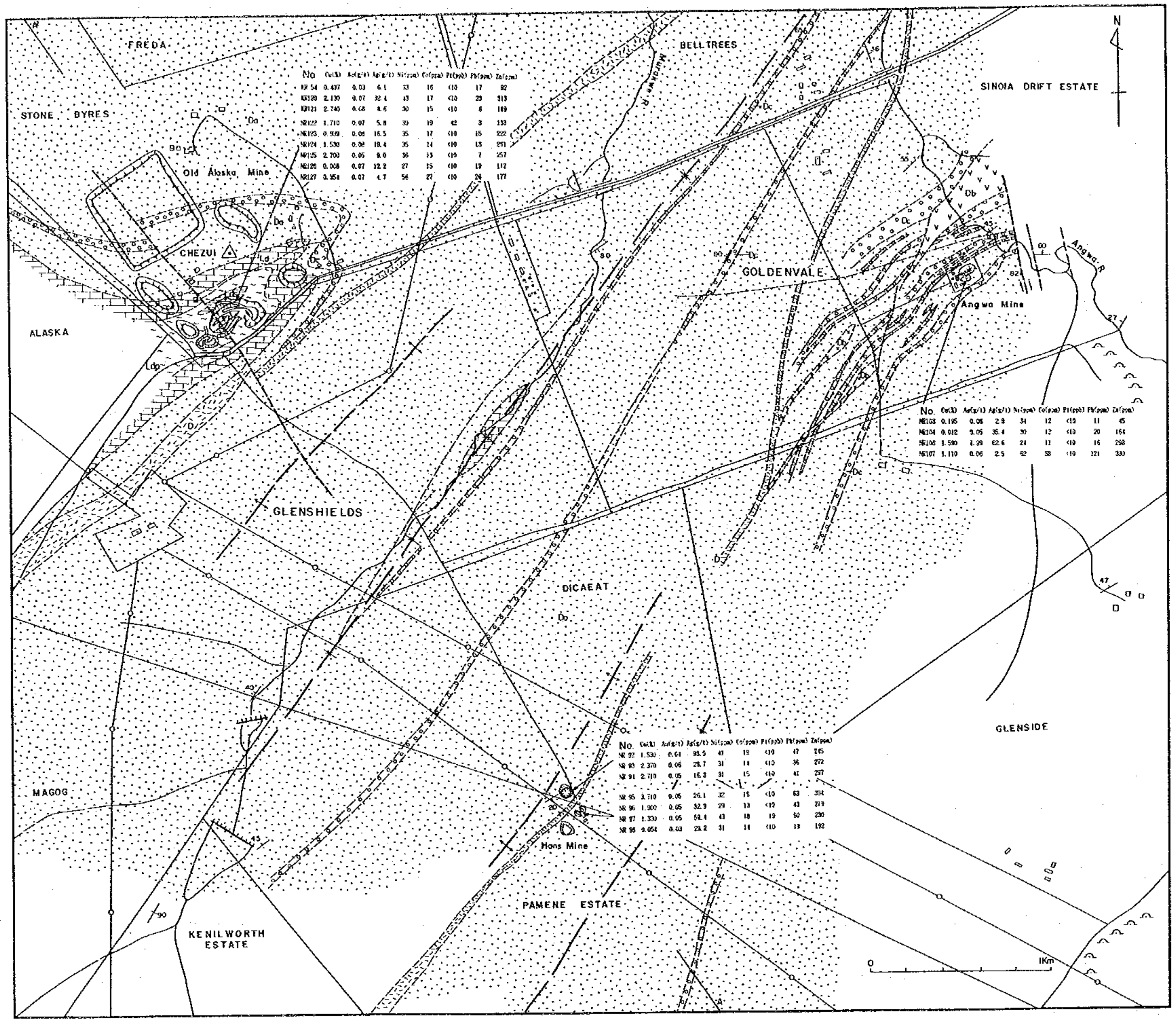
No.	Rock names	Locality	Coordinate		Au	Ag	Cu	Ni	Co	Pb	Zn	Pt
			Latitude	Longitude	(ppm)	(ppm)	(%)	(ppm)	(ppm)	(ppm)	(ppm)	(ppb)
KR 44A	quartz vein	Shamrocke East	16°26.16'S	30°1.73'E	0.06	3.8	0.030	67	23	24	37	46
KR 48A	amphibolite	Shamrocke Mine	16°25.78'S	30°0.33'E	< 0.01	4.5	0.057	151	88	15	181	< 10
KR 48C	amphibolitic rock	Shamrocke Mine	16°25.78'S	30°0.33'E	0.14	4.2	0.700	34	21	4	110	< 10
KR 48D	dolomitic rock	Shamrocke Mine	16°25.78'S	30°0.33'E	0.17	4.4	2.250	71	44	9	299	< 10
KR 49B	amphibolitic rock	Shamrocke Mine	16°25.78'S	30°0.33'E	0.55	8.1	3.470	90	46	4	517	< 10
KR 49C	sandstone / amphibolite	Shamrocke Mine	16°25.78'S	30°0.33'E	0.52	7.8	3.340	128	57	22	2.008	< 10
KR 49E	schist	Shamrocke Mine	16°25.80'S	30°0.28'E	0.08	5.3	0.974	24	21	11	82	< 10
KR 52	siliceous rock	Shamrocke West	16°25.91'S	29°58.41'E	0.05	5.2	0.027	27	47	13	116	< 10
KR 54	dolomite(malachitization)	Old Alaska Mine	17°23.99'S	30°0.17'E	0.03	6.1	0.437	33	16	17	82	< 10
KR 60	arkose	Mangula, Underground	16°53.31'S	30°9.58'E	0.22	23.1	2.080	17	15	5	185	< 10
KR 61	quartz-magnetite vein	Chirombozi	16°50.63'S	30°10.57'E	0.03	4.5	0.036	20	16	8	142	< 10
NR 3	arkose with malachite	Mangula Opencut	16°53.31'S	30°9.59'E	0.04	16.1	2.520	30	12	10	274	< 10
NR 72	amhibolitic rock	Norah Mine	16°52.20'S	30°9.52'E	0.10	22.9	1.890	111	86	19	451	< 10
NR 73	arkose	Norah Mine	16°52.20'S	30°9.52'E	0.02	2.6	0.018	28	14	4	6	< 10
NR 74	arkose	Norah Mine	16°52.20'S	30°9.52'E	< 0.01	2.3	0.023	51	26	44	899	< 10
NR 75	quartz vein in dolerite	Norah Mine	16°52.20'S	30°9.52'E	3.86	68.9	6.370	25	15	63	699	< 10
NR 76	arkose	Norah Mine	16°52.20'S	30°9.52'E	0.04	3.0	0.006	30	15	2	9	< 10
NR 78	arkose	Norah Mine	16°52.20'S	30°9.52'E	0.27	170.0	13.000	33	21	160	1,667	< 10
NR 79	doleritic basalt	Norah South	16°57.21'S	30°9.52'E	0.30	43.1	4.250	46	33	33	519	< 10
NR 80	arkose	Mangula, Underground	16°52.31'S	30°9.59'E	0.06	3.1	0.162	30	18	8	28	< 10
NR 81	arkose	Mangula, Underground	16°52.31'S	30°9.59'E	0.04	3.0	0.038	41	19	34	83	< 10
NR 82	arkose-conglomerate	Mangula, Underground	16°52.31'S	30°9.59'E	0.06	20.4	1.680	34	20	39	190	< 10
NR 83	arkose	Mangula, Underground	16°52.31'S	30°9.59'E	0.06	3.6	0.615	20	15	15	83	< 10
NR 84	quartz vein in arkose	Mangula, Underground	16°52.31'S	30°9.59'E	8.05	33.2	2.000	45	27	87	245	< 10
NR 92	arkose(malachitization)	Hans Mine	17°22.47'S	30°1.95'E	0.04	93.5	1.830	41	19	47	245	< 10
NR 93	arkose(malachitization)	Hans Mine	17°22.47'S	30°1.95'E	0.06	28.7	2.370	31	14	36	272	< 10
NR 94	arkose(malachitization)	Hans Mine	17°22.47'S	30°1.95'E	0.05	16.3	2.710	31	15	41	297	< 10
NR 95	arkose(malachitization)	Hans Mine	17°22.47'S	30°1.95'E	0.05	26.1	3.710	32	15	63	394	< 10
NR 96	arkose(malachitization)	Hans Mine	17°22.47'S	30°1.95'E	0.05	32.9	1.900	29	13	43	217	< 10
NR 97	arkose(malachitization)	Hans Mine	17°22.47'S	30°1.95'E	0.05	59.4	1.330	43	18	60	230	19
NR 98	arkose(malachitization)	Hans Mine	17°22.47'S	30°1.95'E	0.03	29.2	0.054	31	14	19	192	< 10
NR103	arkose	Angwa Mine	17°32.96'S	30°3.37'E	0.06	2.9	0.195	34	12	11	45	< 10
NR104	arkose with quartz vein	Angwa Mine	17°32.96'S	30°3.37'E	0.05	35.4	1.230	30	12	20	164	< 10
NR106	arkose	Angwa Mine	17°32.96'S	30°3.37'E	1.99	62.6	1.590	24	11	16	298	< 10
NR107	quartz vein in dolerite	Angwa Mine	17°32.96'S	30°3.37'E	0.06	2.5	1.110	62	38	121	330	< 10
NR112	schist, basic rock origin	United Kingdom Mine	17°4.67'S	30°11.24'E	0.12	10.6	0.253	222	128	18	808	21
NR113	qz vein	United Kingdom Mine	17°4.67'S	30°11.24'E	0.19	45.9	2.690	11	1	25	162	< 10
NR114	qz vein	United Kingdom Mine	17°4.67'S	30°11.24'E	0.04	1.2	1.450	24	7	10	38	< 10
NR115	qz vein	United Kingdom Mine	17°4.67'S	30°11.24'E	0.07	2.1	0.092	26	8	19	47	< 10
NR116	qz vein	United Kingdom Mine	17°4.67'S	30°11.24'E	0.05	1.3	1.470	15	3	5	18	< 10
NR117	qz vein	United Kingdom Mine	17°4.67'S	30°11.24'E	0.17	5.6	1.460	11	2	9	40	< 10
NR118	qz vein	United Kingdom Mine	17°4.67'S	30°11.24'E	0.06	1.2	0.807	17	6	17	28	< 10
NR120	dolomite(malachitization)	Old Alaska Mine	17°23.99'S	30°0.17'E	0.07	32.4	2.130	43	17	23	313	< 10
NR121	dolomite(malachitization)	Old Alaska Mine	17°23.99'S	30°0.17'E	0.06	8.6	2.740	30	15	6	189	< 10
NR122	dolomite(malachitization)	Old Alaska Mine	17°23.99'S	30°0.17'E	0.07	5.8	1.710	39	19	3	133	42
NR123	dolomite(malachitization)	Old Alaska Mine	17°23.99'S	30°0.17'E	0.08	16.5	0.939	35	17	15	222	< 10
NR124	dolomite(malachitization)	Old Alaska Mine	17°23.99'S	30°0.17'E	0.08	19.4	1.530	35	14	13	261	< 10
NR125	dolomite(malachitization)	Old Alaska Mine	17°23.99'S	30°0.17'E	0.05	9.0	2.700	36	13	7	257	< 10
NR126	dolomite(malachitization)	Old Alaska Mine	17°23.99'S	30°0.17'E	0.07	12.2	0.008	27	15	19	112	< 10
NR127	dolomite(malachitization)	Old Alaska Mine	17°23.99'S	30°0.17'E	0.07	4.7	0.354	56	27	26	177	< 10
NR136	arkose	Avondale Mine	17°17.86'S	30°4.11'E	0.06	3.6	0.005	82	42	13	140	< 10
NR137	arkose	Avondale Mine	17°17.86'S	30°4.11'E	0.08	11.5	0.446	37	26	12	138	< 10

Table II-2-4 Result of physical property measurement.

Name of Mine and Mineralized Area	Locality Coordinates	Situation	Type of deposits	Mineralized Metal	Ore reserve	Metal grade	Main ore minerals	Accessory minerals	Gangue minerals	Host rock	Present Production
(1)Hans	17°25.47'S 30°01.95'E	closed	Stratabound and disseminated ore	Cu, Ag	0.3million tons Cu1.0%	AgMax93.5g/t CuMax3.71%	Mal, Bo, Cc	Cp	—	Arkose Conglomerate	
(2)Angwa	17°23.96'S 30°03.37'E	Operating	Stratabound and disseminated ore	Cu, Ag	4.5million tons Cu0.95%	AgMax62.6g/t CuMax1.59%	Bo, Cc, Cp	Py, Mt, Hem	—	Arkose Conglomerate	16,000t/m Cu0.6%
(3)Old Alaska	17°23.87'S 30°00.87'E	closed	Stratabound and disseminated ore	Cu, Ag	5million tons? Cu1.5%	AgMax62.6g/t CuMax1.59%	Mal. Bo, Cc	Cp, Py, Cv, Mt, Hem	—	Lomagundi. G Dolomite	
(4)Shackleton	17°18.08'S 30°02.67'E	closed	Stratabound and disseminated ore	Cu, Ag	6million tons Cu1.2%		Bo, Cc	—	—	Arkose Conglomerate	
(5)Avondale	17°17.86'S 30°04.11'E	Operating	Stratabound and disseminated ore	Cu, Ag	4.4million tons Cu0.9%	Ag 11.6g/t Cu 0.45%	Cc	Bo. Cp	—	Arkose Conglomerate	16,000t/m Cu0.8%
(6)United Kingdom	17°04.67'S 30°11.24'E	closed	qz-cal Vein	Cu, Ag		AgMax45.9g/t CuMax2.69%	Mal. Cc	Cv	Qz, Cal, Hem	Arkose	
(7)Milliam	16°53.31'S 30°09.59'E	Operating	Stratabound and disseminated ore	Cu, Ag, Au Pt, Pd, Se	60million tons Cu1.0%	AgMax33.2g/t CuMax13.0%	Bo, Cc, Cp	Py, Mt, Hem	—	Arkose Conglomerate	4,000t/d Cu0.7%
(8)Norah	16°56.21'S 30°09.16'E	Operating	Stratabound and disseminated ore	Cu, Ag, Ag	8million tons Cu1.2%	AgMax170g/t CuMax13.0%	Cp, Bo, Cc	Py, Cv, Sph, Mt. Hem	—	Arkose Conglomerate	
(9)Shamrocke	16°25.78'S 30°09.52'E	closed	Stratabound and disseminated ore	Cu, Ag, Au	5million tons Cu1.0%	AgMax 8.1g/t CuMax3.47%	Po, Cp	Cub, Sph, Py, Mc, Mt	—	MetaArkose	
(10)Nyamamyoko Hill	16°50.63'S 30°10.57'E		qz-mt Vein	Au, Ag?	Extension2km	Au0.03g/t Ag4.5g/t	—	Hem, Mt	—	Granite	
(11)Rivington	17°00.40'S 30°04.82'E		Banded iron	Fe			Mt, Hem	—	—	slate	
(12)Zawi	17°13.88'S 30°01.58'E		Dolomite	Dolomite			Dolomite	—	—	Lomagundi. G Dolomite	
(13)Hilltop	17°19.01'S 30°07.74'E		Slate	slate			slate	—	—	Lomagundi. G slate	

Abbreviations

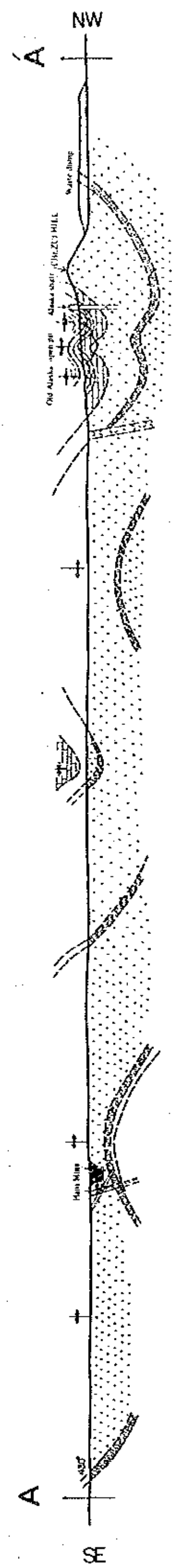
Py:pyrite Mc:marcasite Po:pyrrhotite Cub:cubanite Cp:chalcopyrite Bo:bornite Cc:chalcocite Cv:covelline Sph:sphalerite
Mt:magnetite Il:ilmenite Hem:hematite Mal:malachite Qz:quartz Cal:calcite Ot:other gangue minerals

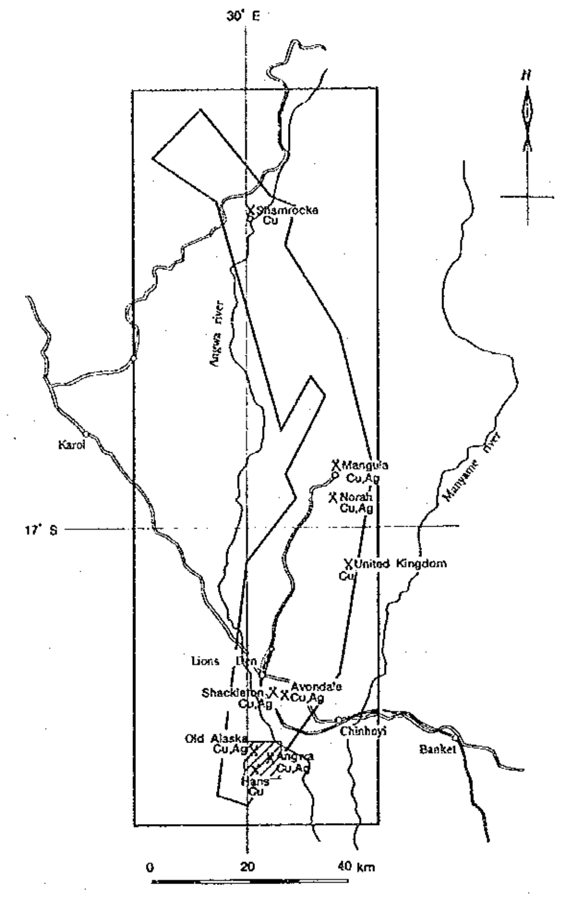


No	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR 54	0.437	0.03	6.1	53	16	<10	17	82
NR120	2.130	0.07	32.4	43	17	<10	29	313
NR121	2.740	0.08	8.6	30	15	<10	6	169
NR122	1.710	0.07	5.8	39	19	42	3	133
NR123	0.959	0.08	16.5	35	17	<10	15	222
NR124	1.530	0.08	19.4	35	14	<10	13	251
NR125	2.700	0.05	9.0	36	13	<10	7	257
NR126	0.008	0.07	12.2	27	15	<10	19	112
NR127	5.954	0.07	4.7	56	27	<10	24	177

No.	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR103	0.195	0.06	2.9	34	12	<10	11	45
NR104	0.912	0.05	35.4	30	12	<10	20	164
NR106	1.590	1.39	62.6	24	11	<10	16	258
NR107	1.110	0.06	2.5	62	58	<10	121	330

No.	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR 92	1.530	0.64	93.5	41	19	<10	47	245
NR 93	2.370	0.06	28.7	31	14	<10	36	272
NR 91	2.710	0.05	16.3	31	15	<10	41	297
NR 95	3.710	0.06	26.1	32	15	<10	63	334
NR 96	1.900	0.05	32.9	29	13	<10	43	213
NR 97	1.330	0.05	54.4	43	18	19	50	230
NR 98	0.054	0.03	23.2	31	14	<10	13	192





Post Magondi Intrusive Rocks

D — Meta dolerite-dolerite

Lomagundi Group

Lds — and stone(Dolomitic)

Ldp — Phyllite(Dolomitic)

Ld — Dolomite

Deweras. Group

Db — Bas pyloclastics

Da — Arkose

Dc — Conglomerate

Strike and dip of Strata

Strike and dip of Schistosity

Strike and dip of Joint

Anticline

Syncline

Fault and fracture Zone

Shaft

Tunnel

Open Pit and Cutting

Ore-Deposit

Waste and Slime dump

Fig.II-2-6 Detail geological map in the Alaska-Angwa-Hans area.

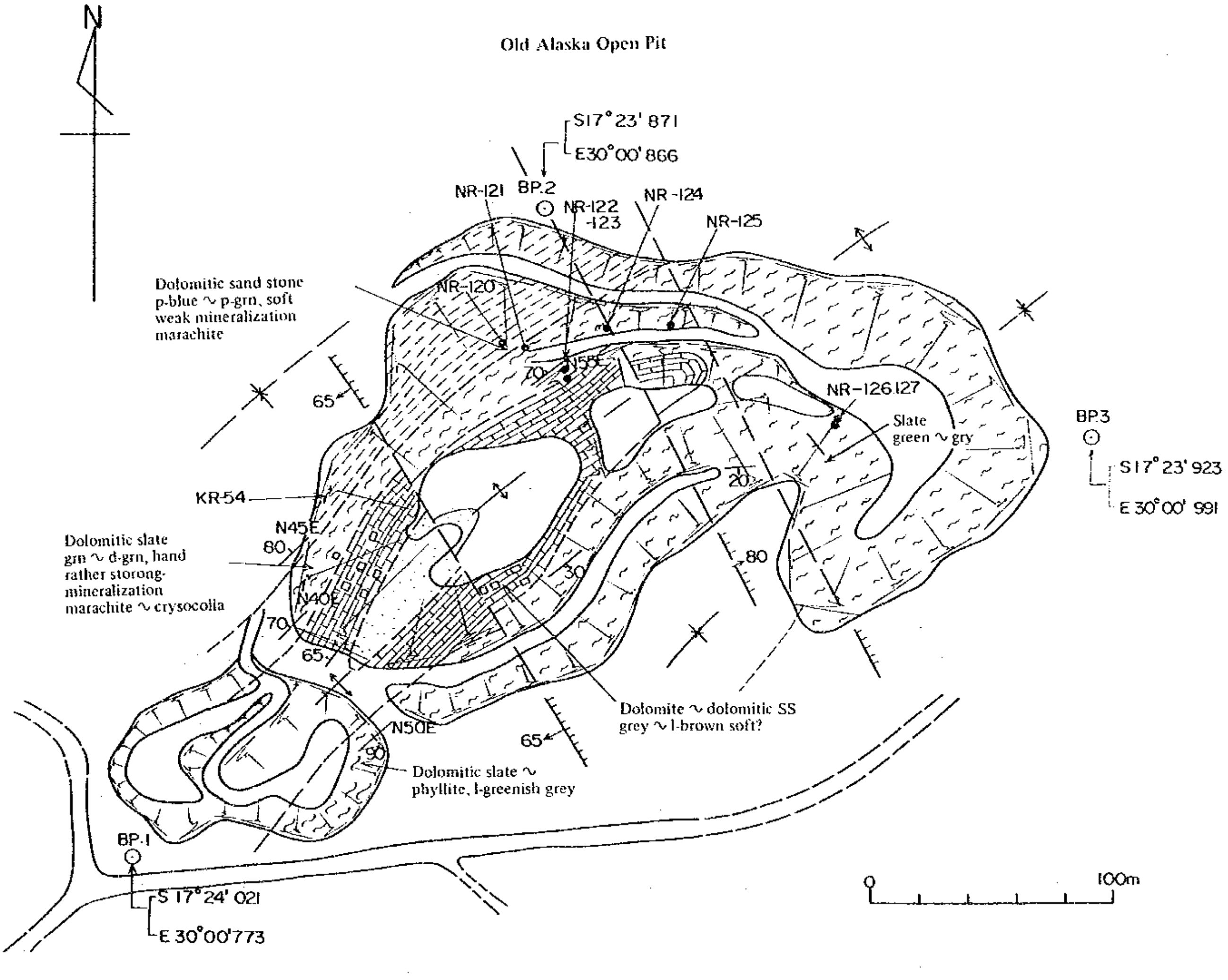


Fig.II-2-7 Sketch around the Old Alaska Mine.

1. The Alaska area (Fig.II-2-6, II-2-7 and II-2-8)

The Old Alaska Mine, the Angwa Mine and the Hans Mine are included in this mineralization zone. Conglomerate and arkose of Deweras Group are widely distributed in this area. They are covered by dolomite and slate of Lomagundi Group in the western area. Doleritic rock (meta-dolerite to epidolite) is recognized as dykes.

Geological structure of Deweras Group shows fold with the NE-SW direction and faults with the direction of NNW-SSE and E-W are recognized.

(1) The Old Alaska mine

location : The skirtof Chezui Hill, 20 kilometres west of Chinhoyi City.

The coordinate of the northern end of opencut is 17°23.871'S and 30°00.866'E

Present situation : Closed. The Vertical shaft at the southern skirt of Chezui Hill and old opencut (approximate 400 metres from the east to the west, 200 metres from the north to the south) are still existing.

History : This mine was considered to be developed in prehistoric age. The detailed history is unknown. Modern development and mining were commenced by MTD Co.Ltd. during 1956 to 1961, and the mining finished in 1977.

Scale: Estimated prehistoric production amount of crude ore is 1,000,000 tons. Production amount during 1929 to 1931 was 93,000 tons (Cu, 9.18 %), 4,000,000 tons during 1961 to 1977 (Cu, 1.5 %, Simpson, 1990).

Geology : The geology around and in the opencut is composed of conglomerate and arkose of Deweras Group, dolomite, dolomitic slate to phyllite and dolomitic sandstone of Lomagundi Group. The geological structure is controlled by main oblique axis with moderate plunge with small anticline and syncline. The structure is cut by fault with the direction of NW-SE.

Ore deposit : Main ore mineral is malachite which occurs as dissemination and thin vein along platy joints and cleavages within dolomite, sandstone and shale of Lomagundi Group. In addition to malachite, chalcopyrite is characteristically recognized with psudomorph of pyrite. Chalcopyrite, natural copper, chrysocolla, cornetite, plancheite, dioptase, cuprite and tenorite were reported as ore minerals(Master, 1991).

By microscopic observation of the polished samples of ore minerals at opencut, network and vein type malachite, bornite and chalcocite with irregular shape, foliated and platy covelline crystal aggregates and small amount of chalcopyrite are recognized. Chalcocite occurs in the thick part of malachite vein. Bornite is replaced by chalcocite, and chalcocite is replaced by covelline. Chalcopyrite appears within bornite with vein or irregular shapes.

Chemical analyses of the samples are as follows :

Samples	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
KR 54	0.437	0.03	6.1	33	16	<10	17	82
NR120	2.130	0.07	32.4	43	17	<10	23	313
NR121	2.740	0.06	8.6	30	15	<10	6	189
NR122	1.710	0.07	5.8	39	19	42	3	133
NR123	0.939	0.08	16.5	35	17	<10	15	222
NR124	1.530	0.08	19.4	35	14	<10	13	261
NR125	2.700	0.05	9.0	36	13	<10	7	257
NR126	0.008	0.07	12.2	27	15	<10	19	112
NR127	0.354	0.07	4.7	56	27	<10	26	177

(2) The Angwa Mine

Location : The Goldenvale farm, 4 kilometres of the eastern part of Old Alaska opencut.

The coordinate of the gate of Mine is 17°23.960'S and 30°03.365'E.

Present situation : In operation

History : Surface drilling was commenced in this mine in 1958. The development including sinking of vertical shaft was commenced in 1965. The regular production was commenced in 1973.

Scale: Ore reserves: 4,500,000 tons, Cu; 0.95 % (Simpson, 1990). Present production of crude ore is 16,000 tons/month (Cu, 0.6 %, Ag, 18 g/ton).

Geology : Geology shows the sedimentation of the unit of conglomerate of Deweras Group, arkosic pelitic rock. It is partly accompanied with pyroclastic rocks. Doleritic dykes exists interruptively from Hans Mine in the western side of this area. Geological structure shows the strike of NE and the dip of 40° to 60° NW with moderate fold.

Ore deposit : The ore deposit is divided into the upper and the lower zone. The upper ore deposit occurs in arkose which is located just under pelitic rock, and controlled by development and succession of the pelitic rock of hanging wall. As the upper ore deposit is more stable in grade and succession compared to the lower ore deposit, the upper ore deposit is the main ore deposit of this mine. On the other hand, the lower ore deposit occurs on conglomerate of foot wall. The scale and thickness are more predominant compared to the upper ore deposit, however, the shape, distribution and grade are irregular. The main ore minerals are chalcocite and bornite, in addition to them, few covelline, chalcopyrite and pyrite are recognized. Occurrence of silver is reported as micro-composition. Chalcocite and bornite frequently show psudomorph of pyrite. These ore minerals occur as dissemination or fine veins filled up among particles within conglomerate and arkose packing within gaps of particles.

By microscopic observation of polished sample of ore minerals at 360 W mining block of the underground, chalcopyrite, bornite, chalcocite with irregular shape, columnar and irregular shaped hematite, and euhedral and granular magnetite are recognized. Chalcopyrite and chalcocite coexists. There is paragenesis of bornite and chalcocite with graphic texture. Some bornites partly change to chalcocite. Magnetite is replaced by hematite, and sometimes it is entirely replaced by hematite.

Chemical analyses of the samples are as follows :

Samples	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR103	0.195	0.06	2.9	34	12	<10	11	45
NR104	1.230	0.05	35.4	30	12	<10	20	164
NR106	1.590	1.99	62.6	24	11	<10	16	298
NR107	1.110	0.06	2.5	62	38	<10	121	330

(3) The Hans Mine

Location : The border of Dicheat farm and Pamane Estate, 3 kilometres south-east of Old Alaska opencut.

The coordinate of the gate of Mine is 17°25.465'S and 30°01.945'E

Present situation : Closed. Surface dimple by collapsing due to mining of old pit, the entrance of inclined shaft, old facilities and mound of waste are still existing.

History : The production was commenced in 1974, and finished in 1976.

Scale : Production amount of crude ore is 30,000 tons (Cu ; 1.0%). The crude ore was transported to Alaska Mine. Reserves of mineral ore is 100,000 tons.

Geology : Geology around the mine is composed of arkose and pelitic rocks of Deweras Group. The mine is located near anticline axis with NE-SW direction.

Ore deposit : The ore deposit is reported to occurs within boundary of pyroclastic rocks of hanging wall and conglomerate, however, ore minerals near the entrance of inclined shaft and at collapsed dimple occur in the country rock of white to pink arkose or green pelitic rock.

Main ore minerals are malachite, bornite, chalcocite and chalcopyrite.Malachite occurs as dissemination and narrows vein along platy joints and cleavages. Weak disseminated bornite, chalcocite and chalcopyrite are recognized.

Chemical analyses of the samples at the collapsed dimple and the entrance of inclined shaft is as follows :

Samples	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR 92	1.830	0.04	93.5	41	19	<10	47	245
NR 93	2,370	0.06	28.7	31	14	<10	36	272
NR 94	2.710	0.05	16,3	31	15	<10	41	297
NR 95	3.710	0.05	26.1	32	15	<10	63	394

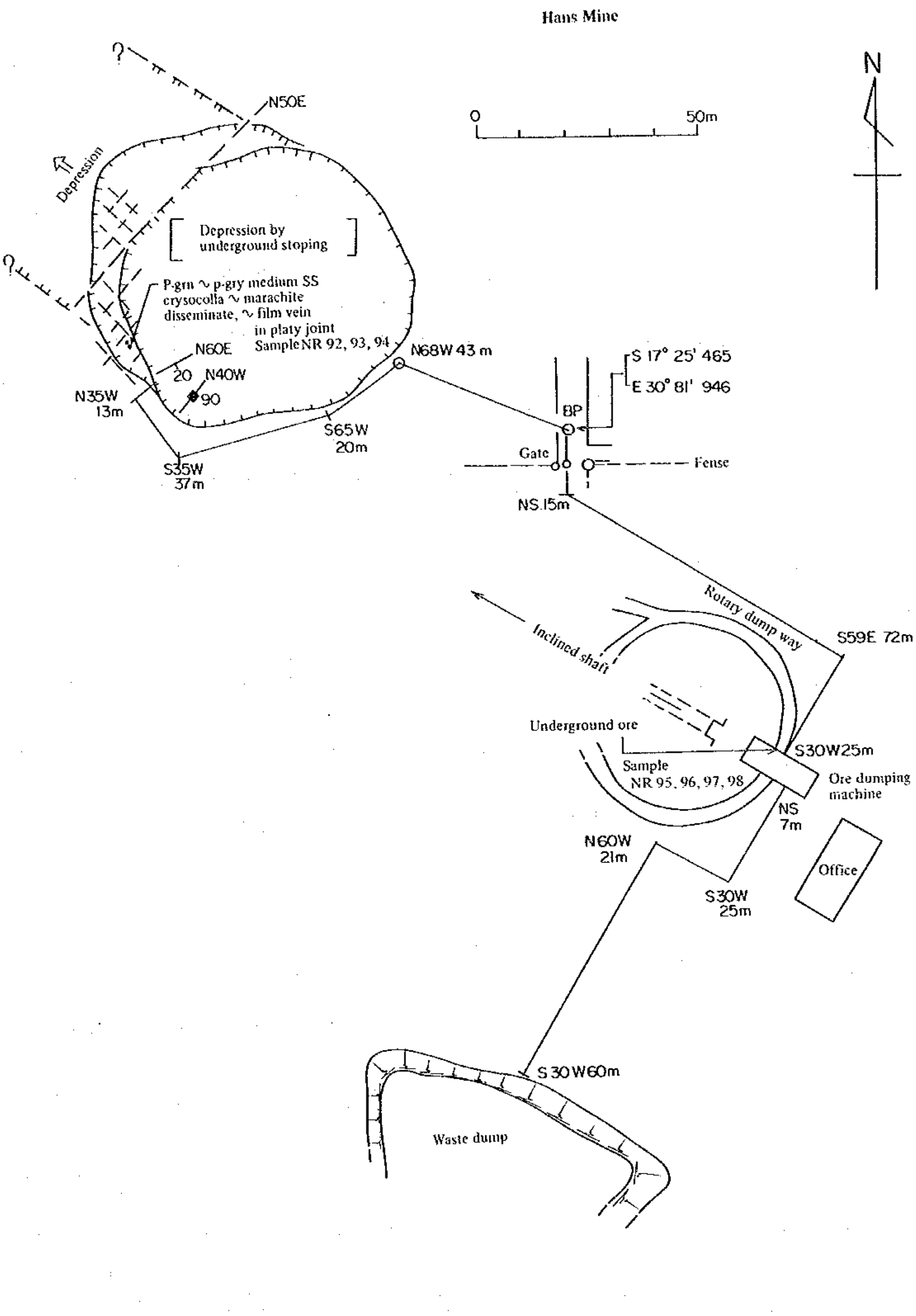


Fig.II-2-8 Sketch around the Hans Mine.

NR 96	1.900	0.05	32.9	29	13	<10	43	217
NR 97	1.330	0.05	59.4	43	18	19	60	230
NR 98	0.054	0.03	29.2	31	14	<10	19	192

2. The Shackleton Mine including the Avondale ore deposit (Fig. II-2-9)

(1) The Shackleton Mine

Location : 9 kilometres north-north-west of Alaska smelter.

The coordinate of the gate of Mine is 17°18.082'S and 30°02.674'E.

Present situation : Although the operation of this mine was finished, the facilities are still operating to treat ore minerals from Avondale Mine, AvonShack, East Shackleton Mine and Angwa Mine.

History: The exploration was commenced by soil geochemical survey in 1958. Based on this exploration, drilling was commenced. Production and regular production were commenced in 1968 and 1972, respectively. Mining was finally finished in August, 1984.

Scale : Production amount of crude ore between 1972 and 1984 was 5,300,000 tons (Cu, 1.33 %) (Simpson, 1990). The amount of production including test mining of crude ore was 6,000,000 tons (Cu, 1.2 %, the document of the Mine).

(2) The Avondale ore deposit

Location: Avondale farm and Maningwa farm, 9 kilometres north of the Alaska Smelter.

The coordinate of the of Mine is 17°17.861'S and 30°04.113'E.

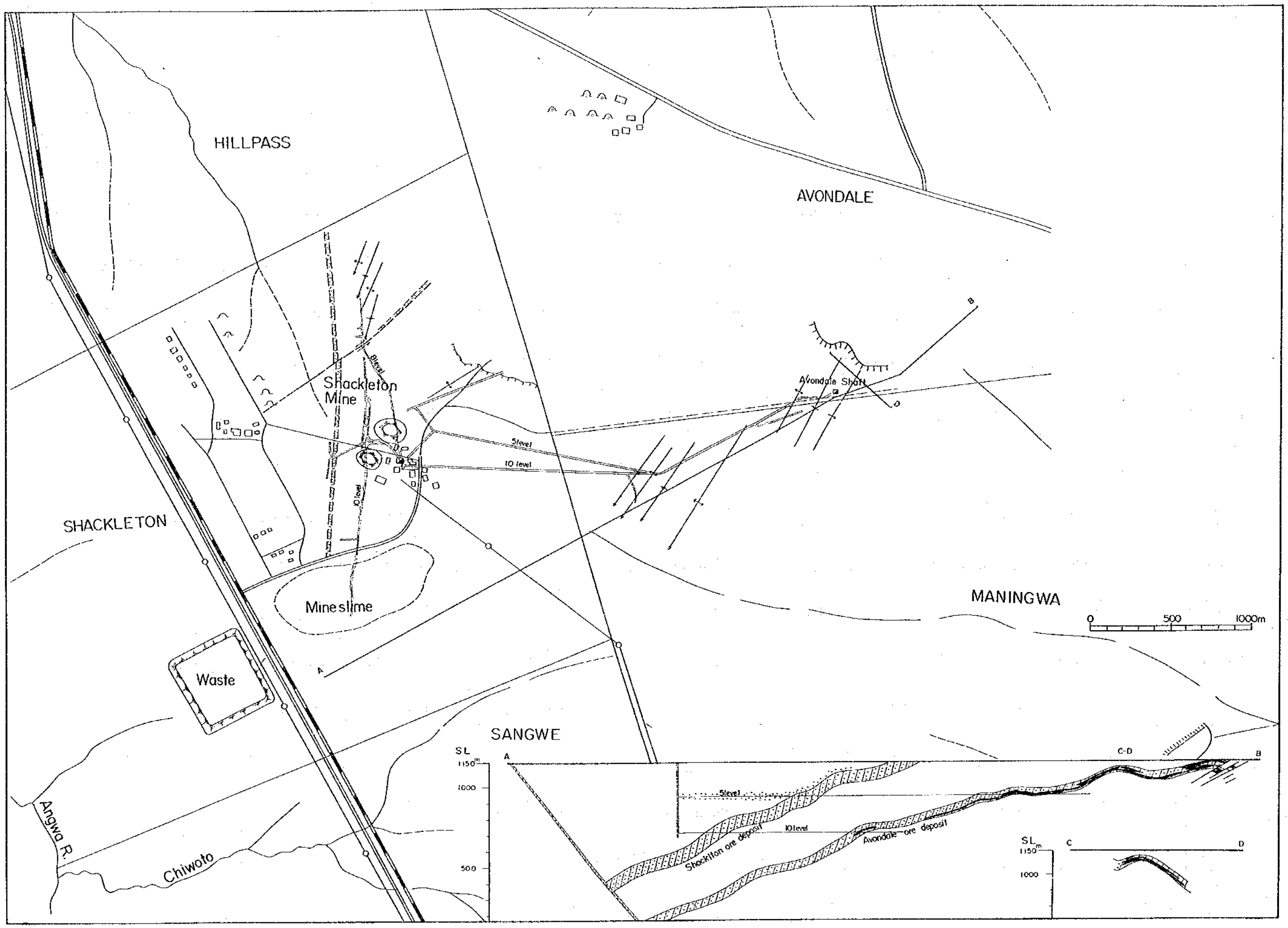
Present situation : In operation. The crude ore is rifted through Shackleton vertical shaft.

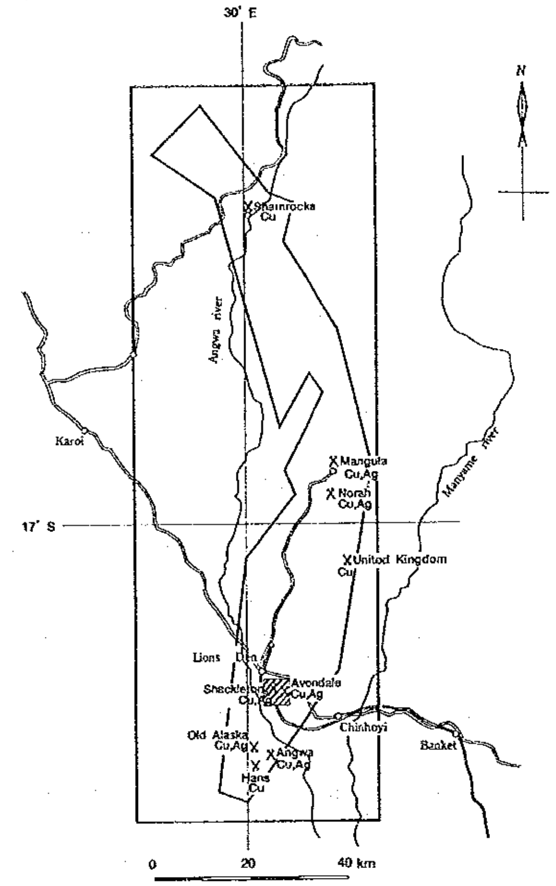
History : This mine was discovered by test drilling for soil geochemical prospecting for geochemical anomaly. The development of transportation level from Shackleton vertical shaft was commenced in 1975, and production was commenced in 1982.

Scale : Ore reserves at initial development is 4,400,000 tons (Cu, 0.90 %). Production amount of crude ore is 1,000,000 tons. Possible mining amount is 2,000,000 tons (Cu, 0.8 %). Present is 16,000 tons/month (Cu, 0.8 %, Ag, 16 g/ton). Based on the recent survey, the succession of the lower ore deposit is recognized.

Geology : The surface of Shackleton and Avondale deposit is widely occupied by cultivated field with a part of wood. No outcrops can be seen in this area.

The Geology based on the existing data including the data of the Mine around the ore deposit is composed of arkose and pelitic rock of Deweras Group. These rocks are composed of conglomeratic sandstone to sandstone of the basement horizon, fine-grained arkose and sandstone of the upper horizon and pelitic to calcarious pelitic rock of the uppermost horizon. They forms a sedimentary cycle, and the sedimentation was made repeatedly. The boundary of each sedimentary cycle shows marked unconformity.





D Dolerite sub-outcrops.

Ore deposit sub-outcrops

Ore bodies

Inferred zonee with copper mineralization potential

Anticline with direction of plunge

Syncline with direction of plunge

Fault

Waste and slime

Shaft

Mining development projected vertically to surface or perpendicularly to the section

Fig.II-2-9 Detail map in the Shackleton-Avondale area.

Geological structure shows moderate anticline with the general trend of NE-SW repeating small folds with NNE-SSW direction. There is prominent fault zone with NNW-SSE direction in the western side of Shackleton ore deposit. Dolerite dyke (Shackleton dyke) is recognized along the fault zone.

Ore deposit : The ore deposit is strata-bounded copper deposit which occurs just under the peritic rock of hanging wall or occurs between the upper and the lower pelitic rock.

The Shackleton Mine is composed of several layered ore deposits which is limited by dykes in the western side. Three main deposits continue to the eastern part of the dykes, however, other ore deposits occur like small dome or like wedge, thick at the boundary part of dykes, thin and disappear at the east. In the western part of the boundary area of dykes,the ore deposit occurs as several thick ore deposits. All of them disappear like wedge. On the other hand, Avondale ore deposit is a single bedded, and occurs along the anticline axis of small fold structure.

Ore minerals are mainly dissemination of chalcocite, bornite and chalcopyrite. A part of them occurs as small vein within the bedding plane or fracture zone.

By microscopic observation of polished samples in Avondale Mine, irregular shaped chalcocite, bornite, chalcopyrite and columnar hematite are recognized. Chalcocite, bornite and chalcopyrite coexist. Bornite sometimes spottedly exists within chalcocite.

Chemical analyses of samples is as follows :

Samples	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR136	0.005	0.06	3.6	82	42	<10	13	140
NR137	0.446	0.08	11.5	37	26	<10	12	138

3. Umboe area (Fig.II-2-10 and Fig.II-2-11)

(1) The United Kingdom Mine

Location : the Inyati farm, 40 kilometres north of Chinhoyi, 20 kilometres SSW of Mangula Mine.

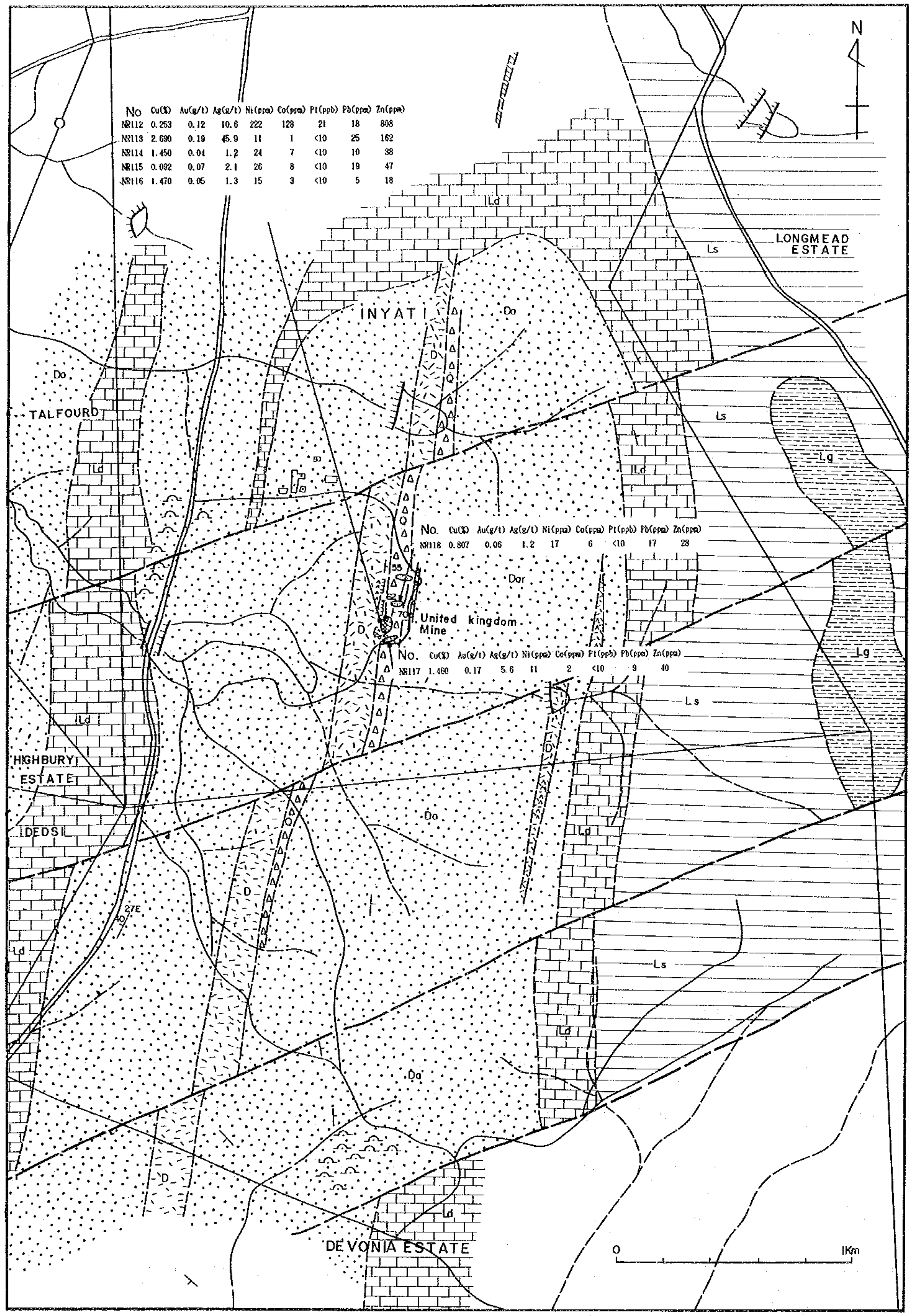
The coordinate of the southern side of opencut is 17°04.670'S and 30°11.235'E.

Present situation : Closed. Opencut, basement concrete of building and trace of trench are still existing.

History : The process of discovery of this mine is unknown. Small mines were operated during 1939 to 1940. After the mining, three trenching and drilling were carried out around 1972, however, re-development was not carried out.

Scale : Production amount of copper is 2.74 tons, Au 59 kg (1939 - 1940, Bartholomews, 1990).

Geology: Arkose of Deweras Group and quartzite, dolomite and shale of the Lomagundi Group is distributed around the ore deposit. In the western part of the Opencut, doleritic dyke intruded with the N-S direction. In the eastern part of the Opencut, quartz-calcite vein intruded parallel to the dyke.



No	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR112	0.253	0.12	10.6	222	128	21	18	808
NR113	2.690	0.19	45.9	11	1	<10	25	162
NR114	1.450	0.04	1.2	24	7	<10	10	38
NR115	0.092	0.07	2.1	26	8	<10	19	47
NR116	1.470	0.05	1.3	15	3	<10	5	18

No.	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR118	0.807	0.06	1.2	17	6	<10	17	28

No.	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR117	1.460	0.17	5.6	11	2	<10	9	40

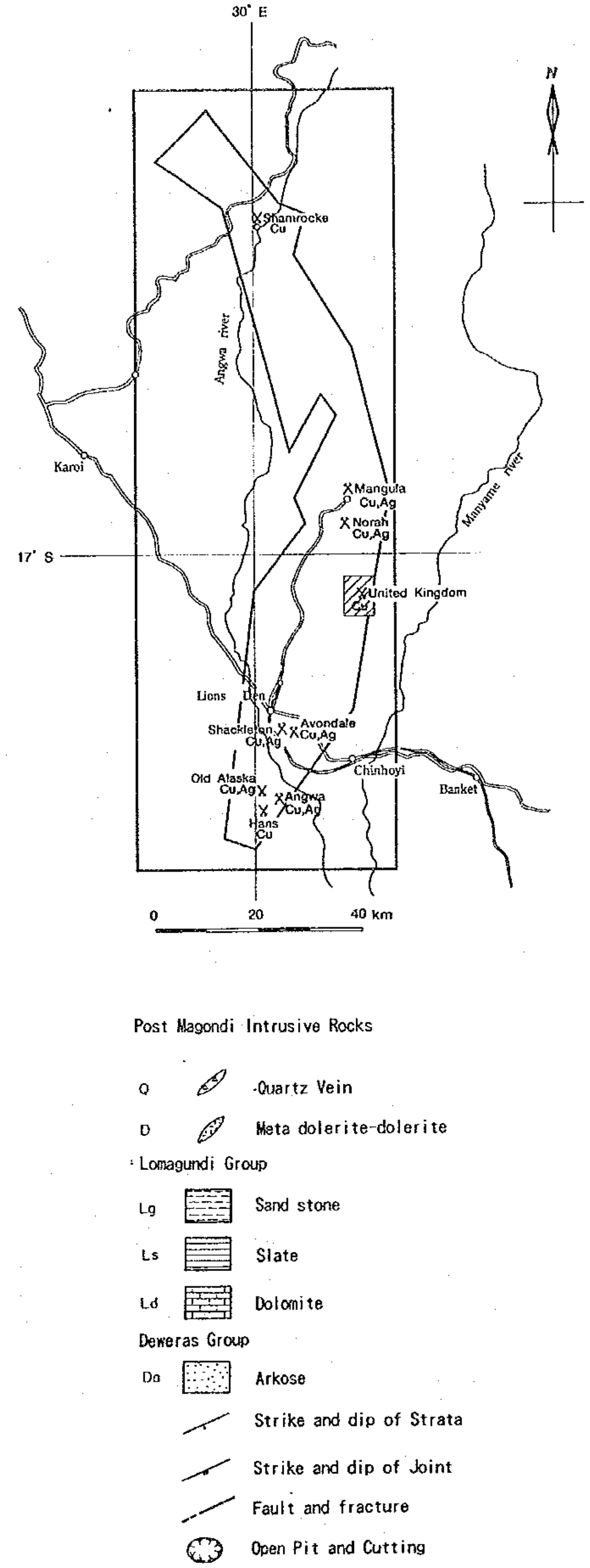


Fig.II-2-10 Detail geological map in the United Kingdom area.

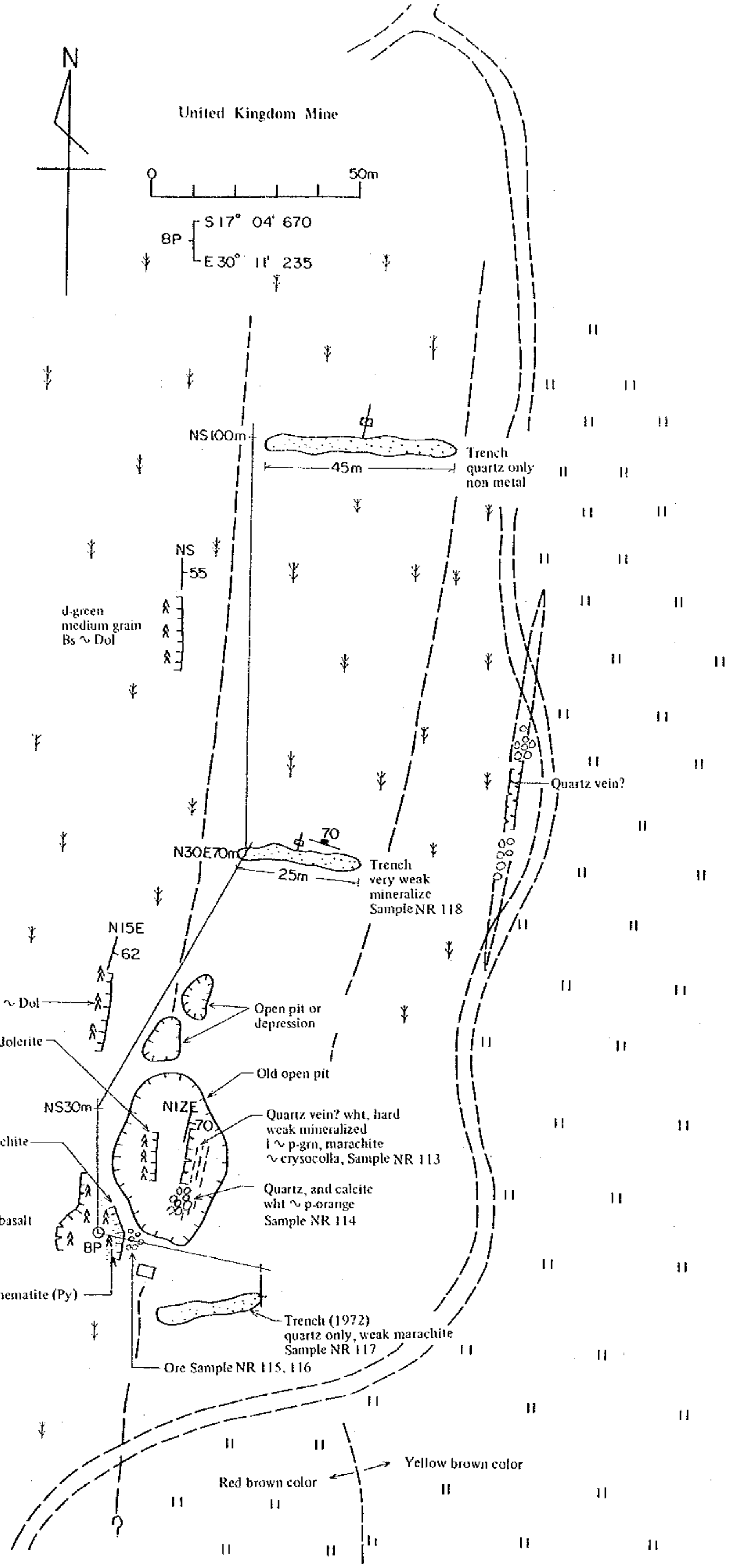


Fig.II-2-11 Sketch around the United Kingdom Mine.

Ore deposit : The ore deposit is ore vein type which occurs in the boundary part of quartz–calcite vein and doleritic dyke. Malachite is the main ore mineral. Weak dissemination of malachite, limonite and hematite is recognized in the boundary part of dyke and quartz–calcite vein, within joints and cleavages along thin quartz–calcite vein, and on the side of dykes.

By microscopic observation of polished samples, irregular shaped chalcocite, platy and foliated covelline which partly replaced chalcocite, and fibrous crystals of malachite aggregates are recognized.

Chemical analyses of samples is as follows :

Samples	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR112	0.253	0.12	10.6	222	128	21 18	808	
NR113	2.690	0.19	45.9	11	1	<10	25	162
NR114	1.450	0.04	1.2	24	7	<10	10	38
NR115	0.092	0.07	2.1	26	8	<10	19	47
NR116	1.470	0.05	1.3	15	3	<10	5	18
NR117	1.460	0.17	5.6	11	2	<10	9	40
NR118	0.807	0.06	1.2	17	6	<10	17	28

4. The Mhangura area (Fig.II–2 12 and Fig.II–2–13)

(1) Miriam ore deposit

Location : 70 kilometres north of Chinhoyi City.

The Coordinate in front of Miriam vertical shaft is 16°53.308'S and 30°09.586'E.

Present situation : In operation. Opencut mining (North Molley, South Miriam, South Molley) was finished. Mining in pit used to Miriam vertical shaft and East vertical shaft is operating.

History : The exploration of this mine was commenced by Anglo American in 1930's. RCV Ltd. explored this mine in 1940. MTD Co.Ltd. obtained the mining right from RCV Ltd. in 1950 and commenced to develop. Production began in 1956.

Scale : Ore reserves is 60,000,000 tons (Cu, 1.0 %). Present production of crude ore is 4,000 tons/day (Cu, 0.7 %, Ag, 8.2 g/ton, Au, 0.068 g/ton). Capacity of mineral processing plant is 4,500 ton/day.

Geology : The basement rock of Archaean granite is distributed in the eastern part of this ore deposit. Arkose, pelitic schist and chlorite schist of Deweras Group distributes in the western side separated by the thrust with N–S direction. Geological Structure shows N–S strike and the dip of E50° – 60°and continues the south to the north.

Ore deposit : The ore deposit occurs within conglomerate, arkose and pelitic rock with the characteristics of alluvial fan sediments. It shows as dissemination or quartz–microcline narrow vein type ore which mineralized along the fracture zone and cleavages. The main ore minerals are chalcocite, bornite and chalcopyrite, and pyrite comes to next. Very small amount of molybdenite,

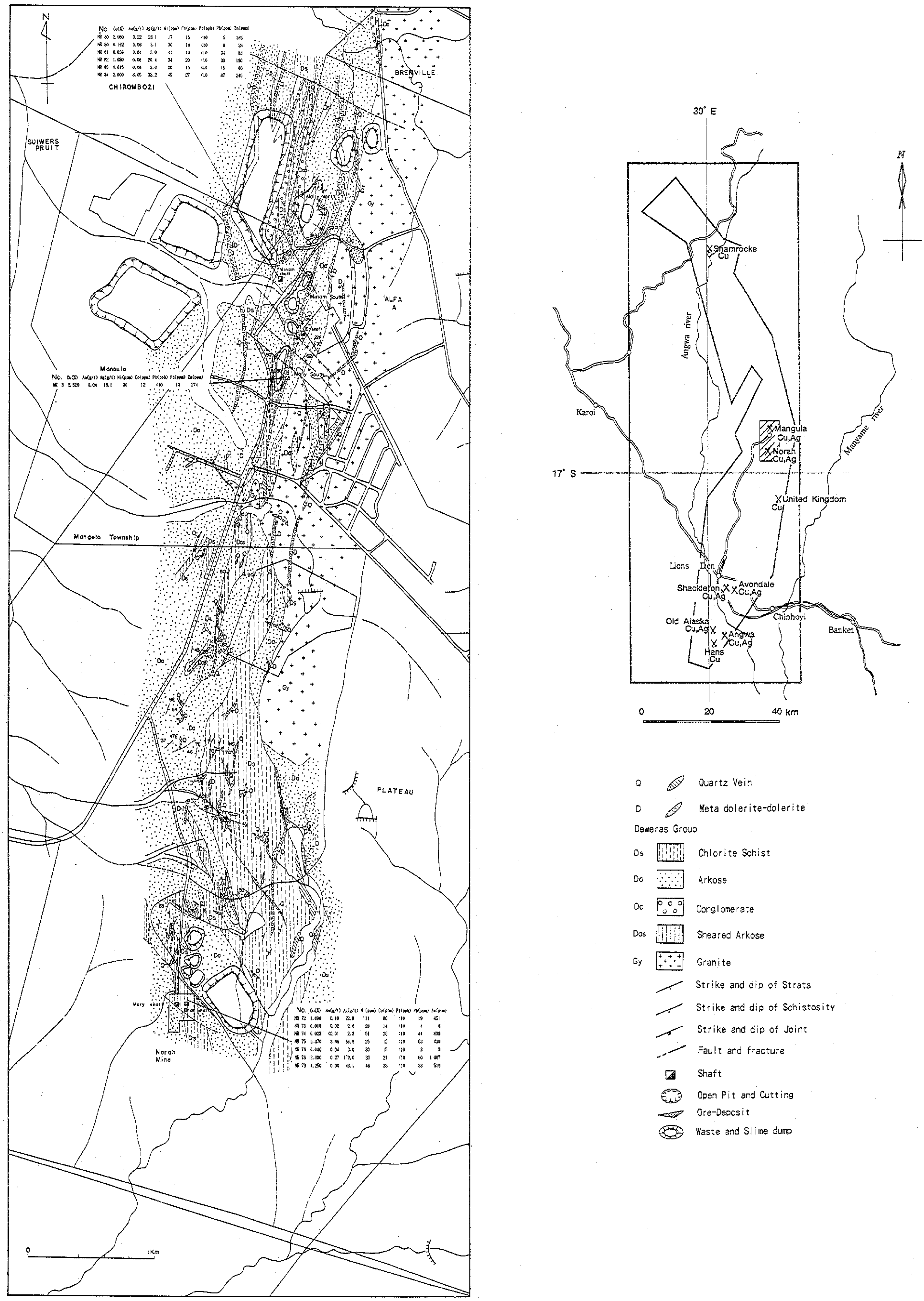


Fig.II-2-12 Detail geological map in Mangula area.

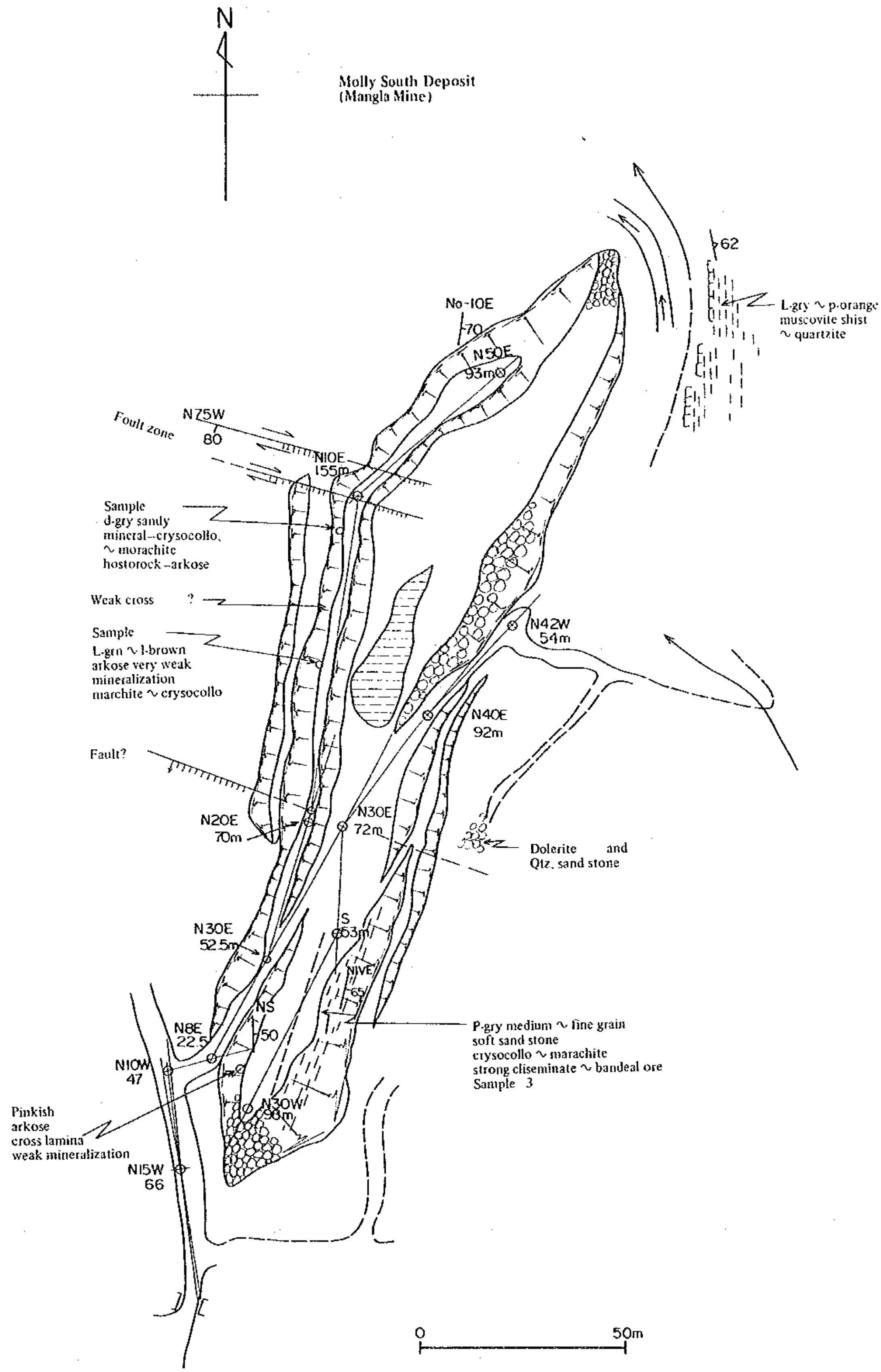


Fig.II-2-13 Sketch at the Molley opencut.

native silver, argentite, wittichentite, uranite and native gold occurrence are reported (Master 1991).

The ore deposit is strong oxidized zone on the surface of South Molley opencut, and shows dissemination of malachite and narrow ore vein.

The surrounding of ore deposit is characterized by hematite. Typical example is recognized in arkosic reddish beds among the bodies of ore deposits. although, strong alteration is not recognized.

By microscopic observation of polished samples, irregular shaped bornite, chalcocite, chalcopyrite, columnar hematite and euhedral granular magnetite are recognized. Bornite, chalcocite and chalcopyrite coexist. Bornite, chalcocite coexist with graphic texture. Some bornites replaced chalcocite. Some chalcopyrites filled among particles of arkose and some include sphalerite are recognized.

Chemical analyses of the samples is as follows :

Samples	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR 3	2.520	0.04	16.1	30	12	<10	10	274
KR 60	2.080	0.22	23.1	17	15	<10	5	185
NR 80	0.162	0.06	3.1	30	18	<10	8	28
NR 81	0.038	0.04	3.0	41	19	<10	34	83
NR 82	1.680	0.06	20.4	34	20	<10	39	190
NR 83	0.615	0.06	3.6	20	15	<10	15	83
NR 84	2.000	8.05	33.2	45	27	<10	87	245

(2) The Norah Mine

Location : The Plateau farm, 5 kilometres south of Miriam deposit.

The coordinate in front of Gate is 16°56.212'S and 30°09.163'E.

Present situation : In operation.

History : The exploration of this mine was commenced by Anglo American in 1930's. RCV Ltd. commenced to develop in 1940's. MTD Co.,Ltd. obtained the mining right from RCV Ltd. in the middle of 1950's. Production of crude ore was commenced in 1972.

Scale : Ore reserves is 8,000,000 tons, Cu, 1.2 %.

Geology : This deposit is located in the southern extending part of Miriam ore deposit. Geology around the mine is the same of Miriam ore deposit area.

Ore deposit : The ore deposit is located in the upper horizon correspond to Miriam ore deposit, and occurs within fine to coarse-grained arkose which shows cross-bedding, and also occurs within dolomitic rock.The hanging wall rock of the ore deposit consists of chlorite-quartz sandstone and chlorite-calcarious schist characterized by containing evaporite thin layer such as anhydrite, barite, celesitite, chlorite, tourmaline and sulphide.

The main ore minerals are chalcocite and chalcopyrite with bornite and pyrite. The ore deposit has clear boundary at the side of hanging wall rock, however, in the side of foot wall rock, has no clear boundary because of poor grading in coarse-grained arkose.

By microscopic observation of polished samples, chalcopyrite, bornite, chalcocite, sphalerite, covelline, hematite and magnetite are recognized. Chalcopyrite, bornite, chalcocite and sphalerite show irregular shapes. Covelline shows platy or foliated. Hematite is long to radial columnar. Magnetite is euhedral. Chalcocite, bornite and chalcopyrite coexist. Chalcocite and bornite with graphic texture are recognized as paragenesis.There are chalcocites which replaced bornite is recognized. There are hematites which are partly replaced magnetite, and which grow radially with euhedral shape to chalcopyrite and bornite.

Chemical analysis of the samples is as follows :

Samples	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
NR 72	1.890	0.10	22.9	111	86	<10	19	451
NR 73	0.018	0.02	2.6	28	14	<10	4	6
NR 74	0.023	<0.01	2.3	51	26	<10	44	899
NR 75	6.370	3.86	68.9	25	15	<10	63	699
NR 76	0.006	0.04	3.0	30	15	<10	2	9
NR 78	13.000	0.27	170.0	33	21	<10	160	1,667
NR 79	4.250	0.30	43.1	46	33	<10	33	519

5. The Shamrocke area (Fig. II-2-14)

(1) The Shamrocke Mine

Location : 80 kilometres north-east of Karoi City.

The coordinate of the opencut is 16°25.78'S and 30°09.52'E.

Present situation : Closed.

History : This mine was discovered in the late 1950's. Rand Mines explored interior and exterior of the mine during 1958 to 1961. The development of the mine was carried out by Nyashere Copper (Private) Limited since the middle of 1960. This mine was operated since 1972 to 1978.

Scale : Ore reserves are approximate 5,000,000 tons. expected residual ore reserves at mining was suspended 1,000,00 tons.

Geology : Graphite schist, quartz-feldspar-hornblende schist, meta-arkose and biotite-actinolite schist are distributed in the ore deposit area.Incline fold structure with plunge of approximate 40°SE is the prominent structure.

Ore deposit : The ore deposit occurs as sulphide dissemination zone in fine-grained calcarious meta-arkose layer within graphite schist.

The ore minerals are mainly dissemination ore of pyrrhotite and chalcopyrite, and small amount

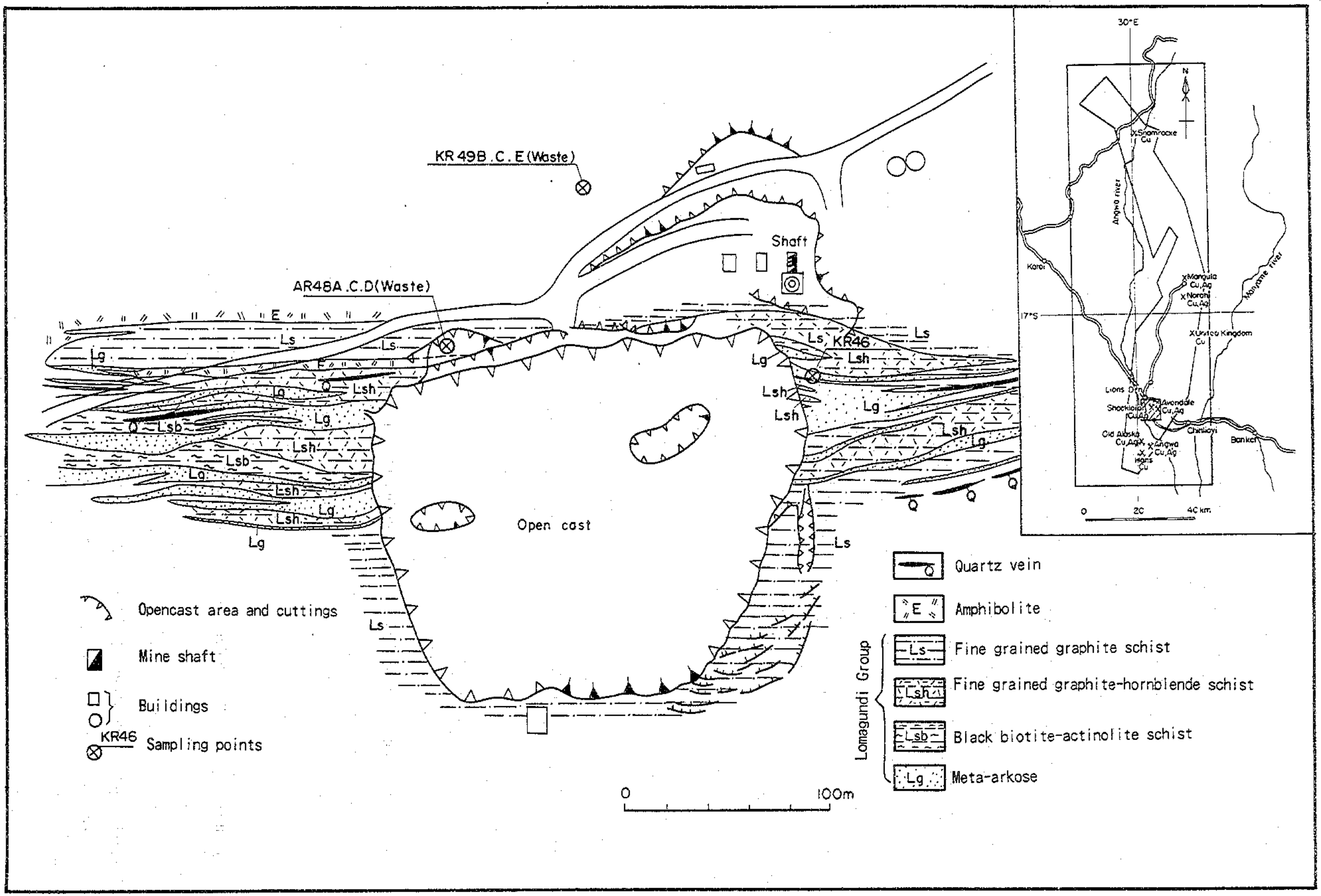


Fig.II-2-14 Geological map in the Shamrocke area.

of arsenopyrite, chalcopyrite, hematite, ilmenite, pentlandite and sphalerite.

By microscopic observation of polished samples, irregular shaped pyrrhotite and chalcopyrite coexist, and marcasite which replaced pyrrhotite are recognized. Platy or foliated cubanite and chalcopyrite by exsolution within chalcopyrite, magnetite with hematite rim, euhedral pyrite and ilmenite, irregular shaped sphalerite and chalcocite which appears sphalerite are recognized, respectively.

Chemical analyses of the samples is as follows :

Samples	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
KR 48A	0.057	<0.01	4.5	151	88	<10	15	181
KR 48C	0.700	0.14	4.2	34	21	<10	4	110
KR 48D	2.250	0.17	4.4	71	44	<10	9	299
KR 49B	3.470	0.55	8.1	90	46	<10	4	517
KR 49C	3.340	0.52	7.8	128	57	<10	22	2,008
KR 49E	0.974	0.08	5.3	24	21	<10	11	82
KR 44A	0.030	0.06	3.8	67	23	46	24	37
KR 52	0.027	0.05	5.2	27	47	<10	13	116

6. Other mineralized areas

(1) Quartz-magnetite vein

Location : Nyamamyoko mountain, 7 kilometres north of Mhangura.

The Coordinate is 16°50.63'S and 30°10.57'E.

Geology : Archaean granite which is the basement rock of this area is distributed. Ore veins are quartz veins occur in granite. They distribute parallel to Nyamamyoko mountains from the north to the south. Ore vein is only composed of quartz. Small ore minerals are scattered by the naked eye.

By microscopic observation of the samples, magnetite and hematite is recognized. There are two hematite. One partly replaces magnetite, the other occurs individually from magnetite as small columnar euhedral crystal.

Chemical analyses of the samples is as follows :

Samples	Cu(%)	Au(g/t)	Ag(g/t)	Ni(ppm)	Co(ppm)	Pt(ppb)	Pb(ppm)	Zn(ppm)
KR 61	0.036	0.03	4.5	20	16	<10	8	142

(2) Bedded iron ore deposit

Location : The north-westen border of Riving farm, 15 kilometres south-west of Mangula.

The coordinate is 16°50.63'S and 30°10.57'E.

Geology : Dolomite and shale of Lomagundi Group distributes successively with the NE–SE direction.
Ore deposit : Iron ore layer occurs only in one group of boulder ore deposit. Judging from collected samples, iron ore deposit occurs within shale parallel to strata. The deposit is composed of several banded iron ore layers with the thickness of several centimetres to ten more centimetres.

Ore mineral is mainly composed of dense and massive magnetite with small amount of hematite by the naked eye observation.

By microscopic observation of polished samples, magnetite and hematite are recognized. There are two kind of hematite. One replaces the margin of magnetite. The other completely replaces whole the magnetite. There are some relic structures of magnetite in euhedral hematite crystals.

(3) Dolomite ore deposit

Location : 1) 8 kilometres SSW of the Old Alaska opencut (17°27.88'S and 29°58.58'E).

2) 1.5 kilometres west of Lions Den (17°15.69'S and 30°01.04'E).

3) 4 kilometres north of Lion Dden (17°13.88'S and 30°01.58'E).

Present situation : All the three mines are suspended to mine.
Geology and ore deposit : Geology of this area is the lowest dolomite strata of Lomagundi Group which is distributed along the border of Deweras Group and Lomagundi Group from the north to the south. The deposit occurs in the dolomite and dolomitic layer. Mining is operated on a small scale in the dolomitic sandstone. It is considered that farmers mined for their own use or tried to explore.

The Alaska Dolomite Mine is located in 5 kilometres west of Chinhoyi (out of this survey area) products approximate 40 % of domestic demand.

(4) The slate mine

Location : 7 kilometres north–west of Chinhoyi.

The coordination is 17°19.01'S and 30°07.74'E.

Present situation : Closed.
Geology and ore deposit : Geology of this area is dark grayish to dark brownish slate of the upper strata of Lomagundi Group which is distributed along Hunyani mountains from NNE to SSW successively. The mining is conducted the strong fissilitic part within this slate for his own use in case of need.

2–4–2 Characteristics of Mineralization

Strata bound disseminated copper sulphide deposit, copper vein type ore deposit accompanied with quartz and calcite vein, banded iron deposit, and dolomite deposit are located in Makonde area. These ore deposits have close relationship to the special horizon, rock facies and geological structure.

Relationship among mineralization and geological horizon, rock facies and geological structure is described in this chapter.

1. Strata bound disseminated copper ore deposit

All the deposits of large scale mines including the mine which is suspended in this area are this strata bound disseminated copper sulphide deposit type. Old Alaska Mine, the Angwa Mine, the Hans Mine, the Shackleton including the Avondale ore deposits in the southern part of this area, the Mangula Mine and the Norah Mine in the central part of this area, the Shamrocke Mine in the northern part belong to this type of deposit.

From the viewpoint of the geological horizon, the ore deposits mainly occur in arkose of Deweras Group, however, the Old Alaska Mine and the Shamrocke Mine occur in dolomite and metamorphic rocks of Lomagundi Group.

From the viewpoint of the rock facies of ore deposit, there is a sedimentary cycle which is composed of one unit of conglomerate, arkose with grading and cross-bedding and pelitic rocks includes various evaporites. The ore deposits generally occur both within just under pelitic rock.

From the viewpoint of mineral assemblage, irregular shaped chalcocite, bornite and chalcopyrite are main ore minerals and dissemination ore minerals packed among particles of country rock are ordinary seen, particularly in small vein along bedding, In cleavage and fracture zone is rarely recognized. Particularly, high grade crude ore includes the mineral dissemination and small vein written above. Besides the accessory minerals, covelline, magnetite and hematite are recognized. In Shamrocke Mine, essential minerals are pyrrhotite and chalcopyrite with small amounts of pyrite, cubanite, chalcocite, covelline, sphalerite, magnetite and ilmenite.

From the viewpoint of grade of crude ore, grade of Au is within the range of 0.01 to 0.5 g/ton and becomes more than 1 g/ton in narrow vein, grade of Ag is always within the range of 1 to 30 g/ton and becomes more than 60 g/ton in narrow vein, and grade of Cu is within the range of 0.01 to 3.5 %. grade of Ni, Co and Pb, is in several 10 ppm. Zn becomes partly more than 1,000 ppm at the Shamrocke Mine and the Norah Mine, but is within several 100 ppm. Pt content in most of the samples is under the detectable limit.

From the viewpoint of related igneous rocks, doleritic dykes always exist near the ore deposits. However, doleritic dykes are often seen even in the non- mineralized zone, therefore, it is difficult to determine that doleritic dykes have relationship to mineralization.

As result, the discussion is summarized as follows :

1) According to expansion of rift valley, vesicular rocks such as conglomerate to arose were widely formed.

2) According to marine transgression, fine-grained politic rocks including evaporates were partly sedimented.

3) Deweras Group was formed due to repeated activity of above 1) and 2).

4) Various scale of fold structure, fault zone and fracture zone were formed by mobile activity.

5) Ore solution rose along the fault zone and fracture zone selectively through vesicular rocks, and fine-grained pelitic rocks formed the cap rock at the time.

6) Through the process, copper sulphide educed, and formed dissemination and narrow vein type ore deposit.

7) Present form of ore deposit was formed by movement after deposition.

2. Metalliferous vein type ore deposit

Only two places of quartz-calcite copper vein (United Kingdom ore deposit) and quartz-magnetite vein (Nyamamyako Hill) were recognized as metalliferous vein type ore deposit.

The former is dolerite dykes with inclined to the east which intruded along anticline axis with the direction of N-S and NNE- SSW of quartz-calcite vein. It is possibly to be formed by the activity which came to next of intrusion of dykes.

On the other hand, the latter is quartz vein occurring within the Younger Granites which is generally extended from the north to south. Similar quartz vein can be recognized in Nangaza Hill and Guma Hill, and they are considered to be formed by tension release in the late stage of granite formation.

Judging from the scale of ore deposits and grade of crude ore, both the types can be recognized neither capability of development nor economical value.

3. Bedded iron ore deposit

This deposit occurs in dolomitic shale of Lomagundi Group, which is so-called banded iron ore deposit. The ore deposit is considered to be by chemical precipitation ore deposit which is formed in marine basin. However, only one boulders ore deposit is recognized in this field. Therefore, the detail is still unknown.

2-5 Physical Properties of Rocks and Ore Samples

2-5-1 The method of Measurement

Measurement of physical properties of rocks and ore minerals which were sampled at the outcrops and in the underground of the mines was carried out. The specimens were cut to the squares with about 6 cm side. Voltage measurement with 10 uA of transmitted current, 3 Hz and 0.3 Hz of frequencies to calculate relative resistivity. Platinum wire (0.4 mm diameter) was used as current and potential electrodes. Polarization ratio (PFE) was calculated using the following equation.

$$PFE=(\rho0.3 - \rho3)/ \rho3 \times 100 (\%)$$

where, ρ0.3 is relative resistivity in 0.3 Hz, ρ3 is relative resistivity in 3 Hz.

2-5-2 Results of Measurement

The measurement was conducted for the specimens which represent the basement gneiss, the Pre-Magondi Intrusive Rocks, the Magondi Supergroup and the Post-Magondi Intrusive Rocks. The measurement results are shown in Table.II-2-5. Resistivity and chargeability of each strata and rock facies are shown in Fig.II-2-15. The relationship between IP and relative resistivity in the specimens of rocks and ore minerals is shown in Fig.II-2-16. The relationship between grade of cop‚ ‑nd IP is shown in Fig.II-2-17. The relationship between grade of copper and relative resistivity is show‥ in Fig.II-2-18. From the characteristics of these Figures, the following points are indicated.

1. Relative resistivity

Resistivity varies from 128 to 13,216 Ω·m. The resistivity of slate is the minimum, and it has the tendency of increasing from arose to conglomerate, through mafic rocks (dolerites, amphibolite, basalt), quartzite, quartz vein, sandstone, granite to dolomite.

Resistivity of the arose of the Deweras Group which is the main horizon occurring ore deposits is high whose value is from 3,000 to 7,000 Ω·m in the specimens which were mineralized by sulphides. The resistivity varies from 500 to 7,000 Ω·m in the specimens which are not mineralized. Therefore, mineralization does not make any effect to the resistivity. On the other hand, the resistivity in the specimens which are mineralized by oxides shows the tendency of relatively slightly low from 500 to 1,000 Ω·m.

The resistivity in dolerites and amphibolites which were mineralized by sulphides markedly varies from 700 to 6,000 Ω·m.

2. Chargeability

The chargeability in arkose which was mineralized by sulphides shows high IP from 5 to 18 % according to the grade of copper. However, the chargeability in arkose which was mineralized by oxides only shows less than 1 % of IP.

The chargeability in dolerite and amphibolite which were mineralized by sulphides shows high IP from 4 to 10 % according to the grade of sulphide.

Graphitic slate shows high IP of approximate 10 %.

The other rocks show low IP of 1 to 3 %.

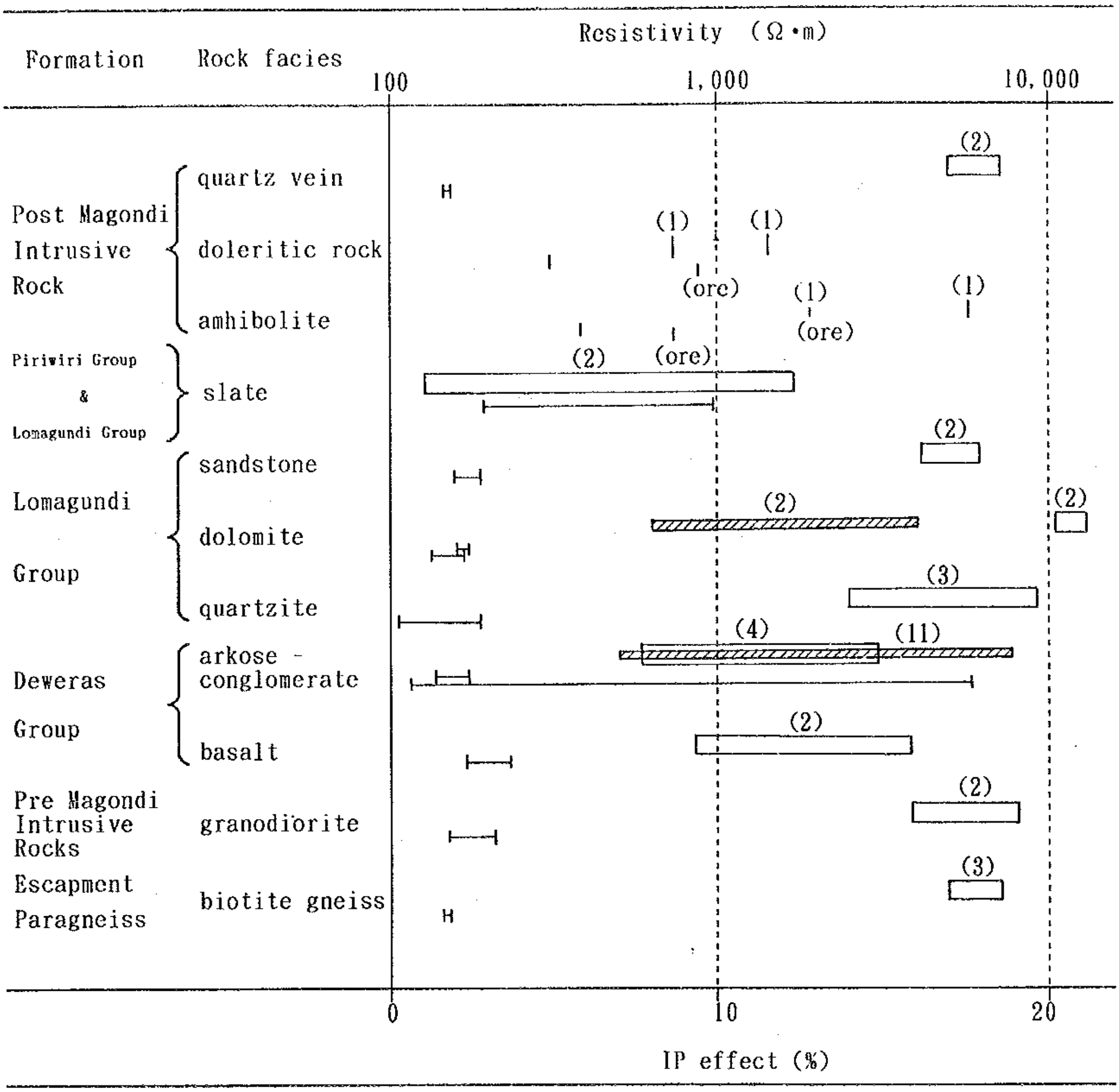
3. Spectral IP

The SIP measurement was carried out for the typical specimens after the measurement of relative resistivity and chargeability, and the examinations about spectral characteristics of ore minerals and

Table II-2-5 Result of physical property measurement

No.	Rock names	Formation	Locality	Coordinate		Resistivity (Ω-m)	IP effect (%)	Assay of Cu (%)
				Latitude	Longitude			
KR 2	arkose	Deweras	Manyamba Estate	17 °21.56 'S	30 ° 1.33 'E	579	2.4	n.a.
KR 3	basalt	Deweras	Freda	17 °22.43 'S	30 ° 1.57 'E	3,792	3.6	n.a.
KR 11	conglomerate-arkose	Deweras	Chipungu A	16 °39.83 'S	30 ° 6.32 'E	3,010	1.4	n.a.
KR 37	gneiss	Gneiss	Doma Safari Area	16 °31.40 'S	30 ° 5.64 'E	1,188	1.8	n.a.
KR 40	gneiss	Gneiss	Doma Safari Area	16 °30.02 'S	30 ° 7.30 'E	2,257	1.8	n.a.
KR 41	schist?, dolomitic	Gneiss	Niruana	16 °36.56 'S	30 ° 9.87 'E	2,320	1.7	n.a.
KR 44A	quartz vein	Lomagundi	Shamrocke East	16 °26.16 'S	30 ° 1.73 'E	7,114	1.8	0.030
KR 48C	amphibole calc-silicate rock	Lomagundi	Shamrocke Mine	16 °25.78 'S	30 ° 0.33 'E	6,338	4.2	0.700
KR 50	amphibolite	Dyke	Doma Safari Area	16 °25.87 'S	30 ° 1.73 'E	5,685	5.3	n.a.
KR 54	dolomite	Lomagundi	Old Alaska Mine	17 °23.87 'S	30 °11.24 'E	618	1.2	0.437
NR 45	quartzite	Lomagundi	Cotswold Estate A	16 °58.27 'S	30 °12.62 'E	2,473	0.2	n.a.
NR 56	arkose-slate	Deweras	Chirombozi	16 °52.43 'S	30 ° 9.80 'E	1,112	2.4	n.a.
NR 57	granodiorite	Younger Granite	Alfa A	16 °53.61 'S	30 °10.20 'E	3,811	1.8	n.a.
NR 61	arkose	Deweras	Plateau	16 °55.03 'S	30 ° 9.12 'E	1,814	1.9	n.a.
NR 63	slate, graphitic	Piriwiri	Robbsdale	16 °56.44 'S	30 ° 6.15 'E	1,660	9.8	n.a.
NR 72	amhibolitic rock	Dyke	Norah Mine	16 °56.21 'S	30 ° 9.16 'E	1,859	8.5	1.890
NR 73	arkose	Deweras	Norah Mine	16 °56.21 'S	30 ° 9.16 'E	2,419	3.2	0.018
NR 76	arkose	Deweras	Norah Mine	16 °56.21 'S	30 ° 9.16 'E	6,949	4.1	0.061
NR 79	doleritic basalt	Dyke	Piringani	16 °57.21 'S	30 ° 9.52 'E	725	9.5	4.250
NR 80	arkose	Deweras	Mangula, Underground	16 °53.31 'S	30 ° 9.59 'E	4,300	2.4	0.162
NR 81	arkose	Deweras	Mangula, Underground	16 °53.31 'S	30 ° 9.59 'E	4,436	2.4	0.038
NR 83	arkose	Deweras	Mangula, Underground	16 °53.31 'S	30 ° 9.59 'E	5,564	5.3	0.615
NR 94	arkose(malachitization)	Deweras	Hans Mine	17 °25.47 'S	30 ° 1.95 'E	498	0.8	2.710
NR 97	arkose(malachitization)	Deweras	Hans Mine	17 °25.47 'S	30 ° 1.95 'E	1,165	0.6	1.330
NR104	arkose with quartz-bornite vein	Deweras	Angwa Mine	17 °23.96 'S	30 ° 3.37 'E	7,689	7.5	1.230
NR106	arkose	Deweras	Angwa Mine	17 °23.96 'S	30 ° 3.37 'E	3,146	17.7	1.590
NR114	quartz vein	Vein	United Kingdom Mine	17 ° 4.67 'S	30 °11.24 'E	4,880	1.6	1.450
NR126	dolomite(malachitization)	Lomagundi	Old Alaska Mine	17 °23.87 'S	30 ° 0.87 'E	1,377	2.0	0.008
NR127	dolomite(malachitization)	Lomagundi	Old Alaska Mine	17 °23.87 'S	30 ° 0.87 'E	3,994	2.2	0.354
NR136	arkose with quartz vein	Deweras	Avondale Mine	17 °17.86 'S	30 ° 4.11 'E	1,436	1.8	0.005
NR137	arkose	Deweras	Avondale Mine	17 °17.86 'S	30 ° 4.11 'E	3,461	4.7	0.446
SR 4	sandstone	Lomagundi	Strathcona	17 °21.75 'S	30 ° 6.88 'E	4,064	2.8	n.a.
SR 9	dolomite	Lomagundi	Kings Peak	17 °19.85 'S	30 ° 8.85 'E	13,216	2.4	n.a.
SR 11	quartzite	Lomagundi	Sinoia Citrus Estate	17 °20.43 'S	30 ° 9.04 'E	9,054	2.5	n.a.
SR 27	quartzite	Lomagundi	Celuk	17 °13.05 'S	30 ° 8.70 'E	3,055	2.1	n.a.
SR 58	dolerite	Dyke	Whindale Ranch	16 °56.75 'S	30 °11.63 'E	1,477	4.9	n.a.
SR 82	granodiorite	Younger Granite	Nyamamyoko A	16 °48.31 'S	30 °10.99 'E	8,056	3.2	n.a.
YR 21	slate	Piriwiri	Hillpass	17 °16.56 'S	30 ° 0.20 'E	128	2.9	n.a.
YR 42	dolomite	Lomagundi	Baruka	17 °19.23 'S	30 ° 6.28 'E	10,528	2.0	n.a.
YR 70	sandy slate origin mica schist	Lomagundi	Robbsdale	16 °56.42 'S	30 ° 5.71 'E	6,119	2.0	n.a.
YR104	basalt with elongated amygdal	Deweras	Bandira	17 °30.91 'S	30 °57.42 'E	835	2.3	n.a.

n.a.: not analysed.



( ) number of measured samples

▭ resistivity

▨ resistivity of ores

├┤ IP effect

Fig.II-2-15 Apparent resistivities and IP of rock samples.

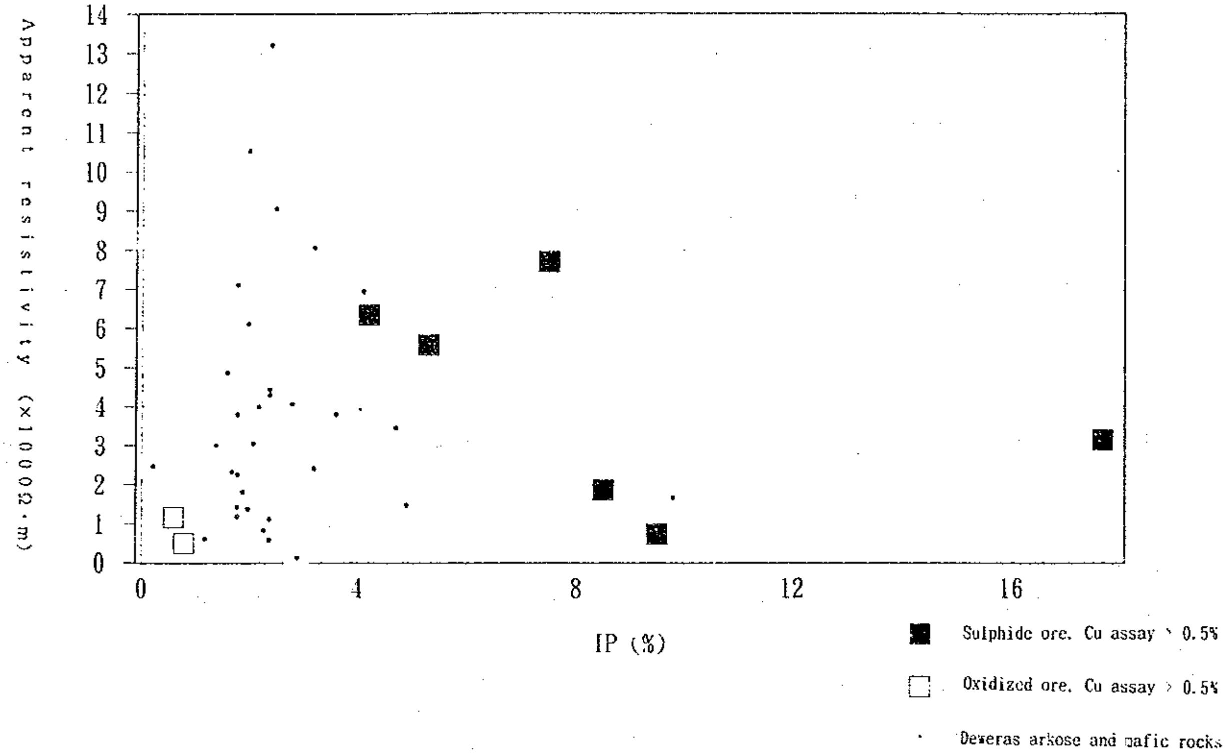


Fig.II-2-16 Relationships between IP and apparent resistivities.

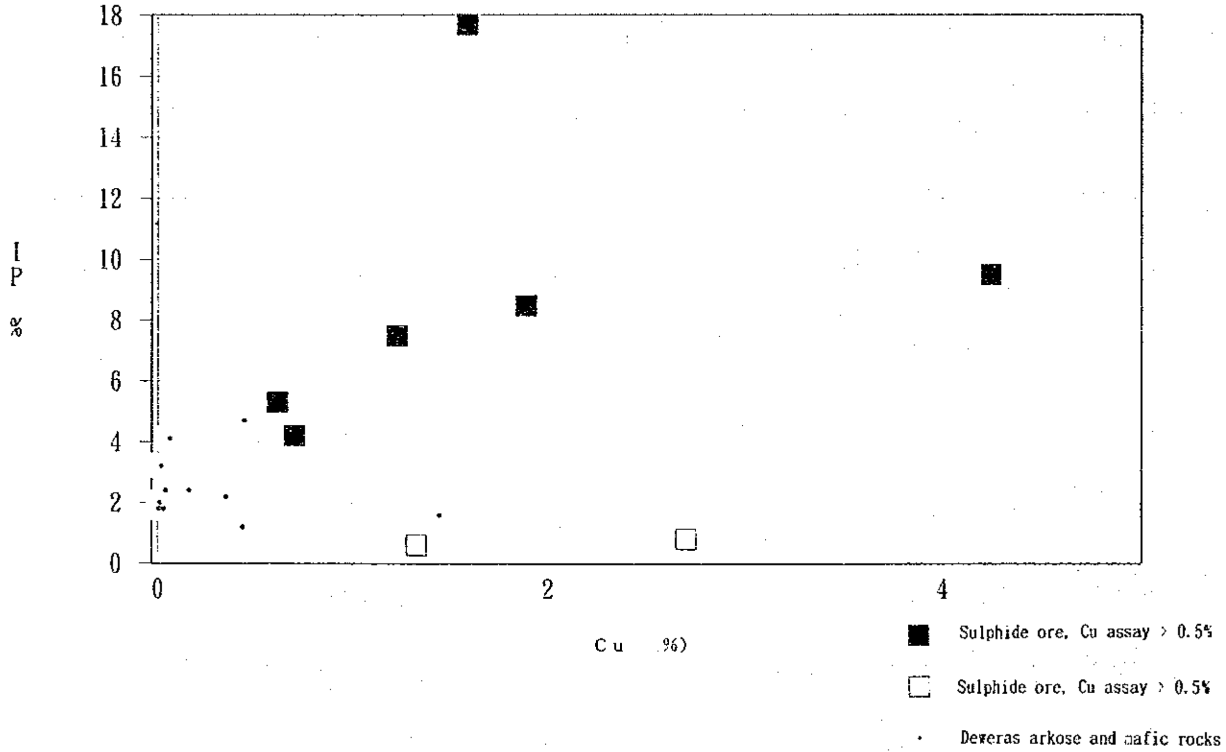


Fig.II-2-17 Relationships between Cu contents and IP effects.

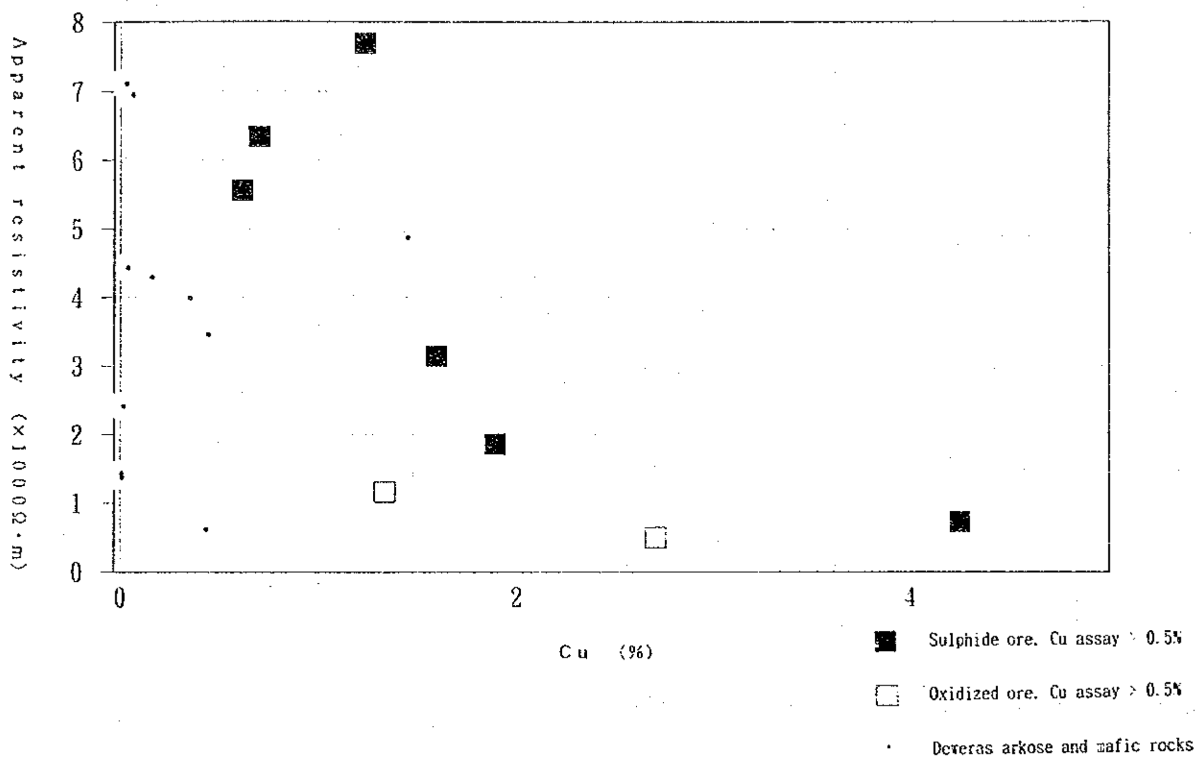
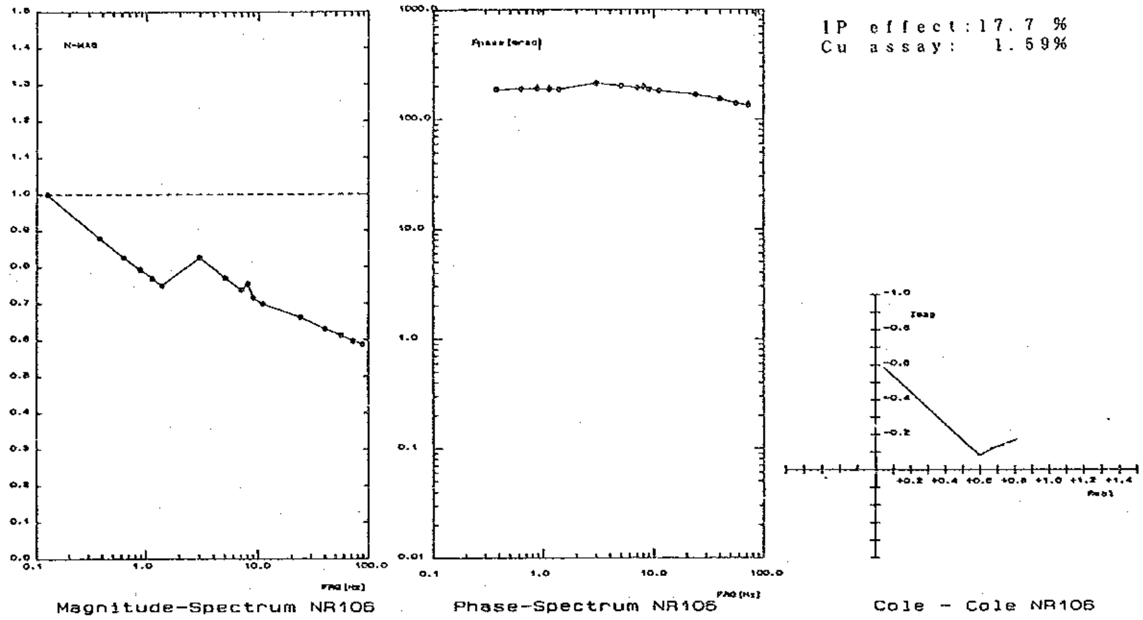


Fig.II-2-18 Relationships between Cu contents and apparent resistivities.

(a) Arkose (sulphide ore)



(b) Arkose (oxidized ore)

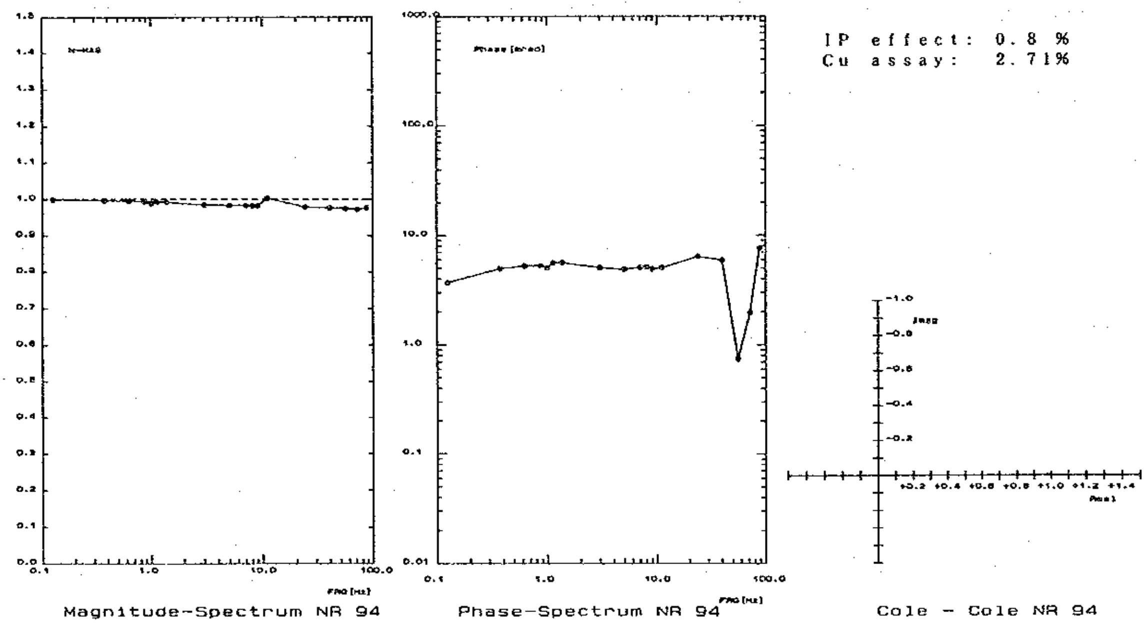
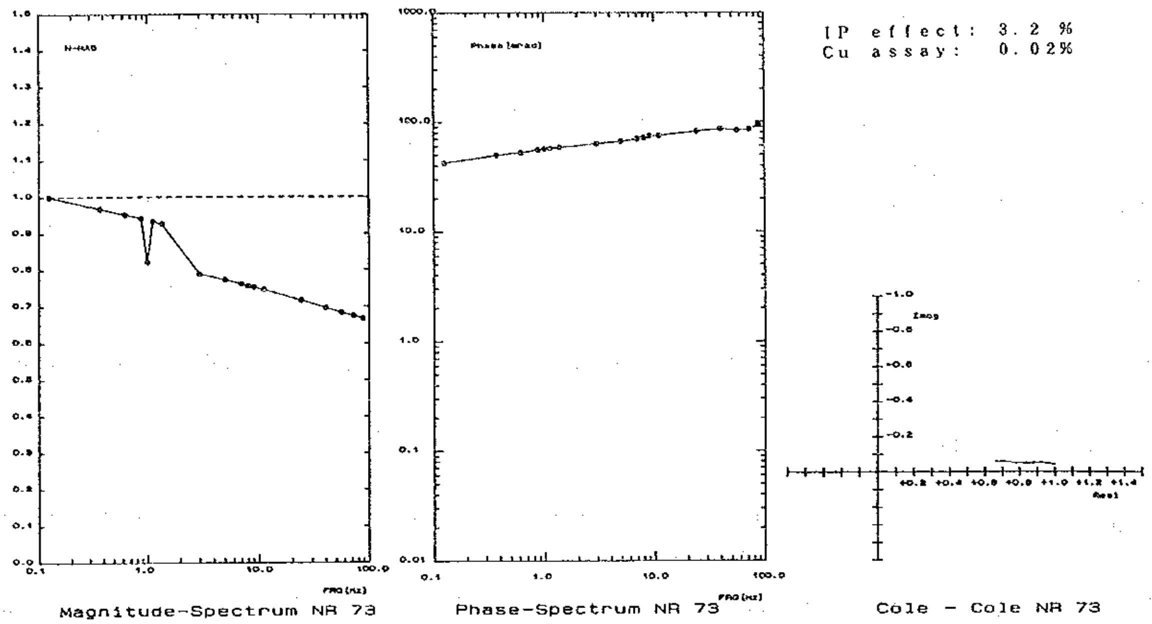


Fig.II-2-19 Spectral IP pattern of rock and ore samples. (1)

(c) Arkose (non ore)



(d) Dolerite (Non mineralization)

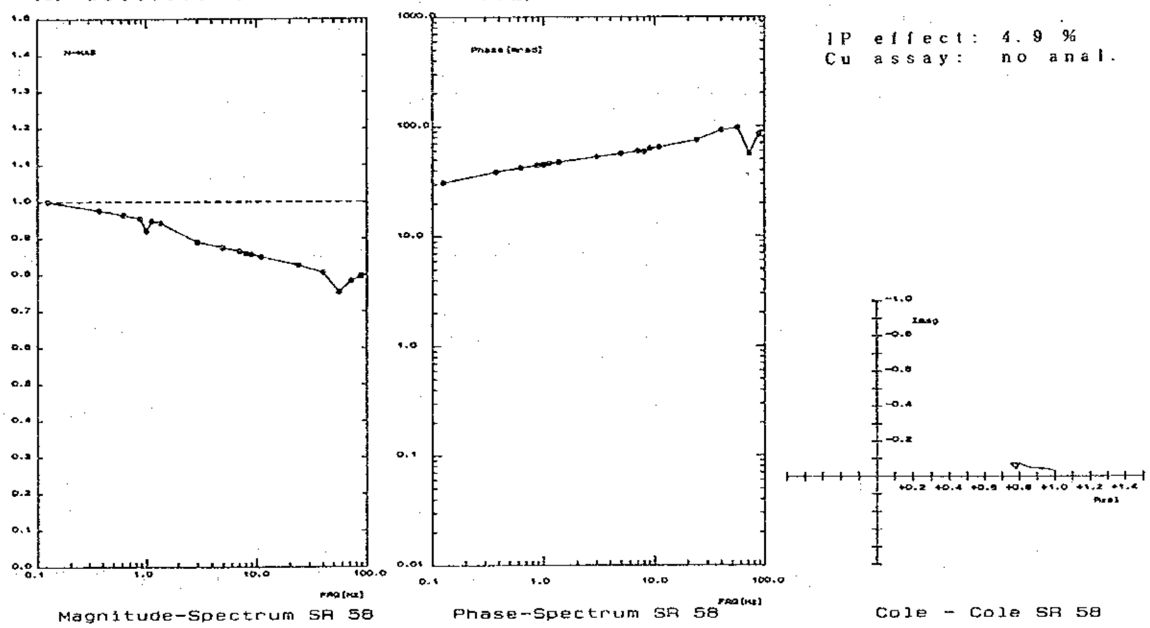


Fig.II-2-19 Spectral IP pattern of rock and ore samples. (2)

rocks. The spectra of typical rocks and ore minerals are shown in Fig.II-2-19. Judging from the Figures, the following facts can be pointed out.

In sulphide ore minerals, the phase difference is big and constant regardless of frequency.

In oxide ore minerals, the phase difference is small and constant regardless of frequency.

In dolerite and arose with little mineralization, the phase difference is small for low frequency, and the phase difference for high frequency constant is 2 or 3 times of that for low frequency.

As regards magnitude, some rocks shows the tendency of increasing or decreasing for high frequency, and some rocks shows constant. There is no obvious difference in relationship between magnitude and mineralization.

From the above facts, the following points must be noticed in case of application of geophysical survey in this area.

1) The arose of the Deweras Group which is the main horizon of ore deposit occurrence in this area shows high IP according to the progress of sulphide mineralization.

2) Resistivity markedly varied, and possibility of effect to the resistivity by sulphide mineralization is little.

3) Mineralized dolerite and amphibolite shows high IP according to progress of mineralization.

4) Although graphitic slate shows high IP of approximate 10 %, the distribution is not recognized within the Deweras Group which is the main horizon of the ore deposit occurrence. Therefore, the graphitic slate can not be interruption factor of IP survey.

5) Judging from the spectral characteristics, variety of the phase differences in ore minerals and rocks are observed.

Chapter 3 Geochemical Surveys

3-1 Soil Geochemical Survey

3-1-1 Selection of Areas for Soil Geochemical Survey

From the economical point of view, the metal resources which can be profitably worked is the copper in the Deweras Group. Though the possibility of the occurrence of Mississippi Valley type lead and zinc ore deposits with the country rock of dolomite and black slate of the Lomagundi Group is considered, it is not the targets of the surveys at present (Simpson 1990). Explorations of mineral ore deposits in this area were continuously carried out since the late 1940's until the middle of 1970's. In the area from the northern part of the Mangula Mine to the southern part of the Alaska Mine, and around the Shamrocke Mine, the detailed geochemical survey of soil and river sediment were carried out over the widely area. In the geochemical anomalous places where were detected by the survey, precise surveys with pit, trenching, and drilling were conducted. On the results of those surveys, the Angwa, Avondale and Shackleton ore deposits were discovered. By the surveys under the past E.P.O.s and the internal data of the ZMDC, most of the soil geochemical anomalous places of a single element of copper were extracted.

The locations where geochemical surveys were conducted are shown in Fig.II-3-1. The areas of potentialities of copper ore deposit occurrences are considered to be the distribution area of the Deweras Group from the central to the southern part, and to be the contact parts of the basement rocks, the Deweras Group, and the Lomagundi Group from the central to the southern part.

The soil sampling areas were determined based on the results of the existing data and geological survey. The standards of the selection of the areas are as follows:

1) the distribution area of the Deweras Group and the adjacent area.
2) the high potentiality place of copper ore deposits judging from the literature survey.
3) not polluted area by mining, dressing and refining.
4) the place which can be positioned with the GPS.

Though the multiple elements have been analyzed in the geochemical surveys in this area, the univariate analysis is mainly applied. Regional multivariate analysis has never been applied regionally. Therefore, the studies to discuss the geochemical outline for the characteristics and anomalies in this target area were carried out by multivariate analysis. The selected 4 areas based on the above criteria are listed from the south as follows:

1) The Alaska area
2) The Umboe area
3) The Mangula North area

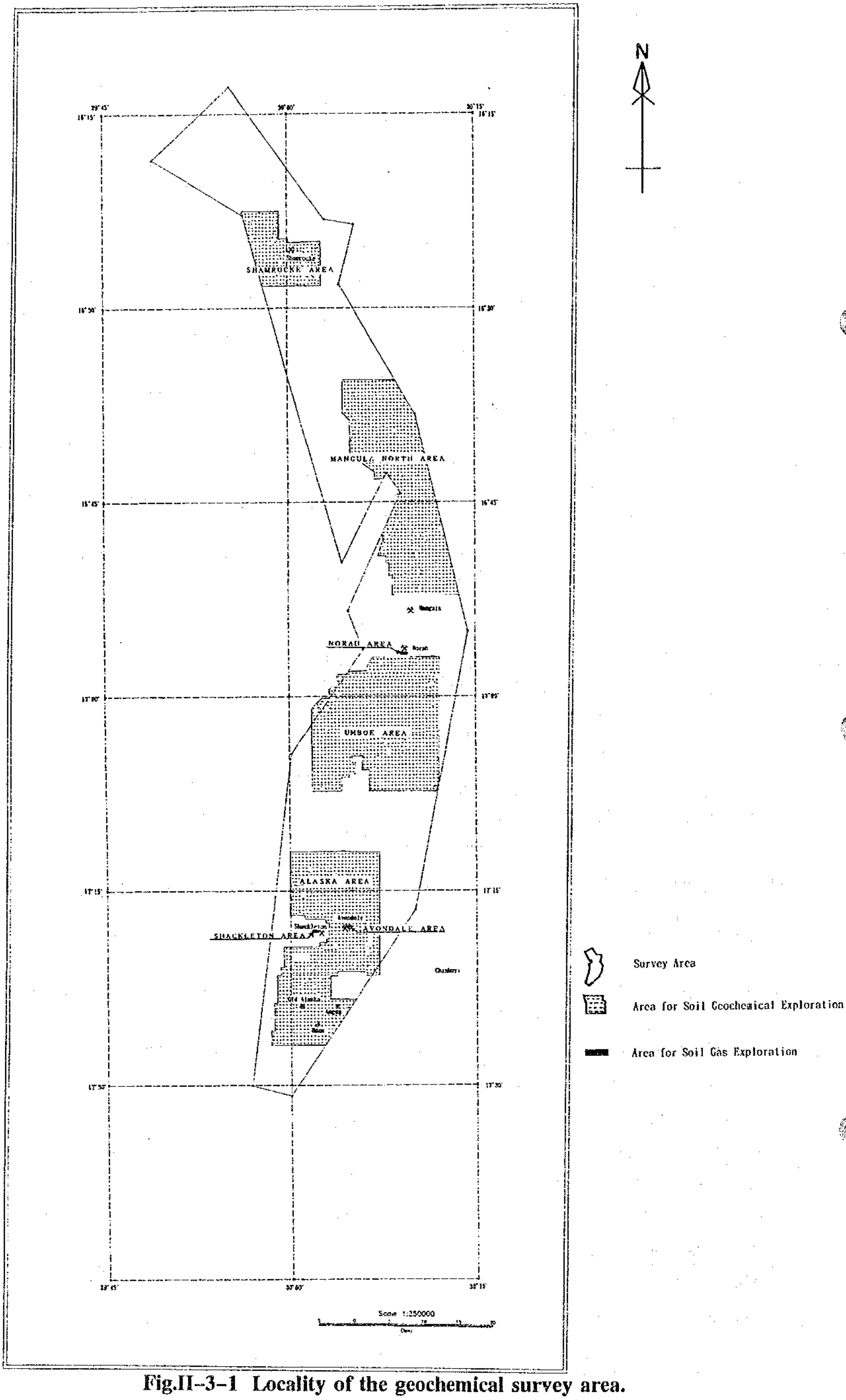


Fig.II-3-1 Locality of the geochemical survey area.

4) The Shamrocke area

The area of the 4 areas of the surveys is 919 square kilometres. 3,676 samples were collected.

The Alaska area is centered by Shackleton and 286 square kilometres. 1,143 samples were collected. In the central part of this area, arkose of the Deweras Group is widely distributed. In the eastern and western wings of the Deweras Group, dolomite and slate of the Lomagundi Group are distributed. The Shackleton Mine including the Avondale ore deposit, the Angwa Mine, the Hans Mine, and the Old Alaska Mine are in this area. Around the former one mines and the Alaska smelter, the surface of the earth is considered to be polluted. Therefore, no samples were collected there.

The Umboe area ranged from the north of Lions Den to the south of the Norah Mine. This area is 297 square kilometres. 1,189 samples were collected. Along the fold axis of the NE-SW direction, arkose of the Deweras Group and dolomite of the Lomagundi Group are distributed. The eastern side of the Deweras Group and the Lomagundi Group contact each other by fault. The United Kingdom Mine is located in the south-eastern part of the area. As sediments are distributed several kilometres wide along the upper reaches of the Munwa river, no sample is collected in this area.

The Mangula North area ranged from the north of the Mangula Mine to the Chitatu farm and is 258 square kilometres. 1,032 samples were collected. In this area, gneiss of the Basement Rocks, the Younger Granite of the Pre-Magondi Intrusive Rocks, and arkose of the Deweras Group are distributed.

The Shamrocke area is centered by the Shamrocke Mine and 78 square kilometres. 312 samples were collected. This area belongs to the Zambezi Mobile Belt. Metamorphic rocks corresponding to the Lomagundi Group and the Deweras Group are distributed. As the sampling points are located in the adjacent of Safari area where is hilly and overgrown with woods, there are some difficulties in receiving conditions of the radio wave from the GPS and traffic conditions to the sampling points.

3-1-2 Sampling

The sampling positions are shown in Appendix 3. The locations were positioned with the GPS. The samples were collected in the interval of every 500 metres (4 samples per 1 square kilometre). After removing the soil in the A layer with pickaxes and shovels, the samples were taken from the B horizon. The depth of the samples were from 30 to 50 centimetres. When the samples were collected, the tone of colour of the soil, the contained rock fragments, and the vegetation were described to understand the adjacent geology. The samples were put through less than 80 meshes in a size of the sieve, and put into sample bags for the further analyses.

3-1-3 Indication Elements

The numbers of the analyzed components are 10. They are Cu, Ag, Au, Fe, Pb, Zn, Co, Ni, As and Hg. The analyzing methods and detectable limits for all the chemical elements are shown in Table

II–3–1. The list of chemical analyses are shown in Appendix A–4.

3–1–4 Statistical Processing of the Analyzed Values

The univariate analysis and multivariate analysis were applied to the results of the chemical analyses. In case of the geochemical data analysis, the frequencies of the population of trace elements are empirically known to follow logarithmic normal distribution (Lepeltir, 1969). It is general that actual populations of geochemical data consist of several kinds of population whose geochemical characteristics are different. Therefore, anomalous values are generally determined by focusing the deviation (anomalous populations) from the logarithmic normal distribution (the background population) which is formed by most of the indication elements. For the univariate analysis in this study, however, the gap between the standard deviation multiplied by an integer and the geometrical mean value are adopted as a threshold in order to define the density distribution of the content of each component, that is, the concentration contour value I_{ij} for i times of the standard deviation is calculated as ;

$$I_{ij} = m_j \times 10^{\sigma_j \times i}$$

where mj and σ_j re the geometrical mean value and the standard deviation for the j–th component, respectively.

Analysed values less than the detectable limit were treated as the half of the detectable limit shown Table II–3–1. Though 4 areas were studied, the statistical processing was carried out in one lump for all the areas.

The principal component analysis was carried out both with all the 10 elements and with 6 elements except Au, Ag, As and Hg of which more than a half of the samples were less than the detectable limits. Discussion is made on the characteristics of the axis of the principal component.

The correlation coefficient matrix was used as the initial matrix.

3–1–5 Evaluation of the Soil Geochemical Anomalies

1. Characteristics of univariate analysis

The geometrical mean values, logarithmic standard deviation, and other basic statistical values are shown in Table II–3–2. The frequency distributions and cumulative frequency distributions of all the components are shown in Appendex A–5.

The characteristics of the statistical values and frequency distributions of the univariate analysis for all over the area are as follows :

Cu: The geometrical mean value and the maximum value are 26.0 ppm and 819 ppm, respectively. The 1.4 % of the population are less than or equal to the detectable limit. The relative frequency

Table II-3-1 Analytical methods and detectable limits of the chemical analyses.

Element	Analytical method[1)]	Detectable limit
Cu	ICP	1 ppm
Ag	AAS	0.1 ppm
Au	AAS (Frameless)	1 ppb
Fe	ICP	0.01 %
Pb	ICP	2 ppm
Zn	ICP	2 ppm
Co	AAS	1 ppm
Ni	ICP	1 ppm
As	ICP (Hydride)	2 ppm
Hg	MA (Cold vator)	1 ppb

1) AAS: Atomic Absorption Spectrochemical method
ICP: Inductivity Coupled Plasma method
MA: Molecular Absorptiometry method

Table II-3-2 Statistical parameter of soil geochemistry.

	Cu (ppm)	Au (ppb)	Ag (ppm)	Pb (ppm)	Zn (ppm)	Fe (%)	Co (ppm)	Ni (ppm)	As (ppm)	Hg (ppb)
All smples										
Geometric average	26.0	1.4	0.08	15.3	48.9	2.17	8.0	51.1	2.2	5.6
Standard deviation (logrithm)	0.45	0.47	0.32	0.39	0.55	0.27	0.34	0.26	0.54	0.14
Deweras Group										
Geometric average	20.4	1.8	0.08	13.2	38.0	1.91	7.2	51.3	2.1	5.8
Standard deviation (logrithm)	0.47	0.49	0.32	0.40	0.55	0.26	0.34	0.26	0.52	0.16

distribution of the Cu shows that there are 3 populations whose maximum frequencies occurred at 8 ppm, 13 ppm, and 40 ppm, respectively, and other populations whose frequencies are less than the detectable limit.

Au: The geometrical mean value and the maximum value are 1.4 ppb and 450 ppb, respectively. The 53.9 % of the population are less than the detectable limit. A remarkable bending point is recognized near 15 ppb, but the frequency of the population of that high concentration is less than 1 %. There is a population whose maximum frequency occurred at near 3 ppb. The cumulative frequency of the population larger than 3 ppb is 26 % of the total. At least the 48 % of the population less than the detectable limit did not belong to the population and can be estimated to form another population of the low concentration.

Ag: The geometrical mean value and the maximum value are 0.08 ppm and 8.5 ppm, respectively. The 79.3 % of the population are less than or equal to the detectable limit. The cumulative frequency distribution curve above the detectable limit is almost linear. This could be because the effective digit is 0.1 ppm or because the population has a large standard deviation. In any case, it is difficult to estimate the population of the asnalyzed value.

Pb: The geometrical mean value and the maximum value are 15.3 ppm and 129 ppm, respectively. The 6.1 % of the population are less than or equal to the detectable limit. The shape of the cumulative frequency distribution curve of the population more than the detectable limit is a declining parabola. Though frequency distribution has 2 peaks near 15 ppm and 25 ppm, these populations cannot be evaluated as the meant values only from these data.

Zn: The geometrical mean value and the maximum value are 48.9 ppm and 6,287 ppm, respectively. The 2.9 % of the population are less than or equal to the detectable limit. There is a clear point of inflection near 200 ppm in the cumulative frequency distribution curve. The population can be divided into the smaller population which has the maximum frequency near 600 ppm and the larger population which has the maximum frequency near 45 ppm.

Fe: The geometrical mean value the maximum value, and the minimum value are 2.17 %, 8.58 %, and 0.22 %, respectively. There is no value less than or equal to the detectable limit. The frequency distribution curve is convex with a gentle slope in the population of the lower concentration. The cumulative frequency distribution curve has bending points near 0.8 %, 1.6 %, and 5 %.

Co: The geometrical mean value and the maximum value are 8.0 ppm and 85 ppm, respectively. The 3.8 % of the population are less than or equal to the detectable limit. The cumulative frequency distribution curve has a broad slope in the low densities. It is difficult to separate some populations.

Ni: The geometrical mean value, the maximum value, and the minimum value are 51.1 ppm, 658 ppm and 3 ppm, respectively. There is no value less than or equal to the detectable limit. The frequency distribution shows that there are a large population with the maximum frequency near 55 ppm and a small population with the peak frequency near 25 ppm. The cumulative frequency distribution curve has bending points near 25 ppm and 100 ppm.

Table II-3-3 The matrix of the correlation coefficients.

(a) All samples

	Cu	Au	Ag	Pb	Zn	Fe	Co	Ni	As	Hg
Cu	1.									
Au	0.20	1.								
Ag	0.15	0.14	1.							
Pb	0.30	0.12	0.09	1.						
Zn	0.44	0.13	0.07	0.41	1.					
Fe	0.55	0.17	0.07	0.45	0.67	1.				
Co	0.47	0.23	0.04	0.34	0.49	0.69	1.			
Ni	0.24	0.26	0.04	0.24	0.26	0.35	0.49	1.		
As	0.11	0.05	0.08	0.04	0.40	0.15	0.11	0.10	1.	
Hg	0.14	0.13	0.11	0.01	0.04	0.03	0.05	0.02	0.10	1.

(b) Deweras Group

	Cu	Au	Ag	Pb	Zn	Fe	Co	Ni	As	Hg
Cu	1.									
Au	0.25	1.								
Ag	0.18	0.15	1.							
Pb	0.29	0.19	0.09	1.						
Zn	0.41	0.23	0.11	0.40	1.					
Fe	0.51	0.30	0.08	0.46	0.63	1.				
Co	0.43	0.30	0.02	0.36	0.46	0.65	1.			
Ni	0.22	0.29	0.02	0.28	0.33	0.42	0.52	1.		
As	0.09	0.06	0.12	0.07	0.43	0.17	0.12	0.14	1.	
Hg	0.19	0.15	0.12	0.04	0.07	0.07	0.07	0.03	0.10	1.

As: The geometrical mean value and the maximum value are 2.2 ppm and 151 ppm, respectively. The 71.4 % of the population are less than or equal to the detectable limit. In general, the concentration of As in granite is about 1 ppm ,so in case of this area, where arkose is dominant, the population less than or equal to the detectable limit are considered to be the majority. Above the detectable limit, there is a population with the peak near 40 ppm. The cumulative frequency less than 40 ppm in this population is about 6 %. This is equivalent to the 12 % of the population.

Hg: The 97.9 % of the population are less than or equal to the detectable limit. Though the cumulative frequencies curve above the detectable limit are linear, the characteristics of the whole populations are not clear.

In case of the area where the Deweras Group are distributed, the geometrical mean values of Cu, Pb, Zn and Fe are less than those for the whole areas by 5.6 ppm, 2.1 ppm, 10.9 ppm, and 0.26 %, respectively. Those of the other elements are similar.

2. Characteristics of the results of bivariate analysis

The correlation coefficients are shown in Table II-3-3. A scatter diagram of representative components are shown in Appendix A-6.

Both for the whole area and for the Deweras Group, all the correlation coefficients are positive.

The combinations whose correlation coefficents are more than or equal to 0.3 are as follows. Fe, Cu, Pb, Zn and Co, the correlation coefficients are between 0.30 and 0.69, which are large. The correlation coefficients of Ni and Fe, Ni and Co, and As and Zn are 0.35, 0.49 and 0.40, respectively. For Au, Ag, As and Hg, the densities whose frequencies are less than or equal to the detectable limit are majority. Hence the population of the analyzed values does not show the real distribution of the population, the correlation coefficients are not reliable.

The correlation coefficients for the Deweras Group are similar to those for the whole area.

3. Characteristics of multivariate analysis

(1) Principal component analysis of 10 components

The basic values of principal component analysis for 10 elements, such as, are the eigenvalues, contribution ratios, factor loadings and contribution are shown in Table II-3-4.

The contribution ratio of the 1st principal component are 33.6 %, which explains nearly one third of the feature of this analytical result. The cumulative contribution ratios of the 1st to the 6th principal components are 82.2 %, which explain the feature of the populations of the analysis data.

The factor loadings of the 1st principal component show that it has positive correlation with all the elements. It has high positive correlation (more than or equal to 0.56) especially with Cu, Pb, Zn, Fe, Co and Ni. As the contribution ratios of Cu, Pb, Zn, Fe and Co are large, the 1st principal components mainly explains these elements. It is known that the contents of Cu, Zn, Fe, Co and Ni increase in

Table II-3-4 Result of principal component analysis(10 elements).

Eigenvalues

	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λ8	λ9	λ10
	3.37	1.21	1.11	0.94	0.89	0.71	0.70	0.48	0.36	0.24

Eigenvectors

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Cu	0.38	0.07	-0.02	0.22	0.25	-0.27	-0.42	0.70	0.00	-0.05
Au	0.19	0.40	-0.46	-0.30	-0.23	0.47	-0.47	-0.08	0.01	0.01
Ag	0.10	0.54	-0.04	0.59	-0.48	-0.26	0.16	-0.13	0.01	-0.01
Pb	0.32	-0.17	-0.04	0.38	0.04	0.69	0.41	0.20	-0.21	-0.04
Zn	0.42	-0.08	0.38	0.00	-0.04	0.11	-0.10	-0.25	0.63	-0.43
Fe	0.47	-0.17	0.05	0.10	0.10	-0.09	-0.12	-0.35	0.03	0.76
Co	0.44	-0.14	-0.17	-0.12	0.05	-0.29	0.02	-0.34	-0.59	-0.44
Ni	0.30	-0.04	-0.37	-0.41	-0.23	-0.24	0.55	0.29	0.31	0.09
As	0.17	0.26	0.69	-0.39	-0.30	0.08	0.05	0.21	-0.34	0.13
Hg	0.07	0.62	0.04	-0.11	0.70	0.02	0.29	-0.13	0.05	0.00

Contribution ratio(%)

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
	33.6	12.1	11.1	9.4	8.9	7.1	7.0	4.8	3.6	2.4

Factor loading

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Cu	0.69	0.08	-0.02	0.22	0.24	-0.22	-0.35	0.49	0.00	-0.03
Au	0.36	0.44	-0.49	-0.29	-0.22	0.39	-0.39	-0.05	0.00	0.01
Ag	0.18	0.60	-0.04	0.57	-0.45	-0.22	0.13	-0.09	0.00	-0.01
Pb	0.58	-0.19	-0.05	0.37	0.04	0.58	0.34	0.14	-0.13	-0.02
Zn	0.77	-0.09	0.40	0.00	-0.04	0.09	-0.08	-0.17	0.38	-0.21
Fe	0.85	-0.19	0.05	0.10	0.10	-0.08	-0.10	-0.24	0.02	0.37
Co	0.80	-0.16	-0.18	-0.12	0.05	-0.25	0.01	-0.24	-0.35	-0.21
Ni	0.56	-0.04	-0.39	-0.40	-0.22	-0.20	0.46	0.20	0.18	0.04
As	0.31	0.28	0.73	-0.38	-0.29	0.07	0.05	0.15	-0.20	0.07
Hg	0.13	0.68	0.04	-0.11	0.66	0.02	0.24	-0.09	0.03	0.00

Contribution

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Cu	0.48	0.01	0.00	0.05	0.06	0.05	0.12	0.24	0.00	0.00
Au	0.13	0.19	0.24	0.09	0.05	0.16	0.15	0.00	0.00	0.00
Ag	0.03	0.36	0.00	0.33	0.20	0.05	0.02	0.01	0.00	0.00
Pb	0.34	0.03	0.00	0.14	0.00	0.34	0.11	0.02	0.02	0.00
Zn	0.60	0.01	0.16	0.00	0.00	0.01	0.01	0.03	0.14	0.04
Fe	0.73	0.04	0.00	0.01	0.01	0.01	0.01	0.06	0.00	0.14
Co	0.64	0.03	0.03	0.01	0.00	0.06	0.00	0.06	0.12	0.05
Ni	0.31	0.00	0.15	0.16	0.05	0.04	0.21	0.04	0.03	0.00
As	0.09	0.08	0.53	0.14	0.08	0.00	0.00	0.02	0.04	0.00
Hg	0.02	0.47	0.00	0.01	0.44	0.00	0.06	0.01	0.00	0.00

order from siliceous rock to mafic rock. It can be estimated that these elements show a similar geochemical behavior except for a phenomena such as the Cu mineralization. In the sampling area, gneiss of the Basement Rocks, the Younger Granite of the Pre-Magondi Intrusive Rocks, arkose and basaltic lavas of the Deweras Group, dolomite quartzite and slate of the Lomagundi Group, and dolerites and quartz veins of the Post Magondi Intrusive Rocks are distributed. Therefore, it is considered that the 1st principal component reflects the varieties of these rocks, and mafic rocks has larger score. The rocks which is affected mineralization are also supposed to have larger score of this component.

The contribution ratio of the 2nd principal component is 12.1 %. The factor loadings of this component shows that it has high positive correlations (more than 0.43) with Au, Ag and Hg. Most of the values analyzed of these elements are less than or equal to the detectable limits. This component has low negative correlations with Pb, Zn, Fe, Co and Ni, while the 1st principal component has relatively high positive correlations with these elements. The contribution values show that this component mainly explains the feature of Ag and Hg in the survey area.

The contribution ratio of the 3rd principal component is 11.1 %. The factor loadings show that the component has high positive correlations with As and Ni and a high negative correlation with Au. The contribution values show that this component explains the feature of As and Au and that it explains nothing about the feature of the populations of Cu, Ag, Pb, Fe and Hg.

The contribution ratio of the 4th component is 9.4 %. The factor loadings show that this component has high positive correlations with Ag and Pb, and low negative correlations with Ni and As. The contribution values show that this component explains the feature of the populations of Ag, Pb, Ne and As, which can not be explained by the 1st to the 3rd principal components. However, there is no explanation about Cu.

The contribution ratio of the 5th principal component is 8.9 %. The factor loadings show that this component has high positive correlations with Hg and relatively high negative correlations with Ag and As. The contribution values show that this component explains the feature of Ag and Hg as the 2nd principal component. However, the meanings of both the components are different as the sign of the eigenvector of Ag is negative while that of Hg is positive.

The contribution ratio of the 6th principal component is 7.1 %. The factor loadings show that this principal component has high positive correlations with Pb and Au. The contribution value shows that this principal component explains the feature of Pb and Au.

As mentioned above, the 1st principal component for 10 elements explains 33.4 %, and the 2nd to 6th principal components mainly explain the feature of Au, Ag, As and Hg, a majority of whose populations are less than or equal to the detectable limits. However, the feature of Cu, which is the metal of the main interest in the survey area, is explained by the 1st and 8th principal components with contribution ratios 48 % and 24 %, respectively. Therefore, these two principal components will be examined later in order to explain the behavior of Cu affected by the variety of the rocks and the mineralization.

(2) Principal component analysis for 6 elements

Among the 10 elements analyzed in this survey, the frequencies of Au, Ag, As and Hg less than or equal to the detectable limit are majority. This means that the variances of these elements are not equal to those of the population. Therefore, the 6 elements excluding 4 elements above mentioned will be discussed below.

The basic statistical values from the results of the principal component analysis for 6 elements, such as, the eigenvalues, contribution ratios, factor loadings and contribution are shown in Table II-3-5.

The contribution of the 1st principal component is 53.0 %. This component explains more than the half of the feature of the geochemical behavior of 6 elements. As the cumulative contribution ratio of the 1st to 4th components is 88.8 %, these 4 principal components will be discussed below.

The factor loadings of the 1st principal component show that it has positive correlations with all the elements. The correlation coefficients are from 0.55 to 0.87, which are high. The contribution values show that this component mainly explains the feature of Cu, Zn, Fe and Co. Like as the 1st principal component for 10 elements, this principal component is estimated to suggest the feature of the rocks which are original materials of the soil.

The factor loadings of the 2nd principal component show that it has negative correlations with Cu, Pb, Zn and Fe and positive correlations with Co and Ni. Especially, the correlation with Ni is 0.76, which is highly positive. The contribution values show that this component explains the feature of Ni.

The factor loadings of the 3rd principal component show that it has a positive correlation with Ni and negative correlations with Cu, Zn, Fe and Co. Especially, the correlation coefficient with Pb is 0.70, which is highly positive. The contribution values show that this component mainly explains the feature of Pb as well as Cu. When the elements of small contents in mafic rocks and siliceous rocks are compared, in general, the contents of Cu, Zn, Fe and Co are larger in mafic rocks than in siliceous rocks, while the content of Pb are larger in siliceous rock than in mafic rock. From the sign of the coefficients of the eigenvalues, the elements which have low correlations with this component reflected existence of mafic rocks.

The factor loadings of the 4th principal component show that it has positive correlations with Cu, Pb, and Ni and negative correlations with Zn, Fe and Co. Especially, the correlation with Cu is 0.53, which is highly positive. The contribution values show that this component mainly explains the feature of Cu as well as Fe.

From the contribution values of these principal component analyses, the principal components which well explain the feature of Cu are the 1st and 8th principal components for 10 elements and the 1st and 4th components for 6 elements. The 8th principal component for 10 elements and the 4th principal component for 6 elements have a similar feature. The sign of the coefficient of the eigenvector of Cu is positive, while those of Zn, Fe, and Co are negative.This structure of the

Table II-3-5 Result of principal component analysis(6 elements).

	Eigenvalues					
	λ1	λ2	λ3	λ4	λ5	λ6
	3.18	0.87	0.72	0.55	0.42	0.24
	Eigenvectors					
	PC1	PC2	PC3	PC4	PC5	PC6
Cu	0.39	-0.22	-0.48	0.72	-0.23	-0.06
Pb	0.34	-0.31	0.83	0.30	0.10	-0.08
Zn	0.43	-0.30	-0.05	-0.56	-0.55	-0.32
Fe	0.49	-0.13	-0.12	-0.24	0.25	0.78
Co	0.46	0.28	-0.17	-0.12	0.64	-0.51
Ni	0.31	0.82	0.21	0.10	-0.40	0.13
	Contribution ratio(%)					
	PC1	PC2	PC3	PC4	PC5	PC6
	53.0	14.5	12.1	9.2	7.1	4.1
	Factor loading					
	PC1	PC2	PC3	PC4	PC5	PC6
Cu	0.70	-0.20	-0.41	0.53	-0.15	-0.03
Pb	0.60	-0.29	0.70	0.22	0.07	-0.04
Zn	0.77	-0.28	-0.04	-0.42	-0.36	-0.16
Fe	0.88	-0.12	-0.10	-0.18	0.16	0.39
Co	0.82	0.26	-0.14	-0.09	0.42	-0.25
Ni	0.55	0.76	0.18	0.07	-0.26	0.06
	Contribution					
	PC1	PC2	PC3	PC4	PC5	PC6
Cu	0.48	0.04	0.16	0.29	0.02	0.00
Pb	0.37	0.08	0.50	0.05	0.00	0.00
Zn	0.59	0.08	0.00	0.18	0.13	0.03
Fe	0.77	0.01	0.01	0.03	0.03	0.15
Co	0.67	0.07	0.02	0.01	0.17	0.06
Ni	0.31	0.58	0.03	0.01	0.07	0.00

eigenvectors give a small value when the contents of Zn, Fe and Co are large and vice versa. This can be used as the index to distinguish the mineralization of Cu and mafic rock. As the coefficients of the eigenvectors of Ag and Au are negative. This structure of the eigenvectors give a small score for Ag and Au mineralization. Therefore, Cu mineralization zone can be extracted by the feature which shows high Cu concentration and high score of the 4th principal component for 6 elements.

4. Characteristics of each area

(1) The Alaska area

There are the Hans Mine, the Angwa Mine, the Old Alaska Mine, Shackleton Mines including the Avondale ore deposit in this area. Besides these mines, the Alaska smelter is located in the south-eastern part of this area. These mines except the Old Alaska Mine, which is worked from the prehistoric time, were discovered by past soil geochemical surveys for Cu and the succeeding precise surveys. The existence of several Cu-anomaly places in the sedimentary rock in addition to the existing mines and ore deposits is pointed out by the past E.P.O.s' surveys. This area has high potentiality of undeveloped copper ore deposits.

Cu concentration indicates relatively high values widely in the southern part of the Shackleton Mine. The concentrations more than 73 ppm is shown in adjacent area of the Old Alaska, Angwa and Hans Mines which are already known. Remarkable Cu anomalies around the outcrops of the Avondale ore deposit is not recognized, and the mineralization zones were not detected with the sampling density in this survey. In comparison to the geological map, the distribution areas of doleritic dykes in the northern part of the Old Alaska Mine and basaltic lava flow of the Deweras Group show the high concentration more than 73 ppm. On the other single element anomalies, Fe concentration reflects the boundary of the arkose of the Deweras Group and the dolomite of the Lomagundi Group in the eastern marginal part of this area. The distributions of the concentrations of Au, Pb, Zn, Co and Ni show the tendency of which harmonizes the distribution of mafic rocks, however, it is difficult to say the high concentration or the low concentration halos which are directly reflected the occurrences of ore deposits like Cu concentration. As regards Ag and Au, the spots whose contents are less than detectable limits are scattered. Therefore, the interpretation by the single element concentration on the ore deposits is difficult.

By the distribution of scores of the 4th principal component of principal component analysis for 6 elements, the high concentration place over m+2σ is widely distributed in the area where is centered by the Old Alaska Mine. The Cu high anomalous concentration place in the northern part of the Old Alaska Mine is excluded from this high score places of this principal component, it is considered that the place is useful as the filter to distinguish the Cu mineralization which is the distribution area of mafic rocks from mafic rocks which have no relationship to the Cu mineralization.

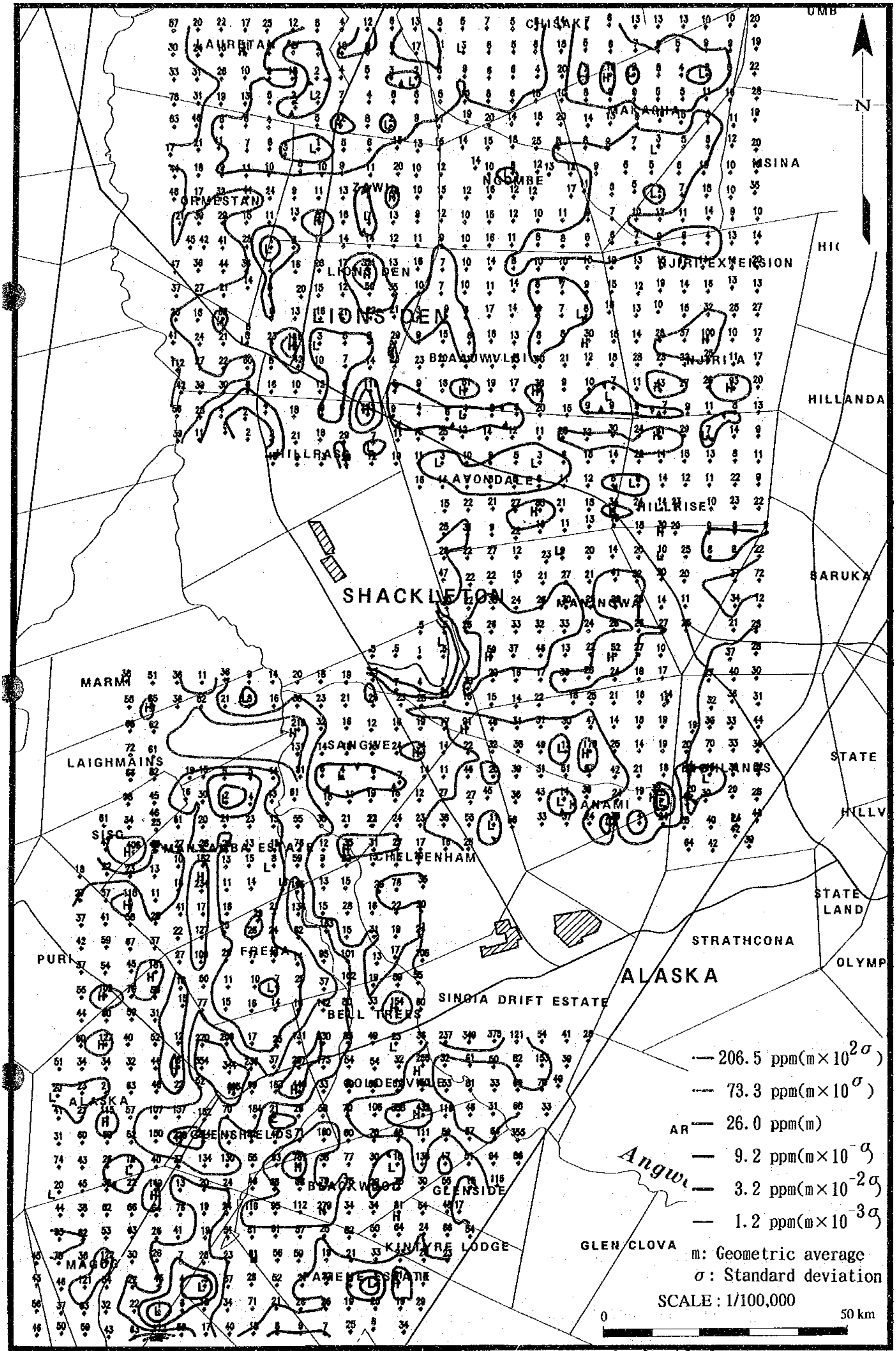


Fig.II-3-2 Distribution of Cu contents in the Alaska area.

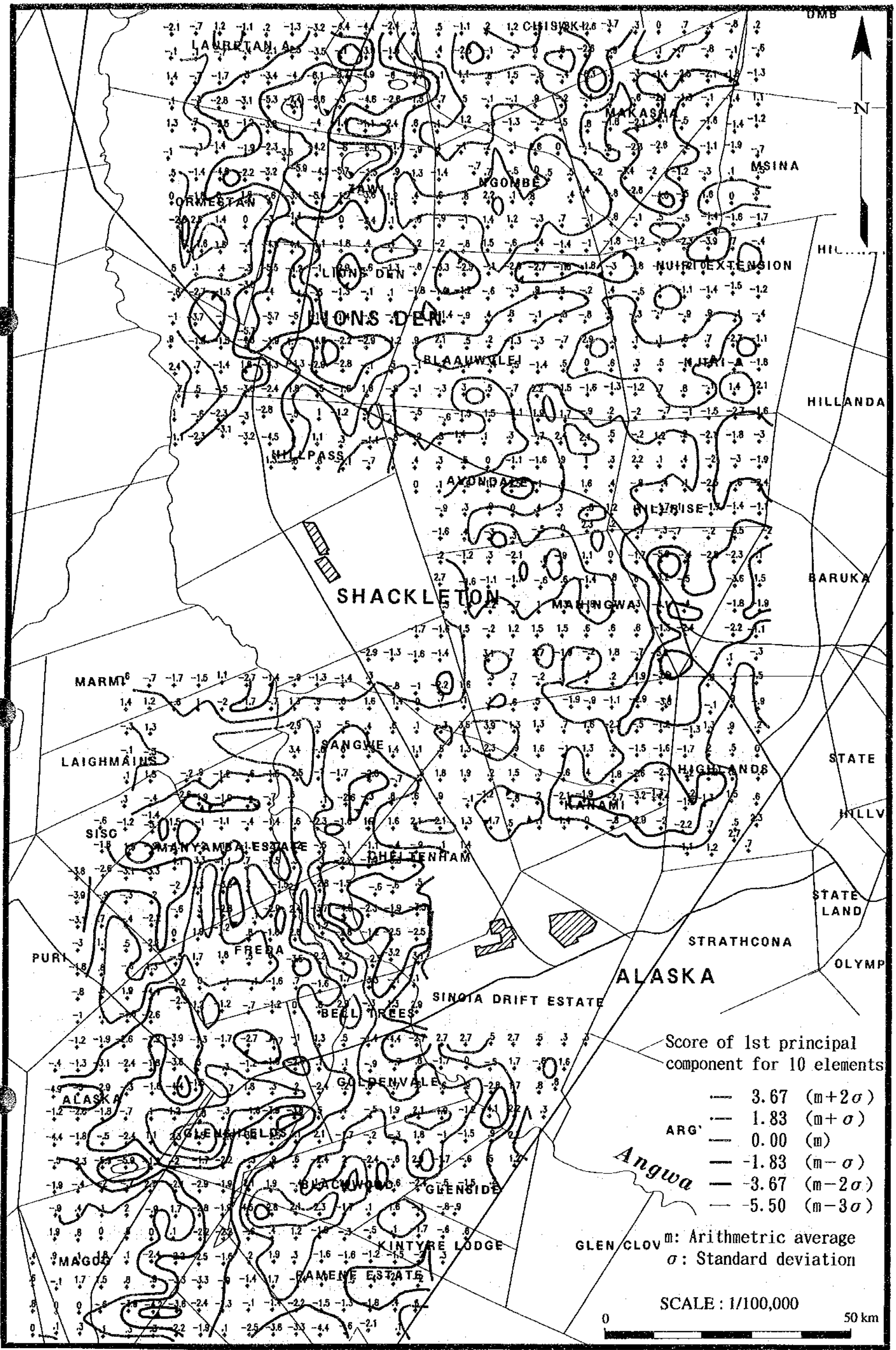


Fig.II-3-3 Distribution of 1st principal component scores(10 elements analysis) in the Alaska area.

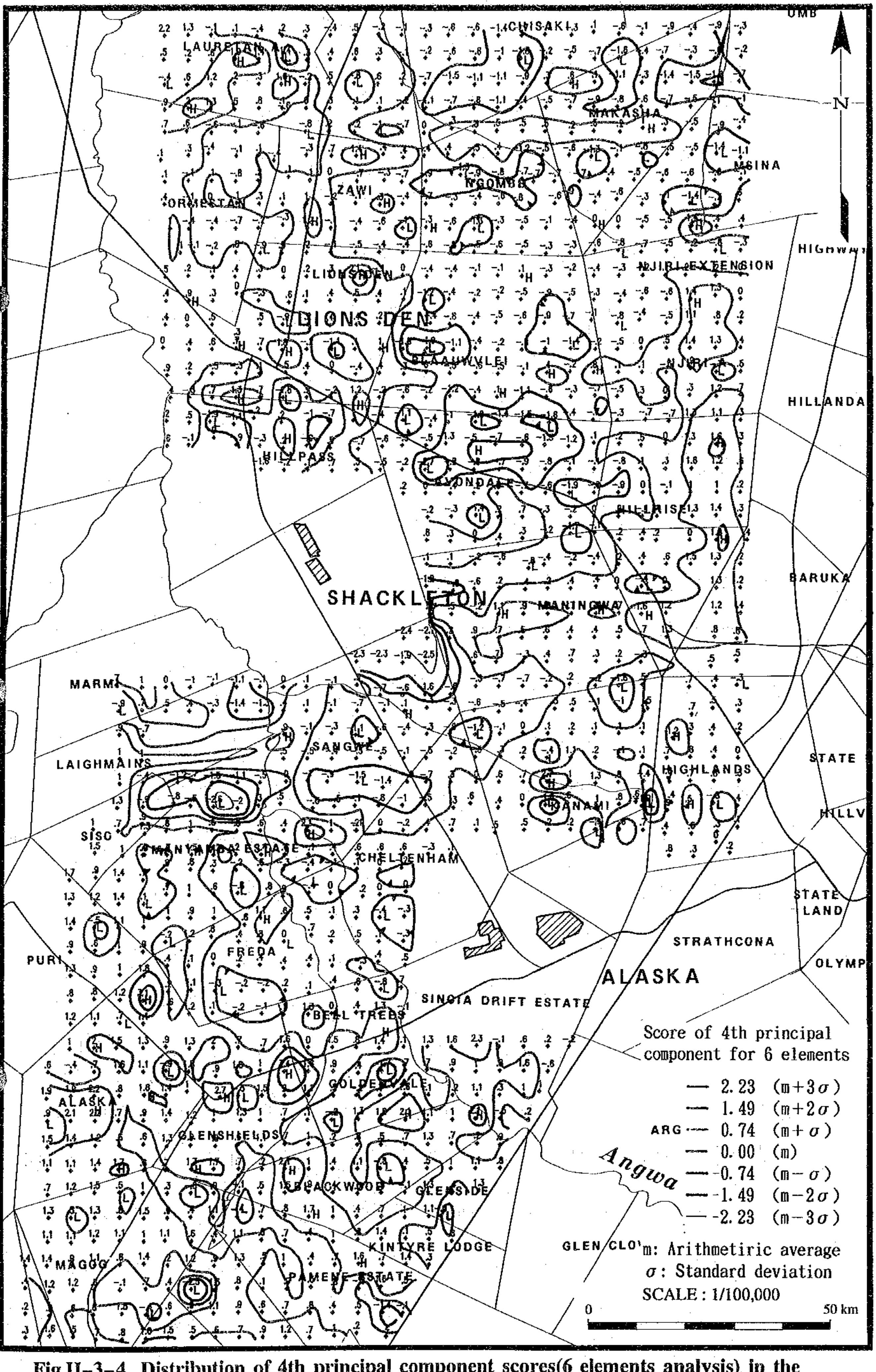


Fig.II-3-4 Distribution of 4th principal component scores(6 elements analysis) in the Alaska area.

(2) The Umboe area

The United Kingdom Mine is located in the south-eastern part of this area. As regards the geology of this area, arkose of the Deweras Group is distributed and dolomite of the Lomagundi Group is distributed surrounding the arkose. Doleritic dykes are intruded into the arkose.

Judging from single component, Cu, Au, Ag and Fe highly concentrate around the existing mine comparing to the surrounding area. Cu concentration has the tendency of higher concentration in dolomite of the Lomagundi Group than in arkose of the Deweras Group. The high concentration is recognized in the distribution area of mafic rocks same as in the Alaska area. The similar tendency for Fe and Zn is recognized, and the distribution of the concentrations of these elements harmonizes the boundary of strata. As regards the distribution area of the arkose of the Deweras Group, there are several places where shows high concentration places more than 73 ppm including the existing mine area. The high concentration zones more than 73 ppm are widely distributed in the Livington, Riversdale and the Zagulen farm areas in the north-western part of this area. The anomalous zones are not shown on the geological map, but, it is considered to correspond to the distribution of mafic rocks by the past E.P.O.s' (No. 74 and 414) surveys. Therefore, the possibility of Cu mineralization in the sedimentary rock is low.

The distribution of scores of the 4th principal component using 6 chemical elements shows high scores of m+2 in the several places including the United Kingdom Mine. Within the high scored places, the scores in the northern part of the United Kingdom mine and the southern part of the Norah Mine correspond to the Cu high anomalous areas.

(3) The Mangula North area

The soil geochemical survey has not been carried out in the northern half of the area. The distribution width of arkose of the Deweras Group is narrower in the part than in the southern part. The width from the east to the west is nearly 4 kilometres. The Basement Rocks and the Younger Granite are widely distributed in the eastern part of this area.

Judging from the single element, Cu concentration is generally low in the distribution area of the Younger Granite, and high anomalies are not recognized. The high anomalous places more than 73 ppm are widely recognized in the distribution area of the Deweras Group, Some of them are distributed in the boundary area of the Basement Rocks and the Younger Granite where does not correspond to the distribution area of mafic intrusive rocks on the geological map. The high anomalous places more than 73 ppm in the distribution area of the Basement Rocks in the Binge and Dwing Farms in the northern part of the area. The verification of the geology of adjacent area is necessary. The same tendency is recognized as the high concentration of Au. The high concentration places of Zn, As and Hg are scattered all over the area regardless of the strata, therefore, interpretation by single element is difficult.

The scores by the 4th principal component for 6 elements are generally low, the places with high

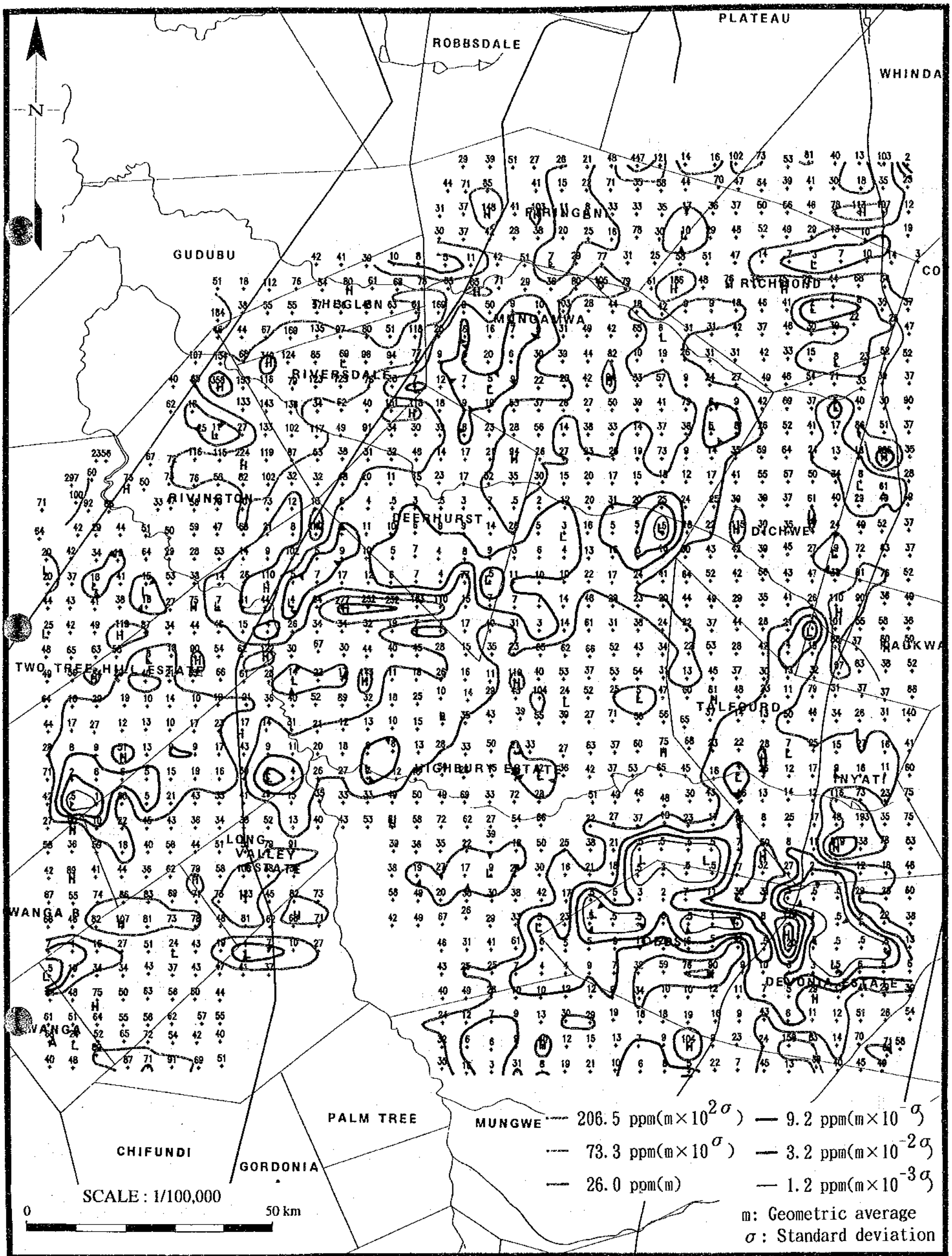


Fig.II-3-5 Distribution of Cu contents in the Umboe area.

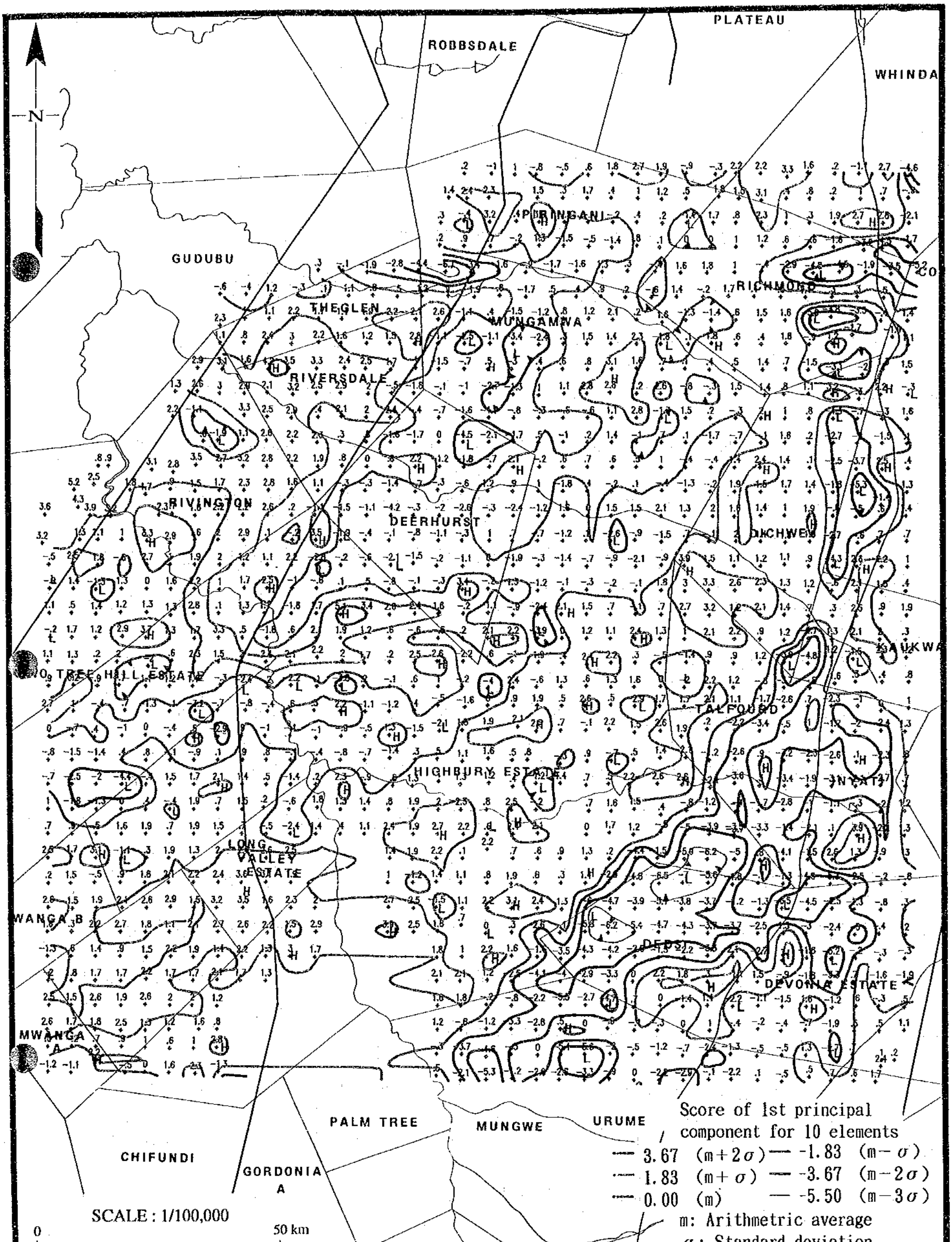


Fig.II-3-6 Distribution of 1st principal component scores(10 elements analysis) in the Umboe area.

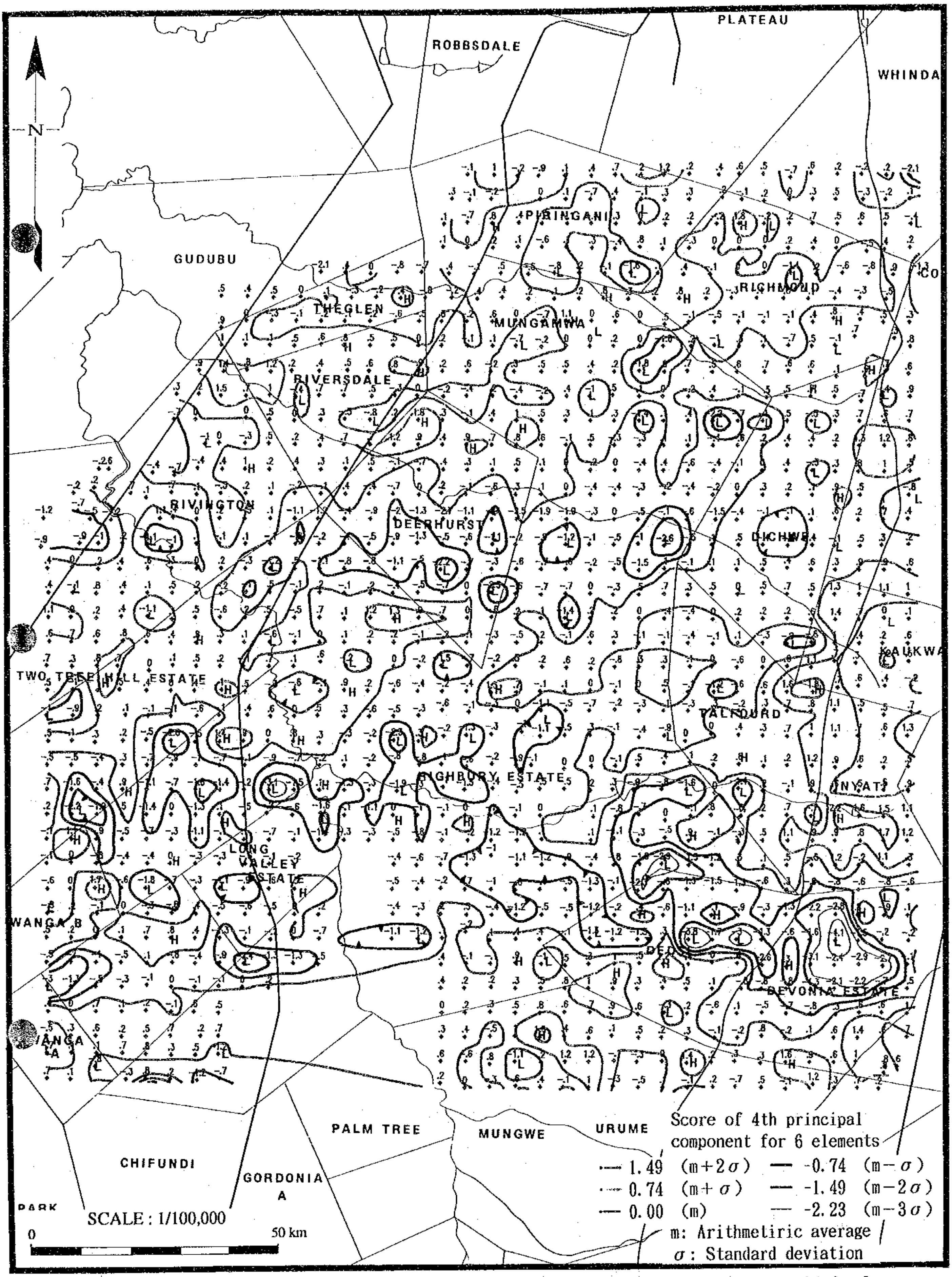


Fig.II-3-7 Distribution of 4th principal component scores(6 elements analysis) in the Umboe area.

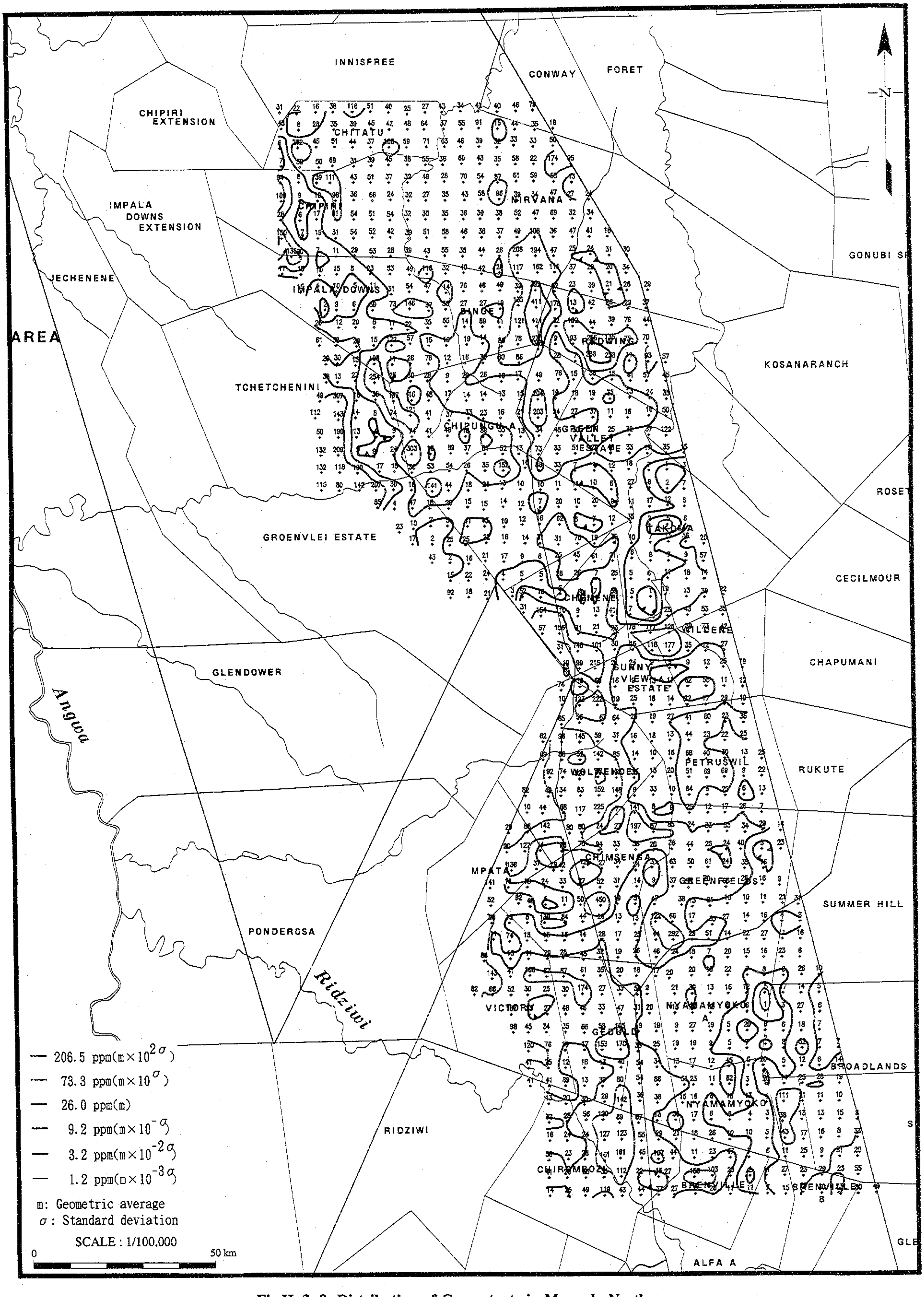


Fig.II-3-8 Distribution of Cu contents in Mangula North area.

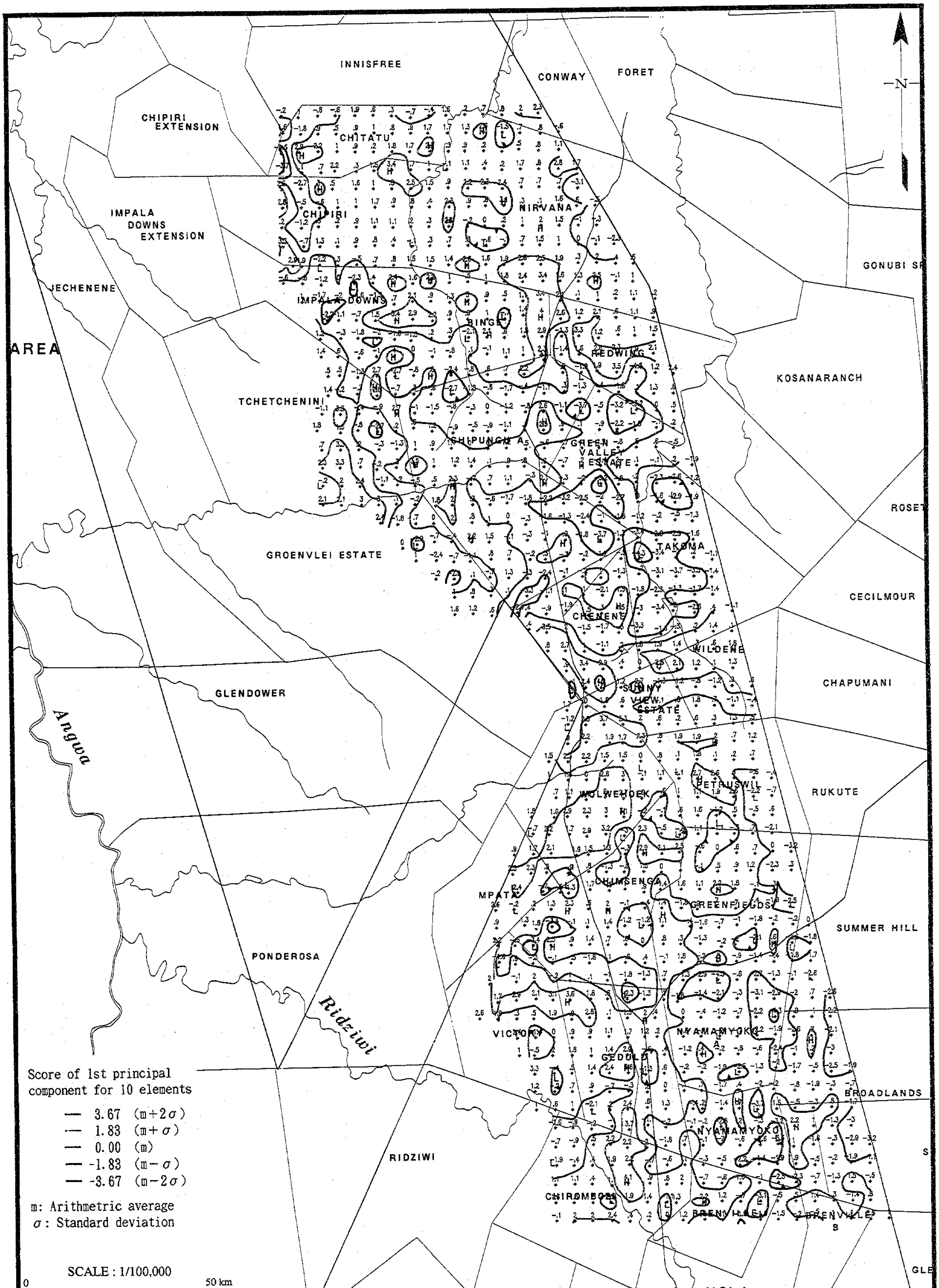


Fig.II-3-9 Distribution of 1st principal component scores(10 elements analysis) in the Mangula North area.

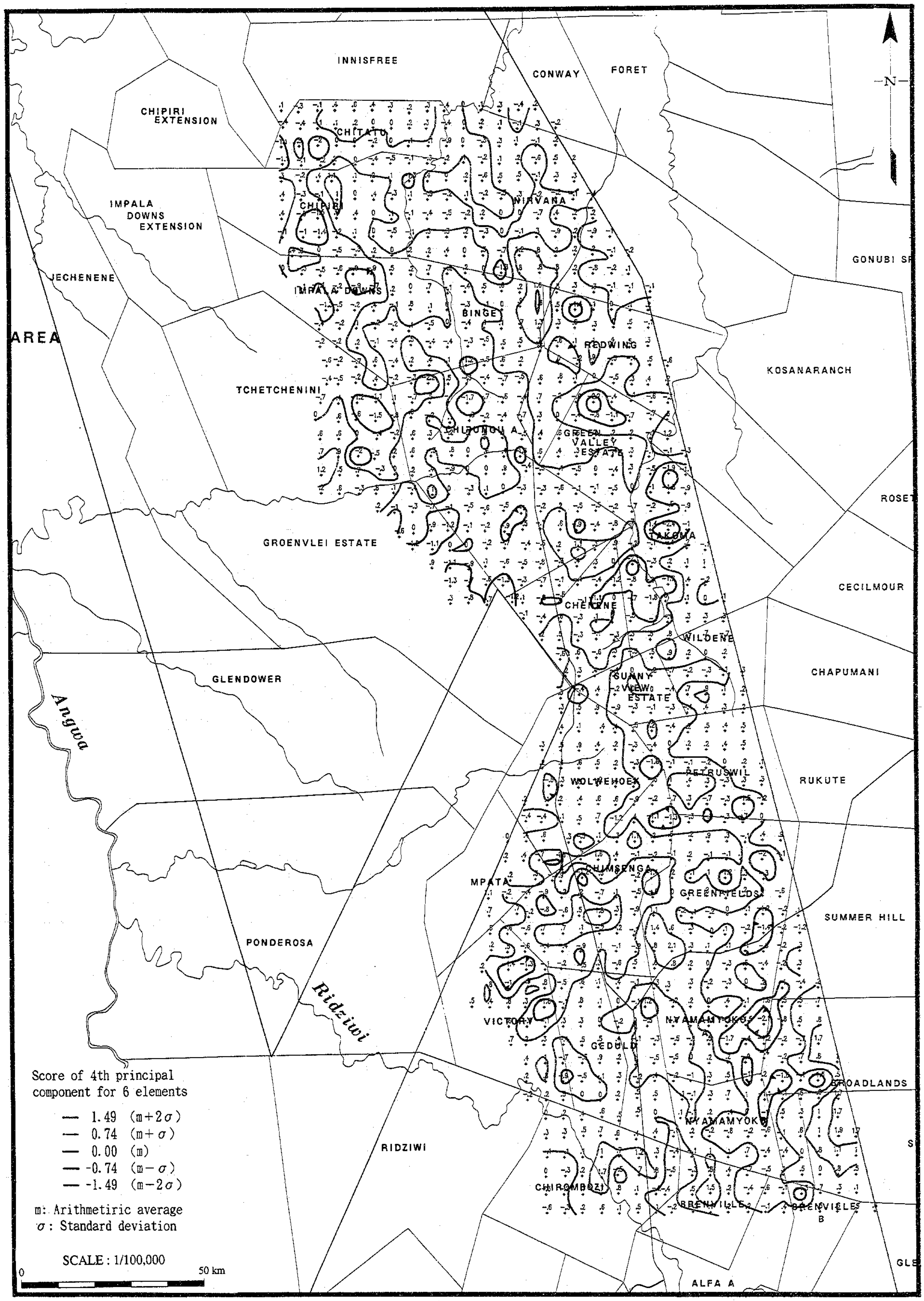


Fig.II-3-10 Distribution of 4th principal component scores(6 elements analysis) in the Mangula North area.

score more than 73 ppm are only two places. All the distribution areas of Cu high concentration (more than 73 ppm) which is corresponded to the distribution of the mafic rocks are less than m + 2σ of this principal component. Within the area of the score less than m + 2σ of this principal component which are recognized the overlapped places by 73 ppm are around the lowest horizon of the Deweras Group from Chilomboji through Greenfieldin to Wilden in the northern Mhangura.

Besides the above distribution, some of them are spotted in the distribution area of mafic rocks.

(4) The Shamrocke area

This area is differ from the other three areas and shows mountainous topography. The Shamrocke Mine is located in this area, and mined copper and silver. The ore deposit occurs within the Lomagundi Group.

Judging from the single element, Cu concentration shows higher in this area than in the other areas, high anomalous places more than 73 ppm are scattered. However, The remarkable anomalous places are recognized around the Mine. The width of chemical anomalous zones which were detected by past E.P.O.s' surveys stretch several ten metres from the east to the west. They cannot be detected by this survey due to the rough sampling interval.

3-2 Gas Chromatography Survey

3-2-1 Selection of the Areas of Gas Chromatography Survey

The gas chromatography survey was carried out in the three selected area around the known ore deposits. The areas are as follows :

1) The sub-outcrops of the Avondale ore deposit ------ Avondale area
2) Just above the Shackleton dyke -------------------- Shakleton are
3) The south of the Norah ore deposit --------------- Norah area

Two intervals of the survey line, 20 metres and 40 metres, were determined, and surveys were carried out based on the scales of the target ore deposits.

3-2-2 Method of Measurement

The measurement was carried out in the holes. The holes which made to drive iron pipes with 2 inches diametre into the soil nearly 50 centimetres and with drew the pipes later. The soil and rock fragments which filled the pipes was described in order to understand the geology around the holes. The holes were left during several days and the measurements were conducted twice. The data were the average value of the twice measurements.

The measurements were also conducted by glass test tubes. This method is as follows: The reagent which changes the colour by the reaction of CO_2 gas was enclosed in the test tube. When some amount

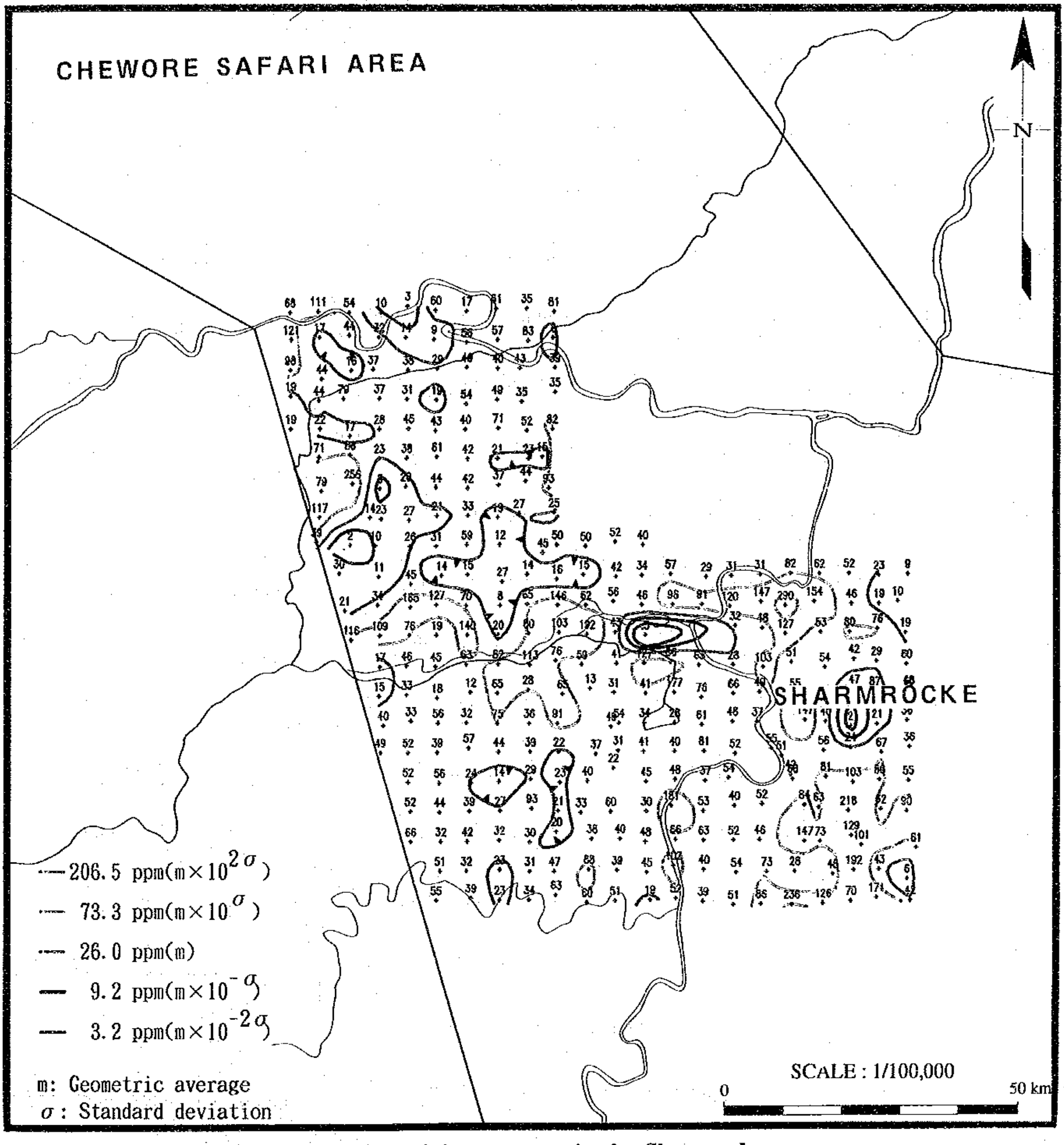


Fig.II-3-11 Distribution of Cu contents in the Shamrocke area.

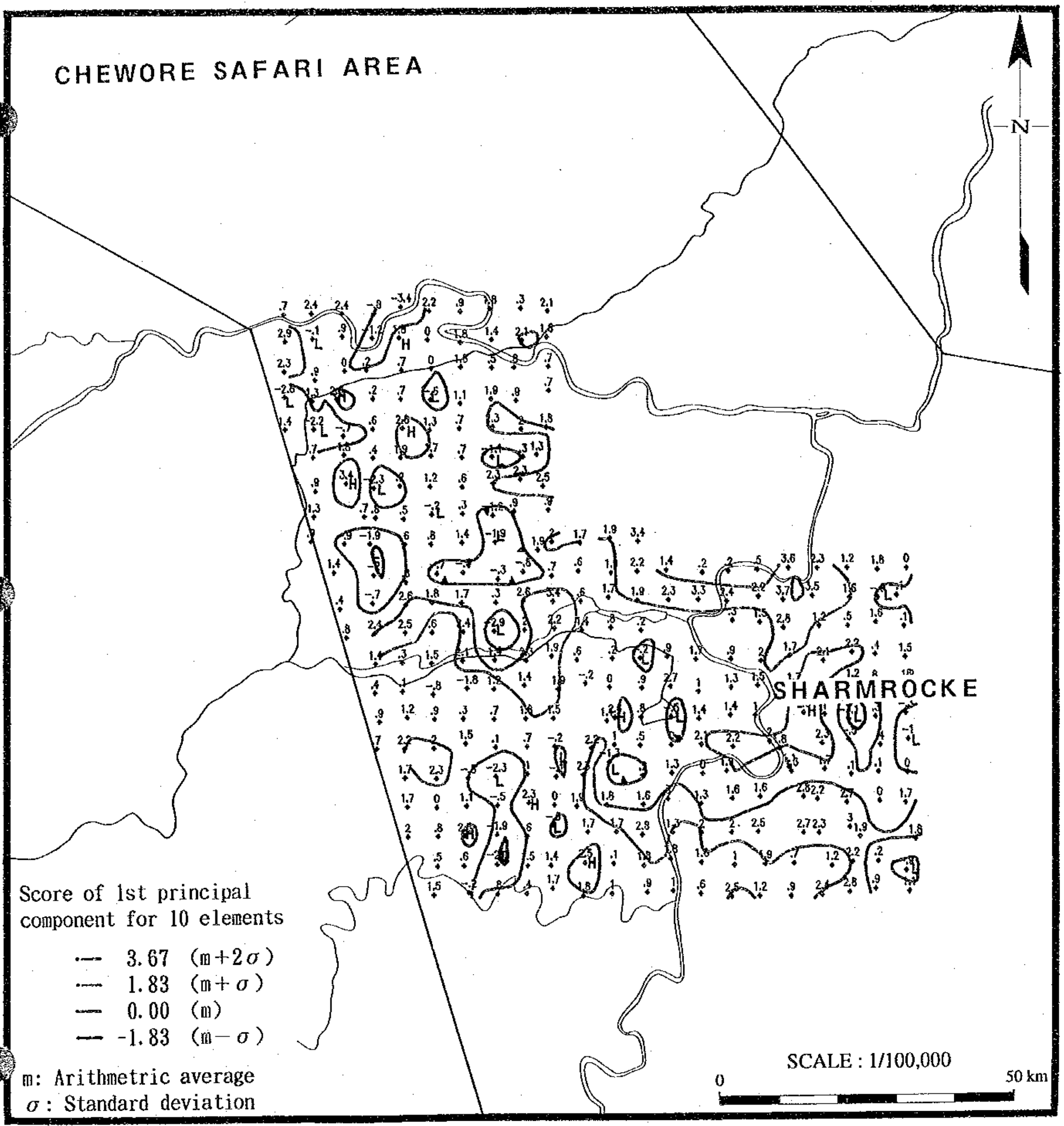


Fig.II-3-12 Distribution of 1st principal component scores(10 elements analysis) in the Shamrocke area.

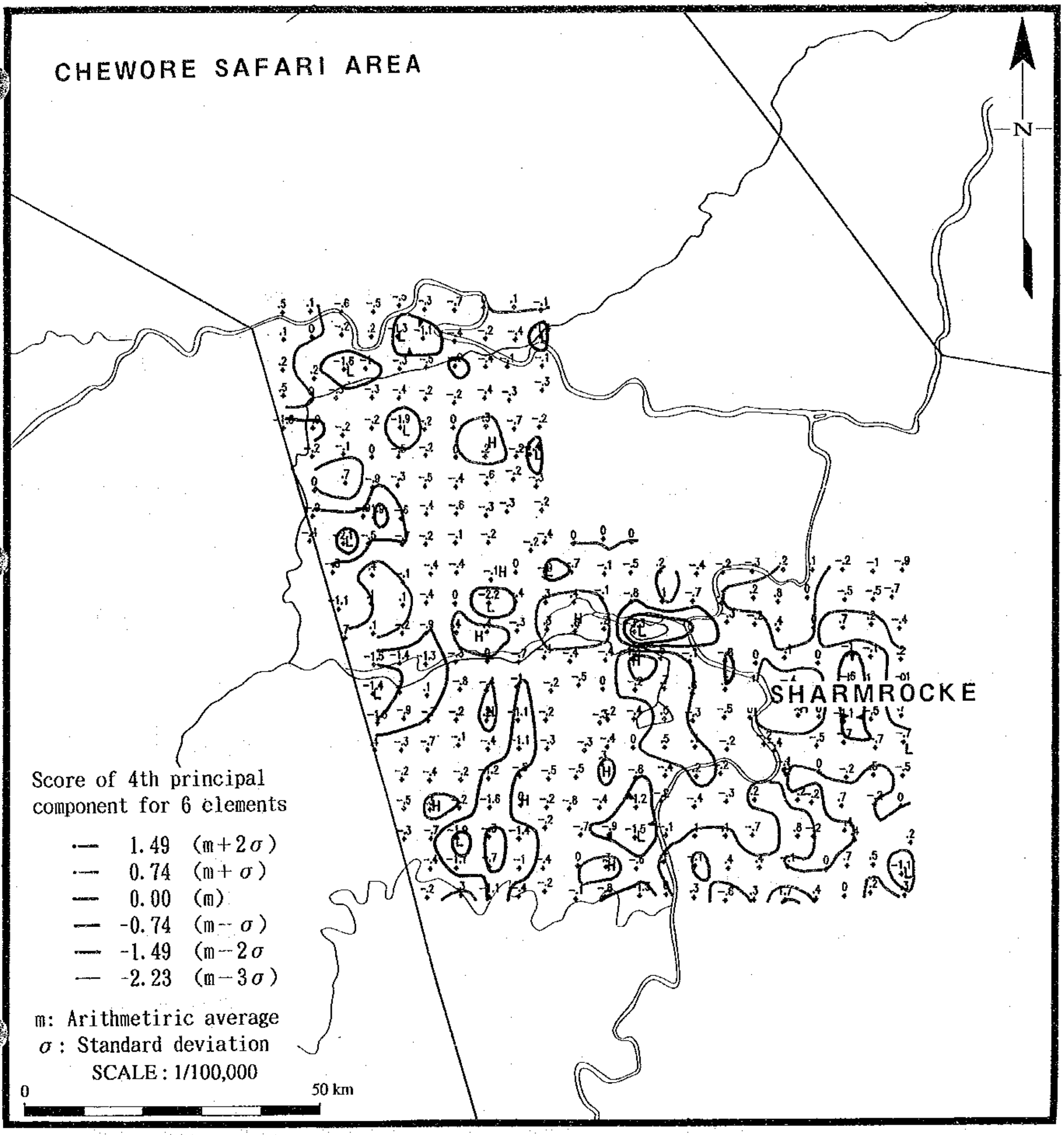


Fig.II-3-13 Distribution of 4th principal component scores(6 elements analysis) in the Shamrocke area.