is identified by the XRD in the specimen of high concentration of Sr.

8. P

Distribution of P content is shown in Fig. II-2-11.

Highly concentrated zones more than 10,000 ppm of P are found in and around the eastern beforsite body. On the other hand, the southern beforsite body contain relatively low contents of P and it contains high contents of P in syenite and gneiss contacted with the southern beforsite body.

Apatite is a dominant mineral which contains P, but also monazaite is identified by the XRD in the specimens highly containing the REEs.

9. Fe

Distribution of Fe content is shown in Fig. II-2-12.

High concentrated zones are found in and around the beforsite bodies and in the rocks which are replaced by aegirine and riebeckite interstitially.

II-2-4 Conclusions

The elements which are worth to consider are REEs, Nb and P in the view of economics in this carbonatite complex.

The REEs' contents in average are high in the carbonatite dyke, the eastern beforsite, the southern beforsite, the sövite and the Nama sequence in order of higher to lower. Respectable concentration of the REEs are found in the carbonatite dyke, but it show a narrow distribution in the area. The high concentrated zone in the Nama sequence is caused by replacement of the interstitial carbonatite and carbonatite veinlets. The REEs' contents in sövite are relatively high, but the respectable concentrations are not found. The REEs' contents of the beforsite bodies have a tendency of the concentration at the marginal zone of the bodies. It is necessary to consider systematically about the relationships between the concentrated zone of REEs, the internal structure of the bodies, the emplacement mechanism of the carbonatite complex and the behavior of the REEs. There is no considerable concentration of the REEs in the porphyritic nepheline syenite (Msp) which was recommended as the REE bearing rock facies by Schommarz (1988).

The high concentrated zones more than 1,000 ppm of Nb are found in and around the beforsite bodies. Localities of the concentrated zones both REEs and Nb are slightly different.

The concentrated zone of P more than 10,000 ppm are found in the eastern beforsite. It shows low contents of P in the southern beforsite body, but high contents at the outer zone of the body. The behavior and distribution of P in and around the MQC is important to consider the genesis of this complex.

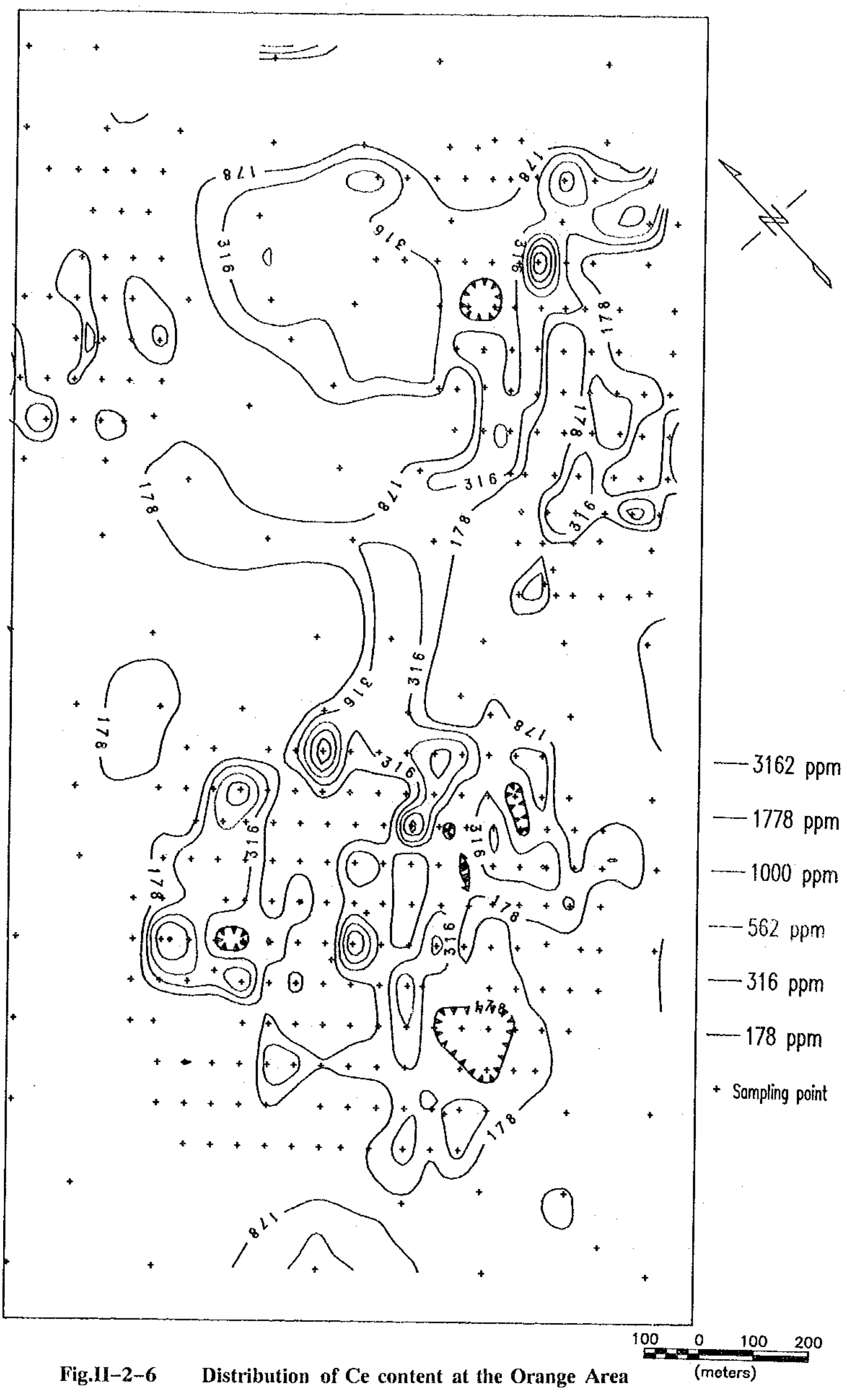

Fig.II-2-6 Distribution of Ce content at the Orange Area

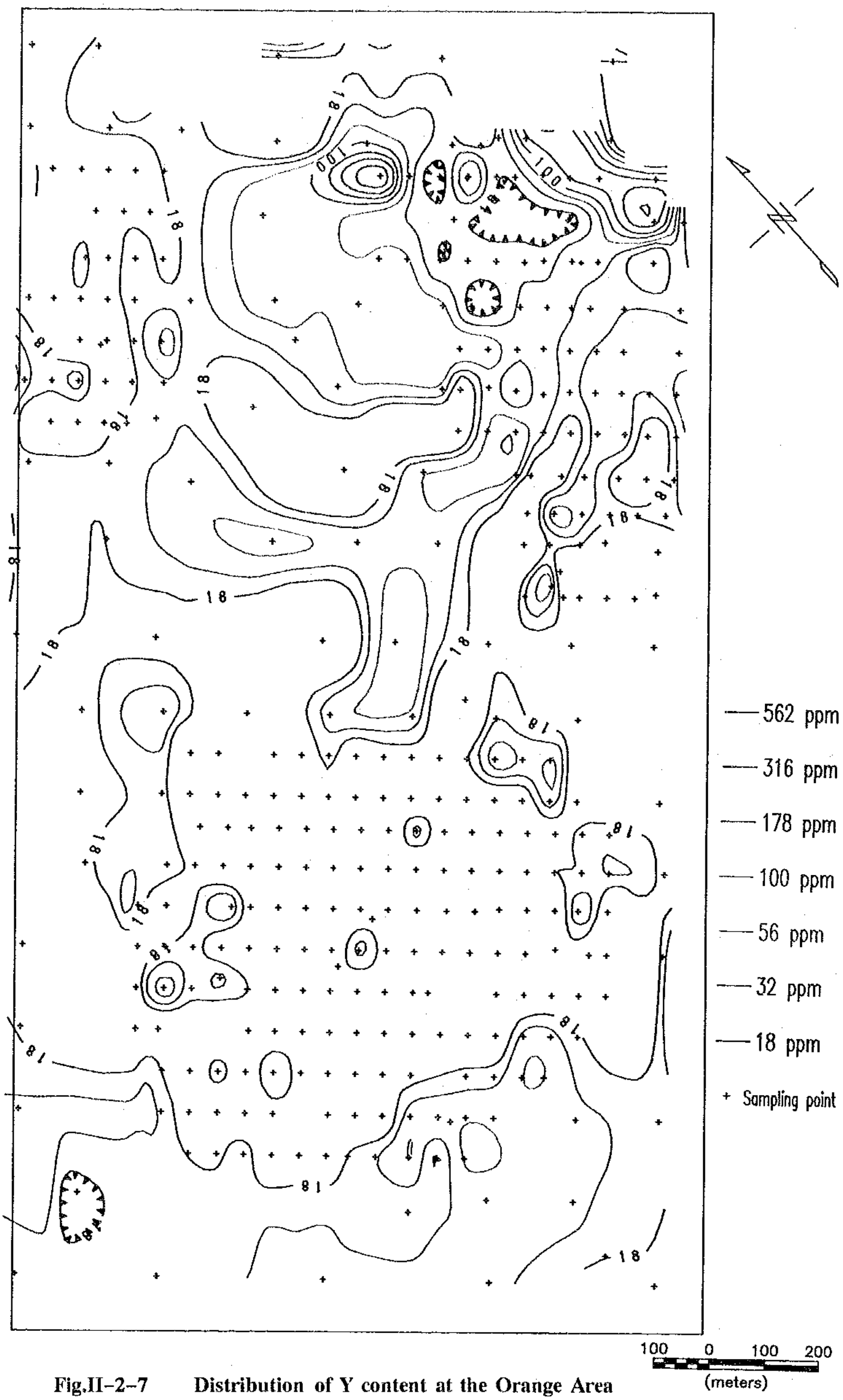

Fig.II-2-7 Distribution of Y content at the Orange Area

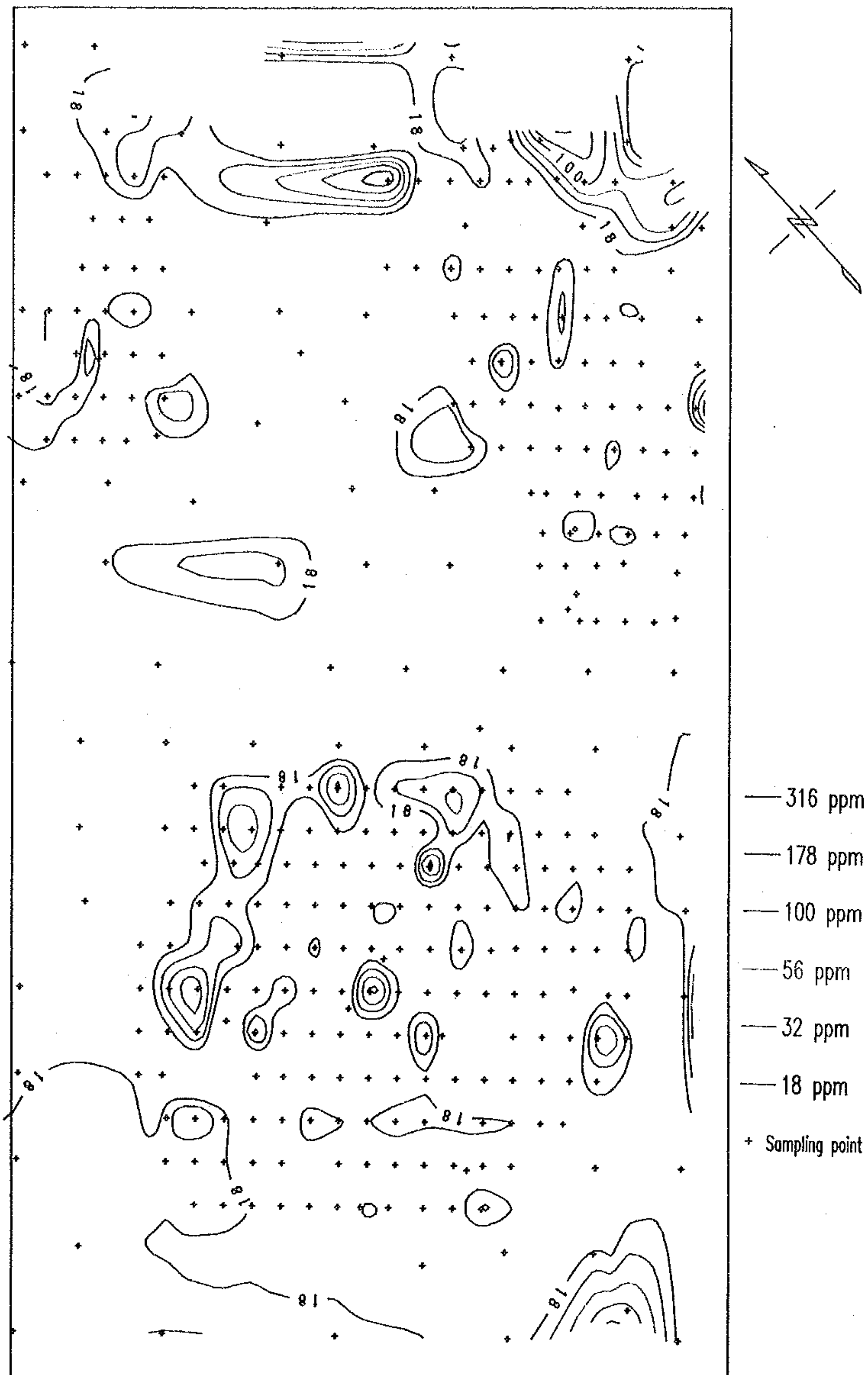

Fig.II-2-8 Distribution of Th content at the Orange Area

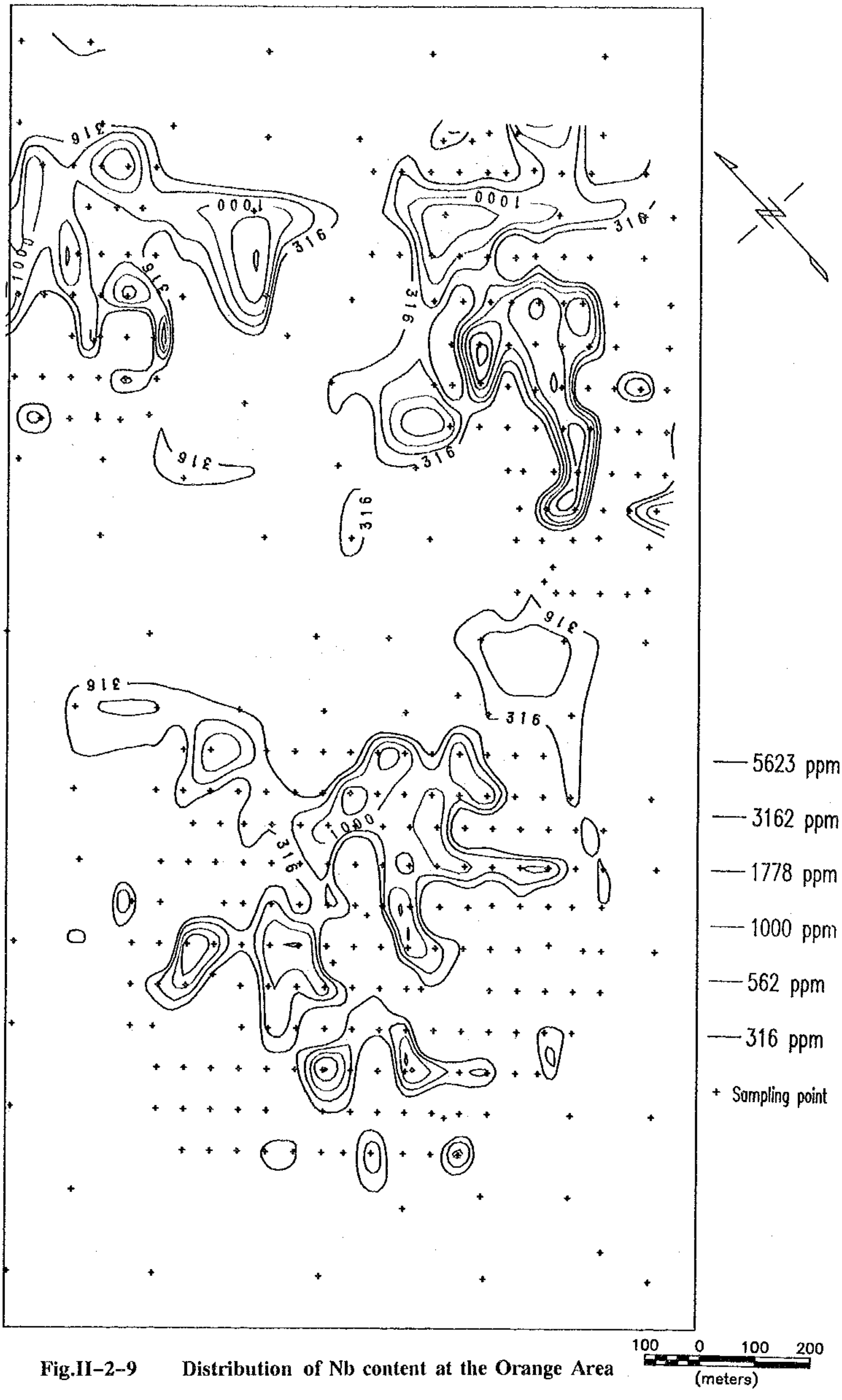

Fig.II-2-9 Distribution of Nb content at the Orange Area

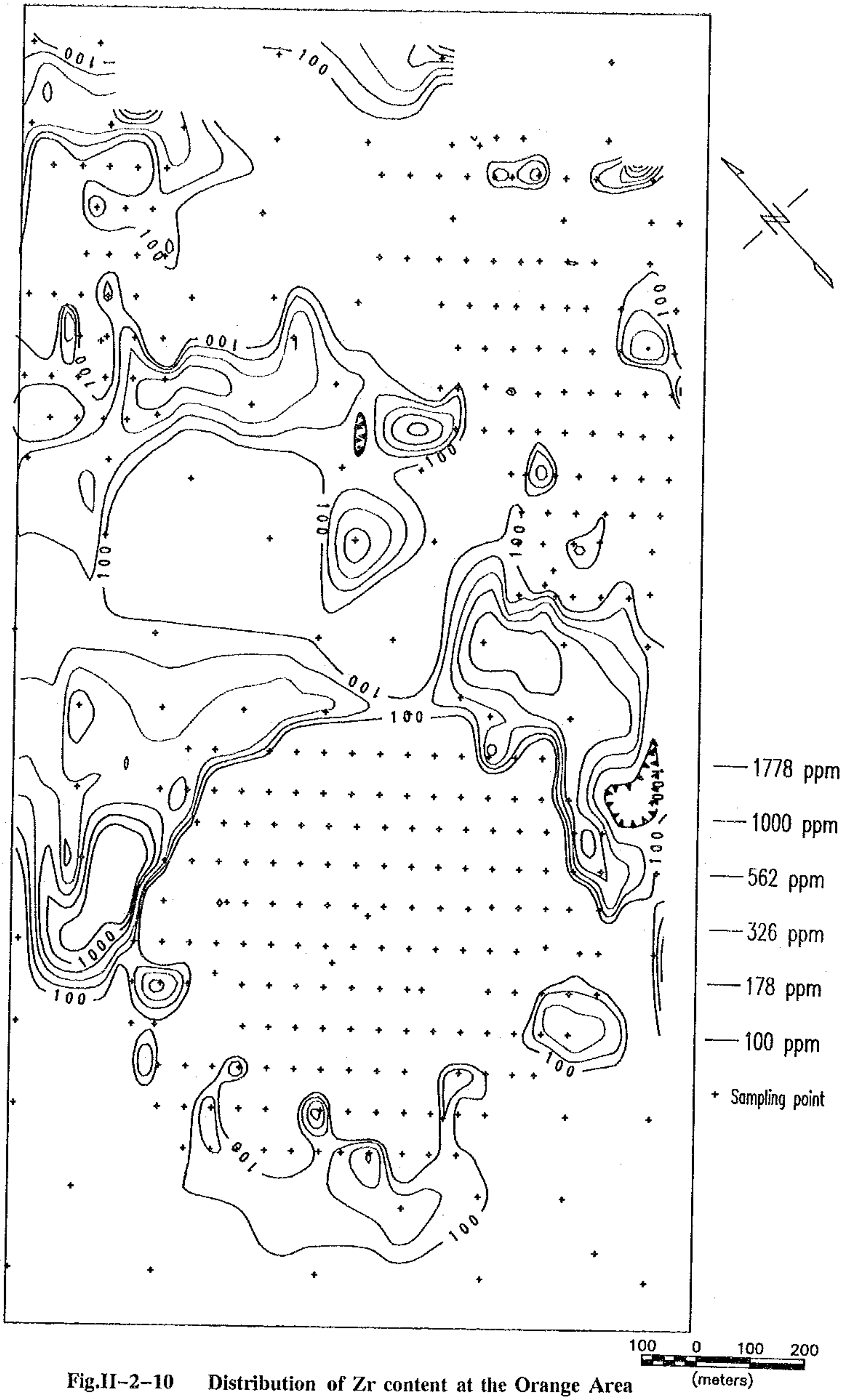

Fig.II-2-10 Distribution of Zr content at the Orange Area

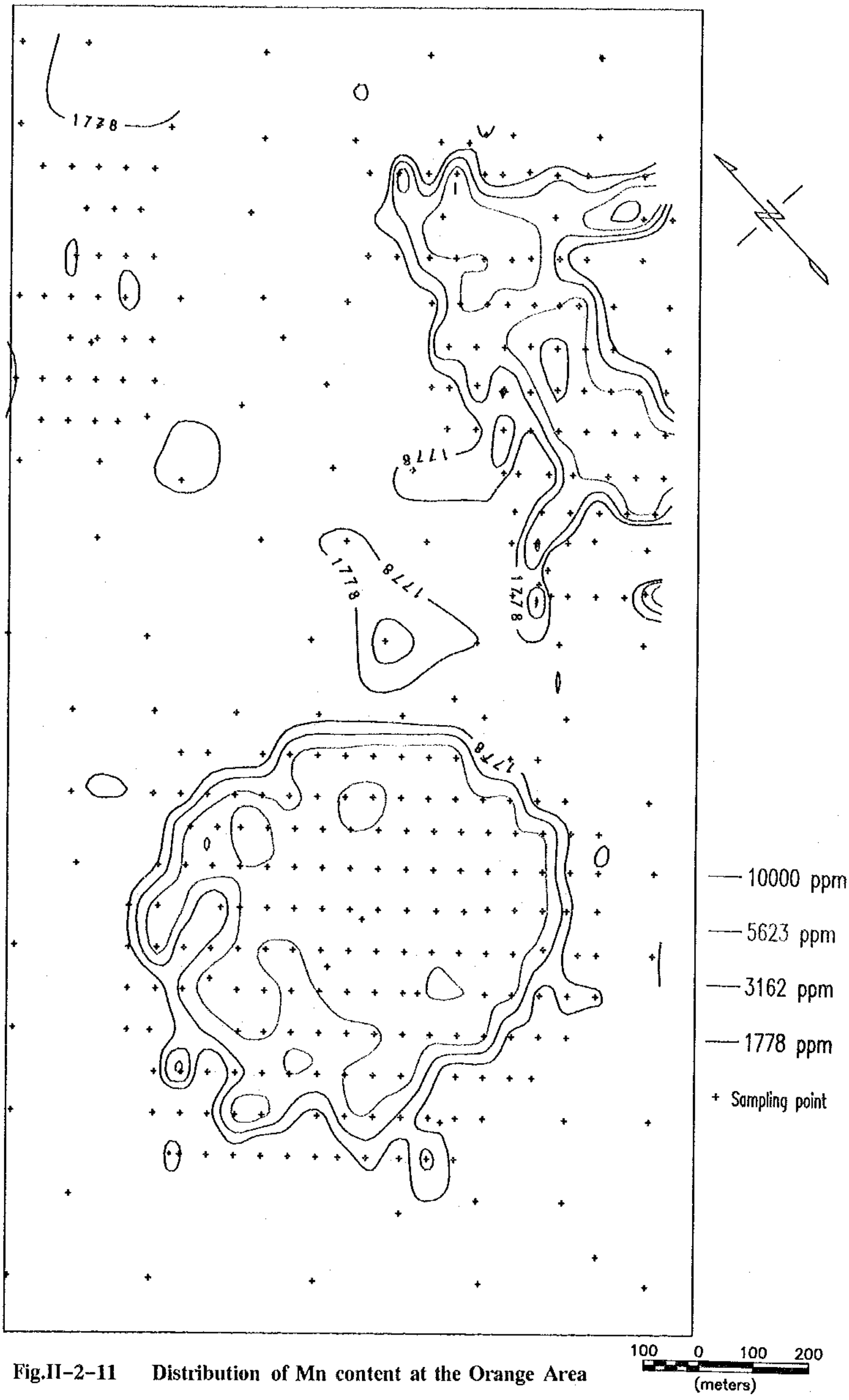

Fig.II-2-11 Distribution of Mn content at the Orange Area

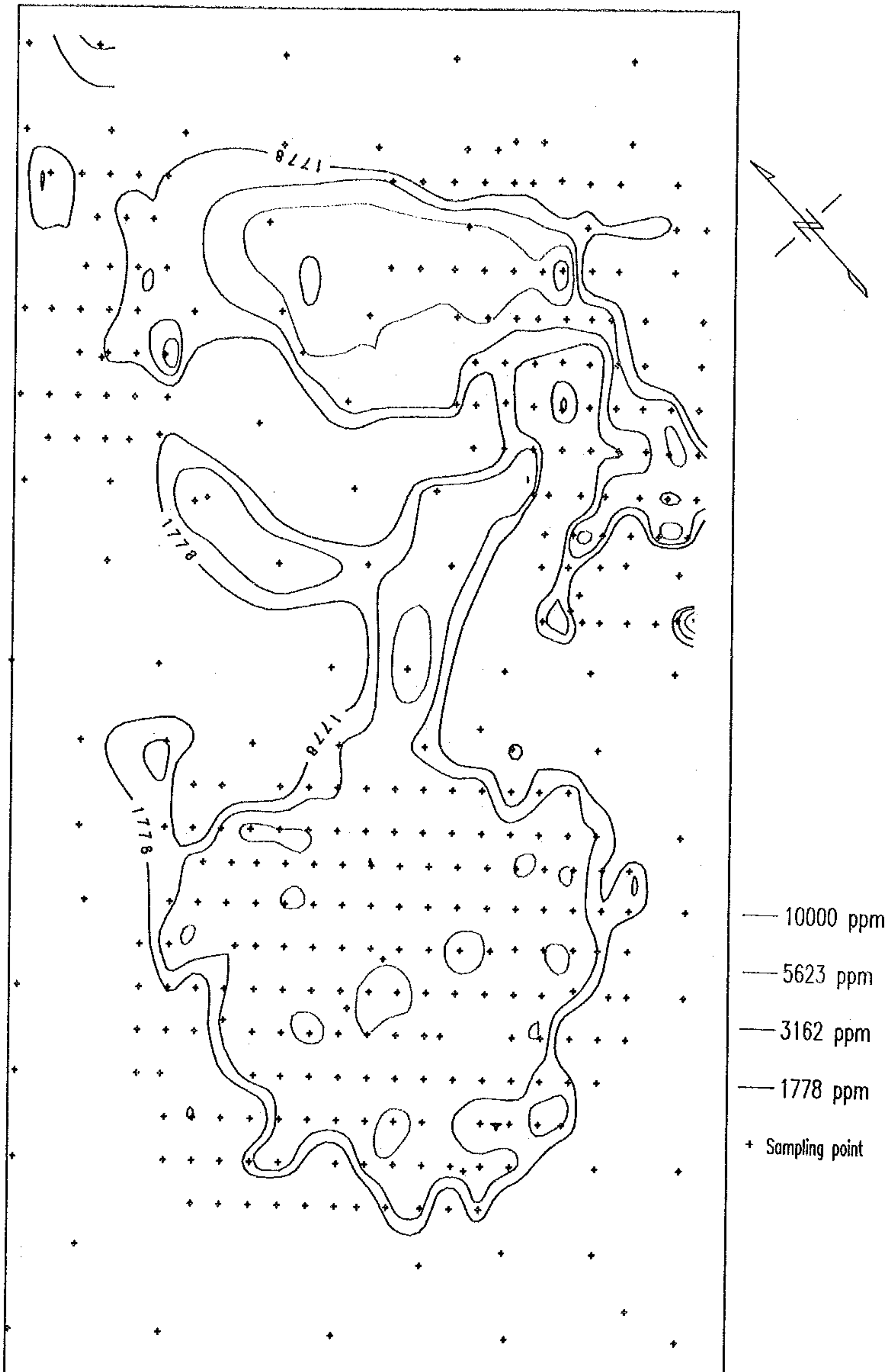

Fig.II-2-12 Distribution of Sr content at the Orange Area

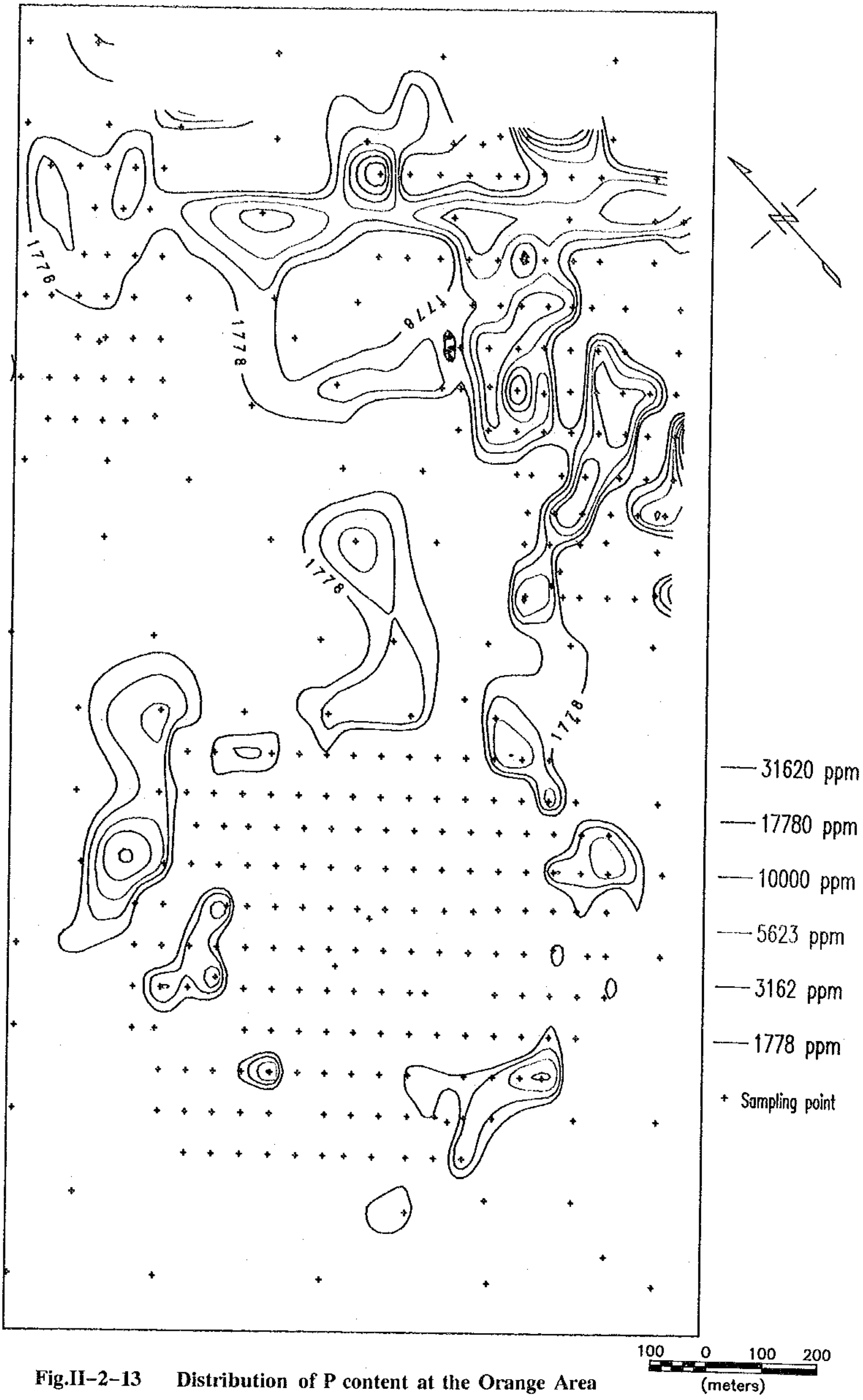

Fig.II-2-13 Distribution of P content at the Orange Area

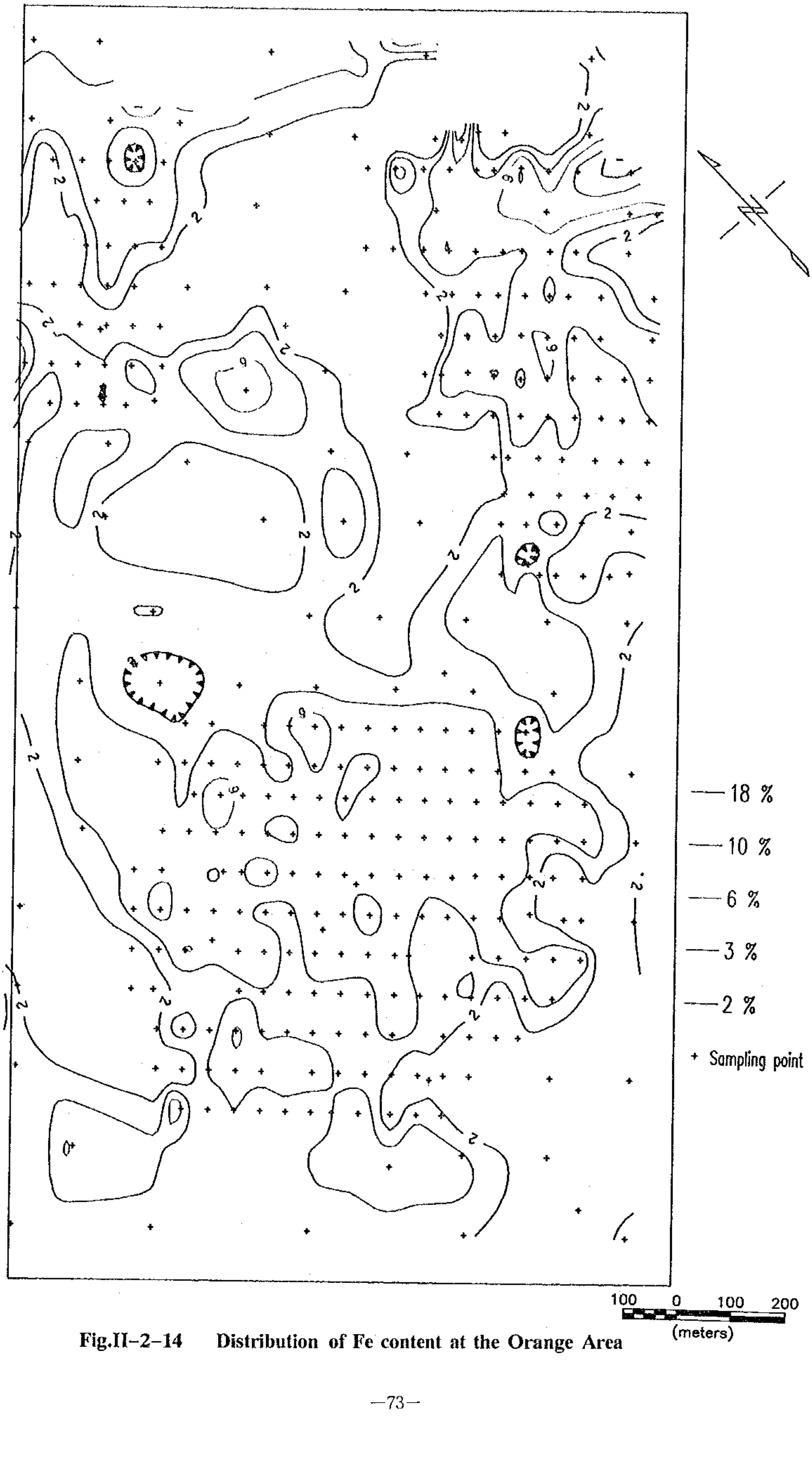

Fig.II-2-14 Distribution of Fe content at the Orange Area

Chapter 3 Kalkfeld area

II-3-1 Survey method

Survey method is same as that of the Kalkfeld area.

The base map for field survey was used to expand the topographic map published by the Government Printer at Pretoria, SWA in 1976 (Sheet No. 2016CC Kalkfeld) in a scale of 1 : 50,000 to that of 1 : 2,500.

The sampling intervals for the whole rock geochemical survey were selected as 150 metres by 100 metres in the general survey area, and 50 metres by 75 metres in the detail survey area.

II-3-2 Geology

II-3-2-1 Regional geology

The regional geological map after GSN (1990) is shown in Fig.II-3-1. There are three carbonatite complexes which have a closely relationship with the situation and genesis. They are arranged along the line of the NE – SW direction, and the distance between each complexes is approximately 15 km. They are called the Osongombo diatreme, the Kalkfeld complex and the Ondurakorume complex in order of location form southwest to northeast. They intruded in the Damara sequence.

II-3-2-2 Details of geology

The geological map and the lithostratigraphy in the area are shown in Fig.II-3-2 and Fig.II-3-3, respectively.

The geology in the area is composed of marble of the Damara sequence (Dm), the Damaran granitoid (Gb and Gp), the Osongombo diatreme, Breccia of marble and granite, and dolerite dyke of the Post Karoo sequence.

Results of the laboratory tests such as rock thin section observation, polished section observation, the XRD analysis and whole rock chemical analysis are shown in Table II-3-1 to Table II-3-4, respectively.

1. Damara Sequence (Dm)

It composed of even-grained marble which has a grain size of 3 to 5 mm in diametre. Foliation with the strike of the NE-SW direction is commonly observed in this area. Graphite bearing marble and blue amphibole bearing marble are found in the northern area, and in the southern area, respectively. Pink material which mainly consists of potassium feldspar, is observed in the marble. Brown carbonatite veins are well developed in the marble surrounding the diatreme.

It shows that the main facies of the sequence in the area is calcite marble, but calcite-dolomite marble exits in the area by microscopic observation and the XRD analysis. Fine pink material

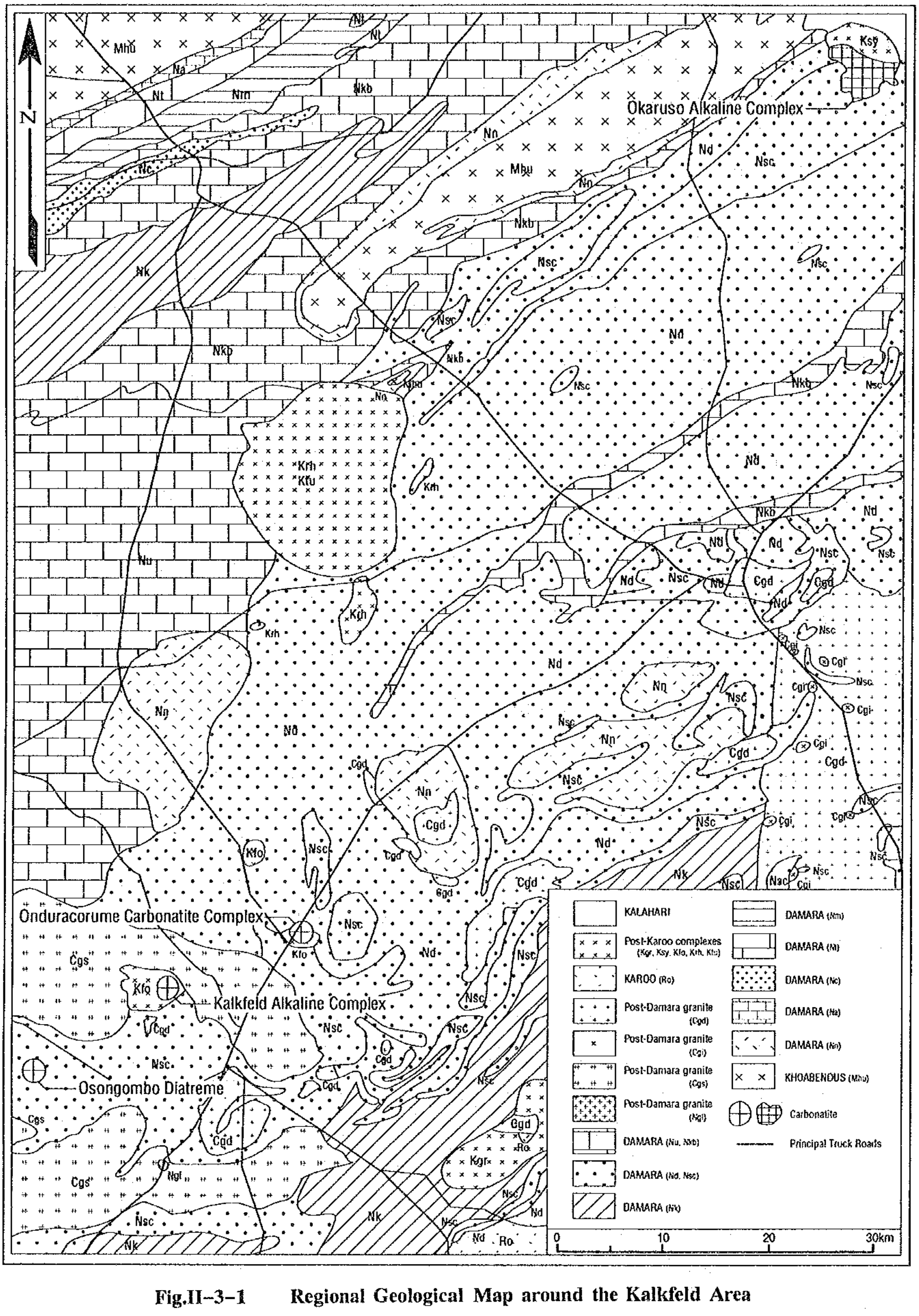

Fig.II-3-1 Regional Geological Map around the Kalkfeld Area

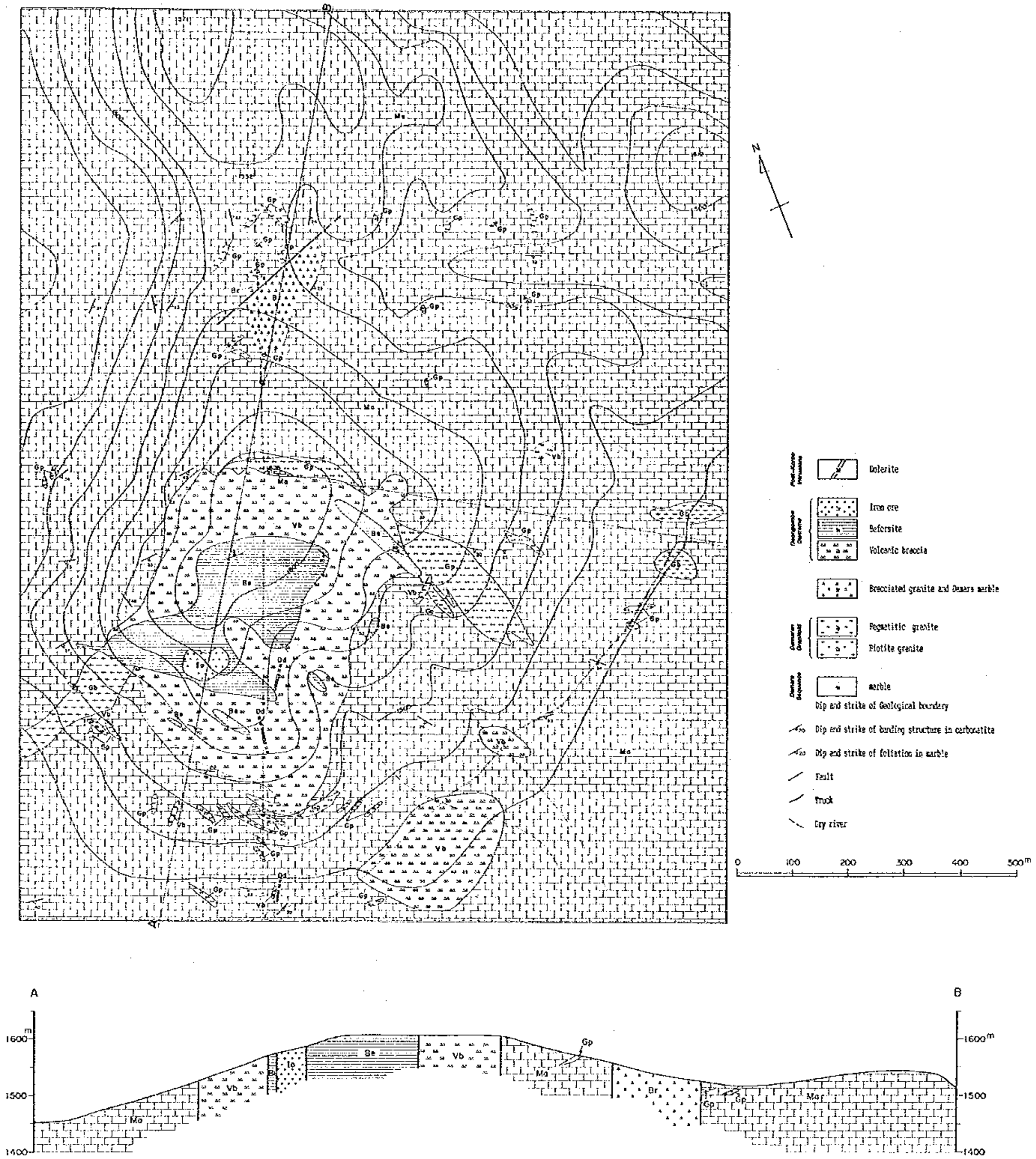

Fig.II-3-2 Geological Map of the Kalkfeld Area

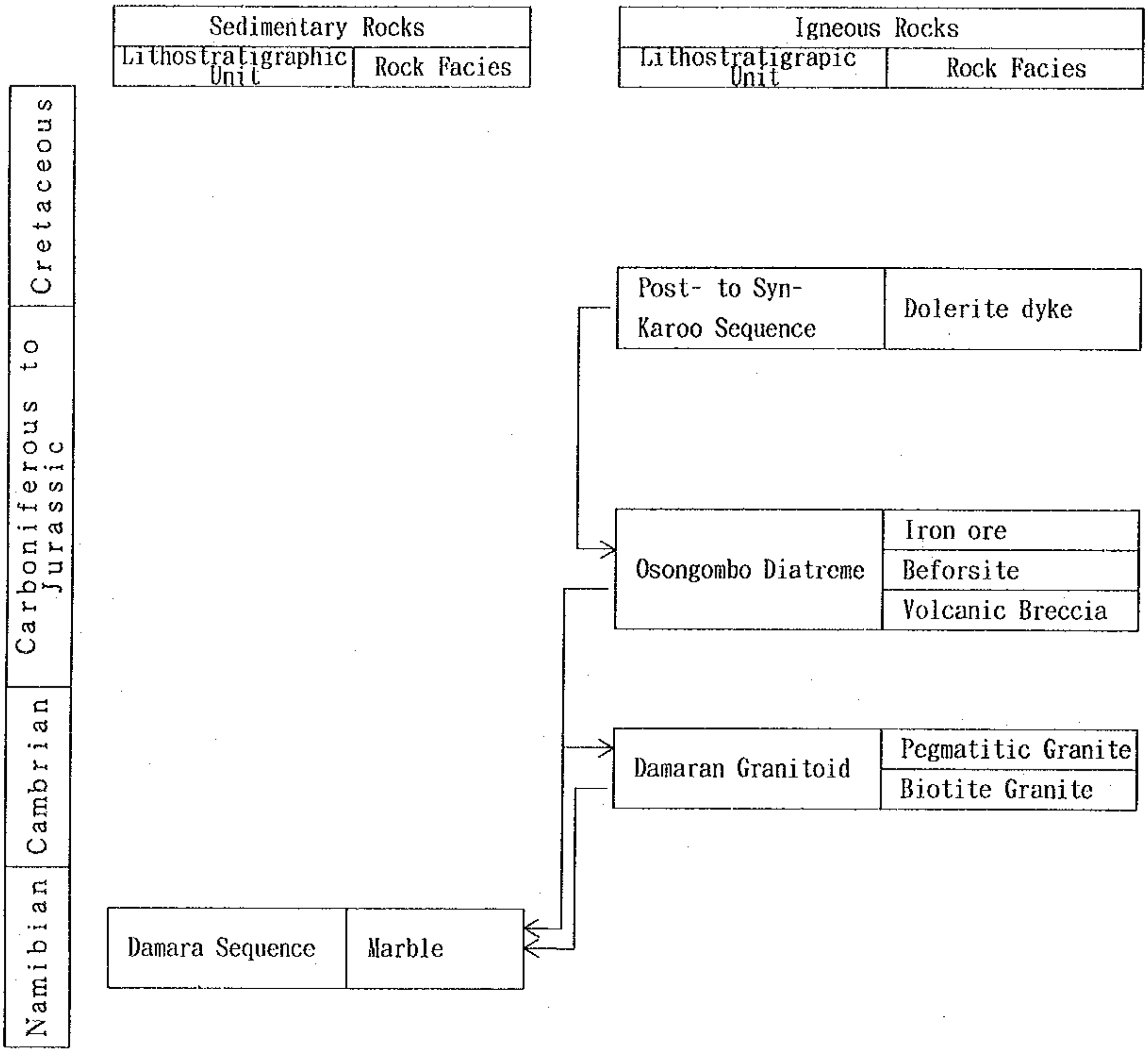

Fig.II-3-3 Lithostratigrapy at the Kalkfeld Area

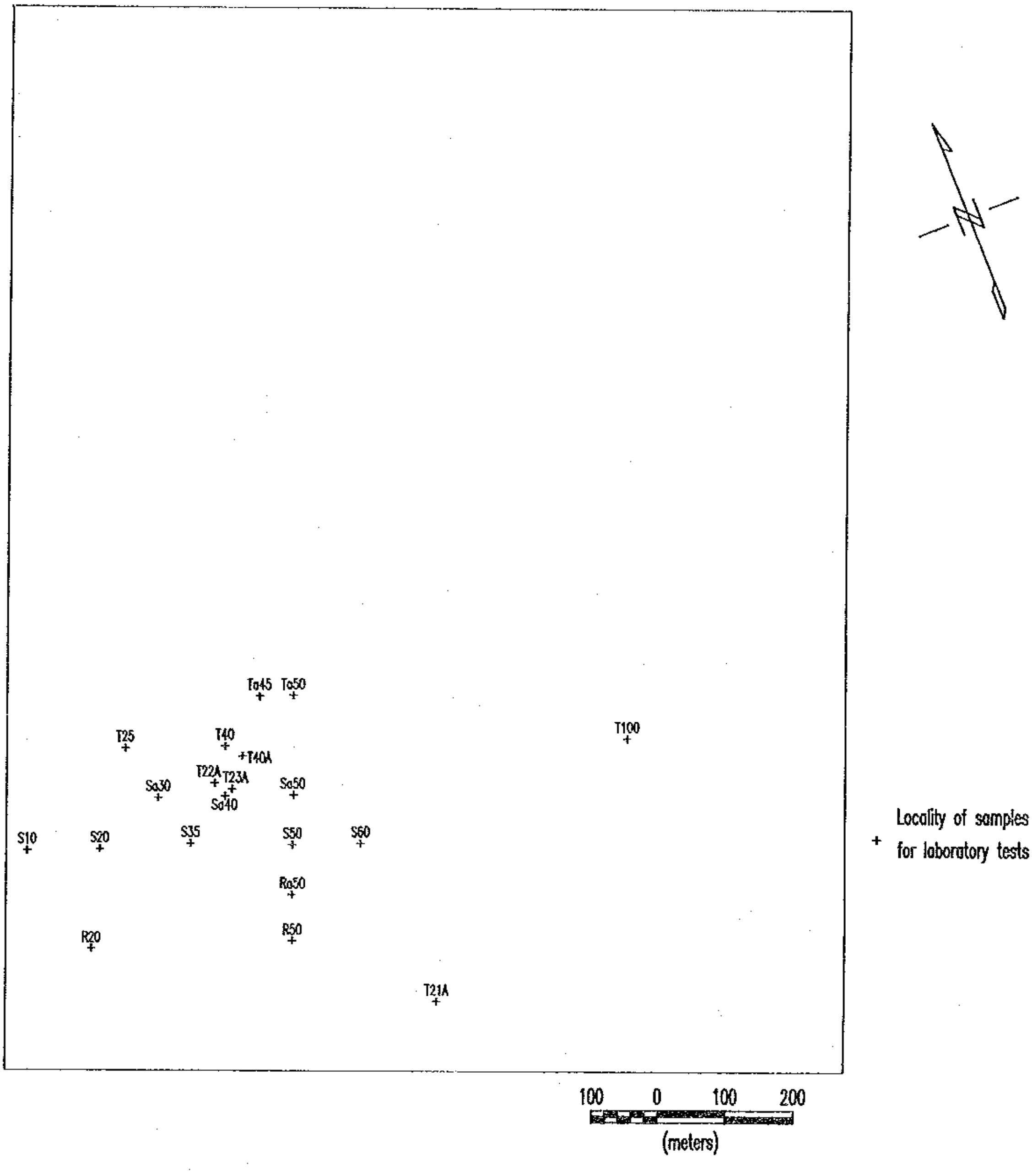

Fig.II–3–4　Sampling Locality for Laboratory Tests at the Kalkfeld Area

TableII-3-1 Mineral Assemblage at the Kalkfeld Area determined by the Microscopic Observation of Thin Sections.

No.	Sample No.	Rock Name	Rock Code	Main rock forming minerals												Accecessory minerals							Secondary minarals				
				Qtz	Pl	Ab	Kfs	Anl	Rbk	Agt	Cpx	Bt	Cal	Dol	Ank	Spn	Rt	Zrn	Ap	Brt	Pyc	Op	Ser	Chl	Cal	FeHO	Py
1	T 40A	Iron ore	Io										△						△	○		◎					
2	S 35	Beforsite	Be				○								◎		△			△	△	△					
3	Sa 40	Beforsite	Be	△		△									△					○		◎		△			
4	Sa 50	Beforsite	Be				○							○					△	○		◎					
5	T 40	Beforsite	Be			◎	○							◎			△		△			○					
6	Ta 45	Beforsite	Be												○				△	○	△	◎					
7	Ta 50	Beforsite	Be	△		○	△						△		◎				△			◎					
8	U 50A	Beforsite	Be	○											◎					○	△	△					
9	U 45	Beforsite	Be	△		△								○		△				○		◎					
10	U 60	Beforsite	Be	△		○	△							◎			△					○					
11	S 20	Carbonatite volcanic breccia	Vb	△		○	◎	○					◎									△					
12	S 50	Carbonatite volcanic breccia	Vb			○	◎		○														△		△	△	
13	S 60	Carbonatite volcanic breccia	Vb	○		◎									○				△			○	△				
14	Sa 30	Carbonatite volcanic breccia	Vb			○	◎		◎	△			◎									○				△	
15	Ua 35	Carbonatite volcanic breccia	Vb	○		○	△								○		△			○		◎					
16	R 50	Pegmatitic granite	Gp	△		◎	◎	△	○				△			△											
17	S 10	Biotite granite	Gb	○		○	○					○						○				△		△			
18	R 20	Calcite marble	Ma		○		○		△		△	△	◎						△			○		△			
19	T 100	Calcite marble	Ma	△		△	○	○					◎									○					

◎:abundant ○:common △:rare

Abbreviation

Qtz:quartz Pl:plagioclase Ab:albite Kfs:potassium feldspar Rbk:riebeckite Agt:aegirine-augite Cpx:clinopyroxene Bt:biotite
Cal:calcite Dol:dolomite Ank:ankerite Spn:sphene Rt:rutile Zrn:zircon Ap:apatite Brt:barite Pyc:pyrochlore
Op:opaque minerals Ser:sericite Chl:chlorite FeHO:ferric hydroxide Py:pyrite

TableII-3-2 Opaque Mineral Assemblage at the Kalkfeld Area determined by the Refractive Microscopic Observation

No.	Sample No.	Rock Name	Rock Code	Oxide and HydroOxide						Sulphide							Remarks
				Mag	MagT	Ilm	Hem	Fe-HO	GoeP	Py	Mc	Po	Mar 1)	Sp	Ccp	Gn	
26	Ra50	Volcanic breccia	Vb	△			△2)	△				△					Fe-HO partly replaces Po
27	Sa40	Beforsite with iron layer	Be	△			●										Fine inclusions of Mag in Hem
28	T 40A	Iron ore	Io				●		△		△						Hem completely replaces Mag/Py
29	T 40	Beforsite	Be			△			◎	△							Fine Py relics remain in GoeP
30	Ta45	Beforsite	Be						△	△			●−◎				Fine Py relics remain in GoeP
31	U 50A	Beforsite	Be							△				△		△	
32	U 45	Beforsite with galena	Be					○		△		◎−○				◎−○	Most of po are replaced by FeHO

●:abundant ◎:common ○:poor △:rare

Abbreviation

Mag:Magnetite MagT:titanomagnetite Ilm:ilmenite Hem:hematite FeHO:Fe:hydroxide GoeP:goethite after pyrite

Py:pyrite Mc:marcasite Po:pyrrhotite Mar:martite Ccp:chalcopyrite Gn:galena

1): Martite consists of Hem which replaces Mag. Some of martite are replaced by Fe hydroxide.

2): Hematite partly/completely replaces magnetite along cracks.

3): Fe hydroxide partly replaces the rim of pyrrhotite.

TableII-3-3 Mineral Assemblage at the Kalkfeld Area determined by the XRD analysis

No.	Sp.No.	Rock Name	Rock Code	Silica and silicate							Carbonate						Oxide			Others			
				Qtz	Ab	Kfs	Rbk	Ag	Phl	Chl	Cal	Mcc	Dol	Ank	Ku	Str	Mag	Hem	Goe	Py	Brt	Ap	Gr
1	T 40A	Iron ore	Io										△				△	△	△		◎		
2	T 22A	Iron ore	Io	○							○		○					△	○		○		
3	T 23A	Iron ore	Io	△							△			○		△		○	○		△		
4	S 35	Beforsite	Be	△		◎	△				△			●		△			△		△		
5	Sa 40	Beforsite	Be	○							△			△			△	○	○		△		
6	Sa 50	Beforsite	Be			◎						○		◎					△		△		
7	T 40	Beforsite	Be		◎	△							●						△				
8	Ta 45	Beforsite	Be									○		●					△		△	△	
9	Ta 50	Beforsite	Be	○	●	△					△		●						△			△	
10	U 50A	Beforsite	Be	◎										●							○		
11	U 45	Beforsite	Be									○		○	○		△		△		○		
12	U 60	Beforsite	Be	△	○	○					○		●						△		△		
13	S 20	Volcanic breccia with brn matrix	Vb	○	●	◎					○			●					△				
14	S 50	Volcanic breccia with brn matrix	Vb	◎	◎	●					○								△				
15	S 60	Volcanic breccia with brn matrix	Vb	●	●	△						○		○					△				
16	Sa 30	Volcanic breccia with brn matrix	Vb		○	◎		○	△	△	○		●						△				
17	T 21A	Volcanic breccia with brn matrix	Vb	△	○	◎					○			◎					△				
18	Ua 35	Volcanic breccia with brn matrix	Vb			◎					○			○	△				△				
19	R 50	Pegmatitic granite	Gp	○	●	●		△			△			○									
20	S 10	Biotite granite	Gb	●	◎	●			○		△												
21	R 20	Marble with carbonatite veinlet	Ma		○	△			△		●			○									
22	T 100	Marble with carbonatite veinlet	Ma	○	○						●			◎		△				△	△		
23	X 100	Graphite marble	Ma				△		△		●		●										△

●:abundant ◎:medium ○:little △:detectable

Abbreviation

Qtz:quartz Ab:albite Kfs:potassium feldspar Rbk:riebeckite Ag:aegirine Phl:phlogopite Chl:chlorite
Cal:calcite Mcc:manganese calcite Dol:dolomite Ank:ankerite Ku:kutnohorite Str:strontianite
Mag:Magnetite Hem:hematite Goe:goethite Py:pyrite Brt:barite Ap:apatite Gr:graphite

TableII-3-4 Chemical Composition of Whole Rock Analysis at the Kalkfeld Area

No.	1	2	3	4	5	6	7
Sample No.	T40A	S35	Sa40	T25	T40	Ta45	Ta50
Rock Name	Iron ore	Beforsite	Beforsite	Beforsite	Beforsite	Beforsite	Beforsite
Rock Code	Io	Be	Be	Be	Be	Be	Be
SiO_2 %	4.86	7.73	10.32	8.46	23.56	2.25	19.26
TiO_2	0.01	0.03	0.01	0.09	0.18	0.01	0.14
Al_2O_3	0.58	3.08	1.60	0.25	7.58	0.24	6.21
Fe_2O_3	49.32	3.59	46.18	11.69	9.71	25.88	5.86
FeO	0.39	9.77	0.26	0.13	2.06	0.13	4.97
MnO	4.69	2.45	3.86	1.86	0.92	3.20	0.91
MgO	2.04	7.28	4.21	4.19	7.03	8.60	7.28
CaO	6.68	23.46	10.40	30.78	14.45	22.58	17.81
Na_2O	0.14	0.27	0.08	0.15	3.91	0.08	3.57
K_2O	0.04	2.08	0.05	0.05	0.62	0.03	0.08
P_2O_5	0.11	0.08	0.15	8.66	0.74	2.66	1.51
CO_2	8.55	34.00	11.10	25.55	20.75	28.20	20.25
$H_2O(+)$	6.58	0.88	6.10	3.30	2.76	4.86	2.34
$H_2O(-)$	0.86	0.56	0.74	0.69	0.63	0.70	0.48
Total	84.85	95.26	95.06	95.85	94.90	99.42	90.67
La ppm	133	922	245	774	291	728	423
Ce	137	1,630	514	1,540	455	1,140	654
Nd	91	382	217	627	158	406	219
Sm	< 0.1	63.0	12.0	135.0	24.0	56.0	37.0
Eu	3.1	17.0	7.0	40.0	6.7	16.0	11.0
Tb	71.0	40.0	102.0	36.0	19.0	46.0	23.0
Yb	2.0	3.0	1.6	11.0	0.8	2.5	1.7
Lu	1.8	1.2	2.3	1.4	0.5	1.2	0.6
Sc	< 0.5	3.9	< 0.5	2.6	2.1	2.1	4.1
Y	14	42	19	326	9	49	40
U	2	7	2	17	1	4	2
Th	123	390	223	560	150	222	176
Nb	< 2	154	< 2	1,840	26	< 2	39
Ta	32	10	28	5	2	25	3
Zr	< 3	< 3	< 3	< 3	7	< 3	5
Sr	947	10,900	1,080	2,960	2,530	2,770	3,350

No.	8	9	10	11	12	13	14
Sample No.	U45	U60	Ua65	S20	S50	S60	T21A
Rock Name	Beforsite	Beforsite	Beforsite	Volcanic berccia	Volcanic berccia	Volcanic berccia	Volcanic berccia
Rock Code	Be	Be	Be	Vb	Vb	Vb	Vb
SiO_2 %	1.33	20.97	21.57	33.82	46.58	56.83	27.34
TiO_2	0.01	0.73	0.26	0.20	0.44	0.52	1.38
Al_2O_3	1.59	6.33	6.89	10.79	11.34	9.52	6.63
Fe_2O_3	15.33	10.07	9.18	3.17	11.80	7.61	7.49
FeO	0.10	1.58	0.13	2.77	0.10	0.13	1.83
MnO	3.33	1.12	1.64	1.33	0.51	0.33	0.97
MgO	7.68	5.90	3.16	3.86	0.61	0.83	7.15
CaO	25.10	13.49	18.67	12.37	4.29	5.08	17.79
Na_2O	0.10	2.57	0.15	3.09	1.95	4.75	1.37
K_2O	0.03	1.62	5.78	4.30	6.94	0.96	4.08
P_2O_5	2.93	0.21	0.11	0.86	0.54	0.21	0.04
CO_2	27.40	18.80	16.85	14.90	3.60	3.60	20.84
$H_2O(+)$	3.26	3.56	3.32	1.14	2.02	1.82	1.60
$H_2O(-)$	0.41	0.65	0.45	0.69	0.60	0.68	0.32
Total	88.60	87.53	88.16	93.29	91.32	92.87	98.83
La ppm	3,502	270	321	926	275	16	585
Ce	5,042	411	496	1,200	473	36	851
Nd	1,834	177	140	255	138	11	478
Sm	330.0	31.0	18.0	37.0	13.0	< 0.1	64.9
Eu	90.0	8.9	4.6	7.9	4.8	0.6	12.6
Tb	48.0	26.0	21.0	20.0	35.0	21.0	7.5
Yb	3.4	1.3	12.0	1.8	1.4	1.5	2.9
Lu	1.0	0.7	0.5	0.6	0.8	0.6	1.6
Sc	5.2	4.6	1.6	2.1	4.7	6.9	14.9
Y	149	12	7	31	18	14	17
U	3	4	1	14	2	1	1
Th	785	345	108	119	135	16	188
Nb	7	226	66	66	102	12	11
Ta	13	13	< 2	5	6	< 2	< 2
Zr	< 3	29	3	60	98	32	176
Sr	3,470	1,160	1,280	4,060	769	286	1,000

mainly consists of potassium feldspar, and it suggests that the marble around the diatreme is effected by alkaline metasomatism.

2. Damaran Granitoid (Gb and Gp)

It is composed of biotite granite and pegmatitic granite sill. Brown carbonatite vein and green aegirine vein are found.

Biotite granite (Gb) intruding in the Damara marble is found in the southwest and the east of the area. the shape of bodies is irregular.

It consists of quartz, plagioclase (albite), potassium feldspar and biotite as main rock forming minerals, and of sphene and opaque mineral as accessary minerals identified by microscopic observation and the XRD analysis. Calcite and chlorite are found as secondary minerals.

Pegmatitic Granite (Gp) widely distributes as a small mass of sill in the marble. It consists of quartz and pink feldspar grain, more or less than 5 mm in diametre.

It consists of quartz, albite, potassium feldspar as main rock forming minerals, and of analcime, riebeckite and sphene as accessary minerals.

3. Osongombo diatreme (Vb, Be and Io)

It is composed of volcanic breccia (Vb), beforsite (Be) and iron ore (Io).

3-1 Volcanic breccia (Vb)

It is distributed in the outer zone of the diatreme and in the marble at the southern part of the area as a small body. The fragments of breccia consist of pink volcanic rock and granite, and matrix is filled with brown carbonates and iron oxide. It shows various rate of fragments and matrix. The boundary between the volcanic breccia and the beforsite is not clear. The surface of the southern volcanic breccia body is widely covered with floater of beforsite and volcanic breccia.

Pink fragments consist of phenocryst of potassium feldspar (5 to 1 mm in diametre), and microcryst of albitized plagoclase and potassium feldspar (1 to 0.1 mm in diametre). Fine quartz, carbonate and opaque mineral are observed in groundmass of the fragments. Small amount of riebeckite and aegirine-augite are observed as mafic minerals.

3-2 Beforsite (Be)

It is distributed in the inner zone surrounded by the volcanic breccia in the diatreme. The surface of the beforsite is brown coloured by weathering of iron oxides. Banding structure caused by different strength against weathering was observed in a part of outcrop. Aggregate of galena was found in the beforsite at 150 m south from the beacon.

It is composed of dolomite and ankerite as main composition. Calcite, kutunahorite, strontianite, barite, quartz, albite, potassium feldspar and riebeckite are identified by thin section observation and the XRD analysis. Barite is commonly identified in this beforsite. Magnetite, hematite, ilmenite, pyrite, marcasite, pyrrhotite, galena, sphalerite and iron hydroxide are identified by polished section observation and the XRD analysis. Galena has a size of 3.5 to 0.2 mm in diametre, and coexist with pyrrhotite and pyrite (Specimen No.U45).

3-3 Iron ore (Io)

It is distributed at the central part of the diatreme. It shows massive. The surface of the iron ore is black to dark brown.

Quartz, calcite, dolomite, ankerite, strontianite, magnetite, hematite, goethite and barite are identified by microscopic observation and the XRD analysis.

4. Breccia of marble and granite (Br)

It is distributed at the northern ridge in the area. It is composed of the breccia of marble and granite, and filled with the brown carbonatite in the boundary of fragments.

5. Dolerite (Dd)

It is distributed in and around the diatreme. The width of the dyke is more or less than 1 m, but details of the distribution is unknown.

II-3-3 Geochemical survey

II-3-3-1 Methodology

Whole geochemical survey was carried out. The area of the diatreme distributed was selected to carried out the detail survey.

The elements of analysis, detectable limits and accuracies are the same as those in the Orange area.

II-3-3-2 Result of whole rock geochemical survey

Sampling locality for the geochemical survey is shown in Fig.II-3-5. Statistic values of result of geochemical analysis are shown in Table II-3-5. The host rocks surrounding the carbonatite diatreme are subdivided into two types of existence of brown coloured interstitial carbonatite vein.

The characteristics of the distribution on each element are as follows:

1. REEs (La, Ce, Nd, Sm, Eu, Tb, Yb, and Eu)

Distribution of Ce content is shown in Fig.II-3-6.

High concentrated zone of Ce is distributed in the beforsite and iron ore of the diatreme. The average value of Ce content in this area is twice higher than that of beforsite in the orange area,

TableII-3-5 Statistical Values of Geochemical Analysis at the Kalkfeld Area

Rock Facies	Rock Code	Nos.	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Yb (ppm)	Lu (ppm)	Sc (ppm)	Y (ppm)	U (ppm)	Th (ppm)	Nb (ppm)	Ta (ppm)	Zr (ppm)	Mn (ppm)	Sr (ppm)	P (ppm)	Fe (%)
Maximum contents																					
OD-Iron ore	Io	3	899	1540	1200	300	70	71	6	8	5	76	3	2260	9	32	19	40300	14400	559	37.82
OD-Beforsite	Be	23	3502	5042	1834	330	90	102	12	2	9	326	17	2290	1840	28	64	29900	10900	37800	32.50
OD-Volcanic Breccia	Vb	36	926	1200	478	65	13	100	14	2	15	70	79	430	498	29	176	16600	8490	9790	30.40
Damaran Granitoid with carbonatite veins	Gp, Gb	5	259	374	111	16	5	28	14	1	3	10	3	104	226	2	61	12000	1840	2070	7.69
Damara Sequence with carbonatite veins	Ma	32	3090	4150	604	94	26	30	17	2	4	149	11	352	223	7	72	16100	5540	16300	8.55
Damaran Granitoid	Gp, Gb	16	116	187	81	18	7	24	25	1	7	70	19	282	151	3	124	1730	435	3490	6.44
Damara Sequence	Ma	52	161	220	134	10	4	9	17	1	3	86	9	140	45	2	26	4650	3250	5110	2.32
Minimum contents																					
OD-Iron ore	Io	3	133.0	137.0	91.0	0.1	3.1	16.3	2.0	1.8	0.5	14.0	2.0	123.0	2.0	2.0	3.0	36300	442	408	31.92
OD-Beforsite	Be	23	20.0	21.0	12.0	0.1	1.6	12.0	0.6	0.3	0.5	4.0	1.0	32.0	2.0	2.0	3.0	1870	879	248	4.90
OD-Volcanic Breccia	Vb	36	16.0	36.0	11.0	0.1	0.6	3.0	0.8	0.2	0.5	4.0	1.0	16.0	2.0	2.0	3.0	1610	286	144	1.00
Damaran Granitoid with carbonatite veins	Gp, Gb	5	10.0	22.0	8.0	1.4	0.7	1.7	0.4	0.1	0.6	7.0	1.0	18.0	2.0	2.0	17.0	125	128	600	0.48
Damara Sequence with carbonatite veins	Ma	32	2.0	4.0	1.0	0.2	0.3	0.6	0.1	0.1	0.5	3.0	1.0	2.0	2.0	2.0	3.0	155	864	310	0.12
Damaran Granitoid	Gp, Gb	16	19.0	41.0	16.0	1.9	0.5	2.4	0.5	0.1	1.3	6.0	1.0	8.0	6.0	2.0	23.0	87	57	210	0.44
Damara Sequence	Ma	52	1.0	1.0	1.0	0.1	0.3	0.1	0.3	0.1	0.3	1.0	1.0	1.0	2.0	2.0	3.0	45	583	180	0.03
Arithmetic Average Contents																					
OD-Iron ore	Io	3	556.3	809.0	640.7	146.7	30.3	38.9	4.0	5.2	2.4	41.0	2.3	885.7	6.0	12.0	8.3	37867	5263	477	34.85
OD-Beforsite	Be	23	672.5	1069.2	367.6	63.4	18.2	33.5	2.7	0.9	4.1	47.0	3.6	356.0	145.1	8.9	14.8	13684	2352	4672	10.86
OD-Volcanic Breccia	Vb	36	323.5	489.6	162.2	22.9	6.3	23.6	4.1	0.7	5.0	20.6	7.1	146.9	125.1	5.3	55.1	6828	1852	2455	7.56
Damaran Granitoid with carbonatite veins	Gp, Gb	5	126.2	201.6	63.4	8.4	2.5	11.8	3.3	0.3	2.5	8.0	2.2	65.6	71.2	2.0	45.4	3665	643	1102	3.81
Damara Sequence with carbonatite veins	Ma	32	246.3	354.5	86.8	14.7	4.0	8.3	7.4	0.4	1.7	33.2	2.9	74.8	52.3	2.2	14.4	2840	2356	1680	2.02
Damaran Granitoid	Gp, Gb	16	57.8	102.5	35.6	5.5	1.6	8.3	6.7	0.4	3.0	19.5	4.6	45.3	48.1	2.1	66.6	553	255	857	2.38
Damara Sequence	Ma	52	13.3	20.4	10.5	1.2	0.7	2.0	9.3	0.2	0.9	10.8	1.4	9.9	6.3	2.0	6.5	489	1488	598	0.50
Standard Deviations																					
OD-Iron ore	Io	3	317.9	574.3	452.8	122.5	28.8	23.3	1.5	2.5	1.8	25.9	0.5	973.8	2.9	14.1	7.5	1744	6464	62	2.4
OD-Beforsite	Be	23	732.7	1094.1	409.5	83.1	23.0	21.4	2.9	0.5	2.3	67.9	3.7	471.2	367.7	7.6	17.6	7785	1975	7932	6.3
OD-Volcanic Breccia	Vb	36	182.0	238.1	83.2	13.8	2.7	15.1	4.7	0.3	3.2	13.6	14.3	91.2	109.6	5.6	42.9	3331	1532	2120	4.5
Damaran Granitoid with carbonatite veins	Gp, Gb	5	92.5	142.1	41.0	5.6	1.5	9.3	5.3	0.2	1.0	1.1	0.7	32.0	80.3	0.0	18.7	4495	644	515	2.3
Damara Sequence with carbonatite veins	Ma	32	553.8	763.0	137.5	22.4	5.5	7.0	6.7	0.3	1.1	31.7	2.4	98.2	56.8	0.9	15.9	3408	1083	2760	1.8
Damaran Granitoid	Gp, Gb	16	29.9	47.6	17.8	3.8	1.5	6.3	7.7	0.2	1.4	19.8	4.3	62.8	40.7	0.2	31.2	498	112	781	1.8
Damara Sequence	Ma	52	28.5	39.0	19.8	1.9	0.6	2.3	5.7	0.1	0.8	12.9	1.3	20.8	9.2	0.0	6.0	813	579	787	0.6
Geometric Average Contents																					
OD-Iron ore	Io	3	423.9	540.9	410.0	10.2	15.6	32.4	3.6	4.4	1.0	32.7	2.3	423.9	3.2	2.0	2.2	37827	1820	473	34.8
OD-Beforsite	Be	23	415.3	652.6	222.2	25.3	10.3	28.9	1.9	0.8	2.9	25.2	2.4	212.2	32.2	5.2	4.9	11253	1961	1742	9.7
OD-Volcanic Breccia	Vb	36	265.9	417.1	138.5	13.8	5.5	20.6	2.4	0.6	3.5	17.1	3.2	117.6	71.8	2.1	33.7	6061	1468	1613	6.7
Damaran Granitoid with carbonatite veins	Gp, Gb	5	79.5	135.5	45.1	6.2	2.0	8.0	1.2	0.3	2.2	7.9	2.0	55.5	22.7	0.5	40.4	1278	390	1003	2.8
Damara Sequence with carbonatite veins	Ma	32	59.7	95.0	29.7	5.0	1.8	6.0	3.8	0.3	1.1	23.8	2.1	33.3	18.7	0.5	6.5	1553	2135	1038	1.5
Damaran Granitoid	Gp, Gb	16	49.7	91.6	31.9	4.6	1.1	6.4	2.5	0.3	2.7	13.4	3.3	29.7	33.3	0.6	58.5	385	224	656	1.8
Damara Sequence	Ma	52	4.7	9.1	2.9	0.5	0.2	0.9	5.9	0.1	0.4	7.2	0.8	2.5	2.0	0.5	2.2	257	1390	435	0.3

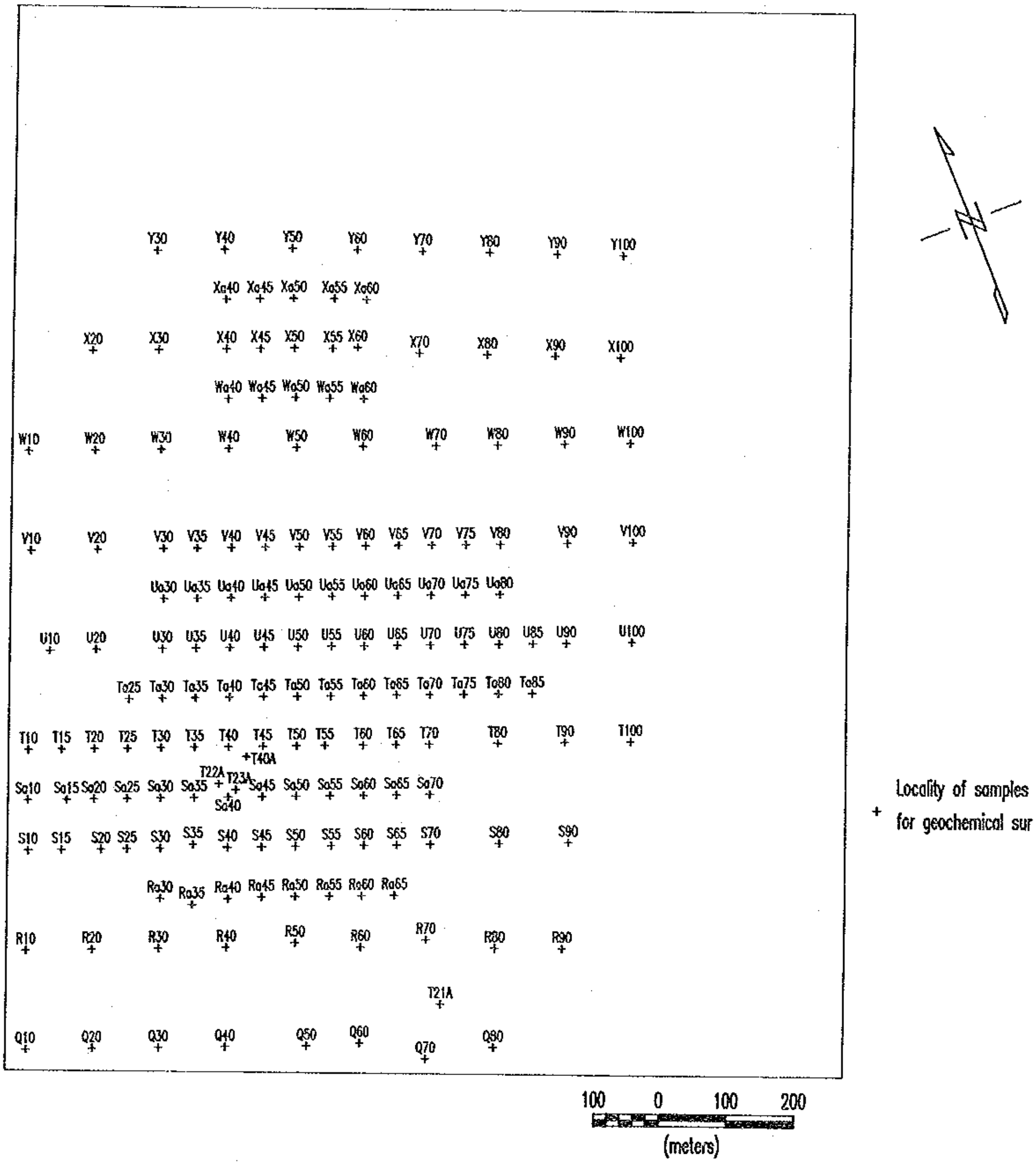

Fig.II-3-5 Sampling Locality for Geochemical Survey at the Kalkfeld Area

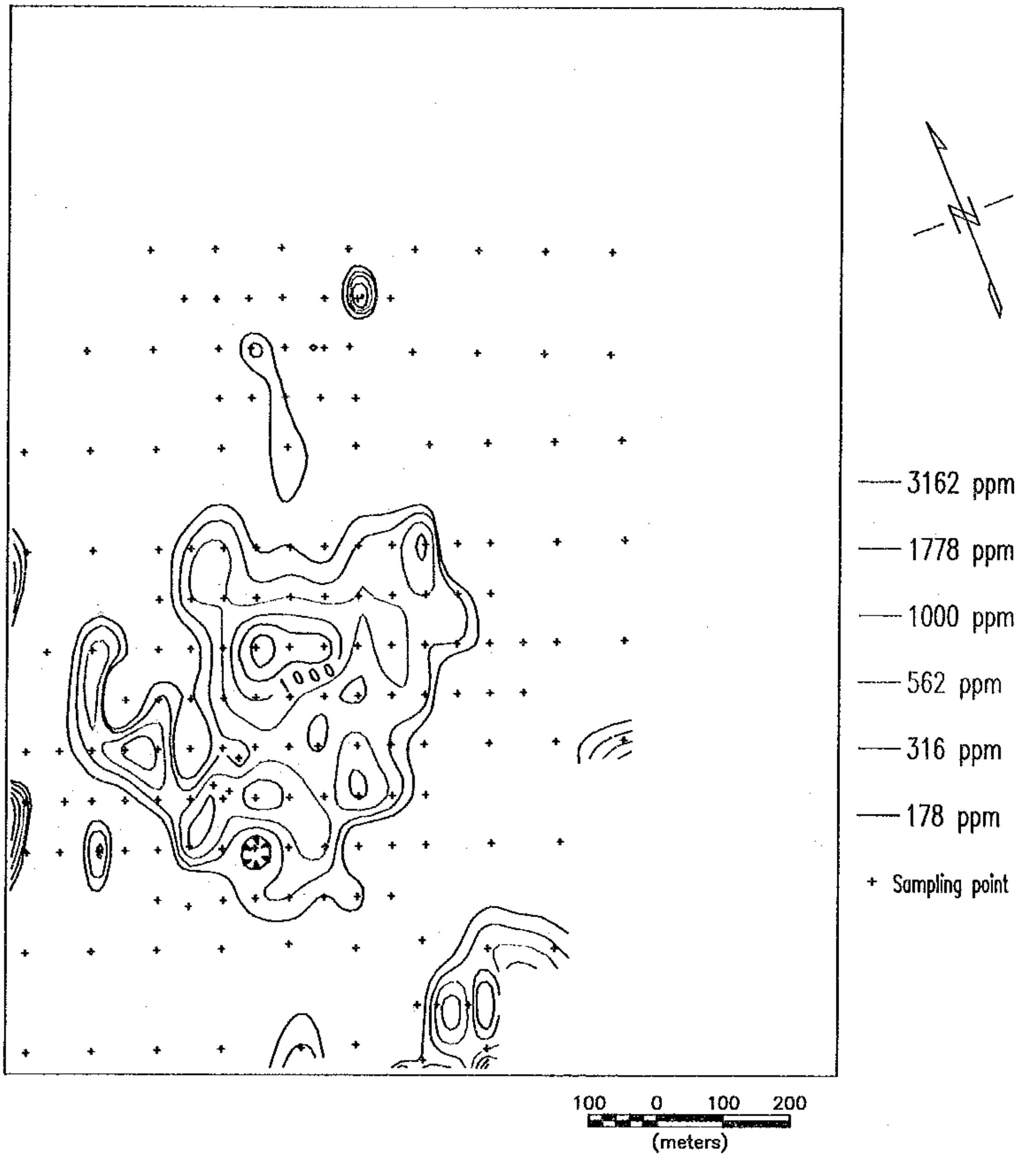

Fig.II-3-6 Distribution of Ce content at the Kalkfeld Area

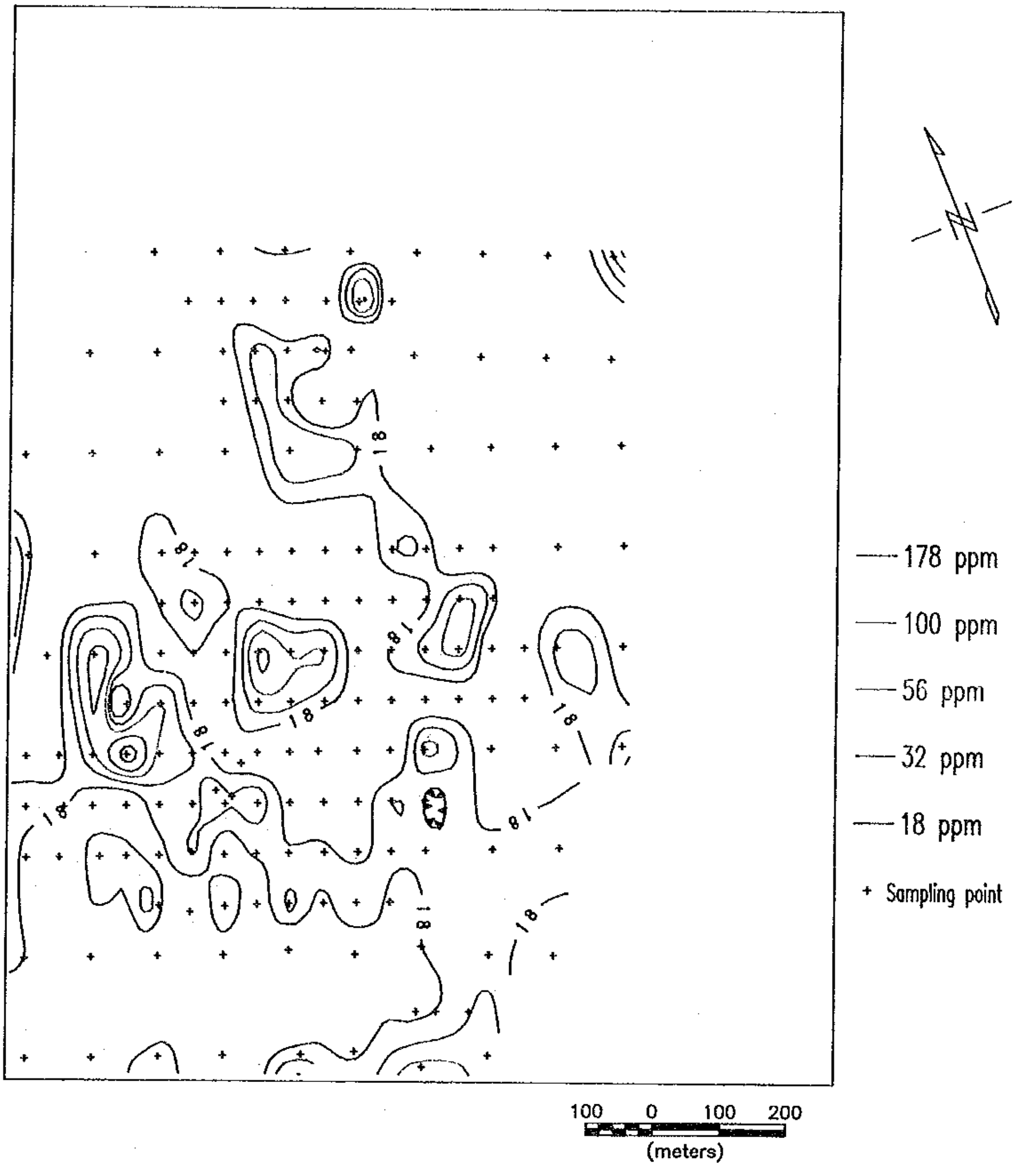

Fig.II-3-7 Distribution of Y content at the Kalkfeld Area

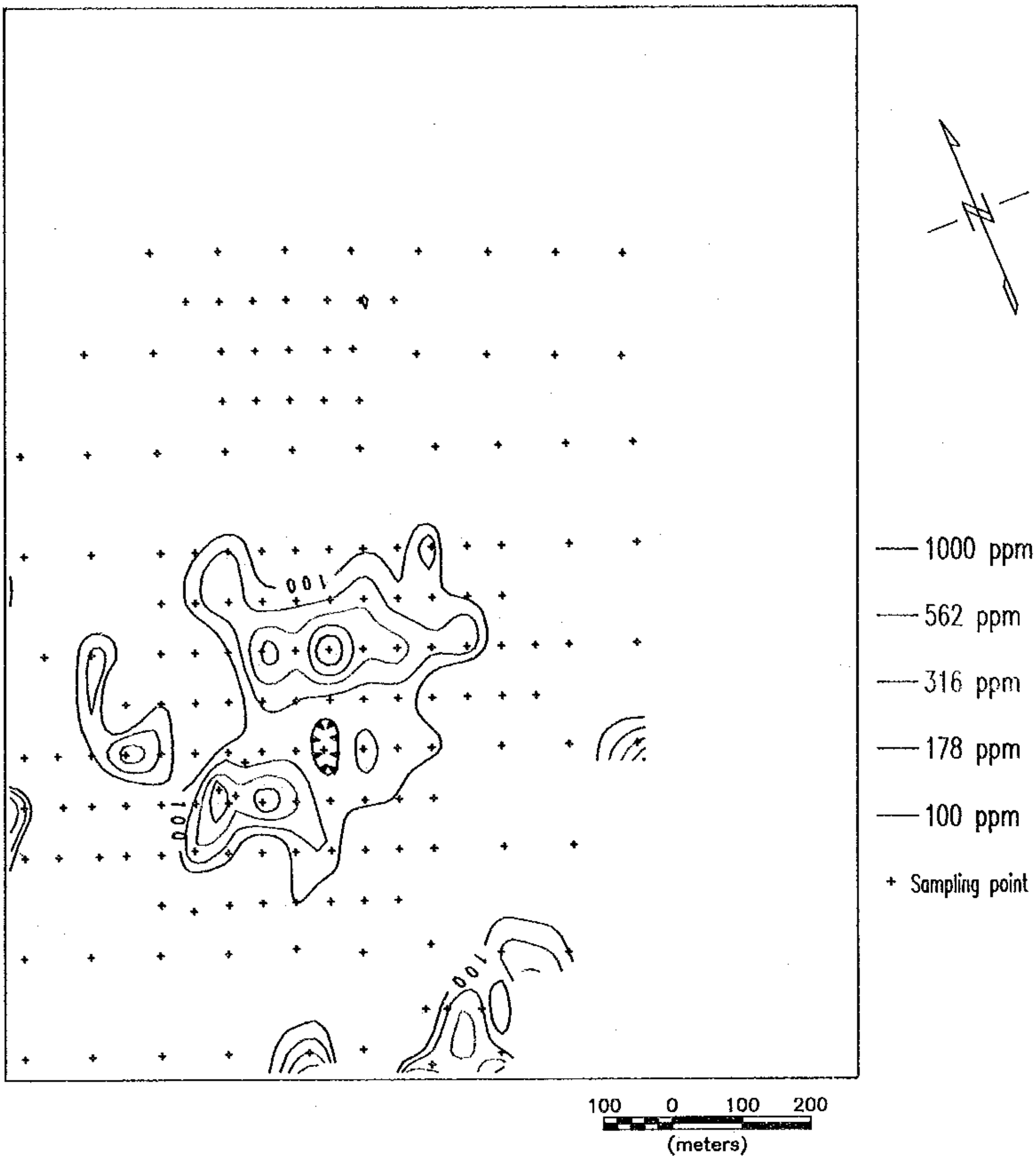

Fig.II-3-8 Distribution of Th content at the Kalkfeld Area

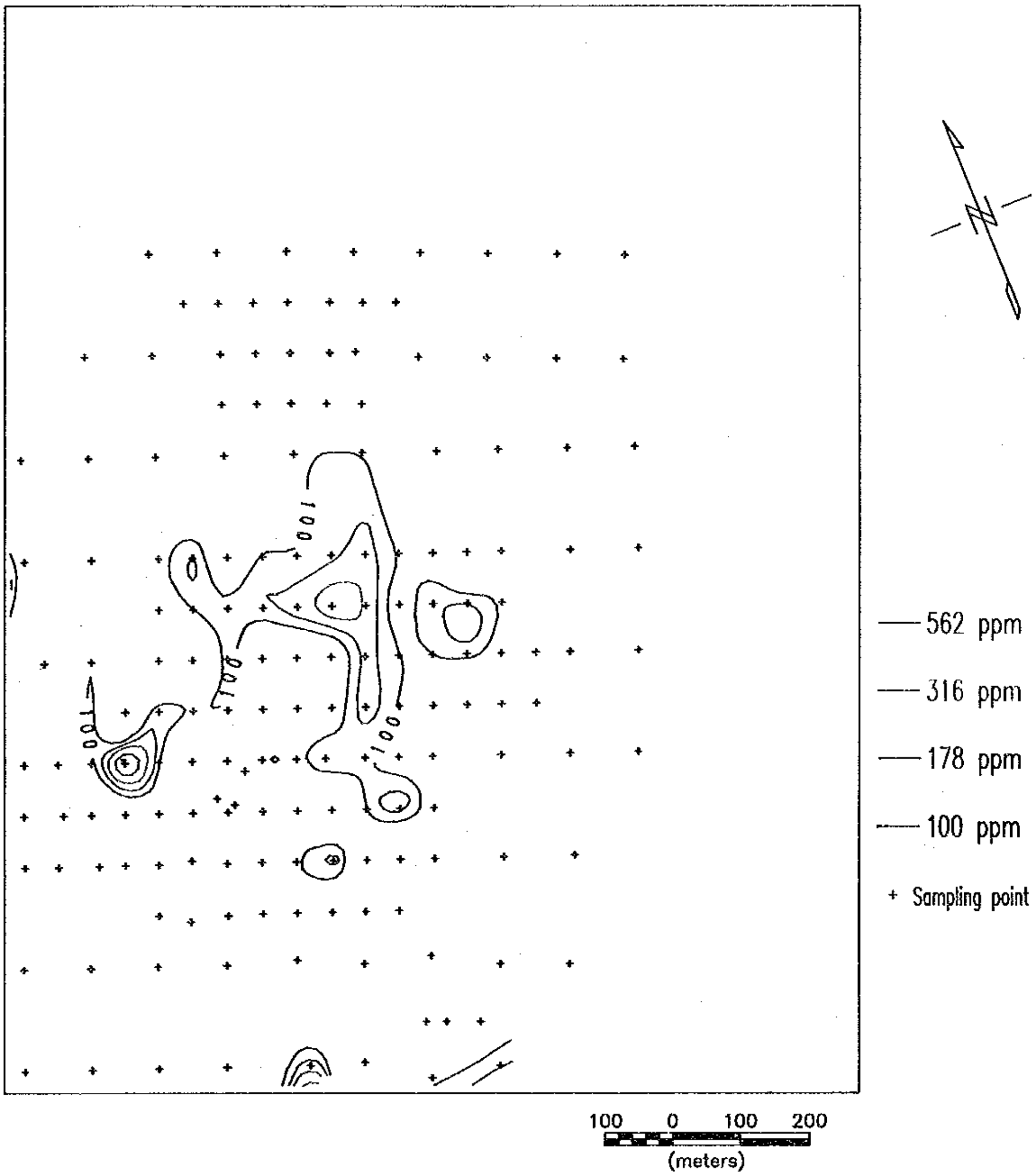

Fig.II-3-9 Distribution of Nb content at the Kalkfeld Area

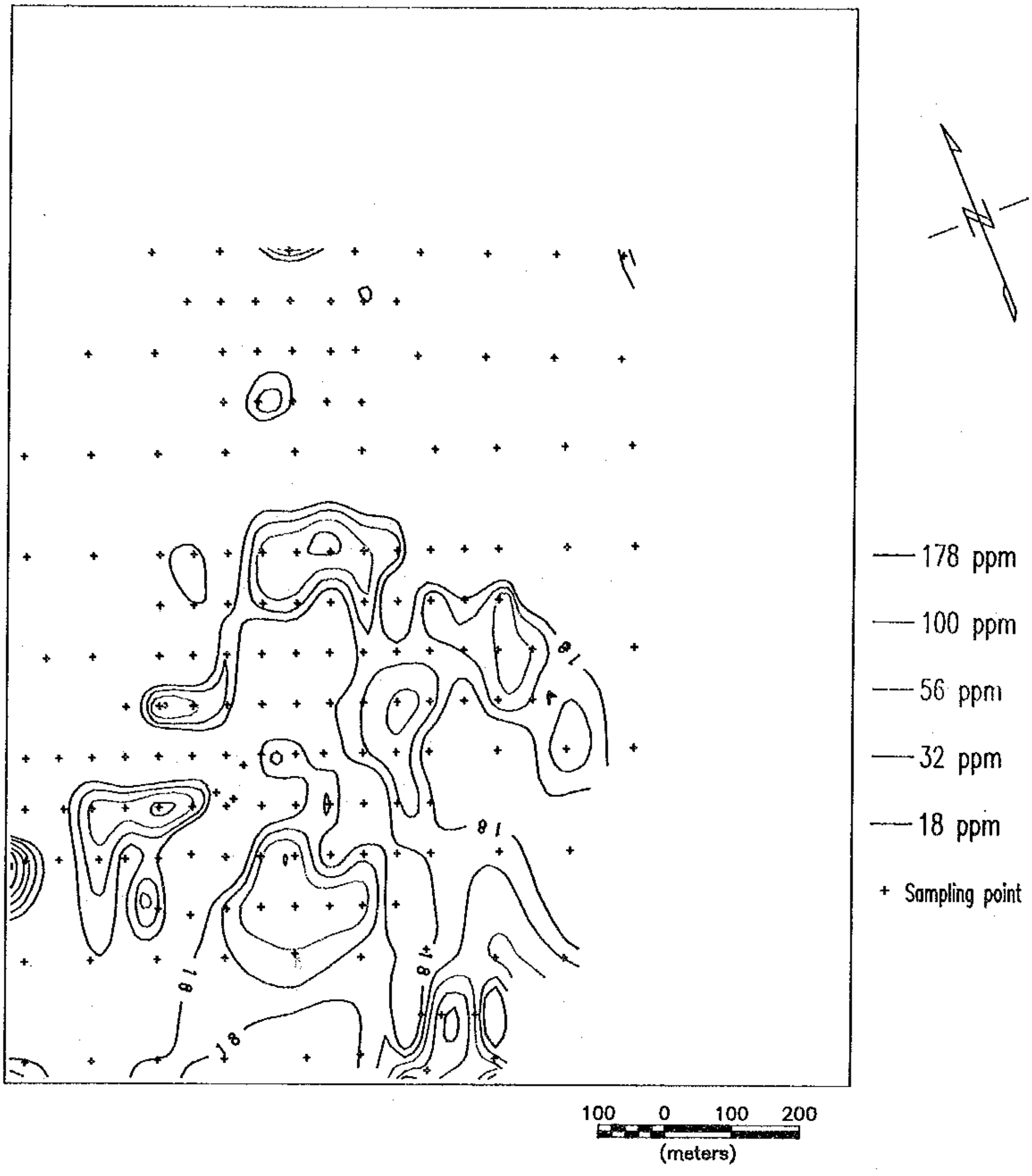

Fig.II-3-10 Distribution of Zr content at the Kalkfeld Area

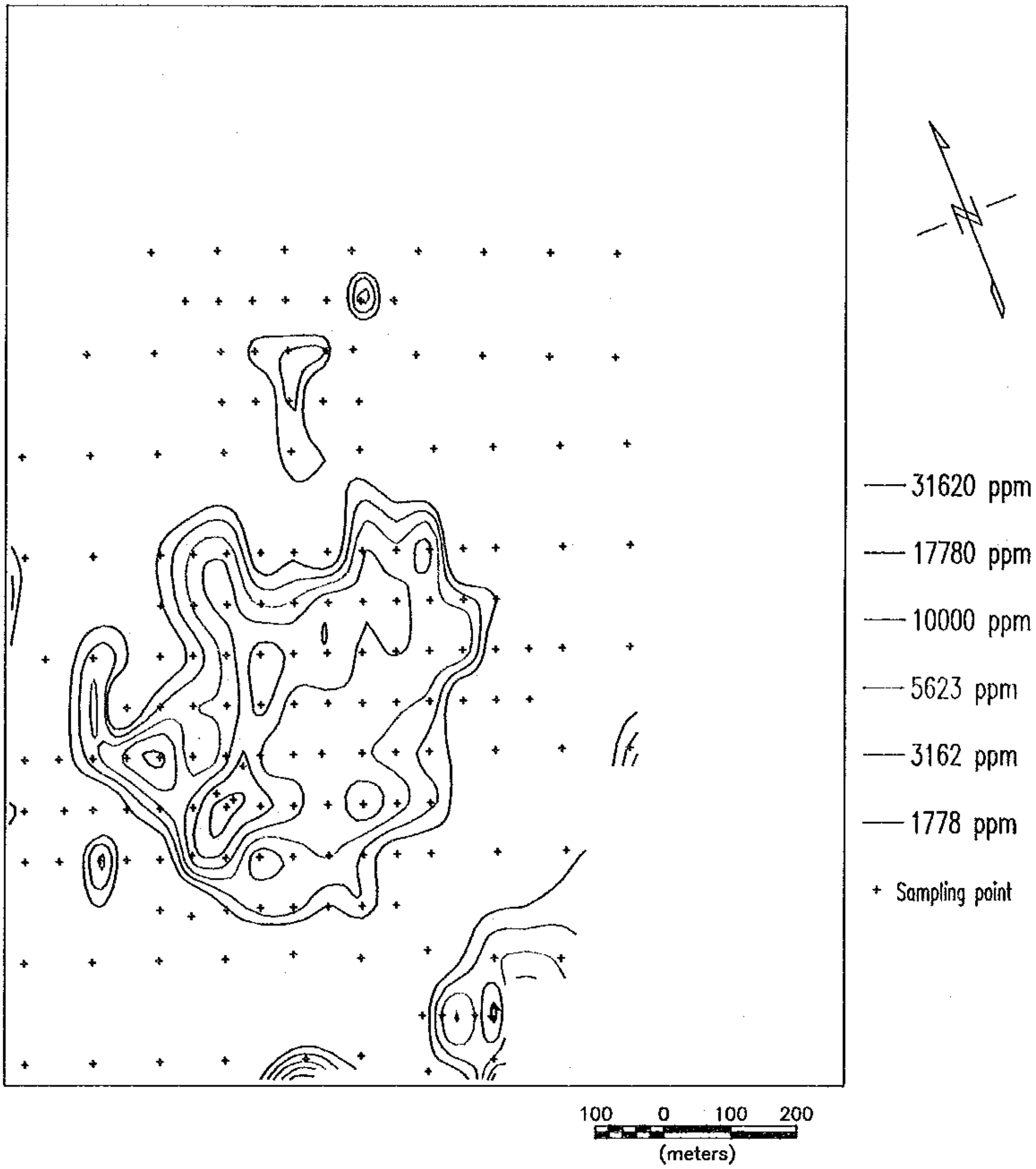

Fig.II-3-11 Distribution of Mn content at the Kalkfeld Area

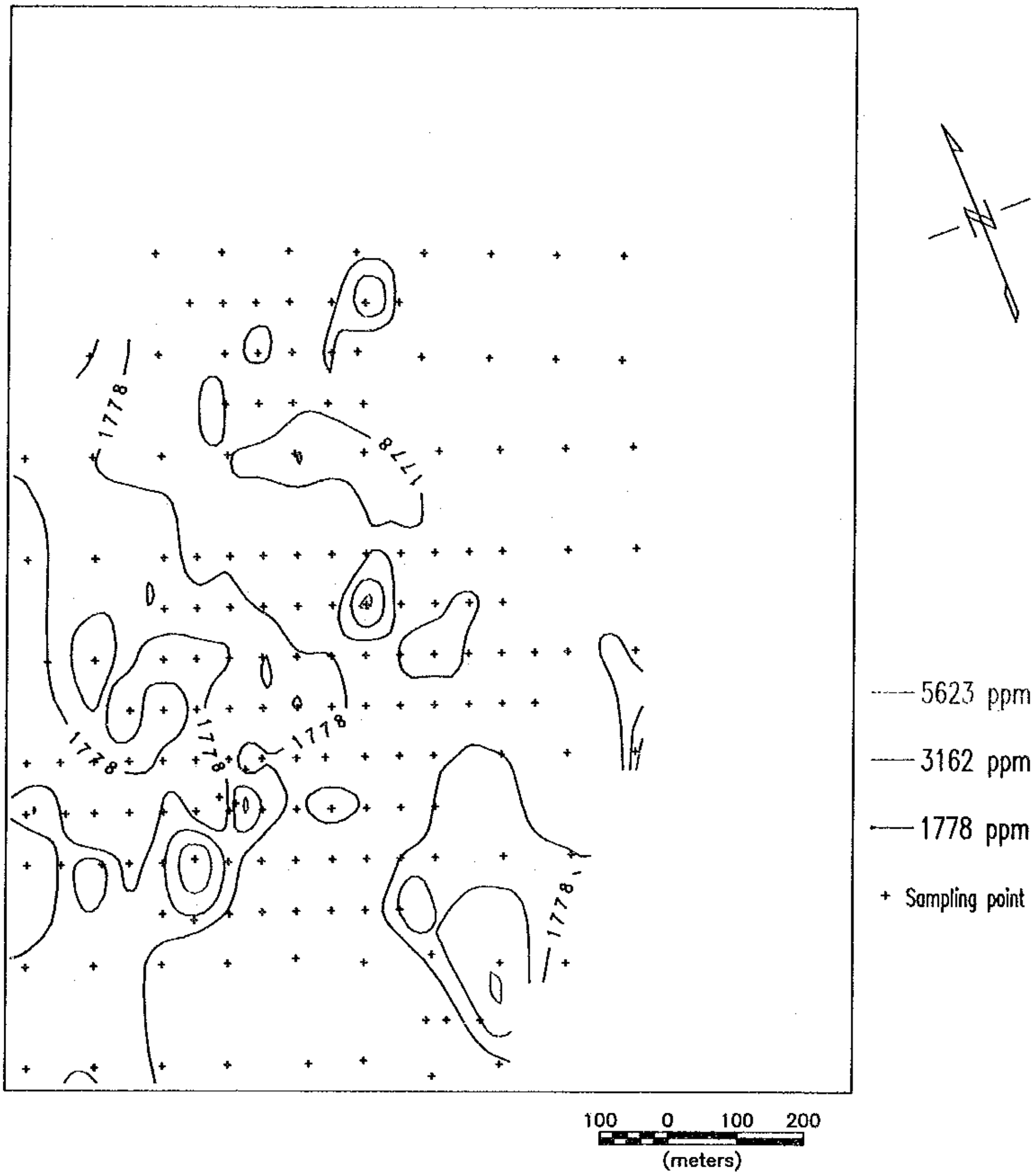

Fig.II-3-12 Distribution of Sr content at the Kalkfeld Area

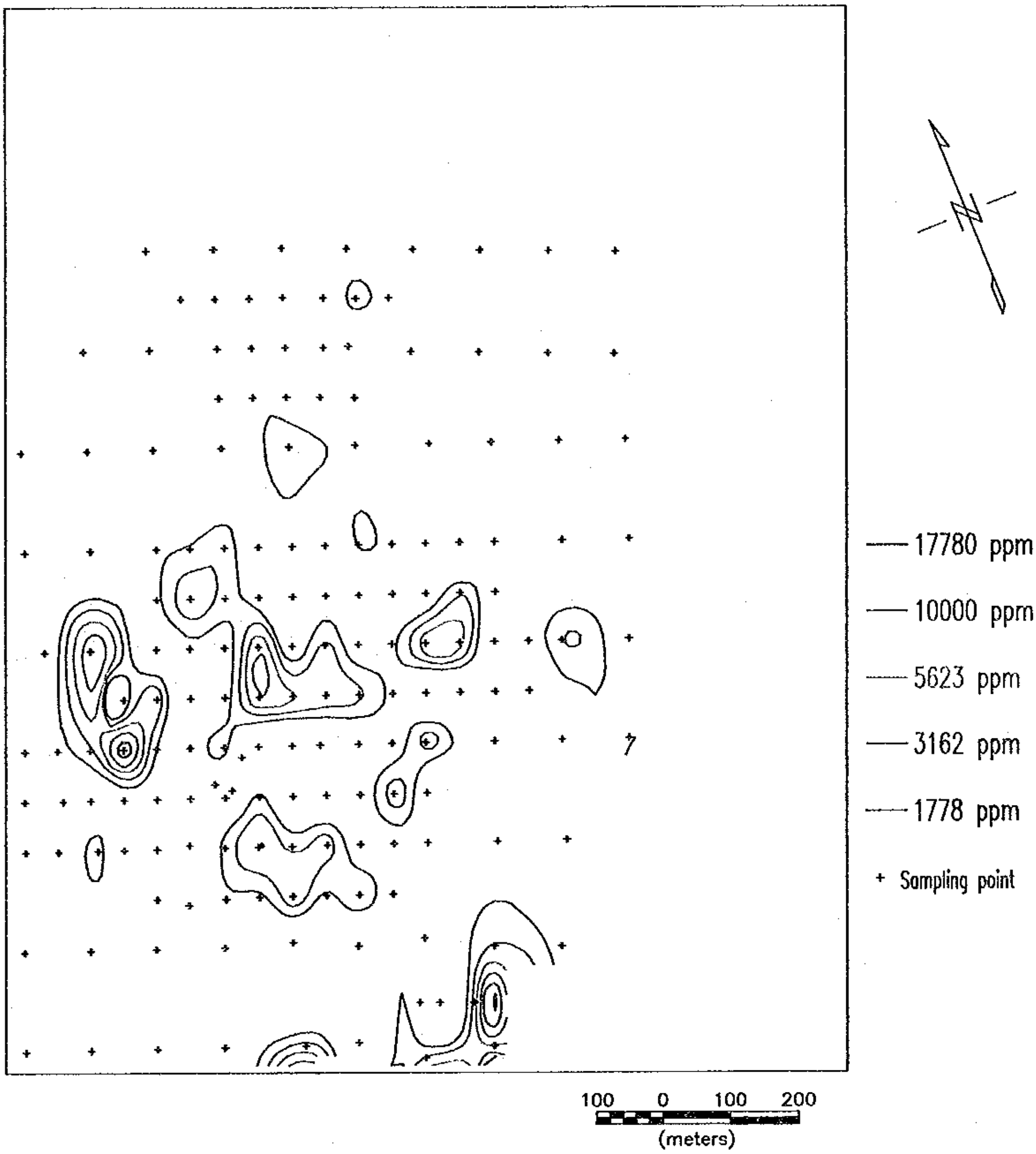

Fig.II-3-13 **Distribution of P content at the Kalkfeld Area**

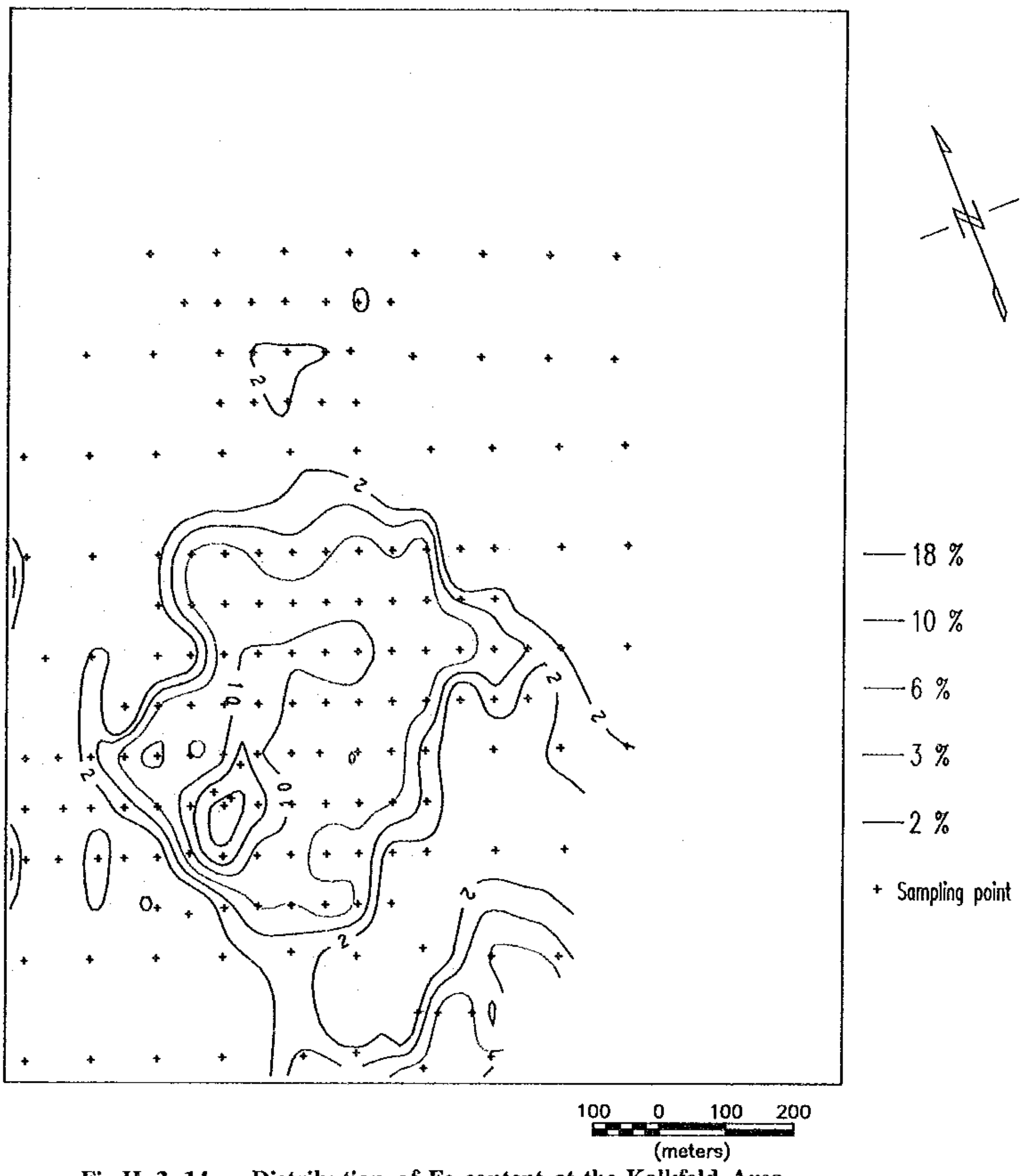

Fig.II-3-14 Distribution of Fe content at the Kalkfeld Area

but extremely concentrated zone more than 10,000 ppm is not found.

2. Sc and Y

Distribution of Y content is shown in Fig.II-3-7.

There is no zone showing remarkable concentration of Y.

3. U and Th

Distribution of Th content is shown in Fig.II-3-8.

The zone of high concentration of Th is concordant with the shape of the diatreme. Average content of Th in the diatreme is 10 times higher than that of beforsite in the orange area. High concentrated zone higher than 1,000 ppm of Th occurs in the iron ore and beforsite rich in Fe. It was described that the iron ore in the Kalkfeld complex contains about 0.5 % ThO_2 (Verwoerd, 1967). It shows similar character in both iron ores.

4. Nb and Ta

Distribution of Nb content is shown in Fig.II-3-9.

There is no high concentrated zone of Ce relative to that in the Orange area.

5. Zr

Distribution of Zr content is shown in Fig.II-3-10.

The content of Zr is relatively high in volcanic breccia and granitoid in the area. The distribution of Zr content shows no remarkable character to discuss.

6. Mn

Distribution of Mn content is shown in Fig.II-3-11.

The high concentrated zone more than 10,000 ppm of Mn occurs in iron ore and beforsite. Some of marble with interstitial carbonatite shows high content of Mn.

7. Sr

Distribution of Sr content is shown in Fig.II-3-12.

The high concentrated zone more than 10,000 ppm of Sr occurs in parts of iron ore and beforsite. Marble also shows relatively high content of Sr relative to the wall rocks in the Orange area.

8. P

Distribution of P content is shown in Fig.II-3-13.

It shows the heterogeneous distribution of P in the same rock facies. In some specimens, high contents more than 10,000 ppm are found.

9. Fe

Distribution of Fe content is shown in Fig.II-3-14.

The distribution of high concentrated zone of Fe is concordant with the shape of the diatreme. It shows the characteristic high concentration of Fe in iron ore and beforsite.

II-3-4 Conclusions

Although many interstitial carbonatite veins occur in marble and granites, there are no remarkable fenitization and alkaline metasomatism.

The high concentrated zones of Ce, Th, Mn and Fe are found in the diatreme. Respectable concentrations of Nb and P in this area are not found to correlate with those in the Orange area.

It shows the difference patterns of the concentration of REEs, Nb, P, Th etc among the two beforsite bodies in the Orange area and the diatreme in the Kalkfeld area. It is necessary to consider the geochemical study based on this survey.

Part III

Conclusion and Recommendation

Part III Conclusions and Recommendation

Chapter 1 Conclusions

The phase I survey of this year contains the literature survey and geochemical survey. The results of this survey are described as follows:

Orange area

1) The area is covered by the Mokolian Namakua metamorphic complex (1,200 Ma) of precambrian age and Nama group sedimentary rocks of cambrian age (560 to 500 Ma). The carbonatite complex intrudes these basement rocks in plutonic plug shape.

2) The carbonatite complex comprise a part of the Kuboos-Bremen line of alkaline rock complexes, which aligns northeast to southwest. The carbonatite complex is formed at the intersection of the Kuboos-Bremen line and post-Karoo faults.

3) The carbonatite complex has four main intrusive centers. The order of the intrusion as syenite, sövite, beforsite, small dykes is observed in some centres.

4) Major minerals of carbonatite are of calcite, dolomite and ankerite. Subordinated minerals are of siderite, manganocalcite, apatite, barite, magnetite, hematite, bastnaesite, monazite and pyrochlore. Last three minerals contain La, Ce, Nd and Nb.

5) Geochemical survey indicates the concentration of La, Ce, Nd, Nb and P in carbonatite complex. Particularly two isolated beforsite bodies and its periphery concentrate La, Ce, Nd and Nb. One of two beforsite bodies concentrates phosphorus.

6) Compared with carbonatite in the Kalkfeld area, Nb and P are dominant.

7) The erosion level is intermediate, because the complex form by erosion indicates shallow plutonic type. Therefore it should be promise for rare earth, Nb and P elements to be dominant at the shallow underground level, compared with other similar carbonatite occurrences as Ondurakorume and Phalaborwa.

Kalkfeld area

1) The area is underlain by the basement rocks which comprise Damara Sequence (720 to 900 Ma) of Precambrian age. Salem Granite (500 to 530 Ma) of Cambrian and carbonatite complex intrude the basement rocks.

2) This carbonatite complex called the Osongombo diatreme and its peripheral carbonatite complexes of Kalkfeld, Ondurakorume and Okorusu, are situated in the Damarand alkaline province, and align straight in the direction of northeast to southwest.

3) Carbonatite complex comprises volcanic breccia, beforsite and iron ore. This complex shows diatreme in intrusive shape. Volcanic breccia, beforsite and iron ore in order intrude in wall rocks.

4) Major minerals of the carbonatite are of dolomite and ankerite. Subordinated minerals are of manganocalcite, calcite, strontianite, apatite, goethite, hematite, barite and pyrochlore. Iron ore and iron rich beforsite contain respectable content of Th.

5) Geochemical survey indicates the concentration of La, Ce, Nd, Th, Mn, Sr and P in the diatreme. Particularly beforsite body concentrates La, Ce, Nd, Nb and P. Iron ore concentrates Th, Mn and Fe.

6) Compared with carbonatites in the Orange area, Th, Mn and Fe are dominant.

7) The erosion level is shallow, because the complex form by erosion indicates volcanic neck type. Therefore it is assumed that REEs, Nb and P would be dominant at the considerably deeper level, compared with other similar carbonatite occurrences.

Chapter 2 Recommendation for the Phase II

The following recommendations for Phase II are proposed based on the results and consideration of Phase I of this fiscal year.

Orange area

It is clarified that beforsitic carbonatite concentrates REEs. But the distribution of the REEs is not homogenous in the beforsitic body. This heterogeneity is caused by the differences of texture and mineral assemblage in the beforsitic body. Therefore to clarify the underground occurrences of rare earth elements, it is important to conduct more detailed geological field survey and geochemical survey. And in addition to the superficial and horizontal distribution of rare earth elements, underground occurrences should be clarified by pilot drilling survey, because prominent concentration at shallow level is expected by other similar carbonatite as Ondurakorume and Phalaborwa. From these view points, Phase II survey should be carried out as follows:

1) Survey area

Two beforsite distribution area and its periphery

2) Survey Method

Geological survey
Geochemical survey
Drilling survey

3)Items of the Surveys

Geological survey
Geological structure survey
Lithology and rock texture survey
Laboratory works
X-ray diffraction, Thin section and Polished Section examinations

Geochemical survey

Rock geochemical survey

Detailed geochemical survey

Chemical analyses

(La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, Sc, Y, U, Th, Nb, Ta, Zr, Fe, Mn, Sr and P)

Drilling survey

Lithology and rock texture survey

Chemical analyses

(La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, Sc, Y, U, Th, Nb, Ta, Zr, Fe, Mn, Sr and P)

Laboratory works

X-ray diffraction, Thin section and Polished Section examinations

Kalkfeld area

The distribution area of beforsitic carbonatite which contains rare earth elements does is not wide. The high concentration of Th and REEs is assumed to be dominant at fairy deep level, compared other similar carbonatite occurrences. Therefore the survey of this area should be done at the other step after the consideration of underground occurrences of the orange area by the Phase II survey.

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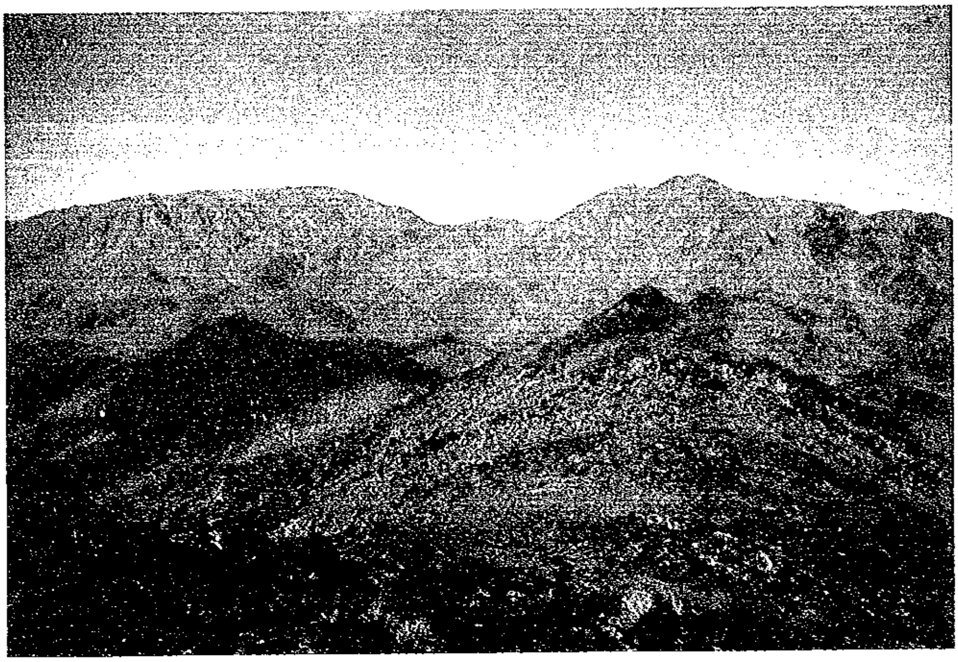
Appendices

A-1 Photographs of Survey Areas

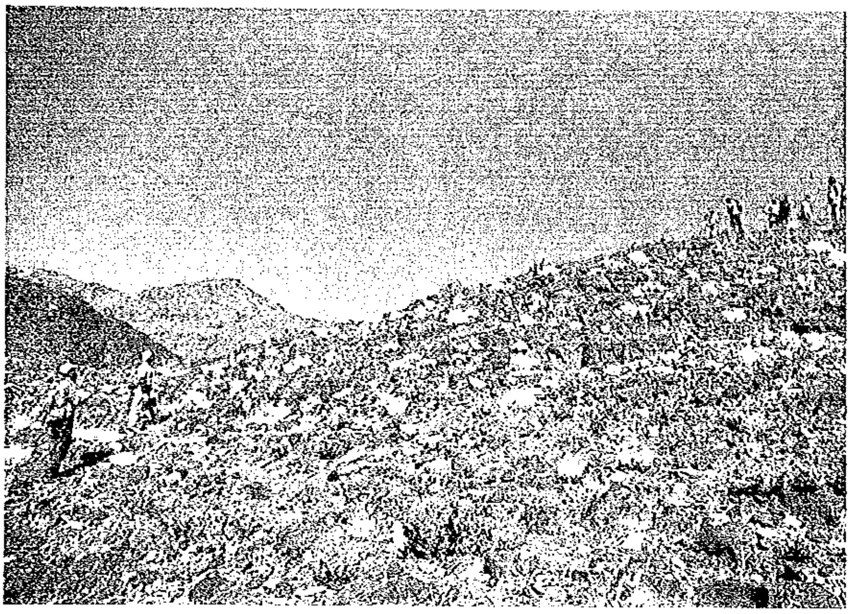
A-1 Photographs of the Survey Area



Overlooking of the Orange Area

Overlooking of the Kalkfeld Area

A-1 Photographs of the Survey Area

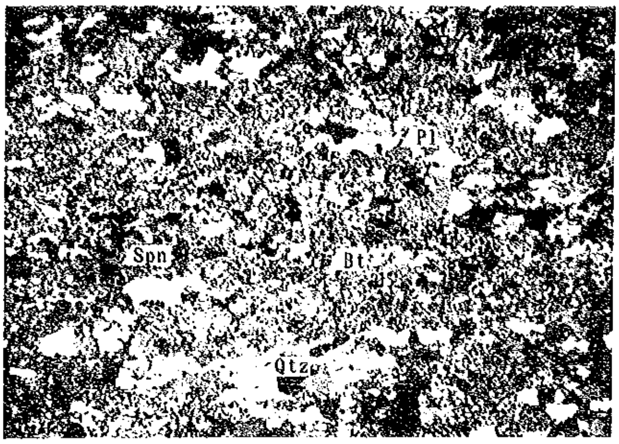


Measurement of a Sampling Line (the Orange Area)

Measurement of a Sampling Line (the Kalkfeld Area)

A-2 Microphotographs of Thin Sections

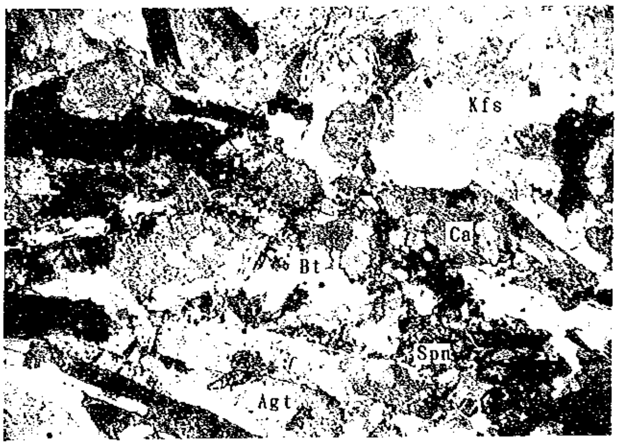
Open nicol 0.7mm



Cross nicol 0.7mm

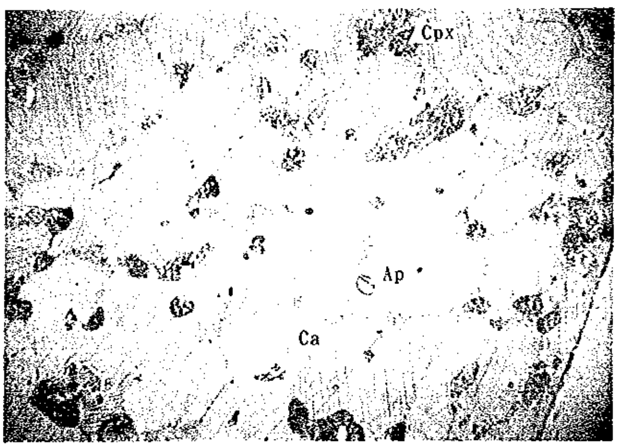
Sample No. A 90
Formation Namaqua Metamorphic Complex
Rock name Gneiss
Locality The Orange Area

Open nicol 0.7mm

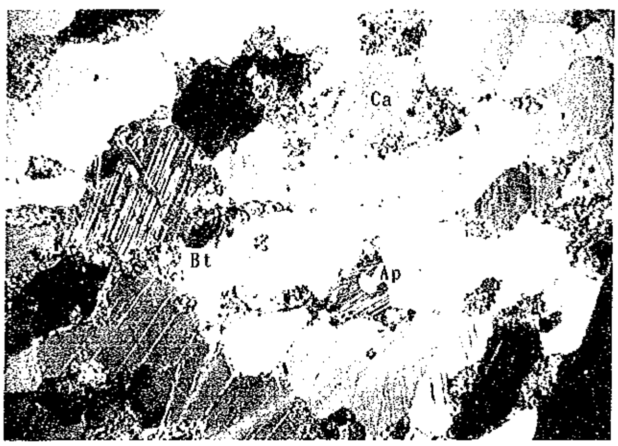


Cross nicol 0.7mm

Sample No. I 80
Formation Marinkas Quelle Carbonatite Complex
Rock name Syenite
Locality The Orange Area



Open nicol 0.7mm



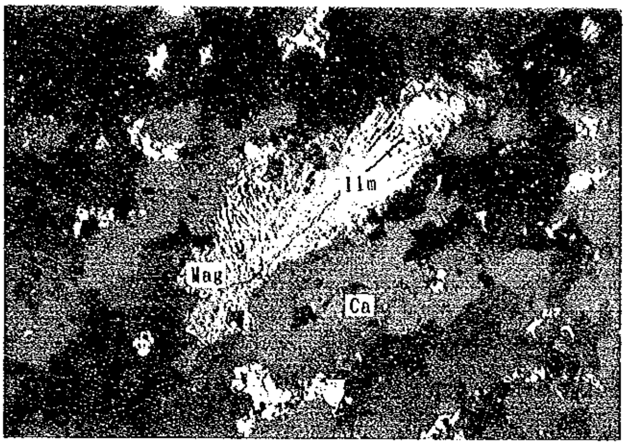
Cross nicol 0.7mm

Sample No. R 20
Formation Damara Sequence
Rock name Calcite Marble
Locality The Kalkfeld Area

A-3 Microphotographs of Polished Sections

Open nicol 0.5mm

Sample No. E 50
Formation Marinkas Quelle Carbonatite Complex
Rock name Beforiste
Locality The Orange Area

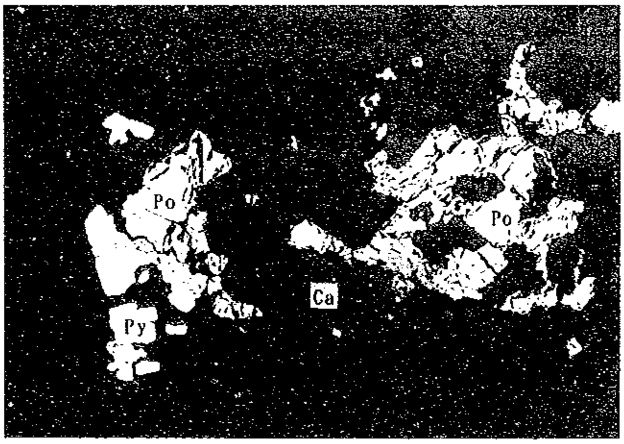


Open nicol 0.5mm

Sample No. Ea 51(No.2)
Formation Marinkas Quelle Carbonatite Complex
Rock name Beforiste
Locality The Orange Area

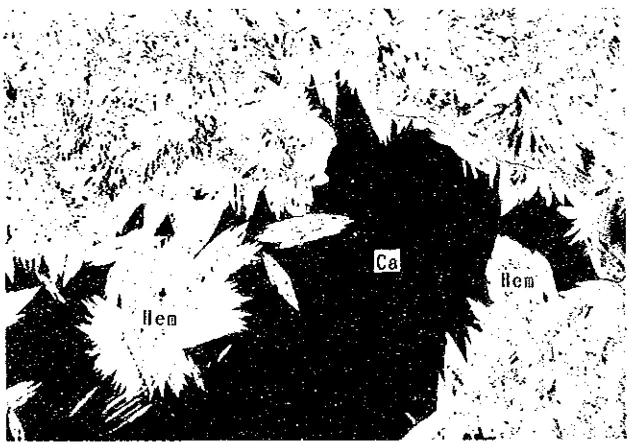
Open nicol 0.5mm

Sample No. N 12
Formation Marinkas Quelle Carbonatite Complex
Rock name Leuco-syenite
Locality The Orange Area



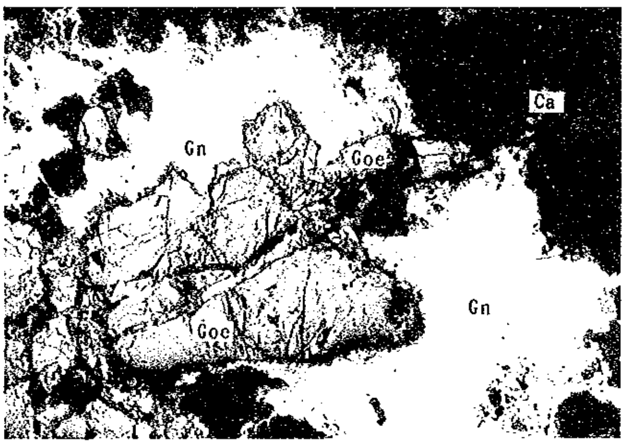
Open nicol 0.5mm

Sample No. Na 12
Formation Marinkas Quelle Carbonatite Complex
Rock name Porphyritic Syenite
Locality The Orange Area



Open nicol 0.5mm

Sample No. Sa40
Formation Osongomo Diatreme
Rock name Beforsite
Locality The Kalkfeld Area



Open nicol 0.5mm

Sample No. U 45
Formation Osongomo Diatreme
Rock name Beforsite
Locality The Kalkfeld Area