PNC TN7410 94-015 TR-GE93-03

Data Compilation of Geoscientific Studies of Tono Uranium Deposits, Central Japan

MARCH 1 9 9 4

TONO GEOSCIENCE CENTER

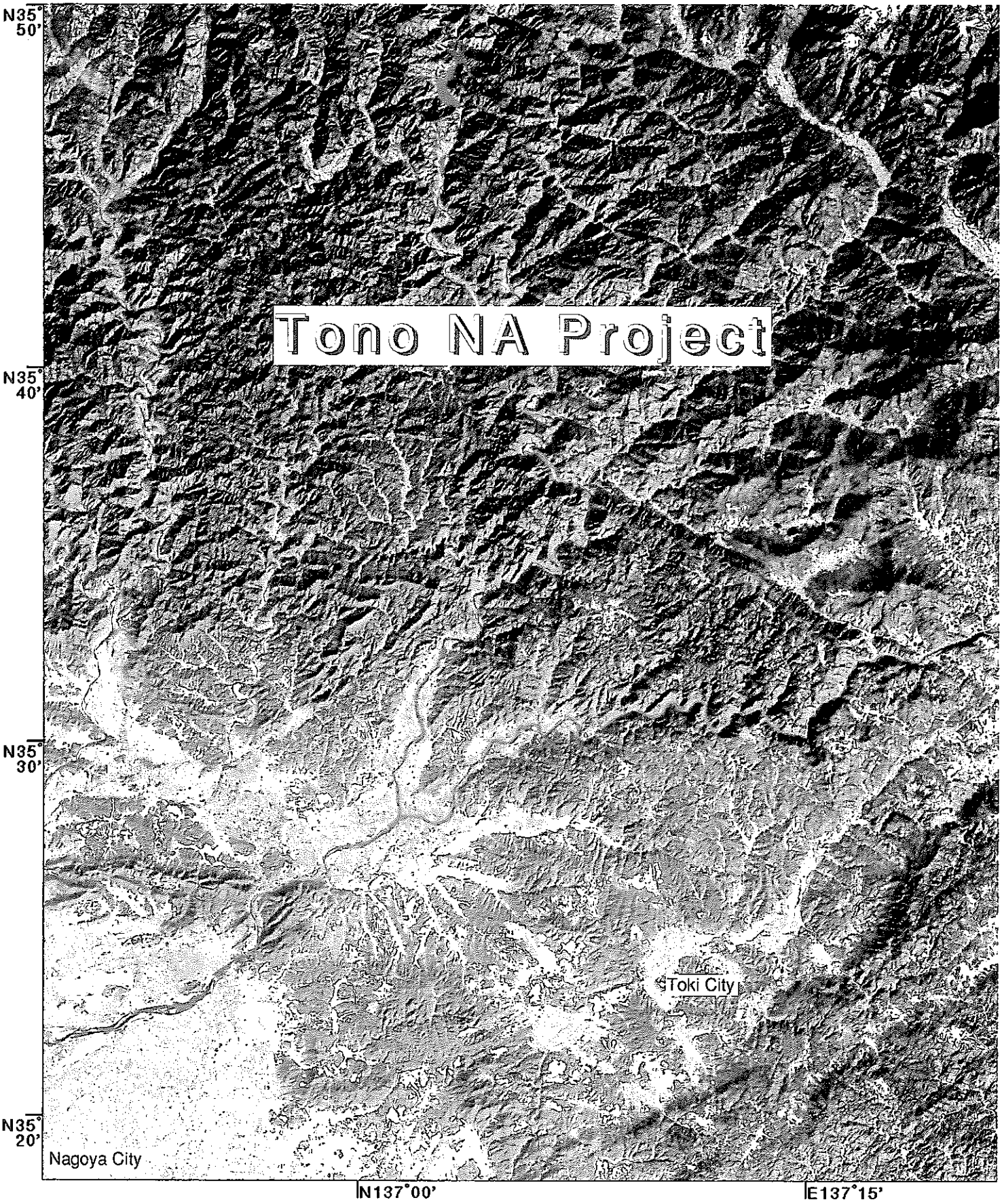
POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION

Data Compilation of Geoscientific Studies of Tono Uranium Deposits, Central Japan

H.Yoshida, T.Seo, T.Nohara, K.Ota, K.Hama, K.Kodama, T.Iwatsuki

CHUBU WORKS
POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION
959-31 SONODO JORINJI TOKI-CITY 509-51 JAPAN

LANDSAT-5 TM 109-35(D) 1985/11/21 NASDA/RESTEC PNC/CHUBU/KID930701



Data Compilation of Geoscientific Studies of Tono Uranium Deposits, Central Japan

CONTENTS

DATA COMPILATION OF GEOSCIENTIFIC STUDIES OF TONO URANIUM DEPOSIT, CENTRAL JAPAN

1. INTRODUCTION

Results to data of the geological, geochemical and hydrogeological studies in the Tono site has been prepared as an aid to discussion of the joint PNC/Nagra Tono Analogue Project (TAP). It forms a outline of a geological, geochemical and hydrogeological studies which have been conducted in the Tono site and includes an data which could be assessed by participants of the TAP.

This catalogue has been compiled as a rather overall information which will act as a basis to evaluate the feasibility of the TAP.

2. GENERAL DESCRIPTION OF THE ACTIVITY IN THE TONO AREA

Tono is the site of Japan's most extensive uranium deposit. The Tono deposits are hosted by Neogene sedimentary rocks. A gallery has been constructed at a depth of 130 meters below ground surface in the Tsukiyoshi ore body, which is the largest one in the Tono area. The ore body has not been exploited, hence, the gallery enables the participants to observe an showing of uranium in a relatively undisturbed state.

The main objectives of the investigations in the Tono area are to provide data for performance assessment modelling and to develop methods for site characterization. The information from Tono will be used as a case study to illustrate how a simplified geological model can be developed from site-specific data. The main field studies have been performed in gallery, several boreholes. Also, hydrological and geochemical instruments have been developed for the hydraulic and geochemical assessments and for underground surveys. The studies include the following components:

- Geology
- Mineralogy and petrology
- Hydrogeology
- Hydrogeochemistry
- Development of instruments

3. LIST OF INFORMATION

Index map of information

(1)Regional scale

Regional scale index

R-1: Location map of the Tono uranium deposits

R-2: Geological map of the Tono area

R-3: Geologic cross section of the Tono area

R-4: Schematic geologic column of the Tono area

R-5: Basement contour map of the Tono area

R-6: Schematic structural map of the Tono area

(2)Site scale

Site scale index

S-1: Map of summit levels of the Tono site

S-2: Uranium distribution map of the Tsukiyoshi ore body

S-3: Chemical and mineral compositions of the each formation

S-4: Results of hydraulic testing in the basement granite

S-5: Distribution of activity ratio ($^{234}U/^{238}U$, $^{230}Th/^{238}U$) for the four points (A, B, C, D) in the Tsukiyoshi ore body

(3)Block scale

Block scale index

B-1: Location map of the boreholes for hydrogeochemical and hydrological investigations

B-2: Sampling points of the groundwater

B-3: Chemistry of the groundwater

B-4: Chemical properties of the groundwater

B-5: δD-$\delta^{18}O$ diagram of the groundwater

B-6: Tritium concentration and ^{14}C ages of the groundwater

B-7: Uranium, radium and radon concentration of the groundwater

B-8: Measurement points of hydraulic conductivities

B-9: Hydraulic conductivities of the basement granite and the sedimentary rocks

B-10: Groundwater pressure (piezo head) contours

B-11: Instruments for the hydrogeochemical and hydrological investigations

B-11-1: PNC groundwater sampler

B-11-2: Multiple piezometer system (MP system)

B-11-3: PNC aquifer testing equipment

B-12: Location map of the facilities in the Tono mine

(4)Detailed scale

Detailed scale index 1

D-1: Information from uranium-series disequilibrium studies carried out on a 1-meter rock cube in the ore zone.

D-1-1: Location map of the sampling area

D-1-2: Results of uranium-series disequilibrium analyses $(25cm)^3$, subcube blocks (64 data)

Detailed scale index 2

D-2: Monitoring data of physico-chemical properties of the groundwater in the ore body zone (KNA-2 borehole)

D-2-1: Schematic view of the monitoring system of the groundwater in the ore body zone

D-2-2: Chemical properties of the groundwater in the ore body zone

Detailed scale index 3

D-3: Information from uranium-series disequilibrium studies carried out on a boring core in the ore body zone (KNA-3 borehole)

D-3-1: Uranium contents and uranium-series disequilibrium of the ore body zone

D-3-2: Uranium contents and radioactivity ratios of rock specimens

(5)Micro scale

Micro scale index

M-1: SEM observation

M-2: Result of impregnation test

M-3: Cathodoluminescence

M-4: Qualitative chemical analyses

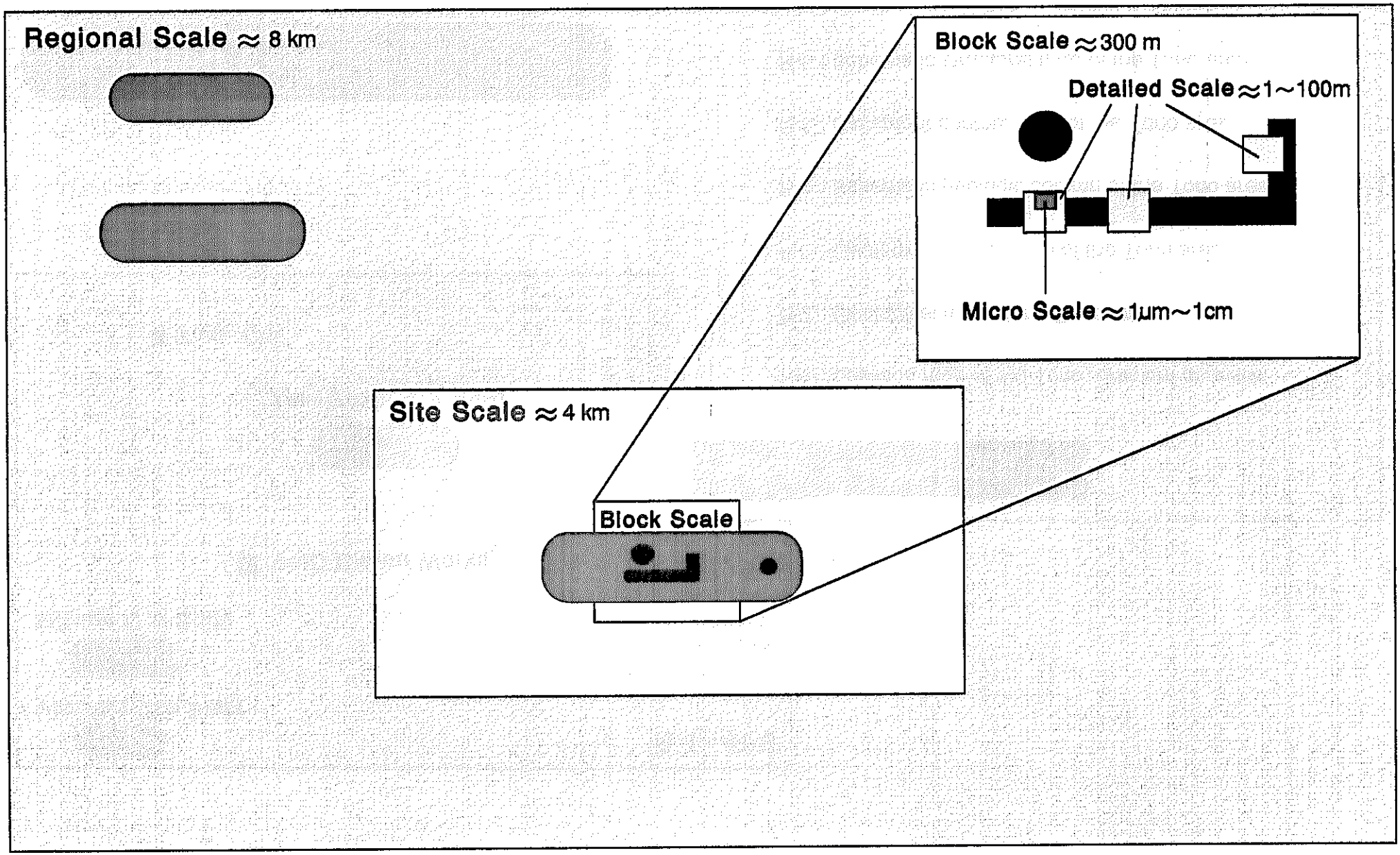
M-4-1: α-autoradiograph

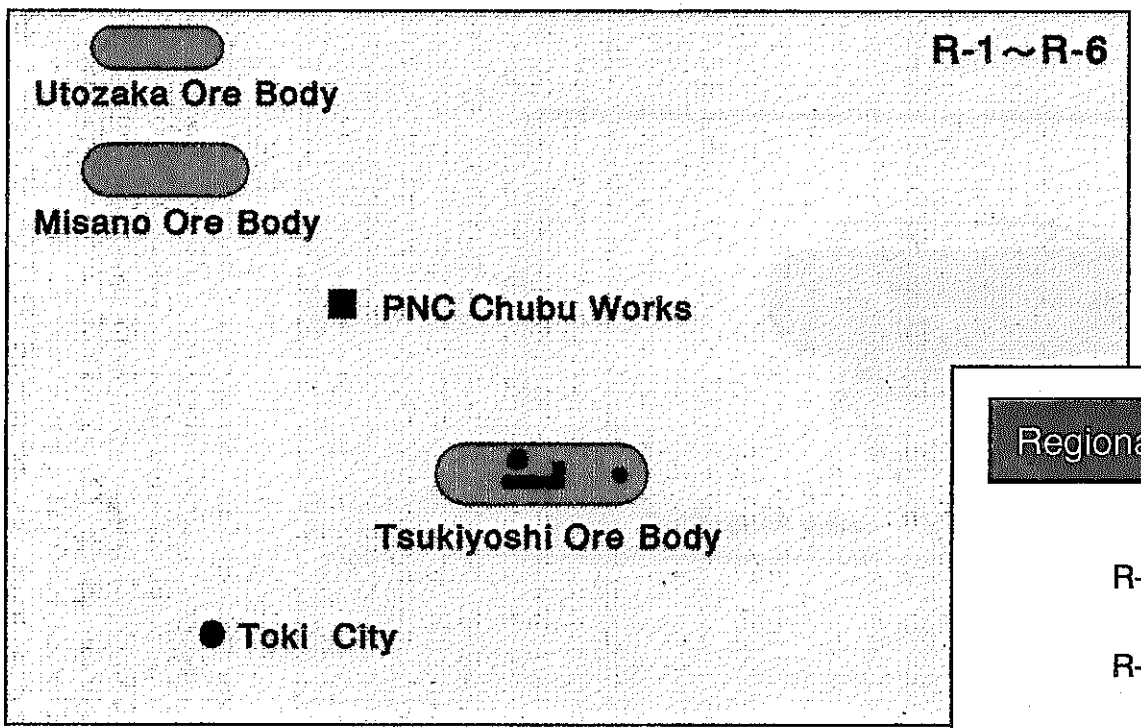
M-4-2: Characteristic X-ray photograph

M-4-3: Line profile

M-5: Quantitative chemical analyses (EPMA)

Index Map of Information





Regional Scale Index ≈ 8 km

Regional Scale Information List

R-1 : Location map of the Tono uranium deposits

R-2 : Geological map of the Tono area

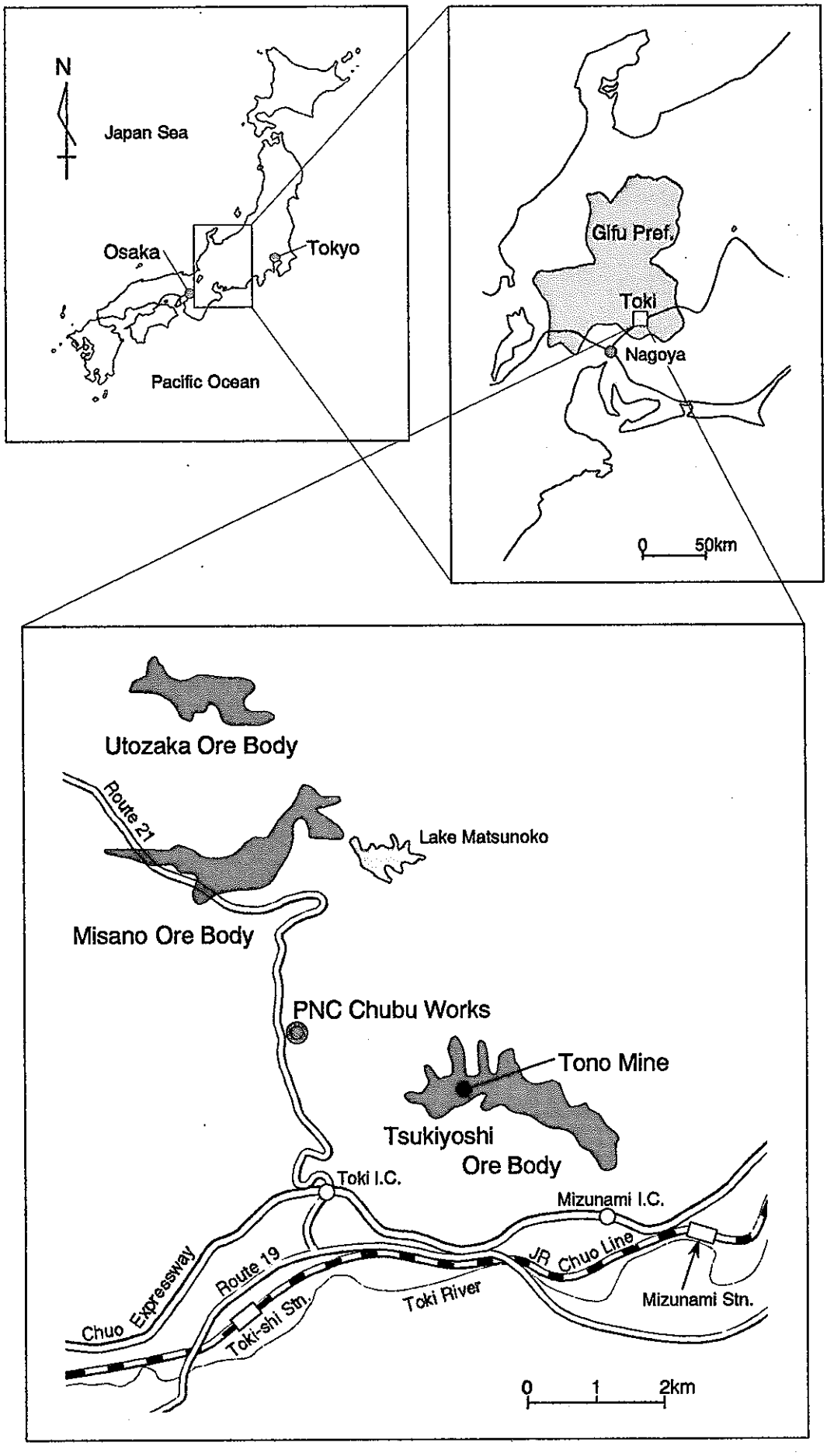
R-3 : Geologic cross section of the Tono area

R-4 : Schematic geologic column of the Tono area

R-5 : Basement contour map of the Tono area

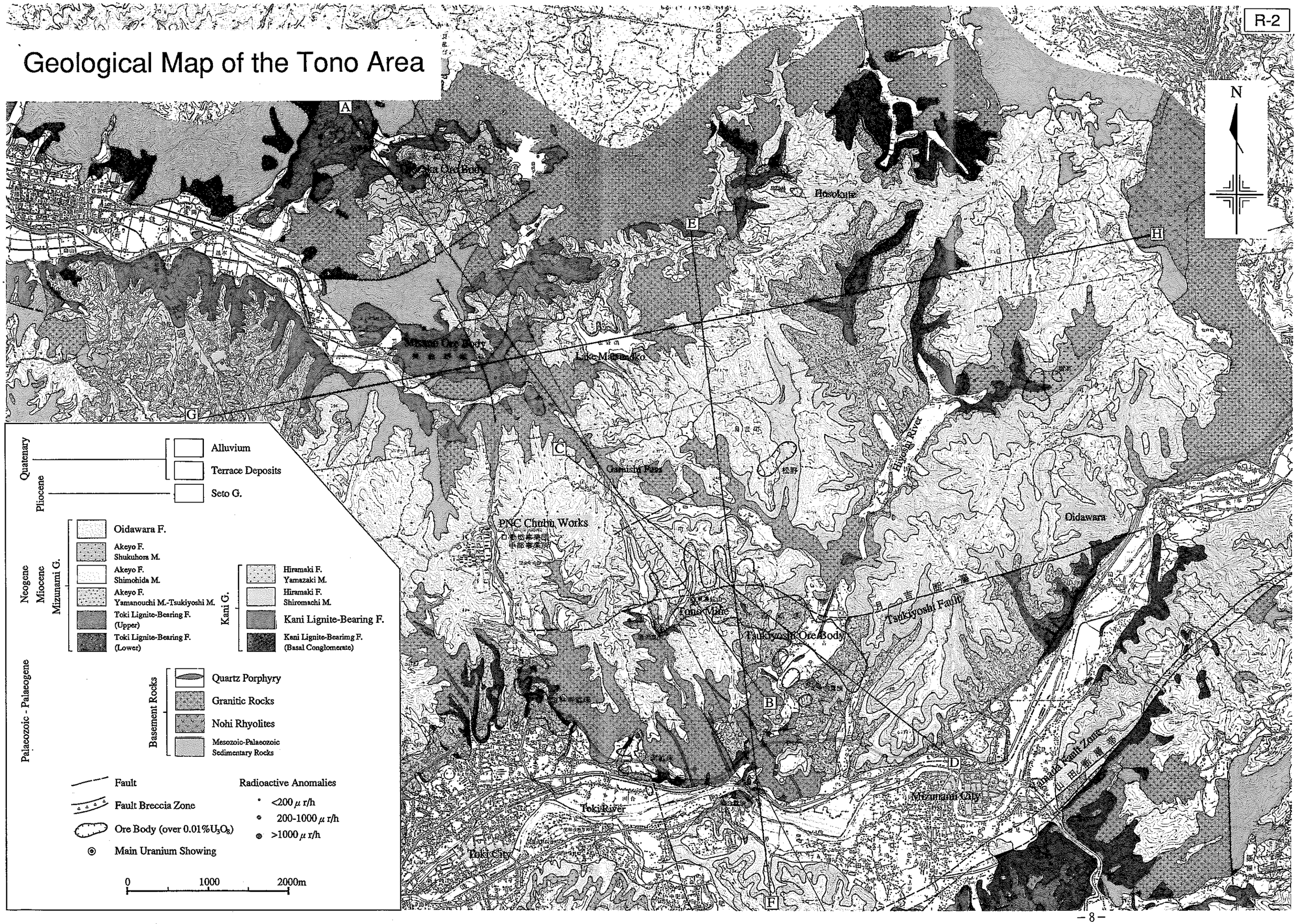
R-6 : Schematic structural map of the Tono area

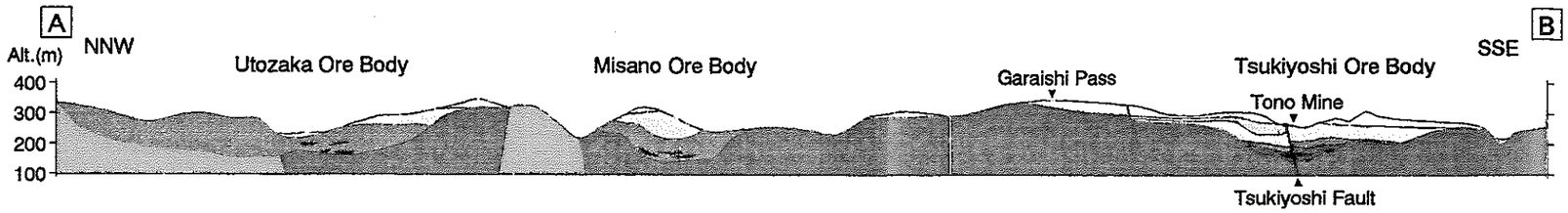
R-1

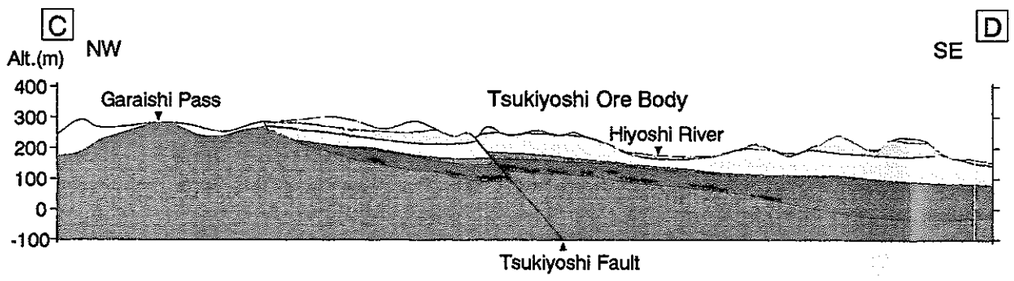


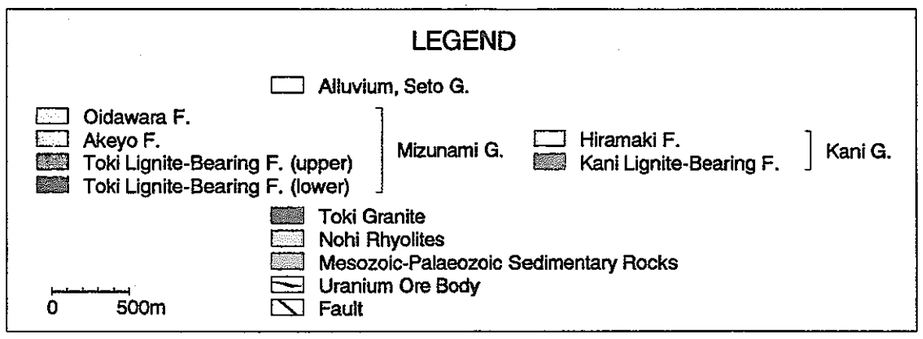
Location Map of the Tono Uranium Deposits

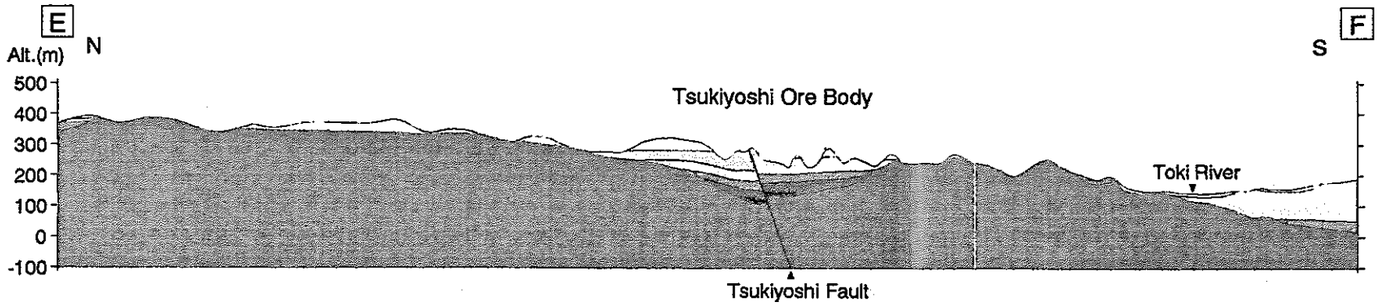
Geological Map of the Tono Area

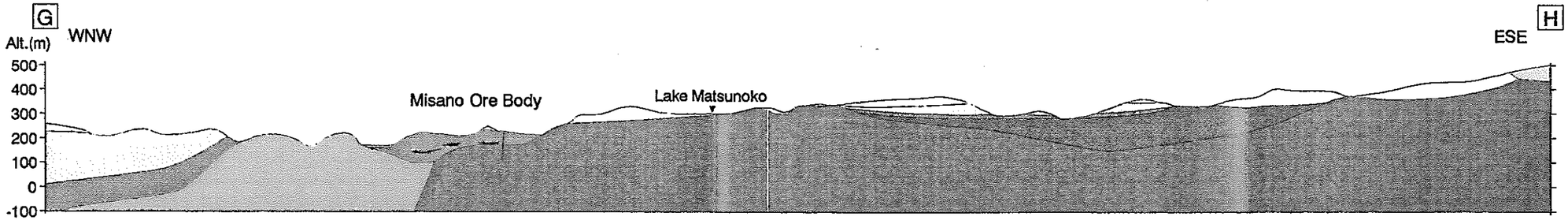




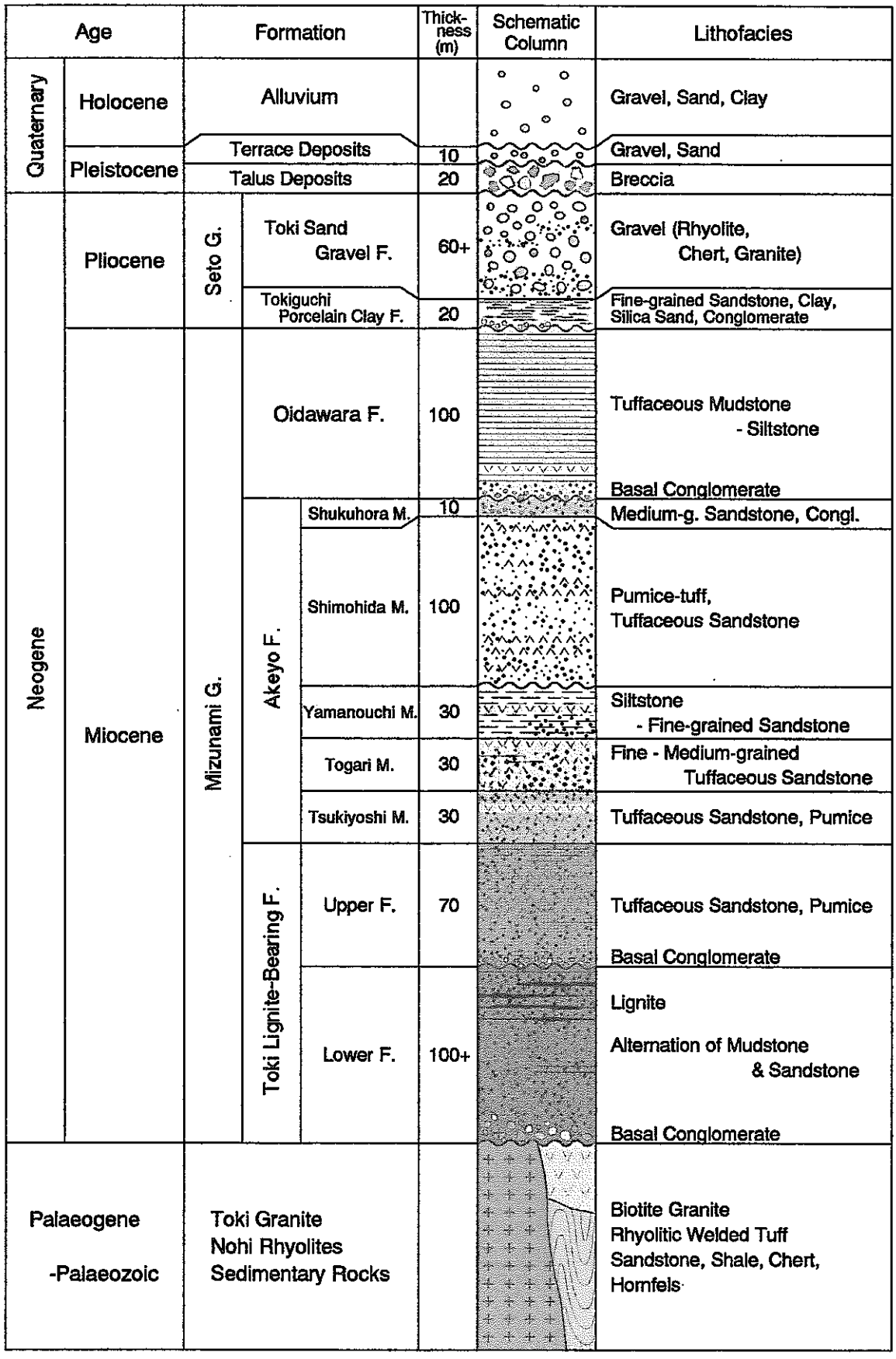








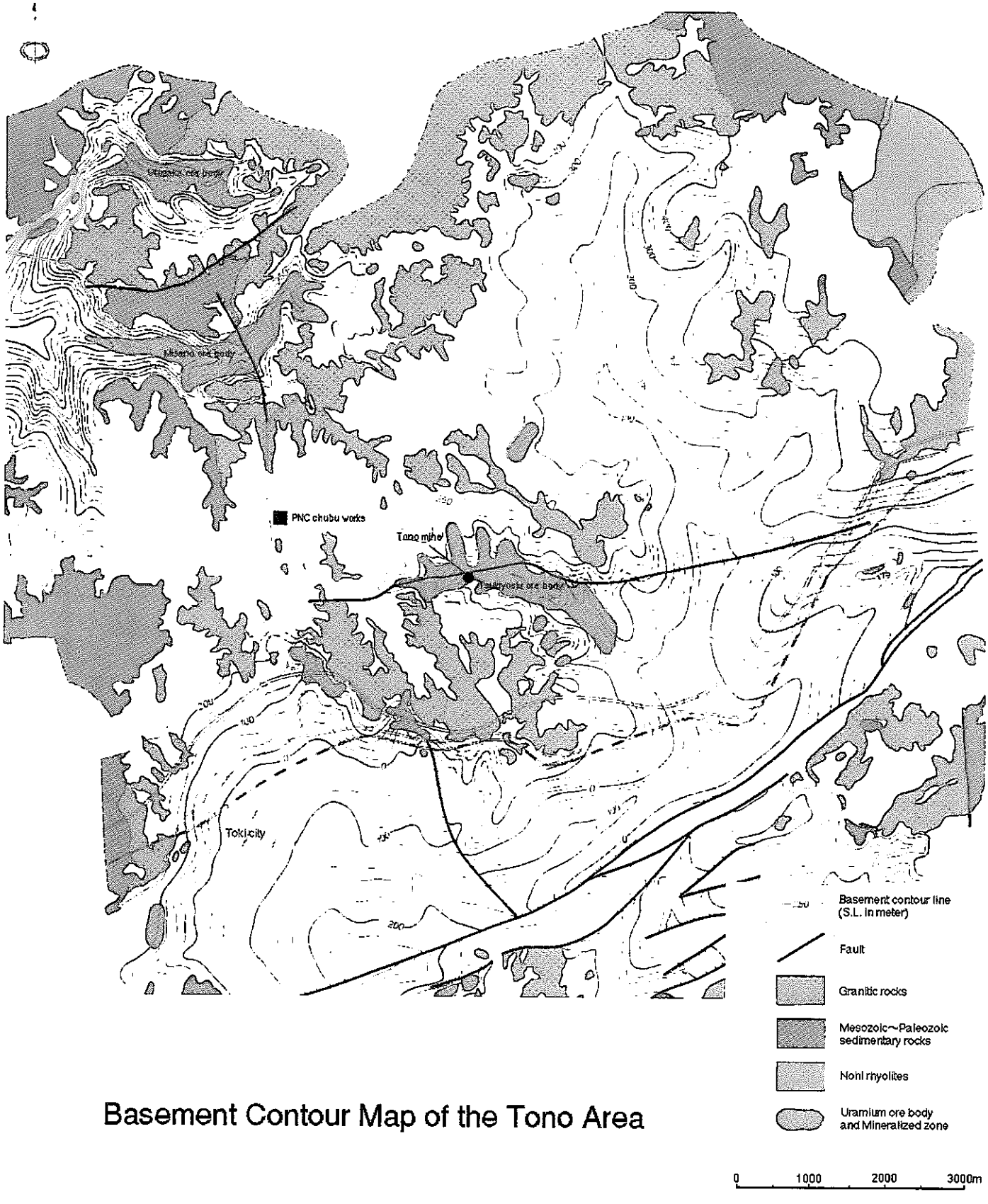
Geologic Cross Section of the Tono Area



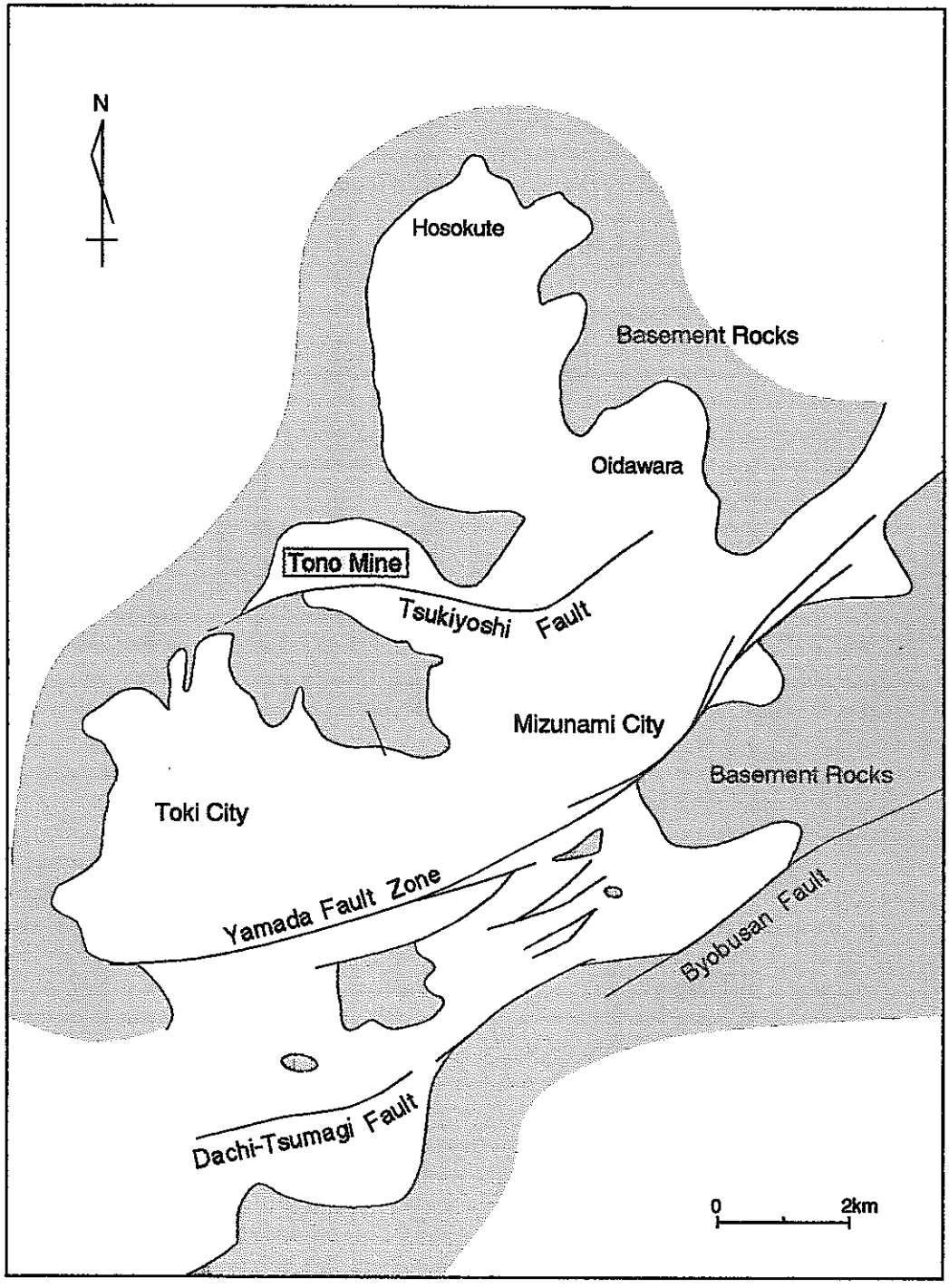
Schematic Geologic Column of the Tono Area

(modified from Itoigawa,1980)

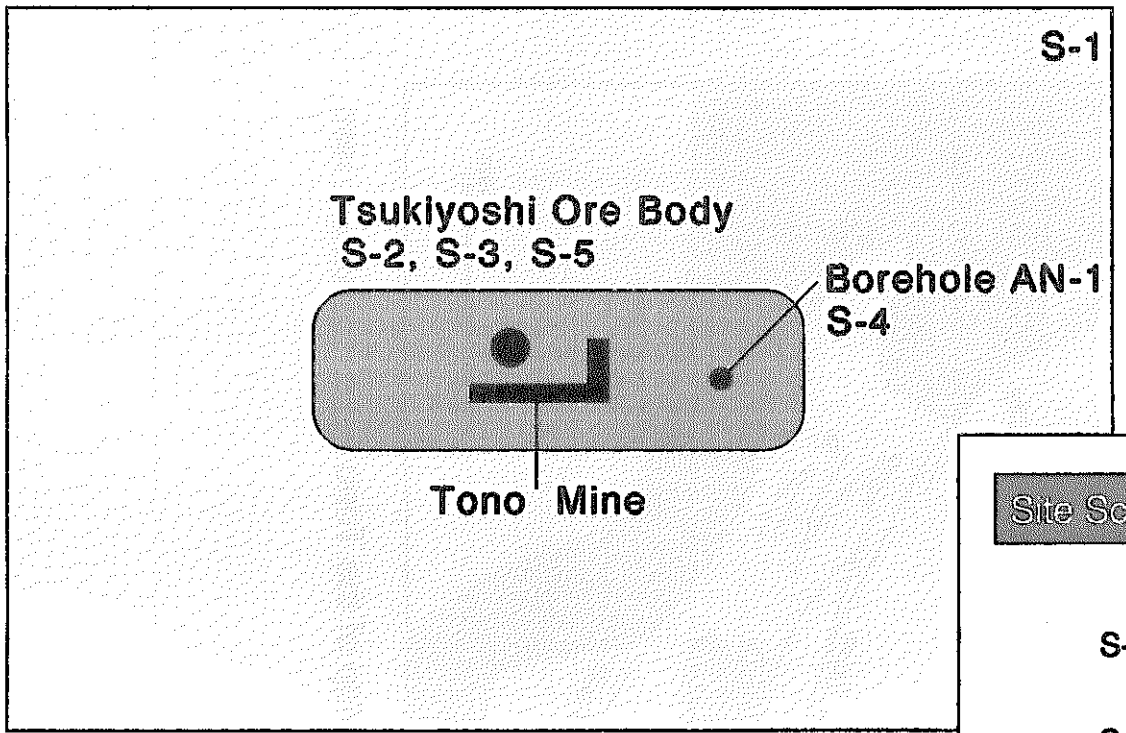
R-5



Basement Contour Map of the Tono Area



Schematic Structural Map of the Tono Area (after Uemura, 1961)



Site Scale Index ≈ 4 km

Site Scale Information List

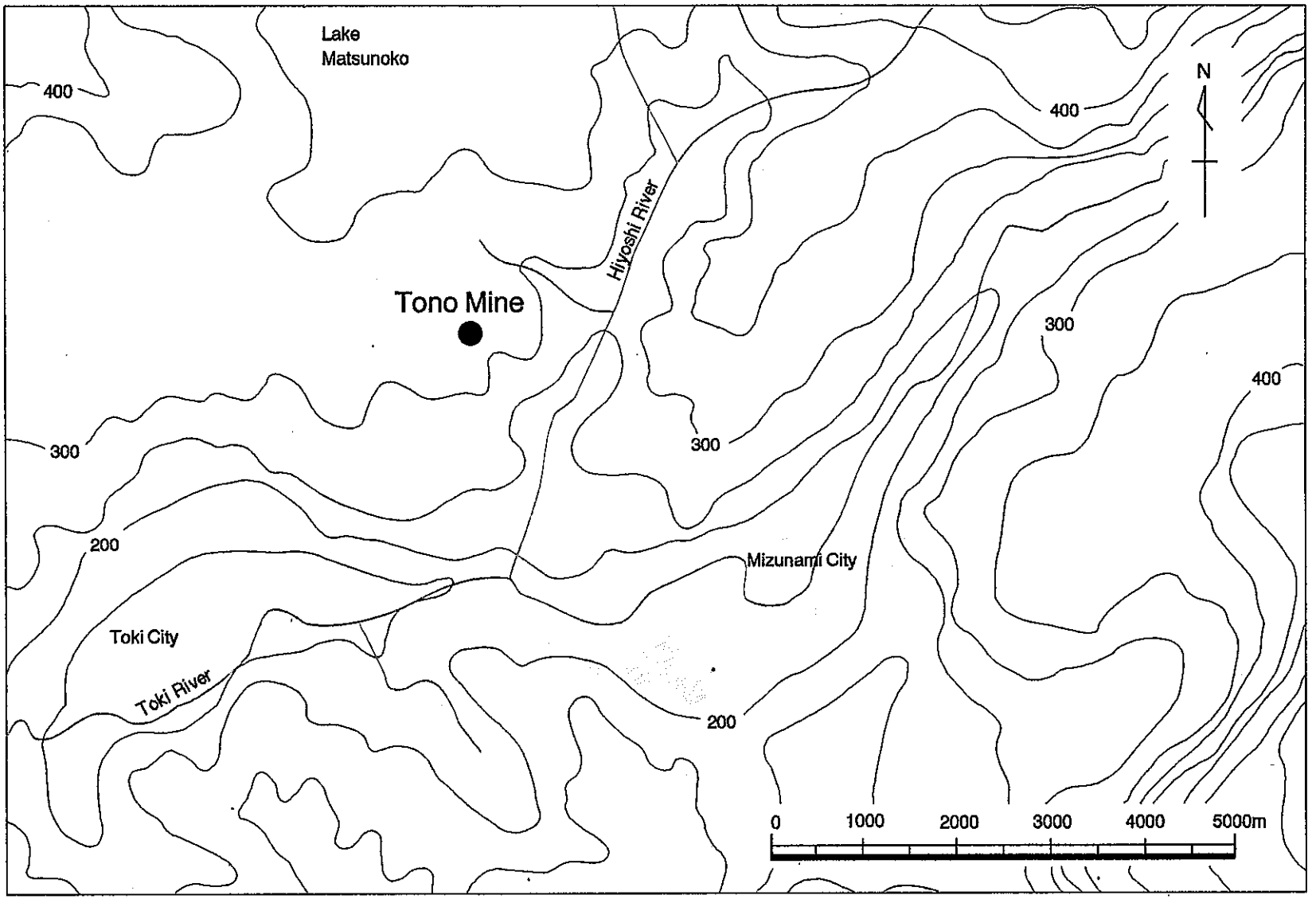
S-1 : Map of summit levels of the Tono site

S-2 : Uranium distribution map of the Tsukiyoshi ore body

S-3 : Chemical and mineral compositions of the each formation

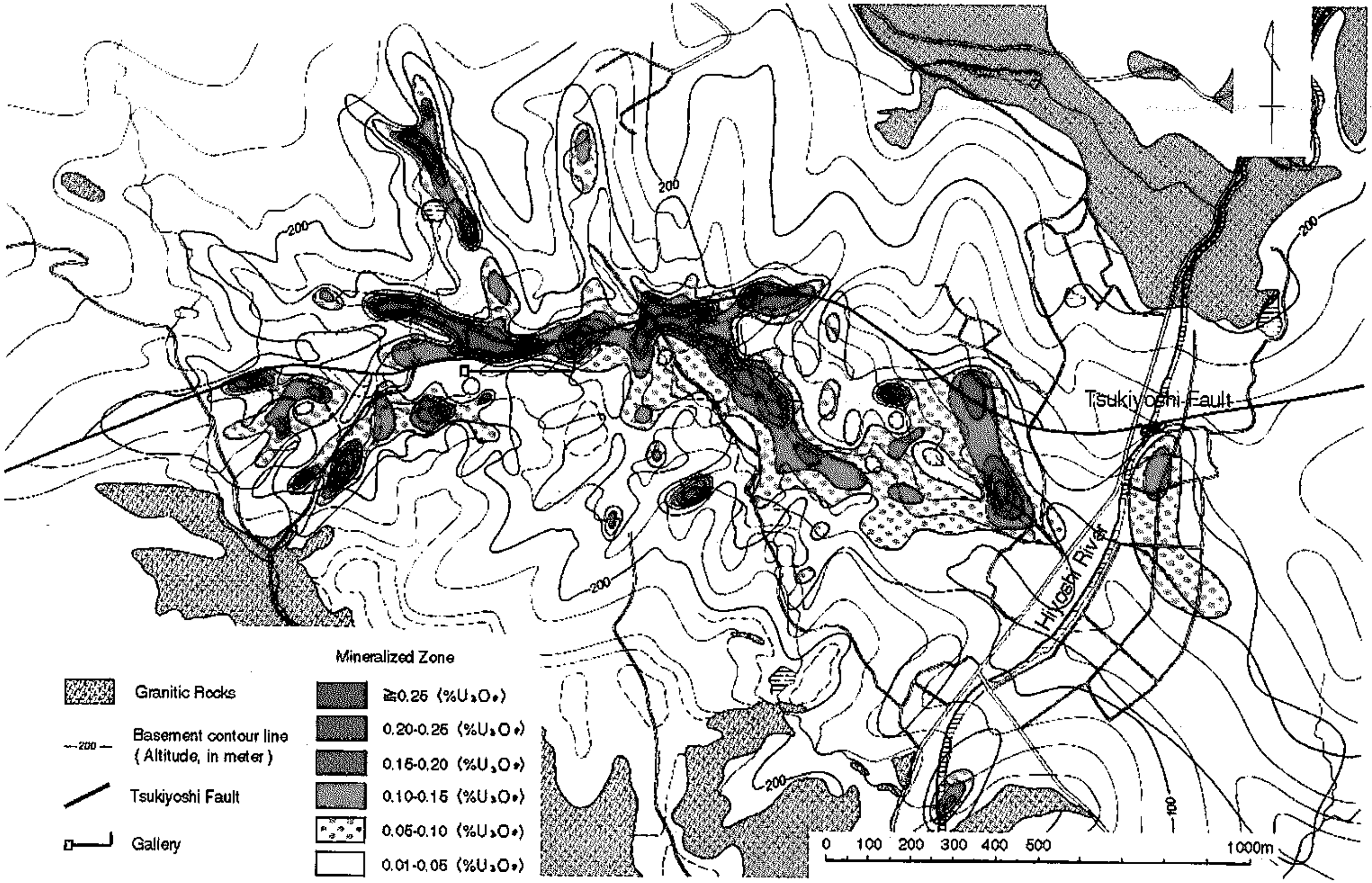
S-4 : Results of hydraulic testing in the basement granite

S-5 : Distribution of ativity ratio ($^{234}U/^{238}U$, $^{230}Th/^{238}U$) for the four points (A, B, C, D) in the Tsukiyoshi ore body



Map of Summit Levels of the Tono Site

S-1



Uranium Distribution Map of the Tsukiyoshi Ore Body

Chemical and Mineral Compositions of the Each Formation

Formation	Oidawara	Akeyo	Toki (upper)	Toki (lower)	Toki (lower)	Toki (lower)	Toki (lower)
Rock Type	Tuffaceous Siltstone	Tuffaceous Medium Sandstone	Tuffaceous Mudstone	Arkosic Fine-Medium Sandstone	Tuffaceous Silt - Fine Sandstone	Lignite-bearing Tuff. Mudstone	Tuffaceous Fine Sandstone
Borehole No.	SN-5	SN-5	TH-3	No.2 Shaft	No.2 Shaft	AN-4	KNA-3
Elevation (m)	247.5	218.5	211.0	146.0	139.0	134.3	123.0
SiO_2 (wt.%)	68.40	59.39	53.26	61.54	45.28	43.94	54.40
TiO_2	0.49	0.82	0.90	0.63	1.09	1.16	0.96
Al_2O_3	12.47	17.64	16.39	15.62	17.46	16.82	16.46
Fe_2O_3	3.26	3.52	5.60	3.02	---	---	3.46
FeO	0.90	1.26	0.39	0.25	---	---	3.19
tot. Fe_2O_3	---	---	---	---	3.75	3.76	---
MnO	0.03	0.09	0.03	0.04	0.05	0.05	0.09
MgO	1.17	1.66	0.99	0.57	1.05	2.26	2.63
CaO	1.67	5.22	3.31	4.11	7.33	4.00	4.61
Na_2O	1.76	3.51	1.36	2.91	2.06	1.80	2.38
K_2O	2.30	1.44	0.31	2.63	1.06	1.12	1.59
P_2O_5	0.12	0.11	0.05	0.79	2.19	0.16	0.07
H_2O +	4.91	4.66	5.18	3.23	6.64	8.81	4.44
H_2O -	1.10	0.78	11.04	2.45	3.70	1.65	3.82
SO_3	---	---	---	0.88	0.33	---	---
S	---	---	---	0.46	1.05	---	---
tot. S	0.67	0.31	0.05	---	---	0.64	---
CO_2	<0.40	<0.40	---	0.22	0.33	---	2.23
tot. C	---	---	0.78	---	1.37	12.92	---
TOTAL	99.25	100.41	99.64	99.35	94.74	99.09	100.33
F (ppm)	---	---	---	1000	---	---	---
Cl	48	330	---	<100	---	38	526
Rb	---	---	---	80	---	---	---
Cs	10	2.6	---	1	---	4.6	0.7
Sr	---	---	---	940	---	---	---
Ba	---	---	---	360	---	---	---
Co	---	---	---	60	---	---	---
Ni	16	14	---	69	---	61	28
Cu	---	---	---	32	---	---	---
Zn	---	---	---	71	---	---	---
Pd	---	---	---	<10	---	---	---
Sn	---	---	---	10	---	---	---
Pb	---	---	---	48	---	---	---
Cr	---	---	---	119	---	---	---
La	---	---	---	---	---	---	---
Ce	---	---	---	---	---	---	---
Nd	18	25	---	---	---	21	14
Sm	---	---	---	---	---	---	---
Eu	---	---	---	---	---	---	---
Tb	---	---	---	---	---	---	---
Dy	---	---	---	---	---	---	---
Tm	---	---	---	---	---	---	---
Yb	---	---	---	---	---	---	---
Lu	---	---	---	---	---	---	---
Th	---	---	---	13	---	---	---
U	6.66	1.75	1.12	8500	45000	820	50
Zr	---	---	---	106	---	---	---
Mo	---	---	---	<10	---	---	---
Se	---	---	---	30	---	---	---
CEC (meq/100g)	36.93	25.28	55.7	---	---	65.70	80.44

S-3

Chemical and Mineral Compositions of the Each Formation (continued)

Formation	Granite	Granite	Granite
Rock Type	Medium grained Biotite Granite	Medium grained Biotite Granite	Medium grained Biotite Granite
Borehole No.	AN-1	AN-1	AN-1
Elevation (m)	30.2	-114.1	-647.7
SiO_2 (wt.%)	76.00	76.98	53.26
TiO_2	0.05	0.05	0.90
Al_2O_3	12.40	12.44	16.39
Fe_2O_3	0.58	0.57	5.60
FeO	0.39	0.35	0.39
tot. Fe_2O_3	---	---	---
MnO	0.05	0.06	0.03
MgO	0.05	0.05	0.99
CaO	0.68	0.67	3.31
Na_2O	3.51	3.93	1.36
K_2O	4.52	4.57	0.31
P_2O_5	<0.01	0.01	0.05
H_2O +	0.44	0.28	5.18
H_2O -	0.15	0.02	11.04
SO_3	---	---	---
S	---	---	---
tot. S	---	---	0.05
CO_2	0.15	---	---
tot. C	--	---	0.78
TOTAL	98.97	99.98	99.64
F (ppm)	---	---	---
Cl	22	---	---
Rb	---	290	---
Cs	8.5	7.7	---
Sr	---	20	---
Ba	---	<30	---
Co	---	0.40	---
Ni	5.6	<4	---
Cu	---	<80	---
Zn	---	16.0	---
Pd	---	---	---
Sn	---	57	---
Pb	---	---	---
Cr	---	10.3	---
La	---	6.1	---
Ce	---	27	---
Nd	11	17	---
Sm	---	3.7	---
Eu	---	0.13	---
Tb	---	1.45	---
Dy	---	6.9	---
Tm	---	2.6	---
Yb	---	10.4	---
Lu	---	2.0	---
Th	---	24	---
U	---	7.5	---
Zr	---	---	---
Mo	---	5.3	---
Se	---	12.6	---
CEC (meq/100g)	108.53	---	---

Chemical and Mineral Compositions of the Each Formation (continued)

Formation	Oidawara	Akeyo	Toki (upper)	Toki (lower)	Toki (lower)	Toki (lower)	Toki (lower)
Rock Type	Tuffaceous Siltstone	Tuffaceous Medium Sandstone	Tuffaceous Mudstone	Arkosic Fine-Medium Sandstone	Tuffaceous Silt - Fine Sandstone	Lignite-bearing Tuff. Mudstone	Tuffaceous Fine Sandstone
Borehole No.	SN-5	SN-5	TH-3	No.2 Shaft	No.2 Shaft	AN-4	KNA-3
Elevation (m)	247.5	218.5	211.0	146.0	139.0	134.3	123.0
Quartz	◎*	○	△	◎	○	○	○
Plagioclase	◎	◎	◎	◎	◎	◎	◎
K-feldspar	×	△	×	○	△	△	△
Biotite		×			×		×
Sericite	△		×	×	×		×
Amphiboles		×			△		×
Ilmenite							
Pyrite	△	△	△	○	○	△	△
Calcite	×	△	×	×	×		△
Dolomite							
Gypsum	×		×				
Montmorillonite	○	○	◎	△	○	◎	◎
Mont.-Chl. reg.**			×		×	×	×
Illite					△		
Chlorite	×	×	×				
Kaolinite	△			△	○	×	△
Clpt.-Hld.***			×	○	○	△	○
Stilbite							○
Lignite				△		○	
Coffinite?				×	△		

Formation	Granite	Granite	Granite
Rock Type	Medium grained Biotite Granite	Medium grained Biotite Granite	Medium grained Biotite Granite
Borehole No.	AN-1	AN-1	AN-1
Elevation (m)	30.2	-114.1	-647.7
Quartz	◎	◎	◎
Plagioclase	◎	◎	◎
K-feldspar	◎	◎	◎
Biotite	×	△	△
Sericite			
Amphiboles			
Ilmenite	×	×	×
Pyrite	×	×	×
Calcite			
Dolomite			
Gypsum			
Montmorillonite			
Mont.-Chl. reg.*			
Illite			
Chlorite	△	×	×
Kaolinite			
Clpt.-Hld.**			
Stilbite			
Lignite			
Coffinite?			

* : ◎ (dominant) > ○ > △ > × (minor)
** : Montmorillonite-Chlorite Regular
*** : Clinoptilolite-Heulandite

S-4

1.Section 947～951m

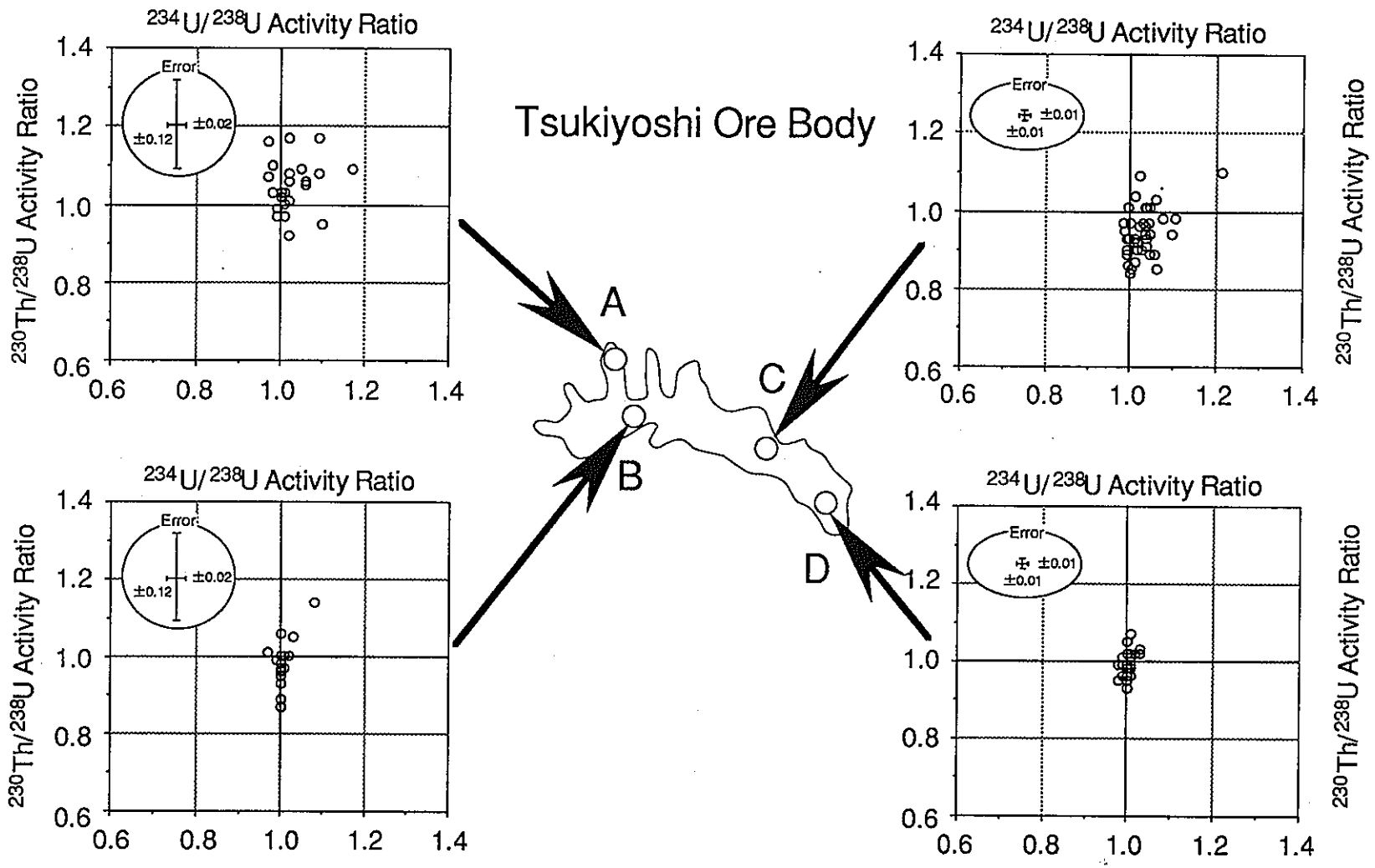
Transmissivity	4.29×10^{-9} m^2/s
Average Hydraulic Conductivity	1.07×10^{-9} m/s
Skin Factor	0.69
Effective Bolehole Diameter	0.025 m

2.Section 277.5～281.5m

Transmissivity	7.22×10^{-9} m^2/s
Average Hydraulic Conductivity	1.81×10^{-9} m/s
Skin Factor	-3.70
Effective Bolehole Diameter	2.0 m

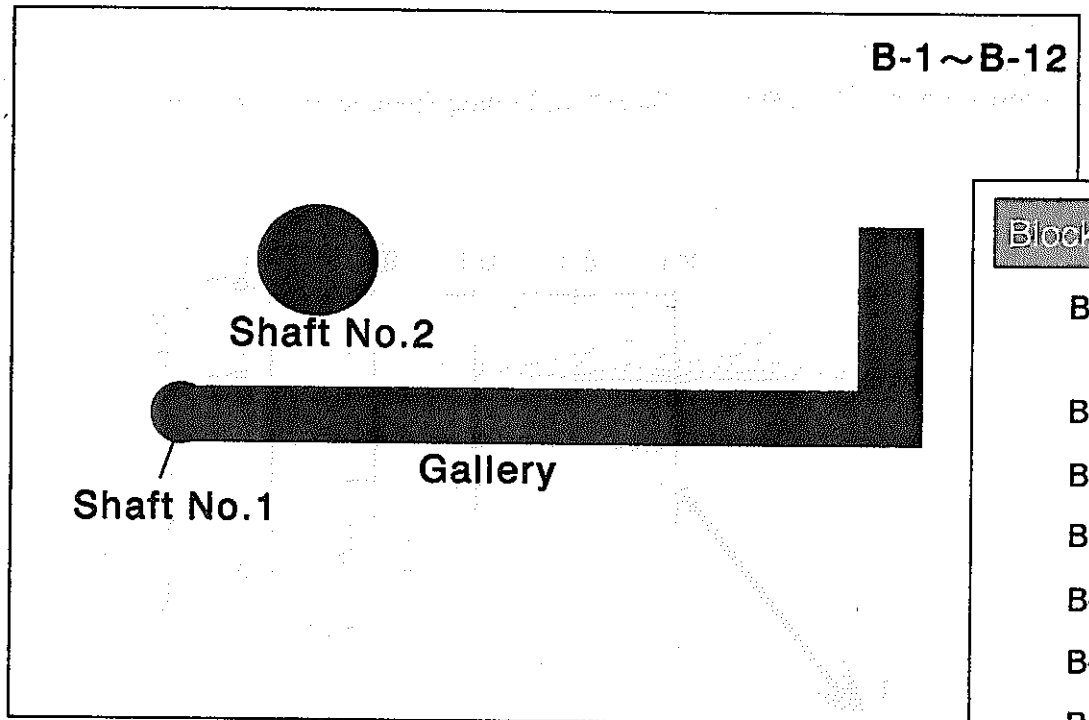
The testing was performed with the Umbilical Hose System .

Results of Hydraulic Testing in the Basement Granite (Borehole Data: AN-1) (after Anderson et al.,1991)



Distribution of Activity Ratio ($^{234}U/^{238}U$, $^{230}Th/^{238}U$) for the Four Points (A,B,C,D) in the Tsukiyoshi Ore Body

(after Nohara et. al., 1992)



Block Scale Index ≈ 300 m

Block Scale Information List

B-1 : Location map of the boreholes for hydrogeochemical and hydrological investigations

B-2 : Sampling points of the groundwater

B-3 : Chemistry of the groundwater

B-4 : Chemical properties of the groundwater

B-5 : δD- $\delta^{18}O$ diagram of the groundwater

B-6 : Tritium concentration and ^{14}C ages of the groundwater

B-7 : Uranium, Radium and Radon concentration of the groundwater

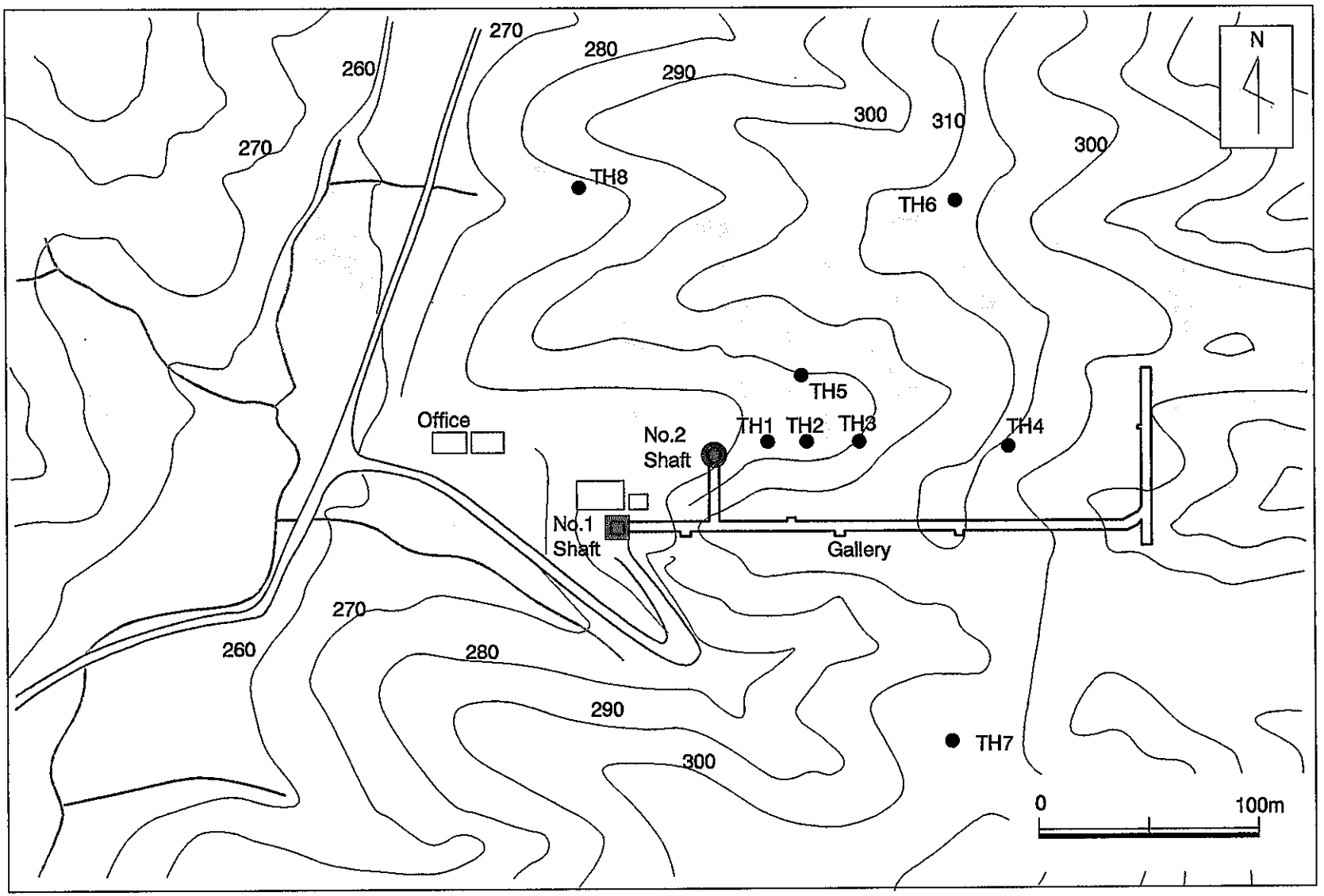
B-8 : Measurement points of hydraulic conductivities

B-9 : Hydraulic conductivities of the basement granite and the sedimentary rocks

B-10 : Groundwater pressure (piezo head) contours

B-11 : Instruments for the hydrogeochemical and hydrological investigations
- B-11-1 : PNC groundwater sampler
- B-11-2 : Multiple piezometer system (MP system)
- B-11-3 : PNC aquifer testing equipment

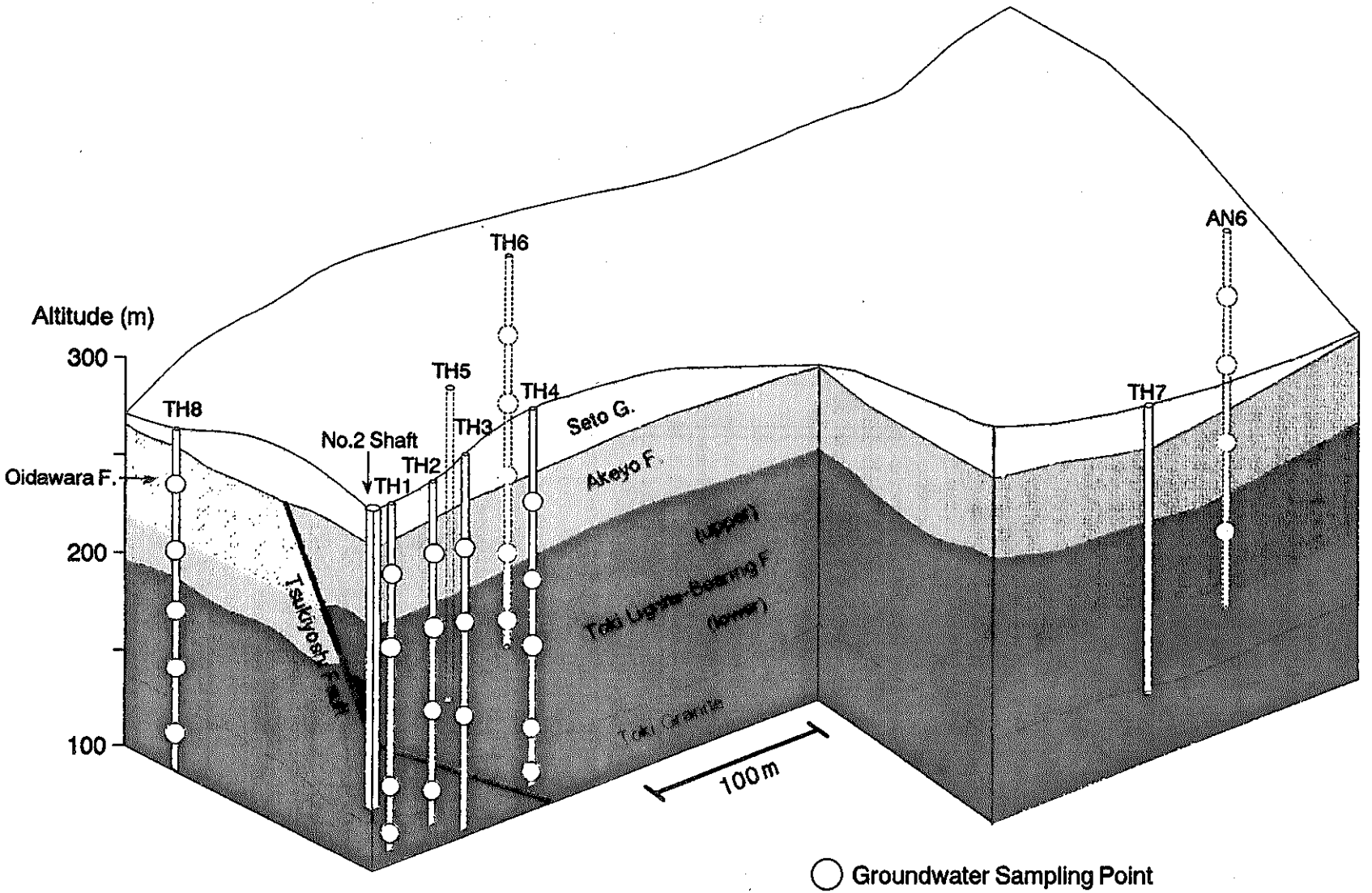
B-12 : Location map of the facilities in the Tono mine



Location Map of the Boreholes for Hydrogeochemical and Hydrological Investigations

(modified from Sugihara et al.,1991)

B-1

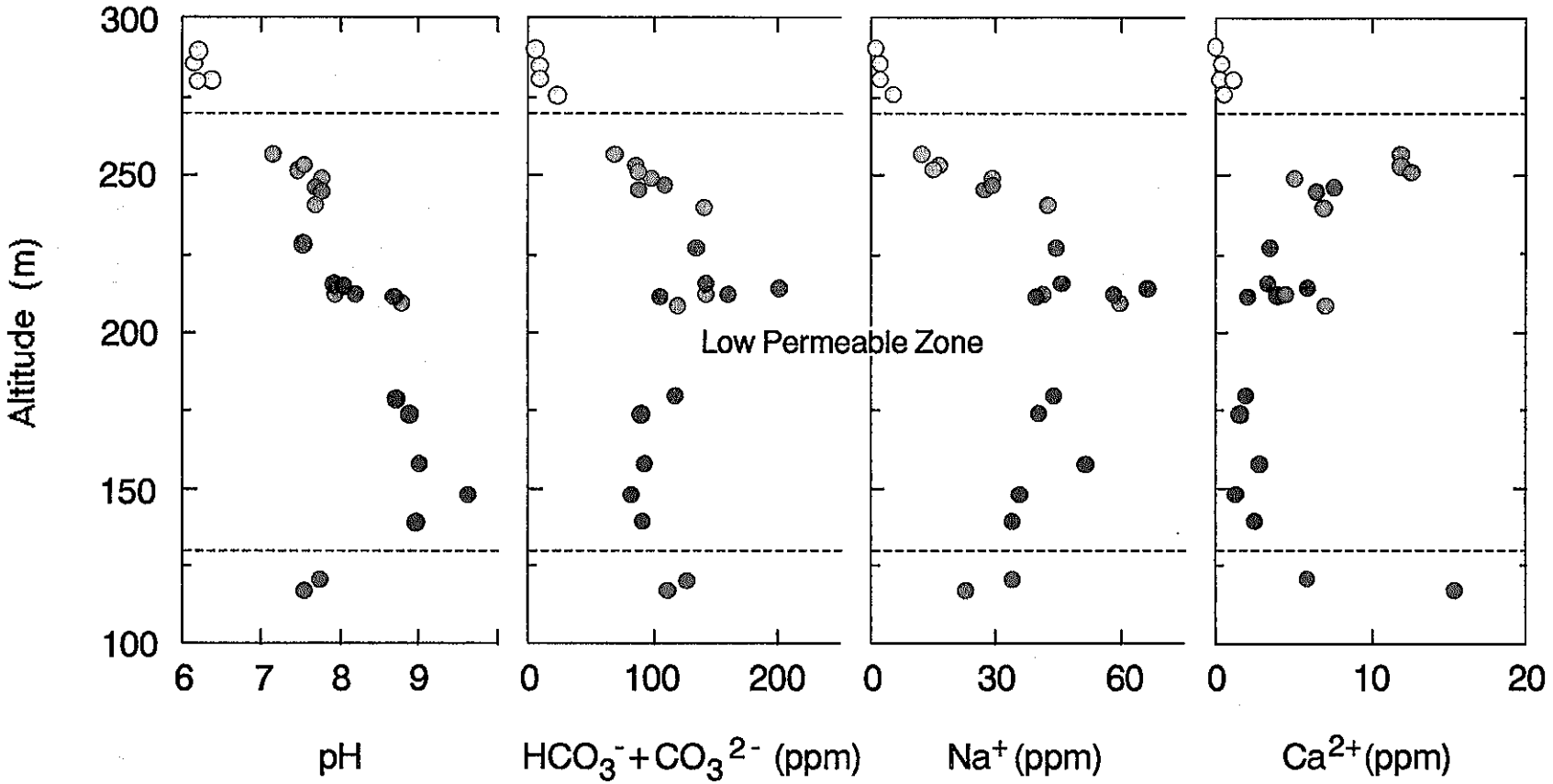


Sampling Points of the Groundwater (modified from Yusa et al.,1993)

Chemistry of the Groundwater

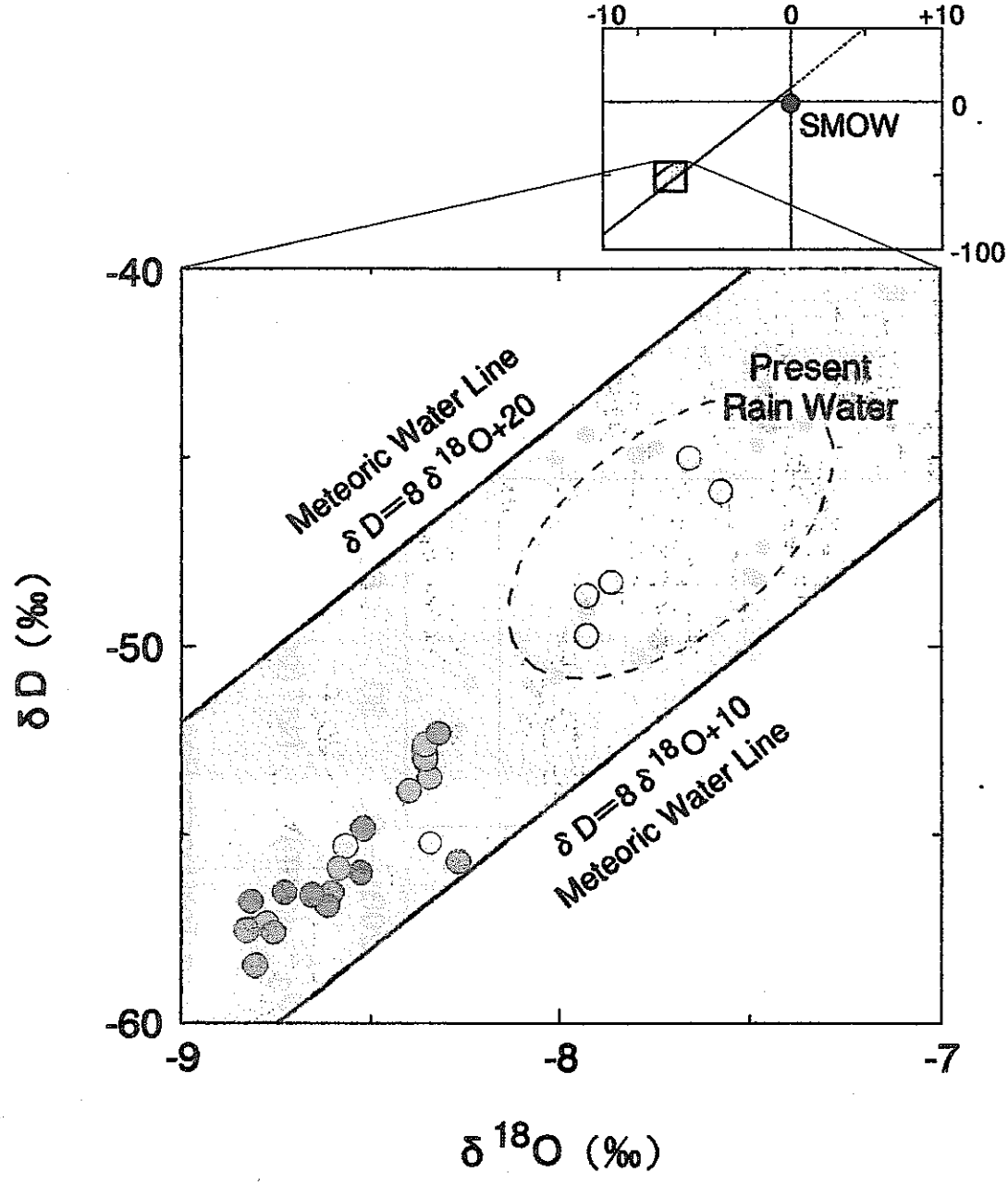
Sampling point	Depth (GL-m)	Alutitude (SL -m)	pH	conductivity (μS/cm)	Si (ppm)	Ti (ppm)	Al (ppm)	Fe++ (ppm)	Fe+++ (ppm)	ΣFe (ppm)	Mn (ppm)	Mg++ (ppm)	Ca++ (ppm)	Sr++ (ppm)	Na+ (ppm)	K+ (ppm)	F- (ppm)	Cl- (ppm)	NO2- (ppm)	PO4--- (ppm)	Br- (ppm)	NO3- (ppm)	SO4-- (ppm)	CO3-- (ppm)	HCO3- (ppm)	U (ppb)	δ D (permil)	δ O-18 (permil)	Tritium (TU)	δ C-13 (permil)	C-14 (% MC)
Surface																															
	0		5.8	246	9.60	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.60	2.40	<0.01	3.0	0.60	0.00	1.40	<0.02	<0.02	<0.02	<0.02	12.0	-	11		-42.8	-7.3	6.2	n.m.	n.m.
Oidawara F.																															
TH-6	68.0	244.8	7.8	171	28.8	<0.01	<0.02	<0.02	<0.02	0.09	<0.01	0.41	7.50	0.04	27.9	2.20	0.73	2.99	0.11	0.11	<0.02	0.23	12.2	-	85	<0.05	-53.7	-8.4	0	-18.5	35.4
TH-8	28.5	246.2	7.7	165	31.3	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.46	7.40	0.05	30.5	1.98	1.04	1.00	<0.02	0.12	<0.02	<0.02	0.29	-	108	<0.05	-57.2	-8.6	0	-15.9	35.2
Akeyo F.																															
TH-1	33.8	252.6	7.6	147	36.0	<0.01	<0.02	<0.02	<0.02	0.07	0.17	1.07	12.1	0.09	18.0	1.61	0.18	1.04	<0.02	0.51	<0.02	<0.02	4.23	-	84	0.40	-52.6	-8.4	0	n.m.	n.m.
TH-2	32.8	256.5	7.2	130	36.3	<0.01	<0.02	<0.02	<0.02	0.58	0.25	1.28	12.1	<0.01	13.7	1.52	0.16	0.86	<0.02	0.25	<0.02	<0.02	4.93	-	70	0.82	-53.7	-8.4	0	n.m.	n.m.
TH-3	46.5	251.1	7.5	143	36.3	<0.01	<0.02	<0.02	<0.02	0.04	0.19	1.17	12.5	0.06	16.3	1.07	0.19	1.93	<0.02	0.53	<0.02	<0.02	5.80	-	88	0.21	-53.5	-8.4	0	-20.1	31.0
TH-4	61.0	248.5	7.6	180	32.3	<0.01	<0.02	<0.02	<0.02	<0.02	0.03	0.48	6.60	0.02	32.3	1.28	0.34	2.76	<0.02	0.19	<0.02	<0.02	5.43	-	105	0.15	-53.8	-8.3	0	-17.4	28.8
TH-6	104.0	208.8	8.8	223	17.4	0.02	<0.02	0.03	0.04	0.06	<0.01	0.09	4.73	0.03	42.7	1.10	2.53	3.73	<0.02	0.04	<0.02	<0.02	35.0	8	73	0.29	-58.3	-8.7	0	-12.3	30.5
TH-8	64.0	212.1	8.1	232	28.4	<0.01	<0.02	<0.02	<0.02	<0.02	0.01	0.14	4.97	0.02	44.7	1.61	1.86	1.27	<0.02	<0.02	<0.02	<0.02	1.18	-	143	0.33	-56.5	-8.5	3	-14.3	40.7
AN-6	14.0	240.1	7.7	219	19.3	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.23	4.57	0.00	29.7	0.82	0.22	0.85	0.10	0.40	<0.02	0.09	1.62	-	94	0.20	-53.5	-8.4	0	-20.7	66.4
Toki lignite-bearing F. (upper)																															
TH-1	70.8	215.6	8.0	257	26.7	<0.01	<0.02	<0.02	<0.02	0.09	<0.01	0.21	4.30	0.02	50.5	1.81	2.85	3.34	<0.02	0.45	<0.02	<0.02	10.7	-	134	1.30	-55.7	-8.5	0	n.m.	n.m.
TH-2	74.8	214.5	8.2	311	24.6	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.23	5.23	0.02	65.0	1.36	2.76	1.11	<0.02	0.78	<0.02	<0.02	1.14	-	181	4.80	-55.9	-8.8	0	n.m.	n.m.
TH-3	85.5	212.1	8.4	271	29.7	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.17	4.13	0.01	62.0	1.33	4.77	1.49	<0.02	<0.02	<0.02	<0.02	1.32	-	159	0.08	-59.2	-8.8	0	-5.2	32.8
TH-4	83.0	227.1	7.6	230	26.3	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.19	3.57	0.01	46.7	1.38	1.46	3.73	<0.02	<0.02	<0.02	0.09	4.69	-	130	0.11	-58.2	-8.4	0	-10.9	27.2
TH-6	132.0	180.8	8.7	370	15.0	<0.01	<0.02	<0.02	<0.02	0.04	<0.01	0.10	6.20	0.03	73.0	1.60	2.83	8.40	<0.02	<0.02	<0.02	<0.02	51.0	7	127	0.37	-58.8	-9.1	0	-13.4	27.0
TH-8	91.0	185.1	7.6	213	4.87	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.10	1.83	0.03	13.3	0.97	0.79	1.90	<0.02	<0.02	<0.02	<0.02	4.80	-	34	<0.05	-56.2	-8.3	2	-11.7	24.0
Toki lignite-bearing F. (lower)																															
TH-1	138.3	148.1	9.5	181	12.9	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.03	1.45	<0.01	38.7	0.28	3.01	1.94	<0.02	0.04	<0.02	<0.02	12.2	-	51	28.0	-55.6	-8.6	0	n.m.	n.m.
TH-2	109.8	179.5	8.6	210	9.57	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.04	1.87	<0.01	45.0	0.54	2.66	2.02	<0.02	0.14	<0.02	<0.02	9.73	-	106	8.40	-57.3	-8.8	0	n.m.	n.m.
TH-3	124.0	173.6	8.8	200	14.1	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.03	1.54	<0.01	40.7	0.43	3.08	3.90	<0.02	0.11	<0.02	<0.02	17.1	-	79	0.39	-58.7	-8.5	0	-12.6	26.5
TH-4	152.5	157.6	9.0	272	10.6	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.03	2.89	<0.01	55.3	0.35	3.50	4.23	<0.02	<0.02	<0.02	<0.02	29.8	-	67	1.80	-57.5	-8.6	0	-10.3	18.1
TH-6	153.0	159.8	9.0	237	6.40	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.02	2.09	0.04	45.0	0.40	4.20	4.30	<0.02	<0.02	<0.02	<0.02	41.0	10	50	1.02	-58.1	-8.4	0	-15.1	12.0
TH-8	121.0	155.1	7.9	145	6.70	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.04	1.07	<0.01	21.3	0.30	0.85	0.93	<0.02	1.29	<0.02	<0.02	3.60	-	53	0.16	-57.1	-8.4	2	-15.8	5.6
Toki granite																															
TH-1	166.3	120.1	7.9	145	9.63	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	0.31	7.00	0.02	36.3	0.90	1.55	2.50	<0.02	0.16	<0.02	<0.02	14.7	-	119	21.0	-52.0	-8.2	1	n.m.	n.m.
TH-6	177.5	135.3	7.8	319	5.60	<0.01	<0.02	<0.02	<0.02	<0.02	0.10	0.41	15.1	0.05	46.0	1.25	1.40	12.1	0.04	<0.02	<0.02	<0.02	82.0	-	75		-55.7	-8.5	2	-14.1	9.6
TH-8	160.0	116.1	7.7	202	8.13	<0.01	<0.02	<0.02	<0.02	0.02	<0.01	0.26	10.7	0.10	15.7	0.79	2.13	0.95	<0.02	<0.02	<0.02	<0.02	2.49	-	71	0.98	-55.1	-8.7	1	-17.8	17.9

n.m. : not measured



Chemical Properties of the Groundwater (modified from Yusa et al.,1993)

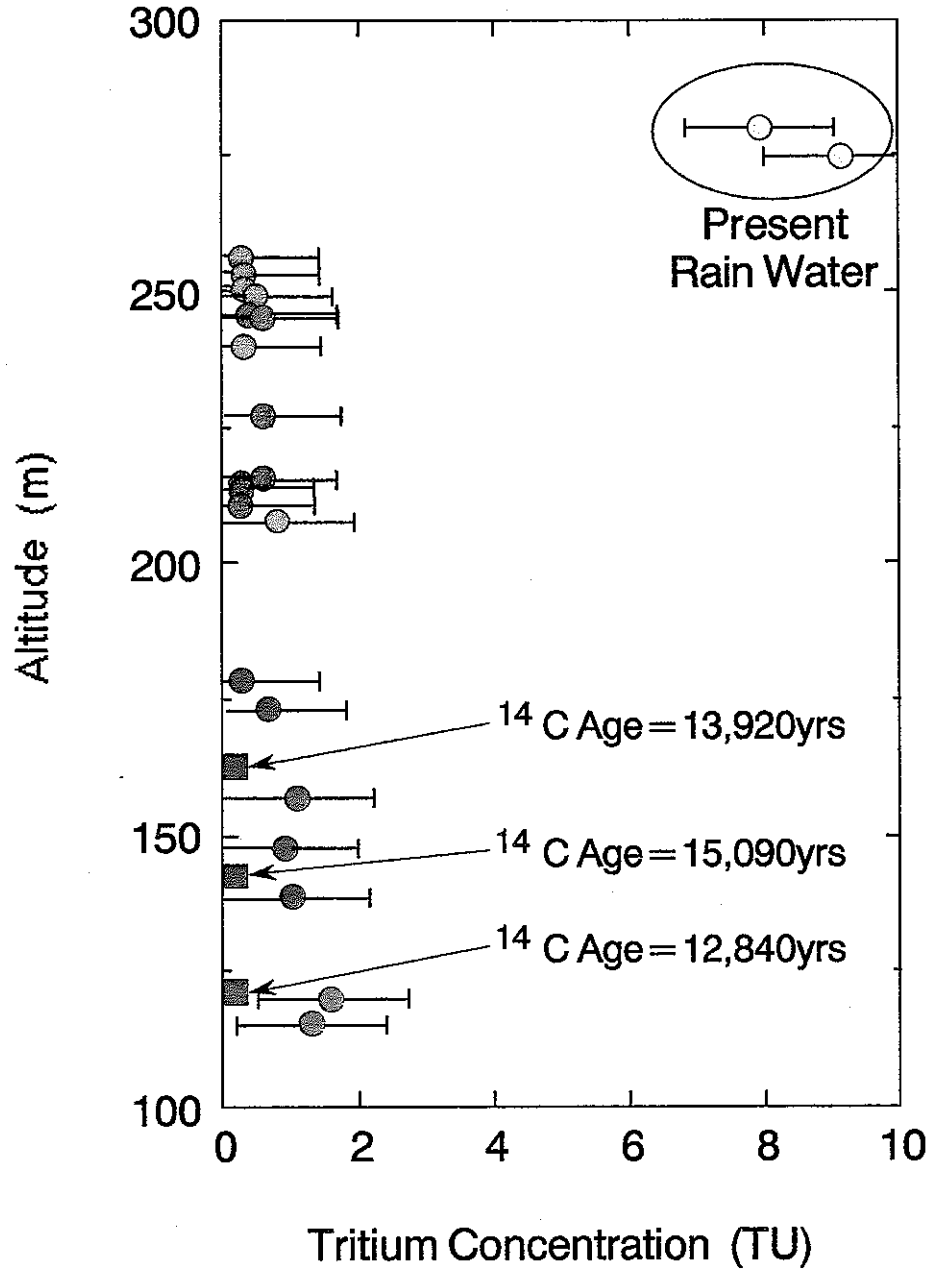
B-5



○ Seto Group
○ Oidawara Formation
● Akeyo Formation
● Toki Lignite-Bearing Formation (upper)
● Toki Lignite-Bearing Formation (lower)
● Toki Granite

δ D— $\delta^{18}O$ Diagram of the Groundwater

(modified from Yusa et al.,1993)



○ Seto Group
● Oidawara Formation
● Akeyo Formation
● Toki Lignite-Bearing Formation (upper)
● Toki Lignite-Bearing Formation (lower)
● Toki Granite

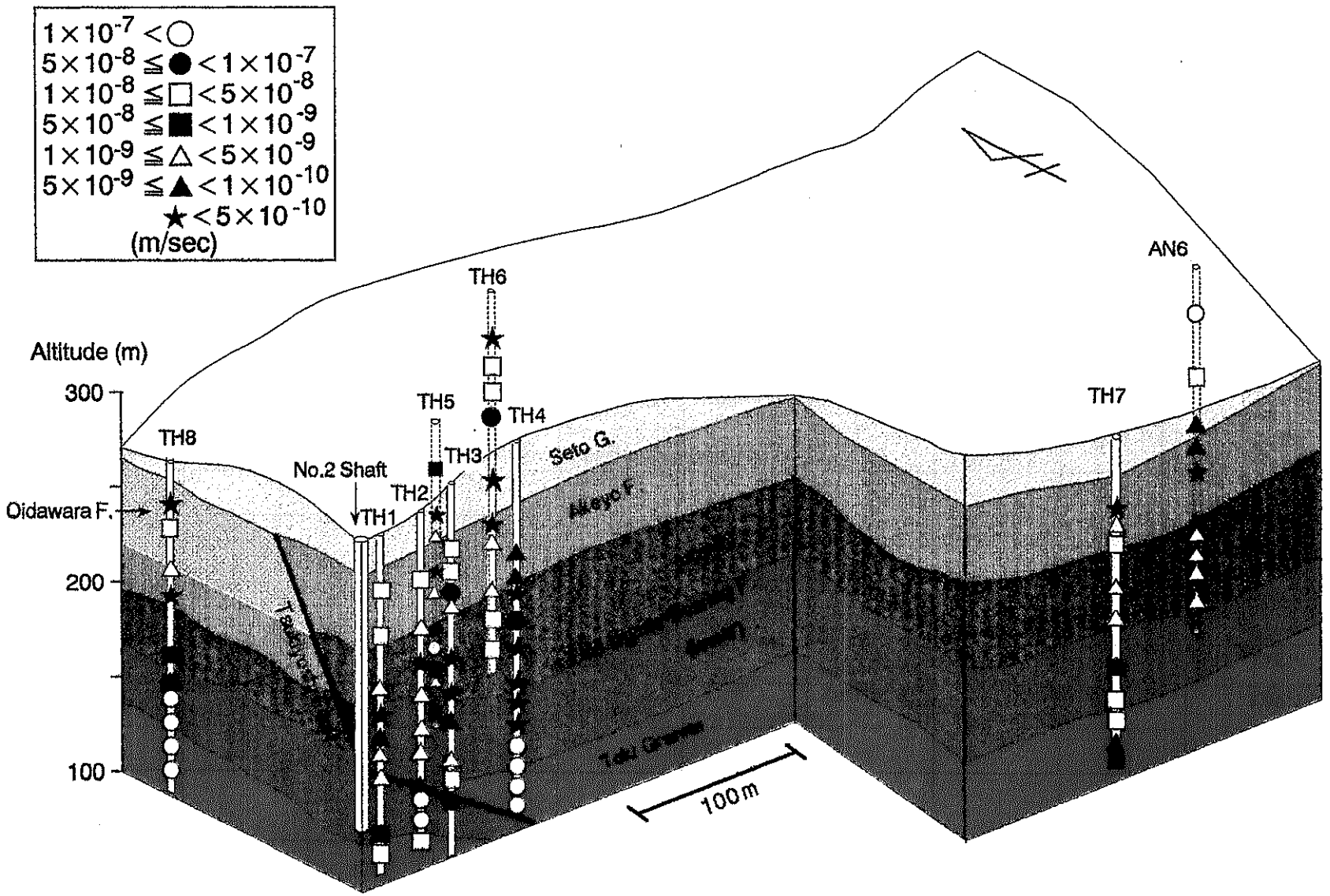
Tritium Concentration and ^{14}C Ages of the Groundwater
(modified from Yusa et al., 1993)

Uranium,Radium and Radon Contcentration of the Groundwater

(modified from Kanai et al.,1990)

Formation	U (μg/l)	Ra※ (Bq/l$\pm\sigma$)	Rn※ (Bq/l$\pm\sigma$)
Surface Water	0.02～0.39	(0.02～0.06)±0.01	157±1
Toki Lignite-Bearing F.	0.06～0.19	0.03±0.01	4.6±0.1
Toki Lignite-Bearing F.	0.01～0.06	(0.02～0.07)±0.01	(94～193)±1
Toki Granite	0.84	0.08±0.01	37.2±0.1

※ All quoted errors are 1 σ uncertainties due to nuclear counting statics only.



Measurment Points of Hydraulic Conductivities

(modified from Sugihara et al.,1991)

Hydraulic Conductivities of the Basement Granite and the Sedimentary Rocks

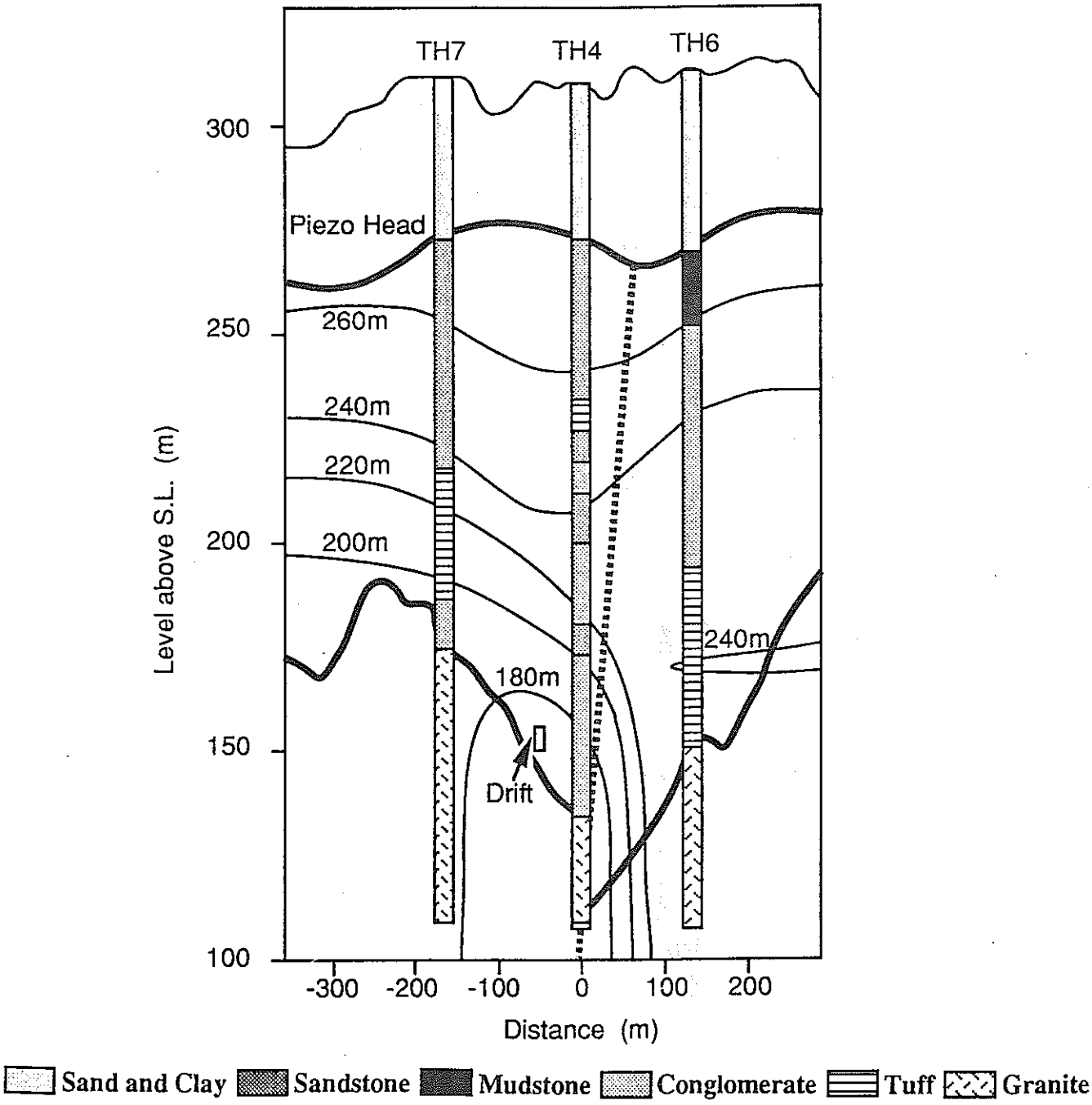
(after Sugihara et al.,1991)

B-9

(Unit of Hydraulic Conductivity: cm/sec)

	TH1	TH2	TH3	TH4	TH5	TH6	TH7	TH8	AN6	SN4	Geometric Average
Seto											
Oidawara						3.20E-8 S 3.16E-6 S		1.02E-8 S			1.0E-7
						2.81E-6 G 6.81E-6 G		3.67E-6 Co			4.4E-6
Akeyo	2.56E-6 S										
		2.18E-6 SC	2.29E-6 S 1.54E-6 S	5.26E-8 SC	6.28E-7 SC		4.24E-8 SC 2.73E-7 Co	1.59E-7 S		1.6E-7 S 1.2E-7 S	3.8E-7
	3.13E-6 S	1.52E-6 SC	8.23E-6 S 4.39E-7 S	5.15E-8 S	4.18E-8 S	4.60E-8 S	4.17E-7 S	8.18E-8 S	1.94E-5 Co	8.6E-8 S 2.6E-7 Co	4.1E-7
Toki(upper)				2.11E-8 S							
		1.84E-8 S	3.69E-8 S	7.41E-6 Co 3.24E-8 Co	1.39E-7 S 3.44E-8 S	2.08E-8 S	1.31E-7 Co		1.35E-6 S 5.06E-8 S	6.5E-6 Co	1.3E-7
	4.53E-7 S	1.13E-7 S	3.87E-8 Co	2.49E-8 Co 4.96E-8 Co	1.27E-7 Co	2.23E-7 S	4.78E-7 S	5.28E-7 S	5.90E-8 Co	1.2E-6 Co	1.5E-7
Toki(lower)	6.29E-8 Co	1.63E-7 S							8.24E-9 Co	2.9E-6 Co	
	2.54E-7 S 1.31E-7 SF	1.00E-7 Co 8.68E-8 SF	8.21E-8 S	3.60E-8 Co	9.38E-6 Co		5.78E-7 Co	7.06E-7 Co	5.65E-8 Co		1.8E-7
	9.71E-7 Co	3.35E-5 S 4.30E-5 Co	6.54E-6 Co	1.17E-5 Co	1.74E-5 Co	1.80E-7 Co	1.73E-6 Co	1.50E-5 Co 3.30E-5 Co	1.35E-7 Co	7.8E-7 Co	4.1E-6
Granite	1.19E-6 F	4.76E-6 W	2.73E-7 W 3.76E-6 F	1.69E-5 W 1.77E-5 C	5.64E-7 W 2.52E-7	2.28E-6 1.16E-6 C	1.84E-6 C	3.01E-5 C 3.63E-5	2.09E-7 W 2.27E-7 C	5.1E-6 W 3.0E-6 C	2.3E-6
				2.07E-5	5.44E-7 C		5.69E-8 C 8.76E-7 C		2.19E-7 W	2.1E-6 5.5E-7 8.34E-7 C 8.05E-8 1.14E-6 C	6.4E-7

(S:sandstone Co:conglomerate F:fault W:weathered C:crack)



Groundwater Pressure (Piezo Head) Contours

(after Sugihara et al.,1991)

B-11-1

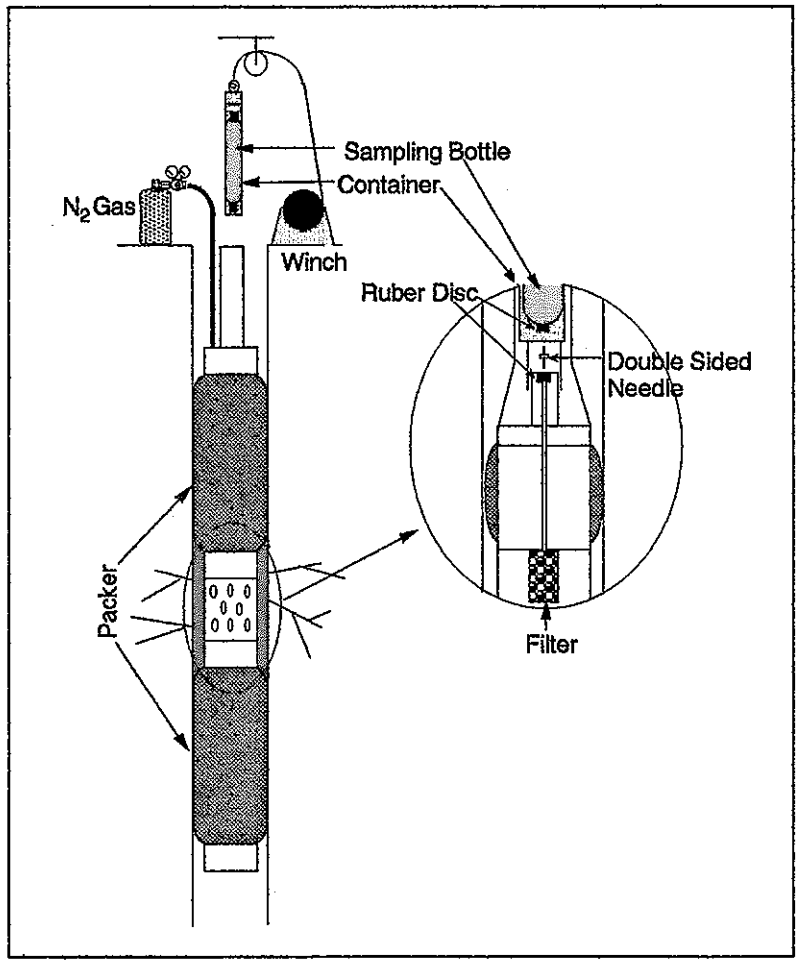
《Specification》

Sampling method : Batch style

Volume of sampling bottle : 500ml

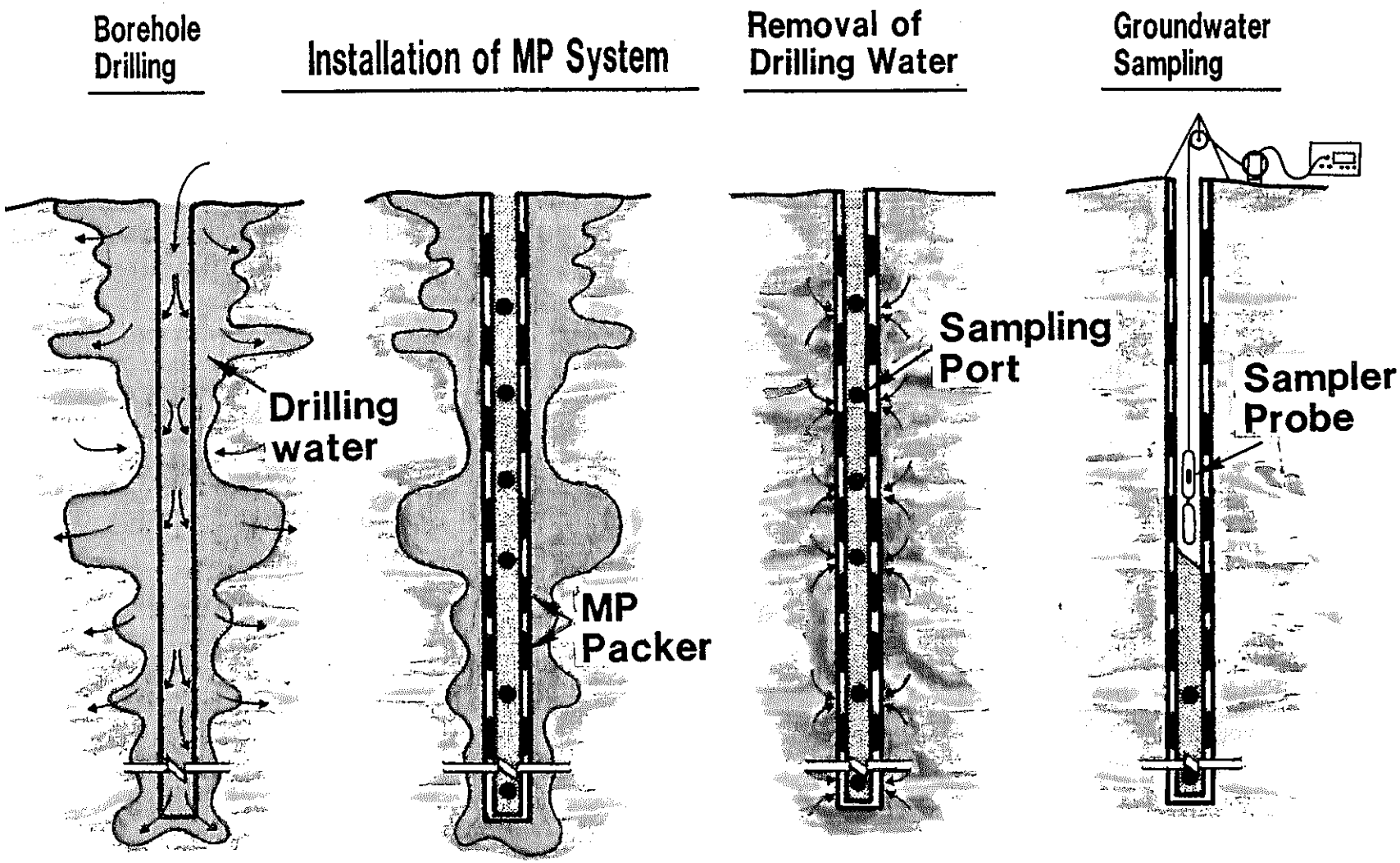
Maximum sampling depth : G.L.-500m

Borehole diameter : ϕ 70～130mm



PNC Groundwater Sampler

(after Yanagizawa et al.,1991)



Multiple Piezometer System

(after Black et al.,1986)

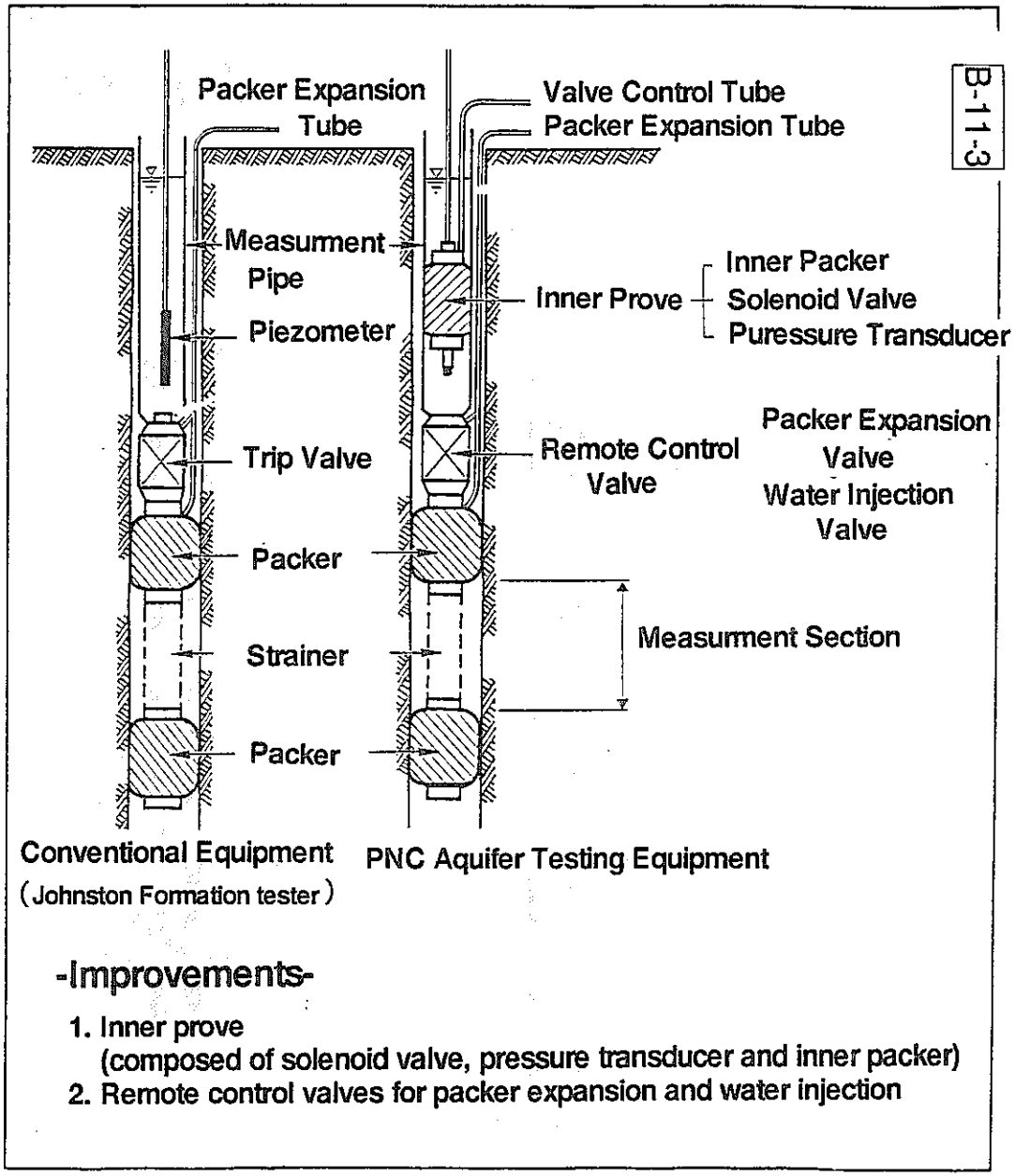
B-11-2

PNC Aquifer Testing Equipment has been developed by Power Reacter and Nuclear Fuel Development Corporation and TAISEI Foundation Design and Resarch Co.,Ltd.
The equipment can measure hydraulic conductivity and pore pressure of low permeable rock mass in a borehole.

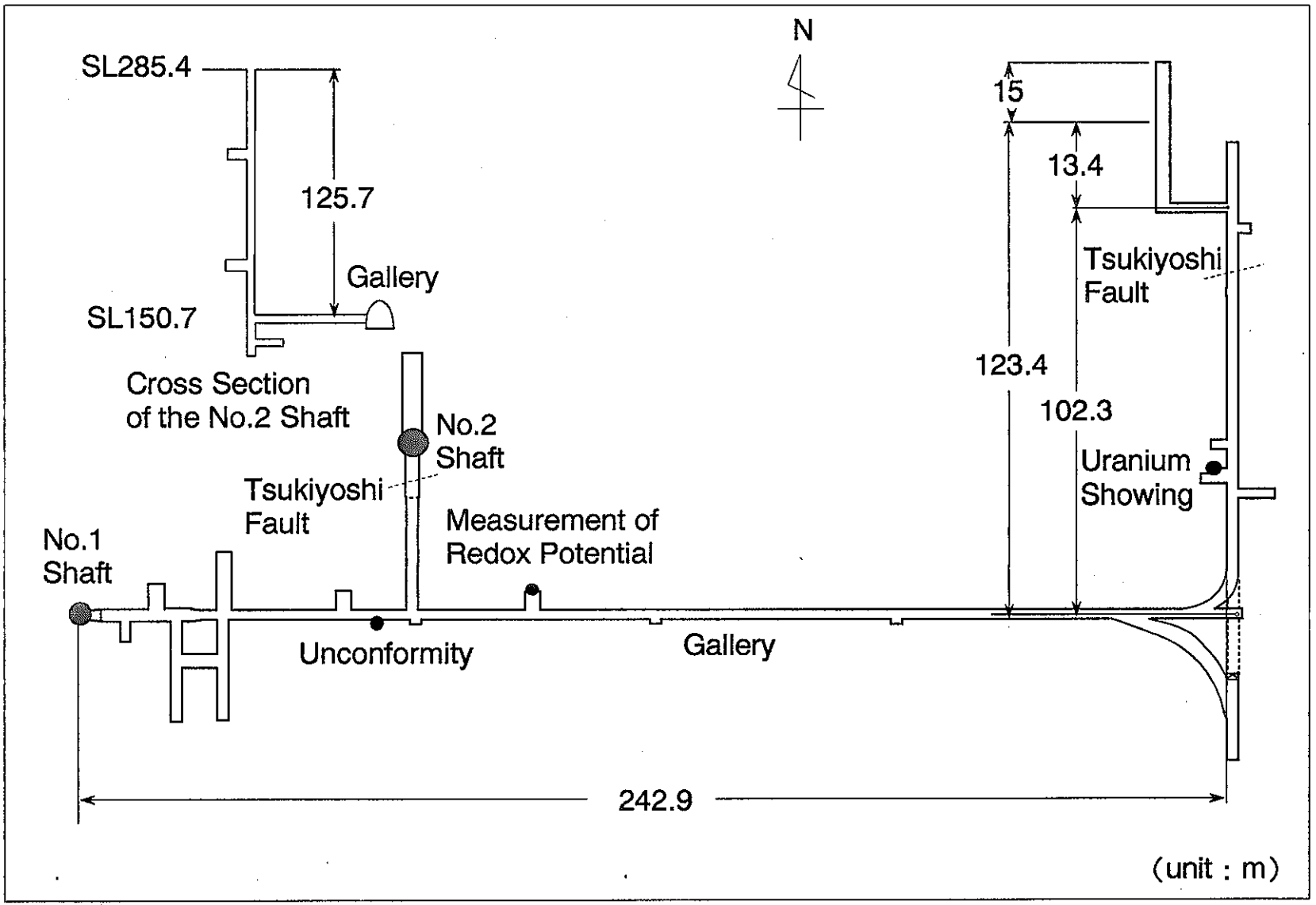
《Specification》

Hydraulic test method : Recovery method, Injection method and Pulse method
Measurement depth : Maximam G.L.-500m
Borehole diameter : 66mm ～ 100mm
Measurement range : 10^{-4} cm/sec ～ 10^{-9} cm/sec of hydraulic conductivity

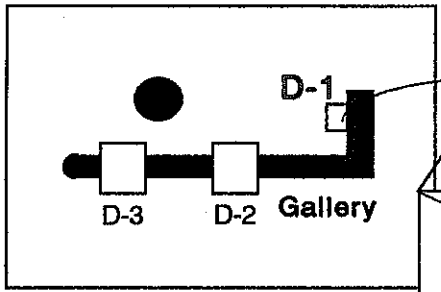
United States patent obtained, and European patent, Canadian patent and Japanese patent pending.



PNC Aquifer Testing Equipment (after Yanagizawa et al.,1986)



Location Map of the Facilities in the Tono Mine
(modified from Yusa and Yamakawa,1992)



Rock Cube
D-1

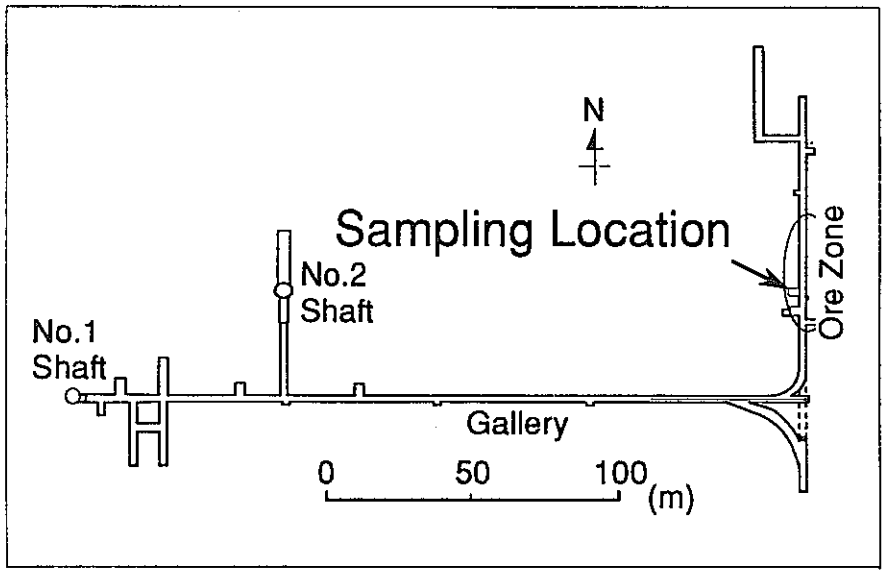
Detailed Scale Information List 1

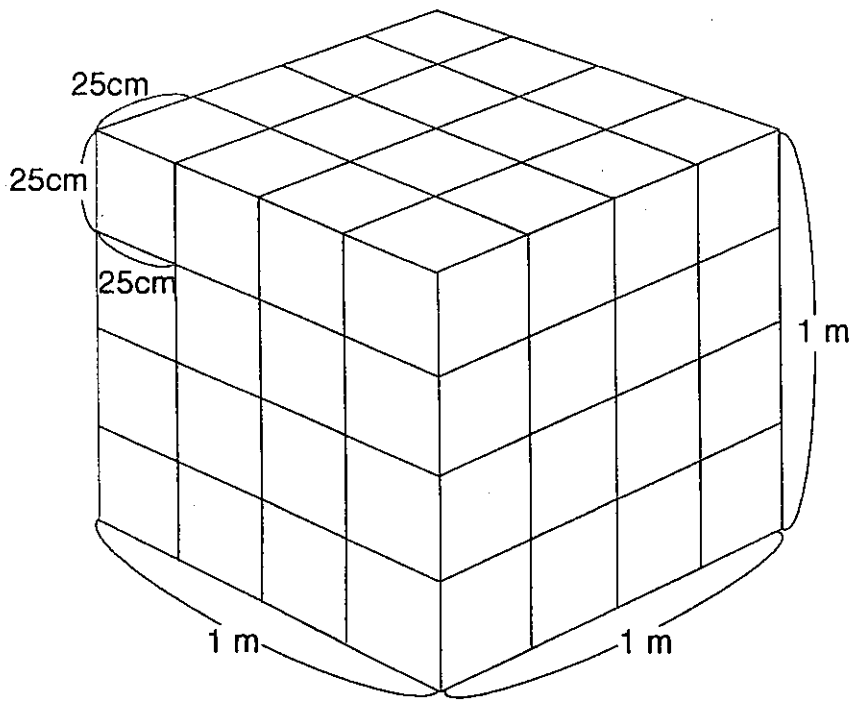
D-1 : Information from uranium-series disequilibrium studies carried out on a 1-meter rock cube in the ore zone

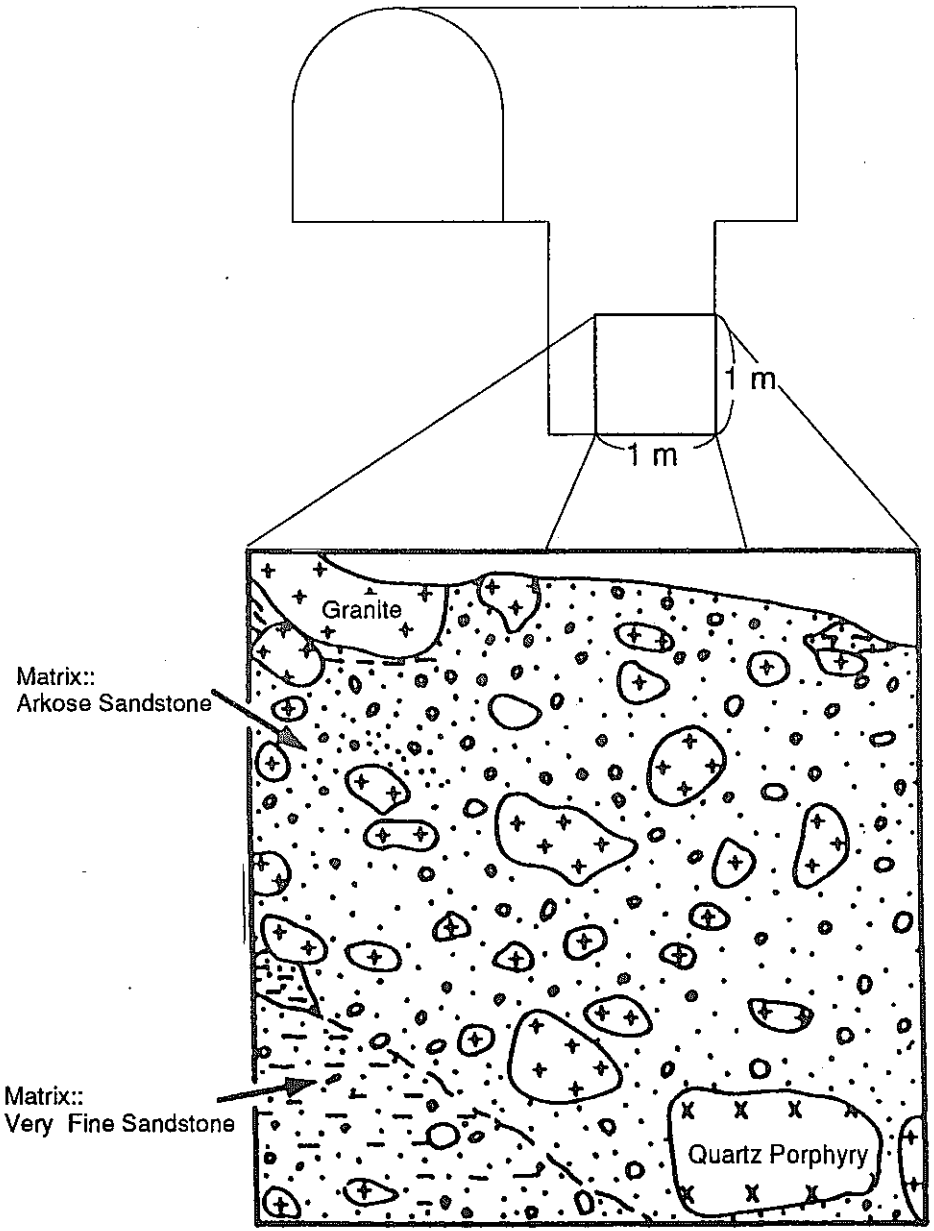
D-1-1 : Location map of the sampling area

D-1-2 : Results of uranium-series disequilibrium analyses $(25cm)^3$, subcube blocks (64 data)

Detailed Scale Index 1 ~ 1m

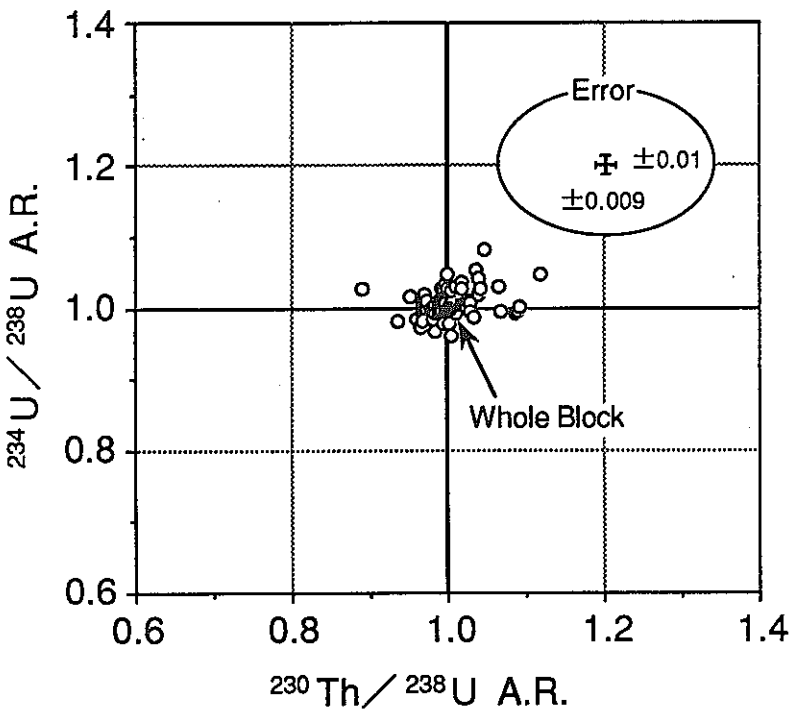


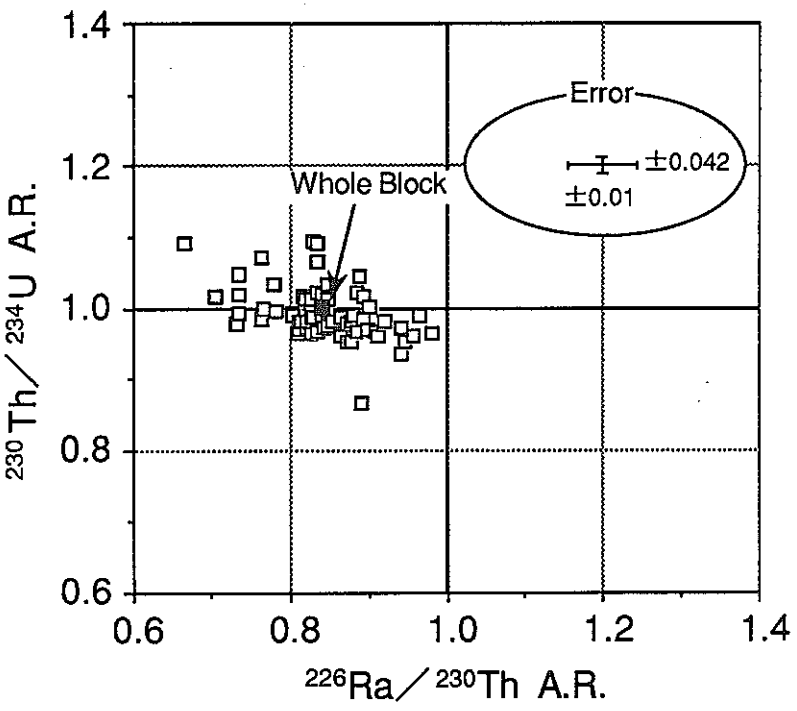




Location Map of the Sampling Area

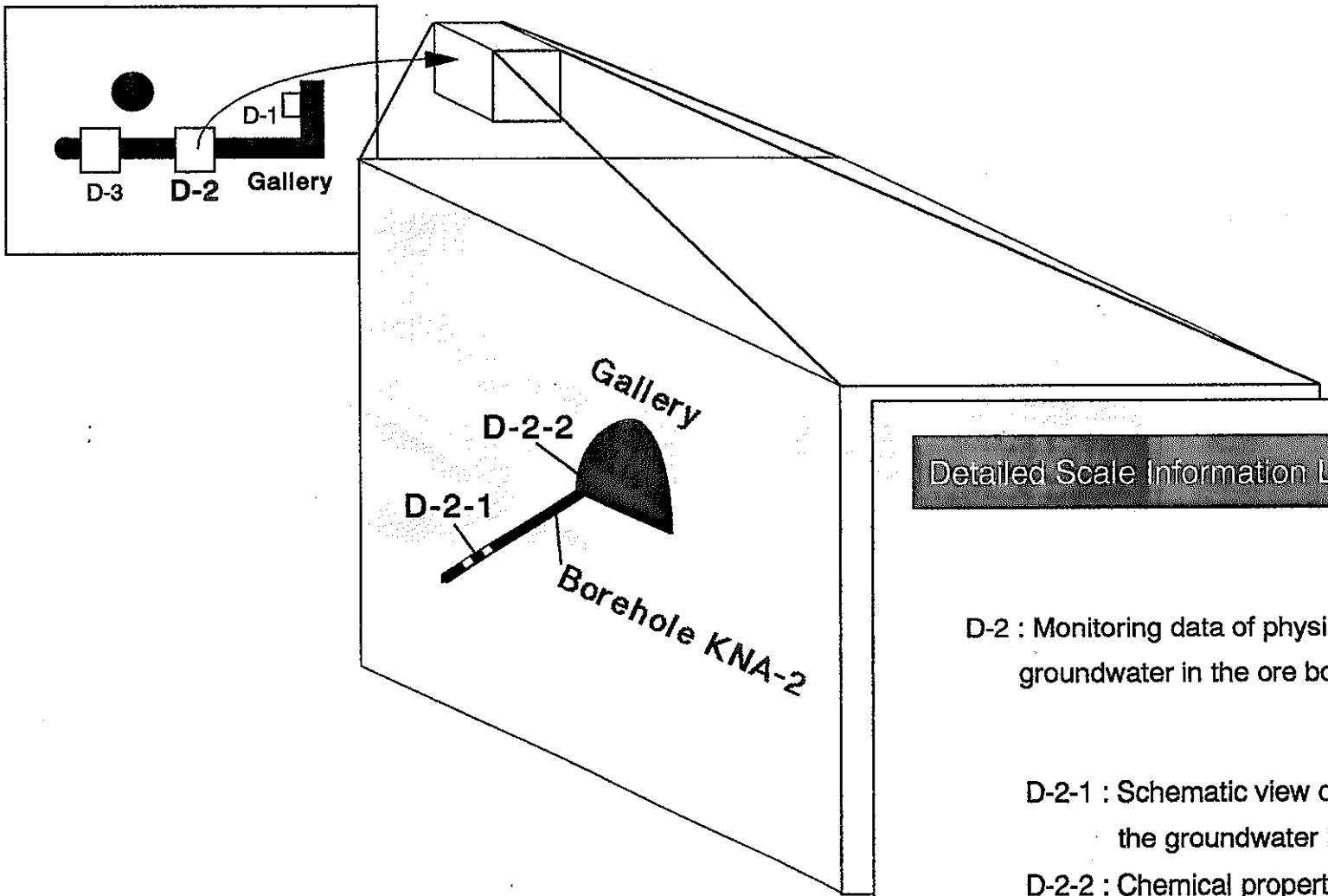
D-1-1





Results of Uranium-series Disequilibrium Analyses $(25cm)^3$, Subcube blocks (64 data)

(after Ochiai et. al., 1989)



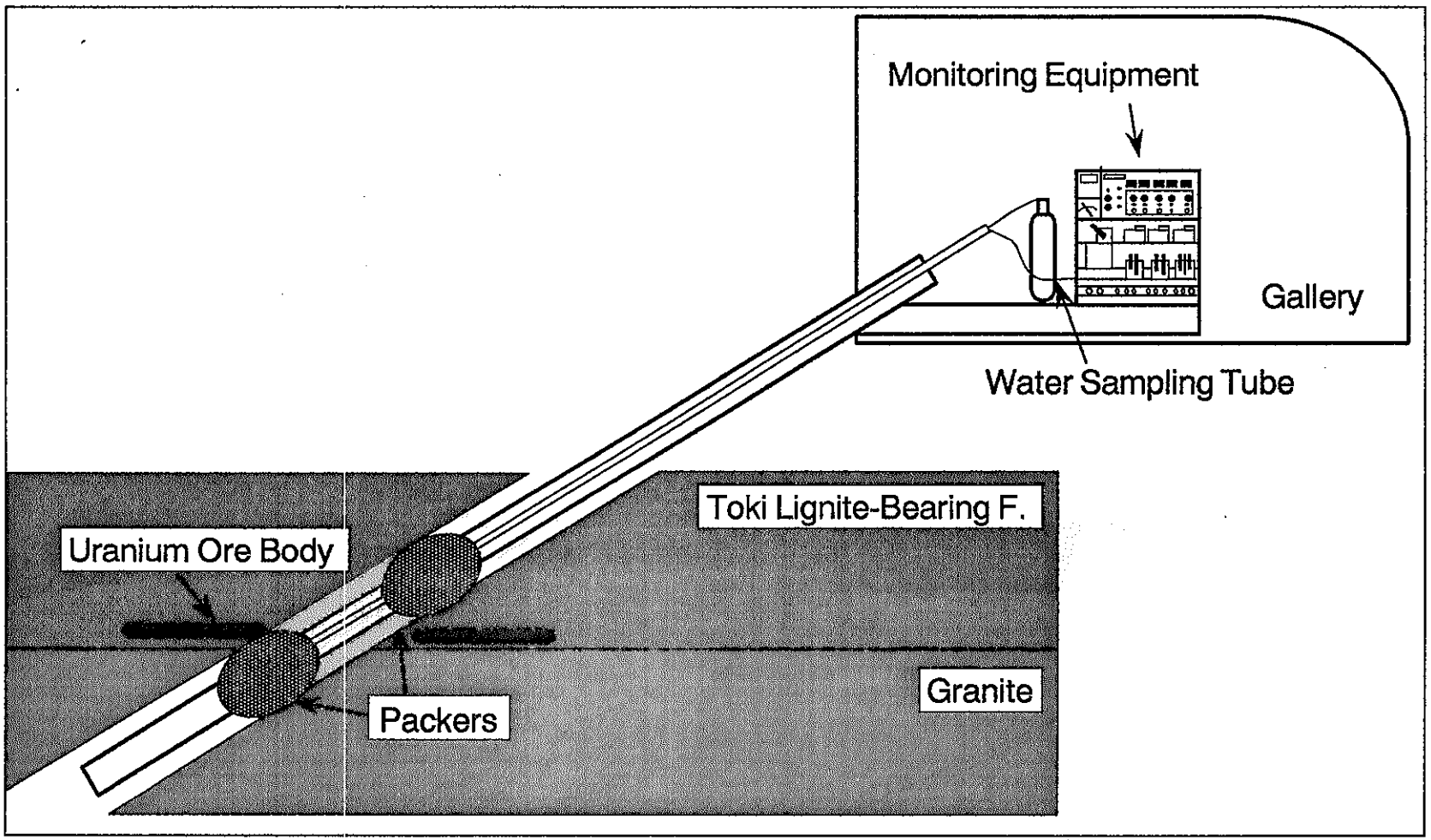
Detailed Scale Information List 2

D-2 : Monitoring data of physico-chemical properties of the groundwater in the ore body zone (KNA-2 borehole)

D-2-1 : Schematic view of the monitoring system of the groundwater in the ore body zone

D-2-2 : Chemical properties of the groundwater in the ore body zone

Detailed Scale Index 2 ≈ 100 m



Schematic View of the Monitoring System of the Groundwater in the Ore Body Zone (modified from Yusa et al.,1993)

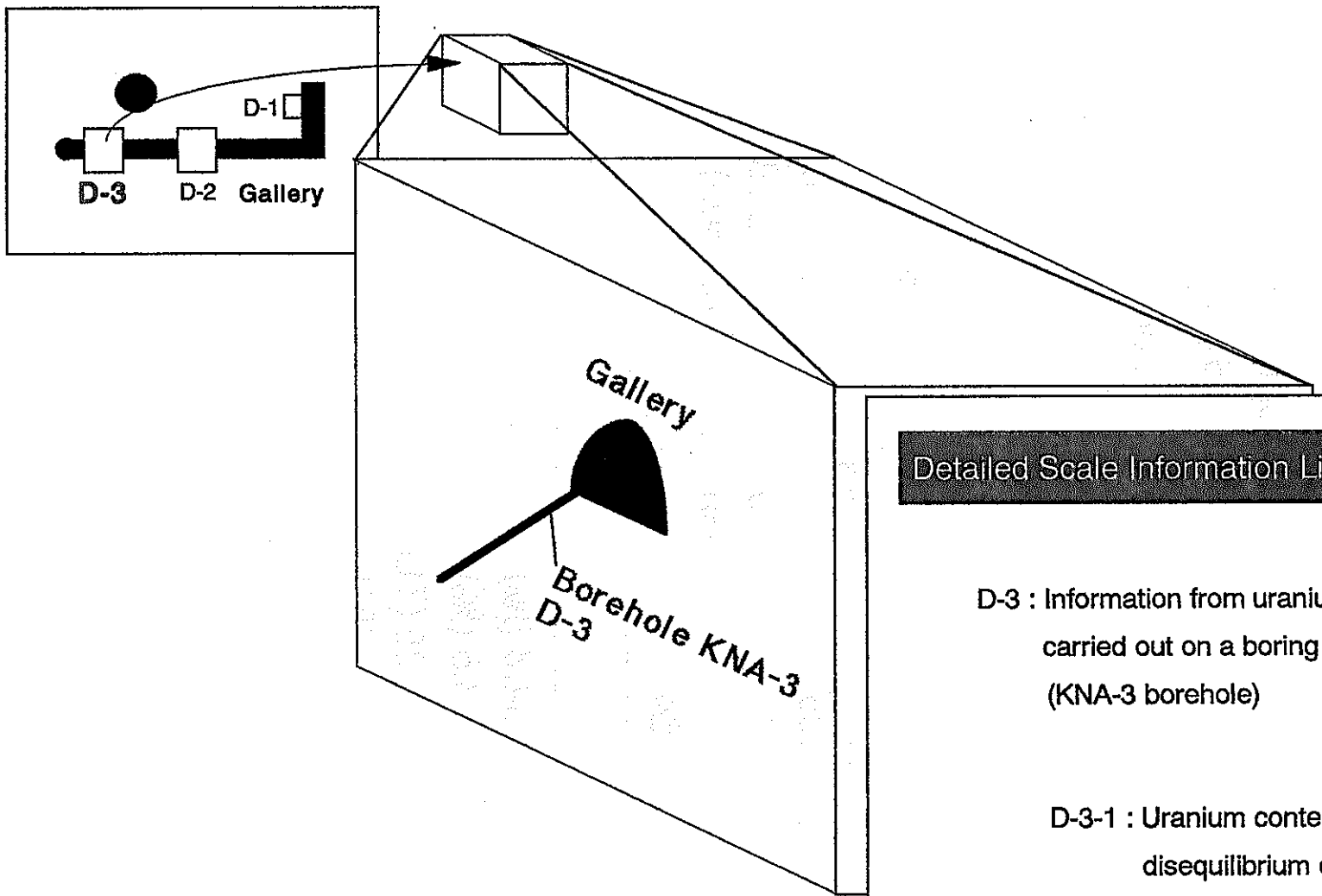
Chemical Properties of the Groundwater in the Ore Body Zone

(modified from Seo and Yoshida,1992)

Sampling Point	:	-153～-155m (G.L.)
Temperature	:	18.5℃
Eh	:	-300 mV
pH	:	9.1～9.2
Dissolved Oxygen	:	0.0 ppb
Electric Conductivity	:	168 μS／cm

Ion	Conc. (ppm)	Ion	Conc. (ppm)
Σ Si	8.7	F^-	3.7
Al	<0.02	Cl^-	1.01
Fe^{2+}	<0.02	SO_4^{2-}	0.71
Fe^{3+}	<0.02	HCO_3^-	95
Mn^{2+}	<0.01	CO_3^{2-}	7
Mg^{2+}	0.05	U	0.10 (ppb)
Ca^{2+}	3.3	Ra	0.02 (Bq/l)
Na^+	39	Rn	193 (Bq/l)
K^+	0.24		

Isotope	
δD	-54.8 (‰)
$\delta^{18}O$	-8.5 (‰)
^3H	<0.25 (TU)
$\delta^{13}C$	-17.6 (‰)
^{14}C	10.8 (% Modern Carbon)
^{14}C age	12840 (year)



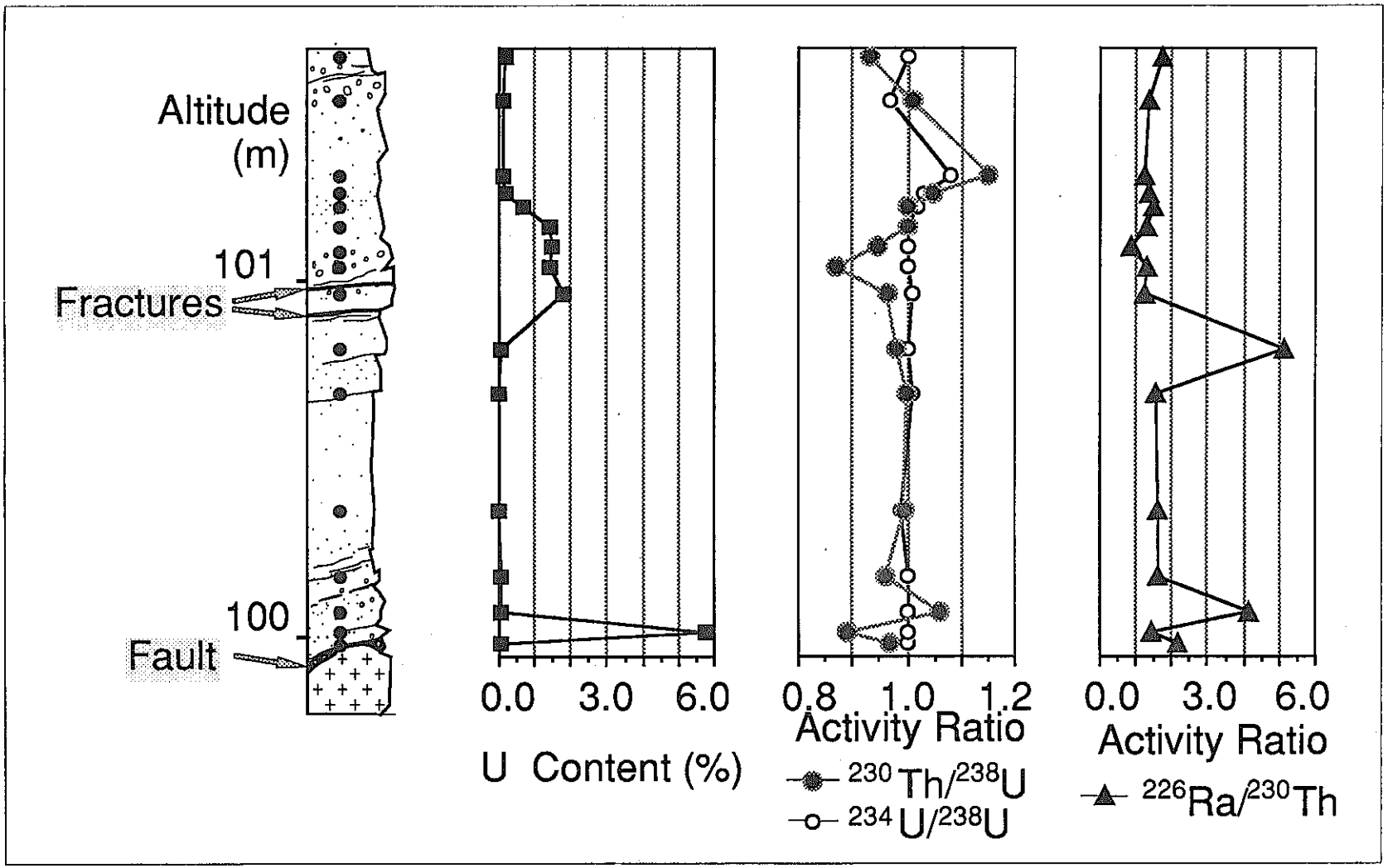
Detailed Scale Information List 3

D-3 : Information from uranium-series disequilibrium studies carried out on a boring core in the ore body zone (KNA-3 borehole)

D-3-1 : Uranium contents and uranium-series disequilibrium of the ore body zone

D-3-2 : Uranium contents and radioactivity ratios of rock specimens

Detailed Scale Index 3 ≈ 50 m



Uranium Contents and Uranium-series Disequilibrium of the Ore Body Zone

(after Nohara et. al. 1992)

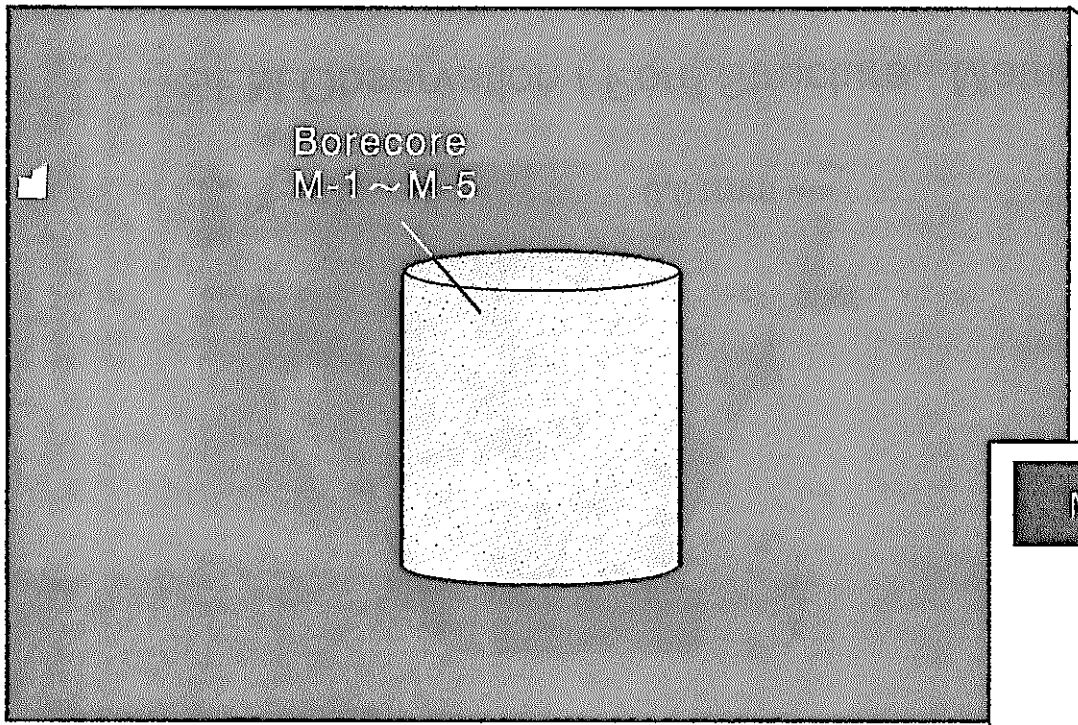
D-3-1

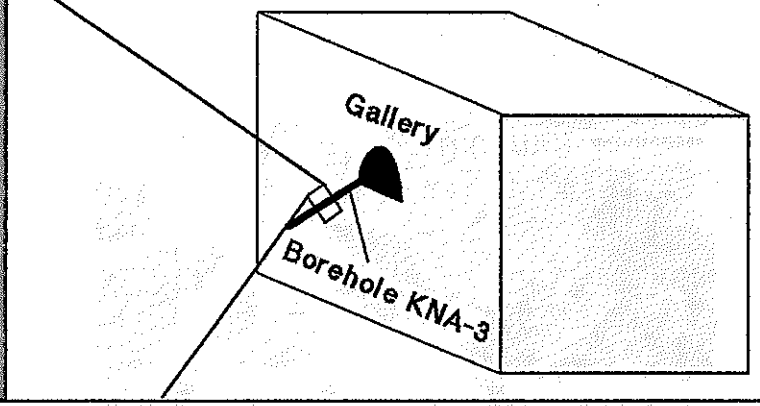
D-3-2

Uranium contents and radioactivitity ratios of rock specimens

Altitude(m)	U (%)	$^{234}U/^{238}U$ A.R.*	$^{230}Th/^{234}U$ A.R.*	$^{230}Th/^{238}U$ A.R.
101.61	0.21	1.00 ± 0.02	0.93 ± 0.10	0.93 ± 0.12
101.50	0.12	0.97 ± 0.02	1.04 ± 0.10	1.01 ± 0.12
101.41	0.11	1.08 ± 0.02	1.06 ± 0.10	1.14 ± 0.12
101.27	0.21	1.03 ± 0.02	1.02 ± 0.10	1.05 ± 0.12
101.25	0.71	1.02 ± 0.02	0.98 ± 0.10	1.00 ± 0.12
101.23	1.45	1.00 ± 0.02	1.00 ± 0.10	1.00 ± 0.12
101.21	1.46	1.00 ± 0.02	0.95 ± 0.10	0.95 ± 0.12
100.851	1.45	1.00 ± 0.02	0.87 ± 0.10	0.87 ± 0.12
100.94	1.81	1.01 ± 0.02	0.96 ± 0.10	0.97 ± 0.12
100.87	0.041	1.00 ± 0.02	0.98 ± 0.10	0.98 ± 0.12
100.71	0.005	1.01 ± 0.02	0.99 ± 0.10	1.00 ± 0.12
100.27	0.018	0.99 ± 0.02	1.00 ± 0.10	0.99 ± 0.12
100.09	0.083	1.00 ± 0.02	0.96 ± 0.10	0.96 ± 0.12
100.02	0.055	1.00 ± 0.02	1.06 ± 0.10	1.06 ± 0.12
100.00	5.74	1.00 ± 0.02	0.89 ± 0.10	0.89 ± 0.12
99.97	0.049	1.00 ± 0.02	0.97 ± 0.10	0.97 ± 0.12

* All quoted errors are 1 σ uncertainties due to nuclear counting statistics only.





Micro Scale Information List

M-1 : SEM observation

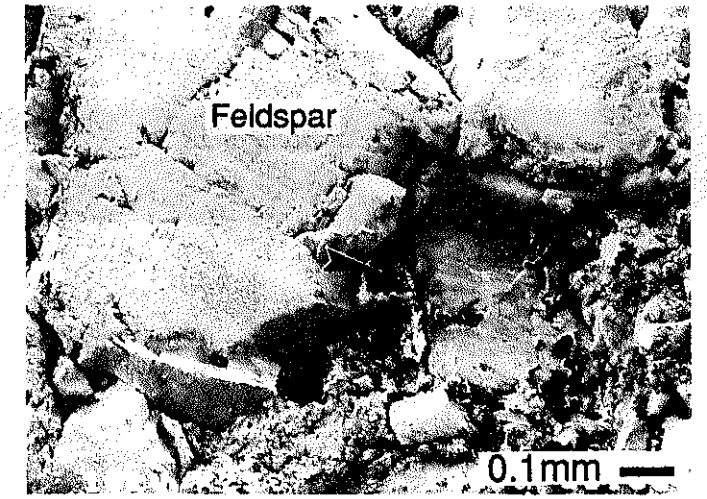
M-2 : Result of impregnation test

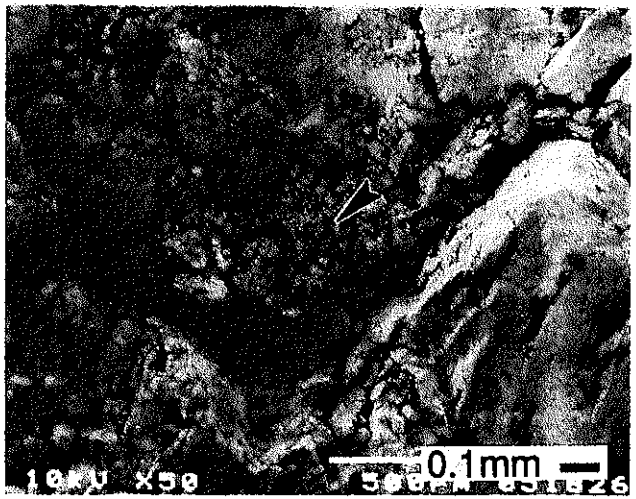
M-3 : Cathodoluminescence

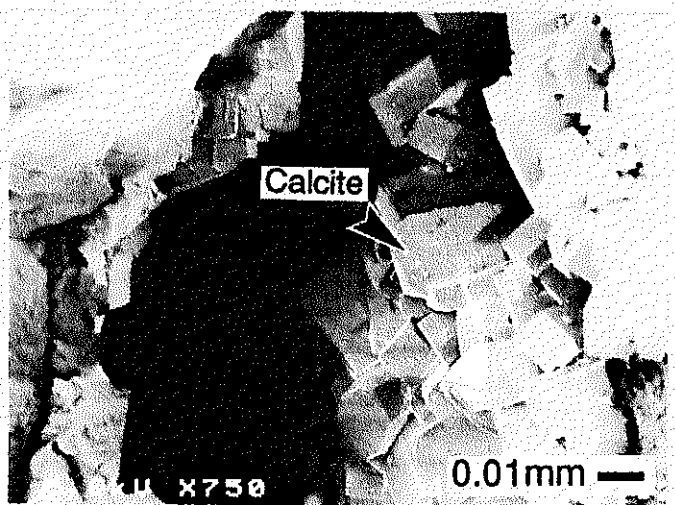
M-4 : Qualitative chemical analyses
- M-4-1 : α -autoradiograph
- M-4-2 : Characteristic X-ray photograph
- M-4-3 : Line profile

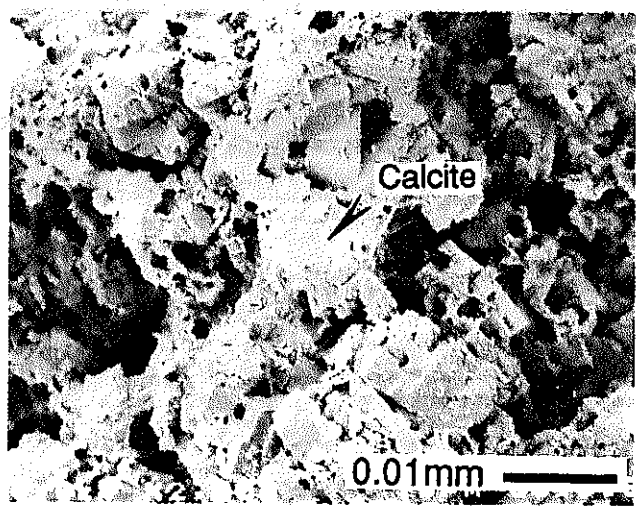
M-5 : Quantitative chemical analyses

Micro Scale Index ≈ 1cm～1μm

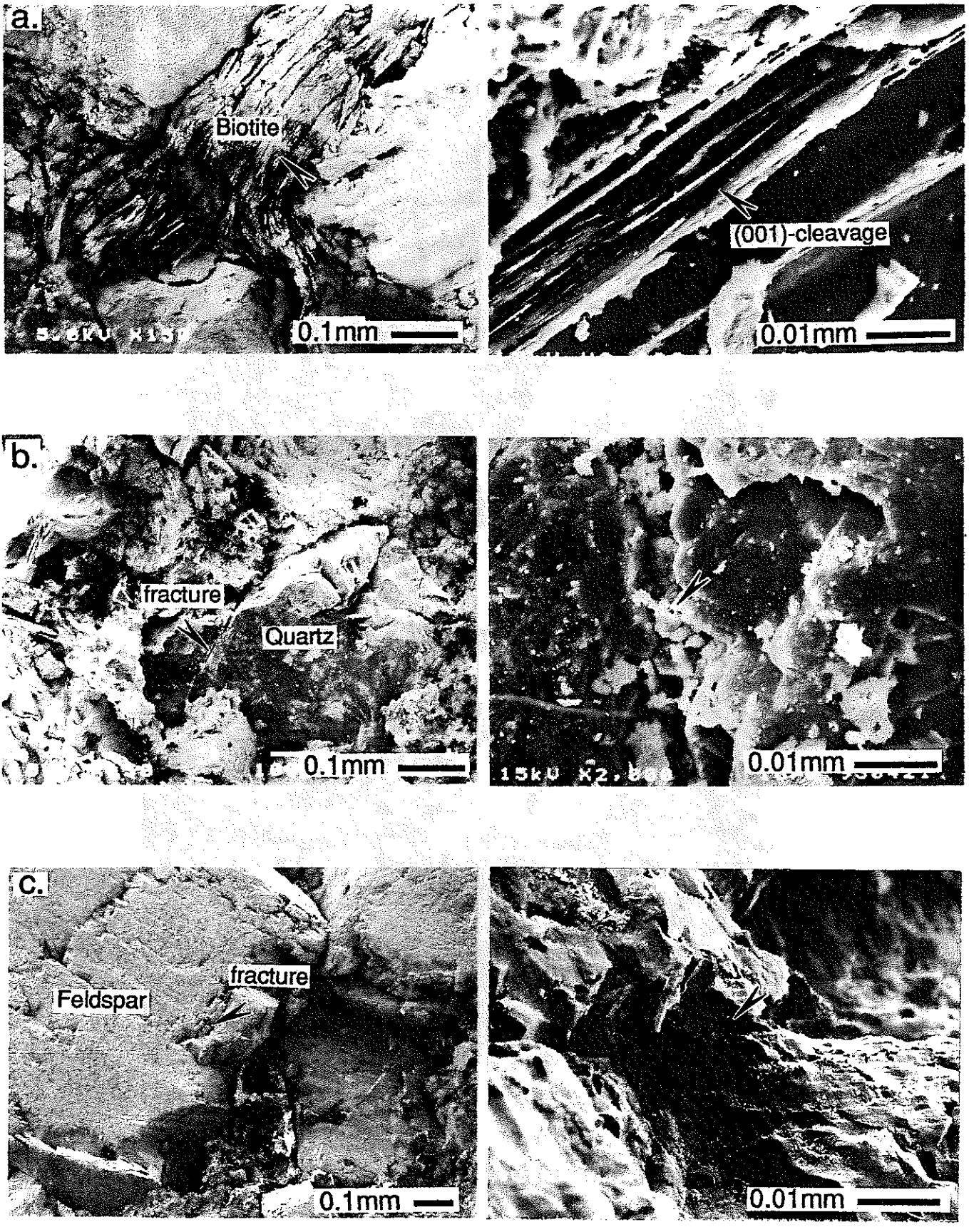






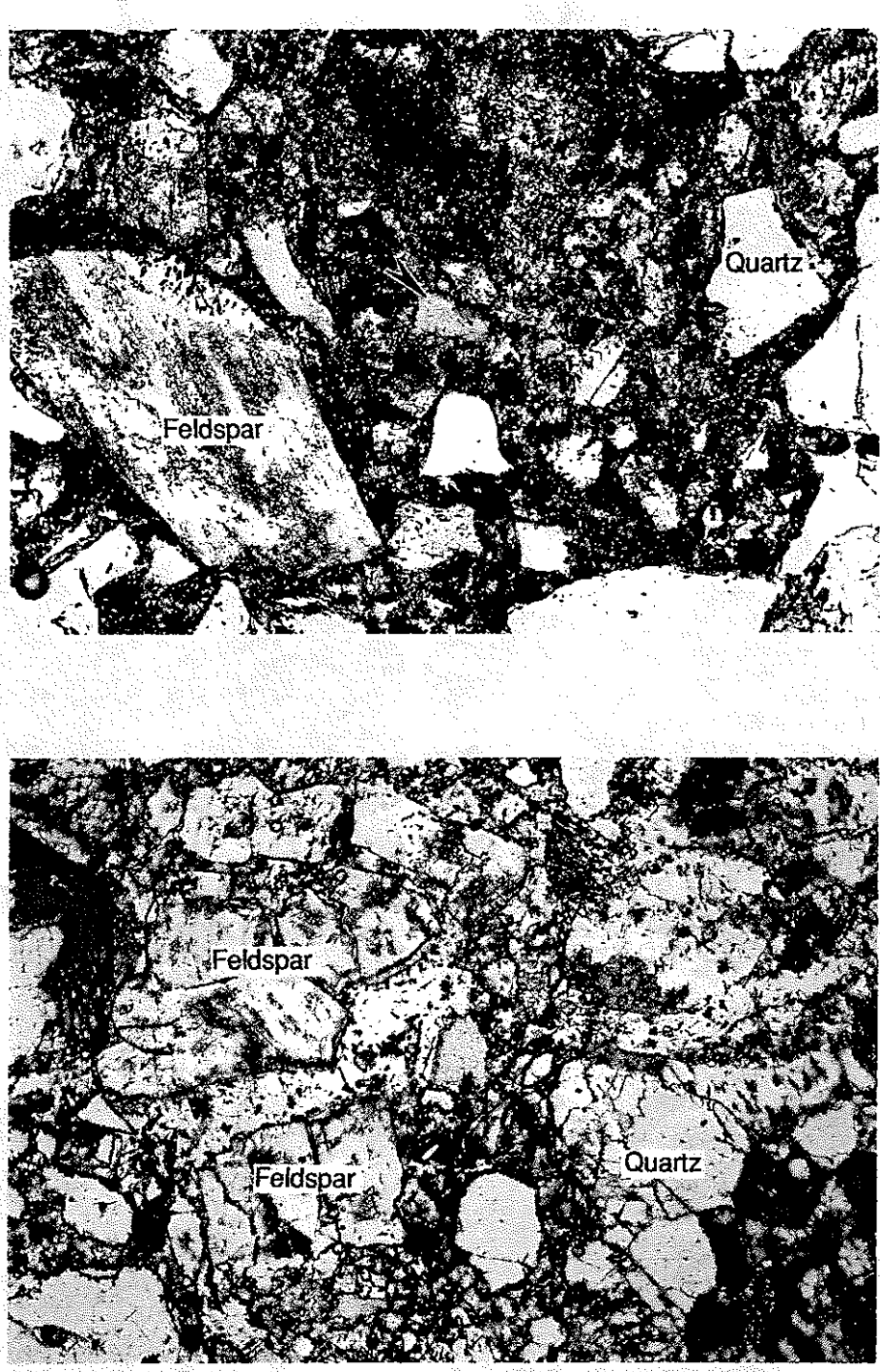


SEM Observation (Pore Structure, Matrix)

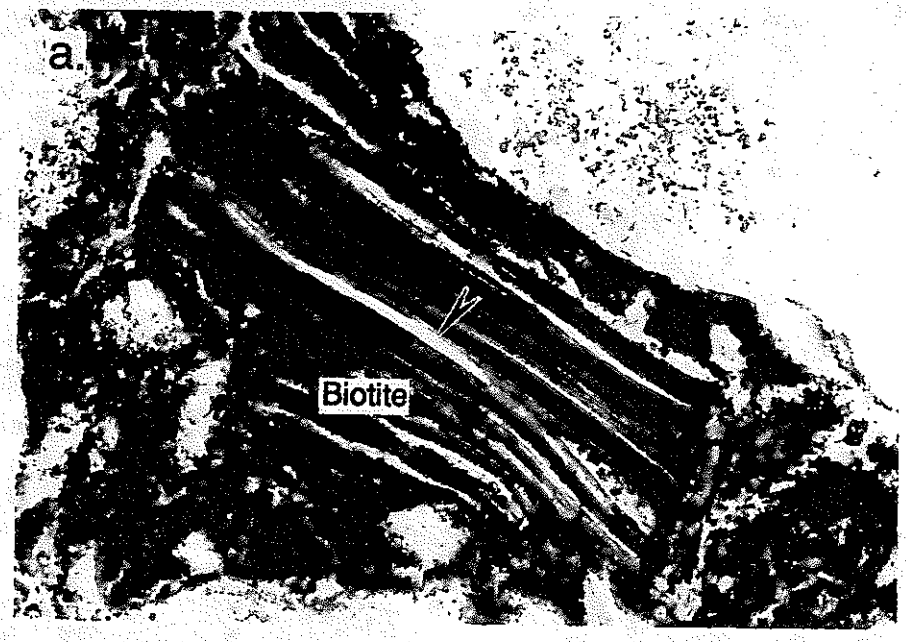


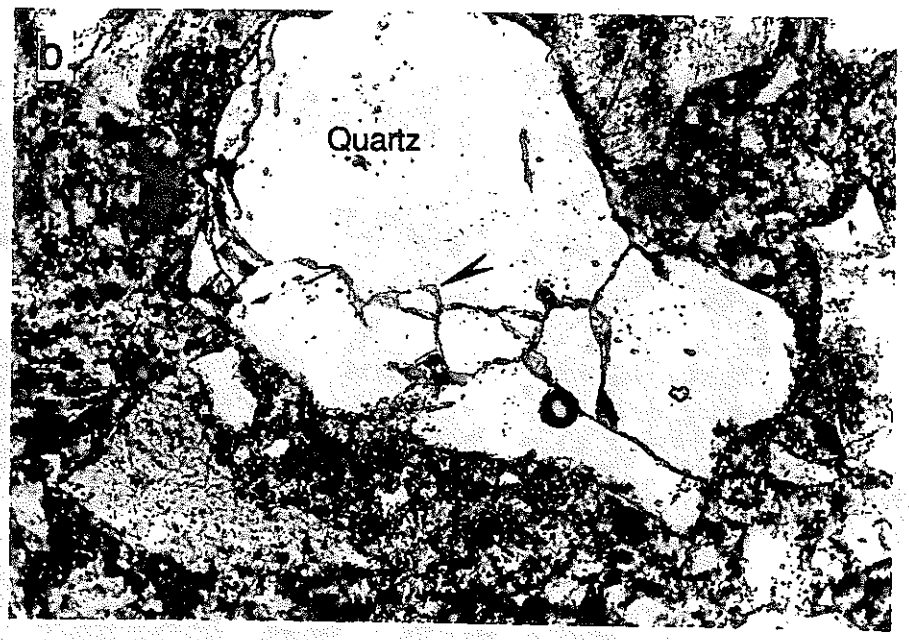
SEM Observation (Pore Structure,
Grain : a.Biotite b.Quartz c.Feldspar)

M-2-1

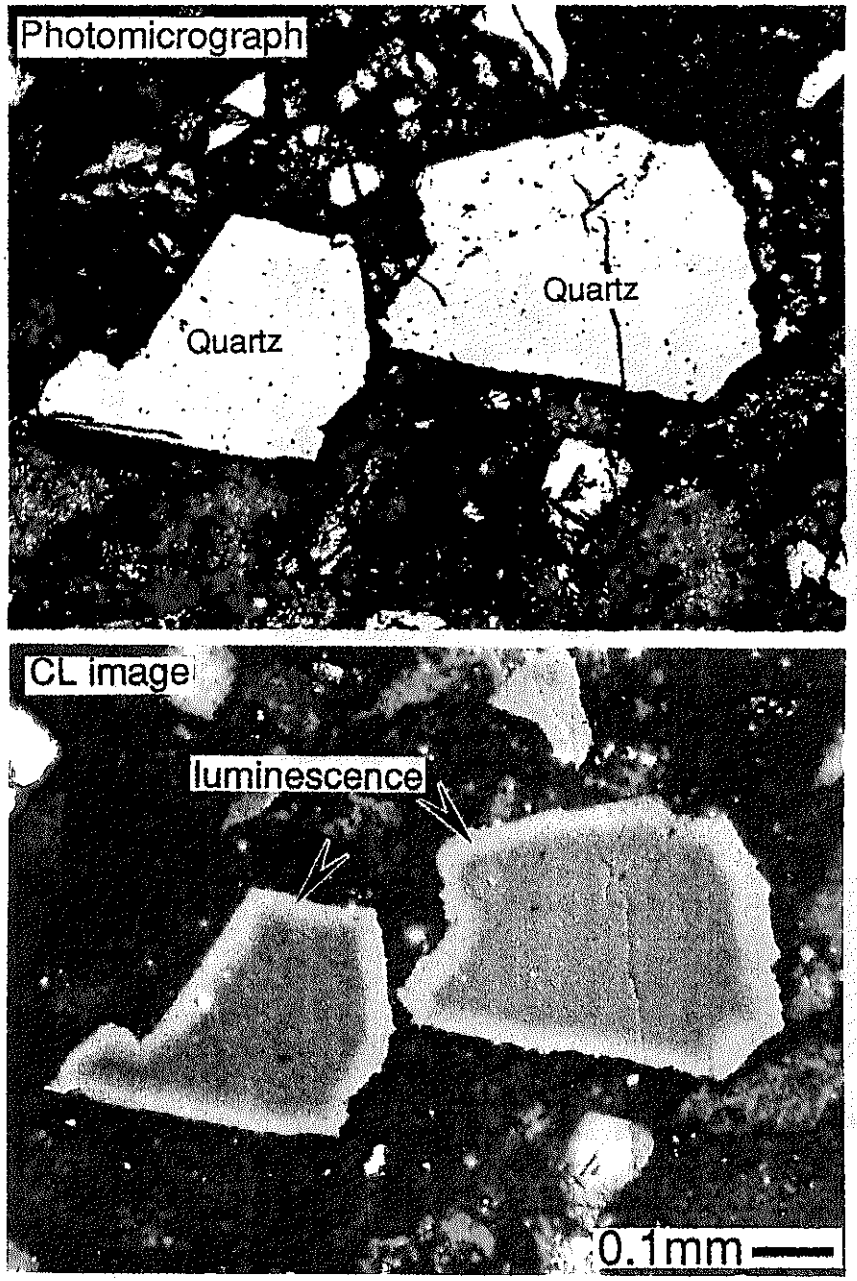


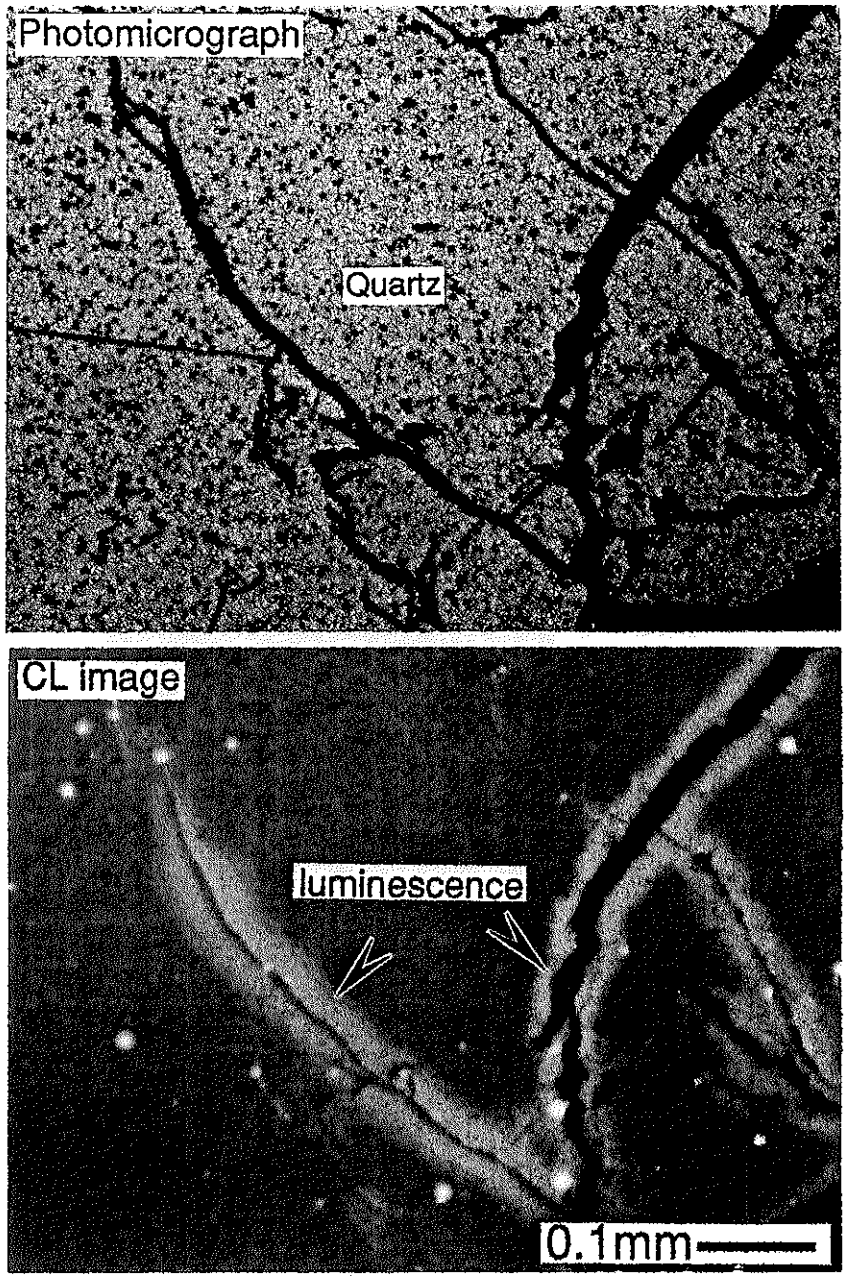
Result of Impregnation Test (Matrix)



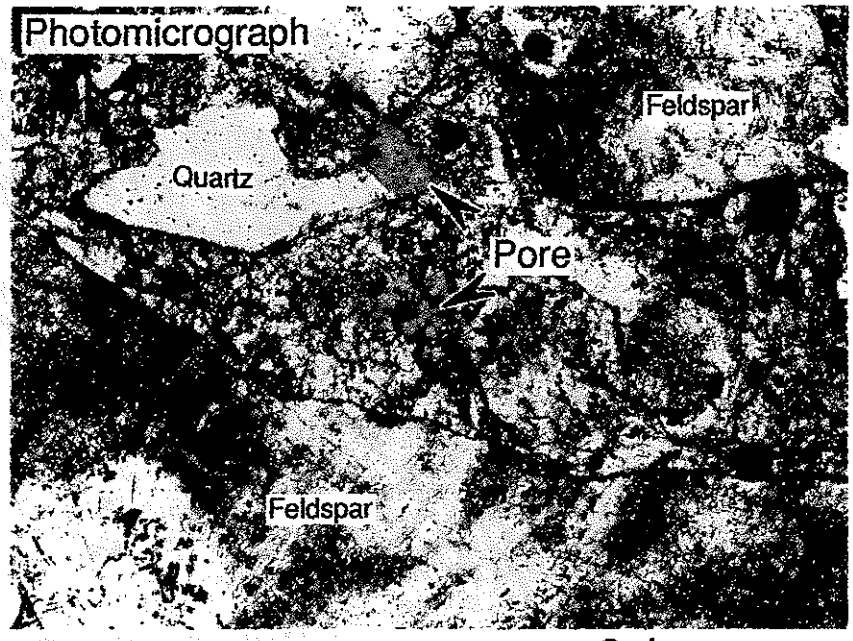


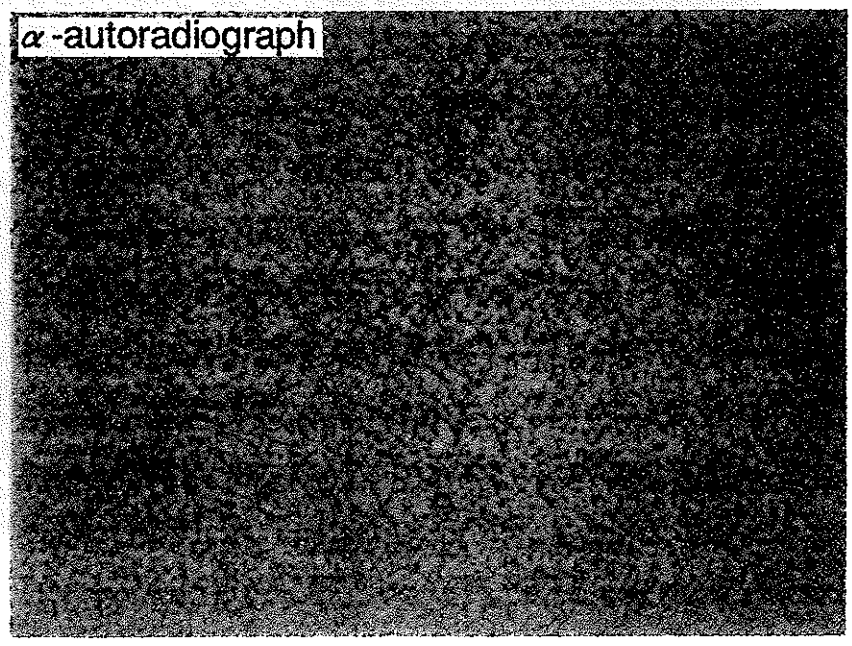
Result of Impregnation Test (Grain : a. Biotite, b. Quartz)





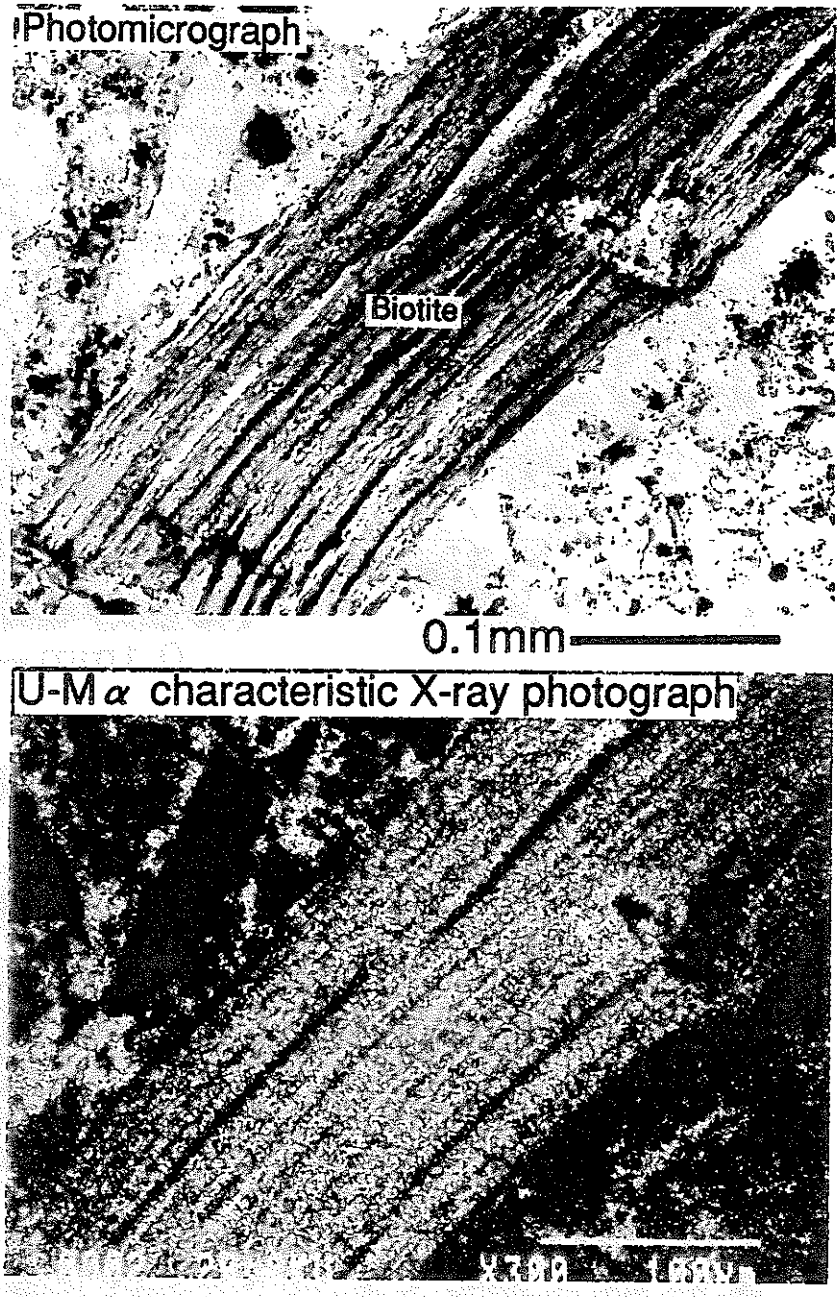
Cathodoluminescence (Quartz)



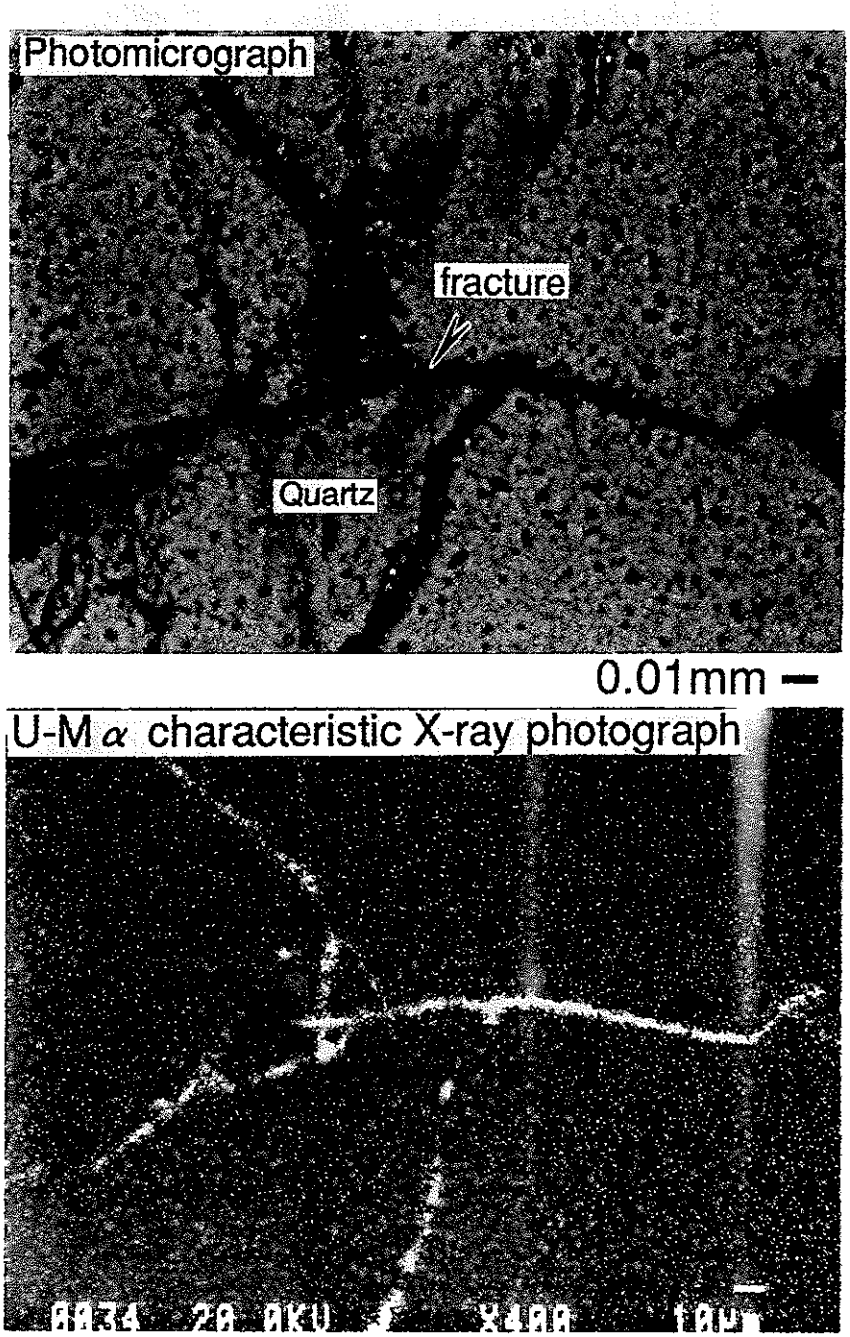


α - autoradiograph (Matrix)

M-4-2

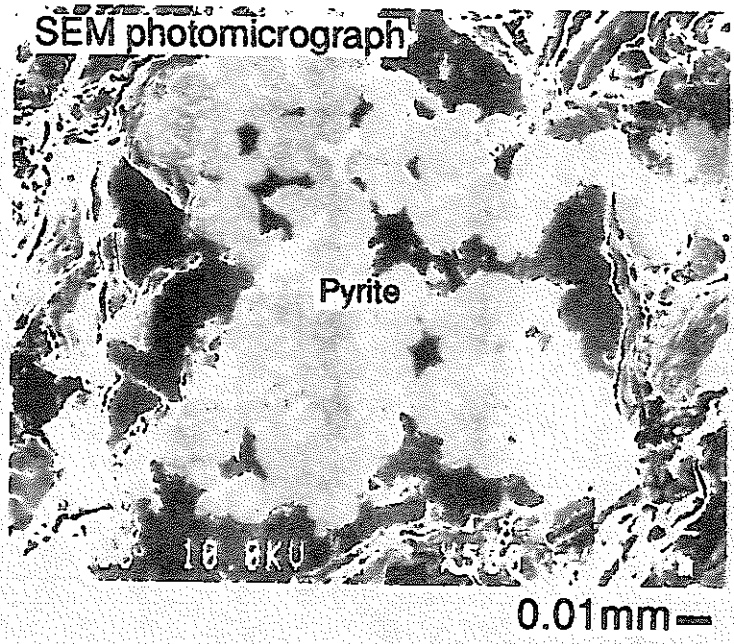


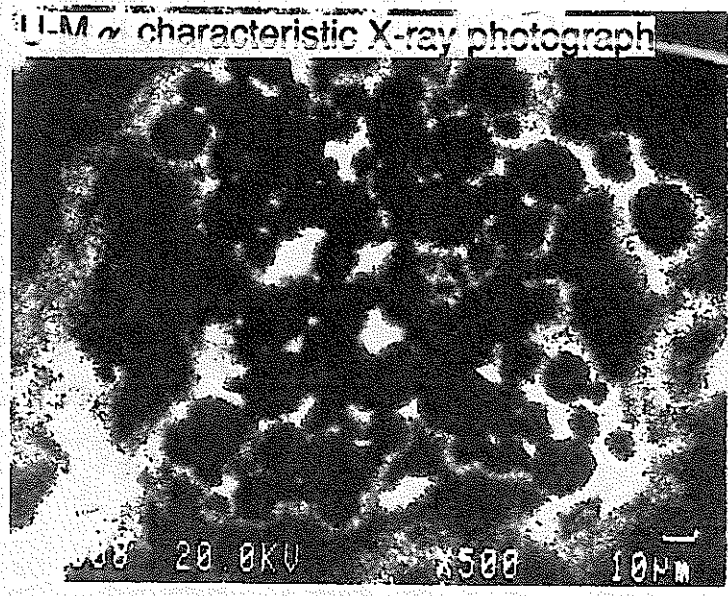
Characteristic X-ray photograph (Biotite)



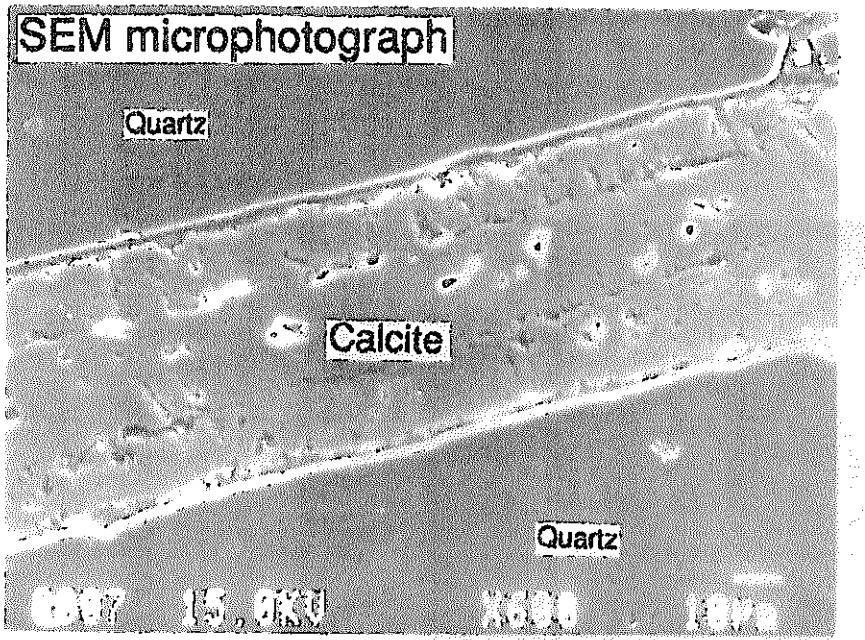
Characteristic X-ray photograph (Quartz)

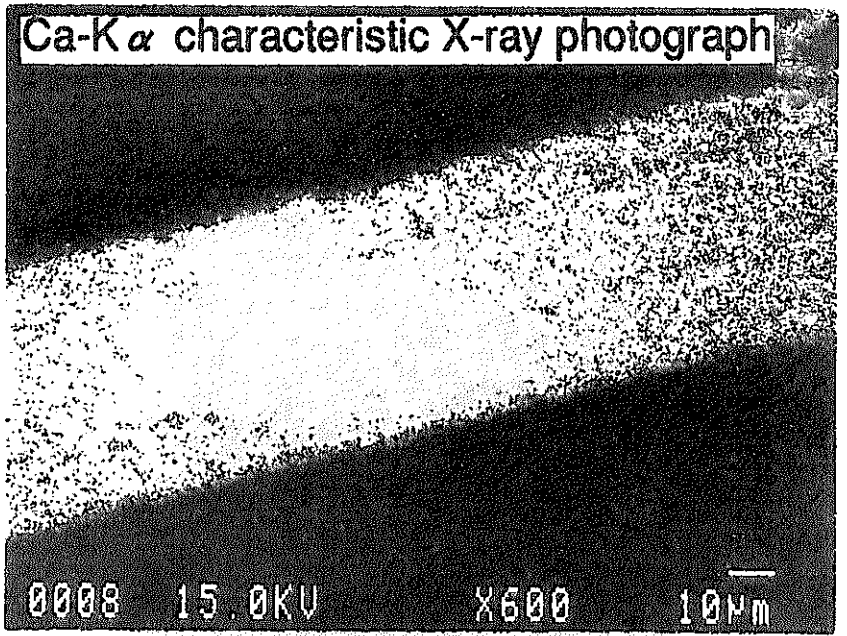
M-4-2

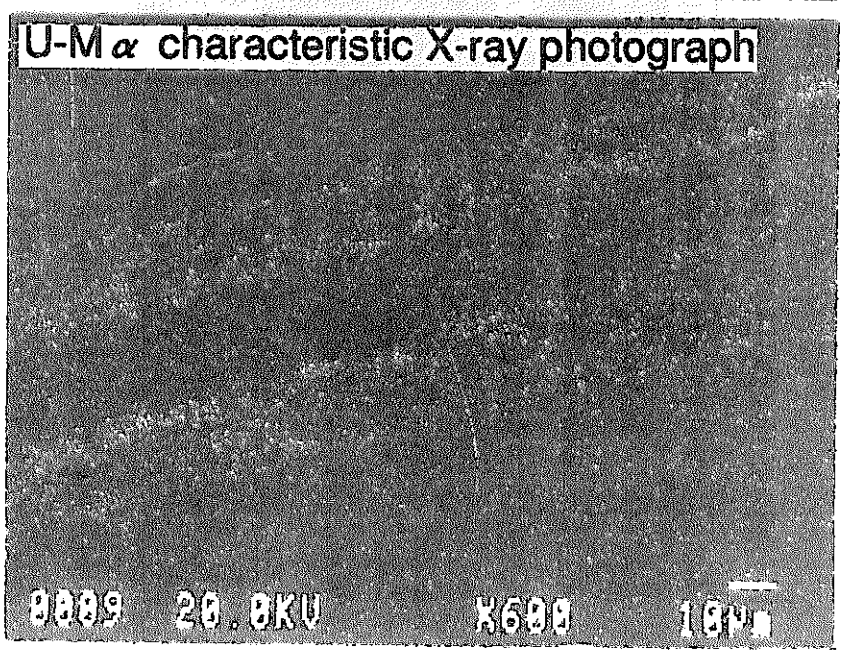




Characteristic X-ray photograph (Pyrite)



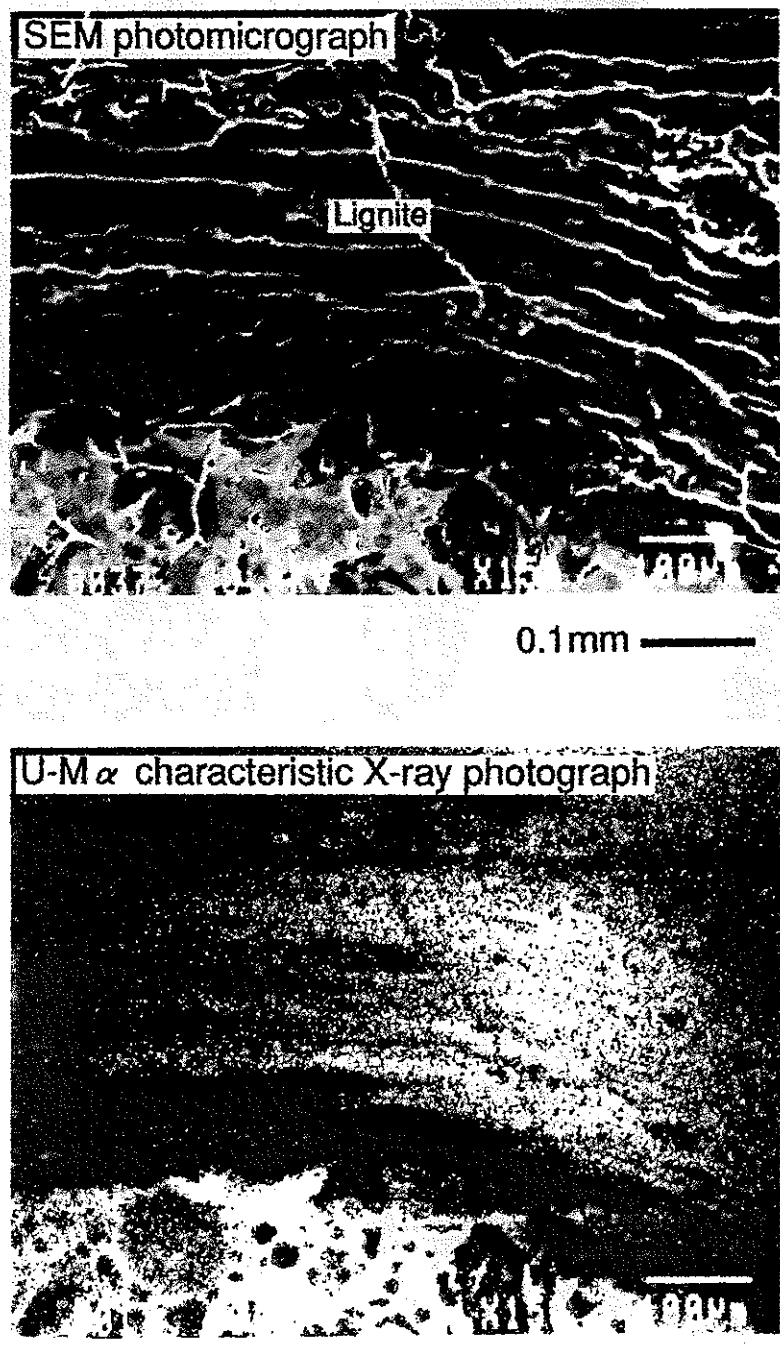




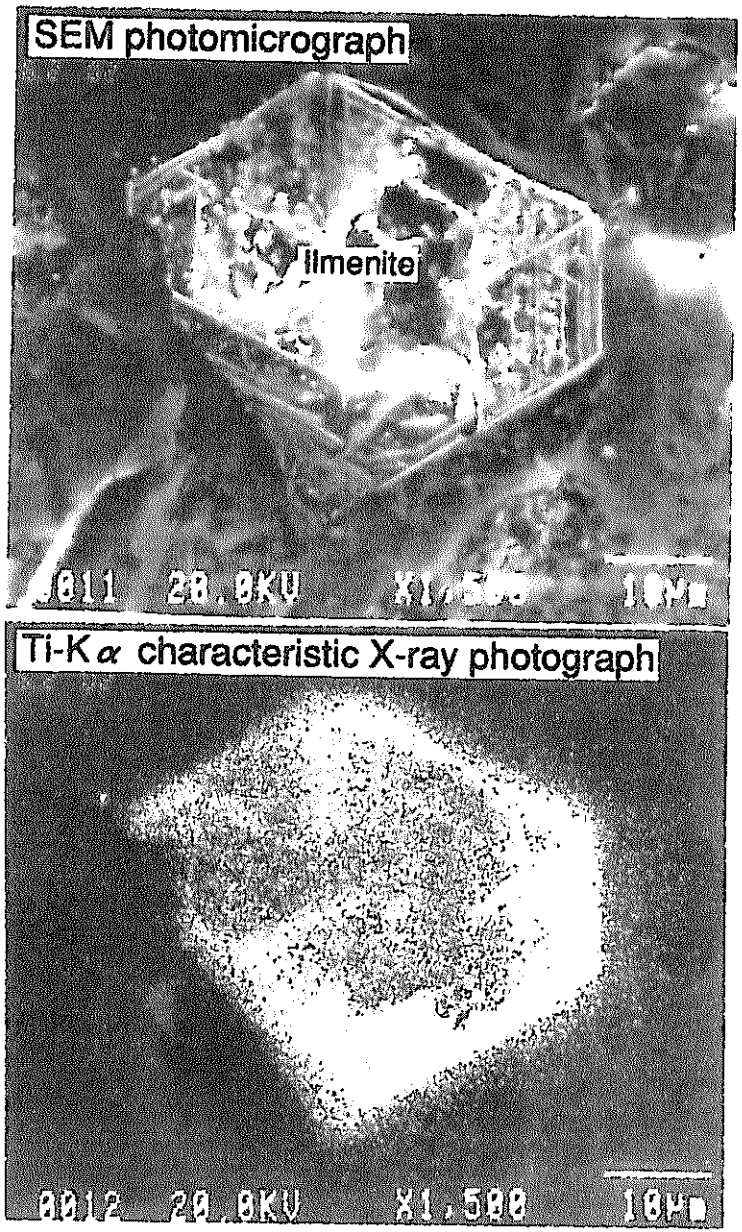
Characteristic X-ray photograph (Calcite)

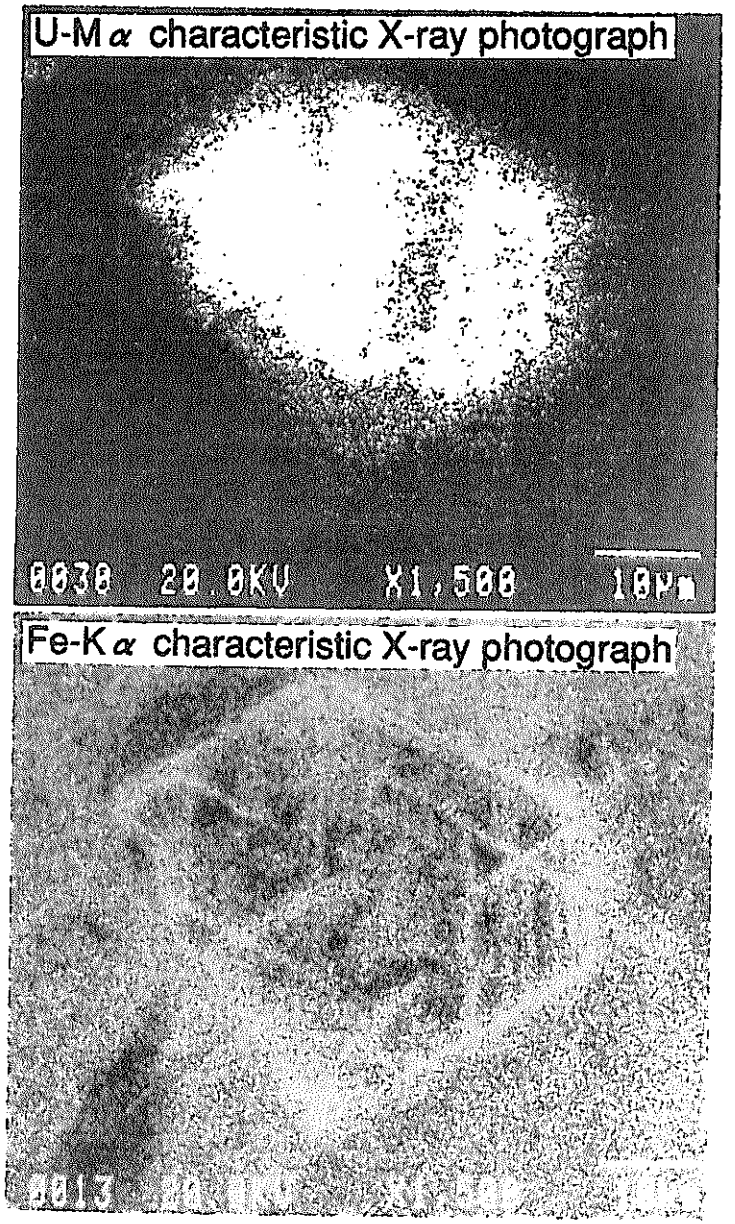
M-4-2

M-4-2



Characteristic X-ray photograph (Lignite)



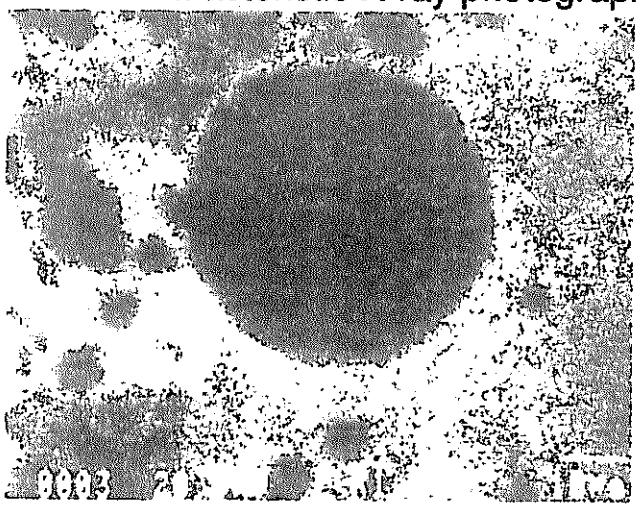


0.01mm

Characteristic X-ray photograph (Ilmenite)

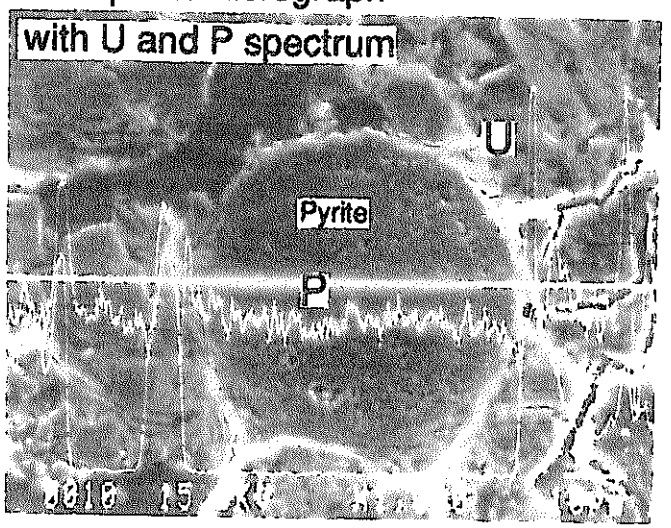
Characteristic X-ray photograph (Ilmenite)

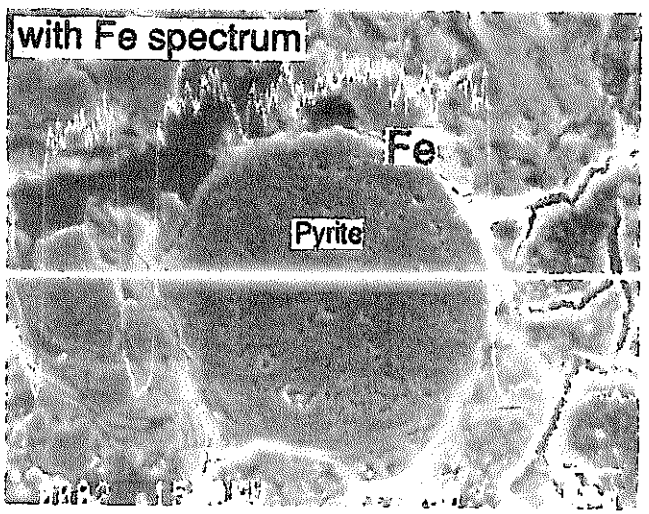
U-Mα characteristic X-ray photograph



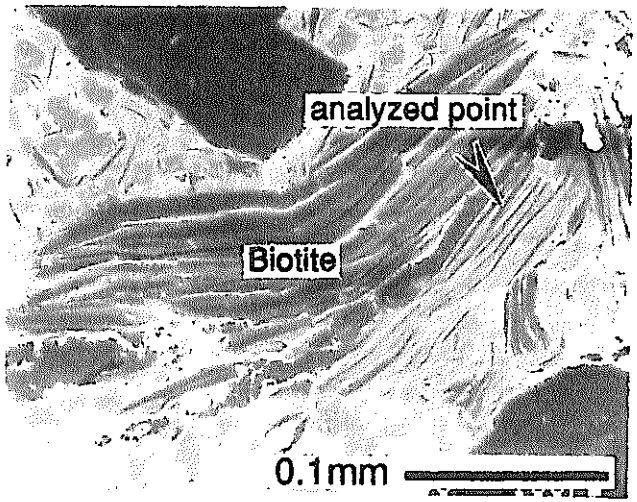
0.01mm

SEM photomicrograph

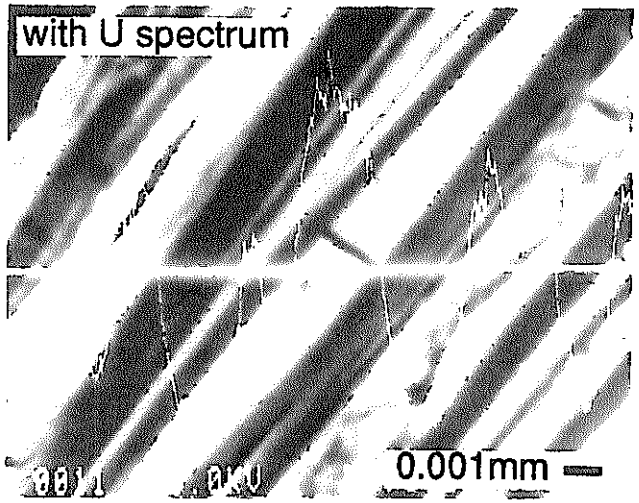


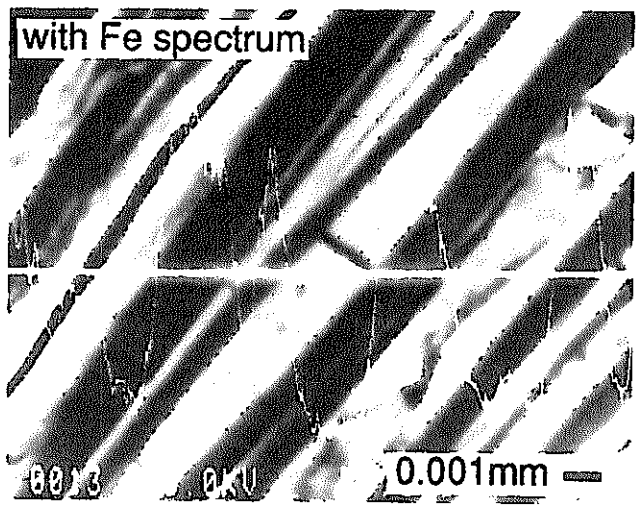


Line Profile (Pyrite)

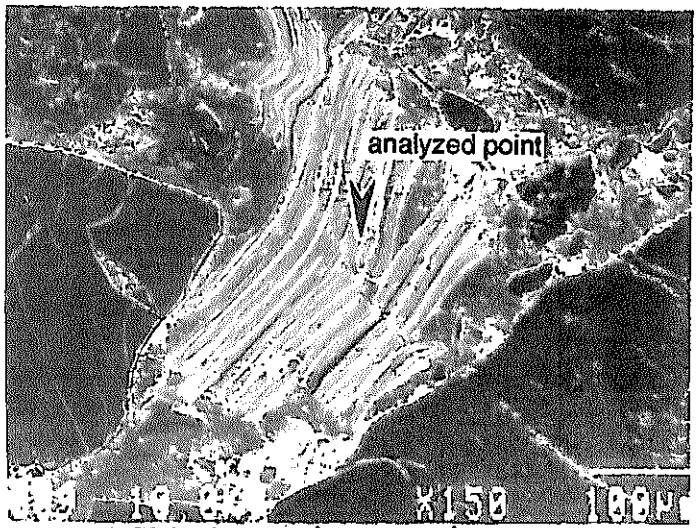


SEM photomicrograph

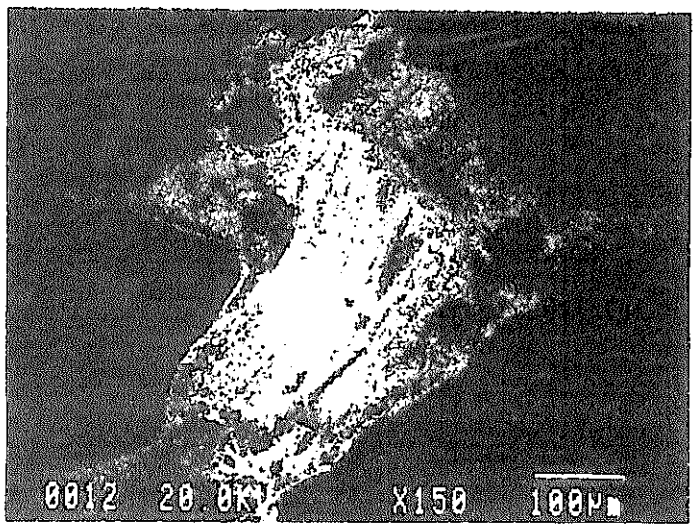




Line Profile (Biotite)



SEM photomicrograph

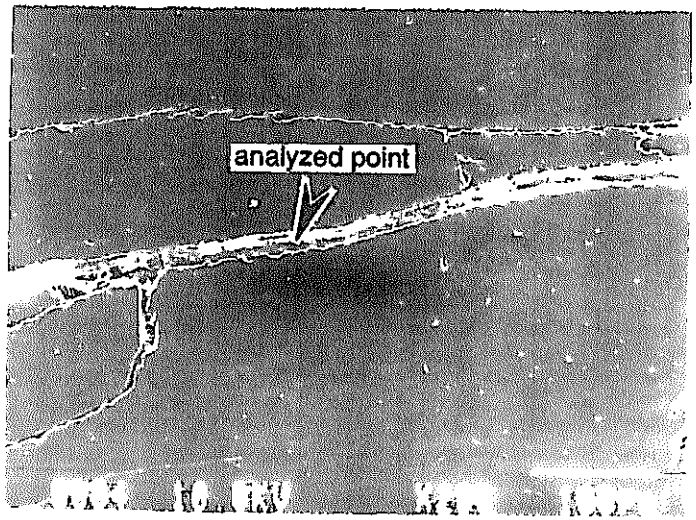


U-M α characteristic X-ray image

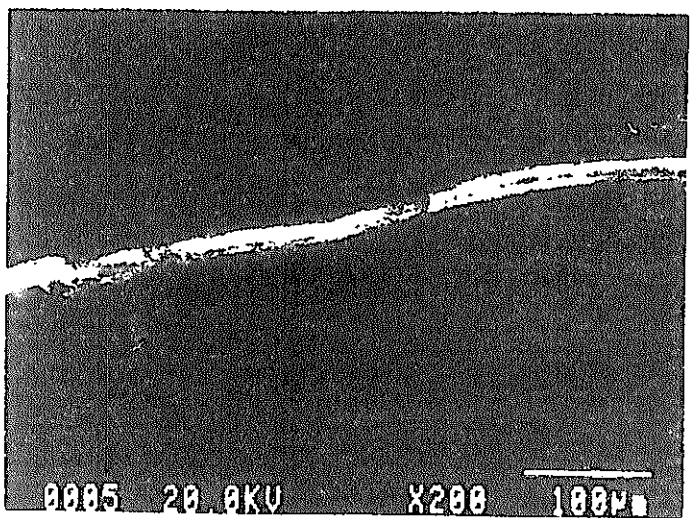
Microprobe Analysis of Biotite

	Wt. (%)
SiO_2	31.5
TiO_2	0.7
Al_2O_3	8.3
FeO	5.0
MnO	0.4
MgO	2.1
CaO	5.8
Na_2O	0.2
K_2O	0.9
P_2O_5	1.0
SO_3	—
UO_2	40.5
Total	96.4

Quantitative Chemical Analysis (Biotite)



SEM photomicrograph



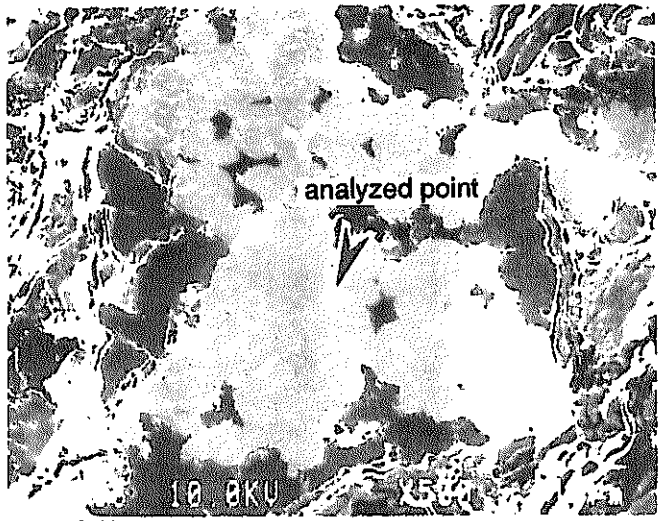
U-Mα characteristic X-ray image

Microprobe Analysis of Quartz

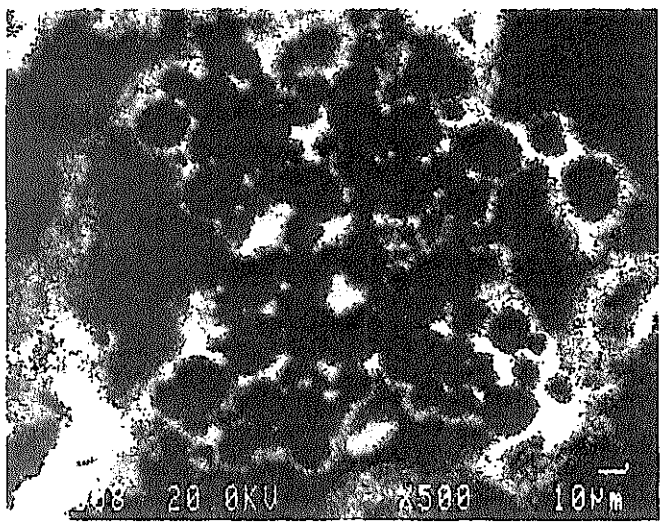
	Wt. (%)
SiO_2	55.4
TiO_2	0.1
Al_2O_3	4.1
FeO	0.8
MnO	0.1
MgO	0.3
CaO	2.6
Na_2O	0.2
K_2O	0.3
P_2O_5	0.1
SO_3	0.1
UO_2	20.5
Total	84.6

Quantitative Chemical Analysis (Quartz)

M-5



SEM photomicrograph



U-M α characteristic X-ray image

Microprobe Analysis of Pyrite

	Wt. (%)
SiO_2	18.6
TiO_2	0.1
Al_2O_3	2.4
FeO	4.9
MnO	0.1
MgO	—
CaO	2.8
Na_2O	—
K_2O	0.2
P_2O_5	0.8
SO_3	3.3
UO_2	57.7
Total	90.9

Quantitative Chemical Analysis (Pyrite)

4. REFERENCES

(1) Andersson, J. E., Andersson, O. and Nilsson, A. C. (1991) : Results of Hydraulic Testing and Groundwater Sampling in Borehole AN-1 at the Shomasama Field in Japan. SKB Report 6.053/15401.

(2) Black, W. H., Smith, H. R. and Patton, F. D. (1986) : Multi-level Groundwater Monitoring with the MP System. Proceedings of the NWWA-AGU Conference on Surface and Borehole Geophysical Methods and Groundwater Instrumentation. Denver, Co., Oct. 15-17 1986, 41-61.

(3) Doi, K., Hirano, S. and Sakamaki, Y. (1975) : Uranium Mineralization by Ground Water in Sedimentary Rocks, Japan. Economic Geology, Vol.70, 628-646.

(4) Doi, K. and Hirano, S. (1990) : Behaviour of Uranium Migration in Epigenetic Uranium Ore Deposits with Reference to Radioactive Waste Isolation in Geologic Media.

(5) Hirose, K., Uchida, M. and Takeda, S. (1991) : Review of Geological Problems on Radioactive Waste Isolation in Japan. Geological Problems in Radioactive Waste Isolation, A World Wide Review, Witherspoon, P. A. (ed.), Earth Sci. Division Lawrence Berkeley Laboratory, Univ. of California, 93-101.

(6) Itoigawa, J. (1980) : Geology of the Miocene Mizunami Group, Japan. Bull. Mizunami Fossil Mus., No.1, 9-42, in Japanese with English Abstract.

(7) Kanai, Y., Sakamaki, Y. and Seo, T. (1990) : Geochemical Behaviour of Uranium Series Nuclides (^{238}U, ^{234}U, ^{230}Th, ^{222}Rn) around the Tono Uranium Mine, Gifu Prefecture, Central Japan. Geochemistry, Vol.24, No.2, 123-132, in Japanese with English Abstract.

(8) Nohara, T., Ochiai, Y., Seo, T. and Yoshida, H. (1992) : Uranium-Series Disequilibrium Studies in the Tono Uranium Deposit, Japan. Radiochimica Acta, Vol.58/59, 409-413.

(9) Ochiai, Y., Yamakawa, M., Takeda, S. and Harashima, F. (1989) : Natural Analogue Study on Uranium Deposit in Japan. Proceedings of 3rd CEC Natural Analogue Working Group Meeting, Snowbird, USA, June 15-17 1988, Come, B. and Chapman, N. A. (eds.), 126-138.

(10) Sato, C., Ochiai, Y. and Takeda, S. (1987) : Natural Analogue Study of Tono Sandstone Type Uranium Deposit in Japan. CEC Radioactive Waste Management Series, Natural Analogues in Radioactive Waste Disposal, Come, B. and Chapman, N. A. (eds.), Graham & Trotman, 462-472.

(11) Seo, T., Ochiai, Y., Takeda, S. and Nakatsuka, N. (1989) : A Natural Analogue Study on Tono Sandstone Type Uranium Deposit in Japan. Proceedings of the 1989 Joint International Waste Management Conference, Oct. 22-28 1989, Kyoto, Japan, Vol.2, 353-358.

(12) Seo, T. and Yoshida, H. (1992) : Natural Analogue Studies of the Tono Uranium Deposit in Japan. Proceedings of 5th CEC Natural Analogue Working Group Meeting and Alligator River Analogue Project(ARAP) Final Workshop, Toledo, Spain, Oct. 5-9 1992, Maravic, H. and Smellie, J.(eds.), 141-146, (Pre-Print).

(13) Sugihara, K., Hirota, M.and Shiraishi, T. (1991) : A Hydrogeological Modelling Process for Sedimentary Rocks. Proceedings of the 7th International Congress on Rock Mechanics of ISRM (International Society for Rock Mechanism), Aachen, FRG, Sept. 16-17 1991, Wittke, W. (ed.), 413-420.

(14) Uemura, T. (1961) : Tectonic Development of the Miocene Sedimentary Basins of East Mino, Central Japan. Jour. Earth Sci., Vol.9, Nagoya Univ., 394-417.

(15) Yamakawa, M.(1991) : Geochemical Behaviour of Natural Uranium-Series Nuclides in Geological Formation. Proceedings of the 3rd International Symposium on Advanced Nuclear Energy Research -Global Environment and Nuclear Energy-, March 13-15 1991, Mito, Japan, 150-158.

(16) Yanagizawa, K., Saito, A., Nishigaki, M. and Hirata, Y. (1989) : Development of New Aquifer Test Method and Its Application to Granite and Sandstone. The Japanese Society of Soil Mechanics and Foundation Engineering. Vol.37, No.7, Ser. No.378, 47-52., in Japanese.

(17) Yanagizawa, K., Nakano, K., Seo, T., Hosobori, K. and Nishigaki, M. (1991) : Development of PNC Groundwater Sampler. Proceedings of the Annual Meeting of Japanese Association of Groundwater Hydrology., Oct. 23-26 1991, 204-207., in Japanese.

(18) Yoshida, H., Yui, M. and Shibutani, T. (1991) : A Study of Influence Factor on Uranium Fixation in the Tono Uranium Deposit. PNC Technical Report, PNC TN7410 91-061.

(19) Yoshida, H., Komuro, K., Yamamoto, M. and Otsuka, Y. (1992) : Influence of Micro Path Structure on Nuclides Migration in Sedimentary Rocks. Abstracts of 29th International Geological Congress, Aug. 24- Sept. 3 1992, Kyoto, Japan, vol.1, 226.

(20) Yoshida, H., Yui, M. and Shibutani, T. (1994) : Flow-path Structure in Relation to Nuclide Migration. -An approach with field investigations and experiments for uranium migration at Tono uranium deposit, central Japan. Jour. Nucl. Sci. Tech. (in press).

(21) Yusa, Y. and Yamakawa, M. (1992) : Tono In-situ Research Facilities for Studies of the Geological Environment. 29th IGC Field Trip Guide Book Vol.3 : Environmental Geology and the Late Quaternary of Japan, Geol. Surv. Japan, 145-154.

(22) Yusa, Y., Ishimaru, K., Ota, K., and Umeda, K. (1993) : Geological and Geochemical Indicators of Paleohydrogeology in Tono Uranium Deposits, Japan. Paleohydrogeological Methods and their Applications, Proceedings of an NEA Workshop, Paris, Nov. 9-10 1992, 117-146.

――技術レポートリスト――

TR/GE 89-01　清水和彦：地質環境データベースシステムの開発研究（基本設計），PNC TN7410 89-029

TR/GE 89-02　仙波毅・尾方伸久・坪田浩二：ボアホールレーダの我が国における花崗岩岩盤への適用試験，PNC TN7410 90-003

TR/GE 89-03　武田精悦（訳）：国際ストリパプロジェクト，PNC TN7410 90-004

TR/GE 89-04　尾方伸久・大澤英昭：地下水特性調査技術開発の現状，検層技術(1)，PNC TN7410 90-005

TR/GE 89-05　尾方伸久・大澤英昭：地下水特性調査技術開発の現状，検層技術(2)，PNC TN7410 90-006

TR/GE 89-06　大澤英昭・吉田英一：深部花崗岩中の割れ目解析－花崗岩岩盤における割れ目特性およびその分布特性に関する研究－，PNC TN7410 90-007

TR/GE 89-07　杉原弘造・二宮康郎：堆積岩盤中における掘削影響評価－掘削による緩み領域の計測・評価手法の研究開発－，PNC TN7410 90-009

TR/GE 89-08　柳澤孝一：広域地下水流動調査の現状について，PNC TN7410 90-021

TR/GE 89-09　吉田英一：粘土質岩中における核種移行試験・研究－ベルギー・モル原子力研究所との共同研究（その１）－，PNC TN7410 90-019

TR/GE 90-01　今井久・柳澤孝一：３次元飽和不飽和浸透流解析プログラムTAGSACの概要，PNC TN7410 90-026

TR/GE 90-02　野原壮・瀬尾俊弘・落合洋治：ウラン鉱床を利用したナチュラルアナログ研究（その１）－ウラン系列核種の放射非平衡について－，PNC TN7410 91-030

TR/GE 90-03　吉田英一：粘土質岩中における核種移行試験研究－ベルギー・モル原子力研究所との共同研究（その２）－，PNC TN7410 91-017

TR/GE 90-04　柳澤孝一・今井久・斎藤章・大澤英昭・中島誠：立坑掘削影響試験における地下水流動影響予測解析，PNC TN7410 91-013

TR/GE 90-05　清水和彦：地質環境の長期的隔離能に係わる天然事象について(1)－気候変動と海面変動－，PNC TN7410 91-010

TR/GE 91-01　H. Yoshida, M. Yui and T. Shibutani :A Study of Influence Fatcor on Uranium Fixation in the Tono Uranium Deposit, Japan, PNC TN7410 91-061

TR/GE 91-02　中野勝志・斉藤章・花木達美：難透水性岩石を対象とした室内透水試験装置の開発，PNC TN7410 91-050

TR/GE 91-03　尾方伸久・大澤英昭・仙波毅・柳澤孝一：多変量統計解析手法を用いた結晶質岩盤の割れ目解析，PNC TN7410 92-001

TR/GE 91-04　石丸恒存・清水和彦：地質環境の長期的隔離性能に係わる天然事象について(2)－火山活動－，PNC TN7410 91-031

TR/GE 91-05　仙波毅・尾方伸久・長谷川健・岩崎浩・渡辺邦夫：ボアホールレーダーによる結晶質岩盤中の割れ目帯調査－釜石鉱山原位置試験場における調査について－，PNC TN7410 92-005

TR/GE 92-01　柳澤孝一・古屋和夫・大澤英昭・若松尚則・梅田浩司：我が国における地盤の透水性に関する調査研究（その１），PNC TN7410 92-015

TR/GE 92-02　佐藤稔紀・石丸恒存・杉原弘造・清水和彦：文献調査による我が国の岩石の物理的特性に関するデータの収集，PNC TN7410 92-018

TR/GE 92-03　瀬尾俊弘・清水和彦：我が国における地下水の水質に関するデータの収集解析，PNC TN7410 92-017

TR/GE 92-04　柳澤孝一・今井久・古屋和夫・若松尚則・梅田浩司：我が国を対象とした地下水流動解析－その１　中部日本を対象にしたた地下水流動解析－，PNC TN7410 92-019

TR/GE 92-05　柳澤孝一・若松尚則・梅田浩司・今井久・古屋和夫：我が国における水理地質学的特性に関する調査・研究，PNC TN7410 92-012

TR/GE 92-06　松井裕哉・杉原弘造・佐藤稔紀・吉岡尚也：堆積岩地山における立坑周りの力学的・水理学的な特性変化，PNC TN7410 92-046

TR/GE 92-07　佐藤稔紀・松井裕哉・杉原浩弘・吉岡尚也：立坑掘削影響試験－地中変位質計測に基づく掘削影響評価－，PNC TN7410 92-051

TR/GE 92-08　湯佐泰久：立坑掘削影響試験ワ―クショップ―発表論文集―，PNC TN7410 92-052

TR/GE 93-01　H. Yoshida, T. Seo, T. Nohara, K. Ota, K. Hama, K. Kodama, T. Iwatsuki :Data Compilation of Geoscientific Studies of Tono Uranium Deposits, Central Japan, PNC TN7410 94-015