Annex

Workshop Materials

WS-1 TEM 1 Outline

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

Transient Electromagnetic (TEM) Survey Workshop

Outline of TEM

Geophysical Survey
Tsugio ISHIKAWA

December 23, 2010

Ministry of Water and Energy
Japan International Cooperation Agency (JICA)

Purpose of the Study

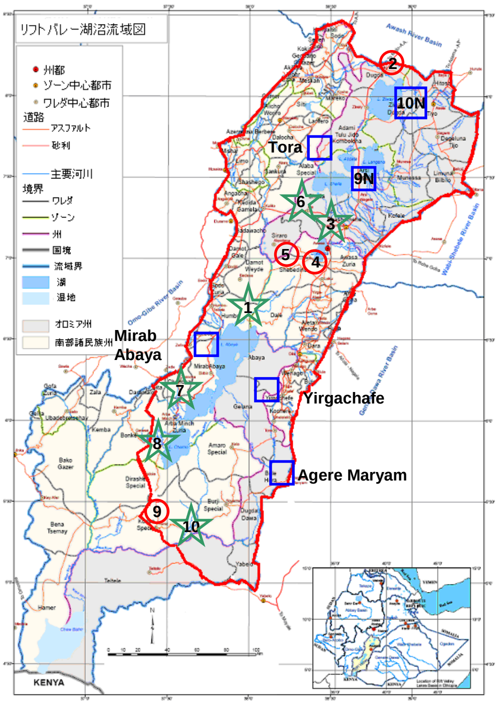
- **The production of hydrogeological maps**
- **To evaluate the groundwater potential of the major aquifers**
- **The establishment of water supply plans for towns of less than about 10,000 people**
- **Mapping Groundwater regions in the area with the aim of improving the Ministry of Water and Energy capacity in water supply planning**

↓ **Geophysical Survey**

- Understand aquifer structure and geometry
- Provide information on water quality
- Select test well drilling points
- Comparison the electrical and electromagnetic sounding results
- Comparison of the geophysical survey and the well drilling data

WS-1 TEM 1 Outline

Location of Project Area



Geophysical Sites
Rift Valley Lakes Basin

○ : VES
□ : TEM(TDEM)
☆ : Both Surveys

Drilling number
: Well drilling site
(except No.9 and No.10)

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Progress of the Geophysical Survey

Item of the work	Quantity	2010						
		Mar.	Apr.	May			Nov.	Dec.
	Survey Point							
VES:Vertical Eectrical Sounding	10Sites 100	First Field Survey						
HES:Horizontal Electrical Sounding	15lines, 7275m							
							Second Field Survey	
TEM:Transient Electromagnetic survey	12Sites, 50							

Geophysical methods for Groundwater Exploration

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Classification of Electrical Methods

- **Electrical Methods**
  - **Electrical**
  - **Electromagnetic**

What does geophysics detect?

◆Electrical conductivity
  Presence of conductive materials
  Clays versus sands and gravel
◆Magnetic susceptibility
  Amount of magnetic minerals
  Volcanics versus sediments

Electrical Soundings




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Measurement Instrument
(Resistivity)

STING R1
Output current : 1～500mA

Electrical Properties

High Resistivity - Low Conductivity Materials
- fresh water
- sand or gravels
- sandstone bedrock
- limestone bedrock

Low Resistivity - High Conductivity Materials
- clays or shale bedrock
- saline water
- sands and gravels saturated with saline water

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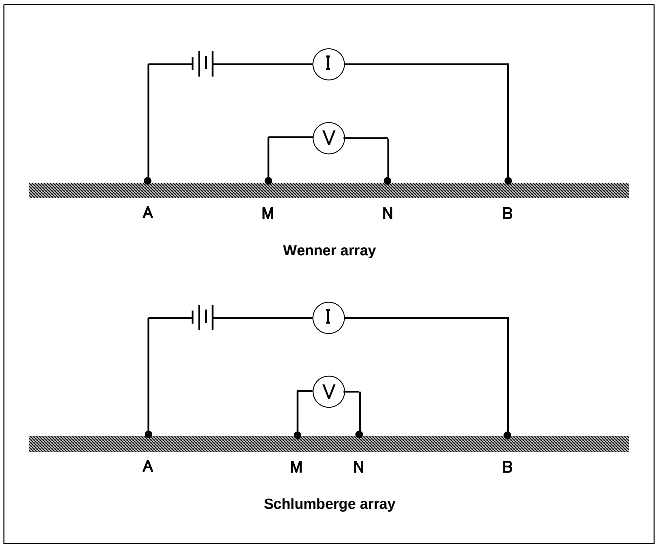
Quantity of Electrical Soundings

Region	Well drilling site No.	Site area	Total number	
			Vertical Electrical	Horizontal electrical
Oromia	2	Berta/Meki	10	1line, 500m
	3	Oyne-Umbure -Chefo	10	1line, 500m
	10	Brindar	10	3lines, 1500m
SNNPRS	1	Abaya Chokare	10	2lines, 775m
	4	Chancho	10	1line, 500m
	5	Fango Damot	10	1line, 500m
	6	Lajo/Yaye	10	1line, 500m
	7	Arbaminch	10	2lines, 1000m
	8	Walesa	10	1line, 500m
	9	Beresa	10	2lines, 1000m
Total	10	10	100	15lines, 275m

Electrode Configuration



HES
(Horizontal Electrical Sounding)

↓

VES

(Vertical Electric Sounding)

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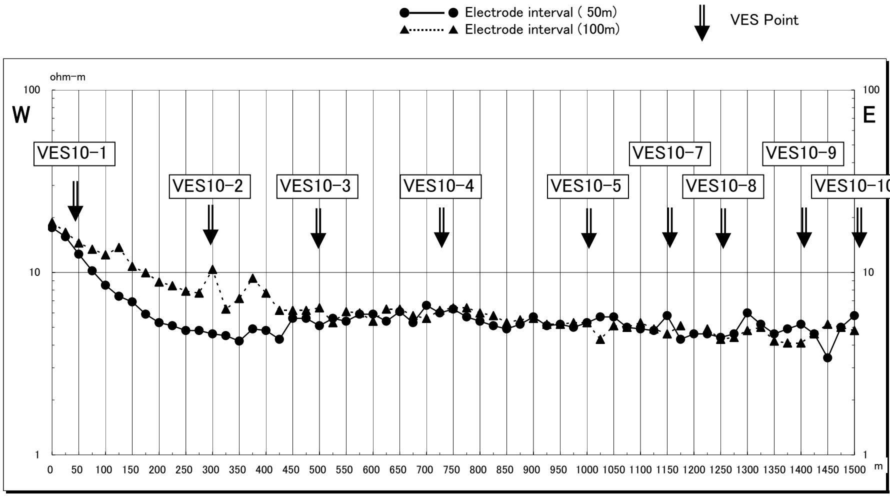
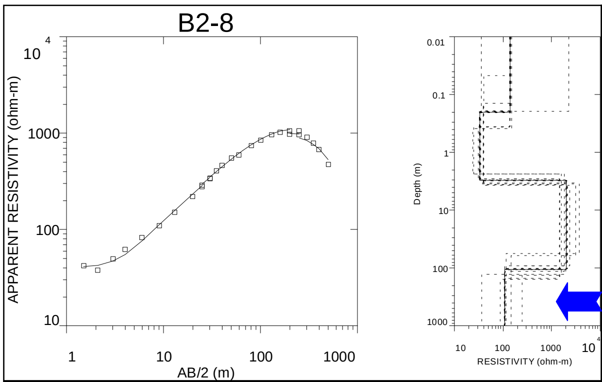


Apparent resistivity profile by horizontal electrical sounding (BH10)

Interpretation by inversion



1st-2nd:topsoil

3rd:dry pyroclastic(tuffs, volcanic,ash)

4th:Highly weathered / fracture rocks or pyroclastic(water bearing aquifer)

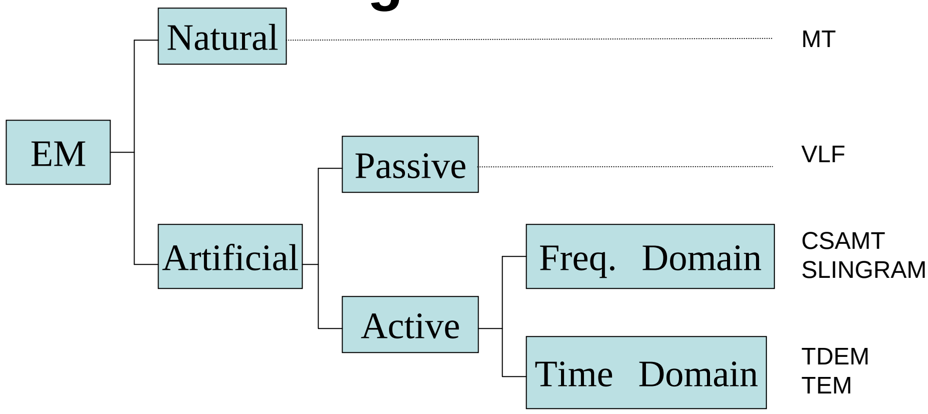
Analytic example of the Electric survey site BH-2 (Berta/Meki) in Oromia region.

The left figure shows the match between the field curve and the theoretical curve computed for the interpreted resistivity structure.

The right figure shows the interpreted subsurface resistivity structure.

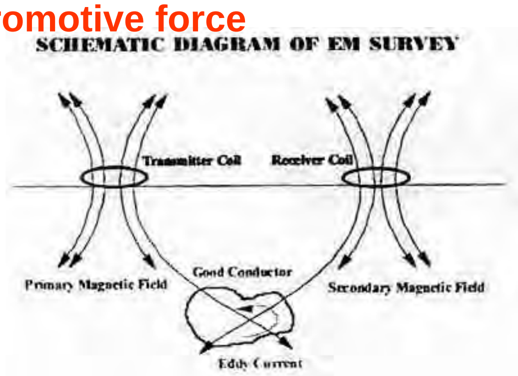
WS-1 TEM 1 Outline

Electromagnetic Methods



- **MT** **Magneto-tellurics**
- **VLF** **Very low frequency**
- **CSAMT** **Controlled Source Audiomagnetotellurics**
- **SLINGRAM** **(This method was originally developed and used in Sweden in the 1930s)**
- **TDEM** **Time Domain Electro-magnetic (also TEM)**

- **What is electromagnetic method?**
  Geophysical methods
  using electromagnetic phenomena
- **What is electromagnetic phenomena?**
  Currents create magnetic fields
  Change of magnetic field creates
  electromotive force



Various EM Equipment

VLF Receiver / Transmitter

Operating frequency

15KHz to 28KHz, depending on VLF broadcasting station

Ground Conductivity Meters

Operating frequency

14.5 kHz

EM38

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Ground Conductivity Meters

Operating frequency

9.8 kHz

EM31

Ground Conductivity Meters

Intercoil Spacings &
Operating frequency

10 m at 6.4 kHz
20 m at 1.6 kHz
40 m at 0.4 kHz

EM34

Slingram

MAXMIN I-8

frequency range of which is from 110Hz to 14.08KHz.

TECHNIQUE USED IN THE FIELD

TDEM

(Time Domain Electro-magnetic Method)

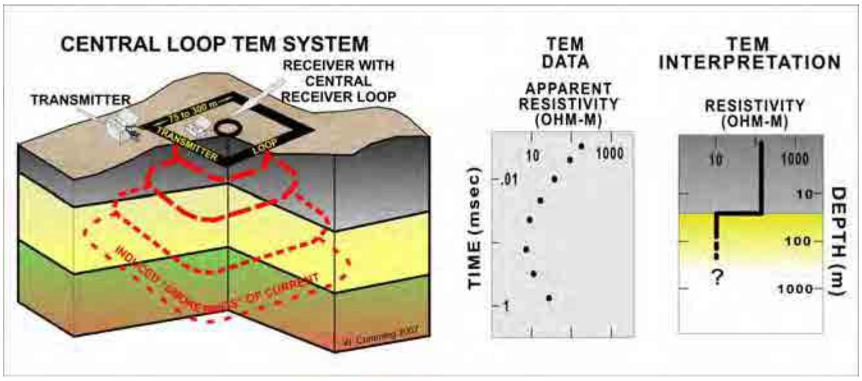
/

TEM

（Transient Electro-magnetic Method）

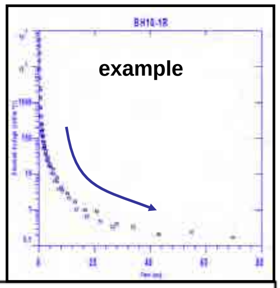
WS-1 TEM 1 Outline

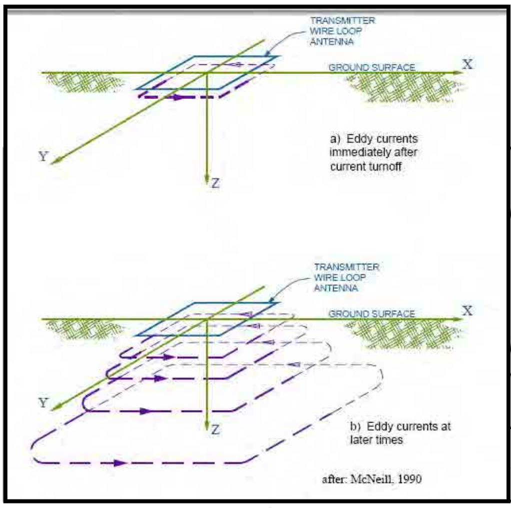
TDEM / TEM

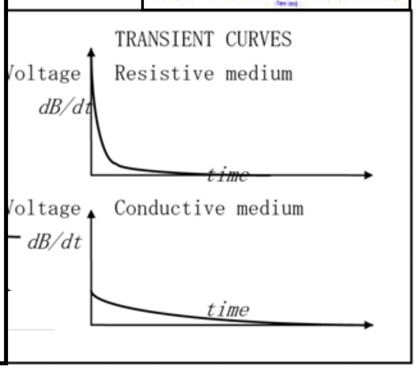


- Pulse current in outer loop, measure signal in inner loop from "smoke rings" of current induced by magnetic field.
- TDEM depth often< 300 m, <<MT
- No electrodes so no static distortion
- Focused so less 2D/3D distortion
- Noisy data or no signal is sometimes misinterpreted

EDDY CURRENTS

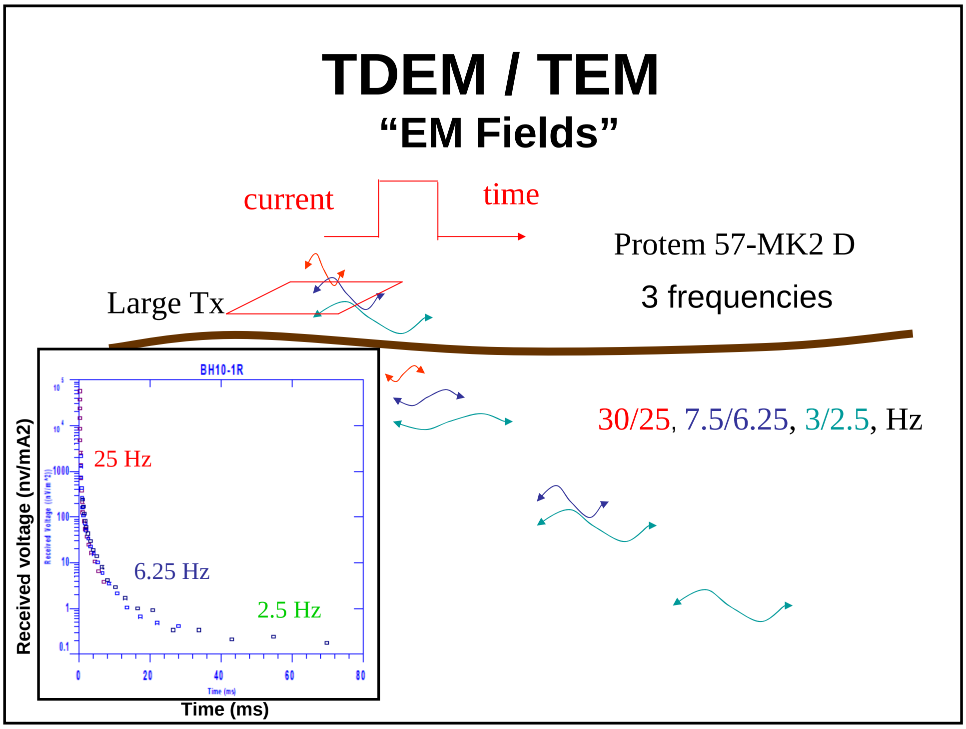


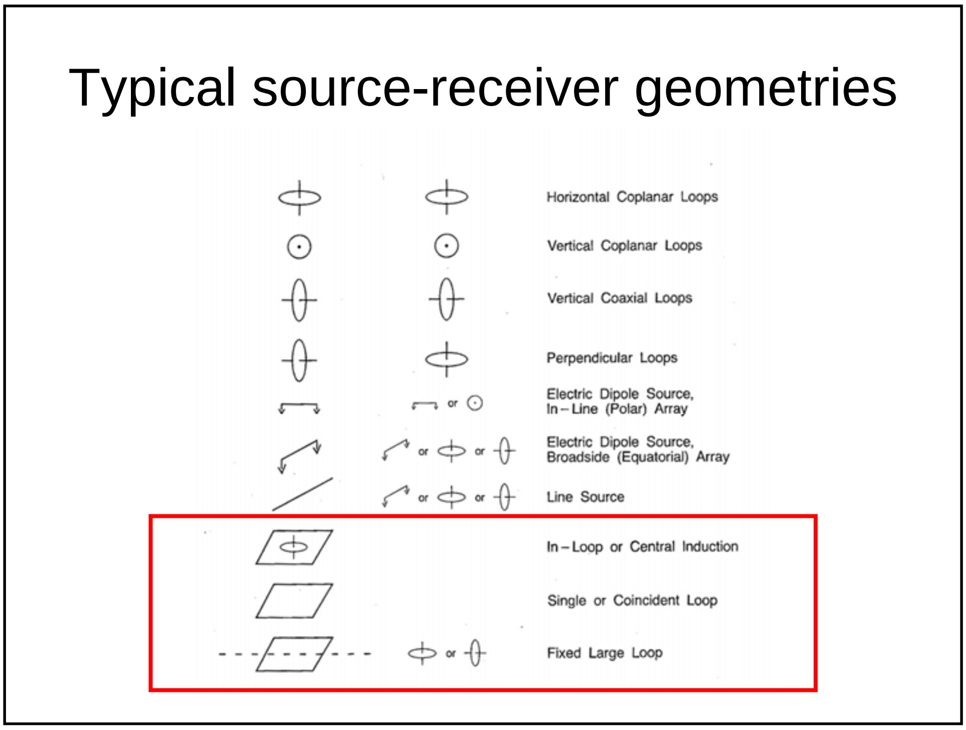




TEM survey configuration and transient curves

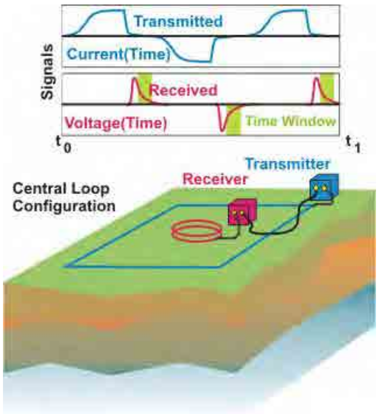
WS-1 TEM 1 Outline





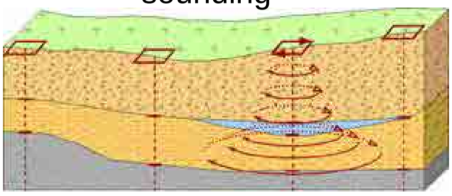
WS-1 TEM 1 Outline

In-Loop or Central induction



Central loop configuration

sounding



PROTEM TIME DOMAIN EM SYSTEM

Protem D Receiver

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PROTEM TIME DOMAIN EM SYSTEM

TEM57-MK2 Transmitter

PROTEM TIME DOMAIN EM SYSTEM

Protem Receiver Coil (Low Frequency) Rx

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PROTEM TIME DOMAIN EM SYSTEM

Generator

PROTEM TIME DOMAIN EM SYSTEM

TEM47 Transmitter (Frequency of 75Hz)

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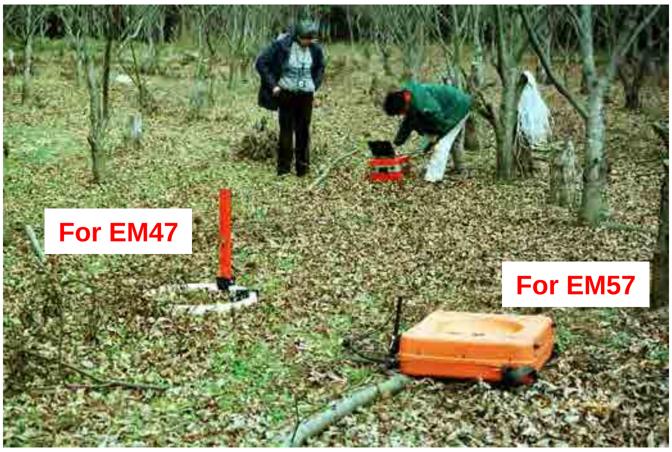
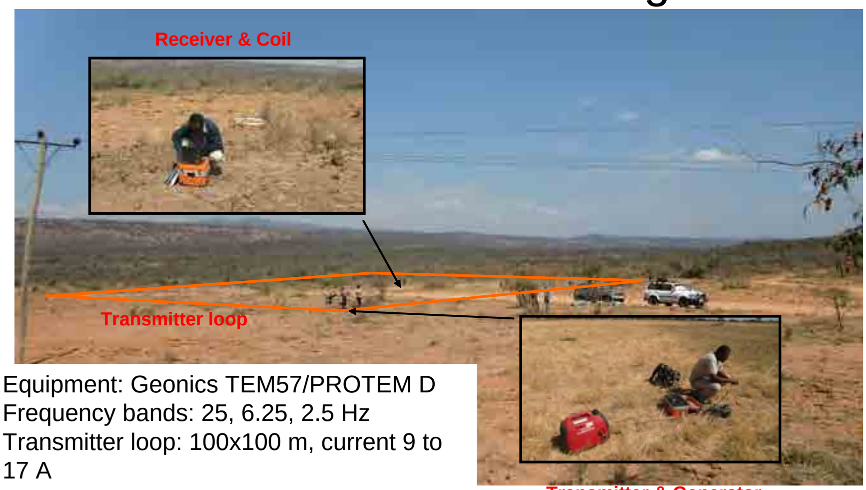
PROTEM TIME DOMAIN EM SYSTEM



Induction Coil

(For EM47:EM57:single component (1D))
(For EM57:(1D) and three component (3D) versions)

Central Induction Coil Configuration



Equipment: Geonics TEM57/PROTEM D
Frequency bands: 25, 6.25, 2.5 Hz
Transmitter loop: 100x100 m, current 9 to 17 A
Receiver loop: 100 coils 1 m diameter
Receiver layout: centre of Tx loop

NOISE

GEOLOGICAL NOISE

- Topography, shallow structures
- Can not improve by source current or stacking
- Serious than environmental noise

ENVIRONMENTAL NOISE

- Noise due to power line, railway, wind, lightning, ground vibration, system noise etc.
- Can be improved by source current, stacking

Summary of TDEM Method

- No galvanic contact required
- No primary field while measuring
- Depth of investigation is controlled by time
- No near field problems
- Less problem of topography, static shift
- Most sensitive to the change of resistivities
- Application to Oil, Geothermal, Civil engineering, Groundwater, Environment
- Many new interpretation programs available
- Several systems are commercially available

Thank you for your attention.

WS-2 TEM 2 Inversion Analysis

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

Transient Electromagnetic (TEM) Survey Workshop

Data Inversion and analysis

Geophysical Survey
Tsugio ISHIKAWA

December 23, 2010

Ministry of Water and Energy
Japan International Cooperation Agency (JICA)

INVERSION by IX1D v3

(Trademark of Interpex Limited)

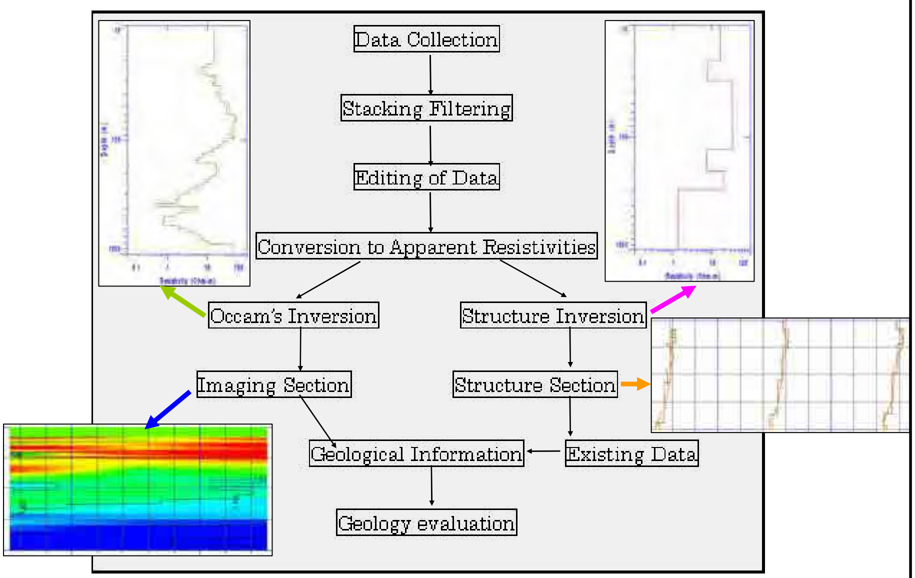
WS-2 TEM 2 Inversion Analysis

OVERVIEW of IX1D

- **IX1D** is a 1-D Direct Current (DC) resistivity, Induced Polarization (IP), Magnetotelluric (MT) and electromagnetic sounding inversion program

- **TEM** data taken with coincident, central or fixed loop configurations can be inverted.

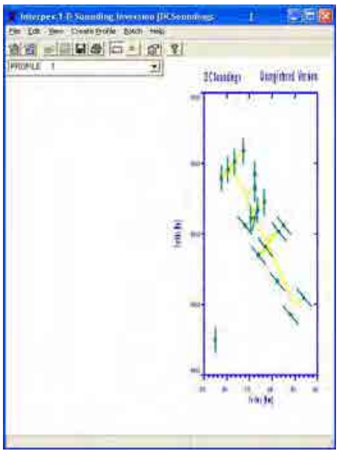
TEM DATA PROCESSING

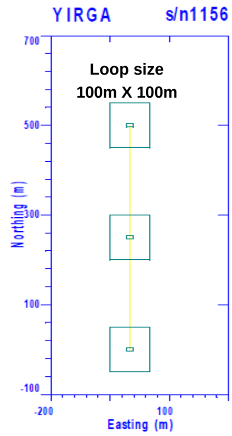


WS-2 TEM 2 Inversion Analysis

Locations of all soundings

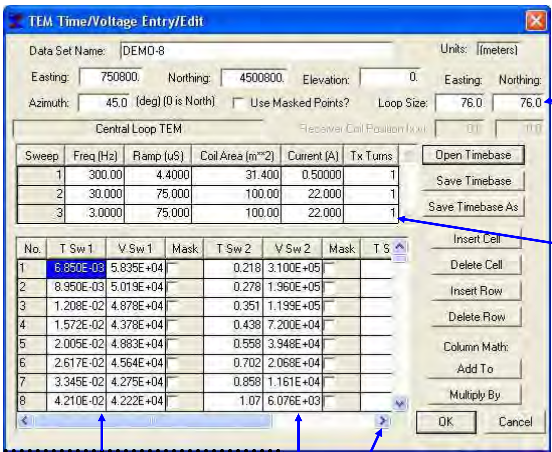
➢Soundings which take place over a distance are displayed along that distance.





➢TEM soundings show the finite size of the source and the receiver is shown as a small box.

TEM Data



- The loop size is the size of the TX loop in the selected units (m or ft). For Fixed Loop data
- there is also a receiver coil position which is relative to the loop center.

- Freq(Hz) : Tx frequency in Hz
- Ramp(μ S) : Ramp turn-off time in microseconds
- Coil Area(m**2) : Effective area of the receiver coil
- Current(A) : Tx current in Amps
- Tx Turns : For a multi-turn
- Receiver coil the effective area is the actual area times the number of turns

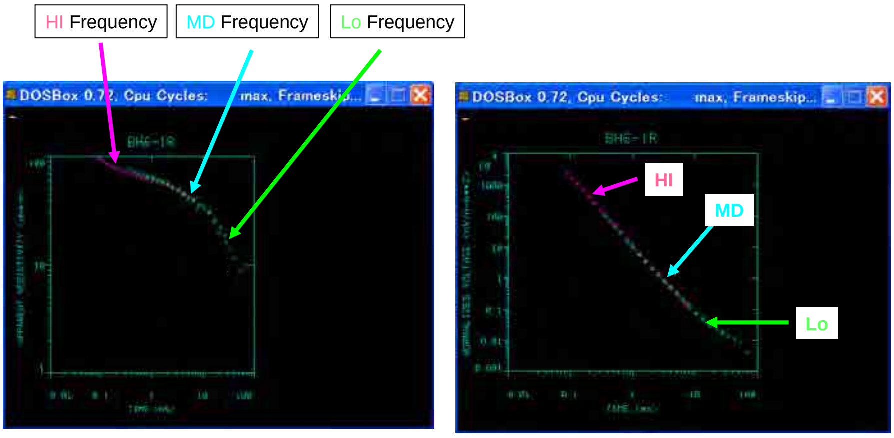
Time and Voltage for the first sweep.

Time and Voltage for the second sweep.

Time and Voltage for the third sweep (the next screen).

WS-2 TEM 2 Inversion Analysis

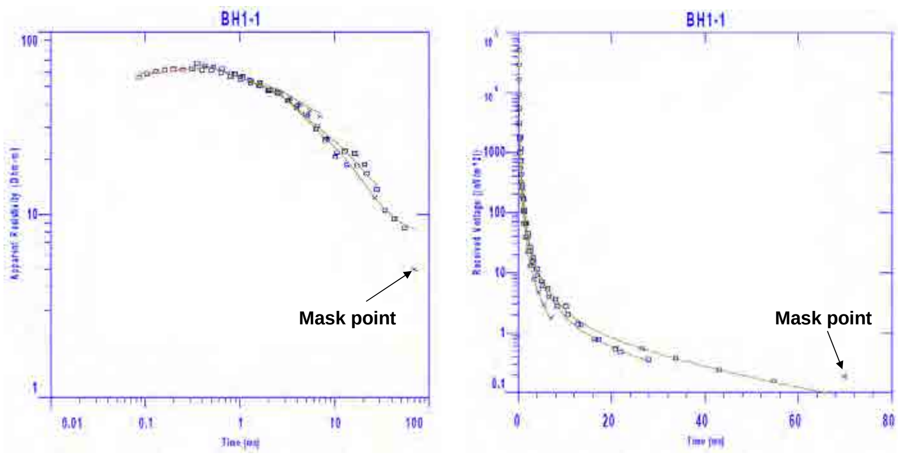
Graphic Display



apparent resistivity voltage

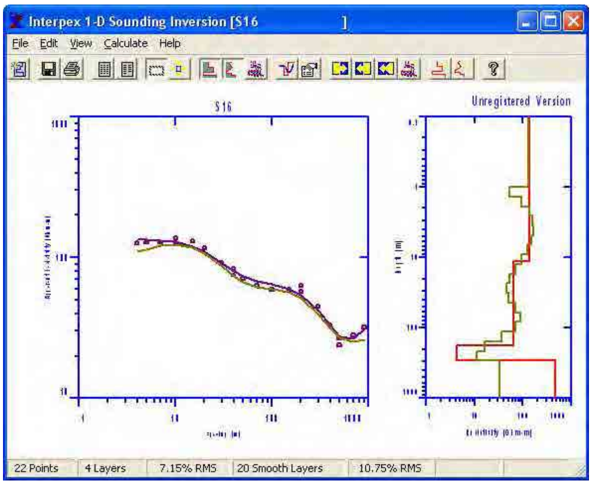
Voltage displays voltage, rather than late time apparent resistivity for TEM Data.

Editing of Data



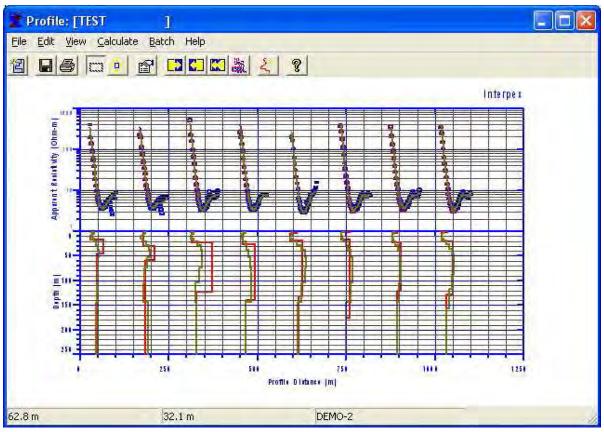
apparent resistivity voltage

Graphic Display



Data and equivalent models will be displayed on the model display.

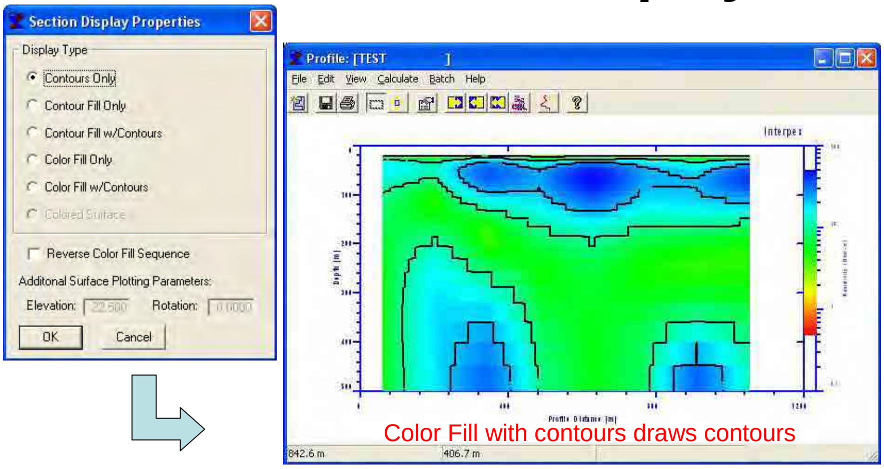
Profile Display Overview



- The Profile Display shows two displays, one for data on top and a second for the model on the bottom.
- Either of these displays can be deselected.

Export data or results or print the graphic

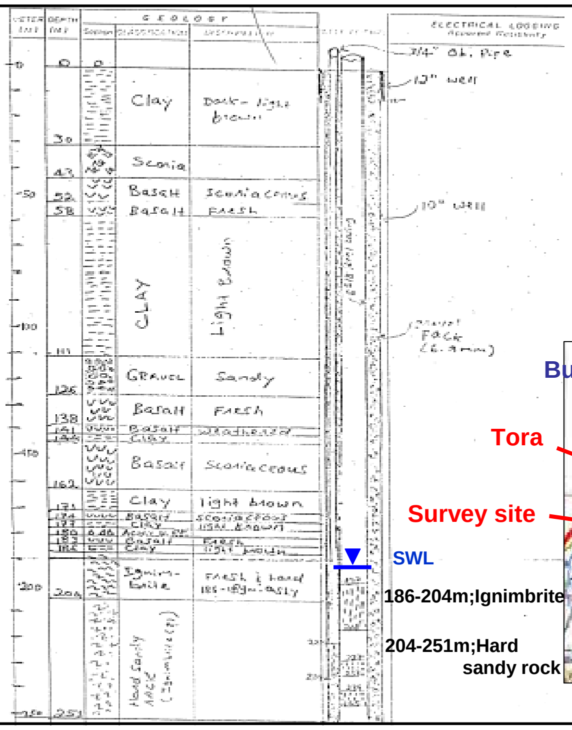
Profile Model Display



Reverse Color Sequence changes the normal range
of red to blue to blue to red.

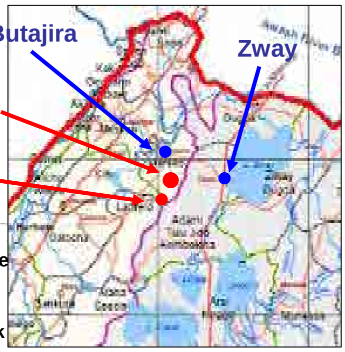
Example of inversion analysis

WS-2 TEM 2 Inversion Analysis

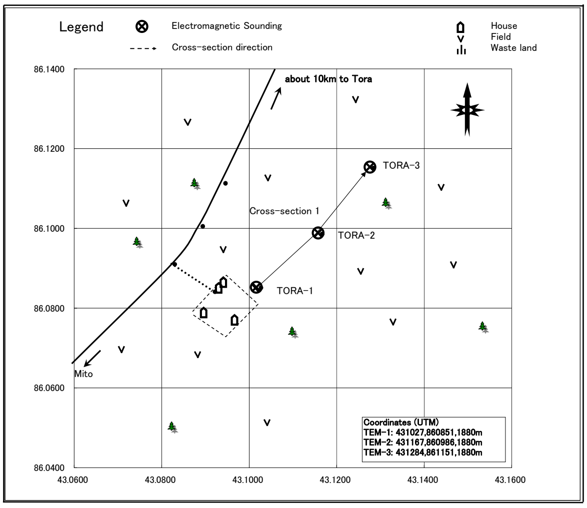


Well data of TORA

Drillied in Aug 28, 1995
Well Depth ; 251m
S.W.L ; 189.10m
Draw Down ; 8.78m
Yield : 3 l/sec

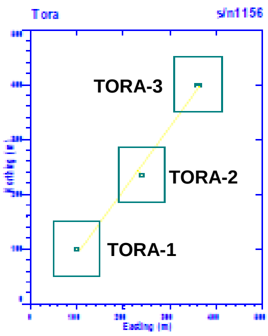


Survey Site near Tora Area

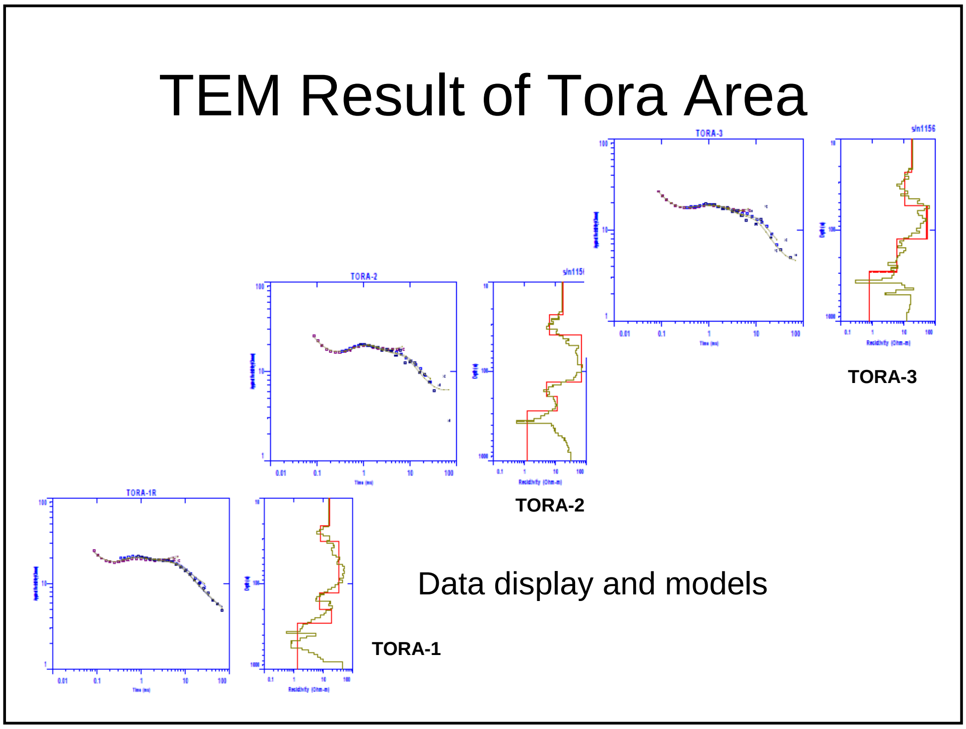


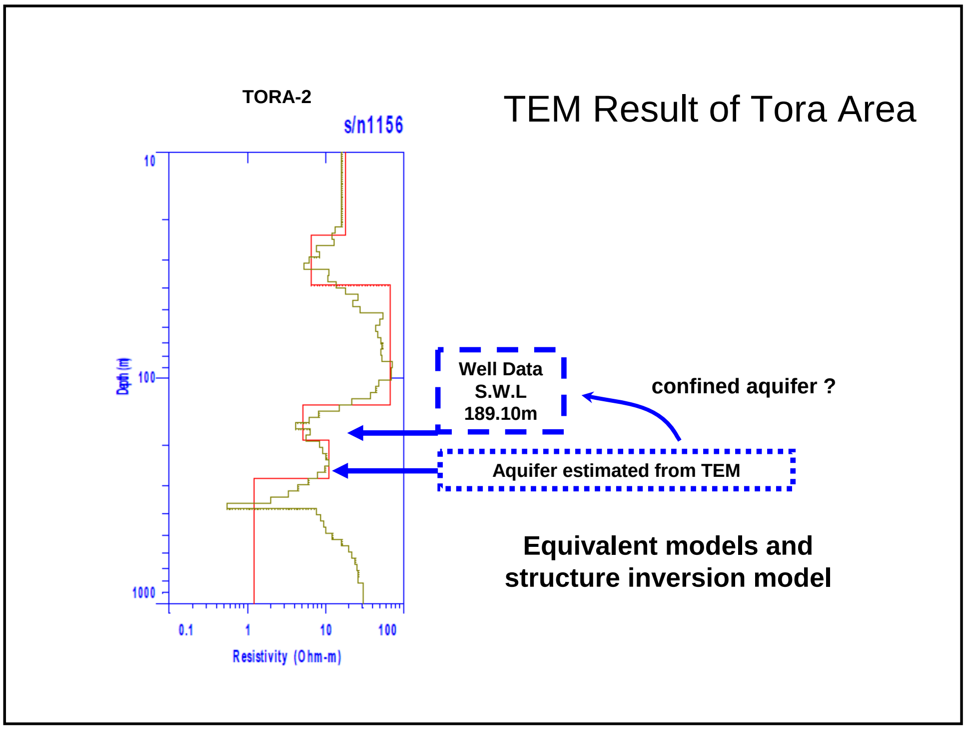
Location map（Anshebeso Kuchi Village）

About 10km southwest of Tora

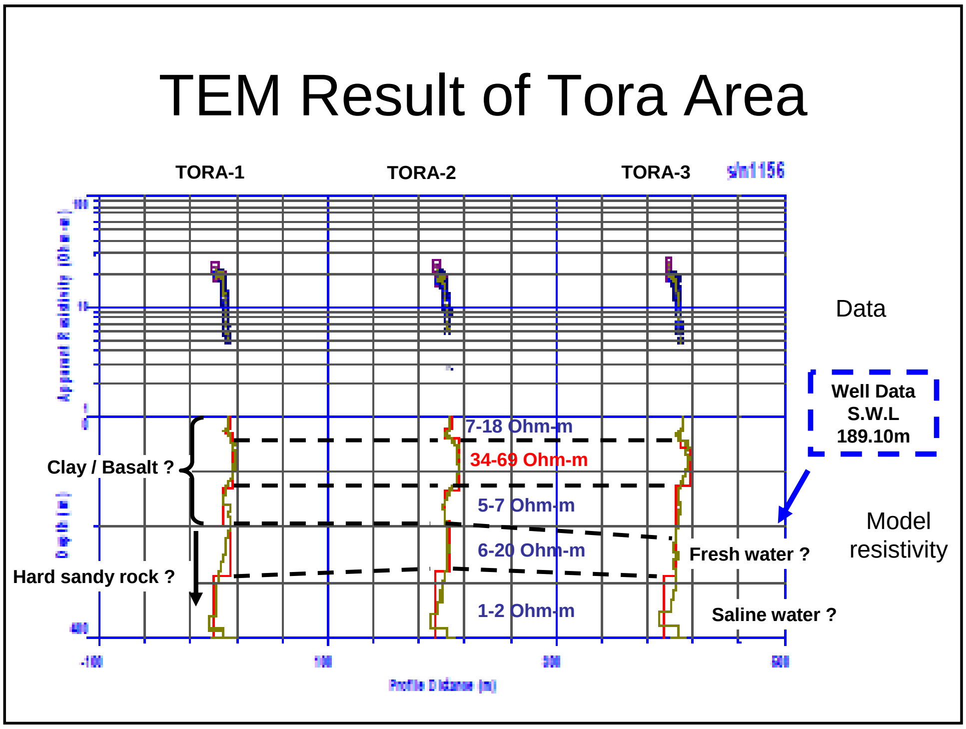


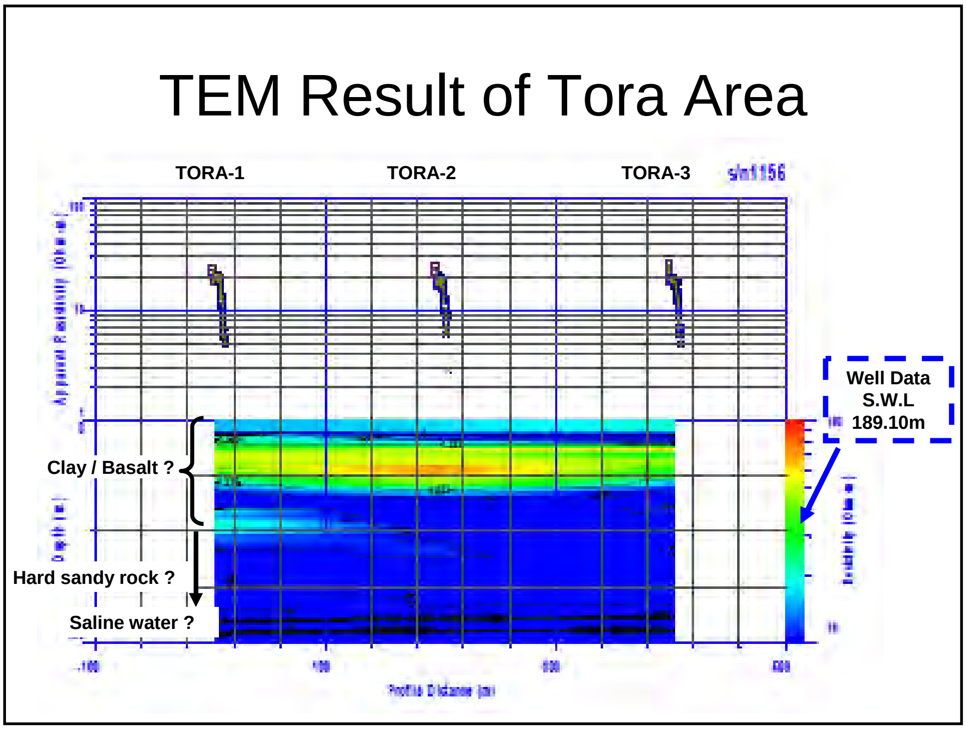
WS-2 TEM 2 Inversion Analysis





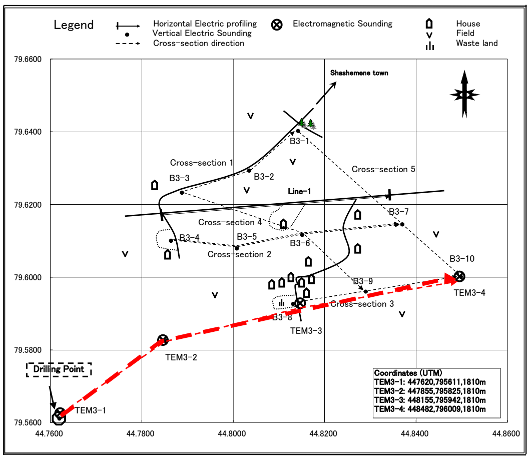
WS-2 TEM 2 Inversion Analysis





WS-2 TEM 2 Inversion Analysis

Comparison of the geophysical survey and the well data (BH3)

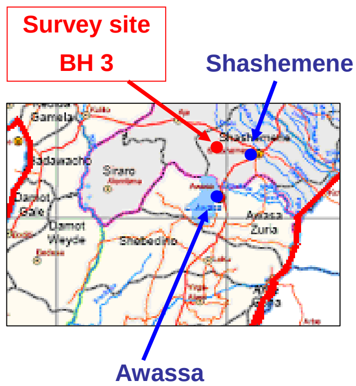


Location map （Borehole No.3 : Oyne Umbure Chefo）

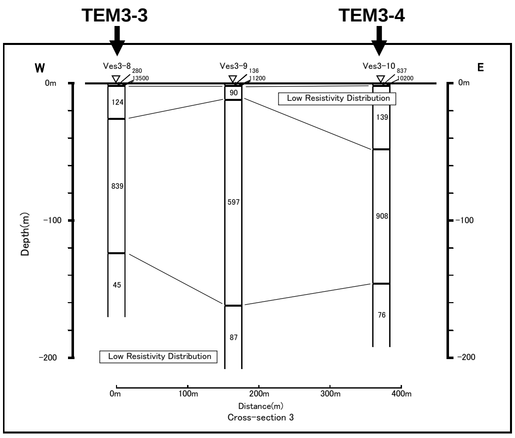
VES : 10 points

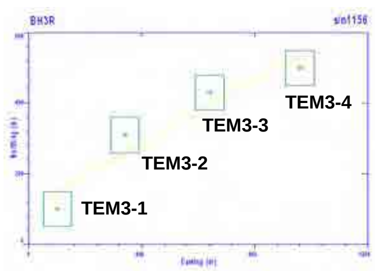
TEM : 4 points

Drilling depth : 250m



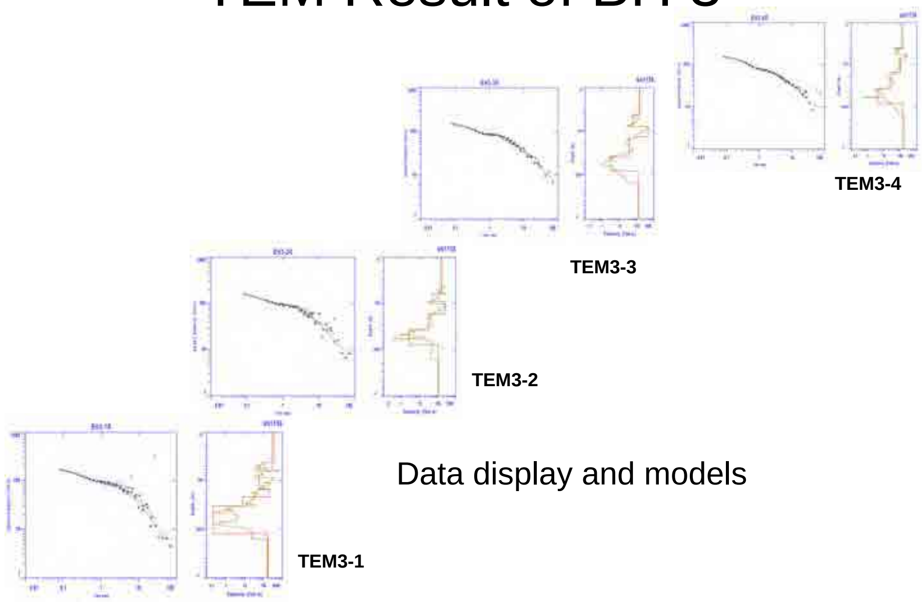
VES Result of BH 3



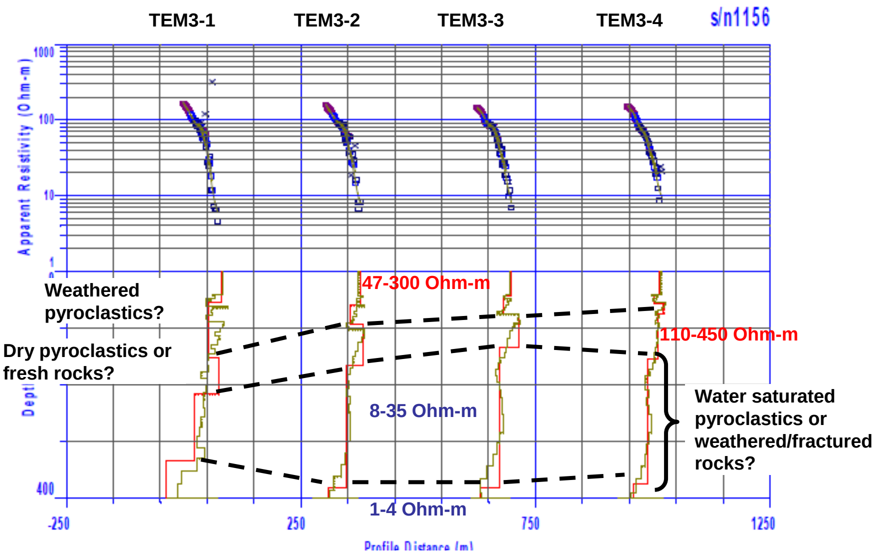


WS-2 TEM 2 Inversion Analysis

TEM Result of BH 3

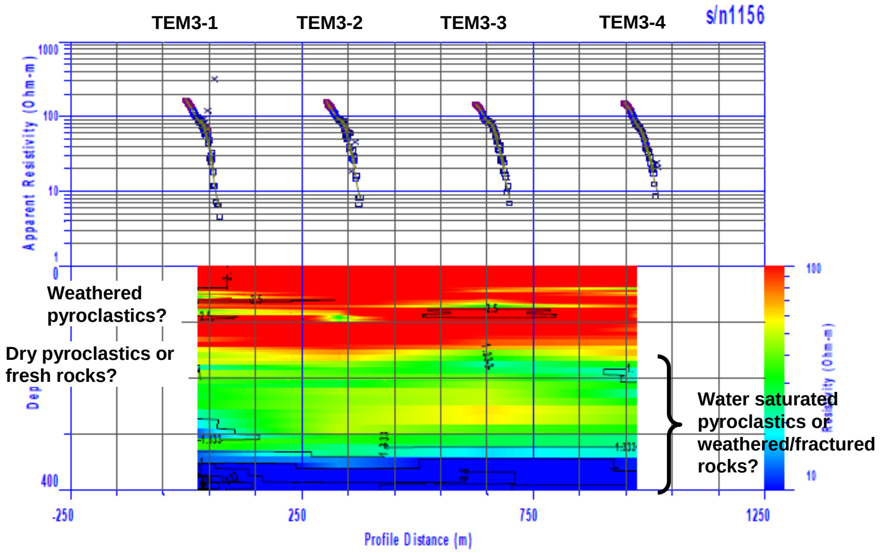


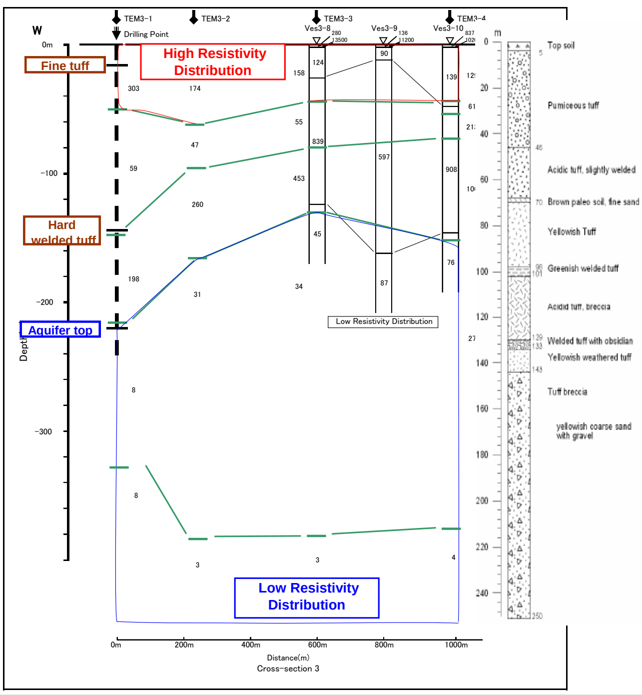
TEM Result of BH 3



WS-2 TEM 2 Inversion Analysis

TEM Result of BH 3





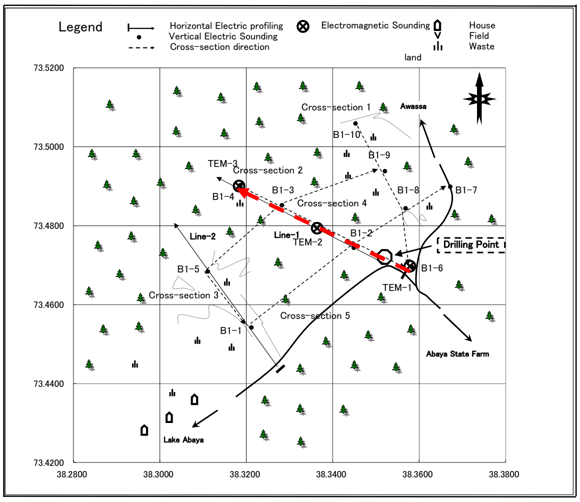
EM Result of BH 3

Result

- **Surface is a middle resistivity layer.**
- **Middle is a high resistivity layer.**
- **Deepest part is a low resistivity layer.**
- **As for the above, the result of the electrical sounding and the TEM investigation almost corresponds.**
- **Aquifer top is the same as the depth of the low resistivity layer of a result of TEM.**

WS-2 TEM 2 Inversion Analysis

Comparison of the geophysical survey and the well data (BH1)



Location map　(Borehole No.1 : Abaya Chokare)

VES : 10 points

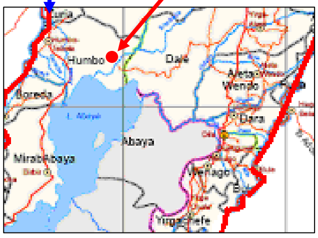
TEM : 3 points

Drilling depth : 150m

Sodo

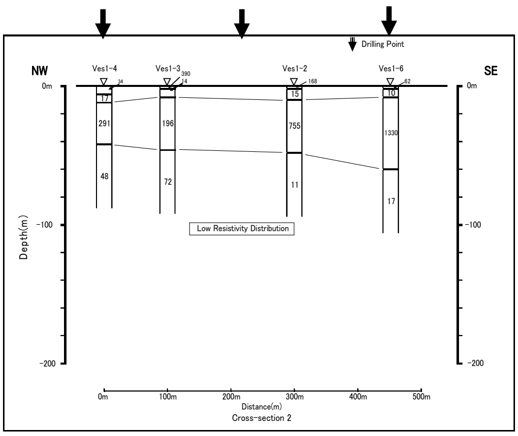
Survey site

BH 1

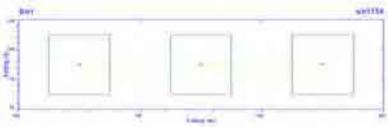


VES Result of BH 1

TEM1-3　**TEM1-2**　**TEM1-1**

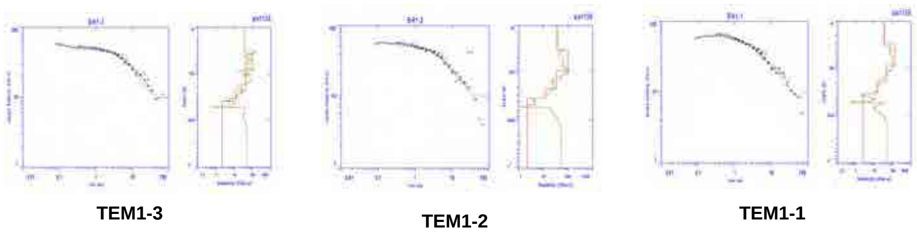


TEM1-3　**TEM1-2**　**TEM1-1**



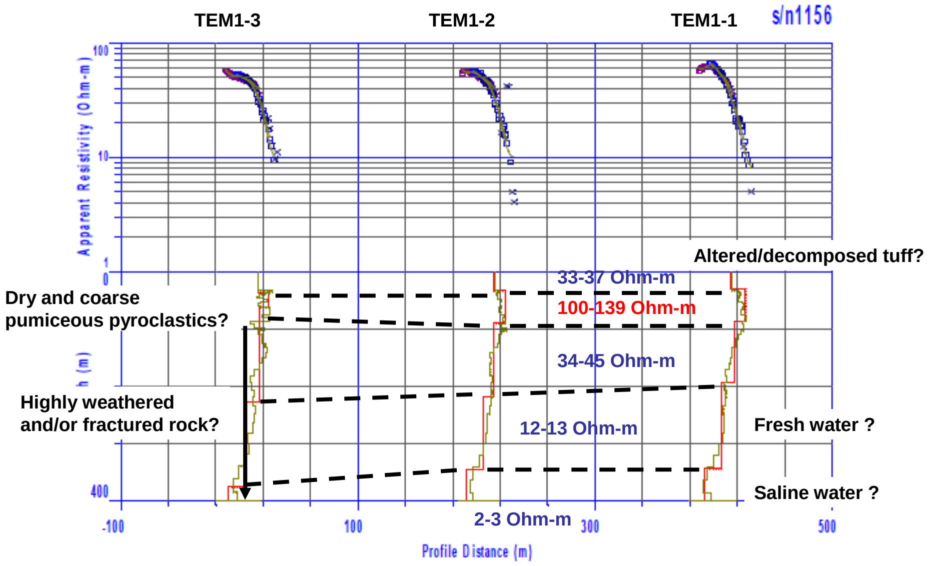
WS-2 TEM 2 Inversion Analysis

TEM Result of BH 1



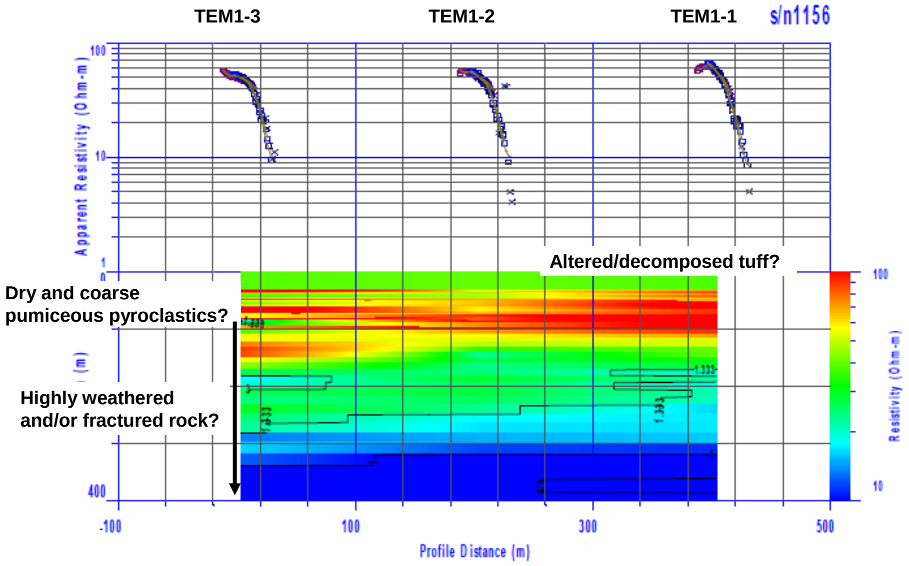
Data display and models

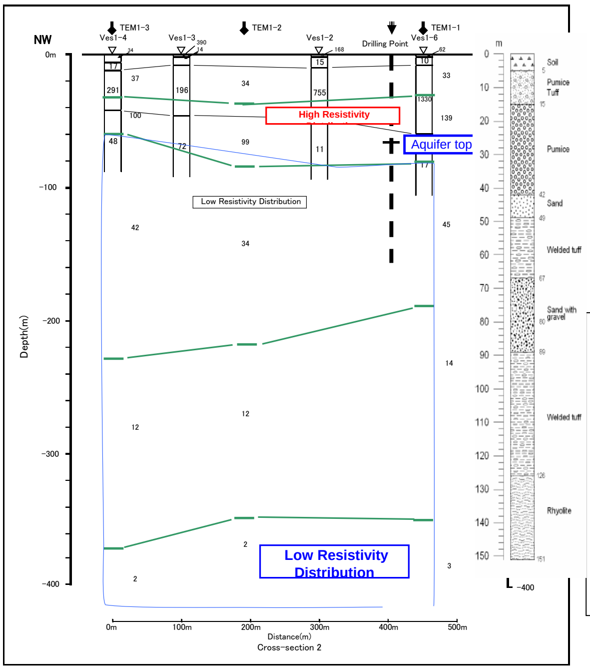
TEM Result of BH 1



WS-2 TEM 2 Inversion Analysis

TEM Result of BH 1





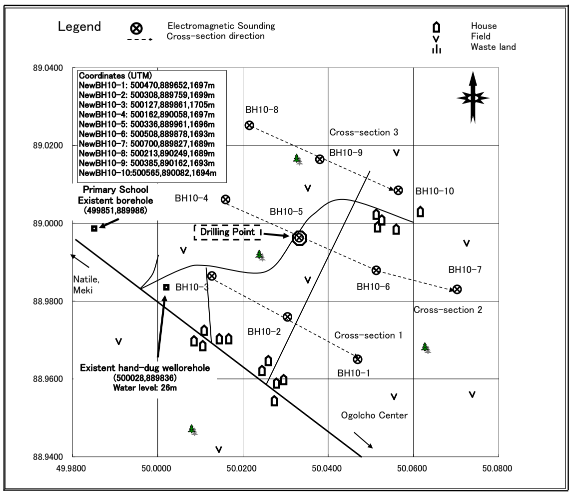
TEM Result of BH 1

Result

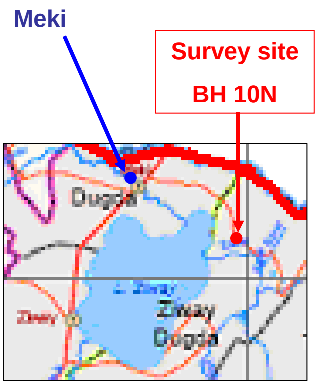
●Surface and Middle is a high resistivity layer.
●Deepest part is a low resistivity layer.
●The result of the VES and TEM almost corresponds.
●Aquifer top is almost the same as the depth of the low resistivity layer of a result of TEM.

WS-2 TEM 2 Inversion Analysis

TEM Result of BH10N



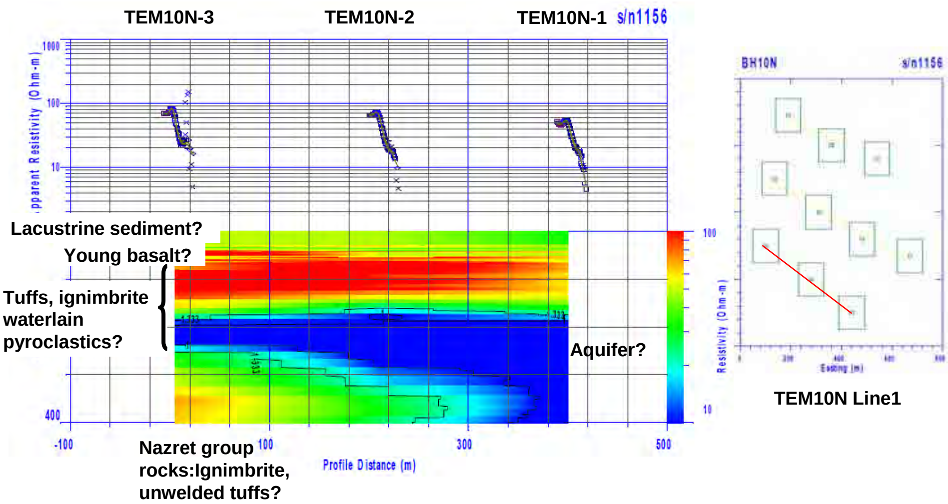
TEM : 10 points
Drilling depth : 150m



Location map （Borehole No.10N : Ubo Bericca）

Ogolcho Area

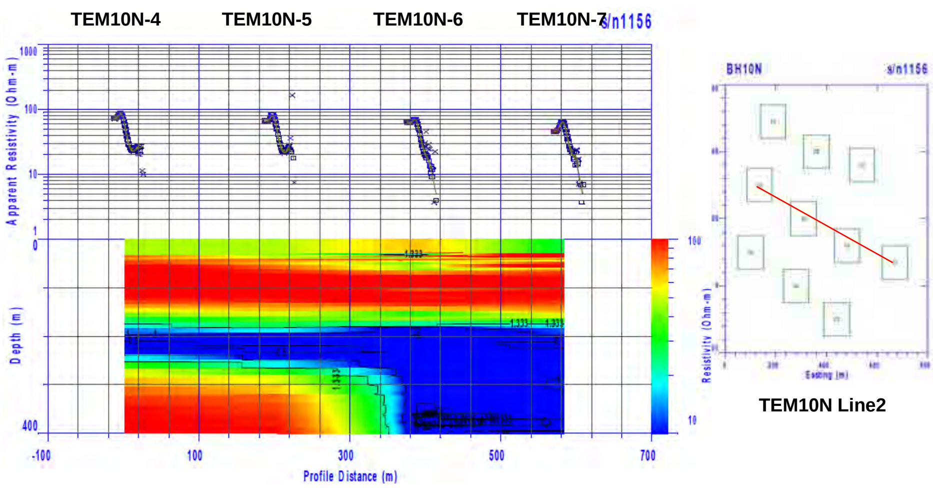
TEM Result of BH10N



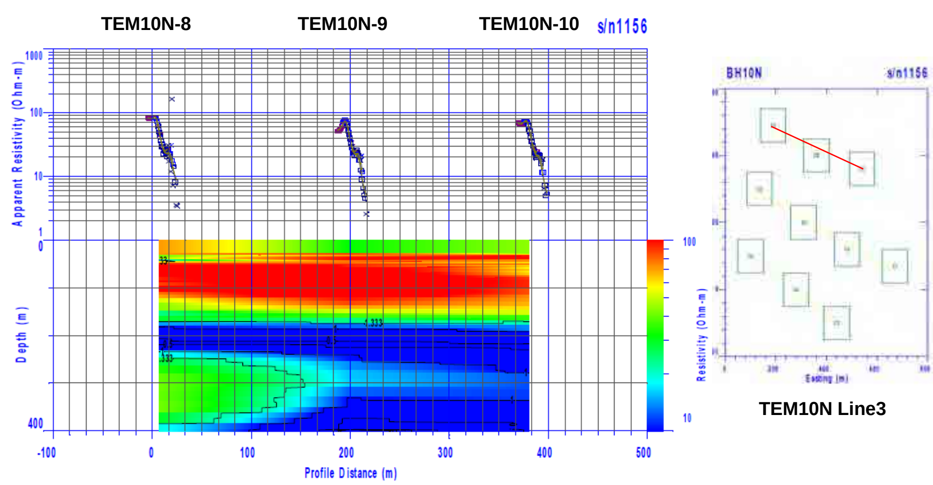
TEM10N Line1

WS-2 TEM 2 Inversion Analysis

TEM Result of BH10N

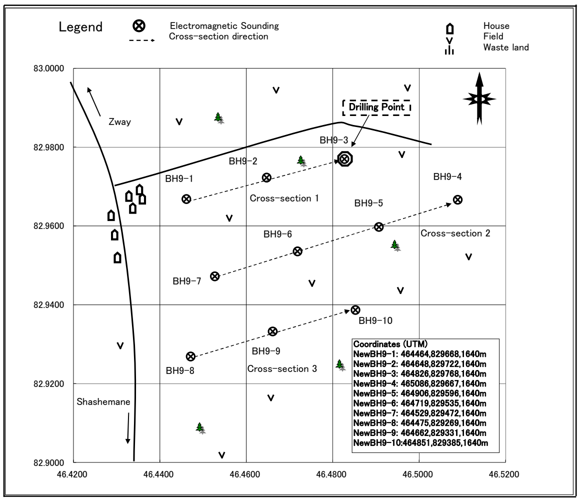


TEM Result of BH10N



WS-2 TEM 2 Inversion Analysis

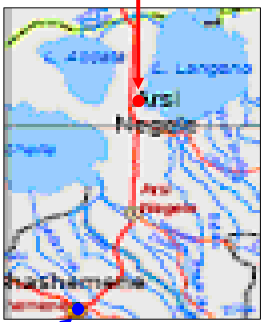
TEM Result of BH9N



Location map （ Borehole No.9N : Dole ）
Langano Area

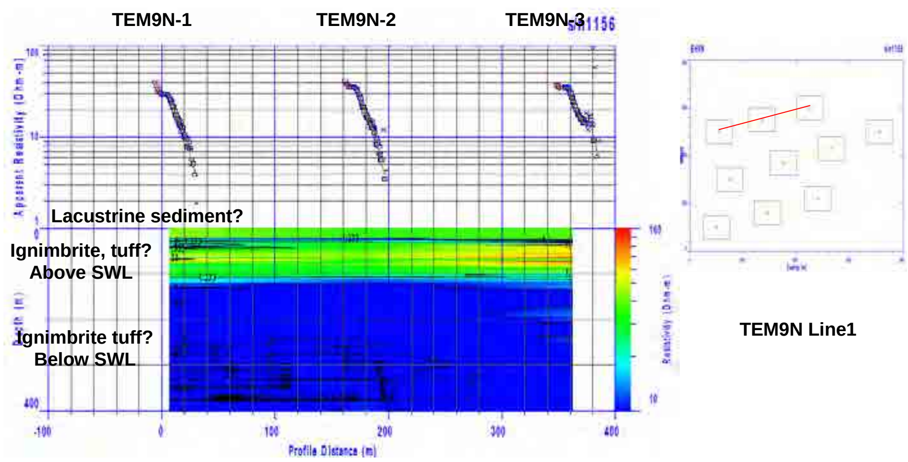
TEM : 10 points
Drilling depth : 150m

Survey site
BH 9N



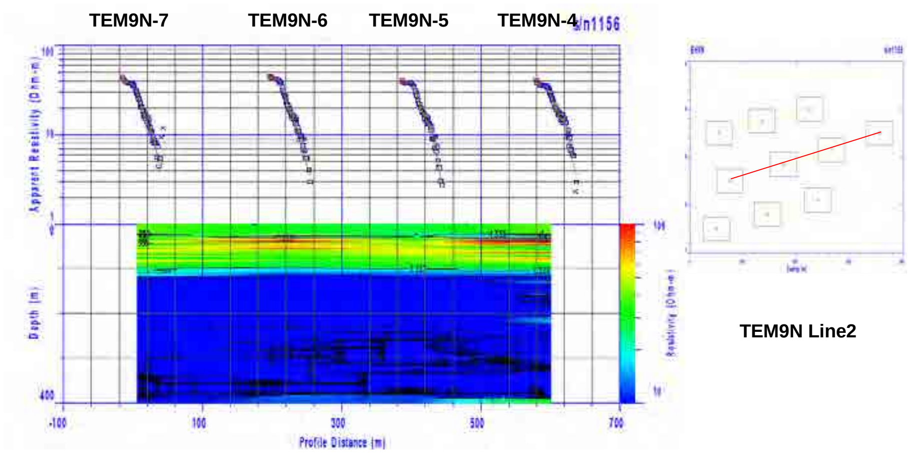
Shashemene

TEM Result of BH9N

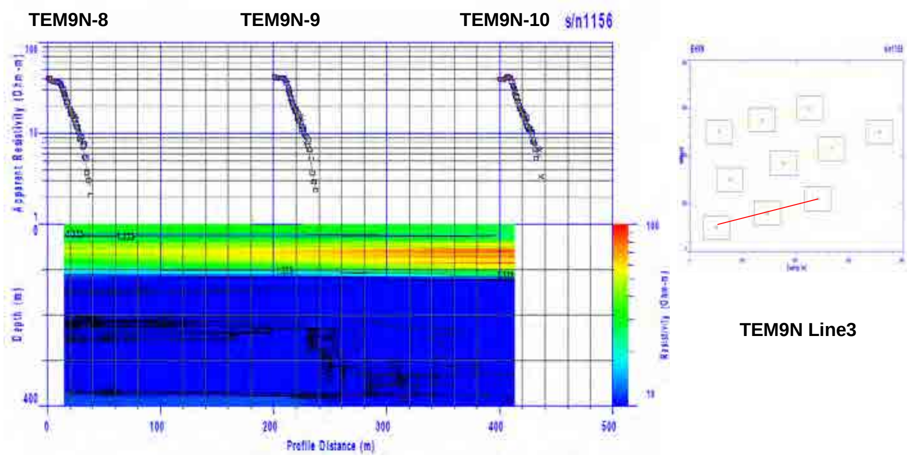


WS-2 TEM 2 Inversion Analysis

TEM Result of BH9N

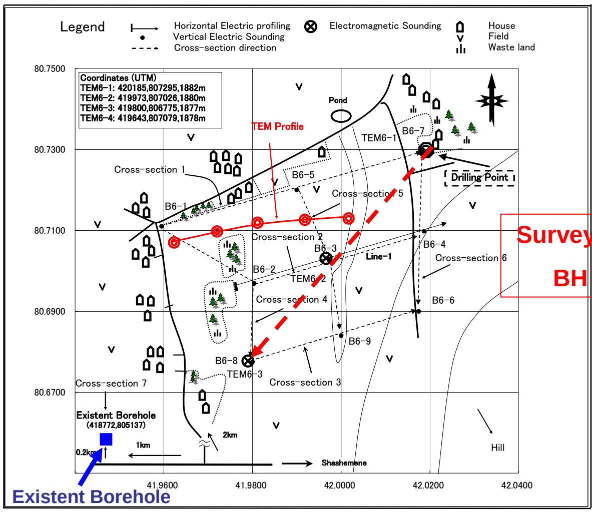


TEM Result of BH9N



WS-2 TEM 2 Inversion Analysis

TEM Result of BH6

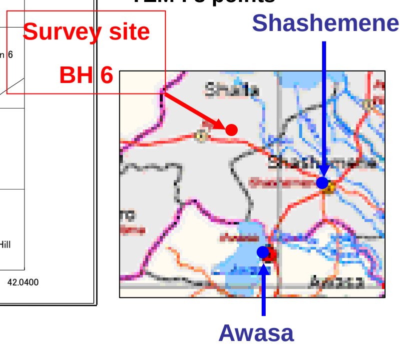


Location map （Borehole No.6 : Yeye Alaba）

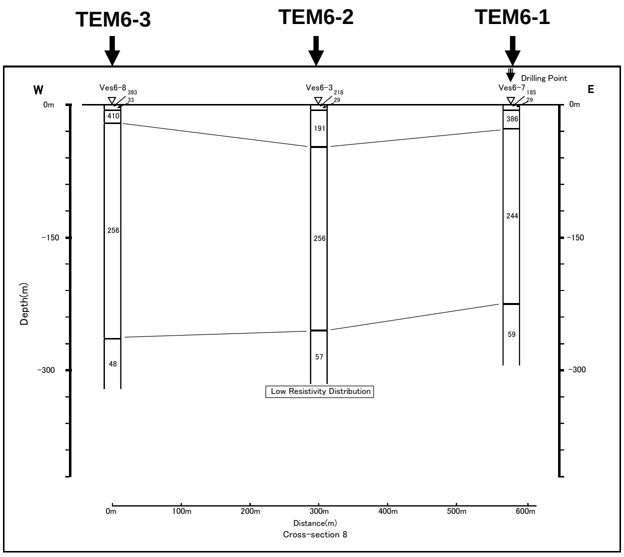
Well data of Yeye Alaba
Drillied in 2002
Well Depth ; 360m
S.W.L ; 273m
Yield : 7 l/sec
Screen position : 318-360m

VES : 10 points

TEM : 8 points



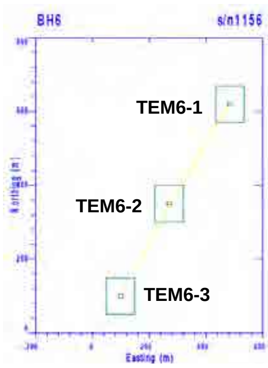
VES Result of BH6



VES : 10 points

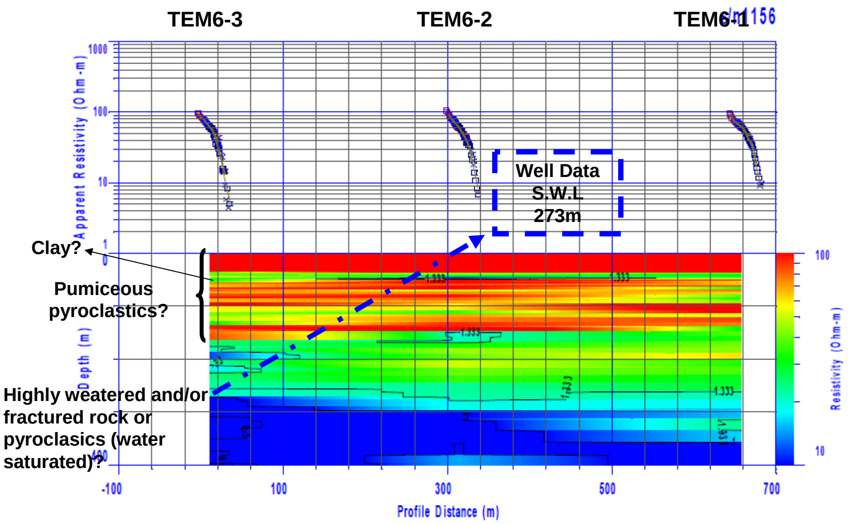
TEM : 8 points

Drilling depth : 400m

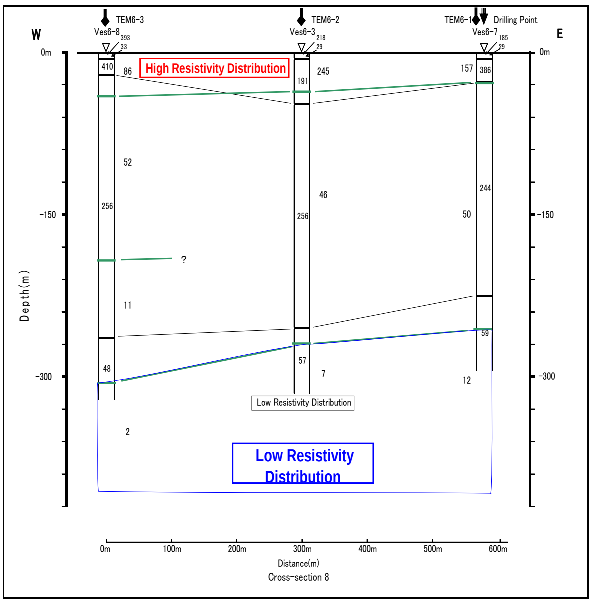


WS-2 TEM 2 Inversion Analysis

TEM Result of BH6



TEM Result of BH6

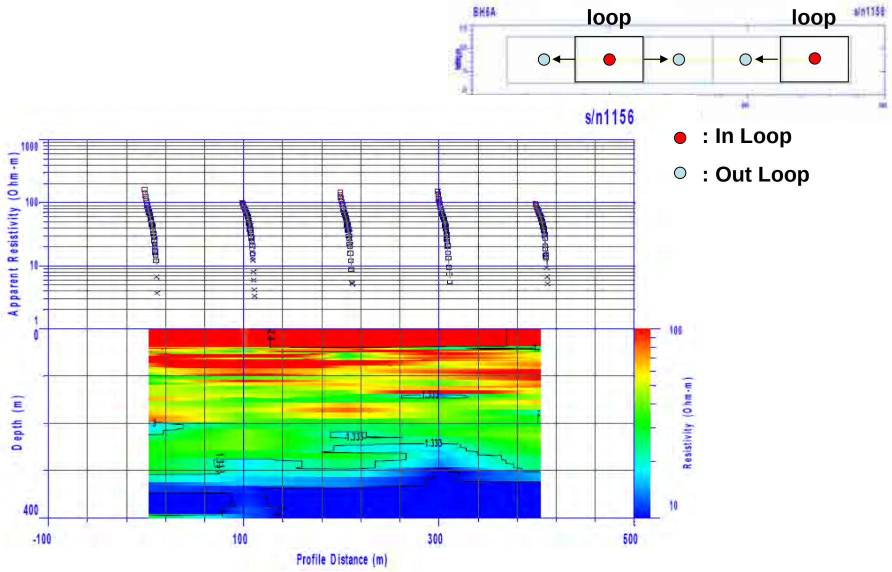


Estimated geology
1st-2nd:topsoil and/or decomposed pyroclastics
3rd-4th:pumiceous pyroclastics
4th-5th:water bearing highly to moderately weathered and/or fractured rock or pyroclastics.

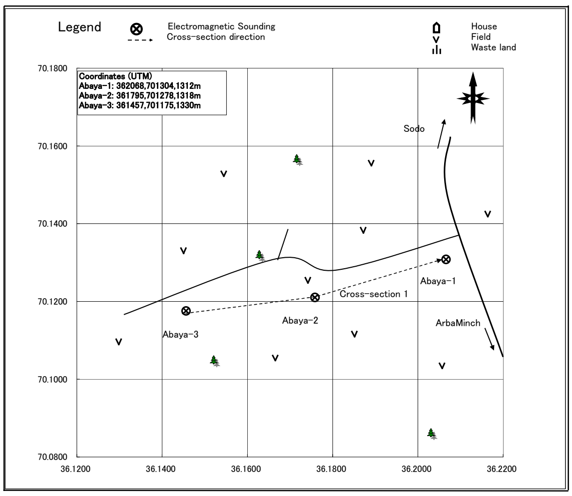
Result
- **Surface and Middle is a high resistivity layer.**
- **Deepest part is a low resistivity layer.**
- **The result of the VES and TEM almost corresponds.**
- **Aquifer top is the same as the depth of the low resistivity layer of a result of TEM.**

WS-2 TEM 2 Inversion Analysis

TEM Result of BH6



TEM Result of Mirab Abaya

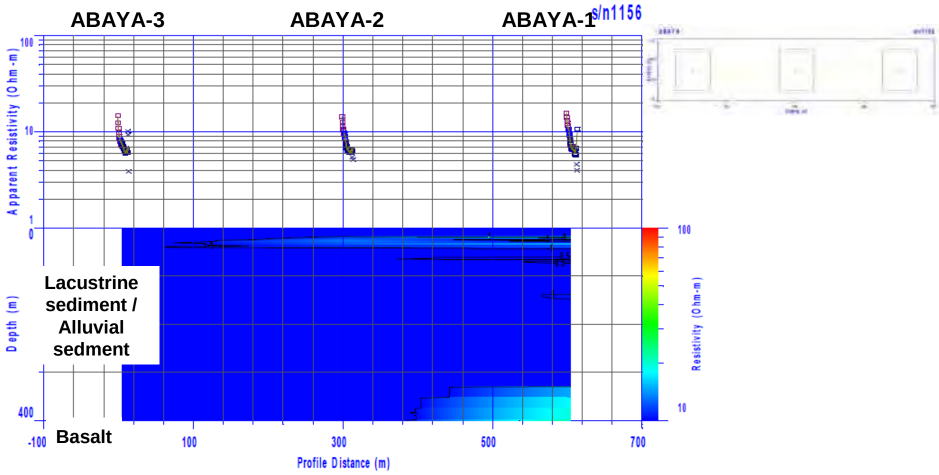


Location map（Mirab Abaya）

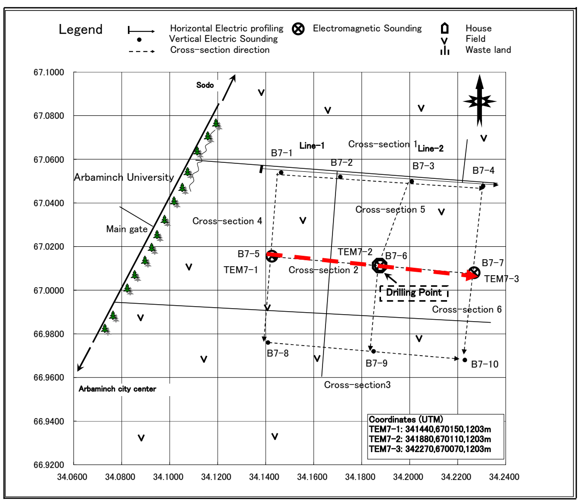
TEM : 3 points

WS-2 TEM 2 Inversion Analysis

TEM Result of Mirab Abaya



TEM Result of BH7



Location map （Borehole No.7 : Arbaminch）

VES : 10 points

TEM : 3 points

Drilling depth : 250m

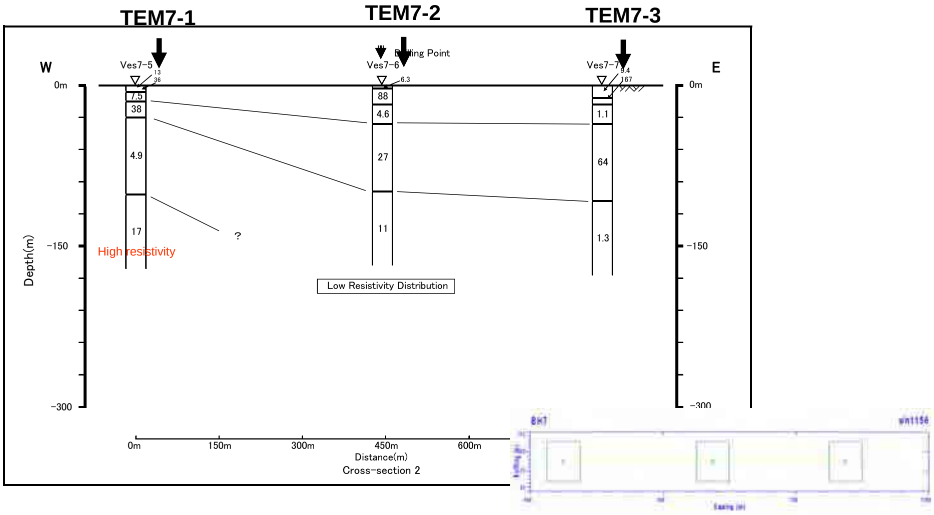
Survey site

Arba Minch

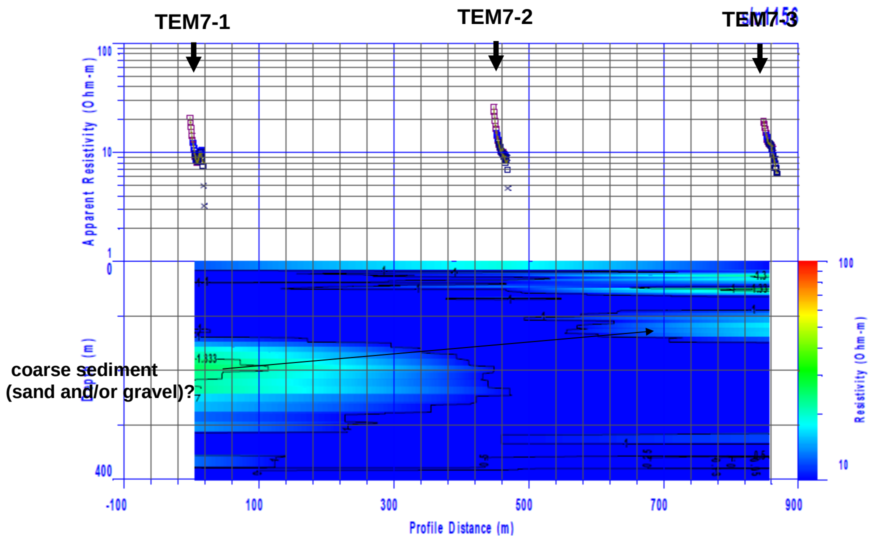
Arba Minch

WS-2 TEM 2 Inversion Analysis

VES Result of BH7

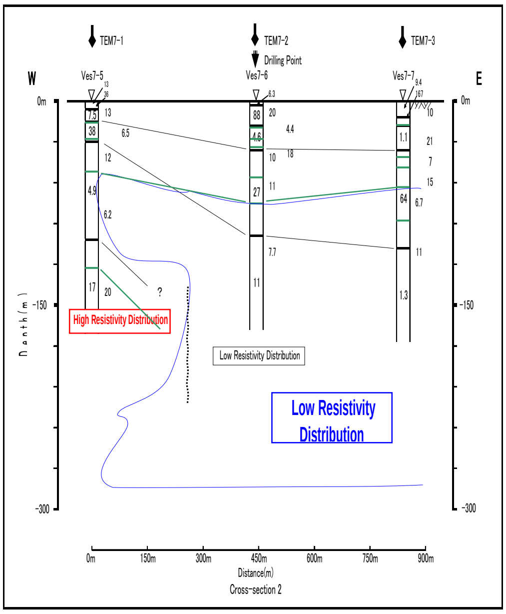


TEM Result of BH7



WS-2 TEM 2 Inversion Analysis

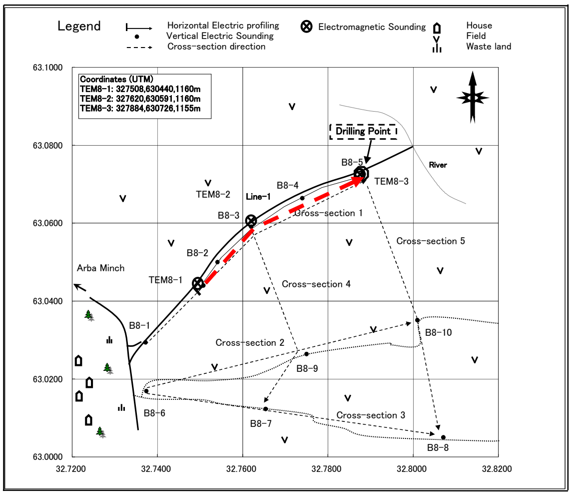
TEM Result of BH7



Estimated geology
1st-2nd:topsoil, gravel
3rd:sedimentary(relatively coarse sediment)
4th-5th:sediment(clayey, silty or saturated with relatively saline water
6th:bedrock or volcanic rock

Result
●Deepest part is a low resistivity layer.
●The result of the VES and TEM almost corresponds.
●The discontinuity of the resistivity is recognized between TEM-1 and TEM-2.

TEM Result of BH8



Location map （Borehole No.8 : Walesa）

VES : 10 points

TEM : 3 points

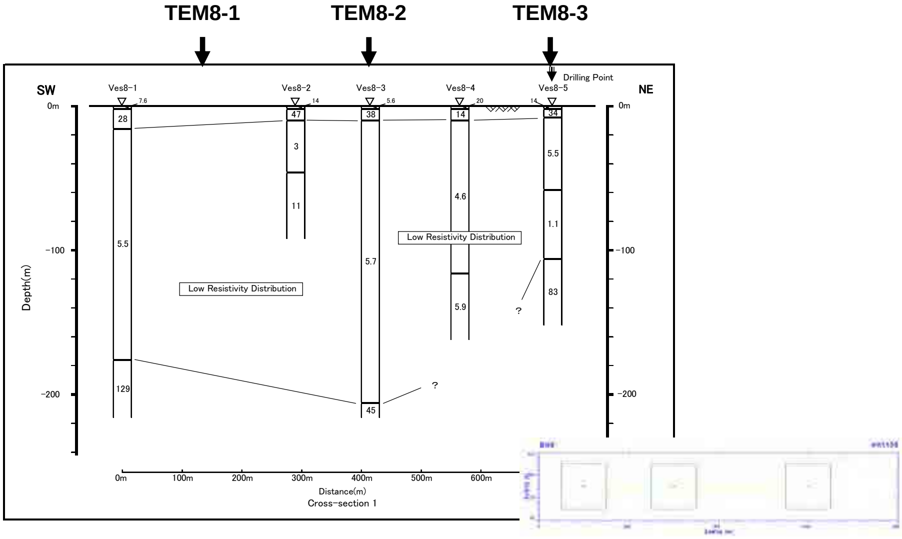
Drilling depth : 250m

Arba Minch

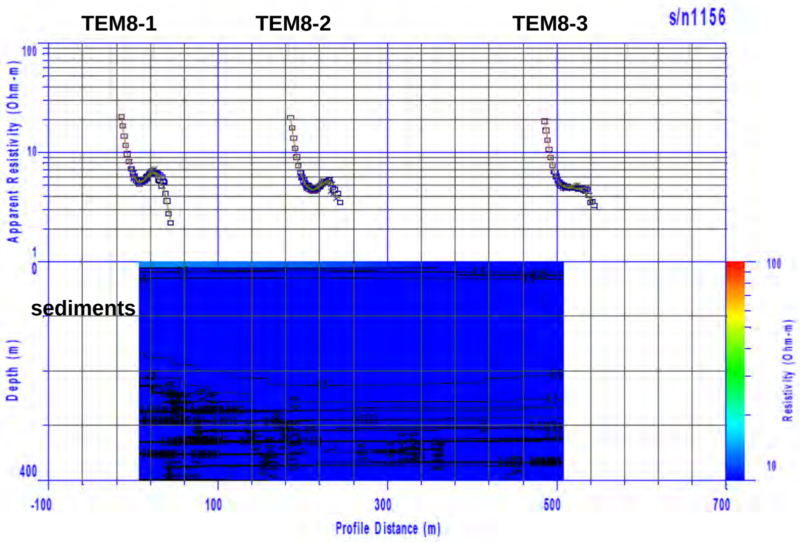
Survey site
BH8

WS-2 TEM 2 Inversion Analysis

VES Result of BH8

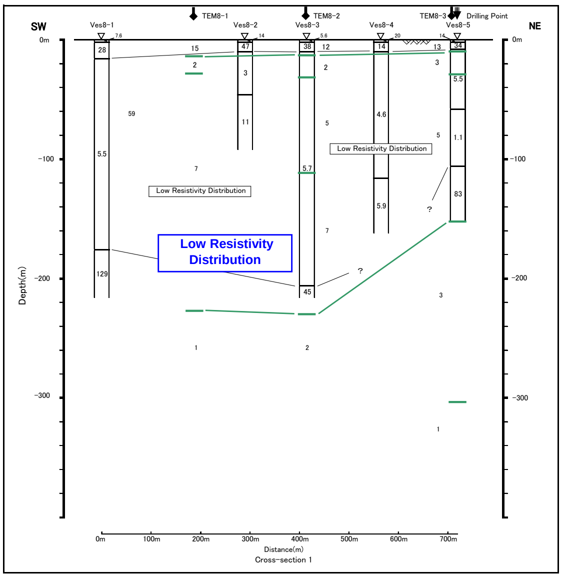


TEM Result of BH8



WS-2 TEM 2 Inversion Analysis

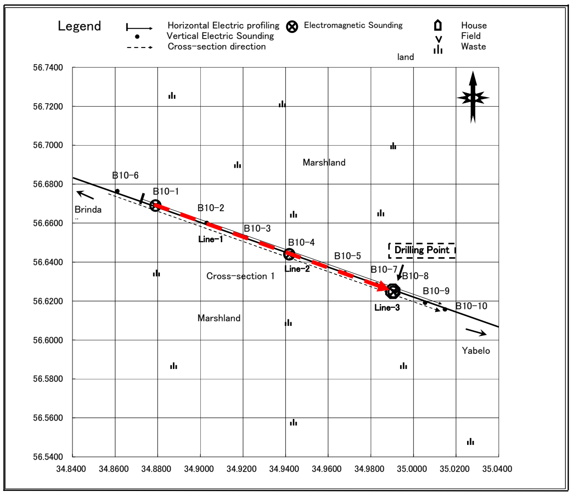
TEM Result of BH8



Estimated geology
1st-2nd:topsoil
3rd:sediments(relatively coarse sediment)
4th:fine grained sediment(saturated with saline water)
5th-6th:bedrock or volcanic rock

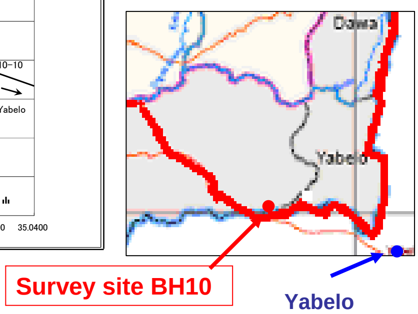
Result
●Surface and Middle is a high resistivity layer.
●Deepest part is a low resistivity layer.
●The result of the VES and TEM almost corresponds.
●Aquifer top is the same as the depth of the low resistivity layer of a result of TEM.

TEM Result of BH10



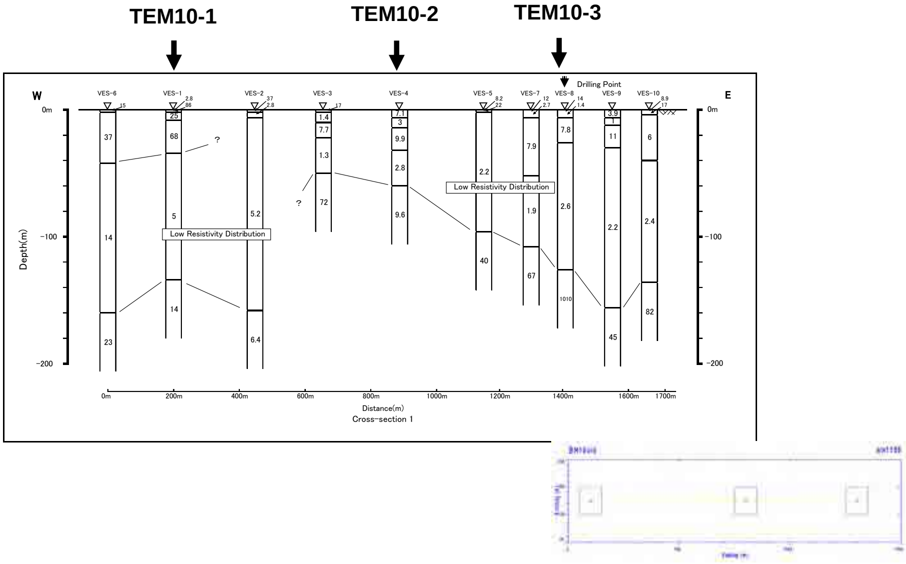
Location map （Borehole No.10 : Brindar）

VES : 10 points
TEM : 3 points

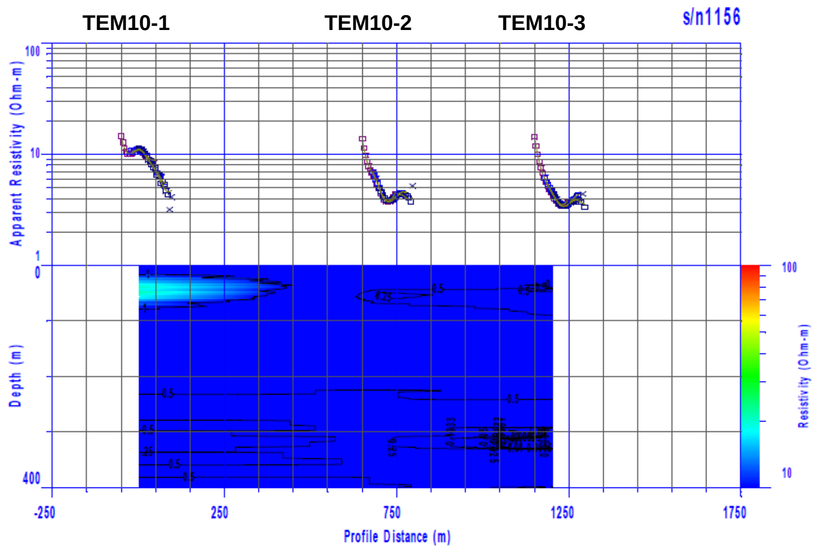


WS-2 TEM 2 Inversion Analysis

VES Result of BH10

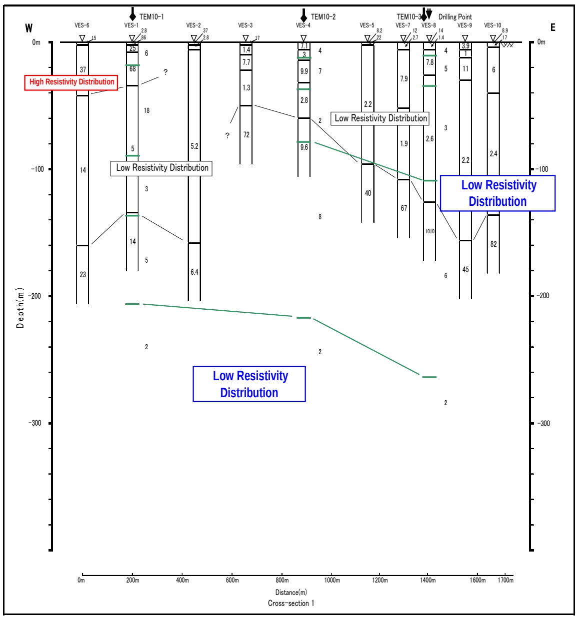


TEM Result of BH10



WS-2 TEM 2 Inversion Analysis

TEM Result of BH10

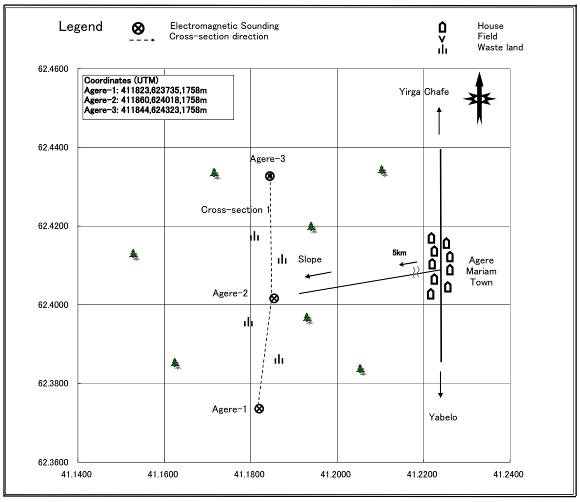


Estimated geology
1st-2nd:coarse sediments(gravel, sand)
3rd-5th:unconsolidated sediments, probably fine grained sediments or saturated with saline water
6th:volcanic rock(basalt)

Result

- **Generally a resistivity is low .**
- **The result of the VES and TEM almost corresponds.**
- **Aquifer top is the same as the depth of the low resistivity layer of a result of TEM.**

TEM Result of Agere Mariam



Location map （Agere Mariam）

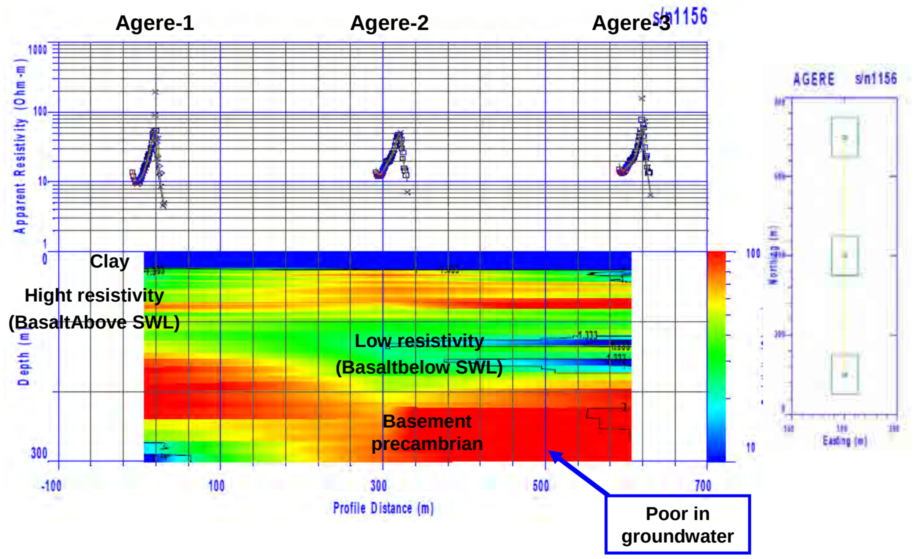
TEM : 3 points

Yirga Chafe

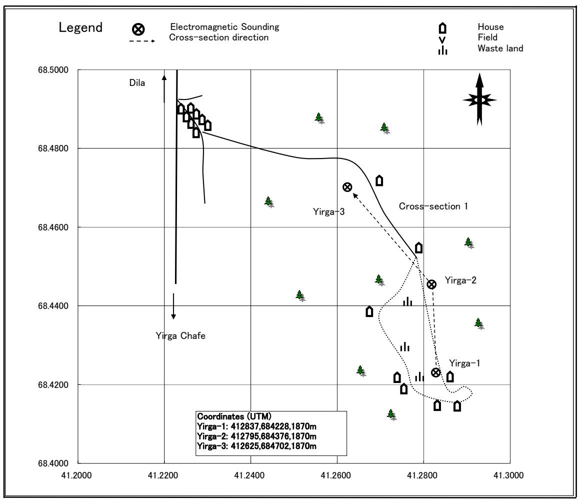
Survey site
Agere Mariam

WS-2 TEM 2 Inversion Analysis

TEM Result of Agere Mariam

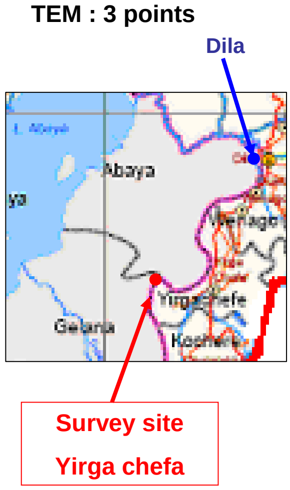


TEM Result of Yirga Chefe



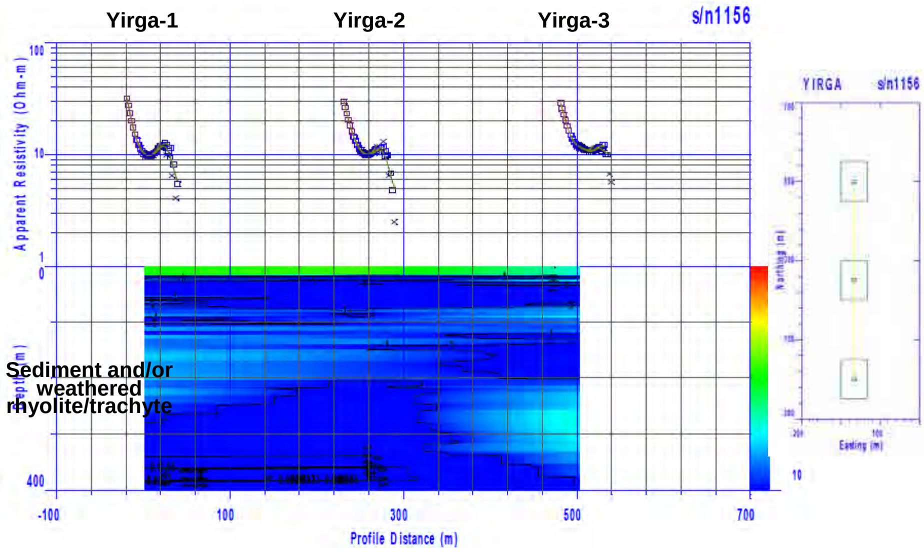
Location map（Yirga Chefe）

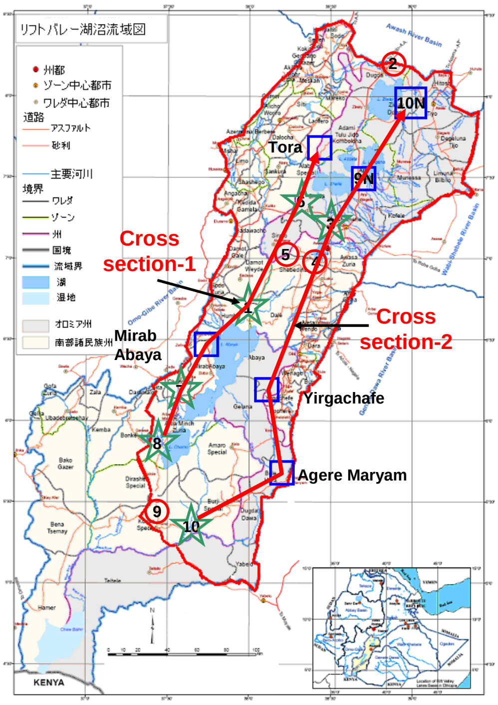
TEM : 3 points



WS-2 TEM 2 Inversion Analysis

TEM Result of Yirga Chefe





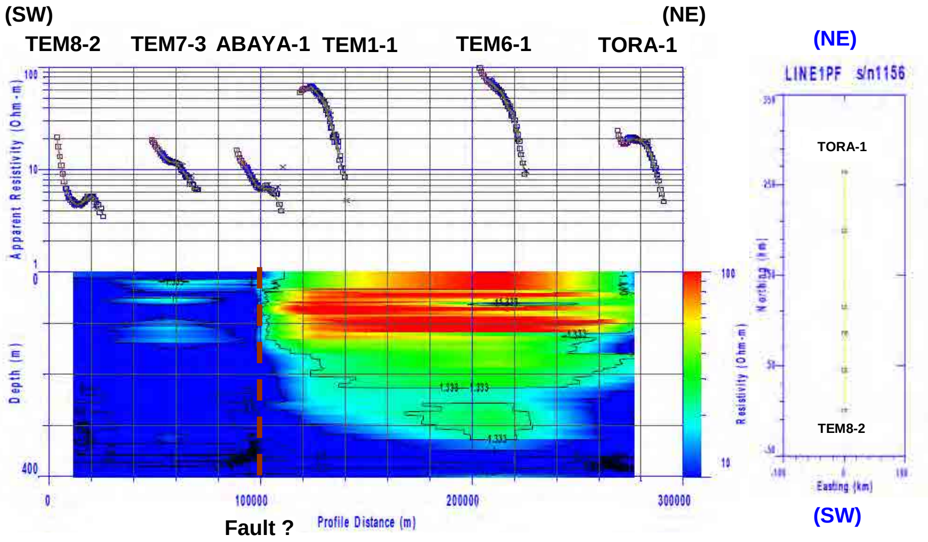
TEM Result of Profile

○ : VES
□ : TEM(TDEM)
☆ : Both surveys

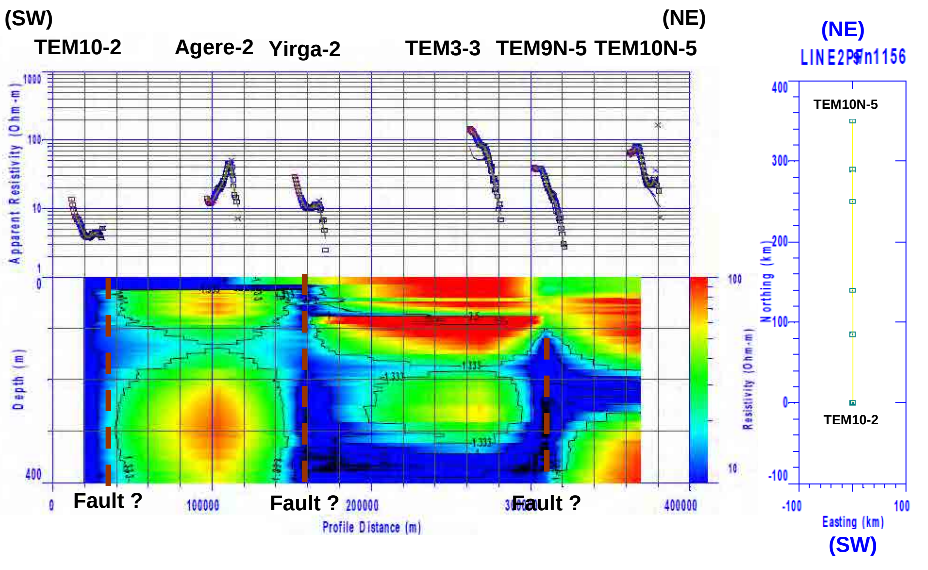
Drilling number
: Well drilling site
(except No.9 and 10)

WS-2 TEM 2 Inversion Analysis

TEM Result of Cross Section1



TEM Result of Cross Section2



WS-2 TEM 2 Inversion Analysis

Thank you for your attention.

The Study on
Groundwater Resources Assessment
in the Rift Valley Lakes Basin in Ethiopia

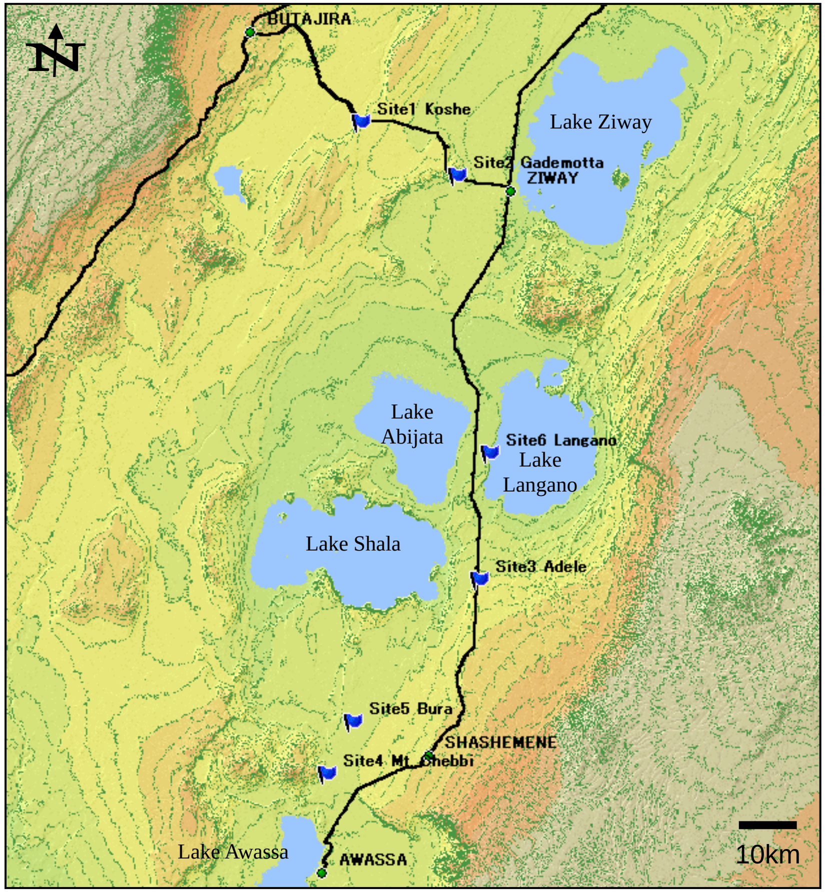
WORKSHOP ON VOLCANIC GEOLOGY

GUIDE BOOK

26 – 27th JANUARY 2011

JICA STUDY TEAM

MAP AND LOCATIONS



	Location	Longitude and Latitude (WGS84)	
1	Koshe	8^{0}00’55.3”N	38^{0}31’32.8”E
2	Gademotta	7^{0}56’50.5”N	38^{0}38’58.9”E
3	Adele	7^{0}25’49.2”N	38^{0}40’37.5”E
4	Mt.Chebbi	7^{0}10’52.5”N	38^{0}28’56.5”E
5	Bura	7^{0}14’52.1”N	38^{0}30’55.5”E
6	Langano	7^{0}35’32.5”N	38^{0}41’27.5”E

SCHEDULE

1st day :26th January 2011 (Wednesday)		Page
8:00	Rendez- vous	
8:00 – 11:00	Move to Koshe	
11:00 - 11:30	**Site 1 :Koshe (Koshe highly welded-tuff)**	**1**
12:00 – 12:45	**Site 2 :Gademotta (Gademotta Rhyolite)**	**3**
13: 00 – 14:00	Lunch in Ziway	
14:00 – 15:00	Move to Adele	
15:00 – 15:30	**Site 3 :Adele (Kuyera highly welded-tuff)**	**7**
15:30 – 17:00	Move to Awassa	
17:00	Arrive at a Hotel in Awassa	
2nd day :27th January 2011 (Thursday)		Page
8:30	Check-out	
8:30 – 9:00	Move to Mt. Chebbi	
9:00 – 9:30	**Site 4 :Mt. Chebbi (Corbetti Volcanics)**	**11**
9:30 – 10:00	Move to Bura	
10:00 – 10:30	**Site 5 :Bura (Awara recent basalt)**	**13**
10:30 – 12:00	Move to Lake Langano	
12:00 – 13:00	Lunch at Sabena Resort, Lake Langano	
13:00 - 13:30	**Site 6 :Langano (Langano poorly welded pumiceous pyroclastics)**	**15**
13:30 – 16:30	Back to Addis Ababa	

TUTOR:

Mr. Toshiaki HOSODA, Volcanic geologist, JICA Study Team

Mr. Hisayuki UKISHIMA, Hydrogeologist, JICA Study Team

Site 1 : Koshe

WHAT TO SEE

- ✓ **Distribution of Welded Tuff**
- ✓ **Structure of Welded Tuff**

Distribution of Welded tuff

Koshe is located in the middle of Butajira and Ziway. Welded tuff is observed along the scarp of NE-SW fault in Koshe. Same type of welded tuff was found at the fault scarp in Tora, south of Koshe, and south of Gademotta hill, indicates this type of welded tuff is widely distributed in this area.

Structure of Welded Tuff

Generally, welded tuff has flattered obsidian structure (*fiamme*), which shows that welded tuff had very high temperature in deposition on the ground (Fig.1).

Welded tuff in Koshe is characterized by containing many non-original fragments such as basalt and rhyolite.

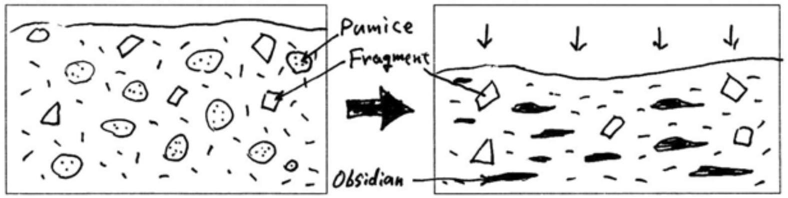


Fig.1: Schematic Diagram shows the formation of Obsidian Lens (*Fiamme*)

Fig.2: Outcrop of Welded Tuff in Koshe

Fig.3: Observation of Welded Tuff in Koshe. Non-original fragments are commonly found with flattered obsidian lens.

Site 2 : Gademotta

WHAT TO SEE

- ✓ **Topography of Gademotta Caldera**
- ✓ **Rhyolite Lava Flow and Obsidian**
- ✓ **Surge Deposit**

Topography

Gademotta hill is located in the west of Ziway. Gademotta hill is crescent rim of Gademotta Caldera. Opposite rim of caldera is not found recently.

GSE (1986) found a NW-SE structural gap from borehole data below Mt. Aluto, and the gap was considered as "the lost rim" of Gademotta Caldera (Fig.4). Thus, the opposite rim might be buried by evolution of Rift Valley Lakes Basin.

The shape of caldera was estimated 28 x 14 km ellipsoid and 300m deep, thus total volume of eruption is estimated around $94km^3$

Rhyolite Lava flows and Obsidian

In the shoulder of Gademotta caldera, Rhyolite lava and obsidian are observed.

Rhyolite lava is intercalated by loose sediments at the Roadside and obsidian is observed at the rim of Rhyolite. Obsidian is considered as chilled margin of rhyolite at this site.

Fig.4: Topography of Gademotta Caldera

Rhyolite lava with flow structure and vertical columnar joint is observed at the quarry in the foot of caldera wall (Fig.5). Generally columnar joint is vertical to the isothermal gradient; therefore that rhyolite lava was cooled by the ground. K-Ar age of this rhyolite is 1.3 – 1.6 Ma (WoldeGabriel et al., 1990) and it indicates that Gademotta volcano was formed at that time.

Deposition of thick pyroclastics is related directly or indirectly

to calderas and most researchers believe that they were erupted from ring fractures concomitant from caldera collapse (R.V. Fisher and H.-U. Schminske 1984). Based on this point of view, Gademotta caldera might be one of the sources of welded tuffs observed in the northern part of Rift Valley Lakes Basin.

Fig.5: Observation of Rhyolite lava at the foot of Gademotta caldera. Vertical columnar joint shows that lava was cooled by the ground.

Surge Deposit

Base surge deposit is found at the shoulder of Gademotta Caldera. Base surge deposit is originated at the very initial period of eruption, and often forms characteristic lamination structure. (Fig. 6)

The direction of base surge is from SE to NW, may indicate that base surge is originated from Gademotta volcano, before the caldera collapse.

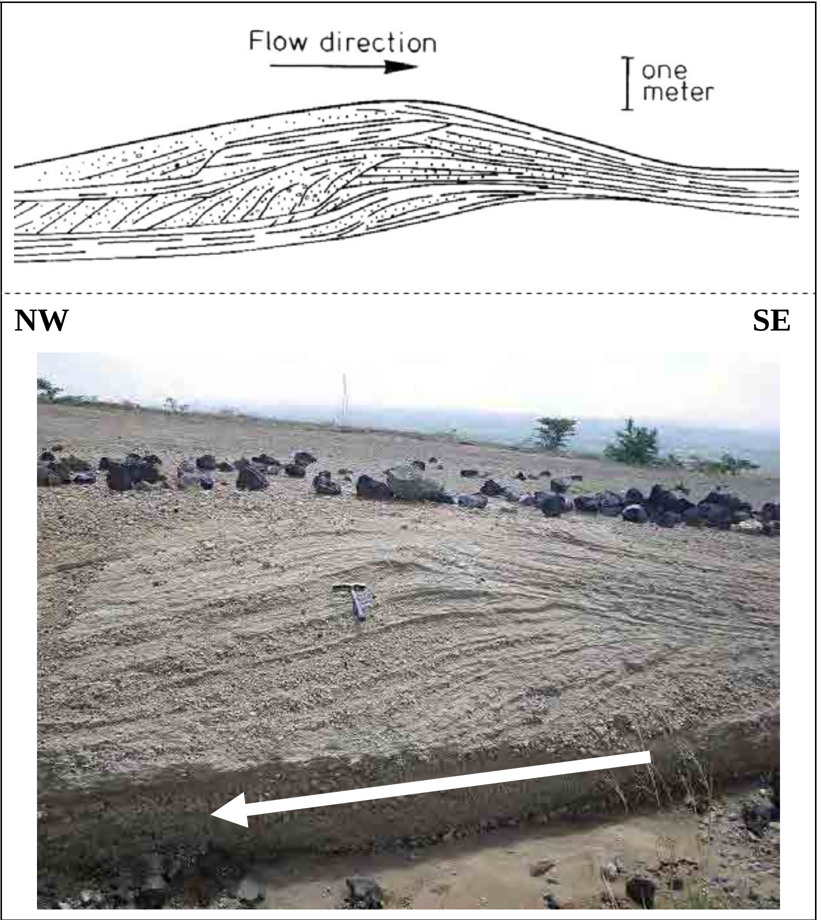


Fig.6: Schematic diagram of Chute-and-Pool structure in surge deposit (upper) and same structure observed at the roadside in the shoulder of Gademotta Caldera (lower). Flow direction is from SE to NW by the structure. (Upper figure is from "Pyroclastic Rocks" by R.V. Fisher and H.-U. Schminske 1984)

Site 3 : Adele

WHAT TO SEE

- ✓ **Structure of Welded Tuff**
- ✓ **Structure of Pumice Tuff**
- ✓ **Boundary between Welded Tuff and Pumice Tuff**

Topography

Adele is located at 7km east of Lake Shala. NNE-SSW active faults and ground cracks are observed at this Area. The outcrop is also located inside the big crack beside the road. Here, yellowish-gray pumice tuff overlies greenish-gray welded tuff .

Structure of Welded Tuff

Greenish-gray welded tuff is observed at the foot of the crack. Structure of welded tuff is different with that in Koshe; large flattered obsidians (*Fiamme*) are common in welded tuff and the length of obsidian is around 30cm maximum.

Structure of Pumice Tuff

Light yellowish-gray pumice tuff is observed at the shoulder of the crack. Many pumices and rock fragments are included in the tuff.

Boundary between Welded Tuff and Pumice Tuff

Boundary between welded tuff and pumice tuff are found at the bottom - middle of slope in the crack. The boundary is unclear. Generally, welded tuff is associated with non-welded part in the pyroclastic flow (Fig 3).

In the study, pumice tuff and welded tuff are classified and described as each formation. However, based on the structure of boundary, those formations have a possibility of single cooling unit.

Fig.7: Ground crack in Adele. The crack is around 20m deep, welded tuff and pumice tuff are observed at the cliff.

Fig.8: Welded tuff in Adele; flattered obsidians (*Fiamme*) are visible.

Fig.9: Boundary between welded tuff and pumice tuff. Boundary is unclear; which is considered that those formations might be single cooling unit.

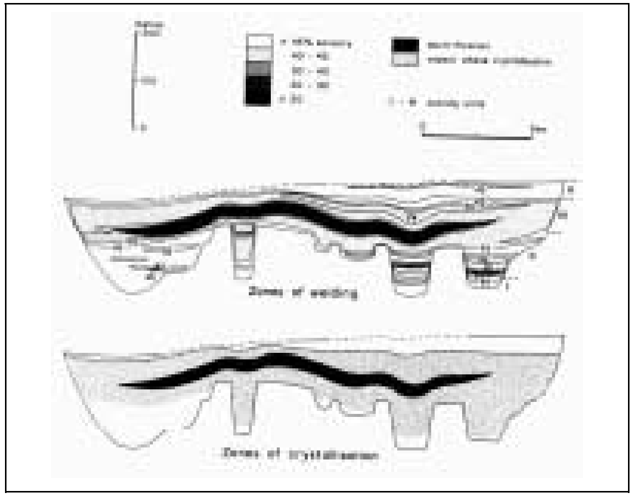


Fig.10: Diagram shows distribution of welded part in single cooling unit in Bandelier Tuff, New Mexico, USA.
(Source: www.nsm.buffalo.edu/courses/gly433/Welded.pdf)

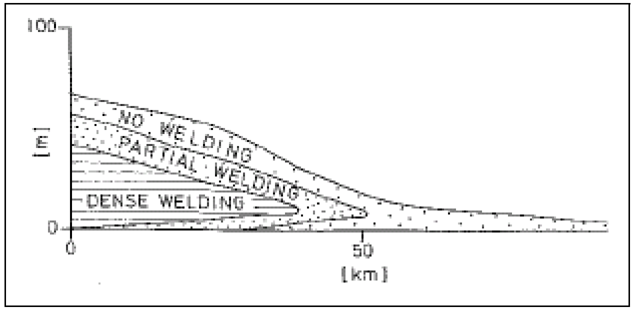


Fig.11: Idealized lateral and vertical configuration of welding zones in a single cooling unit. (from “Pyroclastic Rocks” by R.V. Fisher and H.-U. Schminske 1984, Fig 8-13 of Page 196)

Site 4 : Mt. Chebbi

WHAT TO SEE

- ✓ **Pumice Fall Deposit**
- ✓ **Obsidian Lava**
- ✓ **Boundary between Pumice fall and Obsidian Lava**

Topography

Mt. Chebbi is a volcano consisting Corbetti caldera, which is located at the northern part of Awassa. Corbetti caldera is consisted of two volcanoes; Mt. Chebbi and Mt. Urji. Mt. Urji is characterized by deposition of pumice fall and Mt. Chebbi is characterized by deposition of obsidian lava.

Pumice Fall Deposit

Pumice fall deposit is widely covered the surrounded area of Corbetti caldera, such as Awasa and Sheshemene town. At the site, pumice tuff is observed on the ground. The thickness of pumice fall deposit is around 2.0m at the roadside of Sheshemene - Awassa road, 1.0 m at Bura (Site 5).

Obsidian Lava

Obsidian cliff is observed at the site. Obsidian is observed at Gademotta caldera as chilled margin of rhyolite, however obsidian lava is observed at this outcrop. Obsidian lava overlies pumice fall deposit at the site. K-Ar age of this obsidian lava is 0.02 Ma, means that the eruption of obsidian was occurred in archeological period.

Fig.12: Outcrop of Obsidian lava (Left, cliff) and pumice fall (Right, on the ground).

Fig.13: Obsidian lava overlies pumice fall deposit.

Site 5 : Bura

WHAT TO SEE

- ✓ **Structure of Basaltic Scoria Cone**
- ✓ **Structure of Pumice Fall deposit**
- ✓ **Relationship between Basaltic Scoria Cone and Pumice Fall Deposit**

Topography

Bura is located at 12km west from Shashemene town. Some basaltic scoria cones are located in this area. Because basaltic scoria is so fresh that volcanic activities of basalt in this area seem to be relatively young.

Structure of Basaltic Scoria Cone

Basaltic scoria falls and small lava flows are stratified at the quarry site. Reddish-gray scoria fall deposit is weakly graded and thin basalt lava is intercalated. The stratification forms scoria cone.

Structure of Pumice Fall deposit

At the top of scoria fall deposits, 1m-thick yellowish-gray pumice fall deposit is observed. Pumice fall deposit is similar as that at Site 4, which might be originated from Mt. Urji. Based on this relationship, it is clear that basaltic scoria cone is performed before the eruption of Mt. Urji.

Fig.14: Basaltic scoria cone (Lower, reddish gray) and Pumice fall deposit (Top, yellowish gray).

Fig.15: Section of pumice fall deposit. The thickness is around 1.0m and slightly normal-graded.

Site 6 : Langano

WHAT TO SEE

✓ **Structure of Pumice Tuff**

Topography

The site is located at western shore of Lake Langano. The western shore of Lake Langano is characterized by the cliffs formed by succession of NNE-SSW faults. Yellowish gray pumice tuff is outcropped at 50m-height cliffs.

Structure of Pumice Tuff

Yellowish gray pumice tuff is massive and includes many pumices and non-original fragments. Matrix is composed of fine volcanic glass.

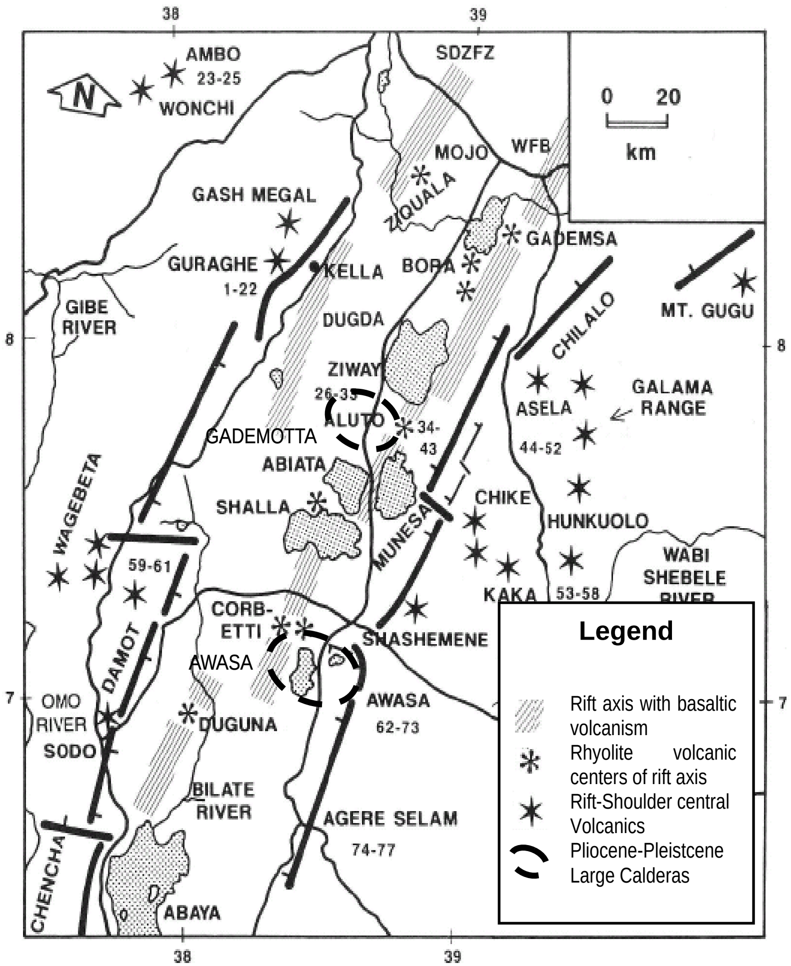
This pumice tuff is thickly distributed in this area and associated by the welded tuff at the bottom.

Mohr et al. (1980) and Le Turdu et al. (1999) considered that those pyroclastic units are originated by collapse of O’a caldera (Lake Shala), and the flow is distributed and thickly deposited at the eastern side of O’a caldera (See Appendix 2).

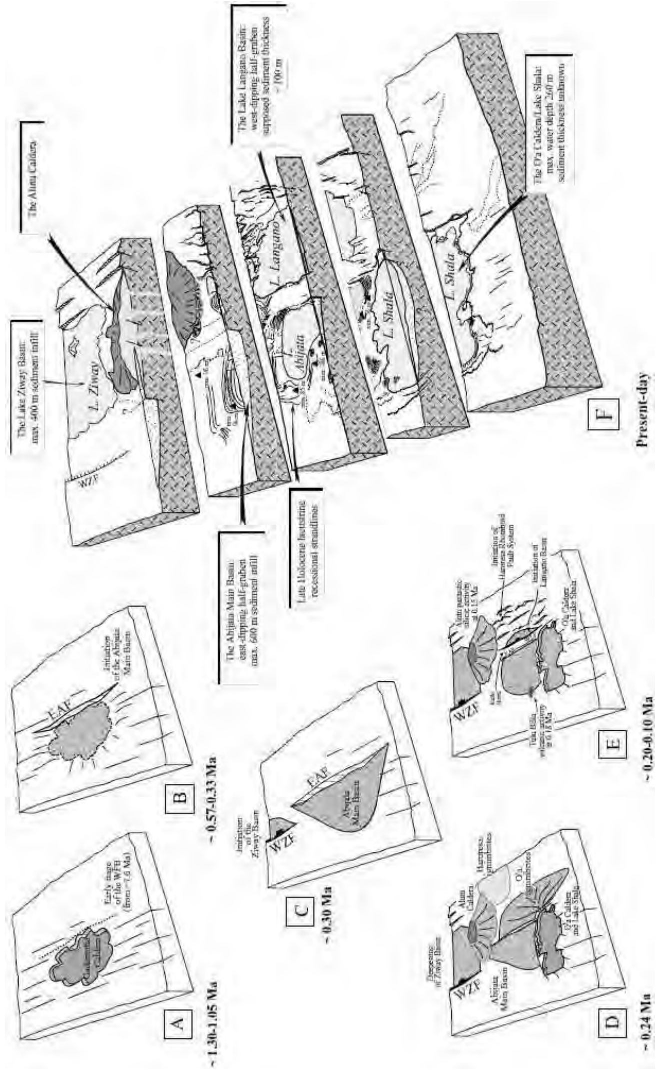
Fig.16: Cliff of Pumice tuff at the western shore of Lake Langano.

Fig.17: Pumice tuff observed at Lake Langano. Pumice tuff is massive and includes many pumices and non-original fragments. Matrix is composed of fine volcanic glass.

Appendix 1: Distribution of Volcanoes and Volcanic activity in the Rift Valley Lakes Basin (modified by WoldeGabliel et al., 1990)



Appendix 2: Schematic Block diagrams of the Evolution of the Ziway–Shala region from the Early Pleistocene to present-day (Le Turdu et al., 1999)



Appendix 3: Stratigraphy of northern part of Rift Valley Lakes Basin (in the Study)

Era	Period/Epoch	Lake Ziway	Lake Langano, Abijata, Shala	Lake Awasa	Major lithology
Quaternary	Holocene	Alluvium	Alluvium	Alluvium	Fine sand - mud
		Bulbula lacustrine deposits	Bulbula lacustrine deposits	Shalo lacustrine deposits	Lake deposits such as gravel, sand and mud
		Mt. Aluto volcanics	Alge volcanics	Corbetti volcanics	Rhyolite lava flows, pumice falls, pumice flow deposits and Obsidian lava flows
		Butajira Recent Basalt	Awara Recent Basalt	Awasa Recent Basalt	Basalt lavas and reddish brown basaltic scoria
		Meki lacustrine deposits		Wondotika lacustrine deposits	Lake deposits such as poorly-sorted gravel, sand, pumice, tuff, and volcanic sand
	Pleistcene	Asela poorly welded pumiceous pyroclastics	Langano poorly welded pumiceous pyroclastics	Shashemene poorly welded pumiceous pyroclastics	Yellowish white rhyolitic pumice tuff
		Kulmusa highly Welded-Tuff	Kuyera highly Welded-Tuff	Mt. Kuwe highly Welded-Tuff	Rhyolitic to andesitic welded tuff
		Ketar river acidic volcano-sedimentary rocks	Lake Shala acidic volcano-sedimentary rocks	Yiega Alem acidic volcano-sedimentary rocks	Rhyolitic tuffs and pumice tuffs
		Gonde Strongly Green Welded-Tuff	Bilate river Strongly Green Welded-Tuff	Hantate Strongly Green Welded-Tuff	Rhyolitic to andesitic welded tuff
		Adami Tulu basaltic pyroclastics	Shala Senbete basaltic pyroclastics	Abaye ridge basaltic pyroclastics	Basaltic tuff breccias and lapilli tuffs
		Ogolche Basalt	Lepis Basalt	Yubo Basalt	Massive basalt lavas
		Lekansho Lake deposits			Lake deposits such as gravel, sand and mud
Neogene	Plio–Pleistecene	Gademotta rhyolite	Aje rhyolite	Wendo Genet Rhyolite	Rhyolite lava flows and rhyolitic tuffs
	Late Miocene to Pliocene	Bofa Basalt		Wijigra Rhyolite	Rhyolitic tuffs/ Basalt lavas and basaltic pyroclastics

All the maps are by SRTM-3 DEM at www.nasa.gov/ and processed by Kasimir3D: www.kasimir3d.com

JICA Study Team Workshop on Volcanic Geology

WS-4 Isotopic Analysis

Characteristics of the Groundwater in the Rift Valley Lakes Basin

- Isotopic Analysis Results -

Technical Transfer Seminar
for the Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

Contents of this Presentation

1. Clarify the nature of the groundwater in the area 10 min
2. Results and interpretation of isotope analysis 20 min
3. Case of utilization of the isotope analysis in Japan 15 min

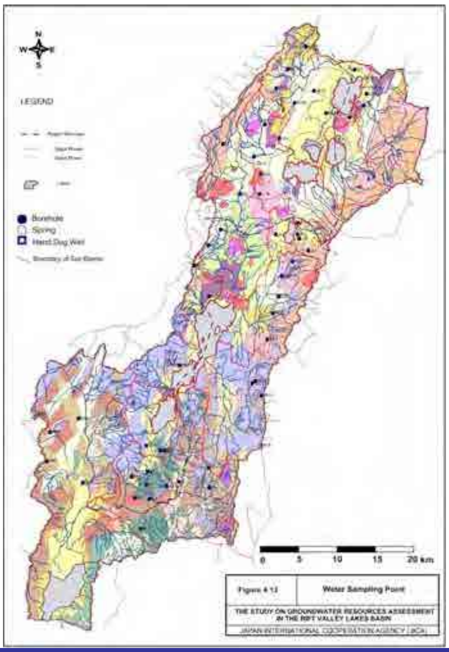
The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

WS-4 Isotopic Analysis

1 Nature of groundwater by water quality analysis

1.1 Sampling point

Bno	BasinName	Samp_P_ID	Geology	SourceType	Eastings	Northings	Remarks
1	Western Ziway-Abjata	WZA1	Qwbh	spring	440353.00	918436.00	
		WZA2	N1_2n	Borehole	449814.00	918599.00	
		WZA3	Qwbh	Borehole	436107.39	901949.82	
		WZA4	Qdi	Borehole	426750.58	887592.79	
		WZA5	Qdi	Borehole	455903.00	885591.00	
		WZA6	Qdi	Borehole	440921.00	876752.00	
		WZA7	Ql	Borehole	465363.00	869206.00	
2	Eastern Ziway	EZ1	Ql	Borehole	487538.00	901548.00	
		EZ2	Ql	spring	495889.00	895142.00	
		EZ3	Ql	spring	502396.00	887587.00	
		EZ4	Ql	Borehole	496746.00	883403.00	
		EZ5	Qwbh	Borehole	494507.00	874562.00	
		EZ6	Ql	spring	485555.00	872111.00	
		EZ7	Ql	Borehole	483552.00	866076.00	
3	Lake Shalla	LS1	Qdi	spring	410040.00	872237.00	
		LS2	Qwpu	spring	414532.00	863503.00	
		LS3	Qdi	Borehole	418241.00	860616.00	
		LS4	Qwpu	spring	403414.00	855821.00	
		LS5	N1_2n	Borehole	429417.53	850002.26	
		LS6	Qwbh	spring	420168.00	844740.00	
4	Lake Langono	LL10	Qdp	Borehole	413811.47	808766.15	
		LL11	Qdi	spring	471440.00	799751.00	
		LL12	Qdi	spring	481628.00	820252.00	
		LL7	Qdi	Borehole	409686.00	836778.00	
		LL8	Qdi	spring	413167.00	831630.00	
		LL9	Qws	Borehole	414848.79	823508.22	
5	Lake Awasa	LA1	Qws	Borehole	443247.00	787145.00	
		LA2	Qdi	spring	458768.00	783746.00	
		LA3	Ql	Borehole	426416.00	778488.00	
		LA4	Ql	Borehole	443296.00	778694.00	
		LA5	Qws	Borehole	444891.00	775368.00	
		LA6	N1_2n	spring	459970.00	773976.00	
		LA7	NQs	Borehole	451604.00	766446.00	
6	Bilate	B1	NQs	spring	412472.00	893811.00	
		B2	NQs	Borehole	385835.00	846152.00	
		B3	Qdi	Borehole	399055.00	808866.00	
		B4	Qdi	Borehole	383940.00	782096.00	
		B5	Qdi	Borehole	374310.00	770488.00	
		B6	Qvs	spring	403650.00	766500.00	
7	Amessa Guracha	AG1	NQs	Borehole	363549.00	755433.00	
		AG2	Qwbp	spring	379661.00	743494.00	
		AG3	Qwbp	Borehole	374898.00	732412.00	
		AG4		spring	354515.00	723336.00	
		AG5	Pv	spring	352367.00	718157.00	
		AG6	Pv	spring	347611.00	713476.00	
8	Gidabo	GID1	Qdp	Borehole	439758.00	758653.00	
		GID2	Qdp	spring	438017.00	753002.00	
		GID3	Qdp	Borehole	431299.00	747854.00	
		GID4	Qdi	hand dug well	428801.00	732211.00	
		GID5	Qa	Borehole	424000.00	720000.00	
		GID6	PNv	spring	427915.00	706700.00	
		GID7	PNv	Borehole	420150.00	701089.00	
9	Kulfo Gina	KG1	Pv	spring	345897.00	704036.00	
		KG2	Pv	spring	342307.00	691646.00	
		KG3	PNv	spring	342008.00	684900.00	
		KG4	Pv	spring	343470.00	682077.00	
		KG5	Qa	Borehole	351823.00	681377.00	
		KG6	Pv	spring	335938.00	664942.00	
		KG7	Qwbp	spring	340514.00	663331.00	
10	Sife Chamo	SC1	Pv	spring	313955.00	652539.00	
		SC2	Qa	spring	325813.00	650053.00	
		SC3	Pv	spring	323955.00	631606.00	
		SC4	Qa	Borehole	326268.00	621806.00	
		SC5	NMt	Borehole	337177.93	618029.40	
		SC6	NMt	Borehole	340044.00	618188.00	
11	Gelana	GEL1	Pv	spring	413097.00	680370.00	
		GEL2	PNv	Borehole	410584.00	669815.00	
		GEL3	PNv	Borehole	408331.00	668006.00	
		GEL4	PNv	Borehole	415473.00	659170.00	
		GEL5	Pcgn4	spring	408449.00	633710.00	
		GEL6	Pv	spring	413840.00	621971.00	
12	Bezo Weyto	BW1	Pcgn4	spring	299599.00	669160.00	
		BW2	Pv	spring	308307.00	666051.00	
		BW3	Pcgn4	Borehole	273518.78	641784.04	
		BW4	Pcgn3	spring	241142.00	645216.00	
		BW5	NQs	Borehole	251506.68	631850.39	
		BW6	Pcgn4	Borehole	248647.00	610123.00	
		BW7	QHr	Borehole	276954.74	593722.42	
13	Konso Localized	KL1	Qa	Borehole	327166.32	602575.18	
		KL2	Pcgn1	Borehole	314963.82	598184.77	
		KL3	NMt	Borehole	326032.44	592626.67	
		KL4	Pcgt4	Borehole	317138.94	582698.21	
		KL5	Pcgn1	Borehole	328439.00	581952.00	
		KL6	NMt	Borehole	341546.24	591483.08	
14	Segen	S1	NMt	spring	366914.00	649685.00	
		S2	Qe	Borehole	351527.97	594777.38	
		S3	Qe	Borehole	374494.00	605132.00	
		S4	Pv	Borehole	374737.00	590400.00	
		S5	Pcgn4	spring	378773.00	581400.00	
		S6	NMt	Borehole	321726.00	559650.00	



1 Nature of groundwater by water quality analysis

1.2.1 Trilinear Diagram (reference)

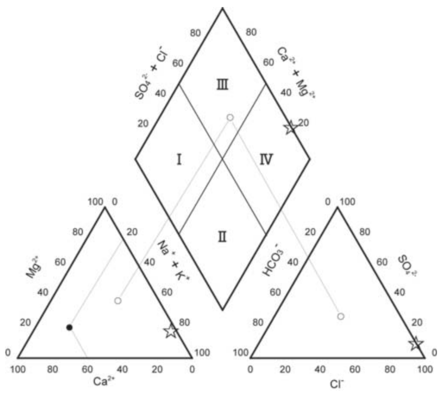


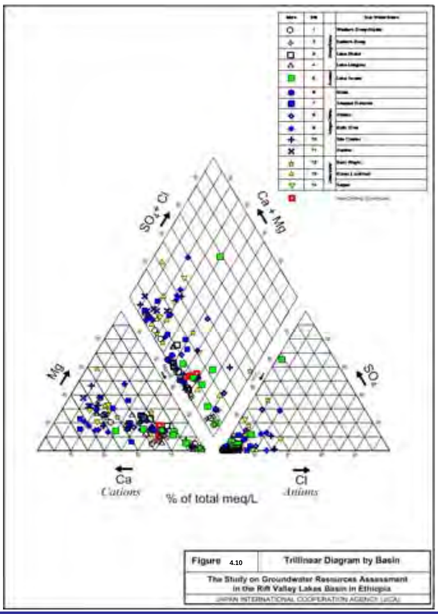
Figure 4.9 :Trilinear Diagram

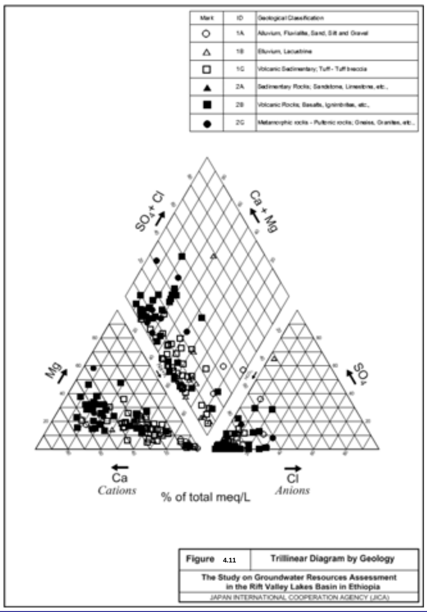
I Ca(HCO3)2 Type (Carbonate hardness): Shallow groundwater, River water
II NaHCO3 Type (Carbonate alkali): Deep groundwater
III CaSO4 CaCl2 Type (Noncarbonate hardness):
IV NaSO4 NaCl (Noncarbonate alkali):Seawater, fossil saline water, hot spring

WS-4 Isotopic Analysis

1 Nature of groundwater by water quality analysis

1.2.2 Trilinear Diagram of the site by basin and geology



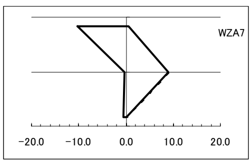


The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

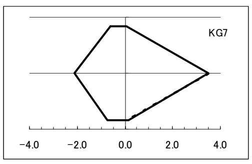
1 Nature of groundwater by water quality analysis

1.3 Hexa Diagram

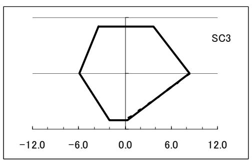
Na-HCO3 type

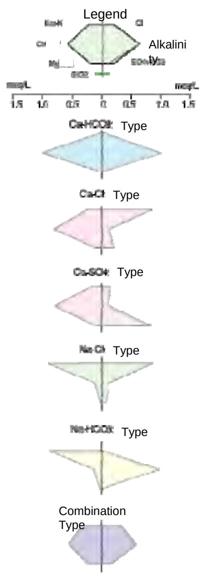


Ca-HCO3 type



Combination type





The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

WS-4 Isotopic Analysis

1 Nature of groundwater by water quality analysis

1.4 Results and Interpretation

1. WQ by sub basins

Chew-Bahir sub-basin and Abaya-Chamo sub-basin are classified as Ca(HCO3)2 type ***→ shallow circulating groundwater***

Awassa sub-basin tends to have a pattern of NaHCO3 type
→ deep groundwater in stagnant groundwater environments

Ziway-Shalla sub-basin has both patterns of NaHCO3 and Ca(HCO3)2

→ Mixture type of groundwater

2. WQ by geology

Groundwater in sandstone, limestone, basalt, pyroclastics, granite and gneiss (2A-2C in the Figure) are categorized as Ca(HCO3)2 type

Groundwater in tuff, tuff breccia, lacustrine and alluvium is classified into NaHCO3 type and NaHCO3 +Ca(HCO3)2

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

2 Isotopic Characteristic of Groundwater in RV area

2.0 Isotope Analysis

1. 93 samples taken at the same place of other WQS
2. Immediately delivered to the AAU Lab
3. Classified by basin and geology

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

WS-4 Isotopic Analysis

2 Isotopic Characteristic of Groundwater in RV area

2.1.1 Isotope Analysis Result

Code	BS_ID	AQ_ID	SOURCE OF SAMPLE	AQUIFER	ROCK FACIES	d ^{2}H (d D)	d ^{18}O
WZA-1	1	1C	Borehole	Qwbh	Basalt flow	-3.39	-2.55
WZA-2	1	2B	Borehole	N1_2n	Igninbrite, Welded tuff	-22.52	-4.74
WZA-3	1	1C	Borehole	Qwbh	Basalt flow	-2.89	-1.98
WZA-4	1	1C	Borehole	Qdi	Igninbrite, Tuff	-4.15	-2.48
WZA-5	1	1C	Borehole	Qdi	Igninbrite, Tuff	-19.63	-3.86
WZA-6	1	1C	Borehole	Qdi	Igninbrite, Tuff	-27.72	-5.21
WZA-7	1	1B	Borehole	Ql	Lacustrine	-16.09	-4.52
EZ-1	2	1B	Borehole	Ql	Lacustrine	3.17	-2.02
EZ-2	2	1B	Spring	Ql	Lacustrine	-1.59	-1.61
EZ-3	2	1B	Spring	Ql	Lacustrine	1.32	-1.01
EZ-4	2	2B	Borehole	Ql	Lacustrine	1.22	-1.19
EZ-5	2	1C	Borehole	Qwbh	Basalt flow	3.26	-0.93
EZ-6	2	1C	Spring	Qwbh	Basalt flow	5.19	-0.88
EZ-7	2	1B	Borehole	Ql	Lacustrine	5.93	-0.92
LS-1	3	1C	Spring	Qdi	Igninbrite, Tuff	6.26	-1.11
LS-2	3	1C	Spring	Qwpu	Pumice tuff, Tuff	-9.81	-3
LS-3	3	1C	Borehole	Qdi	Igninbrite, Tuff	-3.18	-2.12
LS-4	3	1C	Spring	NQs	Undivided Sediments	-17.92	-4.5
LS-5	3	2B	Borehole	N1_2n	Igninbrite, Welded tuff	24.53	4.66
LS-6	3	1C	Spring	Qdi	Igninbrite, Tuff	6.15	-2.51
LL-10	4	1C	Borehole	Qdp	Pyrocrastics	-1.11	-1.34
LL-11	4	1C	Spring	Qdi	Igninbrite, Tuff	-1.59	-1.61
LL-12	4	1C	Spring	Qdi	Igninbrite, Tuff	-6.7	-1.93
LL-7	4	1C	Borehole	Qdi	Igninbrite, Tuff	0.04	-2.04
LL-8	4	1C	Spring	Qdi	Igninbrite, Tuff	5.28	-0.38
LL-9	4	1C	Borehole	Qws	Silicica	0.97	-1.39
LA-1	5	1B	Borehole	Ql	Lacustrine	10.71	-0.28
LA-2	5	1C	Spring	Qdi	Igninbrite, Tuff	3.29	-2.02
LA-3	5	1B	Borehole	Ql	Lacustrine	22.64	2.09
LA-4	5	1B	Borehole	Ql	Lacustrine	3.32	-1.47
LA-5	5	1C	Borehole	Qws	Silicica	5.32	-0.81
LA-6	5	2B	Spring	N1_2n	Igninbrite, Welded tuff	-0.74	-2.48
LA-7	5	1C	Borehole	NQs	Undivided Sediments	2.28	-1.98

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

2 Isotopic Characteristic of Groundwater in RV area

2.1.2 Isotope Analysis Result

Code	BS_ID	AQ_ID	SOURCE OF SAMPLE	AQUIFER	ROCK FACIES	d ^{2}H (d D)	d ^{18}O
B-1 June 16/10	6	1C	spring	NQs	Undivided Sediments	10.11	-1.87
B-2 June 16/10	6	1C	Borehole	NQs	Undivided Sediments	1.99	-2.55
B-3	6	1C	Borehole	Qdi	Igninbrite, Tuff	-7.56	-2.51
B-4	6	1C	Borehole	Qdi	Igninbrite, Tuff	-0.94	-0.99
B-5	6	1C	Borehole	Qdi	Igninbrite, Tuff	-2.9	-1.38
B-6 June 09/10	6	1C	spring	Qvs	Volcanic Sediments	-15.23	-3.48
AG-1	7	1C	Borehole	NQs	Undivided Sediments	0.83	-2.55
AG-2	7	1C	Spring	Qwbp	Basalt	1.35	-2.54
AG-4	7	1C	Spring	NQs	Undivided Sediments	4.58	-1.76
AG-5	7	2B	Spring	Pv	Basalt	3.5	-1.99
AG-6	7	2B	Spring	Pv	Basalt	2.3	-1.83
GID-1	8	1C	Borehole	Qdp	Pyrocrastics	4.07	-2.31
GID-2	8	1C	Spring	Qdp	Pyrocrastics	4.07	-0.14
GID-3	8	1C	Borehole	Qdi	Igninbrite, Tuff	5.03	-0.16
GID-4	8	1C	Hand dug well	Qdi	Igninbrite, Tuff	5.01	-0.14
GID-5	8	2B	Borehole	N1_2n	Igninbrite, Welded tuff	5.05	-0.15
GID-6	8	2B	Spring	PNv	Igninbrite	5.02	-0.13
GID-7	8	2B	Borehole	PNv	Igninbrite	5.96	-1.05
(GID-8)Ag-3	7	1C	Borehole	NQs	Undivided Sediments	4.31	-1.04
KG-1	9	2B	Spring	Pv	Basalt	-8.49	-2.7
KG-2	9	2B	Spring	Pv	Basalt	-5.18	-2.42
KG-3	9	2B	Spring	PNv	Igninbrite	-2.89	-2.34
KG-4	9	2B	Spring	Pv	Basalt	-3.23	-2.62
KG-5	9	1A	Borehole	Qa	Alluvium	1.96	-1.42
KG-6	9	2B	Spring	Pv	Basalt	4.07	-2.31
KG-7	9	1C	Spring	Qwbp	Basalt	-0.42	-2.3

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

WS-4 Isotopic Analysis

2 Isotopic Characteristic of Groundwater in RV area

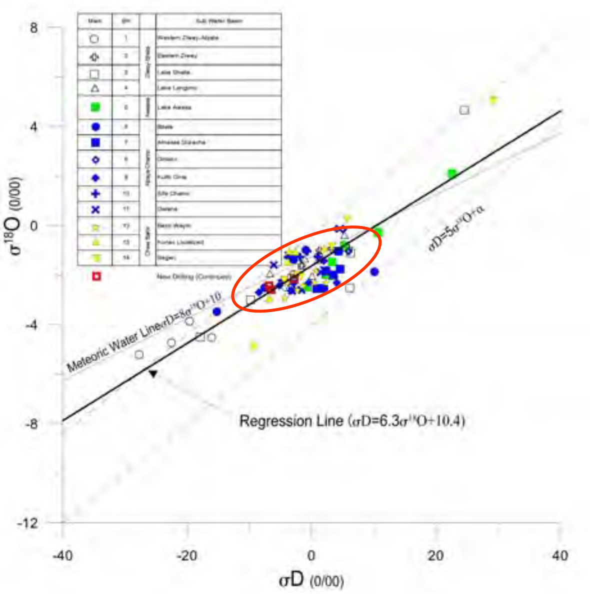
2.1.3 Isotope Analysis Result

Code	BS_ID	AQ_ID	SOURCE OF SAMPLE	AQUIFER	ROCK FACIES	d^2H (d D)	$d^{18}O$
SC-1	10	2B	Spring	Pv	Basalt	-0.71	-1.05
SC-2	10	1A	Spring	Qa	Alluvium	1.05	-1.27
SC-3	10	2B	Spring	Pv	Basalt	-4.74	-2.21
SC-4	10	1A	Borehole	Qa	Alluvium	-3.78	-1.27
SC-5	10	2B	Borehole	NMt	Basalt	-1.85	-1.27
SC-6	10	2B	Borehole	NMt	Basalt	-2.81	-1.27
GEL-1	11	2B	Spring	Pv	Basalt	-1.6	-2.6
GEL-2	11	2B	Borehole	PNv	Igninbrite	1.43	-1.89
GEL-3	11	2B	Borehole	PNv	Igninbrite	2.03	-1.79
GEL-4	11	2B	Borehole	Pv	Basalt	-3.16	-2.64
GEL-5	11	2C	Spring	Pcgn4	Gneiss	-6.07	-1.59
GEL-6	11	2B	Spring	Pv	Basalt	-3.7	-1.2
BW-1	12	2B	Spring	Pv	Basalt	0.5	-2.31
BW-2	12	2B	Spring	Pv	Basalt	-4.33	-2.93
BW-3	12	2C	Borehole	Pcgn4	Gneiss	0.68	-1.83
BW-4	12	2C	Spring	Pcgn3	Gneiss	-2.29	-2.6
BW-5	12	2B	Borehole	NPv	Basalt	-1.31	-2.45
BW-6	12	2B	Borehole	Pv	Basalt	-4.01	-2.31
BW-7	12	1A	Borehole	QHr	Fulviatile	2.27	-2.32
KL-1	13	1A	Borehole	Qa	Alluvium	-9.29	-4.81
KL-2	13	2C	Borehole	Pcgn1	Gneiss	-3.57	-1.04
KL-3	13	2B	Borehole	NMt	Basalt	-2.62	-1.05
KL-4	13	2C	Borehole	Pcgt4	Granite	-3.82	-1.46
KL-5	13	2C	Borehole	Pcgn1	Gneiss	2.09	-0.92
KL-6	13	2B	Borehole	NMt	Basalt	-6.78	-2.94
S-1	14	2B	Spring	NMt	Basalt	-4.43	-2.2
S-2	14	1B	Borehole	Qe	Ellivium	-1.72	-2.05
S-3	14	1B	Borehole	Qe	Ellivium	-2.34	-1.99
S-4	14	2C	Borehole	Pcgn4	Gneiss	29.21	5.04
S-5	14	2B	Spring	Pv	Basalt	5.69	0.26
S-6	14	2B	Borehole	NMt	Basalt	3.27	-0.84
RVS BH-2	15	1C	Borehole	Qdi	Sand, Gravel, Tuff	-2.81	-2.17
RVS BH-1	15	1C	Borehole		Sand, Gravel, Pumice	-6.82	-2.44
RVS BH-3	15	1C	Borehole		Tuff breccia	-6.53	-2.59

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

2 Isotopic Characteristic of Groundwater in RV area

2.2 Overall Plot of Isotope Analysis Result by Basin

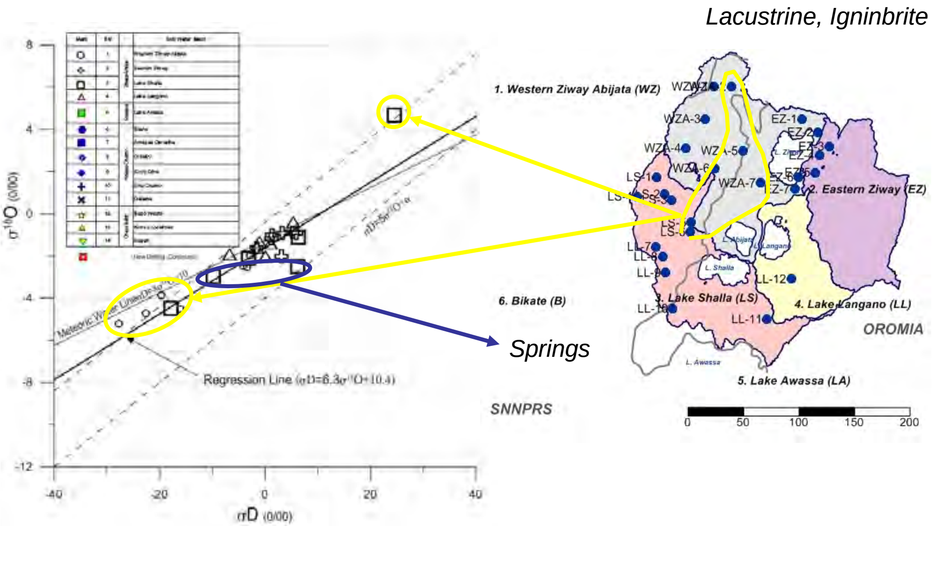


The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

WS-4 Isotopic Analysis

2 Isotopic Characteristic of Groundwater in RV area

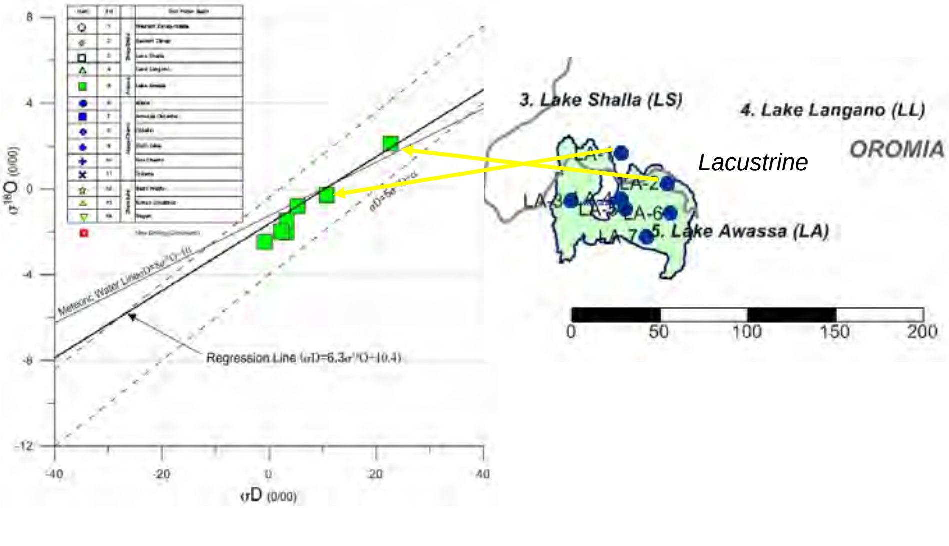
2.2.1 Isotope Analysis Result by Basin (Ziway Shalla)



The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

2 Isotopic Characteristic of Groundwater in RV area

2.2.2 Isotope Analysis Result by Basin (Awassa)

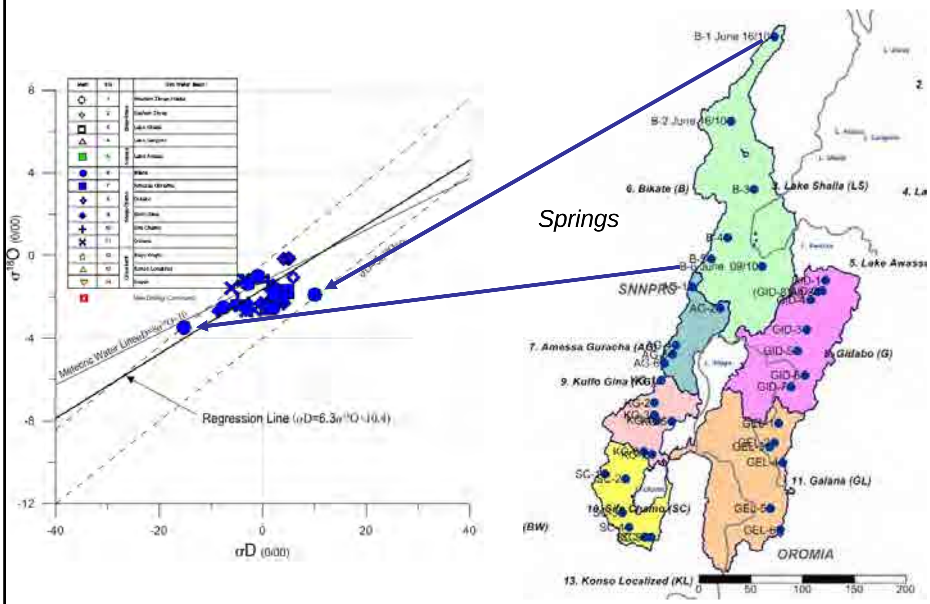


The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

WS-4 Isotopic Analysis

2 Isotopic Characteristic of Groundwater in RV area

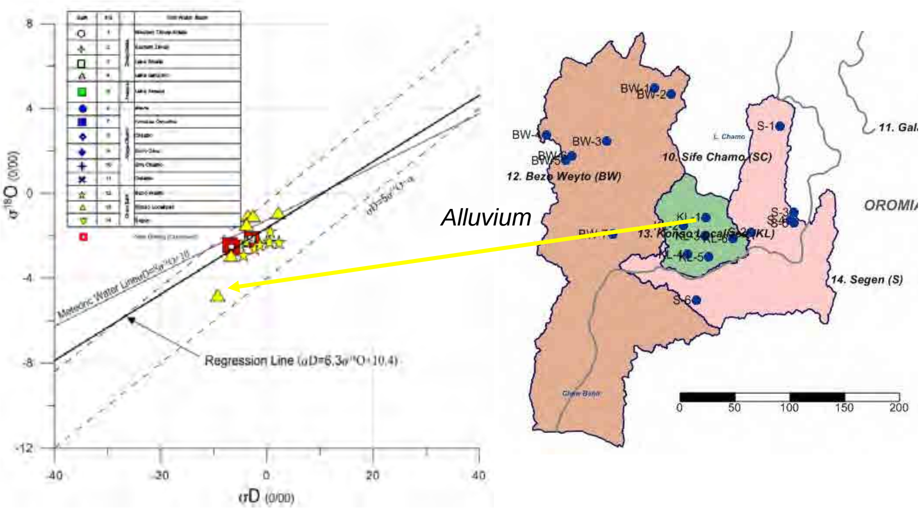
2.2.3 Isotope Analysis Result by Basin (Abaya Chomo)



The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

2 Isotopic Characteristic of Groundwater in RV area

2.2.4 Isotope Analysis Result by Basin (Chew Bahir)

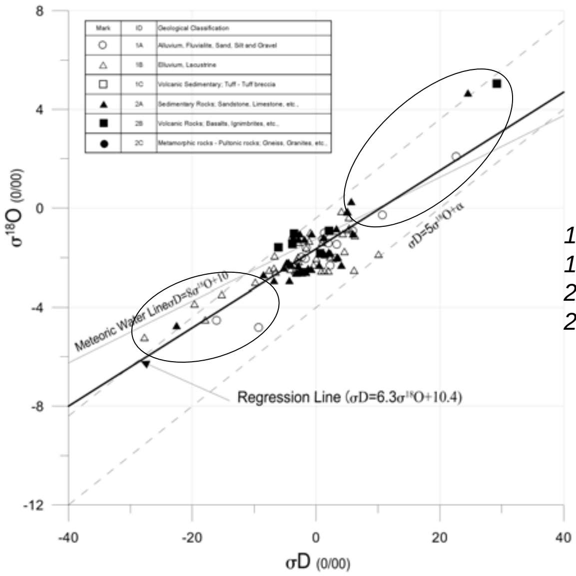


The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

WS-4 Isotopic Analysis

2 Isotopic Characteristic of Groundwater in RV area

2.3 Isotope Analysis by Geology



1A (Alluvium)
1B (Lacustrine)
2A (Sedimentary)
2B (Ignimbrite)

2 Isotopic Characteristic of Groundwater in RV area

2.4 Summary

1. **Most of the results fall into just below SMOW and/or along the meteoric line.**

2. **The abnormal values fall into the following criteria**

By Basin
- Northern side of Lake Ziway and Shalla and springs
- Northern side of Lake Awassa
- Springs at cliff edge at Bilate sub basin

By Geology
- Mostly in sediments and pyroclastics

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

2 Isotopic Characteristic of Groundwater in RV area

2.5 Interpretation

1. Anomaly can be found in the Northern Lake side sediments

There are some similarities with hydrothermal activated area. The water in the sediments can be easily affected by the potential hydrothermal activity.

Assumption
Originally, isotopic components were the meteoric water, but was affected by hydrothermal water ? Relation with fluoride

2. Some springs at the escarpment has irregular values

High altitude springs has different isotope composition. Not big difference but there are some variety than other sources.

Assumption
The springs located at high elevation = ? Altitude affect or deferent water origin

3 Case of utilization of the isotope analysis in Japan

Estimation of the Sources and Flow System of Groundwater in Fuji-Gotenba Area by Stable Isotopic Analysis and Groundwater Flow Simulation

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[2] Graduate School of Systems Engineering, Wakayama University, 930, Sakaedani, Wakayama-shi, Wakayama 640-8510
[3] Faculty of Systems Engineering, Wakayama University, 930, Sakaedani, Wakayama-shi, Wakayama 640-8510
[4] Kirin Holdings Company, Limited, Central Laboratories for Frontier Technology, Center for Food Safety Science, 3, Miyahara, Takasaki-shi, Gunma 370-1295
[5] Kirin Beverage Company, Limited, 1, Kanda-Izumicho, Chiyoda-ku, Tokyo 101-8645

(Received 20 May 2009, Accepted 15 July 2009)

WS-4 Isotopic Analysis

3 Case of utilization of the isotope analysis in Japan

Understanding the source and chemical character of the groundwater provides an important strategy for the quality management of mineral water and food materials. In order to identify a source and the flow paths of groundwater used for mineral water, the water quality and stable isotopes of hydrogen and oxygen of well water in Gotenba city were studied. The electrical conductivity and chemical character of sampled water are similar to those of well water and spring water discharged elsewhere around Mt. Fuji. The hydrogen and oxygen isotopic ratios of water samples indicate their origin to be solely meteoric and the oxygen isotopic ratios suggest that the groundwater mainly originated from the mountain-side of Mt. Fuji at altitudes of from 1500 m to 2300 m. A subsequent simulation of groundwater showed that the distribution of the total head and the Darcy velocity are down streamlines from mountain-sides toward the study area in Gotenba city. The altitudes of discharge obtained by the simulation are above 2000 m, and these correspond well with altitudes estimated from $\delta^{18}O$ values of the samples.

Keywords : Mt. Fuji ; groundwater ; stable isotopic analysis ; groundwater flow simulation.

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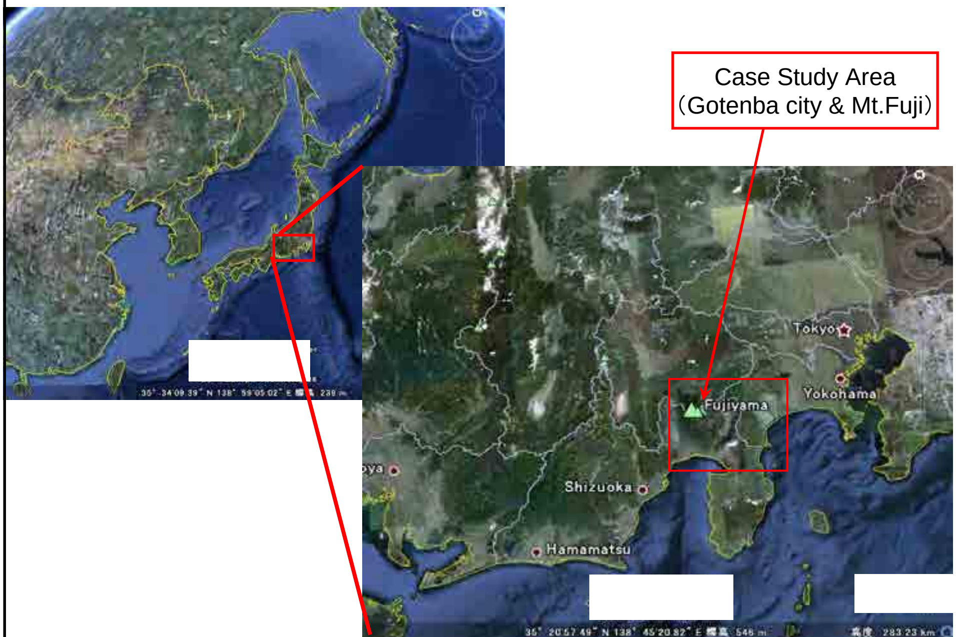
3 Case of utilization of the isotope analysis in Japan



The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

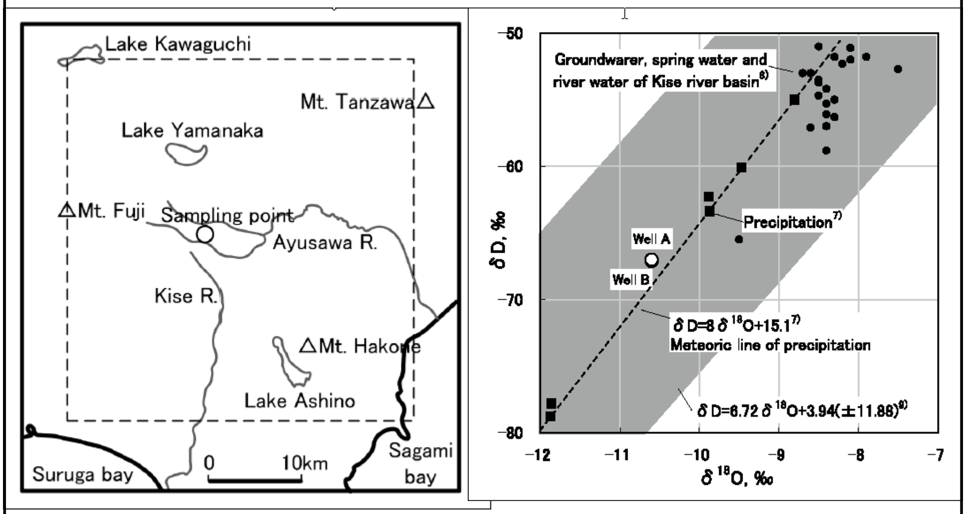
WS-4 Isotopic Analysis

3 Case of utilization of the isotope analysis in Japan

Case Study Area Outlook
(Sampling point lies in Gotenba city and very near to Mt.Fuji)

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

3 Case of utilization of the isotope analysis in Japan



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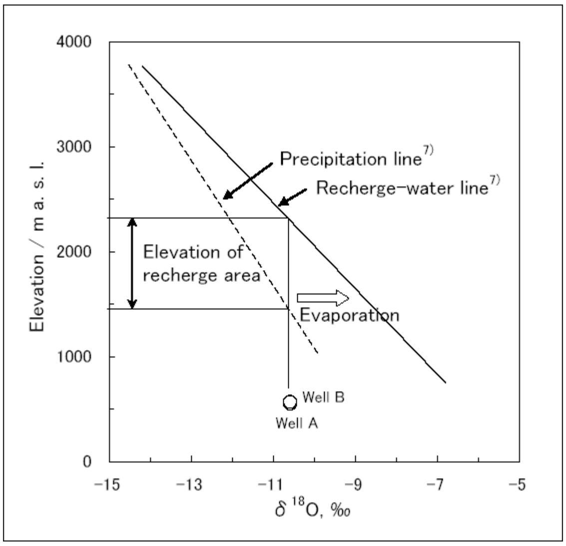
3 Case of utilization of the isotope analysis in Japan

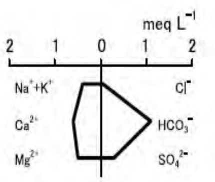


The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

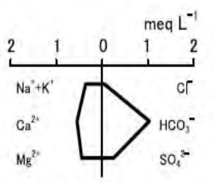
3 Case of utilization of the isotope analysis in Japan

Table 1 Chemical composition and stable isotope ratio of water samples

Sample name	pH	Tem, ℃	ORP/ mV	EC/ $mS\ m^{-1}$	Chemical composition/$mg\ L^{-1}$							Stable isotope ratio, ‰	
					Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	δD	$\delta^{18}O$
Well A	8.4	13.2	141	18.5	7.9	1.7	12	6.0	1.7	67	14	−67.1	−10.6
Well B	8.5	10.9	140	14.6	7.3	1.6	11	5.4	1.8	63	12	−67.0	−10.6



Groundwater from well A



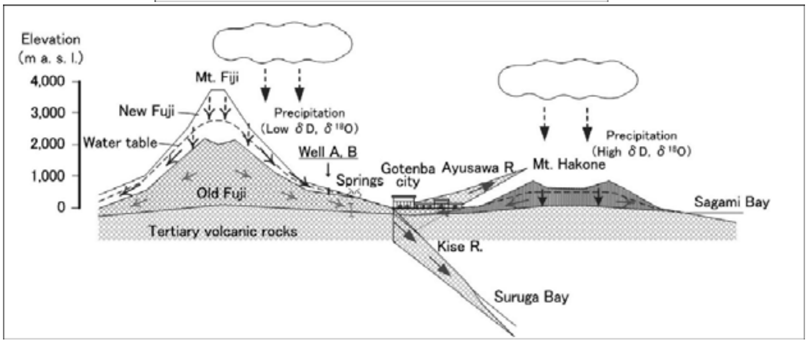
Groundwater from well B

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

WS-4 Isotopic Analysis

3 Case of utilization of the isotope analysis in Japan

Boundary conditions	Side and bottom	Impermeable
	Top (Ground surface)	Infiltration 1.9～8.8 mm d^{-1}
	River	Presser head : 0 m
Finite element method grid	Number of elements	67872
	Number of layers	6 (minimum thickness is 10 m)
Method of analysis	Saturated-unsaturated three-dimensional seepage analysis	



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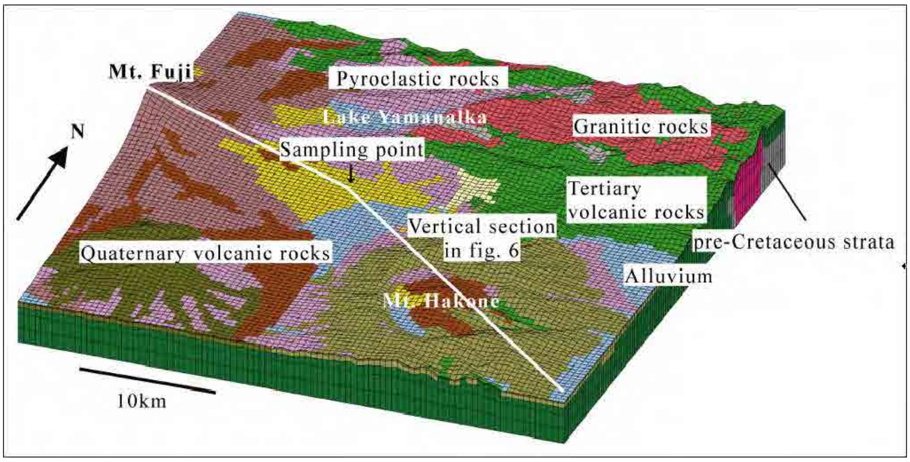
3 Case of utilization of the isotope analysis in Japan



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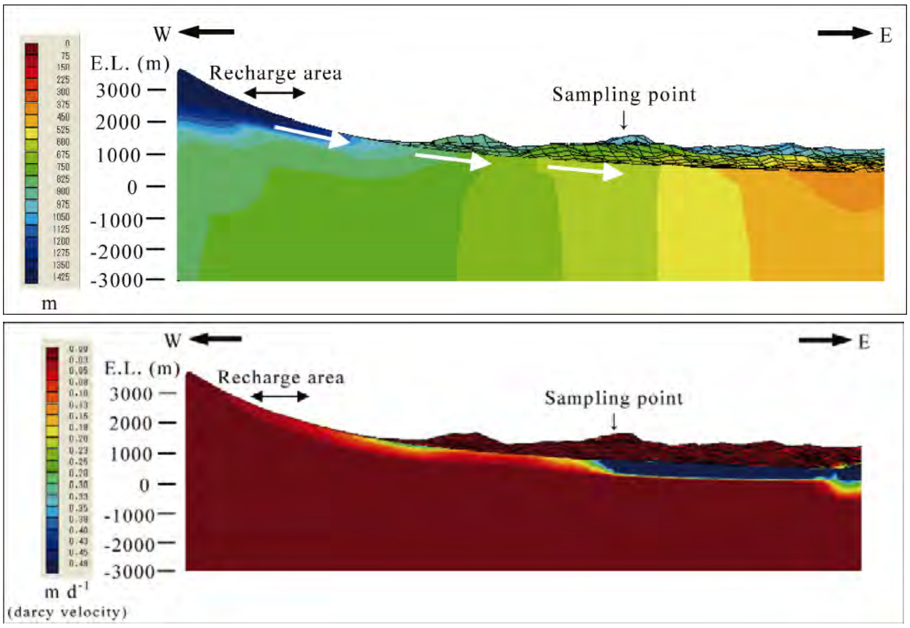
WS-4 Isotopic Analysis

3 Case of utilization of the isotope analysis in Japan

Table 3 Geology and Property

Rock type	Hydraulic conductivity $k \times$ m s^{-1}	Effective porosity, %
Alluvium	1.0×10^{-2}	15
Quaternary volcanic rocks	1.2×10^{-5} ~ 3.0×10^{-7}	15
Tertiary volcanic rocks	3.3×10^{-6}	2
Granitic rocks	4.0×10^{-7}	1
pre-Cretaceous strata	5.8×10^{-7}	1

3 Case of utilization of the isotope analysis in Japan



WS-4 Isotopic Analysis

END

THANK YOU FOR YOUR ATTENTION

The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin

WS-5 GIS Guidebook

The Study on Groundwater Resources Assessment
in the Rift Valley Lakes Basin

GIS Workshop

GIS utilization on groundwater development study

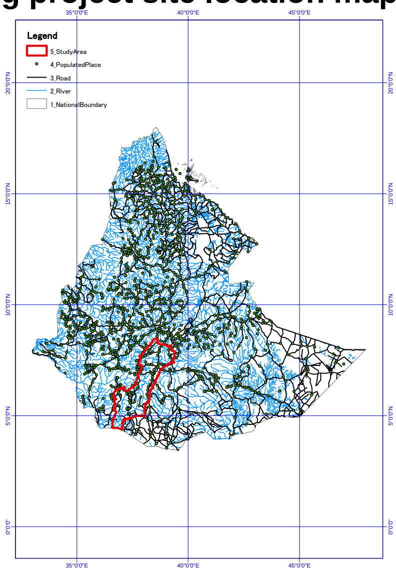
May, 2011

WS-5 GIS Guidebook

CONTENTS

WS-5 GIS Guidebook

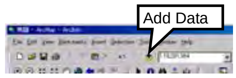
1. Case study 1: Making project site location map

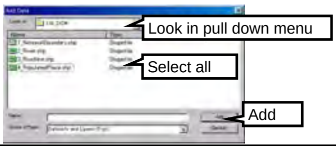


(Output example/image)

1.1. Start ArcMap and open a map document & Add data to a map document

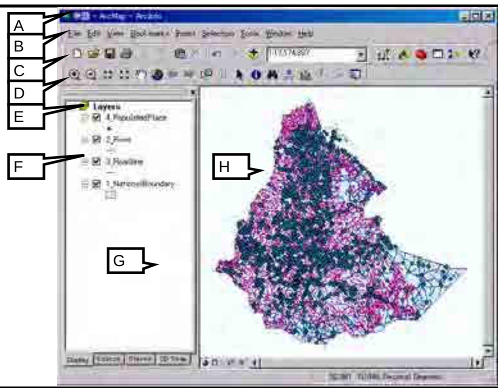
1) Click the Start menu, point to All Programs, Point to ArcGIS, and then click ArcMap.
2) Click the Add Data button.
3) Click the **Look in pull down menu**, point to the folder of **C:¥GIS¥001_shp**, and select the all item using shift key, and then click Add.





1.2. Get acquainted with the ArcMap interface

A) Title bar
B) Menu bar
C) Standard tool bar
D) Tools toolbar
E) Data frame: A data frame is a container for a map's layers.
F) Layer: A layer is an organized set of geographic features.
G) Table of contents: it contains a list of all the layers in ArcMap.
H) Map display



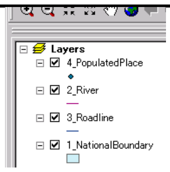
1.3. DCW (Digital Chart of the World): www.maproom.psu.edu/dcw/

- The Digital Chart of the World (DCW) is a comprehensive digital map of Earth. It is freely available as of 2006, although it has not been updated since 1992.
- The primary source for this database is the United States Defense Mapping Agency's (DMA) Operational Navigation Chart (ONC) 1:1,000,000 scale paper map series produced by the US, Australia, Canada, and the United Kingdom.
- The thematic layers of the DCW are: Political/Ocean (country boundaries), Populated Places (urbanized areas and points) ,Roads, Railroads, Drainage System, Hypsographic data, River and etc.
- The service is decommissioning the DCW due to inaccurate and out of date data. For up to date data; Natural Earth Data site. (url is http://www.naturalearthdata.com/)

WS-5 GIS Guidebook

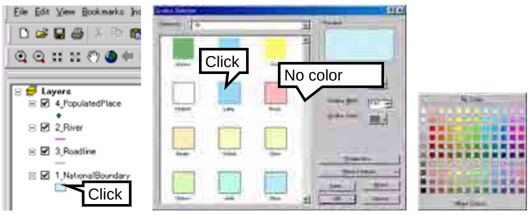
1.4. Layer control (Turn layers on and off)

1) In the table of contents, you can turn layers on and off by check/uncheck the check box
2) You can change the order layers by mouse-driven drag & drop. In ArcMap, bottom layer is placed the back side of the map display.



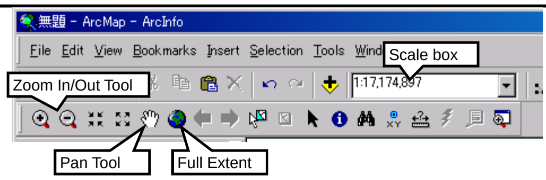
1.5. Symbolize a layer in ArcMap

1) In the table of contents, click the symbol box below the 1_NationalBoundary layer.
2) Click the pull down menu of fill color in options box, select the No color and click OK to apply the new symbol
3) Click the symbol below the River, select the River and click OK.
4) Click the symbol below the Road, select the Major Road and click OK.
5) Click the symbol below the Populated Places, select the Major Road and click OK.



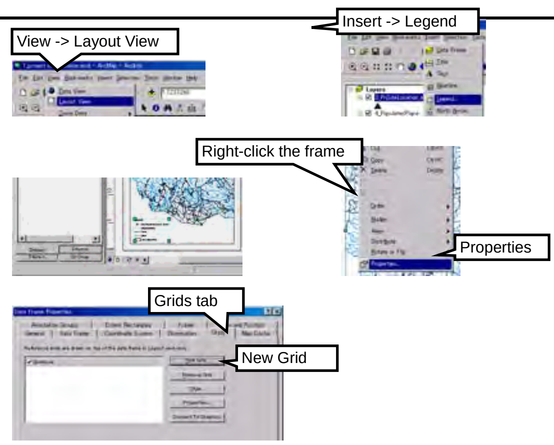
1.6. Explore scale in ArcMap

1) Look at the Map Scale box; you can confirm/change the scale of the map.
2) On the Tools of the toolbar, click the Zoom In tool, and then draw a rectangle with your mouse around the extent of the center.
3) Click the Pan Button; you can shift the map location.
4) Click the Full Extent button; you can see the full extent of the layers in the map display.



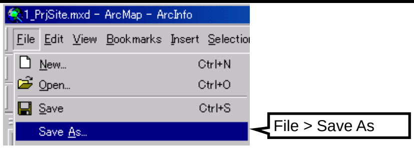
1.7. Map layout for printout

1) From the **View** menu, choose **Layout View**.
2) From the **Insert** menu, choose **Legend**, click Next 4 times, and click Finish.
3) You can see the legend box, move the box to left bottom side of the layout by mouse-driven drag & drop.
4) Right-click on the frame of map, click **Properties**, click **Grids tab**, click **New Grid** button, click Next 3 times, click Finish, click **Style** button, choose **Graticule with sub ticks**, click OK, and then click OK
5) You can see the grid of Lon-Lat. If you have a printer, you can printout from Print in File menu.



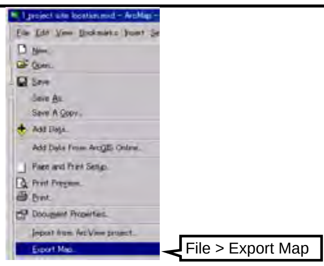
1.8. Save the map document

1) From the **File** menu, choose **Save As**.
2) In the dialog box, browse to your **C:¥GIS¥000_mxd** folder
3) In the File name box, type **1_StudyArea**, click Save, and close ArcMap
4) For check the saved file, browse to your **C:¥GIS¥000_mxd** folder, double-click **1_StudyArea.mxd**.



1.9. Export a map to PDF

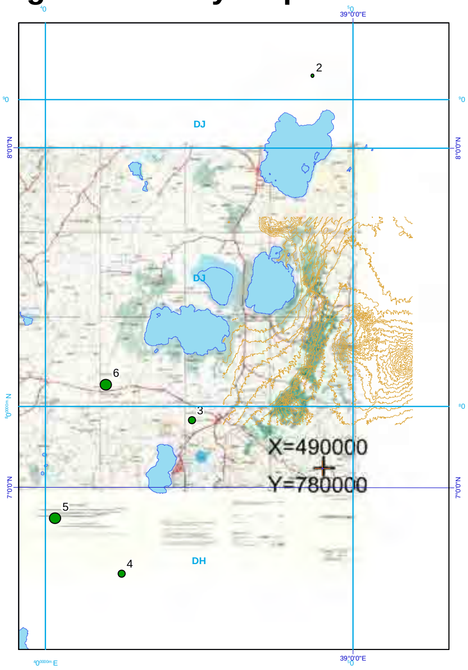
1) From the **File** menu, choose **Export Map**.
2) In the dialog box, browse to **C:¥GIS¥002_pdf**, and choose the **PDF (*.pdf)** from pull-down of File type, and then click Save.
3) For check the saved file, browse to your **C:¥GIS¥002_pdf folder**, and double-click "1_StudyArea.pdf", and then you can confirm the map by PDF. (required Acrobat Reader)



1.10. What is ArcGIS

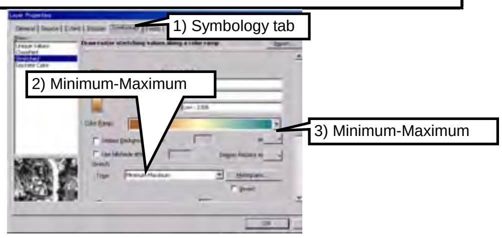
- ArcGIS is a suite consisting of a group of geographic information system (GIS) software products produced by ESRI. At the desktop GIS level, ArcGIS can include:
  - **ArcReader**, which allows one to view and query maps created with the other Arc products;
  - **ArcView**, which allows one to view spatial data, create layered maps, and perform basic spatial analysis;
  - **ArcEditor** which, in addition to the functionality of ArcView, includes more advanced tools for manipulation of shapefiles and geodatabases; or
  - **ArcInfo** which includes capabilities for data manipulation, editing, and analysis.
- **Components**: ArcGIS Desktop consists of several integrated applications, including ArcMap, ArcCatalog, ArcToolbox, and etc..
  - **ArcCatalog** is the data management application, used to browse datasets and files on one's computer, database, or other sources. In addition to showing what data is available, ArcCatalog also allows users to preview the data on a map. ArcCatalog also provides the ability to view and manage metadata for spatial datasets.
  - **ArcMap** is the application used to view, edit and query geospatial data, and create maps. The ArcMap interface has two main sections, including a table of contents on the left and the data frame(s) which display the map. Items in the table of contents correspond with layers on the map.
  - **ArcToolbox** contains geoprocessing, data conversion, and analysis tools. It is also possible to use batch processing with ArcToolbox, for frequently repeated tasks.
- **Extensions**: There are a number of software extensions for ArcGIS Desktop to provide added functionality, including 3D Analyst, Spatial Analyst, Network Analyst and etc..
  - **ArcGIS Spatial Analyst** is an extension to ArcGIS Desktop that provides powerful tools for comprehensive, raster-based spatial modeling and analysis. Using ArcGIS Spatial Analyst, you can derive new information from your existing data, analyze spatial relationships, build spatial models, and perform complex raster operations. Self-documenting models make it easy for others to understand the spatial analysis process applied, examine what-if scenarios, and compare results.

2. Case study2: Making field survey map



(Output example/image)

2.1. Explore DEM (Digital Elevation Model) data



1) Launch ArcMap
2) Click the **Add Data** button, and browse to **C:¥ GIS¥201_aster**, double-click **dem.img**
3) Click the **Add Data** button, and browse to **C:¥ GIS¥001_shp**, double-click **6_Lakes.shp.**
4) Double-click **dem.img** layer, click **Symbology tab**, choose **Minimum-Maximum** from the pull-down menu of Stretch-Type, and change the **color ramp** (for example brown-green type), and then click OK.
5) You can see the elevation on the map.

2.2. What is ASTER/DEM (Digital Elevation Model)?

- ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is a **Japanese** sensor which is one of five remote sensory devices on board the Terra satellite launched into Earth orbit by NASA in 1999. The instrument has been collecting surficial data since February 2000.
- ASTER provides high-resolution images of the Earth in 15 different bands of the electromagnetic spectrum, ranging from visible to thermal infrared light. The resolution of images ranges between 15 to 90 meters. ASTER data are used to create detailed maps of surface temperature of land, emissivity, reflectance, and elevation.
- On 29 June 2009, the Global Digital Elevation Model (GDEM) was released to the public. A joint operation between NASA and **Japan's** Ministry of Economy, Trade and Industry (METI), the Global Digital Elevation Model is the most complete mapping of the earth ever made, covering 99% of its surface.

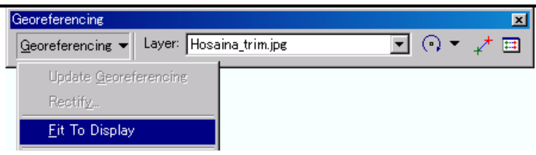
	ASTER GDEM	**SRTM3**	**GTOPO30**
Data source	ASTER	Space Shuttle Radar	Many institutions in the world
institution	METI/NASA	NASA/USGS	USGS
Start over	2009 -	2003 -	1996 -
times	2000 -	11days (2000)	
resolution	30m	90m	900m
accuracy	7m- 14m	10m	30m
cover	N83 - S83	N60 - S56	Global

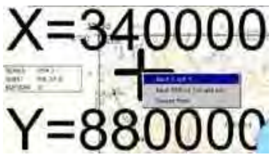
2.3. Making contour lines

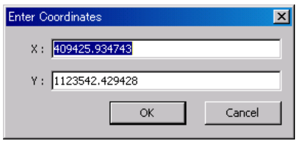
1) Activate the spatial analyst tool (if you can not see the tool bar, select Tools > Extensions, check the Spatial Analyst, right-click tool bar area, select the Spatial Analyst)
2) Cick the Spatial Analyst > Surface Analysts > Contour
3) In the Contour dialog, set the Input surface: **dem img**, Contour interval: **25,** click folder icon of Output features, browse **C:¥GIS¥301_analysis¥01_contour**, type **contour_100m**, click Save, click OK

2.4. Geo-referencing

1) **Add Data** button, and browse to **C:¥ GIS¥104_scan**, click **TopoMap_Hosaina.jpg**, click Add.
2) From **View** > **Toolbars** , click **Georeferencing**, select "TopoMap_Hosaina.jpg" from pull-down menu of the toolbar, and then click **Georeferencing** > **Fit To Display**.
3) Click **Add Control Points** in Georeferenceing toolbox
4) **Left-click** point of "X=340000, Y=880000" and **Right-click** > **Input X and Y** > input "X=340000, Y=880000". And input the lower right point of "X=490000, Y=780000" using the same way.
5) Click **Georeferencing**, choose **Update Georeferencing** to save the result.
6) Save the map.

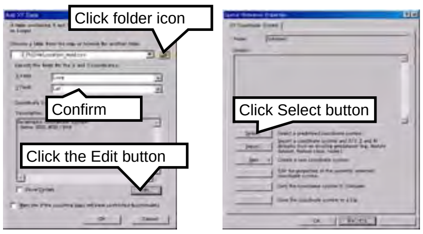


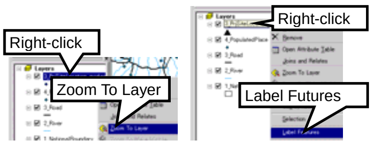




2.5. Plot drilling points location

1) From the Tools menu, choose **Add XY Data**
2) Click folder icon, browse to your **C:¥GIS¥003_db** folder, double-click **DrillingSite.xls,** and double-click **Sheet1$**.
3) Confirm **X** Field: **Easting**, **Y** Field: **Northing**.
4) Click the **Edit** button, click the Select button of the Spatial Reference Properties dialog, and Double-click **Projected Coordinate Systems** > **UTM** > **Other GCS** > **Adindan UTM 37N.prj**, then click OK, and then click OK.
5) Right-click **Sheet1$ Events** on the table of contents, click **Zoom To Layer.**
6) Right-click **Sheet1$ Events** on the table of contents, click **Label Futures**.
7) You can see the drilling points and name on the map.





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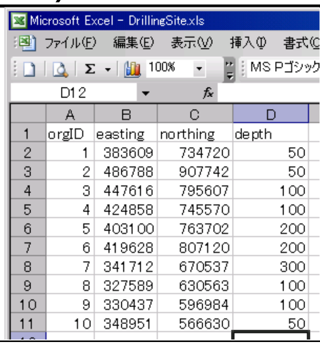
2.6. Add the attribute data to SHP (Database link)

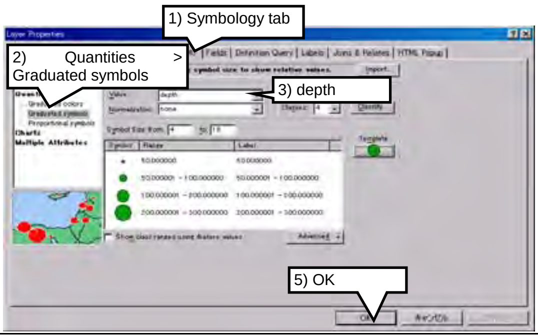
1) Right-click **Sheet1$ Events** on the table of contents, click **Remove**.
2) Browse to **C:¥GIS¥ 003_db**, and double-click **DrillingSite.xls.**
3) Type **depth** in cell of "**D1**" as a name of column (please make sure to do not use space and hyphen as a name of column)
4) Fill cells of the **depth** column any/given value.
5) From File menu, choose **Save**.
6) Shift ArcMap, import **DrillingSite.xls.** as a same way of 2.5



	A	B	C	D
1	orgID	easting	northing	depth
2	1	383609	734720	50
3	2	486788	907742	50
4	3	447616	795607	100
5	4	424858	745570	100
6	5	403100	763702	200
7	6	419628	807120	200
8	7	341712	670537	300
9	8	327589	630563	100
10	9	330437	596984	100
11	10	348951	566630	50

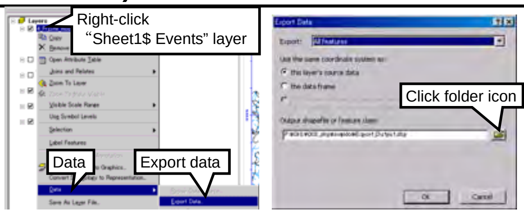
2.7. Thematic map

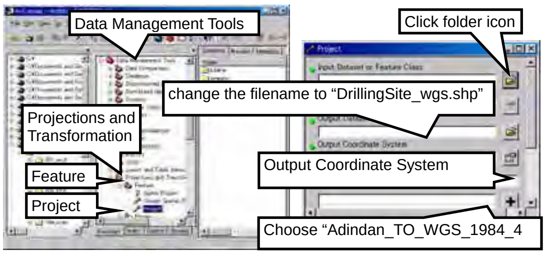
1) In the table of contents, double-click the layer name of **Sheet1$ Events**.
2) Click **Symbology tab**, click **Quantities>Graduated symbols**, choose **depth** from Value of Fields, and change the Classes to **3**, and then the click OK.
3) You can confirm the classification result on the map.

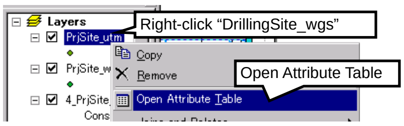


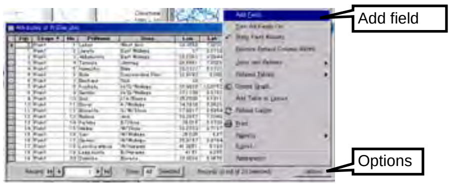
2.8. Export a layer to SHP & coordinate (WGS <> UTM)

1) Right-click **Sheet1$ Events** layer, point to **Data**, click **Export data.**
2) Click folder icon, browse to **C:¥GIS¥003_db**, type **DrillingSite_utm**, click Save, and click **OK**, the dialog will be display, click **No**.
3) Launch **ArcCatalog** (from Windows Start menu or ArcCatalog button in toolbar of ArcMap), click Arc Toolbox button in toolbar of ArcCatalog).
4) Double-click **Data Management Tools** > **Projections and Transformations** > **Feature** > **Project**
5) Click folder icon of the Input Dataset or Feature Class, browse **C:¥GIS¥003_db**, double-click **DrillingSite_utm.shp**, click the icon of Output Coordinate System, click **Select** button, double-click **Geographic Coordinate Systems** > **World** > **WGS 1984.prj**, and click OK, change the filename to **DrillingSite_wgs.shp**, choose **Adindan_TO_WGS_1984_4** form the pull-down of Geographic Transformation, click **OK**.
6) You can see **DrillingSite_wgs.shp**, add this SHP file to ArcMap **by mouse-driven drag & drop**.
7) Right-click **DrillingSite_wgs** layer, click **Open Attribute Table**, click **Options** button, click **Add field**, type "**lon**" as Name, choose **Double** as a Type, click OK









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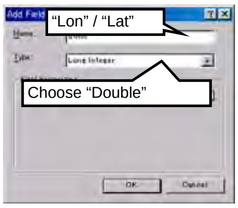
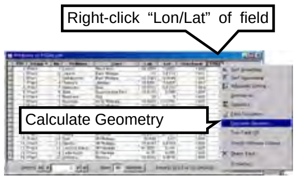
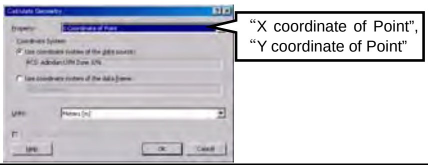
8) Right-click **"lon" of field title**, click **Calculate Geometry**, choose **X coordinate of Point** as a Property, click OK.
9) Add the "**lat**" in the same way.
10) You can see value of WGS.

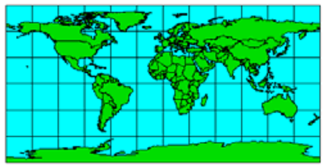




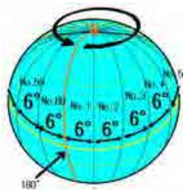


2.9. Map Projection/Coordination

- Land Surface: Arc(Geoid)
  - Geodetic System
    - **Reference Ellipsoid; Spheroid Definition** (e.g. WGS84, Bessel)
    - **Datum**; **Centroid Definition** (e.g. WGS84, Tokyo)

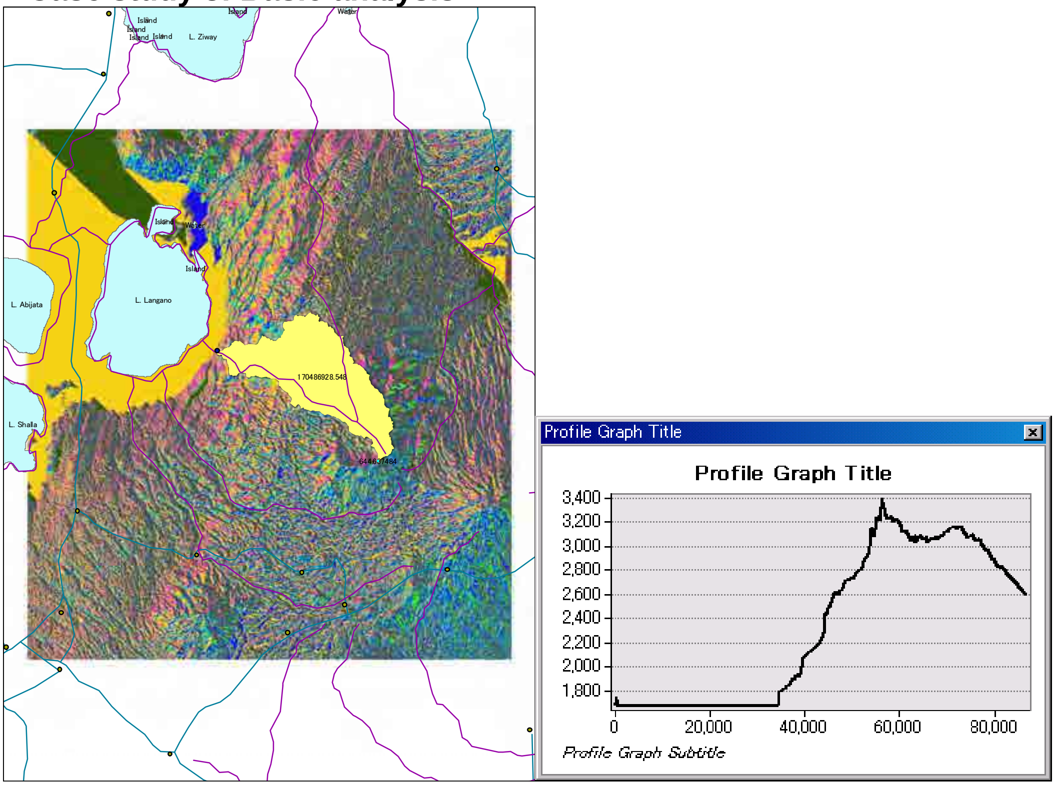


- Map: Plane
  - **Map Projection** (e.g. Azimuthal , Conic, Cylindrical)
- Universal Transverse Mercator (Transverse Mercator Cylindrical Projection)
  - A whole surface of the Earth is divided by 6° in longitude.

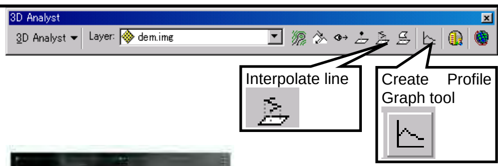


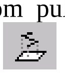
Zone No.	Longitude
No.1	180-186
No.37(Addis)	36-42
No.60	174-180

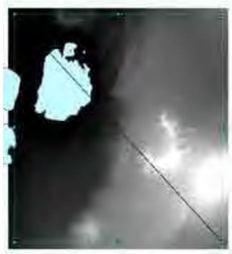
3. Case study 3: Basic analysis

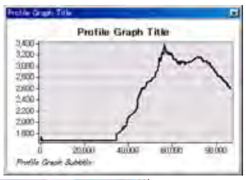


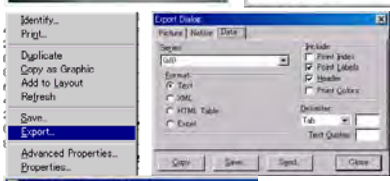
3.1. Cross section

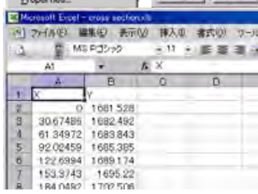


1) Launch ArcMap
2) Click the Add Data button, and browse to **C:¥ GIS¥001_shp,** double-click **6_Lakes.shp**.
3) Click the Add Data button, and browse to **C:¥ GIS¥ 203_aster_gdem,** select **dem.img**, and click Add, and then right-click **dem.img** on the table of contents, click **Zoom To Layer.**
4) From **View** > **Toolbars** , click **3D Analyst**, select "dem.img" from pull-down menu of the toolbar, and then click  Interpolate line tool.
5) Draw the line on the dem. (to finish the drawing: double click)
6) Click  the Create Profile Graph tool, you can see the cross section line as a graph.
7) Right click on the graph, and select export, click the Data tab, and select the Excel, click the Save button, browse to **C:¥ GIS¥003_db,** type **cross section** as a file name, click Save, and then click Close.
8) You can confirm the output result.



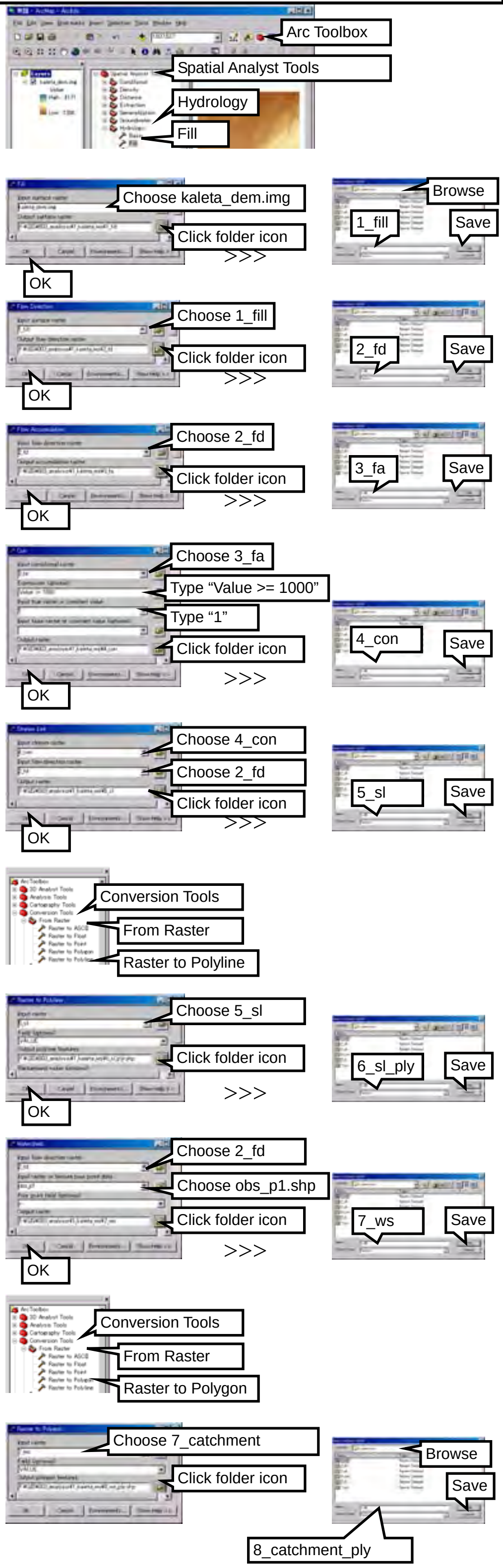






3.2. Make Watershed/Basin using DEM (including preprocessing, making stream)

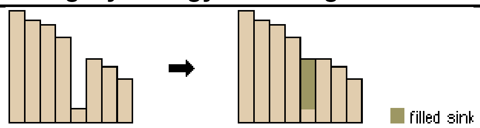
1) Launch ArcMap
2) Click the Add Data button, and browse to **C:¥ GIS¥001_shp,** double-click **6_Lakes.shp**.
3) Click the Add Data button, and browse to **C:¥ GIS¥ 203_aster_gdem,** select **dem.img**, and click Add.
4) Click Arc Toolbox icon.
5) Double-click **Spatial Analyst Tools > Hydrology > Fill**, choose **dem.img** from the pull-down menu, click folder icon of the Output, browse **C:¥GIS¥301_analysis¥02_catchment,** type **1_fill** as a file name, and click Save, and then click OK.
6) Double-click **Flow Direction** in the toolbox, choose **1_fill** from the pull-down, click folder icon of the Output, type **2_fd** as a file name, and click Save, and then click OK.
7) Double-click **Flow Accumulation** in the toolbox, choose **2_fd** from the pull-down, click folder icon of the Output, type **3_fa** as a file name, and click Save, and then click OK.
8) From the toolbox, double-click **Conditional** > **Con** in Spatial Analyst Tools, choose **3_fa** from the pull-down, type **"Value >= 1000"** in Expression box, type **"1"** in the box of Input true raster or constant value, click folder icon of the Output raster, type **4_con** as a file name, and click Save, and click OK.
9) Double-click **Stream Link** in **Hydrology**, choose **4_con** from the pull-down menu of Input stream raster, choose **2_fd** from the pull-down menu of Input flow direction raster, click folder icon of the Output raster, type **5_sl** as a file name, and click Save, and click OK.
10) From Arc Toolbox, double-click **Conversion Tools > From Raster > Raster to Polyline**, choose **5_sl** from the pull-down menu of Input raster, click folder icon of the Output polyline features, browse **C:¥GIS¥301_analysis¥02_catchment**, type **6_sl_ply** as a file name, and click Save, and then click OK.
11) Click the Add Data button, and browse to **C:¥ GIS¥301_analysis¥02_catchment**, double-click **101_obs_point.shp**.
12) Double-click **Watershed** in Hydrology, choose **2_fd** from the pull-down menu of Input flow direction raster, choose **101_obs_point** from the pull-down menu of Input raster or feature, click folder icon of the Output raster, browse **C:¥GIS¥301_analysis¥02_catchment**, type **7_catchment** as a file name, and click Save, and then click OK.
13) From Arc Toolbox, double-click **Conversion Tools > From Raster > Raster to Polygon**, choose**7_catchment** from the pull-down, click folder icon of the Output, browse



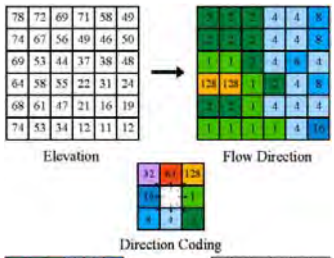
C:¥GIS¥301_analysis¥02_catchment, type **8_catchment_ply** as a file name, click Save, and click OK.

3.3. Making process of watershed boundary using Hydrology Modeling

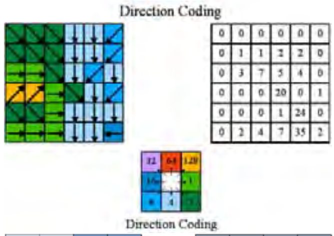
1) **The Digital Elevation Model (DEM)** is a cell-based raster data referring to the surface of the Earth. Each cell contains an elevation data which represents the elevation of the cell.



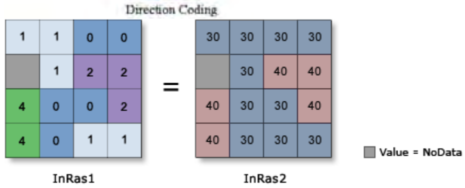
2) **Fill Sinks:** Sinks, which affects internal drainage, may cause undesirable result when calculating flow direction. Therefore it is required to fill sinks in order to create depressionless DEM.
3) **Flow Direction:** Flow direction in each cell of the DEM is determined and the directions are referred by 8 numbers ranging 1 to 128. Direction data is stored in each cell as a number correlated to its direction.



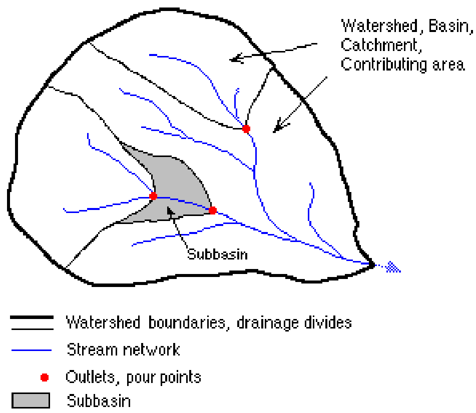
4) **Flow Accumulation:** The Flow Accumulation dialog calculates accumulated flow based on the raster data of the Flow Direction. The accumulated flow is the accumulated weight of all cells flowing into each down-slope cell.



5) **Conditional:** Performs a conditional if/else evaluation on each of the input cells of an input raster.



6) **Stream Network:** The Stream Network dialog provides a stream in case of precipitation as a shape file (i. e. file form of figures for the ArcGIS) based on the Flow Direction and the Flow Accumulation.
7) **Watershed:** This area is normally defined as the total area flowing to a given outlet or pour point. These areas are the output of the Watershed tool. The boundary between two watersheds is referred to as a watershed boundary or drainage divide. An outlet, or pour point, is the point at which water flows out of an area. This is the lowest point along the boundary of the watershed. The cells in the source raster are used as pour points above which the contributing area is determined. Source cells may be features, such as dams or stream gauges, for which you want to determine characteristics of the contributing area.

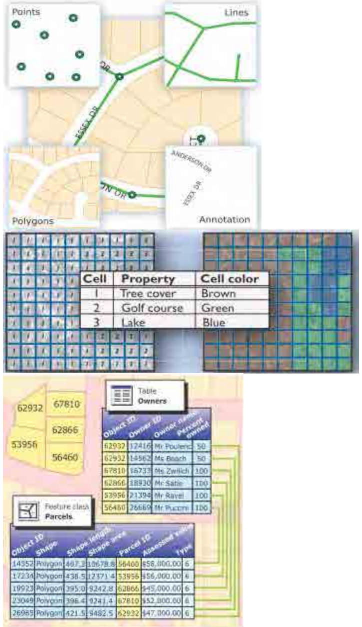


3.4. Calculation of catchment area

9) Right-click **8_catchment_ply** layer, click Open Attribute table, click Add field from Option button, type “area” in Name box, choose Double from pull-down menu of Type, and then click OK.
10) Right-click column name of area, click Calculate Geometry, choose Area from pull-down menu of Property, chose Square Kilometers from pull-down menu of Units, and then click OK.

3.5.　Types of geographic datasets

- **Vector**
  - Points
  - Lines
  - Polygons
- **Raster**
- **Associated attribute tables**

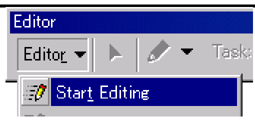


4. Case study 4: Data convert from hardcopy to softcopy (digitizing)

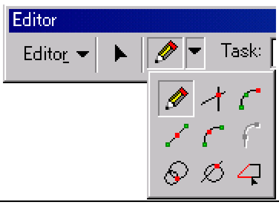
4.1. Making SHP file (polygon)

1) Launch **ArcCatalog**, browse to **C:¥GIS¥301_analysis¥03_geology**, right-click on vacant area of contents window, point to **New**, click **Shapefile**, type **geology** as a Name, choose **polygon** as Feature Type, click **Edit** button, click **Select** button, double-click **Projected Coordinate Systems** > **UTM** > **Other GCS** > **Adindan UTM Zone 37N.prj**, click OK x 2.

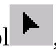
4.2. Digitizing



1) Launch ArcMap
2) Click the Add Data button, and browse to **C:¥GIS¥104_scan,** select **Geologicalmap_Awasa.jpg**, and click Add**.**
3) Click the Add Data button, and browse to **C:¥GIS¥ 301_analysis¥03_geology,** select **geology.shp.**
4) Set the scale 1:100,000
5) From **View** > **Toolbars** , click **Editor**.
6) Click **Editor button** on Editor tool bar, click **Sketch tool** icon  on Editor Toolbar, and select **geology** from the pull-down menu of the Editor toolbar
7) **Draw a polygon**: Trace a boundary line of a geology by click with your mouse
8) **Close a polygon**: when you close the traced polygon: double click
9) **Trace Tool**: Click the sketch tool  on Editor Toolbar, and select trace tool . Select edit tool , and then click a polygon which you want to trace it.
10) Save: Click **Editor** on Editor toolbar > **Stop Editing**, click **Yes** to Save the edits.



4.3. Input the attribute data to the traced polygon

1) Right-click **geology** layer, click **Open Attribute Table**, click **Options** button, click **Add field**, type **"name"** as Name, choose **Text** as a Type, click OK
2) Double-click **geology** layer, click **Labels** tab, change the Label Field from **Id** to **name**, and click OK, and then right-click **geology** layer > select **Label Features**.
3) Click **Editor button** on Editor tool bar, click edit tool , click a polygon which you want to it, and then type geology name to the name column.
4) Double-click **geology** layer, click **Symbology,** select the Categories > Unique values > Value Field: name, click Add All Values > OK.
5) You can change the color from table of contents.