ANNEX 3.3.1

GEOLOGY

THE STUDY ON WATER SUPPLY SYSTEM
FOR SIEM REAP REGION IN CAMBODIA

FINAL REPORT
Vol. III SUPPORTING REPORT

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ANNEX 3.3.1 GEOLOGY

1. Introduction

Geological investigation for 4 Alternative water resources was started from December 1996 and completed by March 1998. Two pilot wells were constructed in the Feasibility Study stage from October 1999 to December 1999. This supporting report is summarized the necessary data regarding geotechnical and geological investigation result until March 1999.

The following items were investigated in the beginning of the Master Plan study;

- Geological survey by site reconnaissance to select the core drilling points of the 8 holes.
- Hydrogeological site reconnaissance for selection of the existing wells to monitor ground water level.

After the above geological and hydrogeological surveys, the electrical sounding and the core drilling with soil laboratory tests were carried out from March to May 1997. The electrical sounding data is compiled in Data Book, and the summary result of the soil laboratory test is in this report. The detail soil test data is compiled in Data Book separately. The interpreted result is finally summarized as shown on the 11 geological profiles by compiling the electric resistivity data and the logs of the 8 core drilling in Attachment-1 and Attachment-2 respectively.

Exploratory well drilling at the 8 locations was carried out after the core drilling from March to May 1997. The work was delayed up to March 1998 due to the unstable political situation.

The purposes of the 8 exploratory wells are:

- to obtain continuous groundwater level records from 8 locations,
- to take the record of the ground movement in 2 stations, and
- to obtain a permeability coefficient, transmissivity, yield capacity and ground water quality by the pumping test from the exploratory wells.

The monitoring system by the continuos and automatic recording for the ground water level and land subsidence or ground movement had established by the beginning of February 1998, and they have been working at present.

Additional soil laboratory test was carried out for the samples taken from surface in January 1998 to use as parameters of the soil. The parameters are also compiled in this report.

The data of ferrite content test of the ground water taken from the existing wells

near the well field and electromagnetic survey were summarized in Annex 3.4.1.

2. Topography

The study area covers Siem Reap Town, a part of the Lake Tonle Sap, the West Baray, and Siem Reap River basin. Siem Reap Town is located on the lake terrace having its elevation from 10 to 15 m, and about 15 km north of the Lake Tonle Sap.

Several isolated peaks are sporadically located on the alluvial plain of river deposits and lake deposits. These are Phnom Bok (El-212 m), Phnom Baken (El-90 m) at Angkor area, Phnom Croom (El-140 m) from north to south in the area. In the northern area of Angkor Heritages, Kulen Mountain ranges continuously in eastwest direction. The shape of ranges is flat-topped mountains.

The Siem Reap River draining 670 km^2 catchment originates north-northeast from Siem Reap Town on the Kulen Mountain at El-420 m. The main stream that collects the runoff from the unique southeast block in the Kulen Mountain flows first northeast direction for about 15 km, until it reaches a gorge from where it changes the flow direction to southeast. The river discharges through this gorge to the plains at El. 50 meters. The river continues to flow to southeast direction towards the ancient diversion structure constructed 950 years ago at Phnum Khat. The tributaries are the O'Rassef stream at Phnom Kbal Sean and Stoeng Stoch streams at Phum Khlat. The original, ancient bed of the main stream continues southwest direction, and is known presently as the O'Phaat and O'Tassiv streams. Running along the northern side of the West Baray to the northwest corner thereof these tributaries turn these direction to southwest in a hardly recognizable bed to become lost in the marshland of Tonle Sap. The present river course diverted at Phum Khat arrives at the Angkor area near the northwest corner of the East Baray and the northeast corner of Angkor Thom. The river flows through Siem Reap Town first southward, and then mildly southeastward. The river eventually discharges into the Lake Tonle Sap at round 5-6 km downstream of Phnom Croom. The total length of the river is about 80 km with an average gradient of 1/190. Gradient of the riverbed in the plain after Kulen Mountain is roughly 1/1,400.

The West Baray is located at 3 km west of Bayon Temple, Angkor Thom, and 10 km northwest of Siem Reap Town. The reservoir was constructed by Suryavarman-I in the second quarter of the 11th century for the purpose of irrigation, drinking, bathing and water feeding for cattle. The size is 2 km for north to south direction, and 8 km for east to west direction. At present the reservoir is well operating for the purposes of mitigation of the flood for Siem Reap Town, irrigation, and for recreation.

3. Geology

The geological maps by "Bird's Eye View" for the boundaries of alluvial and diluvial deposits, pliocene deposits and basement rocks are shown in Figure 3.1 to Figure 3.3.

The geology in the study area is categorized in the following four groups:

1) Alluvial deposits (thickness: 10-20 m)

The layer is composed of unconsolidated fine sand near the Lake Tonle Sap, and coarse sand at upstream of the Siem Reap River. The top portion of this layer in the upstream of the Siem Reap River consists of fan deposits. Thin lenticular clay layers are intercalated. The layer is called as younger alluvium aquifer in the Hydrogeological Map of Lower Mekong Basin (1992).

2) Pleistocene deposits (thickness: 10-30 m)

The layer has various components, i.e., unconsolidated coarse sand to fine sand, boulders from underlain formations such as Pliocene claystone and bedrock. In addition, middle and/or bottom portions of this layer contained of laterite and/or basal pebbles and gravel in frequent places. The deposits are called as older alluvium aquifer in the Map (1992).

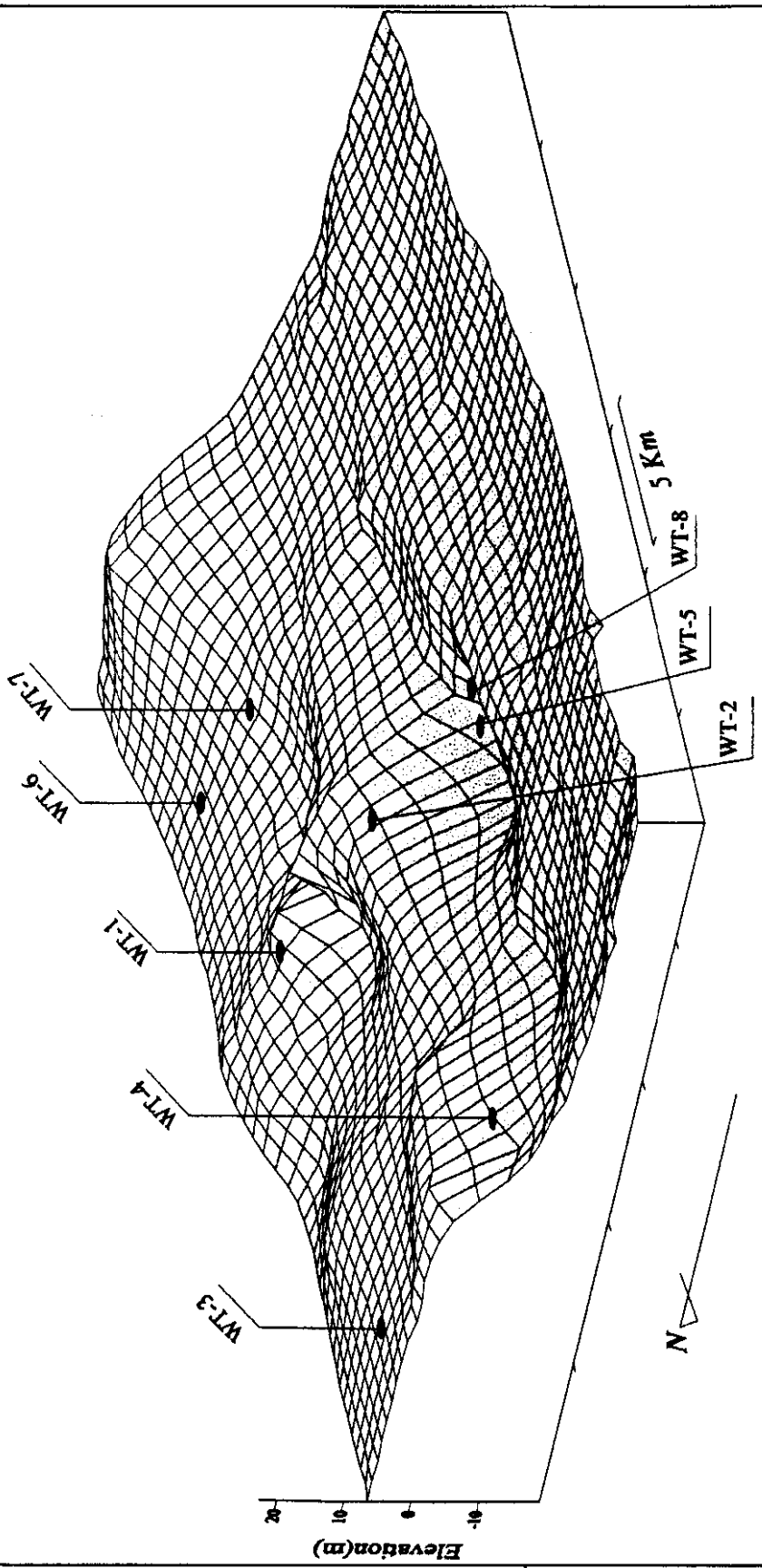
3) Pliocene formation (thickness: 20-50 m)

The formation is composed of claystone. The drilling core sample shows well-consolidated and cylindric core. At the top portion of the formation, it has laterite patches in many places. The formation seems very poor ground water potential due to clayey matrix and very well consolidated.

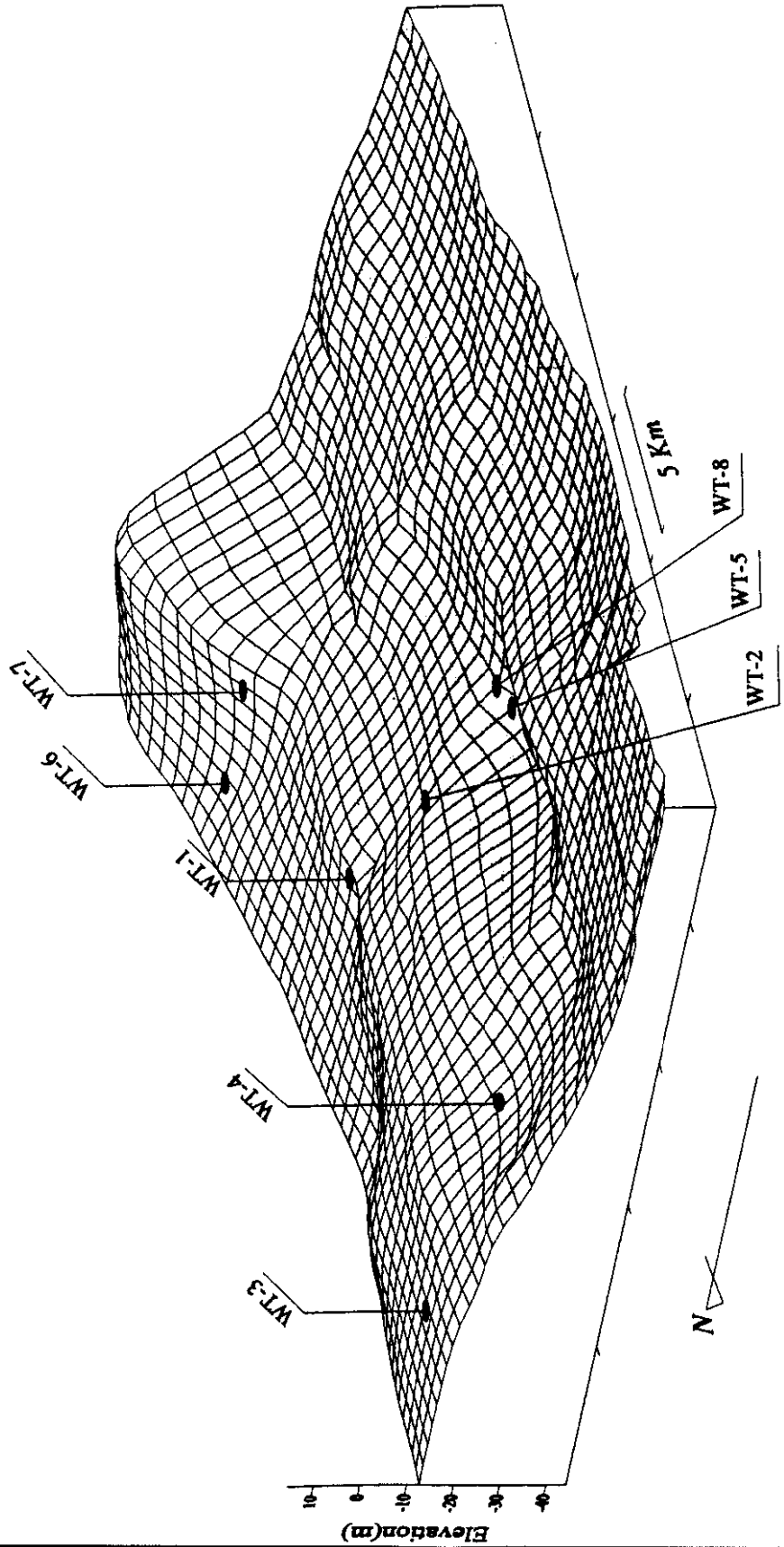
4) Bed rocks in Upper Jurrasic to Tertiary

The formations are composed of sandstone, siltstone and shale of Upper Jurrasic, rhyolitic tuff and tuff breccia of Upper Jurrasic, diorite to granodiorite, and andesite to basalt intrusions of Late Mesozoic to Tertiary. The general strike and dip of the Upper Jurassic sedimentary rocks are northwest to southeast and 30 • SW from outcrops and distribution.

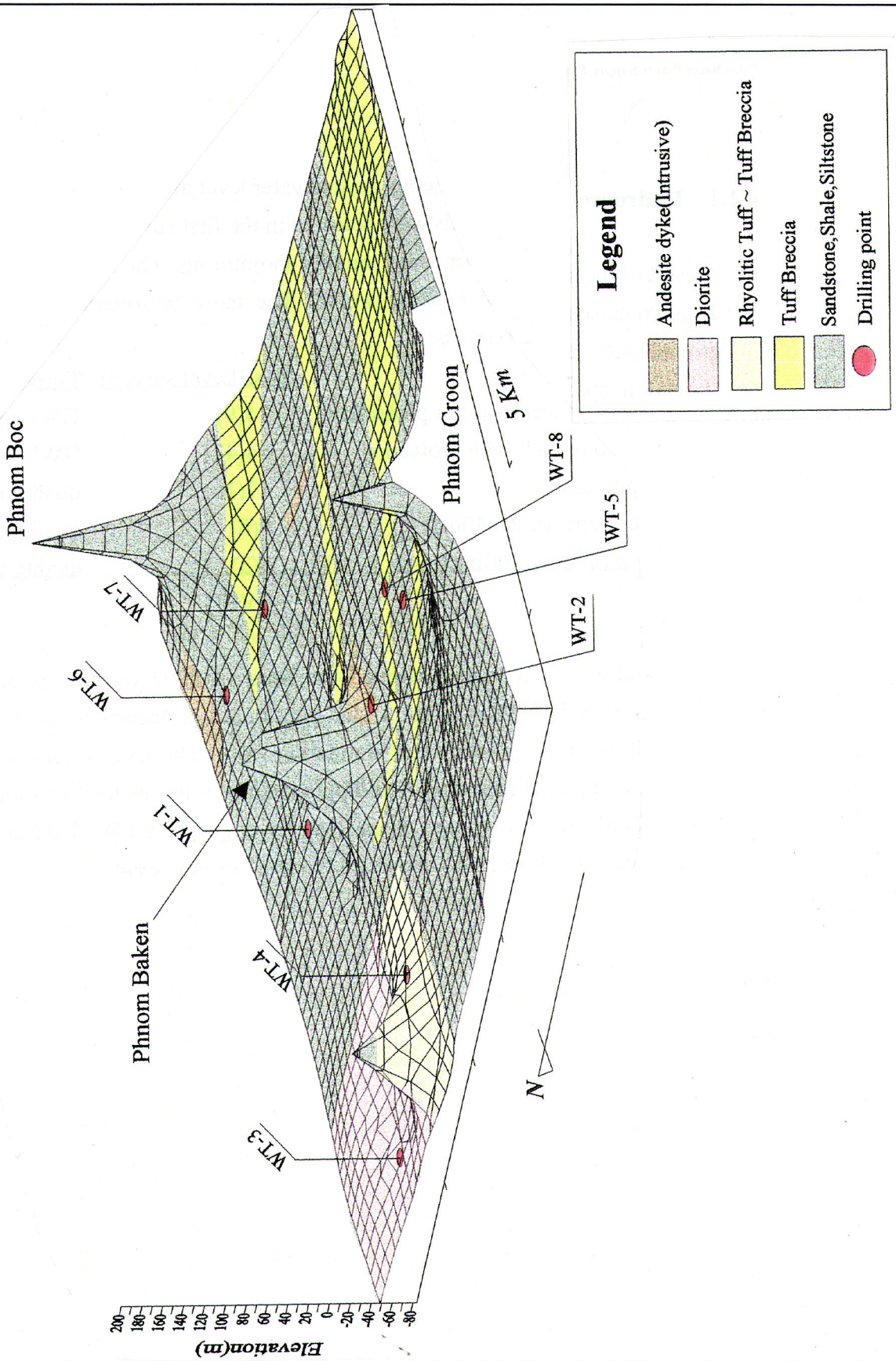
Table 3.1 is a summary result of geological sequence with geotechnical information.



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 3.1 Bird's Eye Viewing Geological Map for Alluvial and Diluvial Deposits by three Dimensions
Japan International Cooperation Agency	



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 3.2 Bird's Eye Viewing Geological Map of Pliocene Claystone by three Dimensions
Japan International Cooperation Agency	



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 3.3** **Bird's Eye Viewing Geological Map of Basement Rock by Three Dimensions**
Japan International Cooperation Agency	

Table 3.1 Geological Sequence of the Project Site

Formation	Geology	Thickness (m)	Electric Sounding	Electric Logging		N-value (blows/30cm)
				Resistivity	Gammma(cps)	
Alluvial Deposits	Coarse to medium Sand (North area)	10 to 15	50 - 3000 (ohm/m)	WT6:70-100 WT1:500 WT3:60-120 WT7:160	WT6:4-16 WT1:1 WT3:4-25 WT7:8-16	WT6:4-17 WT1:4-43 WT3:8-32 WT7:2-20
	Medium to fine Sand (South area)	15 to 20	50 - 1100 (ohm/m)	WT2:100-160 WT4:40-200 WT8:10-20 WT5:CP	WT2: WT4:8-18 WT8:5-20 WT5:4-10	WT2:6-50 WT4:4-17 WT8:8-38 WT5:6-22
Pleistocene Deposits	Coarse to medium Sand(stone) with Boulders (North area)	10 to 25	74 - 1900 (ohm/m)	WT6:60-100 WT1:200-500 WT3:80 WT7:120-160	WT6:10-20 WT1:1 WT3:14-16 WT7:6-16	WT6:22-50 WT1:18-50 WT3:21-50 WT7:18-40
	Medium to fine Sand(stone) with Boulders (South area)	20 to 30	20 - 400 (ohm/m)	WT2:80-120 WT4:120-200 WT8:10-20 WT5:200-400	WT2:6-12 WT4:6-18 WT8:10-20 WT5:8-18	WT2:18-50 WT4:16-50 WT8:25-50 WT5:21-50
Pliocene Claystone	Silty Claystone (North area)	20 to 50	11 - 300 (ohm/m)	WT6:40-60 WT1:200 WT3:20-60 WT7:120-200	WT6:12-20 WT1:1 WT3:5-25 WT7:12-16	WT6:50< WT1:50< WT3:50< WT7:50<
	Claystone (South area)	50	70 - 200 (ohm/m)	WT2:40 WT4:30-70 WT8:10-20 WT5:100-200	WT2:4-16 WT4:8-18 WT8:10-15 WT5:10-18	WT2:50< WT4:50< WT8:50< WT5:50<
Bed Rocks Tertiay to Upper Jurassic	Shale, Sandstone Siltstone	-	less than 10 (ohm/m)	WT1:10,WT5:20, WT6:10,WT7:5	WT1:5,WT5:8-18, WT6:10-18,WT7:14-16	
	Ryolitic Tuff		11 - 40	WT4:20-30	WT4:8-18	
	Tuff Breccia		12 - 110	WT8:5-10	WT8:10	
	Granodiorite		63 - 540	WT3:100-200	WT3:10	
	Andesite Intrusive		30- 3000	WT2:30-40	WT2:	