

5.4 °ñ..³ ŸÇ . »ñ»½Ù³ ŸáoÇ ëáØ³ ŸùÝ»ñ

5.4.1 ˜ »ËÝÇÍ ˜ 3 Ý ˜ »ñÍ ñ3 µ3 Ý3 ˜ 3 Ý ˜ Ñ3 ˜ ˜ áðÅñáðÝÝ»ñÇ °ñ..3 Ý ˜ Ù3 Ø3 ÙÇ ˜ Ñ3 ñ3 ˜ -3 ñ..Ùáðí ˜ ÙÇó 1»åÇ ˜ Áí ˜ ˜ Ù ˜ Ù3 ñ½Ç ˜ Ñ3 ñ3 ˜ Ç ˜ Ù3 øÁ

(1) ÀÝ¹Ñ³ Ýáõñ å³ ÙÙ³ ÝÝ»ñ

200áöë³ Ŧ 5.4.1 P»ñi ³ . ñáóÁlláöY .. ý³ óç³ Y»ñ

D ³ ē ³ ī	Ü ³ Y /· áóÍY	zÝí 3 ÝáôÙ	Ü ³ óç ³ Ý»ñ
Dáráó»Ý	g/c	zÉlláóí Ç ³ É Yëi í 3 ſù	Í áâÇx, x ³ É ³ û ³ náöi, 3 í 3 ½, Ü ³ Yñ yñ ³ Íóç ³ Ý»ñ
	c3	Èçñú ³ lçY · náöÝí	Üñµ ³ N ³ i Çí · náöÝí »ñ
	k/c	Í áélláóí Ç ³ É Yëi í 3 ſù	Ö ³ É ³ û ³ náöi, ÍáâÇx, Ü ³ Yñ yñ ³ Íóç ³
	c2	ÐáÓÙ ³ N ³ nÙ ³ Y · náöÝí, Ü ³ ē ³ Üµ Í áélláóí Ç ³ É Yëi í 3 ſù (åÇY ¹ /A ³ lë ³ lçY/ NáÓÙ ³ N ³ ní 3 í i áöy, í áöy ³ µ»ñlåç ³)	Üñµ ³ N ³ i Çí · ááöÝí ` áñáß ü ³ Y ³ ÍáôÅ ³ Üµ 3 í 3 ½áí " ÍáâÇxáí
	c1	ÐáÓÙ ³ N ³ nÙ ³ Y · náöÝí, Ü ³ ē ³ Üµ Í áélláóí Ç ³ É Yëi í 3 ſù (åÇY ¹ NáÓÙ ³ N ³ ní 3 í Yëi í 3 ſù ³ lçY ³ å ³ ñ)	Üñµ ³ N ³ i Çí · náöÝí, ÁYíN ³ Yáöñ ³ éÜ ³ Üµ í 3 nÜñ ³ B ³ í 3 Y ³ í 3 . áóÍY
	k/b	z ní 3 í 3 Y ¹ C Yëi í 3 ſù	Í áâÇx, Ö ³ É ³ ü ³ náöi, 3 í 3 ½Ý»ñ, Ü ³ Yñ yñ ³ Íóç ³ áñáß ü ³ Y ³ ÍáôÅ ³ Üµ
Pleistocene	BA	í 3 ½ ³ Éí	A ³ lë ³ lçY åÇY ¹ 3 å ³ ñ
	TU	í áöy	ØçççY í 3 ní náöÅ ³ Y 3 å ³ ñ
	TB	í áöy ³ µ»ñlåç ³	ØçççY í 3 ní náöÅ ³ Y 3 å ³ ñ
	PY	äçñáí É ³ eí Çí /Nñ ³ µ»ñlåç ³ lçY/ ÝláöÅ»ñ	äçñáí É ³ eí Çí YláöÅ»ñ, ÷ ÈñáöY
oññáñ ¹³ lçY	SE	Üëi í 3 ſù ³ lçY ³ å ³ ñry rock	zÉ` ní Çí, 3 í 3 ½ ³ û ³ ñ, ÍáY. ÉáÜ»ñ ³ í

5.4 Yerevan Cemetery Landslides

5.4.1 Technical Geological Features from Yerevan City the Southeast to Kotayk Marz South

(1) General Condition

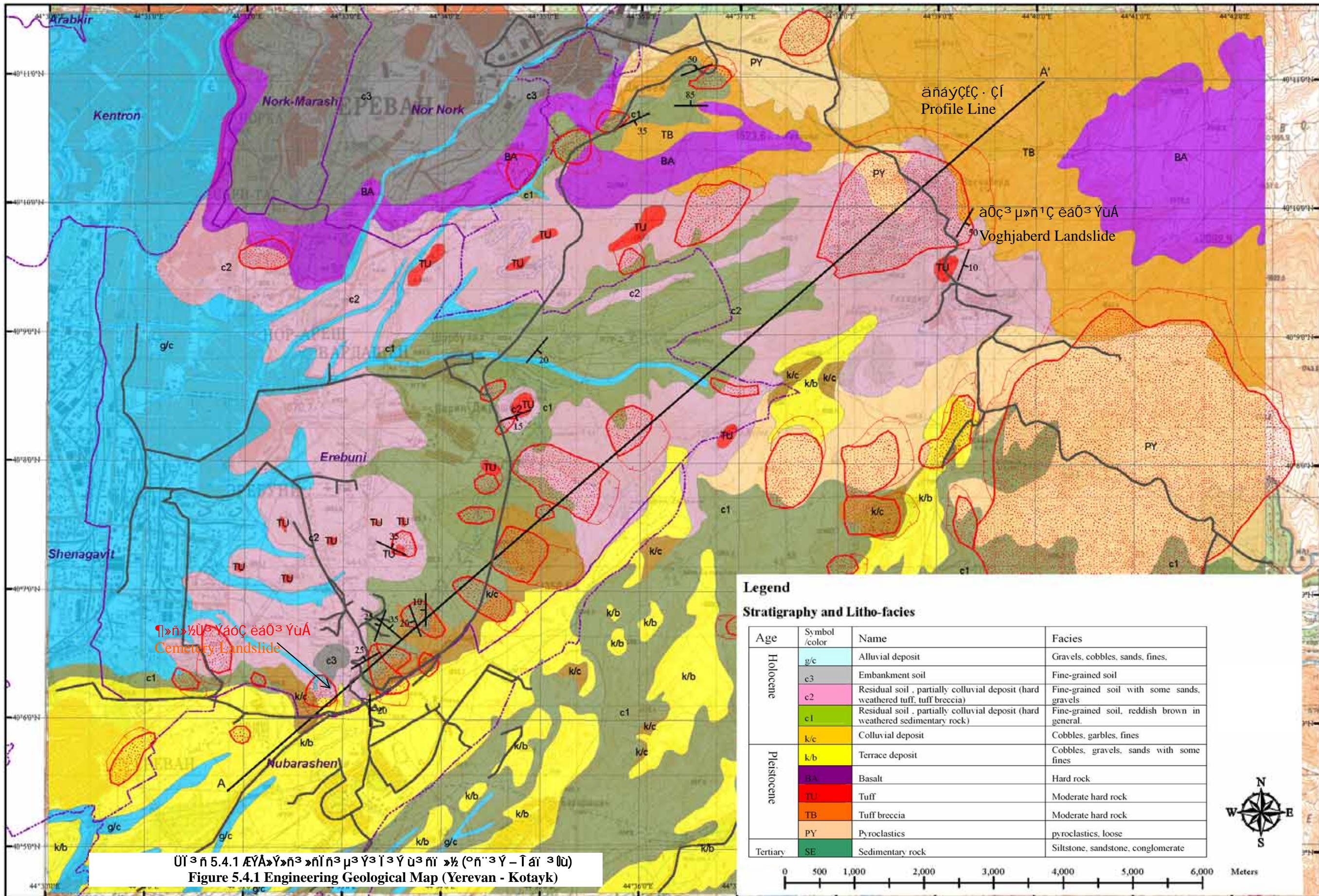
The region along by-pass road M-15 of Yerevan City to Kotayk Marz is a concentrated zone of landslides.

The geological features which are the primary causes of the landslides are described here.

Figure 5.4.1 and Figure 5.4.2 show the geotechnical engineering situation in these areas. Table 5.4.1 shows stratigraphy and facies of these areas. The landslides in this region have been generated chiefly because the residual soil is of sedimentary rock or tuff origin. Landslides are caused more easily among rocks of both origins. “Terrace deposit”, “Pyroclastics” and “Mudflow” are distributed at, or near, the head of the landslide. These materials are pervious or partially pervious, and they supply underground water to the landslides.

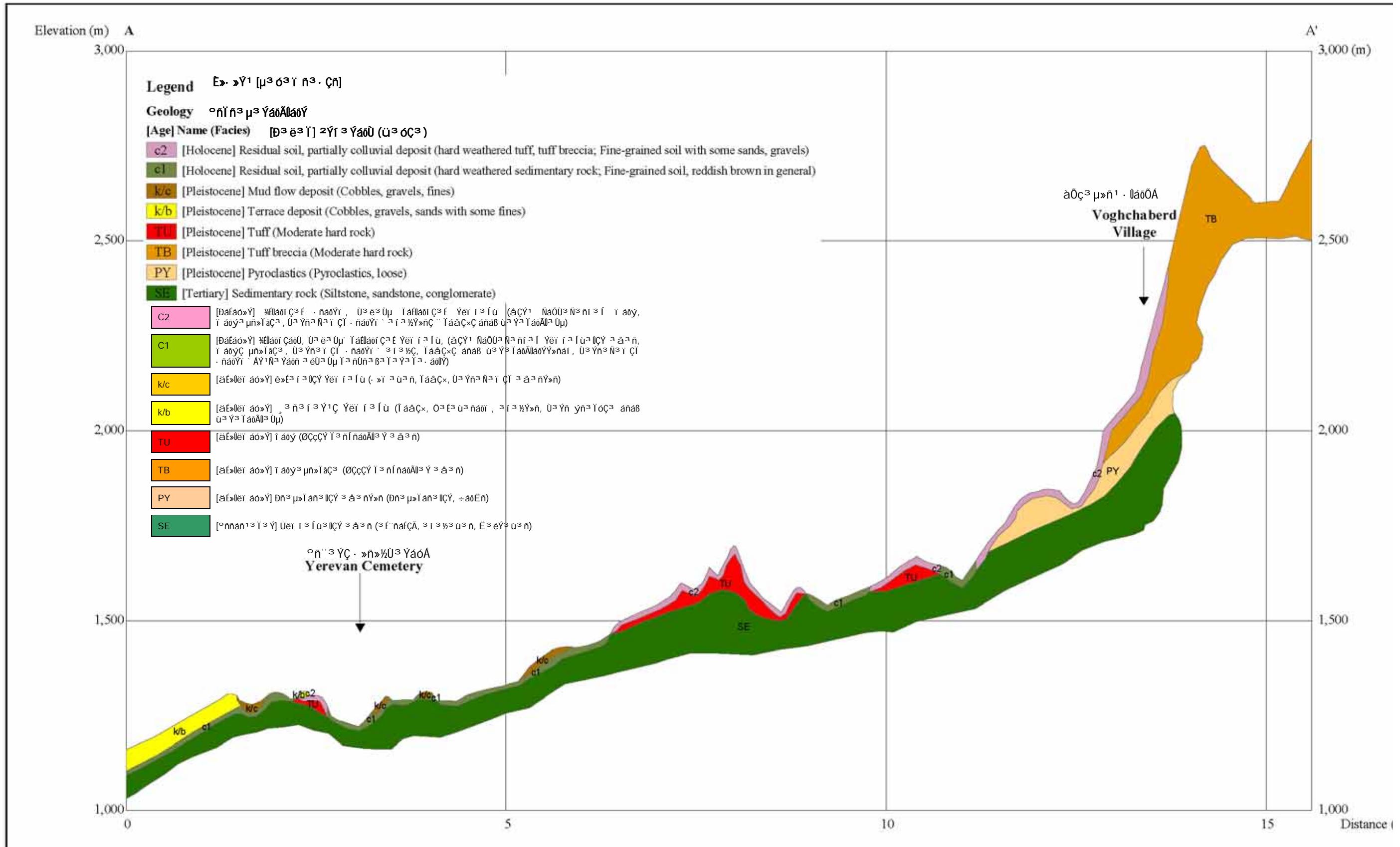
Table 5.4.1 Stratigraphy and Facies

Age	Symbol /color	Name	Facies
Holocene	g/c	Alluvial deposit	Gravels, cobbles, sands, fines,
	c3	Embayment soil	Fine-grained soil
	k/c	Colluvial deposit	Cobbles, garbles, fines
	c2	Residual soil , partially colluvial deposit (hard weathered tuff, tuff breccia)	Fine-grained soil with some sands, gravels
	c1	Residual soil , partially colluvial deposit (hard weathered sedimentary rock)	Fine-grained soil, reddish brown in general.
	k/b	Terrace deposit	Cobbles, gravels, sands with some fines
Pleistocen	BA	Basalt	Hard rock
	TU	Tuff	Moderate hard rock
	TB	Tuff breccia	Moderate hard rock
	PY	Pyroclastics	pyroclastics, loose
Tertia ry	SE	Sedimentary rock	Siltstone, sandstone, conglomerate



ԸՆԴՀԱՆՈՒՐ 5.4.1 ՀԵԿԱԳՐԻ ՏՐՈՒՄ ՄՅԱ ՀՅԱ ԵՐԵՎԱՆ - ԿՈԴԱԼԻ ՀԱՐԱՐԵԴ

Figure 5.4.1 Engineering Geological Map (Yerevan - Kotayk)



ՈՒՅ 3 5.3.2 ԷՐԵՎԱՆԻ ՅԱՆԱԿԱՐԱՎՈՐ ՀԱՆՐԱՊԵՏՈՒԹՅՈՒՆ

H:V=1:10

Figure 5.3.2 Engineering Geological Map (Yerevan Kotayk)

(2) äñáþé»Ù³ ÙçÝ· ÑáØÙ³ Ñ³ ní áØ · E½áðÙÝ»ñç Ù³ T »ñ · áðÙÃ Ñ»Bí áðÙ³ Ùµ ³ e³ ç³ óÝáØ · ñáðÝi »ñ

(2) Problem Soils Erasible and Easy Forming Surface of Rapture

(a) ĐáØÙ³ Ñ³ ñÙ³ Ý Ýeī í³ Í Ù³ ÙÇÝ³ å³ ñç Ì³ íç · ñáøÝī Á (c1)

ĐáÓÙ³ Ñ³ ñí ³ Ŧ Yéi ³ Ŧ Ù³ lÍçÝ ³ á³ ñíç T³ Ŧ Á E³ ØÝ ³ ³ ñí³ Ŧ áóÙ áóÝÇ . »ñ»½Ù³ YáóÇ eáÓ³ Yùç Ù³ T»ñ áólÁÇ »ÝÄ³ Ù³ eáóÙ: ²lë . ñáóÝi Á Ñ»Bí ÑáÓÙ³ Ñ³ ñí»ÉÇ ³ ³ T³ Y Ùç ù³ YÇ EáBáñ EáÓaí ³ T³ Ñáñ»ñ: ²lë . ñáóÝi Á/ ÑáÓÙ³ Ñ³ ñí ³ E ³ á³ ñÁ á³ ñáóÝ³ TáóÙ ³ ÚáÝi ÚáñçEáÝÇi Ç/ áóéááÓ T³ Ŧ ÙçÝ»ñ³ EÝ»ñ, áñáÝù TáóÙ ³ TÍ áóÙ »Ý Ä³ ñÙ ³ á³ ñíç e³ ÑÙ³ YÇ Úáí ³ T³ lÙáóÙ ³ T³ ½ÙáóÙ »Ý á³ ÷ ³ ½³ YÓ ó³ ñí³ ¹çÙ³ ól' áóÝ T³ Ŧ Ç B»ñi : ¶»ñ»½Ù³ YáóÇ eáÓ³ YùáóÙ, »»Øùí ³ Ùç Ù³ T»ñ áólÁÁ T³ ñ»ÉÇ ³ T³ ñíµ»ñ»É ³ lë áçÝ¹ ÑáÙ³ Ñ³ ñí ³ Ŧ ³ E ñáÉÇi Ç Ù»ç (¹»ØÝ³ Í áóÝ B³ T³ Y³ T³. áóØÝ . áóØÝÇ):

(a) The clay soil of weathered sedimentary rock (c1)

The clay of weathered sedimentary rock is widely distributed around the subsurface of the cemetery landslide. This soil is erodable, and some big piping halls are admitted. This soil/weathered rock contain montmorillonite/ swelling clay minerals that accumulate in the vicinity of fresh rock boundaries and form an extremely low-strength clay layer. In the cemetery landslide, surface of rupture is recognized in this hard weathered silt stone (yellowish brown color).



Üeří ī 3 Ŧù³ ŦiçÝ 3 å³ ñÇ Ü»ñi³ óåôÜÝ»ñ
(i áôý³ ŦiçÝ 3 ī 3 ½³ û³ ñ), . »ñ»½Ü³ ŸáóÇ
3 ñ .. ŦiçÝ 3 Ŧù³ eåôÜ

Outcrops of sedimentary rock (tuffaceous sandstone), the east of the cemetery

(μ) äCÝ¹ ÑáÖÙ³ Ñ³ ñí ³ Í i áöýC Í ³ Í ³ ÙCÝ . ñáöÝ

Í ³ ñÙñ³ ß³ Í ³ Ý³ Í ³ . áóñÝÁ ³ Ù¹ . ñáðÝí Ç ÝÍ ³ Í »ÉÇ Ñ³ Í Í ³ ÝÇß ¿: ¶ñáðÝí Á µÝáñáßí áóÙ ¿ áñå»ë
ÙÇççÝ /á³ ÷ ³ í áñ/ ¹çëå»ñëçí /á³ ÷ ³ ÿ³ Ýó ÑáñÙ³ Ñ³ ñ»ÉÇ/ . ñáðÝí : ²øé . ñáðÝí Á/ÑáñÙ³ Ñ³ ñÙ³ Ý
³ á³ ñÁ á³ ñáðÝ³ Í áóÙ ¿ Ú»Ýí ÚáñçéáÝÇí / áóéåáØ Í ³ í Ç ÙÇÝ»ñ³ ÉÝ»ñ:



ÊáÔáí ³ Ŧ ³ ÙçÝ ³ Ýóu` 1 Ù»ï ñ ï ñ³ Ù³ . Íáí ,
áñÁ ³ é³ ç³ ó»É ï NáÔÙ³ Ñ³ ñí ³ Í åçÝ¹
Ýëi ³ Ù³ ÙçÝ ³ å³ ñç Ŧ ³ Í ³ ÙçÝ ß»ñi áôÙ
Piping hole, 1 meter diameter which was
admitted in the clay soil of hard weathered
sedimentary rock

(b) The clay soil of hard weathered tuff

Reddish brown color is a remarkable feature of this soil. This soil is moderately dispersive (very erodable). This soil/weathered rock contain montmorillonite/ swelling clay minerals



The clay soil of hard weathered tuff distributed east of the Arinberd cemetery

(c) ¶ñáóÝi ³ ÙçÝ çáõñ Ù³ i ³ i ³ n³ ñáõ Ä³ ÷ ³ Yó»Éç Yéi ́ ³ Ùý»ñ

(c) Permeable terrace deposit and colluvial deposit

Terrace deposit/ colluvial deposit (old landslide accumulation)/ pyroclastics are pervious or partially pervious material. This material supply underground water to the above mentioned hydraulically problematic soils. Scarps of the landslides are admitted in the vicinity of the boundary of these pervious deposit and the clay soil of hard weathered sedimentary rock/tuff (c1,c2).



Pervious deposit/ terrace deposit and scarps of landslide

Â3 ÷ 3 Ŷó»ÉÇ Ÿeří ī 3 Ŧù/ ē3 n3 ī 3 Ŷ1Ç Ÿeří ī 3 Ŧù .. ēáÔ3 ŶùÇ eří 3 nå»ñ

5.4.2 °ñ..³ Ý ù³ Ø³ ùÇ . »ñ»½Ù³ ÝáoÇ eáØ³ ÝùÇ ÇÝÅ»Ý»ñ³ »ñI ñµ³ Ý³ I³ Ý N³ i I³ ÝÇßÝ»ñ

(1) êáÖ³ Ýüç TáÝýÇ· áõñ³ óÇ³ .. åñáyÇÉÝ»ñ

Đó» ī 3½āī áoĀl³ Y 3 BÉ 3 ī 3 YūY» N̄C BÝānN̄C ā 3 n̄k³ μ³ YÍ »É YÝ ēáO³ YūC N̄ēi 3 T »Vñ³. Cí Á /IaYÝC. áoñ³ óC³ YÍ

(ÜÍ 3 n 5.4.3) " Ýñ³ åñáyÝCÉÝ»ñÁ (ÜÍ 3 n 5.4.4.):

ÚT³ nÝ» ñ 5.4.5- 5.4.9 óáðlÓ »Ý t³ ÉCé Ó³ E³ ET U³ Y ËaÓar³ t³ ÚCÝ á³ ÷ Cä è³ nuaÍ Cñ³ t³ Y³ ó³ t³

ÜÁÝÇÍ áñçÝ. Ç „ · ñáðÝí ³ ïlçÝ çñç Ñ»í ³ ÉáðñÙ³ Ý ³ ñ¹ïlæðÝùÝ»ñÁ, áñáÝù í Í ³ ïlæðÙ »Ý éað³ Ýùç ×»ðÙù³ Ý Ù³ Í »ñ¹áðñÁç áñáýçéÝ³ »ñç Ù³ èçÝ:

(2) êáõ³ Ýùç å³ i ×³ éÁ

Í ³ Ý »»ÓÙÚ³ Ý Ù³ ñ»ñ»éÝ»ñC Ñ»BÍ ³ é3 ç3 ðÚ3 Ý ³ é3 C Ú3 Ý .. ÉA³ ÝÇá ³ Í x3 éÝ»ñ, áñáÝU »Ý.

-Í ³ Ý E » É É ³ Ù Ý ³ Í ³ Í ³ É áéá· áóÙ

-Üáñá: »É cñ³ i³ n̄ Éáñáí³ i³ Ý»ñÁ. ³ n̄ i³ ÑáéÁ i³ ÝÉ»Éá :

Æ ÉñáðÙÝ 1ñ³ Ý, eii áð. »É 1ñ»Ý³ ÅC ó³ ÝóÁ 3 jÝ Ù³ e»ñáðÙ, áñii »Ó í Ý³ eÁ 3 Ù»Ý³ Ù»Í Ý;:

î í ï³ É å³ ñçý H-15 x³ ý³ å³ ññç eå³ e³ ñïÙ³ ý EÝ1çñÁ ³ e³ çý³ ñ»ñÁ äç: eå³ e³ ñïÙ³ ý ³ ßE³ i ³ ýùý»ñç
í³ i ³ ñïÙ³ ý Å³ ù³ ý³ i ³ ýññ³ Å»ßi TÉÇÝÇ í³ i ³ ñ»é ñáõ³ éçóùç í³ éáðòÙ³ ý ³ ßE³ i ³ ýùý»ñ, áñÁ ñ³ bÍ ç ³ eÝç
eäõ³ ýuc tåýyc: aõñ³ óc³ ý, " ³ å³ ñáí »é í³ ýáý³ í áñ 1ñ»ý³ Åc ó³ ýoc ³ ßE³ i ³ ýùå:

5.4.2 Engineering Geological Features of Yerevan City Cemetery Landslide

(1) Landslide Configuration and Profiles

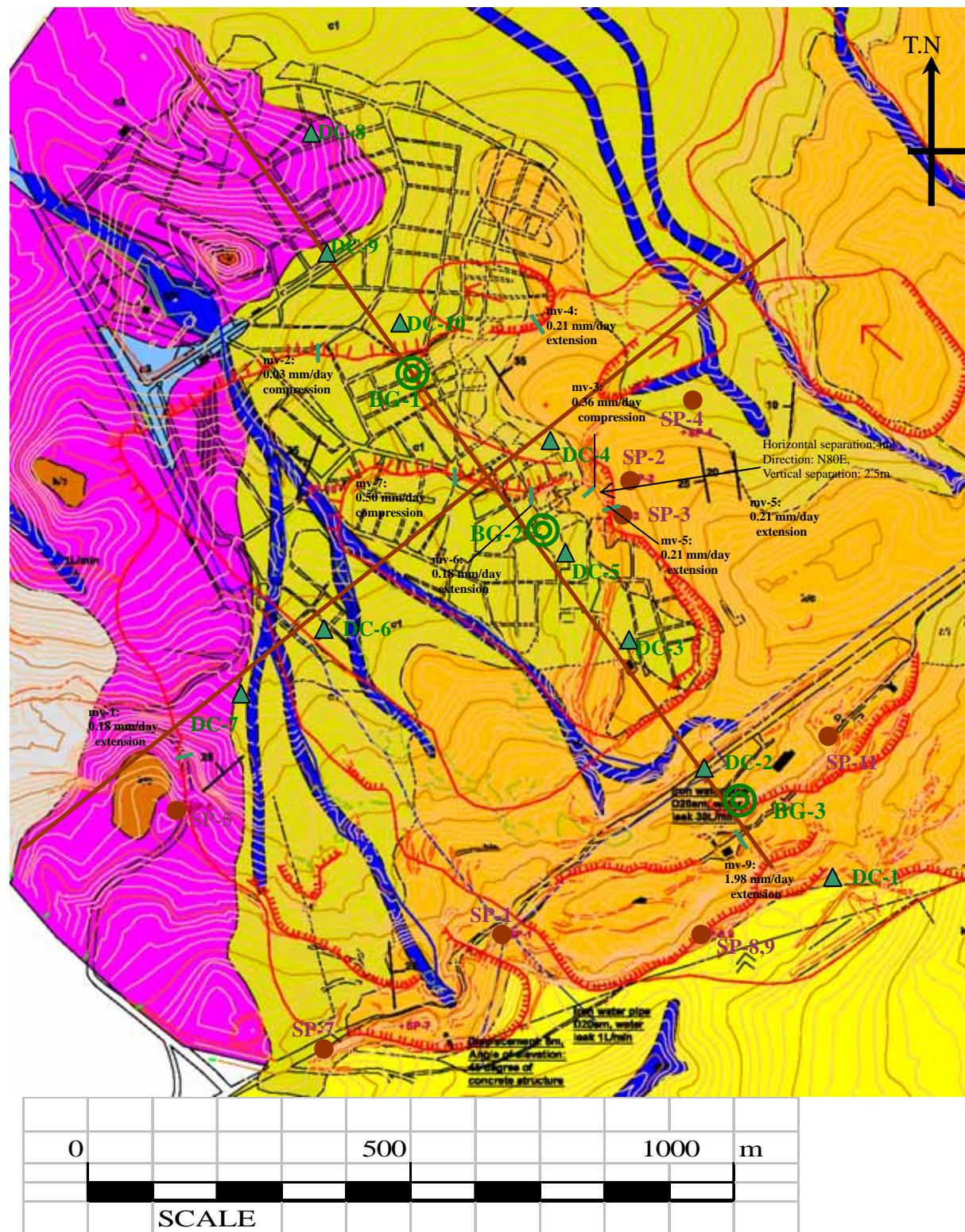
Investigation activities make clear landslide configuration (Figure 5.4.3) and profiles (Figure 5.4.4. and Figure 5.4.5)

Figure 5.4.6 to 5.4.10 shows pipe strain gauge monitoring results and ground water prospecting results, evidences of profiles of landslide surface of rupture.

(2) Cause of landslide

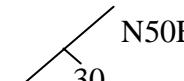
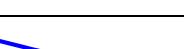
There are primary causes for the formation of surface ruptures as follows:

- Weathered sedimentary rock/ soil is very erodable, and piping holes form easily, it also contains montmorillonite/ swelling clay minerals. Accumulation of montmorillonite around the boundary with fresh rock forms the weak layer for rupture.
 - In case of dip slop (dipping of stratum and slope surface is almost same direction) as the cemetery (dipping of stratum is almost 20 degrees), the weak layer easily becomes the surface of rupture.
 - Highly permeable deposit is distributed behind the landslide, precipitations percolate easily, and the groundwater is supplied from the permeable deposit to weathered sedimentary rock/ soil. Underground water makes the weak layer deteriorate, the ground water makes the weathered sedimentary rock/ soil moist and heavy, and as a result the movement of the landslide becomes larger.
 - Vertical or high angle weak zone such as a fault may exist in the edge part of the landslide block. But there is no evidence.
 - There are water supply pipes, and some portions are leaking. These leaks increase the supply of underground water. (Along the H-15 road areas have been used as orchard for 25 years. Drainage and water leak from water pipe are induced causes of landslide activities.)



LEGEND

È»· »Ý 1

ÉáñáôñÁlláôÝ Ã³ ÷ ³ Yó»ÉçáôÁlláôÝ Dip and strike		N50E 30	éï³ ñâ Scarp	
é»ÓÙÙ³ Ý Å³ Í í³ ñ Compression Ridge			²Óµlåöñ Water Spring	 20L/min
Ø³ Í »ñ·åølÅ³ lçÝ çñ»ñ Surface Water		20L/min	þ³ ñÁí áÔ ÷ ³ llí »ñ Í »ñ³ ß³ ñÁÙ³ Ý ³ ñ³ . áoÁlláôÝ /ù. -ñáÍ , 2005/ Movable beam Displacement speed(Aug-Oct, 2005)	 mv-1
Dáñ³ Í ³ Yóù Drilling	 BG-1		ÜÙåöß³ ñí åóÙ Sampling	 SP-1
çÝ³ üçí Táçç Ã³ ÷ ³ Yó»ÉçáôÁll³ Ý Í »ëí Dynamic Cone Penetration Test	 DC-1			

Ð³ ë³ Ì Age	ÜÙ³ Ý/ · áóÙÝ Symbol /color	2Ýí 3 ÝáðÙ Name	üáñÙ³ óç³ Facies
ÐáðáºÝ Holocene	g/c	²ffáðí lÙ³ É Ýéí í 3 lÙÝ»ñ Alluvial deposit	Éáðáñ · f³ ù³ ñ, · f³ ù³ ñ, 3 1 3 ½ Ýñµ³ Ñ³ í ÇÍ ËðáÝáí Gravels, cobbles, sands, fines
	c3	¹ »ñáí Ç · ñáðÝí Ý»ñ Embankment soil	Üñµ³ Ñ³ í ÇÍ · ñáðÝí Ý»ñ Fine-grained soil
	c2	ØÝ³ óáñ 1³ lCÝ · ñáðÝí Ý»ñ, Ü³ èÝ³ í Ç Í áðáñ lÙ³ É Ýéí í 3 lÙÝ»ñ /Éçéí ÑáðÙÝ³ Ñ³ ñí 3 í áðý, í áðýáµñ»í Íá³ Ý»ñ/ Residual soil , partially colluvial deposit (hard weathered tuff, tuff breccia)	Üñµ³ Ñ³ í ÇÍ · ñáðÝí Ý»ñ 3 1 3 ½ Ç .. . f³ ù³ ñ Ç ð³ ñáðÙ³ lÁðAl³ Üµ Fine-grained soil with some sands, gravels
	c1	ØÝ³ óáñ 1³ lCÝ · ñáðÝí Ý»ñ, Ü³ èÝ³ í Ç Í áðáñ lÙ³ É Ýéí í 3 lÙÝ»ñ /Éçéí ÑáðÙÝ³ Ñ³ ñí 3 í Ýéí í 3 lù³ lCÝ 3 ð³ ñÝ»ñ/ Residual soil , partially colluvial deposit (hard weathered sedimentary rock)	Üñµ³ Ñ³ í ÇÍ · ñáðÝí Ý»ñ 1 3 ñÙñ 3 -ß³ 1 3 Ý³ 1 3 · áóÙÝ Fine-grained soil, reddish brown in general
	k/c	Í áðáñ lÙ³ É Ýéí í 3 lÙÝ»ñ Colluvial deposit	Éáðáñ · f³ ù³ ñ, · f³ ù³ ñ, Ýñµ³ Ñ³ í ÇÍ ËðáÝáí Cobbles, garbles, fines
	k/b	³ ñ 3 1 3 Y 1 3 lCÝ Ýéí í 3 lÙÝ»ñ Terrace deposit	Éáðáñ · f³ ù³ ñ, · f³ ù³ ñ, 3 1 3 ½ Ýñµ³ Ñ³ í ÇÍ ËðáÝáí Cobbles, gravels, sands with some fines
äfðleíí áðºÝ Pleistocene	BA	¹ 3 ½ 3 Éí Basalt	Í 3 ñ ñ 3 ð³ ñÝ»ñ Hard rock
	TU	í áðý Tuff	÷á+áÉí 3 1 3 ñ ñ 3 ð³ ñÝ»ñ Moderate hard rock
° ñáñ 1 3 Í 3 Y Tertiary	SE	Üéí í 3 lù³ lCÝ 3 ð³ ñÝ»ñ Sedimentary rock	Í 3 1 3 3 1 3 ½ 3 Ü³ ñ»ñ, 3 1 3 ½ 3 û³ ñ»ñ, ÍáY. ÉáÜ»ñ 3 í Ý»ñ Siltstone, sandstone, conglomerate

ÜÍ³ ñ 5.4.3. *ÆÝÅ»Ý»ñ³ -»ñÍ³ ñ³ µ³ Ý³ Í³ Ý Ù³ ñÍ³ »½ /º ñ³³ Ý Ù³ Ø³ ÙÇ . »ñ³ ïÙ³ ÝáØÇ eáØÝù/*

Figure 5.4.3 Engineering Geological Map (Yerevan Cemetery Landslide)

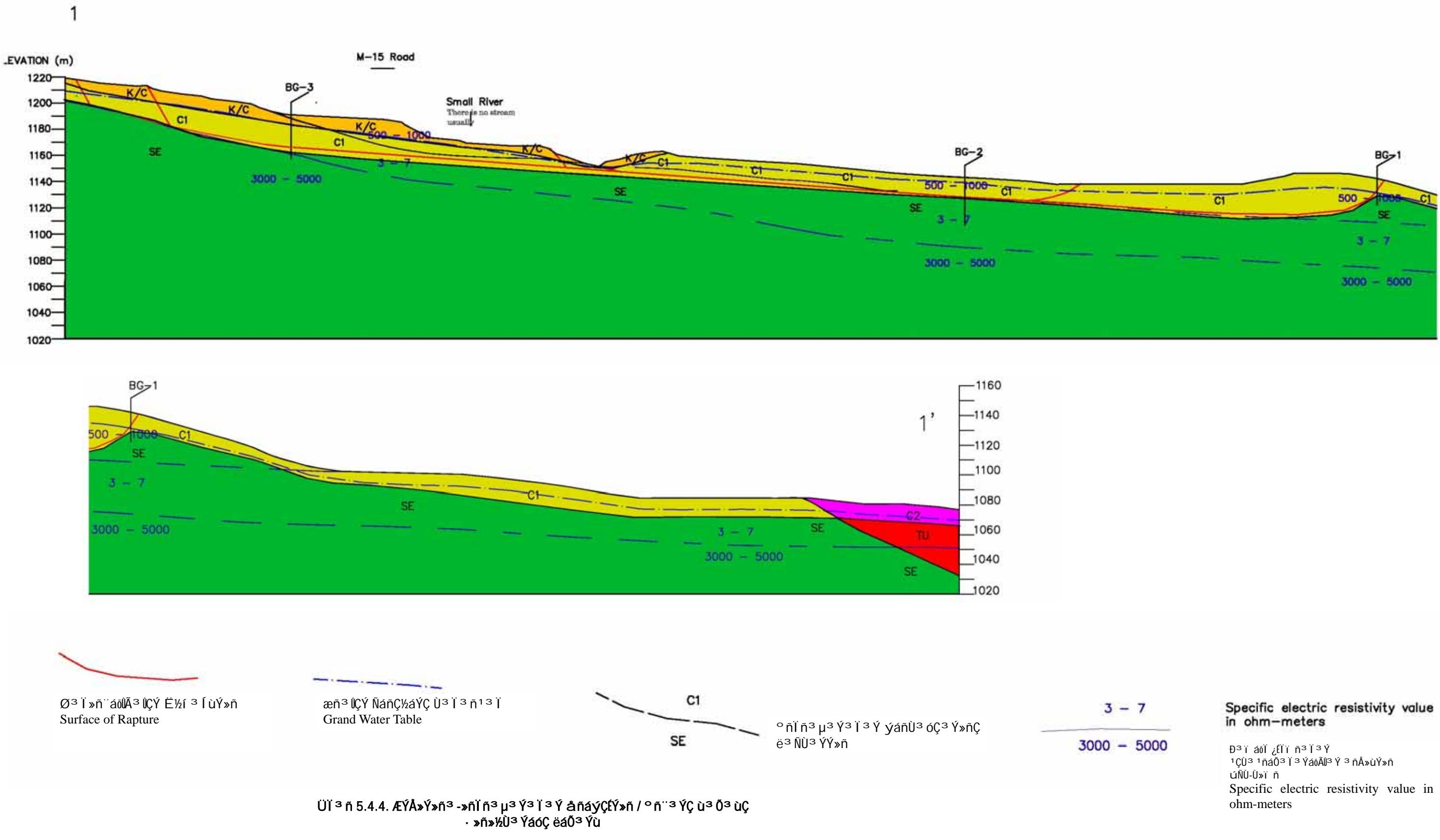
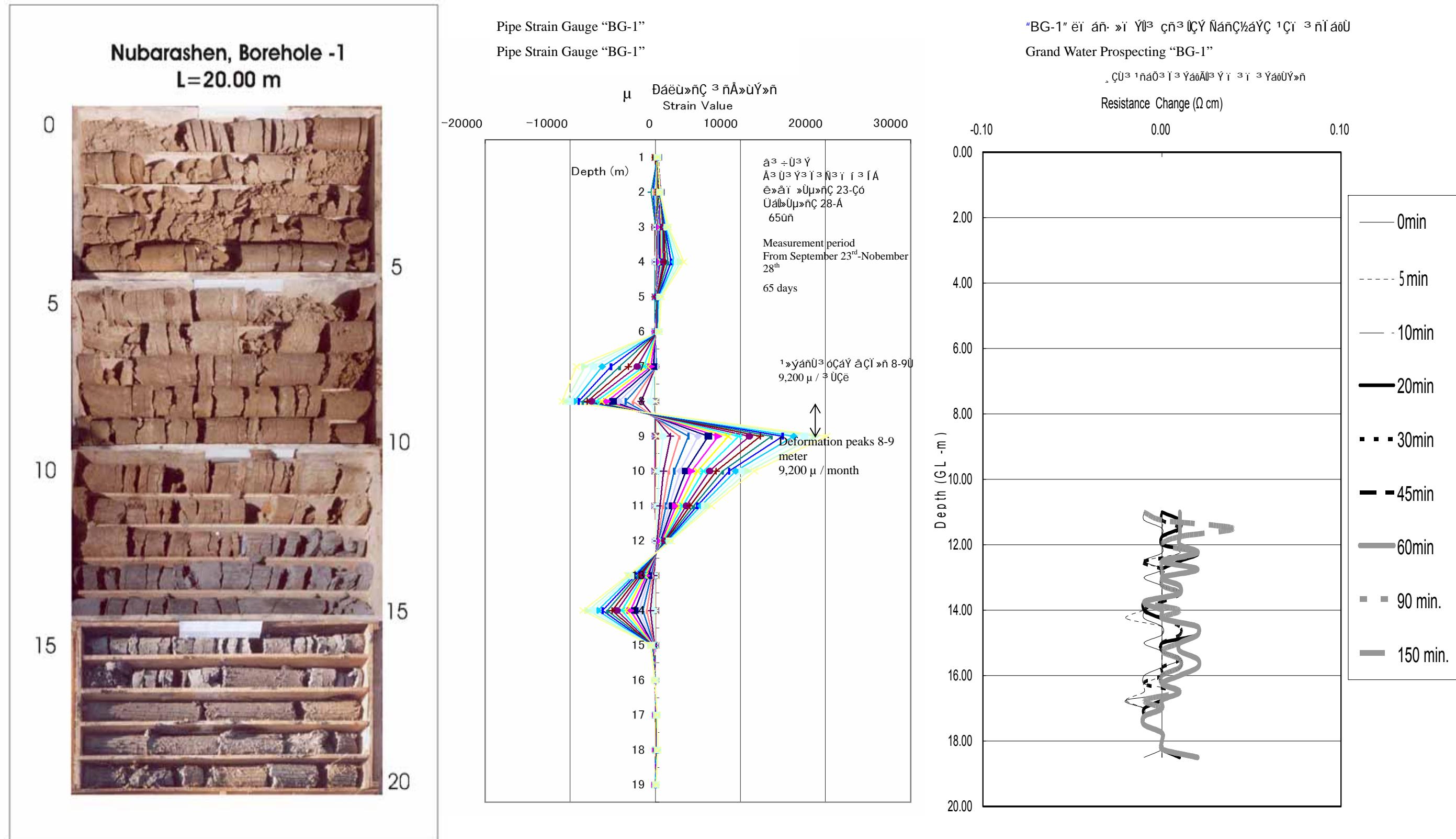
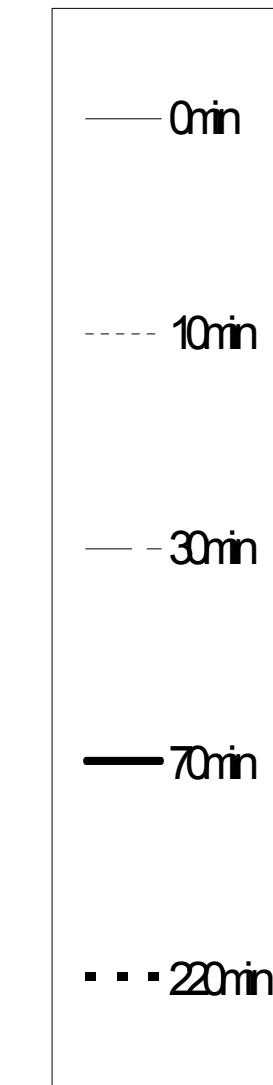
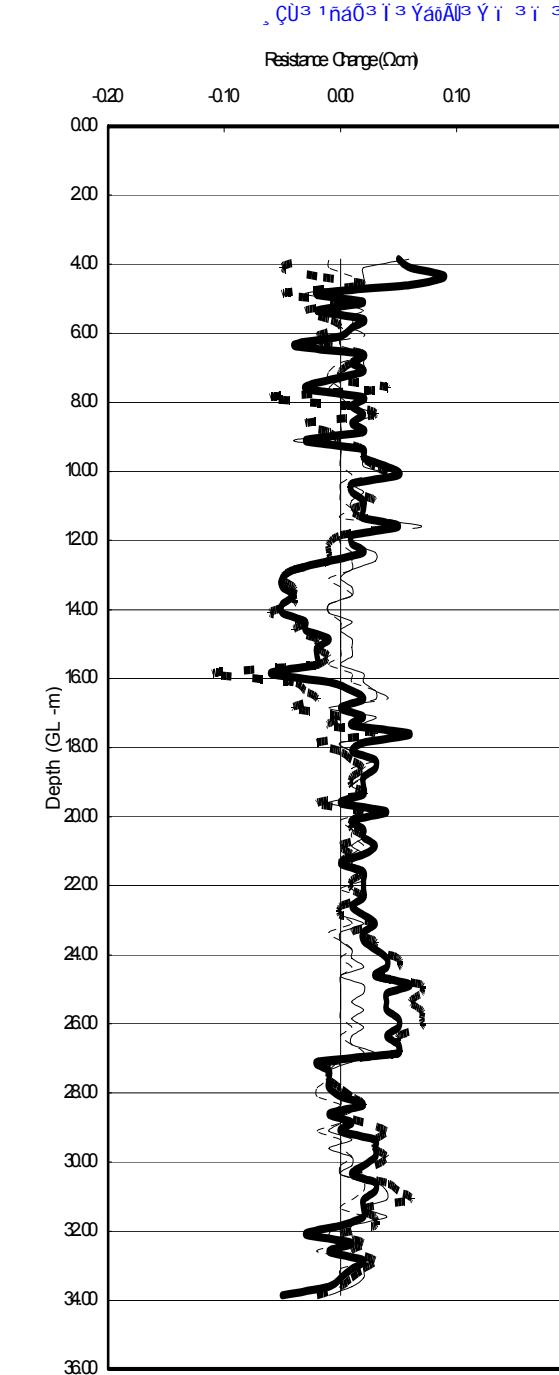
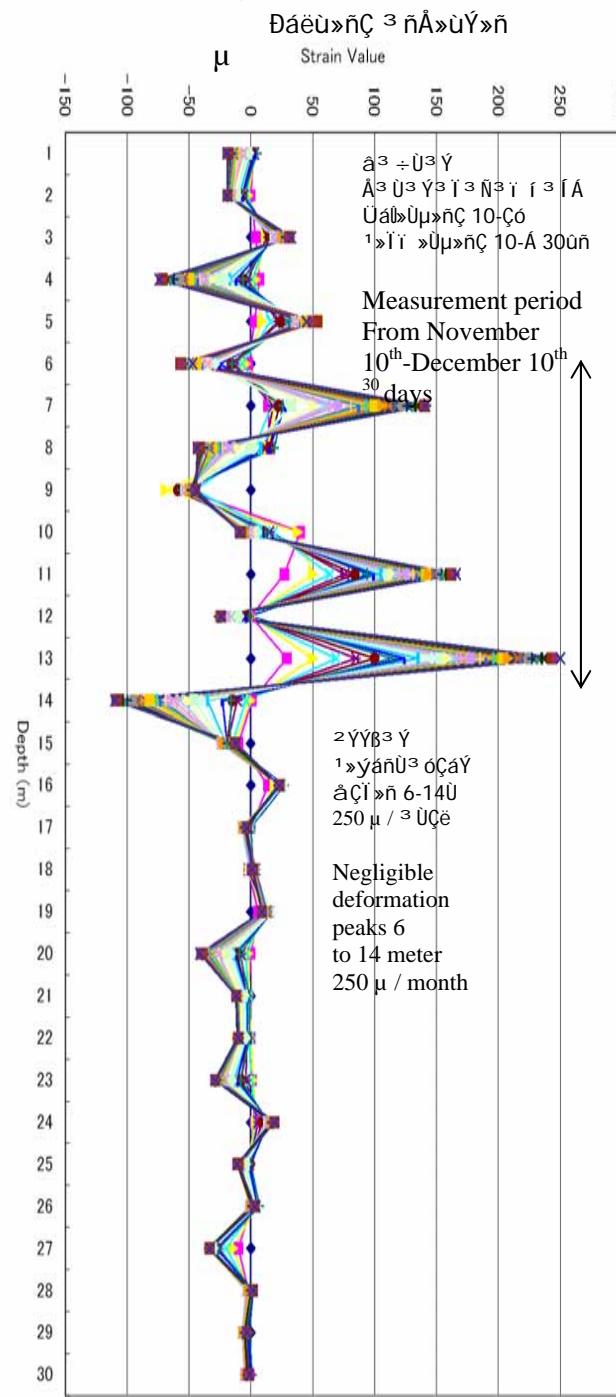
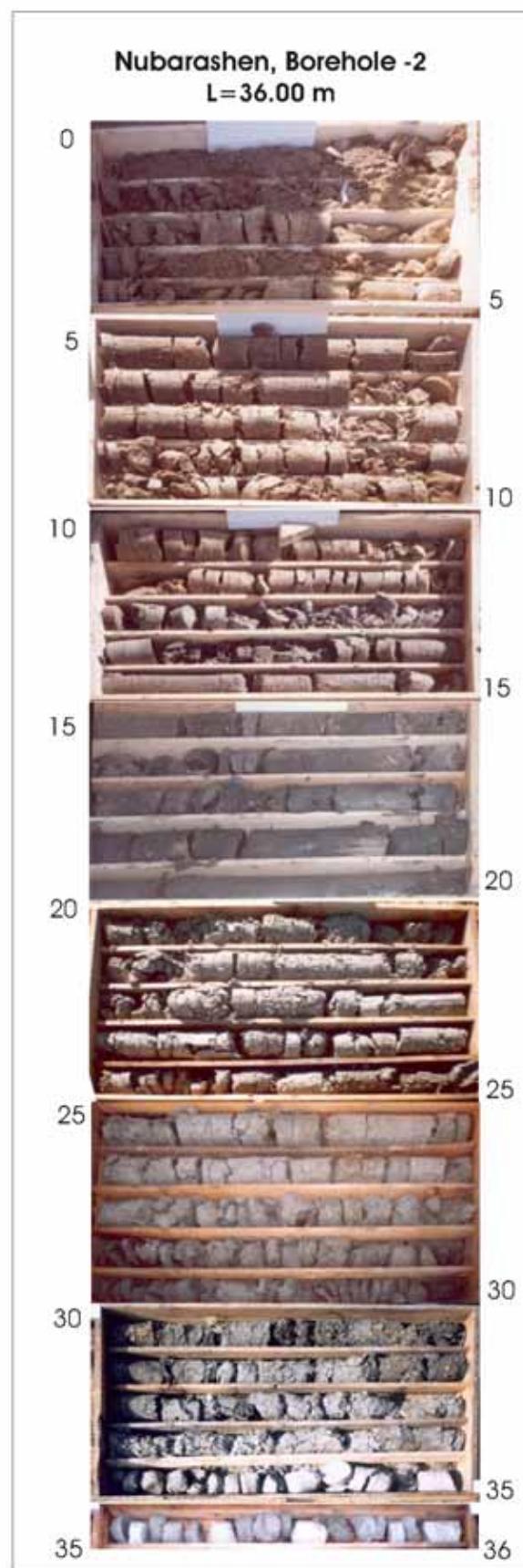


Figure 5.4.4 Engineering Geological Profile (Yerevan Cemetery Landslide)



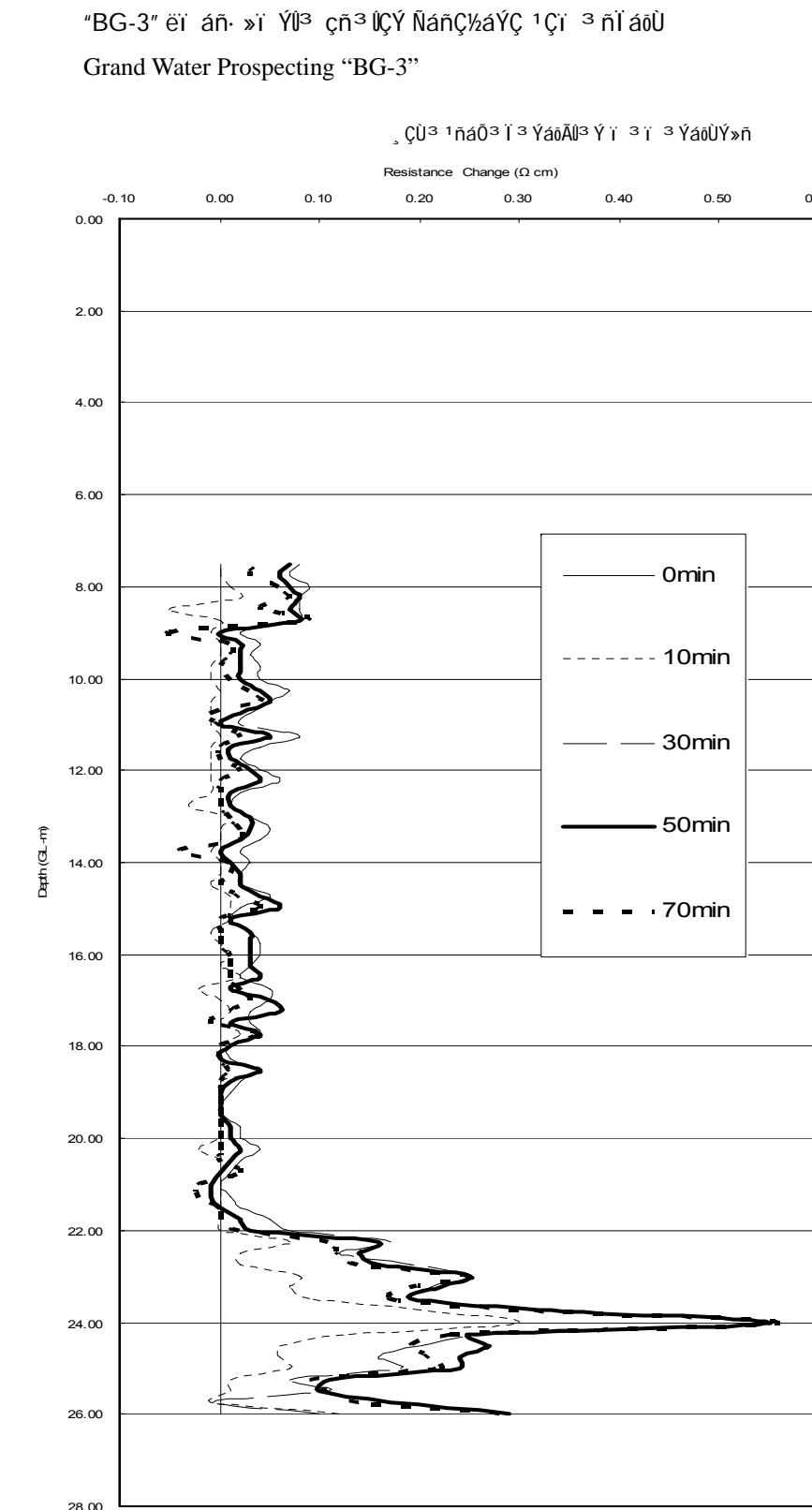
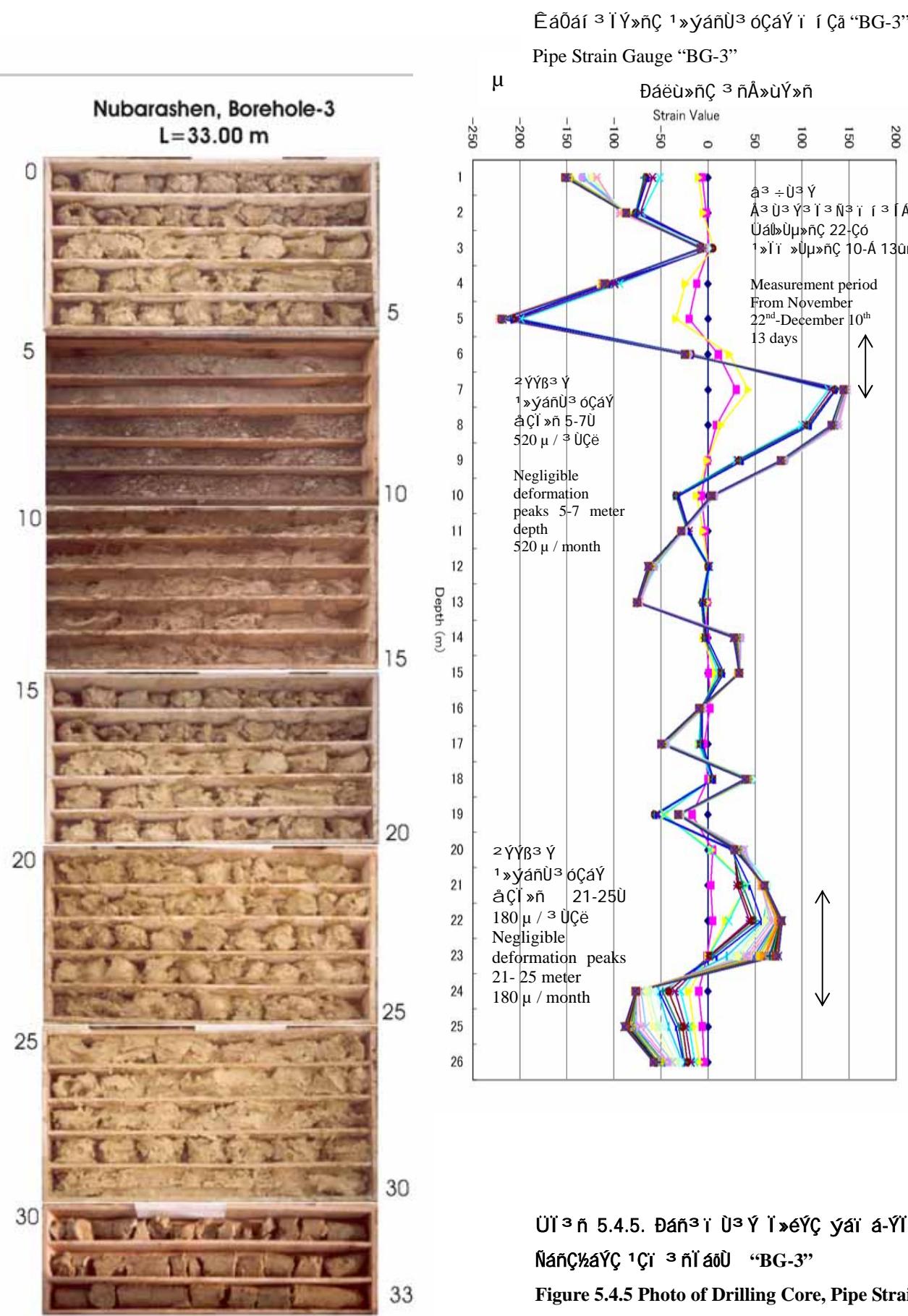
ÜT³ n 5.4.5. Dáññ³ T Ü³ Y T³éYÇ yáí á-YI³ n, Eáðáí³ T Y³»ñç 1»yáññ³ 6ç³ lç T 1 çBç – ÜaÝçí áñçY. /1çí³ níñáñU/, eí áñ· »í l³ çñ³ lçY NáñçñáÝç 1çí³ níñáñU “BG-1”

Figure 5.4.5 Photo of Drilling Core, Pipe Strain Gauge Monitoring, and Grand Water Prospecting of “BG-1”



ÜLÜK 5.4.5. Đáhñ³ İ ÜZÜÝ ÇÝ YÄÍÍ³ ñ, Eäðäf³ TÝ»ñç 1»ýáññ³ ðç³ İÇ T ÇBÇ – ÜaÝÇI áñçÝ. /1ÇI³ ñíÍáññ/, eñ áñ- »İ ï³ çñ³ İÇÝ ñáñç³ áÝÇ 1ÇI³ ñíÍáññ “BG-2”

Figure 5.4.5 Photo of Drilling Core, Pipe Strain Gauge Monitoring, and Grand Water Prospecting of “BG-2”



ÜÍ³ ñ 5.4.5. Dáñçí ï Ü³ Ý ï»éÝç ýáí á-ÝÍ³ ñ, Eáðáí³ ïÝ»ñç ¹»ýáñÙ³ 6ç³ ïç í ççç – ÜáÝçí áñçÝ. /¹çí³ ñíáðÙ/, eï áñ· »ï ï³ çñ³ ïçÝ ñáñççáÝç ¹çí³ ñíáðÙ “BG-3”

Figure 5.4.5 Photo of Drilling Core, Pipe Strain Gauge Monitoring, and Grand Water Prospecting of “BG-3”