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GEOLOGIC ROAD LOG FROM VANADZOR TO THE COAL DEPOSITS OF ANTARAMUT, ANTARAMUT TO DZORAGYUKH, AND DZORAGYUKH TO VAAGNI, NORTH-CENTRAL ARMENIA

By

Florian Maldonado[1], Arthur Martirossian[2], Samvel Harutunian[2] ,
Gourgen Malkhasian[2], and Brenda S., Pierce[3]

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[1] U.S. Geological Survey, Denver, CO 80225
[2] Armenian Ministry of Environment and Interior Resources, Yerevan, Armenia
[3] U.S. Geological Survey, Reston, VA 20192

Geologic road log from Vanadzor to the coal deposits of Antaramut, Antaramut to Dzoragyukh, and Dzoragyukh to Vaagni, north-central Armenia

INTRODUCTION

In July, 1993, Participating Agency Service Agreement (PASA) No. CCN-0002-P-ID-3097-00 was signed between the Department of the Interior, the U.S. Geological Survey (USGS), and the U.S. Agency for International Development (USAID). The PASA included Annex 3, Task to Assist in the Assessment of Armenia's Coal Resources, that resulted in the preliminary assessment of the solid fuel resources of Armenia. The results of that preliminary assessment have been reported by Warwick and others (1993) and Pierce and others (1994). A memorandum of understanding was signed in 1995 between the Armenian Ministry of Environment and Interior Resources (formerly the Armenian Ministry of Energy and Fuel) and the USAID to conduct an evaluation of coal and other fossil fuel in Armenia. In 1995, another PASA between the USGS and the USAID was signed. The PASA included Coal Annex 5, Coal Exploration and Resource Assessment of Armenia. This agreement included initiation of a drilling program that began in 1996 in the Ijevan area (fig. 1) and continued in the Antaramut area (fig. 1). This geologic road log is the result of field investigations in the Antaramut area (figs. 1 and 2) during July of 1997. Other geologic road logs of interest include logs for the southern half of Armenia edited by Aslanian (1984) and for the Ijevan area by Warwick and others (1999). The USGS has also published two abstracts on the Ijevan area (Warwick and others, 1996) and on the tectonics of Armenia (Maldonado and others, 1996).

The following is a geologic road log that describes Tertiary and Quaternary rocks of Eocene and Holocene age along the road from Vanadzor to Antaramut, Antaramut to Dzoragyukh, and Dzoragyukh to Vaagni. The stops are shown on figure 2.

GEOLOGIC ROAD LOG
Vanadzor to Antaramut

Km

0.0 **Stop 1**--The trip begins at the southeastern edge of the town of Vanadzor on the eastern end of a bridge over the Pambak River, and the intersection of Highway 330 and the road that goes north to Alaverdi (fig. 2). A gas station and cemetery are located near the intersection. The area is within a right-lateral strike-slip fault zone that is referred to as the Amasia-Sevan fault zone that parallels the northwest-southeast trending valley. An earthquake occurred along this fault zone on December 7, 1988, at 11:41 AM. The epicenter was located about 21 km west of Vanadzor near the town of Spitak, and resulted in the loss of at least 24,000 lives. The low slopes north of the intersection are mostly colluvium. The high cliffs are composed of interbedded volcanic rocks with volcaniclastic rocks. The volcanic rocks appear to be altered ash-flow tuffs that weather greenish gray (5G6/1) to dark greenish gray (5G4/1) and are intensely fractured, brecciated, and sheared, probably because of massive movements within the strike-slip fault zone. Oblique and horizontal slicken-sides are common indicating strike-slip movement.

2.4 **Stop 2**--This outcrop consists of silcified greenish-gray (5GY 6/11) bedded tuffaceous sandstone, tuffaceous siltstone, and a trace of carbonaceous shale. The predominately volcaniclastic beds appear to separate sequences of lava flows and volcanic mudflow breccias that are interbedded with the flows. The rocks are part of a structural complex that form a limb that dips about 60 degrees to the southeast. The eastern part of the outcrop might have been thrusted over shallower dipping sedimentary rocks that are located on the western part of the outcrop. These rocks might be equivalent to the coal-bearing package of rocks that are observed at Antaramut (fig. 2) that we refer to informally as the coal-bearing sequence of Antaramut. This unit will be discussed in more detail at Antaramut (stop 17).

Figure1. Index map of Armenia showing area (rectangle) of geologic road log.

3.6 **Stop 3**--This stop is located near a check point station at the intersection of the Pambak River and a tributary exiting from the south, near the village of Gugark. The rocks between stops 2 and 3 are predominately metavolcaniclastic rocks that include metamorphosed tuffaceous sandstone, metasiltstone (argillite) with some interbedded mafic lava flows. The rocks are intensely sheared, silificied, and hydrothermally altered. This succession of rocks has been folded forming small anticlines and synclines.

5.3 Note the restaurant near the km post 12. Metavolcaniclastic rocks are exposed along the roadside between stop 3 and the restaurant.

5.8 **Stop 4**--Fluvial channel deposits on the left side of the road might represent an ancestral Pambak River or a paleo-tributary to the river. The trend of part of the deposit appears to follow a different route than the present day Pambak River at this point, however, some of the deposits parallel the river. The river is incised in the metavolcaniclastic rocks and is located on the right side of the road.

6.3 Here begins the southern outskirts of the village of Pambak

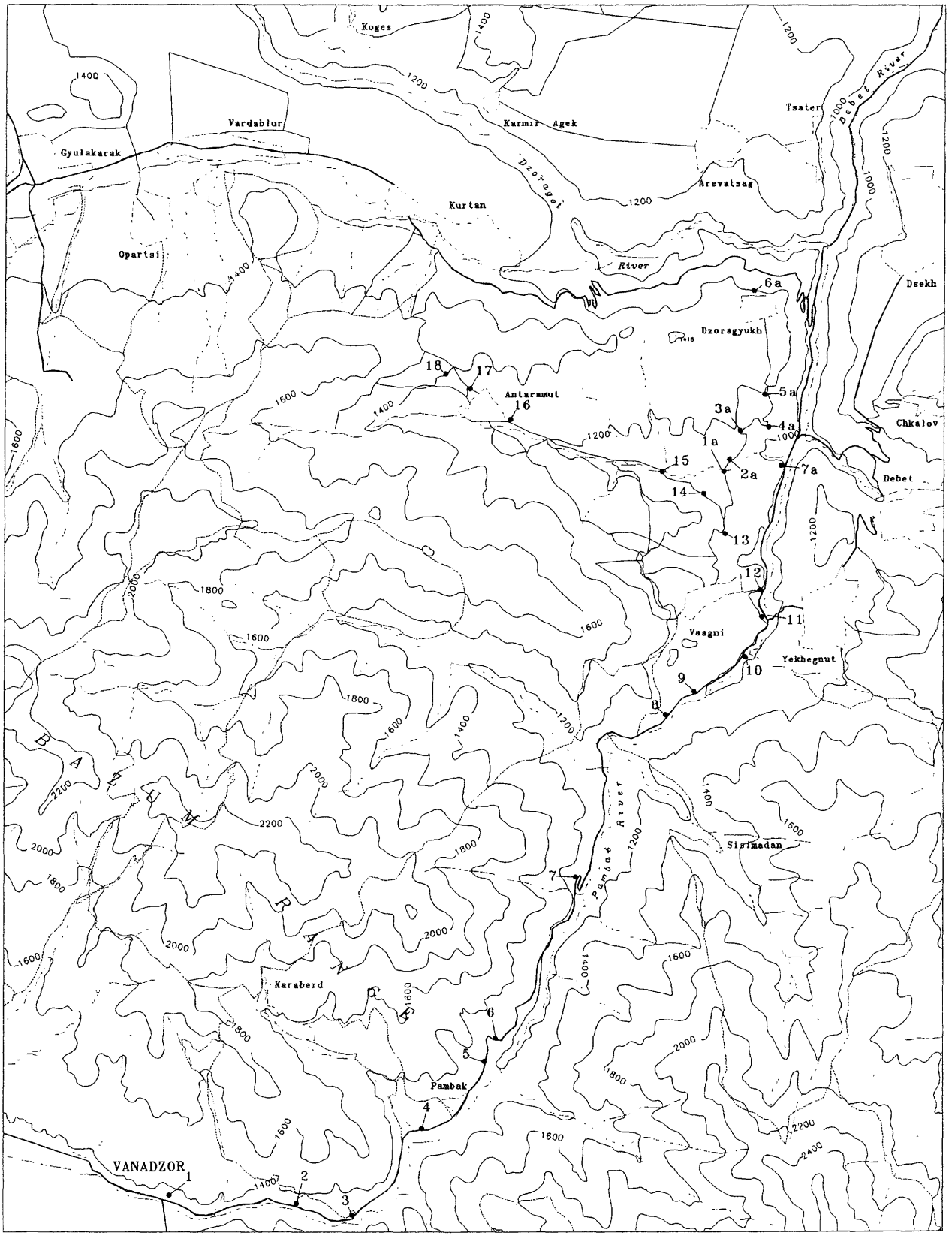

Figure 2. Map showing geologic road log stops from Vanadzor-Antaramut-Dzoragyukh-to Vaagni, north-central Armenia.

7.3 **Stop 5**--This outcrop shows an intrusive-igneous contact with the metavolcaniclastic rocks in the southwestern part of exposure about 20 m north of a spring. The contact has a high angle with a granodiorite intrusive body that might be part of a batholith. This body is part of a complex of intrusions composed of rocks that are reported to range form granodiorite to diorite that is approximately four km wide (in a southwest-northeast direction) that might be components of a batholith. The intrusions are reported to be middle Eocene in age. The sedimentary rocks have been silicified and metamorphosed to hornfels probably by the intrusive bodies. The fluvial channel deposits discussed at stop 4 are here observed to overlie the hornfels and granodiorite. The channel deposits contains large boulders, some the size of a Volkswagen Bug, but most clasts are boulder to gravel size. As the log proceeds to the next stop note the many intrusive bodies exposed in the road cuts.

7.9 **Stop 6**--Here intensely sheared granitic intrusion are exposed. Note the common spheriodial weathering.

11.4 **Stop 7**--This stop is located on a switch back of the highway. Hydrothermally altered rocks are exposed that might have been part of a fine-grained dioritic intrusive body: the rocks are intensely fractured, sheared, and stained with iron-oxide.

13.5 Note the Amush Restaurant.

15.1 Note km post 22

15.8 **Stop 8**--Exposed at this stop is an outcrop of bedded sedimentary rocks dipping about 55° degrees to the northeast that are probably part of the limb of a syncline. The rocks are composed of coarse- grained, cross-stratified, tuffaceous sandstone with an ash-flow tuff(?) at the base of the sequence. The rocks may be equivalent to part of the coal-bearing sequence of Antaramut as discussed at a previous stop. At Antaramut, this package of rocks underlies the tuff of Antaramut, an ash-flow tuff that will be described at subsequent stops.

16.2 **Stop 9**--Exposed at this stop is an outcrop of pale red (5R6/2) to grayish red (5R4/2) crystal-poor, ash-flow tuff. The tuff contains feldspar phenocrysts, and exhibits well developed foliation of pumice that strike N 40°E and dip 30° NW. This ash-flow tuff might overlie the sedimentary rocks described at stop (8), and probably underlies the tuff of Antaramut exposed at the next stop. The tuff might be equivalent to a crystal-poor tuff that underlies the tuff of Antaramut near the village of Antaramut, that overlies or is interbedded with the coal-bearing sequence of Antaramut. At Antaramut, the equivalent tuff has been altered to a lighter-color, or, the tuff might be a completely different ash-flow tuff.

18.0 **Stop 10**--This stop is located just south of the southwestern entrance to tunnel, where an outcrop of an ash-flow tuff sheet occurs. We refer to this ash-flow tuff sheet, informally, as the tuff of Antaramut that will be described in detail at stop 14. The middle part of this sheet is exposed here. The foliation of the pumice of the tuff strikes N 80°E and dips 45°-55°NW. The sedimentary rocks exposed at stop 8 and the pale-red, crystal-poor, ash-flow tuff at stop 9, occur stratigraphically, below the tuff of Antaramut. This package of rocks forms the south limb of a syncline that dips to the north-northwest, toward the village of Vaagni. We refer to this structure as the Vaagni syncline. These rocks also form the northeast limb of an anticline that is located south of the tunnel. The Pambak River might partly follow the axis of this anticline.

18.4 **Stop 11**--This stop is located just northeast of the tunnel exit on the left side of the road where another outcrop of the tuff of Antaramut is exposed. The tuff of Antaramut will be described in detail at stop 14.

18.7 **Stop 12**--Turn left toward the village of Vaagni. Outcrops of clinopyroxene-plagioclase-bearing mafic lava flows that are intensely brecciated are exposed. These mafic rocks overlie the tuff of Antaramut, and are referred to here as the mafic rocks of Antaramut, and will be described at stop 15. The outcrops might be a complex of landslides. About 300 m west of this outcrop, the exposures on the right side of the road are a sequence of alternating channel and overbank deposits of a river system that might overlie lacustrine deposits of Holocene age. The mafic rocks of Antaramut are exposed from stops 12 and stop 18.

20.5 Note the second of two cemeteries on the right side of the road.

21.4 **Stop 13**--Exposed at this stop are outcrops of clinopyroxene-plagioclase-bearing mafic lava flows that are intensely brecciated. Locally, grayish red (10 R 4/2) weathering siltstone and coarser-grain sedimentary rocks are interbedded with the lava flows. The rocks form the north limb of the Vaagni syncline.

21.8 **Stop 14**--Pull over near the powerline. This area and the Antaramut area to the north have been mapped by Maldonado and others (1999). The massive outcrop to the northeast is the tuff of Antaramut that dips to the northeast forming the north limb of an anticline that we refer to as the Antaramut Creek anticline. This limb also forms the south limb of a larger fold that we refer to as the Dzoragyukh synclinorium. Both folds will be discussed at a later stop. The tuff of Antaramut is a very important marker unit in the region, so we will describe it in detail here. The tuff is an ash-flow sheet composed of three parts: upper, middle, and lower. The upper part weathers pale-green (10G6/2), light-bluish gray (5B7/1), and greenish-gray (5G6/1). The tuff is partially to moderately welded and contains phenocrysts of plagioclase, hornblende, and biotite phenocrysts. The upper part is lithic rich, composed mostly of intermediate volcanic lithic fragments. Pumice are as long as 10 cm and have been altered to a moderate green (5G5/6) color. The upper part usually forms a slope overlying the middle part. The middle part weathers pale-red (10R6/2) to pale-yellowish brown (10YR6/2), is moderately to densely welded, crystal rich, and contains phenocrysts of plagioclase, hornblende, biotite, and pyroxene (?). Hornblende from this unit has been dated at 40.45±0.38 Ma using the $^{40}Ar/^{39}Ar$ method (Lisa Peters, Geochronology Lab, New Mexico Bureau of Mines and Mineral Resources, written commun., 1998). The tuff commonly contains intermediate lava lithic fragments but less than the upper and lower parts. The pumice are as long as 10 cm. The middle part usually forms a cliff above the lower part. The lower part weathers light bluish-gray (5B7/1), is partially to moderately welded, and contains phenocrysts of plagioclase, hornblende, and biotite. The lower part resembles the upper part, and is also rich in lithic fragments, most of which are intermediate in composition lava fragments and as long as 5 cm. The pumice have also been altered to a greenish color. As indicated earlier, the tuff is a maker unit that can be used in coal exploration in the Antaramut area. The tuff of Antaramut is extremely thick here but thins toward Antaramut. Its relationship to the coal-bearing sequence will be discussed at the Antaramut stop.

The tuff of Antaramut is overlain by a thick sequence of mafic rocks composed of lava flows, flow breccias, and occasional thin interbedded intervals of volcaniclastic rock. The lavas include basaltic, basaltic-andesitic, and andesitic flows. We referred to these rocks as the mafic rocks of Antaramut. The rocks weather dark gray (N3), brownish-gray (5YR4/1), light-brownish gray (5YR6/1), and grayish-red purple (5RP4/2). The rocks are typically porphyritic and contain clinopyroxene, plagioclase, and olivine(?) phenocrysts in a fine- to medium-grained groundmass. Flows are dense to vesicular with vesicles commonly filled with silica. Locally, the lava flows are pillowed where they overlie volcaniclastic rocks. The volcaniclastic rocks weather pale red (5YR6/2), grayish-red (10YR4/2), medium gray, (N5), and olive-gray (5Y4/1). The volcaniclastic intervals are as much as 3 m thick and contain bedded sandstone, siltstone, and conglomerate. The mafic rocks are separated from the underlying tuff of Antaramut by a package of volcaniclastic rocks that form a slope. These rocks will be describe at stop 16. The mafic

rocks generally erode to form slopes, and are the major rocks exposed in the Dzoragyukh synclinorium (north of this stop) where they form small anticlines and synclines within the synclinorium.

23.0 **Stop 15**--This stop is at the intersection of the road to the village of Antaramut and Antaramut Creek. Here, we see outcrop of clinopyroxene-plagioclase mafic lava flows of the mafic rocks of Antaramut. To the east along creek, the tuff of Antaramut is exposed in the north limb of the Antaramut Creek anticline that will be described in the second part of the road log (stop 1a).

25.6 **Stop 16**--This stop is on the east side of the village of Antaramut. Here, an outcrop of clinopyroxene-plagioclase mafic lava flows of the mafic rocks of Antaramut is underlain by bedded volcaniclastics rocks. The volcaniclastic rocks separate the mafic rocks of Antaramut from the tuff of Antaramut that is exposed about 30 m up the creek near a spring. The volcaniclastic rocks consist of interbedded thin to thick bedded, yellowish-gray (5Y7/2) weathering tuffaceous siltstone and sandstone, very pale-blue (5B8/2) weathering tuffaceous mudstone, and tuffaceous conglomerate. A grayish red (10R4/2) weathering sandstone and siltstone interval is present at the top of the unit. Locally, but not exposed at this outcrop, the unit contains a dark gray (N3) weathering carbonaceous siltstone. Pillow-like structures are present in the mafic lava flows just above the volcaniclastic rocks. The outcrop is intensely fractured, and this might be related to a fault present in the valley that contains the creek. A series of small anticlines and synclines are exposed at this outcrop that may be related to a strike-slip north of the stop.

27.1 **Stop 17**--This stop is at the top of a hill at the north end of Antaramut. An outcrop of the mafic rocks of Antaramut is exposed here. A cemetery is located approximately 300 m east of this stop. The stop is on a south-dipping limb of an anticline that we refer to as the Antaramut anticline. The south limb is composed of the mafic rocks of Antaramut, which is underlain by the tuff of Antaramut. The anticline is cored by the coal-bearing sequence of Antaramut. Although this unit is only exposed in a small outcrop northeast of Antaramut, it has been penetrated by a drill hole. The high ridge to the north contains the middle part of the tuff of Antaramut. Dipping to the north, the middle part forms the north limb of the Antaramut anticline. The axial area of the anticline has been eroded out and the area has been covered by colluvium. The axial area might be composed of interbedded tuffaceous sandstone, carbonaceous shale, and thin coal beds about one meter thick. Interbedded mafic lava flows, that have been penetrated by some drill holes on the anticline might also be part of this unit. As mentioned earlier, we have referred to these rocks as the coal-bearing sequence of Antaramut. A small outcrop of this unit is exposed in a minor drainage located about 0.5 km northeast of Antaramut. The unit is exposed in a shear zone, and has been extremely altered and oxidized. The rocks there are overlain by a small outcrop of the tuff of Antaramut. These rocks might be equivalent to the metavolcaniclastic rocks exposed along the highway between Vanadzor and Vaagni.

Our work on the stratigraphy and structure of the greater Antaramut area has resulted in the development of a model for coal exploration. Our geologic mapping has revealed a complex of anticlines and synclines in the area. The anticlines appear to be the major drilling targets in this exploration model, while the synclines are ruled out because the strata overlying the coal-bearing sequence of Antaramut are too thick to penetrate. The axis of the anticlines are usually cored by the rocks of Antaramut, therefore, the rocks are closer to the surface than in the synclines. The tuff of Antaramut is present in most of the folds and can aid in identifying the type of fold. The tuff is a marker bed of regional extend, and is easily identified in the field. By determining the foliation of the pumice in the tuff, one can determine if the tuff is forming the limb of a syncline or an anticline.

27.8 **Stop 18**--Here we see an outcrop of the tuff of Antaramut that forms the limb of an anticline that dips about 42° to the southeast. The outcrop is characterized by bedding plane faults and some brecciatiation. This suggests internal deformation, probably related to the folding of the rocks.

To begin the road log from Antaramut to Dzoragyukgh, drive back to stop 14.

Antaramut to Dzoragyukh

0.0 The Trip begins at the powerline at stop 14 of road log from Vanadzor to Antaramut. Drive south.

0.3 Take a first left turn on to the road to Dzoragyukh. The view north is described at stop 15 of the previous road log. The light-colored cliffs are composed of the tuff of Antaramut and are overlain by the mafic rocks of Antaramut. Note the apple orchard to the northeast. The outcrops above the orchard are Pliocene basaltic lava flows that overly the tuff of Antaramut. These rocks will be described at a later stop.

1.4 **Stop 1a**--Stop at the intersection of the creek and the road. The outcrop of the tuff of Antaramut on the north side of the creek is dipping north forming the north limb of the Antaramut Creek anticline and the south limb of a syncline that is involved in the Dzoragyukh synclinorium. The tuff exposed south of the creek is dipping to the south forming the south limb of the Antaramut Creek anticline and the north limb of the Vaagni syncline. The creek is essentially following the axis of the anticline.

1.8 **Stop 2a**--Here we see another outcrop of the tuff of Antaramut. Note the slope of the lower part of the unit and the cliff of the middle part. Notice also that the lower part of the tuff is lithic rich.

2.3 **Stop 3a**--Notice that the middle part of the tuff of Antaramut is a densely welded zone characterized by cooling joints and again forms a cliff. This middle part of the tuff is crystal rich and contains fewer lithic fragments than the lower and upper parts of the tuff.

2.9 **Stop 4a**--This stop is on an overview looking east to the main highway to Alvaverdi (fig. 1) and the Pambak River, and northeast to the confluence of the Bebed and Pambak Rivers (fig. 2). Directly below this overview is a small village, with the tuff of Antaramut forming a cliff just to the south. Here, the tuff is forming the south-dipping limb of the Antaramut Creek anticline described at stops 1a and 2a. Stop 4a is on the north-dipping limb of that anticline, and also forms the south limb of a syncline involved in the Dzoragyukh synclinorium north of the stop. The axis of the anticline is located in the valley below the overview. The core of the anticline has been partly eroded but this cannot be confirm since the area is overlain by colluvium. This might potentially be a good area to drill for the coal-bearing sequence of Antaramut. A Pliocene basaltic lava flow caps the tuff of Antaramut to the northeast of the stop and forms a lone peak. The lava flows weather medium dark gray (N4), are vesicular to dense and contain phenocrysts of plagioclase in a medium-grained groundmass. The same sequence of lava flows show strong columnar jointing east-southeast of the stop across the Pambak River.

3.5 **Stop 5a**--This stop is at the powerline and a Khachkar (stone cross) for an overview of several interesting structures. Looking to the far south, toward the village of Vaagni, the Vaagni syncline can be seen. The ridge just south of Vaagni forms the south limb of the Vaagni syncline and the north limb of an unnamed anticline that is located south of Vaagni. The limb is composed of the tuff of Antaramut and the overlying mafic rocks of Antaramut. The tunnel on the main highway to Vanadzor cuts through this limb. Looking to the near southwest toward Antaramut creek, we see the Antaramut Creek anticline described at the previous stops. The

south-dipping limb of the Antaramut Creek anticline forms the north limb of the Vaagni syncline.

Note the Khachkar located at this stop. Khachkars usually mark a grave site, however, this khachkar denotes a place to pray. Notice the black marks caused by the burning of candles. Also notice the star that is not really a star but rather the intersection of two triangles. One triangle points up to the heavens, and the other points down towards the earth.

4.1 Note the deposits of river gravels on the right side of road that represent a paleoriver channel.

4.7 This is the village of Dzoragyukh with a view of the Dzoraget River. Notice the columnar jointing in the Pliocene basaltic lava flows exposed along the cliffs.

Dzoragyukh to Vaagni

6.0 **Stop 6a**--Here we see Pliocene basaltic lava flows overlying the tuff of Antaramut. This is part of the same basaltic lava flows described at stop 4a. The flows are very thick and commonly pillowed. The flows fill a paleovalley that is now occupied by the present Dzoraget (below the stop), Pambak (to the east), and Debed Rivers (to the northeast). Locally, channel deposits and possible lacustrine beds occur interbedded with the lava flows. The lacustrine beds were probably deposited during damming of the river system by the lava flows.

7.3 Note the intersection of road with the main road north to Kurtan.

11.4 Note the intersection of the Alaverdi-Vanadzor road with the Kurtan road.

14.0 **Stop 7a**--Here we can see an outcrop of the tuff of Antaramut dipping to the south forming the south limb of the Antaramut Creek anticline. The Pambak River lies east of the stop. East of the river is an exposure of the tuff of Antaramut that is overlain by the Pliocene basaltic flows previously described.

16.3 Return to stop 12 of the road log from Vanadzor to Antaramut.

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