STRATIGRAPHY AND GEOLOGIC MAP OF TERTIARY COAL-BEARING DEPOSITS, SHIRAK REGION, NORTHWESTERN ARMENIA

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INTRODUCTION

Armenia is a land-locked country that occupies approximately 29,760 km^2 within the lower Caucasus Mountain region. Historically, Armenia as part of the Soviet Union, relied on imported fossil fuels and nuclear energy for electricity generation. This importation of fuels has prompted a search for internal exploitable resources. Several regions of Armenia have been and are currently undergoing resource assessment for solid fuel resources, namely coal. Pierce and others (1994) summarize many of the coal areas within Armenia. Several studies have been done to assess the oil and gas potential of Armenia and are summarized in Wheaton and others (1995).

PURPOSE OF STUDY

This study is part of a continuing coal exploration and resource assessment of Armenia by the United States Geological Survey (USGS) and the Armenian Government, funded by the United States Agency for International Development (USAID). The purpose of this specific study was to locate and assess potential coal and carbonaceous rock deposits in the Shirak region of northwestern Armenia (figs. 1 and 2). Unpublished USSR reports are available that describe occurrences of coal and carbonaceous shale in the Shirak region. Using these reports and older 1:50,000 scale geologic maps, we attempted to assess the coal-bearing rocks in this region and accomplish the following goals: 1) locate and describe coal or carbonaceous shale described in the USSR reports, 2) determine the stratigraphic position of these deposits, 3) correlate these deposits, if possible and 4) produce 1:25,000 scale geologic maps of these deposits and associated units.

Field work for this study was conducted between August 18 and October 23, 1998. Due to the short field season and shortage of translated publications, the material covered below is not a comprehensive review of this region. Rather, emphasis was placed on determining the extensiveness of the coal-bearing units and the correlation of isolated outcrops. Most of the geologic interpretation found herein, is a combination of what we learned from existing internal reports and investigations and observations made during the field season.

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REGIONAL GEOLOGY

Several 1:50,000 scale geologic maps and a few smaller scale maps are available for parts of the Shirak region (Kharazian, 1991). These maps do not show fold axes and lack current plate tectonic interpretations (i.e., thrust faults). Chronologic control is poor for many of the published map units. Faunal control is available for some units but localities are few and widespread. Many of the geologic units have been correlated regionally to localities of known ages but they are based on distant regional correlations. The following sections briefly describe the geology as it relates to the study area.

STRATIGRAPHY

Rocks of Late Cretaceous to Quaternary age are exposed in the Shirak region. These strata are composed primarily of volcanic, sedimentary, and ophiolitic rocks. The volcanic rocks are composed of andesitic to basaltic pyroclastic ash-flow tuff and lava flows. The sedimentary rocks are composed of carbonate, clastic, volcaniclastic, and alluvial deposits. These rocks are divided into several suites and are summarized by Kharazian (1990) and briefly described below. Several measured sections relevant to our study have been translated from Kharazian (1990) and listed in Appendix A. Additional descriptions and details on the coal-bearing units are described in the following sections and Appendix B.

Late Cretaceous - Ophiolite Suite

The oldest rocks in the Karmrakar area (pl. 1, unit Kmo) are an ophiolite suite mapped as pre-Coniacian apo-peridotite (Kharazian, 1991). The ophiolite suite is composed of ultramafic rocks, consisting mostly of peridotite, serpentinite, and gabbro.

Late Cretaceous — Sepasar and Gorgaran Suites

The Coniacian to Maastrichtian Sepasar and Gorgaran suites (pl. 1, unit Kmu) are mapped in the Karmrakar and Mets Sariyar areas (Kharazian, 1991). These rocks are composed of limestone, chlorite-rich clastic rocks, and tuffaceous sandstone and siltstone (Tables 2 and 3, Appendix A). These rocks lay in apparent conformability on the ophiolite suite. The Cretaceous rocks of this region have good faunal age control from micro- and macro-fauna, such as *Inoceramus*, *Scaphites*, *Terebratulina*, *Gryphaea*, *Echinocaorys*, *Globotruncana*, and *Psuedotextularia* (Kharazian, 1990).

A fossil specimen (sample # SP-1) collected from the Gorgaran suite north of Karmrakar (Plate 1) was identified by Alla Papoyan (Republic of Armenia Academy of Sciences) as *Spiractaeon variospirates* (upper Coniacian, 87.5-88.5 Ma).

Tertiary to Eocene — Maralsar suite

The lower Eocene Maralsar suite (pl. 1, unit Tvu) is mapped in the Mets Sariyar area (Kharazian, 1991). This suite occurs as a narrow band that transgressively overlaps the Gorgaran suite (Kharazian, 1990). These rocks consist of limestone and arenaceous limestone with minor conglomerate noted in some areas (Kharazian, 1990; Table 4, Appendix A).

Tertiary to Eocene — Shirak Suite

The middle Eocene Shirak suite (pl. 1, unit Tvu) is mapped in the Karmrakar, Mets Sariyar, and Jajur mine areas (Kharazian, 1991). These rocks consist of a thick section (up to 1080 m) of interbedded volcanogenic and marine rocks (Table 5, Appendix A). The volcanic rocks are intermediate to mafic lava and ash-flow tuff. The marine units consist of limestone, sandstone, shale, and volcaniclastic rocks.

Two additional units are differentiated herein that include andesitic lavas and a coal-bearing unit. The andesite flow unit occurs in the middle of the section and prominently caps several small hills and benches in the Karmrakar and Jajur Mine areas (Pl. 1 unit Tva). It is commonly thick (greater than 15 m) and readily recognizable. This porphyritic lava flow has a fine groundmass with phenocrysts of plagioclase and pyroxene. The plagioclase (An45-65) phenocrysts display albite twining and are quite large (as large as 0.5 cm) while the pyroxene phenocrysts tend to be smaller (as large as 0.3 cm). Thin-section analyses from this study indicate the rock has a hyalopilitic texture where the radial-oriented microlites are composed of plagioclase and pyroxene. In hand sample, the brown-colored aphanitic groundmass and associated mafic minerals give the rock a black and slightly glassy appearance. This unit serves as a marker bed within the Shirak suite.

The coal-bearing unit is herein called the black shale sequence and outcrops along a band from northeast of Maissian to west of Mets Sariyar (Pl. 1, unit Tbs). This unit locally contains coal and carbonaceous rocks. It occurs stratigraphically above an orange-colored, slightly recrystallized, fractured limestone. The black shale unit contains abundant claystone and siltstone with minor thin beds of volcaniclastic sandstone and localized limestone and conglomerate. The coal is lignite to sub-bituminous in apparent rank (Pierce and others, 1994) and arenaceous at the Mets Sariyar and Bandevan measured section sites (Tables 9 and 11, Appendix B). The coal beds throughout the extent of the sequence are thin (less than 20 cm) and discontinuous. Sections have been measured in this unit in the Karmrakar and Mets Sariyar areas (Tables 11 and 12, Appendix B). The section north of Karmrakar serves as the type section for this unit (Table 12, Appendix B).

Tertiary to Eocene — Pambak Suite

The rocks of the Pambak suite are predominately composed of volcanogenic sediments and include tuffaceous siltstone, tuff breccia, and andesitic lava (Kharazian, 1990). They have been mapped and described for the Amassia area (fig 2; Table 6, Appendix A).

Tertiary to Oligocene and Miocene — Bandevan Suite

The rocks of the Bandevan suite are exposed within a small syncline between the villages of Amassia and Bandevan on the east bank of the Akhurian River (fig. 2). These rocks consist of claystone, siltstone, and sandstone with minor conglomerate and coal. Many of the finer-grained units are carbonaceous and/or contain coaly fragments. The coal is very thin (less than 5 cm), discontinuous, and low in apparent rank (lignite?). Aslanian and Rudzyanski (1954) measured a section of these deposits (Table 7, Appendix A) which was reported in Kharazian (1990). A section measured during this study is reported in Appendix B.

The deposits between Amassia and Bandevan have poor age control. Kharazian (1990) reported that only small freshwater gastropods and fish fragments have been found. Aslanian (1958) has identified and reported *Ginnamomum lanceolatum*, *Planorbis* sp., *Herbetocypris achurianensis*, *Bythinia* sp., and *Encipris* sp., for this suite.

Coal-bearing deposits of the Jajur mine occur in a bowl-shaped depression north of Mets Sariyar (pl. 1, unit Tbs) and are listed as part of Bandevan suite (Kharazian, 1990). A thrust fault has been exposed within the mine and shows that the upper portion of the deposit has been repeated (fig. 3). The coal-bearing section at Jajur contains six coal beds. Bed number one (from the bottom) is not currently exposed in the open-pit mine but has been penetrated by drilling. Bed number 2 is the thickest, nearly 2 m. Bed number 6 is also thick, ranging from 1.2 to 1.5 m. The remaining coal beds (numbers 2, 3, and 4) are thin (on an average, approximately 30 cm) but continuous across the entire mine area. Several of the claystone and siltstone units within the section contain numerous gastropod and pelecypod fossils. A section measured during this study is reported in Appendix B.

The age of the coal-bearing unit at the Jajur mine is not well documented. Discussions with Kharazian (1998, personal communication) and published reports have indicated that the age of the fossils at Jajur range from middle Eocene (Talanian and Azatian, 1953) to Oligocene (Aslanian and Rudziansky, 1954) to Pliocene (Baicharov, 1939) to Quaternary (Paffenholts, 1940). Kharazian (1990) reports that some investigators believe the deposits at Bandevan to be analogous to the upper Oligocene to lower Miocene Dilijan suite (more than 80 km away, fig. 1). Marginal marine and terrestrial deposits of the Dilijan suite occur in the Stepanavan region of Armenia on the northern flank of the Bazum Range, south of the village of Gerger (Sarkissian and Grigorian, 1964). They have good faunal control based on *Nummulites vascus* and *N. incrassatus* (Sarkissian and Grigorian, 1964).

The deposits between Amassia and Bandevan and the units in the Jajur mine have been correlated with the Dilijan suite based primarily on physical character alone (Sarkissian and Grigorian, 1964; Kharazian, 1990). This singular point has been used to assign the Oligocene-Miocene age to these deposits. Based on the discrepancies in faunal data at Jajur, differences in apparent coal rank, and the unevaluated regional tectonic relations of these units, age determination or grouping of the deposits between Amassia and Bandevan and the Jajur mine with the Dilijan suite should be used with caution.

Tertiary to Miocene and Pliocene — Jajur Suite

The Jajur suite is divided into two subsuites. The lower subsuite is composed of andesitic ash-flow tuff and the upper subsuite is composed primarily of andesitic lava (Table 8, Appendix A). These units occur in the Maissian to Lernut areas (fig. 2, pl. 1, unit Tv) and to the northwest of the village of Amassia (fig. 2; Kharazian, 1990). Age control on these deposits is limited to physical correlation to known Neogene Ante-Caucasus-Voghchaberd, Vardenis, Bichenag, Goderdzi, and other composite volcanic fields (Kharazian, 1990).

Quaternary to Present

In the Shirak area, alluvial and lacustrine rocks are intercalated with volcanic rocks. The lacustrine rocks occur along the edge of the Shirak Basin and are composed of siltstone, sandstone, and claystone. The volcanic rocks consist of ash-flow tuff and lava flows that covered and preserved the paleotopography of the region. Some of the ash-flow tuff in the lower valleys of the Shirak range probably originated from the Aragats volcanic field and have a relative date of 700,000 yBP. Colluvium is common with the steep terrain of this region and most of the present stream valleys have Recent deposits of alluvium. The Shirak region is covered by a well-developed soil profile that limits geologic exposures.

TECTONIC SETTING AND SEQUENCE OF EVENTS

The rocks of the Shirak area record a long and complex history of deposition, folding, faulting, and thrusting. This area has been affected by several compressional and transform tectonic events. Gravity-block slide movement is one hypothesis used by a few Armenian geologists to explain the multiple thrust faults of the area (Vardanian and Elbakian, 1996). The present study attempts to use previous geologic interpretations and observations made during field mapping to reinterpret the tectonic setting of the Shirak area (pl. 1). Because of the time limits of this study, this overview should be considered a general regional hypothesis of events.

The geologic record exposed in the Shirak region begins with Late Cretaceous marine limestone that was deposited on top of oceanic seafloor ophiolitic rocks. These rocks - limestone, chlorite-rich clastic rocks, and tuffaceous sandstone and siltstone of the Sepasar and Gorgaran suites - probably developed on a passive margin along a continental shelf. The chlorite- and serpentine-rich clastic rocks developed from the transport and alteration of mafic minerals onto the passive margin, probably from a continental coastal volcanic range. Up-section, the sedimentary rocks progress from an offshore marine reef environment to one of active deposition of mafic material. Ash and other tuffaceous material were incorporated within the sediments developing in this setting.

A hiatus is suggested by the lack of Paleocene rocks in this area. Lack of depositional accumulation or erosion of deposited material may explain the hiatus.

The Eocene rocks of Maralsar, Shirak, and Pambak suites show a slow succession from offshore marine limestone formation to a basin actively receiving volcanogenic input. Mafic to intermediate lava and tuff are intercalated with volcaniclastic sandstone (graywacke) and arenaceous and tuffaceous limestone. This thick sequence of strata (>2000 m) probably developed in a back-arc basin or possibly a fore-arc basin.

Up-section, the volcaniclastic rocks become interbedded with thin beds of terrigenous rocks. Near the top of the section, abundant black mudstone, siltstone, and sandstone are interbedded with carbonaceous shale and thin discontinuous coal beds. The coals and carbonaceous deposits were probably formed in near shore, isolated swamps or marshes.

The input of terrigenous clastic material up-section may represent the closing of the back-arc basin as the arc moved towards the continent. In the study area, the Eocene section is tilted 50-75° in a northerly direction. The arc-continent collision may be partly responsible for tilting and folding the Eocene section. However, whether the arc-continent collision or another tectonic mechanism was responsible for the tilting of the Eocene sections is beyond the scope of this study.

Kharazian (1990) reports several anticlinal-synclinal pairs within the Eocene section (Table 1, Appendix A). This has not been noted in the Shirak study area. Dip variations in the Mets Sariyar area (pl. 1) are related to a large strike-slip fault (pl. 1) and these dip variations may have been interpreted improperly. Outside the study area, evidence for folding of the Eocene section was observed.

The Bandevan suite was correlated to Oligocene-Miocene aged deposits from other regions. The depositional environments for the coal and coaly mudstone of this suite may be similar to that of the Eocene coal-bearing units, but with higher amounts of terrigenous input into the resultant coaly mudstone. This siltstone- and claystone-rich suite probably developed in a fluvio-lacustrine environment. Based on the poor chronologic control of these deposits, they may be lateral equivalents of the Eocene deposits above. If this is true, no Oligocene-early Miocene depositional event was recorded in the study area.

Two faulting events can be constrained between late Eocene and middle Miocene time. The first event is an extensive period of compression that resulted in thrusting Cretaceous-aged rocks over the previously tilted Eocene section. At the base of the thrusted Cretaceous blocks, thin slices of ophiolite or ophiolite debris is commonly noted. These blocks of Cretaceous rocks were thrusted from a northerly direction. This relation can be seen on the thrust block northwest of Karmrakar where the leading edge of the block has been recumbently folded (pl. 1). This thrusting event also affected the deposits in the Jajur Mine area, creating a small thrust plane that repeats the coal-bearing section and repeats several units within the Cretaceous section (pl. 1). Furthermore, we believe that the thrusting-recumbent folding combination of events, seen in the

Karmrakar area (pl. 1), are part of the same system that is responsible for the repetition of coal-bearing strata that are present in about a third of the Jajur coal field.

The second faulting event is noted by a major strike-slip fault zone (pl. 1) that is oriented west-northwest by east-southeast. This fault zone tracks beneath the villages of Mets Sariyar and Krashen (pl. 1). If the black shale and andesitic lava sequences are correlatable between Mets Sariyar and Jajur mine area, then the sense of movement on this fault is left-lateral.

An extensive paleosol developed on top of the tilted Eocene section. This paleosol probably began developing shortly after the Eocene rocks were tilted and continued until middle Miocene time. The relation of this paleosol to the thrusting of the Cretaceous blocks could potentially elucidate the age of thrusting if the degree of paleosol development could be ascertained. However, the paleosol has not been mapped beneath the faulted contact and thus no relation can be established at this time. Potentially the paleosol could have been removed by the thrusting event.

During Miocene and Pliocene time, large volumes of andesitic ash-flow tuff and lava of the Jajur suite were emplaced across the paleotopography. These volcanic units covered much of the Eocene section and portions of the thrust block in the Karmrakar and Lernut areas (pl. 1). These units are thought to have flowed south into the Shirak basin and are now covered by lacustrine and alluvial units (Kharazian, 1990).

By Quaternary time, erosion created a 'window' through the Jajur suite, exposing the Eocene section between Karmrakar and Lernut areas (pl. 1). Deposition of alluvium filled many of the erosional valleys during this time with several alluvial sequences readily identifiable. Fine-grained lacustrine rocks accumulated in the Shirak basin during the early Quaternary time (Kharazian, 1990). About 700,000 ago, ash-flow tuff from the Aragats volcanic field flowed to the north up into the valleys in the Shirak area, covering the previous valley fill and eroded topography.

COAL-BEARING UNITS

The purpose of this study was to assess the coal-bearing units described in former USSR and Armenian reports for this area. Many of the outcrops were difficult to find due to limited latitude and longitude descriptions. When possible, inquiries were made with the local villagers who are very knowledgeable about the area and knew what coal-related activities had been conducted. Several outcrops were found based on help from the villagers.

Undeterminable Coal Occurrences

Coal was reported at N40° 56' by E44° 00' near the village of Pokr Sariyar (fig. 2). The USSR report describes the outcrop as composed of upper Tertiary claystone and carbonaceous shale with partings of hard brown coal. Younger tuff and lava are reported to be covering this outcrop. A limited search of the hillside above the village did not reveal any coal-bearing outcrops. The upper sections of the surrounding hills were not examined and it is possible that the coal may be near the top of the hills under the reported volcanic units. Detailed mapping of the units may reveal that the lava and tuff belong to the Mio-Pliocene Jajur suite. This may suggest that a stratigraphic relation exists where the black shale sequence would be directly below the volcanic units, similar to the Karmrakar (fig. 2) areas, reported herein.

Hard coal was reported in the Aghvesi Bner valley, one km northwest of Dzorashen at N40° 56' by E44° 04' (fig. 2). The outcrop is described as typical porphyrites and tuffogenic rocks with remnants of ancient river terraces on both sides. Within the claystone of the terrace deposits, insignificant pieces of coal were reported. The lower portion of the valley was searched and no coal-bearing outcrop was noted. Volcanogenic material in the soil horizon was altering to a black, soapy-feeling substance and may have been mistaken for coal.

Coal was reported near the village of Bashgyukh at N40° 56' by E43° 57' (fig. 2). According to the villagers there is no coal in this area, but they knew of the Jajur coal mine to the southwest. Based on the area noted by the coordinates, the USSR report may have been referring to the coal at the Jajur Mine.

A 0.6 m thick coal bed with associated carbonaceous shale was reported by Baicharov (1939) 18 km east of Gyumri between the villages of Jurashen and Tsakhkaber in the Harsnakar Mountain area. Baicharov described the outcrop as Eocene hills sticking up through the Golgat volcanic sheet. The general description of this report made locating the outcrop impossible and the coordinates provided were not specific (N40° 45' by E44° 05'). The area along the northern edge of a flow from the Sharai volcanic field was searched but the outcrop was not found. The area north of Harsnakar peak was searched where the 1:50,000 scale geologic map noted a lava sheet. This plateau was not covered by lava, but rather was covered by rounded boulders of lava, probably resulting from colluvial action from the nearby peak (vent). The foreman of the Jajur Mine informed us that this outcrop was on the south side of Harsnakar Peak near several houses where he had evaluated the coal but had determined it uneconomical. This area was checked, but no coal outcrop was found. Volcaniclastic mudstone and siltstone appeared to have been altered by sills from the Harsnakar vent and may have been mistaken for coal.

Lenses and partings of sooty coal were reported near the village of Keti (fig. 2) on the right bank of the Aranki-dzor River at N40° 52' by E43° 50'. The coordinates place the deposit near the village. An older villager told us that the outcrop was northeast of town in the hills. The area was searched and a sheep herder was asked the same question. The herder told us that the outcrop was near the Keti orchards. The orchard is located 0.5 km from the Maissian coal outcrop (see below), probably the area described by the herder, and maybe the outcrop of question in the report. Therefore, we think that the Keti outcrop described in these reports is actually the Maissian occurrence of coal.

Bandevan Outcrop

Combustible shale was reported between the villages of Amassia and Bandevan at N40° 57' by E43° 48' (fig. 2). The USSR report describes the combustible shale as 5 discontinuous beds of bituminous, clayey, silty rocks with thicknesses of 1 to 5 mm. The outcrop occurs on the south bank of a tributary stream that joins the Akhurian River. According to a villager, this outcrop was previously explored by adit and backhoe but only small amounts of coal were removed. During this study, a partial section was measured through the carbonaceous units of this outcrop (Appendix B).

A coal-bearing portion of this outcrop is downstream from the measured section (N40° 57' 49.58" by E43° 48' 24.92"; Table 9, Appendix B). The coal-bearing strata appear to have been affected by the east-west oriented fault that is directly north of the small creek. These units appear to be stratigraphically lower than the section measured upstream. The outcrop contains yellow siltstone and claystone with minor discontinuous coal beds. The claystone beds contain slickensides. The remaining coal or carbonaceous shale at this location consists of four to five small discontinuous bands (1-3 cm thick) of apparent low-rank coal. Exposed outcrop thickness of the coal-bearing zone is 7.7 m.

These deposits occur in a small syncline that has been asymmetrically eroded and subsequently covered by a lava flow. Drilling along strike of the outcrop, possibly in or just west of the village of Amassia (fig. 2) could provide additional outcrop trend information.

This outcrop has poor chronologic control. As noted above, these deposits have been correlated to the Dilijan suite and given a similar age of late Oligocene to early Miocene.

Jajur Mine Outcrop

The Jajur Mine (pl. 1) was in operation southeast of Bashgyukh (fig. 2) (N40° 55' 55.34" by E43° 57' 17.80") during our field study. A measured section of the coal-bearing unit in the mine can be found in Table 10, Appendix B. Additional descriptions of this unit were discussed above. This outcrop appears to be constrained within a bowl-shaped depression, surrounded by alluvium, that has been reported to be a syncline (Kharazian, 1990). The area surrounding the mine was searched for continuation of the coal-bearing unit but no further exposures were noted.

Karmrakar Outcrop

Coal was reported near the village of Hatsik (fig. 2, pl. 1, N40° 51' by E43° 52'). No coal was found near this village and based on the coordinates it may be referring to the Maissian coal outcrop. A villager from Karmrakar (fig. 2) led us to a different outcrop 0.25 km northwest of Karmrakar along a small stream valley. He told us that his father used to burn this material but it contained a lot of ash. The outcrop occurs along the banks of a small stream flowing south along the western side of Karmrakar (pl. 1). The outcrop is about 30 m north of a small east-west road that crosses the stream. The outcrop consists of black, slightly carbonaceous shale with thin hard interbeds of sandstone and siltstone. The beds dip steeply to the north. At this location, the outcrop is about 10 m thick. Based on mapping of this unit, it is part of the black shale sequence that extends from northeast of the Maissian outcrop location (fig. 2, pl. 1) to northeast of Karmrakar.

A section of this unit (black shale sequence) was measured north of Karmrakar (pl. 1). At this location, the section is thicker and better exposed (Table 12, Appendix B). It consists mostly of black shale with thin interbeds of limestone and volcaniclastic sandstone and siltstone. No coal or definite carbonaceous shale was reported in the measured section location.

The Karmrakar outcrop is located near the top of the Eocene section and in angular continuity with known beds of Eocene age (pl. 1). Based on these relations, it is probably late Eocene in age.

Mets Sariyar Outcrop

Coal was reported near the Jajur railway station (N40° 53' by E43° 56') on the bank of the Arkhvali River (pl. 1). The outcrops were described as occurring on the southern limb of the Jajur anticline within material described as landslide deposits. One 0.5 m thick coal-bearing unit was described as a complex structure of thinly laminated sandstone, carbonaceous/argillaceous shale and coal. The USSR report suggests that these beds are similar to the coal-bearing units near Maissian (fig. 2) and are probably within the same stratigraphic horizon of the Eocene section.

A villager directed us to this outcrop which is located west of Mets Sariyar (fig. 2, N40° 53' 10.59" by E43° 55' 32.38"). The area had been excavated by backhoe along the east bank just below the confluence of two streams. The small remaining outcrop contained two lignite beds just above the confluence on the southwest bank of the northerly stream. A section was measured at this outcrop and reported in Table 11, Appendix B. This outcrop may not be in-situ due to block rotation from the strike-slip fault zone nearby (pl. 1).

Another small bed of vertically oriented lignite occurs in the western tributary upstream from the confluence outcrop. This lignite bed is similar to the ones at the measured section location but is in a different orientation. It appears to be more consistent with the surrounding Eocene units and therefore possibly undisturbed.

An additional outcrop of this deposit is located in the next large north-south drainage to the east (N40° 53' 23.14" by E43° 55' 56.12"). Only one seam, approximately 40 cm thick, of lignite is noted at this location. This bed contains abundant silt and sand with the upper 5 cm being laminated carbonaceous shale, similar to the measured section locality.

Based on mapping in this region, these beds appear to be within the Eocene section but may lie near or within a large strike-slip fault zone. The high degree of variability of bedding and the change of dips may suggest a small syncline but this may also be related to faulting.

Due to the uncertainty of this outcrop, age determination is questionable. These deposits are similar in characteristics to the Maissian and Karmrakar outcrops (pl. 1). The surrounding Eocene rocks are similar to those in other areas. Based on these relations, this outcrop is tentatively correlated to the black shale unit and assigned a late Eocene age.

Maissian Outcrop

Coal was reported 1.5 km northeast of Maissian village (fig. 2, N40° 52' by E43° 52'). In the USSR reports, the coal is described as brown, high-ash lignite. The report describes 5 lenticular beds of coal interbedded with clayey carbonaceous shale over an outcrop trend of 300 meters, including several exploration adits. The report describes the coals as confined to the middle part of the Miocene Jajur suite which angular-unconformably overlies the Cretaceous and middle Eocene deposits.

An outcrop was found along a stream below the confluence of a tributary stream and near a stock pond (pl. 1). It occurs as an eroded window through the younger lava and tuffs of the Jajur suite. This outcrop has been worked by backhoe equipment and several remnant adits are noted on both stream banks. We were informed that this outcrop was once worked by a local briquetting company. Coal was extracted and briquettes were made and sold in Gyumri (fig. 1). A local herder mentioned that the coal was mined by villagers from Maissian (fig. 2) several years ago and used as stove fuel. A single coal bed located at stream level is exposed along an east-west track for about 15 meters. Above the coal bed are brown and green claystone beds that are overlain by a series of interbedded yellow siltstone and claystone with minor sandstone. The yellow beds are oxidized and heavily fractured. The cliff has been affected by colluvial action due to the backhoe cut.

Five small pits were dug in an attempt to determine bedding attitude and bedding relations with the overlying units. The coal appears to be up to 20 cm thick and the contact with overlying beds is sharp. Two attitudes were measured, one from the coal bed and one in the overlying brown mudstone. The strike of these beds is essentially east-west with dips more than 70 degrees (pl. 1). An east-west orientated backhoe cut excavated downstream missed cutting the coal bed because it was stratigraphically lower than the coal beds. A north-south oriented trench would potentially reveal the nature of the coal outcrop. A section was not measured at this locality due to inaccessibility of the coal and the fractured and rotated nature of the upper yellow sandy units. Drilling north of the stream on the small hill may help determine the outcrop extent and stratigraphic position of the coal-bearing units.

The age control of the Maissian outcrop is poorly documented. This outcrop is physically correlated with deposits from other areas (Kharazian, 1990; E. Kharazian, 1998, personal communication) that have a faunal age of Messinian (upper Miocene). The strike and dip of the Maissian outcrop is similar to the Eocene units to the east and north of this locality. Upstream to the north past the confluence, similar yellow-colored deposits occur near the top of the Eocene section (pl. 1). The characteristics and attitude of bedding of the black shale unit in other localities examined in this study and the Maissian outcrop are similar. Based on these physical relations, the Maissian outcrop is herein correlated to these deposits and assigned a late Eocene age.

MAP INTERPRETATION (Plate 1)

For this study, a 1:25,000 scale geologic map (pl. 1) was produced to assess the stratigraphic and lateral relations of the coal-bearing strata. The topographic base map was digitized from 1:50,000 scale USSR topography maps by Mihran Aslanyan. Specific suites of rocks are not differentiated due to the limited time for field work. Other characteristic units are differentiated if they were useful for determining stratigraphic or structural relations.

CRETACEOUS UNITS

The Cretaceous ophiolite suite is mapped as undivided (Kmo, pl. 1). It is prominent in the Karmrakar area and commonly occurs at the lowest part of the upper plate of the major thrust faults. One small outcrop area and float material were mapped with the over-thrust block north of Mets Sariyar. This unit was not positively identified in the Jajur mine area.

The Cretaceous units are mapped as undivided marine rocks (Kmu, pl. 1). They included portions of the Sepasar and Gorgaran suites of Kharazian (1990). One subunit consists of green and white sandstone beds and was differentiated to aid in recognition of the Kms unit in other areas. These siliceous sandstone beds are fine- to coarse-grained, poorly sorted, and thin- to medium-bedded. They contain angular to subrounded grains of quartz with authigenic chlorite and abundant volcanic lithic fragments. In thin-section, the sandstone contains abundant feldspar, predominantly twinned plagioclase and zoned feldspar with inclusions of apatite and volcanic glass. Chert is the dominant cement but clay (possibly illite/smectite and/or kaolinite) is also common. The green sandstone unit varies in thickness but can be about 30 meters thick. Stratigraphically it occurs above a thick unit consisting of white, coarsely-crystalline limestone beds and below a thin unit consisting of purple, finely-crystalline limestone beds (fig. 3). Above the purple limestone unit, a series of dark green, chlorite-rich, altered ash beds and claystone is interbedded with tan tuffaceous siltstone and sandstone. This series of beds is well exposed north of Karmrakar near the strike and dip symbol with 23° dip (pl. 1).

A similar stratigraphic unit was mapped above the Jajur Mine area. The section present at this location is not as thick as the Karmrakar section and has been cut by several faults. Due to the faulting, this section at Jajur has repeated sections of green and white chlorite-rich, siliceous sandstone, purple limestone, tuffaceous siltstone, and chlorite-rich, altered ash beds and claystone (pl. 1). Petrographically they are similar in composition and texture to those describe north of Karmrakar (see above). Due to the physical character and petrographic similarity of these rocks above the Jajur Mine, they are correlated to the Kms and other units north of Karmrakar even though the ophiolite and white limestone units are not present at Jajur Mine location.

EOCENE UNITS

The Eocene section is mapped as undivided (Tvu, pl. 1) and includes portions of the Maralsar, Shirak, and Pambak suites of Kharazian (1990). Two units within the Shirak suite were differentiated (described in previous section), an andesitic lava sequence (Tva, pl. 1) and the black shale unit (Tbs, pl. 1). The andesitic lava sequence occurs near the middle of suite and serves as distinguishable marker bed. Locally, the black shale unit is coal-bearing and is mapped along an outcrop band from the Maissian coal outcrop to Mets Sariyar coal outcrop (pl. 1). It has also been tentatively mapped in the Jajur Mine area (see above). This unit locally contains slickensides and rotated bedding. It appears to have been affected by the thrusting of the Cretaceous section or by movement on the east-west trending strike-slip fault zone.

A paleosol is recognized and mapped in the study area (Tp, pl. 1). It occurs on the eroded surface of the tilted Eocene rocks and is preserved in most areas beneath the volcanic units mapped as Tv (pl. 1).

MIOCENE-PLIOCENE UNITS

The Miocene-Pliocene units in the study area are part of the Jajur suite (of Kharazian, 1990) and are mapped as undivided volcanic units (Tv). The andesitic ash-flow tuff and lava flows within the study area only occur in the Karmrakar and Lernut areas. They cover much of the higher elevations. Northeast of Karmrakar, this unit covers the top and southern side of a small hill (pl. 1). This unit apparently flowed over and draped the existing paleotopography.

QUATERNARY UNITS

The Quaternary units are mapped as several different units. Potentially the oldest

Quaternary unit in this area is the Shirak Basin lacustrine units (Qs, pl. 1; Kharazian, 1998, personal comm.). Only a small outcrop is exposed of this unit northeast of Maissian (pl. 1).

A series of alluvial valley filling events (Qal, pl. 1) are not differentiated from modern alluvium in the study area. There are probably multiple alluvial events (cut and fill) recorded within this unit and back-filled many of the exposed valleys.

An ash-flow tuff, probably from the Aragats volcanic field located southeast of the area, is mapped in the study area (Qvt, pl. 1). It is essentially flat-lying and apparently filled many of the lower paleovalleys after the deposition of much of the older Qal units.

STRUCTURE

Several thrust blocks were mapped in the study area. These blocks consist of Cretaceous aged rocks that have been thrusted over Eocene strata. The thrust plane is essentially flat and the blocks appear to be stacked in a Sevier-style thrust system. In several areas, the ophiolitic rocks occur above the thrust plane. Ophiolitic rocks are commonly associated with thrust faults throughout Armenia.

The coal-bearing strata at the Jajur Mine display evidence of thrusting (fig. 4). This thrusting has repeated some of the coal beds and appears to be on a much smaller scale than the regional thrusting events and maybe mimicking the larger thrust faults.The hills north of the Jajur Mine are mapped as Cretaceous units (pl. 1). These Cretaceous rocks have not been recognized at this location prior to this study but are mapped further to the north above the village of Bashgyukh (Kharazian, 1991). A zone of highly brecciated and oxidized material occurs in several areas below the Cretaceous rocks.

Along the road west of Bashgyukh (fig. 2), this brecciated material has been extracted by heavy equipment. Springs in this area are aligned at similar elevations and coincide with the brecciated zones. These relations, in addition to the petrographic and physical characters described above, were used to interpret a thrusted fault block of Cretaceous strata similar to ones noted north of Karmrakar and Mets Sariyar.

In the Mets Sariyar and Krashen areas, a wide zone of brecciated, rotated, and oxidized Eocene strata were mapped. Strata within the black shale unit (Tbs, pl. 1) west of Mets Sariyar contain slickensides and have indications of block rotation. This wide zone is interpreted as a large, east-west trending strike-slip fault zone. If correlation and continuation of the units at the Jajur mine with other strata of the black shale unit in the Karmrakar area are correct, then the sense of movement on this fault is left-lateral. However, the main sense of the larger strike-slip faults throughout Armenia is right-lateral.

Evidence of left-lateral movement maybe supported by the presence of Jajur suite rocks in the study area. The volcanic rocks of the Jajur suite are also reported north of the Amassia-Bandevan area (fig. 2; Kharazian, 1990) and north of a strike-slip fault mapped in the area (Kharazian, 1991). If the strike-slip fault at this location is related to the one near Mets Sariyar, then the volcanic rocks (Tv, pl. 1) of the Jajur suite in the Karmrakar-Lernut area were probably transported to this location by left-lateral movement along this fault system.

The study area reportedly contains several folds (Kharazian, 1990; E. Kharazian, 1998, personal communication). The fold axes are not mapped on the 1:50,000 scale geologic maps (Kharazian, 1991). The Eocene section appears to be folded with an apparent anticlinal structure observed north of Pokrashen (fig. 2, pl. 1) on both sides of Lernantsk Pass. The rocks in this location generally dip in opposite directions but are more chaotic on the south side of the pass where several orientations can be noted. The relations in this area may be related to the large strike-slip fault zone near Mets Sariyar (pl. 1).

In contrast, this study has been unable to clearly document the existence of folded strata in the study area. The Eocene section consistently trends east-west with steep dips to the north (50-75°). Reported thickness for the Eocene rocks are over 2100 m (Kharazian, 1990). This thick Eocene section and the repetition of bedding created by the large strike-slip fault near Mets Sariyar, suggest that folding is not necessary to explain the large outcrop areas shown on the geologic maps (Kharazian, 1990; pl. 1).

RECOMMENDATIONS FOR FURTHER WORK

The geology of the Shirak region is structural complex and rocks units are homogeneous in character. Soil development and the rolling topography limit geologic exposures. Because of these factors and the limited field work allotted for this study, several areas need further detailed study and evaluation.

CORRELATION OF UNITS

The correlation of the black shale sequence between Bandevan, Jajur, and areas to the south could be strengthened by additional chronologic information. Identification of the fossil material at Jajur needs further evaluation and could potentially provide valuable faunal control. The coal and black shale units need to be analyzed for pollen and other micro- and macrofauna that could be used to date these units. Leaf and woody material was found in the carbonaceous deposits at Bandevan. Further examination of this material would benefit age and correlation potential of these units. Due to the structural complexity of this region, the use of isotopic dating may be a better tool to delineate the structural complexities present in the study area.

MAPPING

The geologic mapping of the study area also needs further consideration. The limited time for field work did not allow for the detailed mapping necessary for understanding the complex structural history of the region. Further detailed mapping between Mets Sariyar and Jajur (pl. 1) would potentially reveal further critical structural relationships. Additional mapping north of Karmrakar towards Pokrashen (pl. 1) would show the orientation and movement of the thrusted Cretaceous blocks in this region. Mapping of this area may reveal the folded nature of the Eocene section on Lernantsk Pass and its relation to the Eocene section in the study area.

Additional mapping, especially towards the Bandevan area (fig. 2), may disclose the relations between the coal-bearing units of Jajur with those in other areas. The fault immediately north of the Bandevan deposits (fig. 2) maybe related to other faults farther to the south and needs evaluation.

Although additional field work is needed to determine the detailed correlations and relations in this complex area, this study did reveal that the Jajur mine site has the only thick, minable coal in the region. Some additional, local drilling to delineate the minable reserve is needed in order to re-open and continue the small Jajur Mine.

However, large scale exploratory drilling is not warranted in the Shirak region. If the coal deposits in the region are correlative, the thickest, best quality coal has been developed at the Jajur mine site, and it quickly thins and/or pinches out in all directions.

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Appendix A

The following measured sections were translated from Kharazian (1990) by Gaggik Papian and reworded by T. Dallegge. The sections are listed as translated and arranged into tabular format. The translation adds uncertainty to some of the descriptive units and many details were not available in the Kharazian paper but may exist in the yet-to-be translated original reports referenced below.

Late Cretaceous

Turonian - Coniacian

Amassia suite: Measured from the bottom to the top by E. Kharazian (1990). Suite constitutes the core of the Karmrakar anticline.

Table 1. Karmrakar anticline section

Unit #	Unit Description	Thickness (meters)
18	Basalt: brown gray and dark gray, almond shaped	23
17	Siliceous rocks: red brown, calcareous	2
16	Jasper: red, thinly laminated, fractured	3
15	Basalt: almond shaped	6
14	Conglomerate: coarsens upward	12
13	Basalt: dark greenish gray, almond shaped	20
12	Limestone: broken, jumbled, silicified, contains small peridotite body	6
11	Tuffites: greenish gray	8
10	Limestone: dark gray, weakly silicified, structureless	15
9	Basalt: dark gray, almond shape	25
8	Diabase: finely crystalline, broken by lens of serpentinite-like material	80
7	Limestone and diabase. Limestone: gray, dense, undulatory, slightly marbleized. Diabase: finely crystalline. Three sequences of limestone separated by diabase.	15
6	Diabase: greenish gray, fine crystalline	30
5	Andesitic basalt: dark gray, contains quartz carbonate veins	100
4	Carbonate rocks: brown, argillaceous	6
3	Diabase: light grayish green, finely crystalline, slightly silicified	12
2	Diabase: greenish gray, finely crystalline	25
1	Andesite: greenish dark gray	30
	Total thickness measured	418

Upper Coniacian

Sepasar suite: Near the villages of Krashen and Mets Sariyar the upper Coniacian deposits are exposed in the form of a narrow band from under the Santonian-Maastrichtian deposits (Kharazian, 1990). Hakobian (1978) measured the following section from the bottom to the top:

Table 2. Sepasar suite section near Mets Sariyar

Unit #	Unit Description	Thickness (meters)
4	Siltstone: reddish brown, calcareous	9
3	Marl interbedded with limestone and sandstone. Marl: greenish gray. Limestone: gray, arenaceous. Sandstone: greenish gray	23
2	Interbedded limestone and siltstone. Limestone: arenaceous. Siltstone: greenish gray, calcareous. Limestone: gray, contains fossil *Inoceramus*	25
1	Conglomerates fining upward to sandstone and siltstone. Conglomerate: arenaceous matrix, pebbles consist of limestone and intrusive and volcanogenic rocks. Sandstone: greenish gray. Siltstone: greenish gray. Fossils abundant: *Scaphites cf. Compressus d'Orb, Nairielia clifficilis d'Orb, Giroides cf. Tenelfus stol, Acteonella uchauxensis cossm, A. crassa (Drej.)*	8
	Total thickness measured	65

Santonian, Campanian, and Maastrichtian stages

Gorgaran suite: Mets Sariyar section as measured by Hakobian (1978) from the bottom to the top.

Table 3. Mets Sariyar Santonian-Maastrichtian section

Unit #	Unit Description	Thickness (meters)
6	Limestone: chestnut brown, thinly laminated, slightly arenaceous, contains fossil *Inoceramus*. In the Krashen river valley – occurrences of gigantic *Inoceramus, Ammonites,* and sea urchins	28
5	Limestone: gray, with marl partings	40
4	Limestone: light gray, slightly argillaceous, contains fossil occurrences of *Inoceramus* in the next valley over	26
3	Limestone: gray, thinly laminated	30
2	Interbedded arenaceous limestone and light gray limestone	11
1	Limestone: dark gray, thinly laminated, changes color upwards to gray and light gray, contains pelecypods	55
	Total measured thickness	190

In the upper part of the carbonate section, dated to Maastrichtian in the Krashen River valley, O.A. Sarkissian (1963) found small foraminifera: *Pseudotextularia, Globotruncana* (Kharazian, 1990).

Paleogene

lower Eocene

Maralsar suite: Veguni and Ptukhian (1967) measured a section on the northern limb of the Krashen-Mets Sariyar anticline (measured from the bottom to the top).

Table 4. Krashen-Mets Sariyar anticline section

Unit #	Unit Description	Thickness (meters)

3	Limestone: arenaceous, shaley. Limestone: dark gray, finely crystalline, argillaceous	15
2	Limestone: gray, finely crystalline, structureless	1
1	Limestone: brown, arenaceous, coarsely crystalline, brecciated	12
	Total measured thickness	28

The limestone of this unit consists of abundant cryptocrystalline calcite particles covered by opaque clayey particles (Kharazian, 1990). The units at this location have been correlated to the fauna-controlled lower Eocene rocks of the Sevan-Shirak synclinorium (Kharazian, 1990).

middle Eocene

Shirak suite: The measured section is exposed 1.5km north of the village of Mets Sariyar on the northern limb of the anticline. Measure from the bottom to the top by Veguni and Ptukhian (1967).

Table 5. Shirak suite section

Unit #	***Unit Description***	**Thickness (meters)**
50	Interbedded tuffaceous sandstone and siltstone. Tuffaceous sandstone: light green, fine-to-medium-grained. Tuffaceous siltstone: light green, fine-to-medium-grained.	70
49	Felsic tuff sheet	0.3
48	Interbedded tuffaceous sandstone and siltstone. Sandstone: greenish gray, fine-grained, laminated (5-7 cm thick). Siltstone: greenish gray, fine-grained, laminated (5-7 cm thick).	120
47	Intercalated beds of tuffaceous sandstone, porphyritic andesite, tuff, and limestone. Sandstone: green, medium-grained, laminated. Limestone: dark gray, occurs and thin beds.	60
46	Felsite-like tuff sheet: greenish gray	0.3
45	Tuffaceous sandstone: greenish gray, coarse-grained, friable	5
44	Breccia: tuffaceous cement, dense, clasts are greenish, 2-5 cm in diameter, and consist of tuffaceous sandstone, tuffaceous siltstone, and limestone, contains poorly preserved *Nummulites*, among which have been identified *N.uroniensis, N.gallensis,* commonly entirely ochered (iron-oxide stained)	10
43	Sandstone: gray, fine-grained, weakly argillaceous	10
42	Limestone: dark gray, coarsely crystalline, dense	0.5
41	Siltstone: green, dense, tuffaceous	6
40	Limestone: dark gray, coarsely crystalline, dense	3
39	Tuffaceous sandstone: gray, coarse-grained, friable	2.5
38	Limestone: coarsely crystalline, medium-bedded (15-20 cm thick), tuffaceous, contains chlorite	21
37	Tuffaceous sandstone: green, fine-grained, calcareous, dense, thinly bedded	45
36	Tuffaceous sandstone: greenish gray, medium-grained, dense, medium bedded (10-25 cm thick)	150
35	Tuffaceous sandstone with tuffaceous siltstone. Tuffaceous sandstone: fine-grained, laminated, in some places silicified, dense. Tuffaceous siltstone: greenish gray, occurs as partings in sandstone.	60
34	Tuffaceous sandstone: coarse-grained, dense	6
33	Tuff breccia: green, tuffaceous cement, dense, clasts consist of volcanogenic	25

Unit #	Unit Description	Thickness (meters)
	rocks	
32	Tuffaceous sandstone: gray, coarse-grained, thinly bedded, dense, contains hematite intercalations	50
31	Limestone: dark gray, finely crystalline, structureless	0.3
30	Tuffaceous sandstone: green, calcareous, thinly bedded, dense, fragmented	5
29	Limestone: finely crystalline, structureless	0.4
28	Tuffaceous sandstone: green, calcareous, thinly bedded, dense, fragmented	7
27	Tuffaceous sandstone: light gray, alternating beds of medium- and coarse-grained, dense, contains iron-oxide staining	20
26	Tuffaceous sandstone: gray, medium-grained, dense, laminated	30
25	Sandstone: calcareous, medium-bedded (15-25 cm thick), iron-oxide staining, some layers contain poorly preserved *Nummulites*, among which were identified: *N.atacicus, N.gallensis*	20
24	Interbedded tuffaceous sandstone and siltstone: Tuffaceous sandstone: green, fine-grained. Tuffaceous siltstone: green.	60
23	Porphyritic andesite sheet	5
22	Tuffaceous sandstone: light gray, fine-grained, dense, laminated	55
21	Tuffaceous sandstone: greenish gray, fine-grained, dense	10
20	Hydrothermally altered brown rock	1
19	Tuffaceous sandstone: light gray, medium-grained, dense	4
18	Tuff breccia: light green	30
17	Tuffaceous sandstone: light gray, medium-grained, dense, contains light green tuffaceous siltstone partings	48
16	Tuff breccia: greenish gray, tuffaceous cement, clasts are represented mainly by volcanogenic rocks	5
15	Interbedded tuffaceous sandstone. Tuffaceous sandstone: dark gray, medium-grained, slightly calcareous, dense, thinly bedded. Tuffaceous sandstone: gray, medium-grained, strongly fissured	15
14	Tuffaceous sandstone: dark gray, medium-grained, friable, strongly fissured, spheroidal	30
13	Tuffaceous sandstone: light gray, calcareous, dense, thinly bedded	5
12	Tuffaceous sandstone: gray, medium-grained, dense	10
11	Tuffaceous sandstone: grayish green, coarse-grained, fissured, friable	1.5
10	Tuffaceous sandstone: light gray, medium-grained, dense	1.5
9	Tuff breccia: green	28
8	Interbedded tuffaceous sandstone and siltstone. Tuffaceous sandstone: greenish gray, medium laminated (20-25 cm thick), dense. Tuffaceous siltstone: gray, thinly bedded	11
7	Tuff breccia: greenish gray, tuffaceous cement, dense; clasts composed of poorly preserved, small, volcanogenic rocks	10
6	Interbedded tuffaceous sandstone and calcareous sandstone: Tuffaceous sandstone: gray, medium-grained. Calcareous sandstone: gray, dense	22.5
5	Tuffaceous sandstone: light gray, fine- to medium-grained, dense, medium bedded (20-30 cm)	6.5
4	Interbedded gray, fine-grained, tuffaceous sandstone and tuffaceous siltstone	4
3	Tuffaceous sandstone: greenish gray, medium-grained	6
2	Tuffaceous sandstone: green, fine-grained, finely fragmented, argillaceous	15
1	Tuffaceous sandstone: dark gray, thinly bedded, fractured, fragmented, contains tuffaceous siltstone partings	10
	Total thickness measured	1080

Pambak suite: The measured section is well exposed on the west bank of Akhurian river, conformably overlying the Shirak suite. Starting from the gas station in Amassia, Kharazian (1990) measured the following section from the bottom to the top:

Table 6. Pambak suite section on Akhurian river

Unit #	Unit Description	Thickness (meters)
21	Hyaloandesite: hydrothermally altered (silicified), fragile	100
20	Hyaloandesites, black	120
19	Gravel and sandstone	45
18	Conglomerate: black-gray, clasts consist of gravel and larger fragments of lava-dark gray weathered andesite; pebble size 20 cm (diameter)	7
17	Andesite: gray, porphyritic, contains plagioclase phenocrysts	65
16	Siltstone: dark gray, calcareous, tuffaceous	12
15	Andesite: greenish gray, porphyritic	80
14	Siltstone: dark gray to black, calcareous, tuffaceous	15
13	Andesite: dense, unit weathers to cliffs	10
12	Siltstone: dark gray to black, calcareous, tuffaceous	8
11	Andesite: greenish light gray, foliation 352, 28°	10
10	Hyaloandesite: dark gray to black	5
9	Siltstone: calcareous	80
8	Interbedded sandstone and siltstone. Sandstone: fine grained, dense. Siltstone: calcareous. Beds oriented with dip azimuth 360, 30°	60
7	Andesite: light greenish gray, dense, finely crystalline, foliation 15, 28°	115.0
6	Siltstone: greenish gray, tuffaceous	60
5	Rhyodacite: dark gray	0.7
4	Siltstone and dacitic andesite. Siltstone: greenish gray, tuffaceous. Dacitic andesite occurs as a thin (15 cm) "layer"	5.5
3	Intercalated green-gray tuffaceous siltstone and thick andesitic lava flows	110
2	Siltstone: light green-gray, calcareous, tuffaceous	35
1	Intercalated andesite and siltstone. Andesite: light green, finely crystalline, foliation 15, 27°. Siltstone: tuffaceous	70
0	Shirak suite: tuffaceous siltstone.	Not measured
	Total thickness measured	1013

upper Oligocene – lower Miocene

Bandevan suite: Oligocene deposits are limited to erosion remains in cores of small synclines in the area near the village of Bandevan, and north of the Jajur train station (Kharazian, 1990). Measured from the bottom to the top by Aslanian and Rudziansky (1954).

Table 7. Bandevan suite section

Unit #	Unit Description	Thickness (meters)
20	Sandstone: light yellow to yellow-gray, medium-grained, contains clay and siltstone partings (0.05-0.1 m thick)	56
19	Siltstone: yellow	13
18	Sandstone: light yellow, medium-grained	5

Unit #	Unit Description	Thickness (meters)
17	Siltstone: dark gray, fine-grained	13
16	Sandstone: yellow, medium-grained	6
15	Siltstone: light yellow to yellow-gray, contains bituminous shale and marl partings (0.05-0.15 m thick)	82
14	Shales: dark gray, bituminous, contains clay and siltstone partings (0.05-0.2 m thick)	7
13	Sandstone: dark gray to yellow, medium-grained	8
12	Shale: dark gray, bituminous, contains siltstone partings (0.05-0.2 m thick)	7
11	Sandstone: yellow, coarse-grained	10
10	Shales: gray, bituminous, contains clay and sandstone partings (0.1-0.25 m thick)	5
9	Sandstone: yellow, coarse-grained	4
8	Shales: gray to dark gray, bituminous	4
7	Sandstone: yellow, coarse-grained	7
6	Shales: dark gray, bituminous, contains siltstone and argillaceous shale partings (0.1-0.25 m thick)	16
5	Yellow-gray and light yellow fine grained siltstone with a reddish tint	14
4	Shale: gray and light brown, contains limestone (finely crystalline) partings	22
3	Claystone: light gray, in some places yellow-gray, arenaceous, laminated, contains thin marl partings	13
2	Sandstone: yellow, fine-grained, argillaceous, dense, laminated	20
1	Conglomerate: yellow, sandy matrix, clasts consist of rounded and angular fragments of andesitic tuff, limestone, gabbro-diorite and porphyritic gabbro	20
	Total thickness measured	232

Neogene

<u>lower middle Pliocene</u>

Jajur suite: Aslanian (Aslanian and Rudziansky, 1954) has measured the following Section on the southern limb of Shirak range, near the village of Karmrakar from the bottom to the top.

Table 8. Jajur suite section

Unit #	Unit Description	Thickness (meters)
4	Andesite: pink-gray to violet-pink, porphyritic – phenocrysts of basaltic hornblende and plagioclase	30
3	Andesite: gray, contains large feldspar phenocrysts	50
2	Tuff breccia: clasts 3-4 cm in size, clay and ash matrix	20
1	Interbedded (0.8-1.2 m) yellow-gray claystone and carbonaceous shale.	25
	Total thickness measured	125

Appendix B

Bandevan-Amassia Measured Section (USGS1, fig. 2)

Date: August 28, 1998

Location: N40° 57' 49.58" E43° 48' 24.92" The locality is between the villages of Amassia and Bandevan in a small east-west tributary of the Akhurian River. The outcrop lies on the north-facing hill, south of the small creek. The base of the section is located in the creek bottom where a small ephemeral runoff valley from the hill enters the creek valley. This erosional cut is the only one on the hill and connects with the saddle above. The section was measured along the edges of this drainage valley.

Name and age of deposit: Bandevan suite. The beds are described as late Oligocene - early Miocene in age (Kharazian, 1990).

Attitude of bedding: The outcrop occurs on the north limb of an east-west trending syncline. The attitude of the beds is N88W 48SW. The other limb of the syncline is exposed on the southwestern side of the hill near the old fortress on the hill. Area of outcrop is very limited and occurs within axis of the syncline.

Other: Color scheme is from the abbreviated Geological Society of America's version of the Munsel color system. Most of this stratigraphic section has been removed by erosion. A lava flow now covers the upper and western portion of the outcrop area. Other units are noted below and above the units described in this section. No one area has a good exposure of entire section. Minor thin discontinuous coal seams are noted near the fault zone contact down stream from this location and presumably stratigraphically lower. On the east bank of the Akhurian River valley, the upper units of this outcrop can be seen. These upper units are predominantly siltstone. At the top of this section, a granule conglomerate was noted below the lava-capped hill.

Section measured from the bottom to the top

Table 9. Bandevan-Amassia measured section

Description of units	**Meters**
Remainder of section is covered by thick soil horizon - no further exposure.	
Unit 17 – Claystone: 10YR 5/2 yellowish-brown fresh surface, weakly calcareous, very laminated, shaley. Unit weathers to slopes.	9+
Unit 16 – Interbedded coaly siltstone, siltstone, claystone, and sandstone. Coaly siltstone: 5Y 7/2 light olive gray fresh surface with 10YR 5/4 moderate yellowish-brown coaly fragments of wood and plant debris (lignitic), calcareous, thin bedded. Siltstone: 10YR 8/6 pale yellowish-orange fresh surface, very calcareous, well indurated, structureless. Claystone: 5Y 7/2 yellowish-gray fresh, calcareous, structureless, blocky fracture. Sandstone: 10YR 6/6 dark yellowish-orange, fine-grained, moderately sorted, rounded, iron-oxide staining abundant, contains very small coaly fragments, calcareous, structureless to medium bedded. Sequence seems to repetitive in places with coaly siltstone then claystone, then siltstone, then sandstone. Entire unit weathers to slopes with 5Y 8/4 grayish yellow appearance. Contact sharp with 17 noted by a lack of carbonaceous material, increase in silt, and change to lighter color.	10.5
Unit 15 – Covered interval.	3.8
Unit 14 – Claystone: 5Y 7/2 yellowish-gray fresh surface, slightly calcareous, laminated, shaley, slightly blocky fracture. No coaly partings noted. Unit varies with some beds shaley and other structureless. Unit weathers to partially covered slopes with ledges.	4.5
Unit 13 – Covered interval.	10.5

Description of units	Meters
Unit 12 – Claystone: 5Y 7/2 yellowish-gray fresh surface, slightly calcareous, laminated, shaley, slightly blocky. No coaly partings noted. Unit varies with some beds shaley and other structureless. Unit weathers to partially covered slopes with ledges.	6
Unit 11 – Interbedded siltstone and claystone. Siltstone: 5Y 7/2 light olive gray fresh surface, slightly calcareous, structureless. Claystone: 5Y 8/4 grayish yellow fresh surface, non-calcareous, laminated, contains magnesium staining in partings. Interbeds vary in thickness with changes from claystone dominant to siltstone dominant. Unit weathers to slope. Contact partially covered with 12.	2.5
Unit 10 – Claystone: 5Y 7/2 yellowish-gray fresh surface, slightly calcareous, laminated, slightly shaley, slightly blocky fracture. No coaly partings noted. Unit weathers to partially covered slopes. Contact with 11 covered by colluvium.	4.3
Unit 9 – Claystone: 5Y 6/1 light olive gray fresh surface, very weakly contains occasional bright coaly fragment in partings, calcareous, well indurated, laminated, shaley. Unit contains occasional areas (lenticular) of very carbonaceous material - almost coal quality with very bright shiny fragments of wood and plant debris. Unit weathers to slopes and ledges. Outcrop only partially exposed from 2 to 8 meters.	22
Unit 8 – Carbonaceous mudstone: N3 dark gray fresh surface, contains bright coaly fragments of wood and plant debris, calcareous, well indurated, weakly laminated to structureless, shaley. At 1 meter unit becomes strongly laminated, very shaley, and contains more silt rich layers. Lamination is defined by alternating bands (~ equal thickness) of silt-rich slightly carbonaceous layers and dark carbonaceous layers. Unit weathers to ledges and covered slopes. Contact gradational with 9 noted by a lack of carbonaceous material, increase in silt, and change to lighter color.	13.8
Unit 7 – Siltstone: 5Y 6/1 light olive gray fresh surface, contains bright coaly fragments of wood and plant debris, calcareous, laminated. Unit weathers to slope. Contact sharp with 8.	3.5
Unit 6 – Carbonaceous mudstone: N3 dark gray fresh surface, has discontinuous (lenticular) areas of very dark color - 5YR 2/1 brownish black, contains bright coaly fragments of wood and plant debris, calcareous, well indurated, laminated, shaley. Unit weathers to ledges and covered slopes. Contact sharp with 5.	2.2
Unit 5 - Siltstone: 5Y 6/1 light olive gray fresh surface, contains bright coaly fragments of wood and plant debris, calcareous, laminated. Unit weathers to slope. Contact sharp with 6.	0.3
Unit 4 - Carbonaceous mudstone: N3 dark gray fresh surface, contains bright coaly fragments of wood and plant debris, calcareous, well indurated, laminated, shaley. Unit weathers to ledges and covered slopes. Contact sharp with 5.	1.9
Unit 3 - Siltstone: 5Y 6/1 light olive gray fresh surface, contains bright coaly fragments of wood and plant debris, calcareous, laminated. Unit weathers to slope. Contact sharp but undulatory with 4.	2.3
Unit 2 – late Oligocene - early Miocene deposits – Carbonaceous mudstone: N3 dark gray fresh surface, calcareous, well indurated, weakly laminated, shaley. At 2 meters bright coaly fragments of wood and plant debris are noted. Unit weathers to ledges and covered slopes. Unit has been post-depositionally deformed by nearby fault zone - bedding is disrupted and deformed. Contact with 3 covered by stream alluvium.	6
Unit 1 - Eocene deposits – granule conglomerate, tuff sandstone, and volcaniclastic sandstone. Units are highly fractured and bedding has been distorted. These units may be within the fault zone immediately north of this location. Contact is covered with 2.	not measure d
Total thickness measured	**103.1**

Jajur Coal Mine Measured Section (USGS2, pl. 1)

Date: September 15, 1998

Location: N40° 55' 55.34" by E43° 57' 17.80" The locality is at the northeast end of the excavated pit (currently). The section starts in a small pit dug to expose the #2 coal seam. Section proceeds up and to the left (SW). Some parts of the pit scrap where not measurable due to access problems. The section then begins again above pit cliff with units 13 through 16 measured at southeast corner of pit where the thrust fault is exposed. The section transfer back to the northeast at top of green claystone unit and resumes up through the loosely consolidated upper yellow section. Section transfers south about 5 meters along slope until two tuffaceous siltstone beds of unit 18 begin to pinch out and begins again at upper tuffaceous siltstone bed in unit 18. Section again transfers further south to a small ledge projection past the contorted and folded beds and begins with more of unit 23 exposed at this location. Unit 12 is not accessible due to cliff exposure and an assumed thickness of 2 meters is reported.

Name and age of deposit: This unit has been correlated with units of the Bandevan and Dilijan suites (Kharazian, 1990). The beds are described as late Eocene to possible Pliocene in age but this is disputed.

Attitude of bedding: The outcrop occurs in what has been described as the Jajur syncline. The attitude of the beds is N32E 30NW. Area of outcrop is very limited and occurs primarily where the open pit mining is currently underway. Previous drilling in the area has discovered coal to the north and northwest. The section is repeated once by a thrust fault that moved the section from the NW or W over the top of the same section. The fault is exposed well in the mine and shows drag folding on leading edge of thrust.

Other: Color scheme is from the abbreviated Geological Society of America's version of the Munsel color system. No unit weathering profile is discussed due to the artificial nature of exposure.

Section measured from the bottom to the top

Table 10. Jajur Mine measured section

Description of units	**Meters**
Unit 26 – Tuffaceous silty claystone: 5Y 8/1 yellowish-gray fresh surface, non-calcareous, weakly laminated, slightly shaley, contains occasional mollusk fragments. Rest of unit removed by bulldozer cut.	0.6 +
Unit 25 – Interbedded tuffaceous siltstone, shaley claystone, and silty claystone. Tuffaceous siltstone: 5Y 8/1 yellowish-gray fresh surface, non-calcareous, weakly laminated, slightly shaley. Shaley claystone: 10YR 6/4 orange yellowish-brown fresh surface, carbonaceous, calcareous, wavy laminated bedded – weathers paper-thin. Silty claystone: 10YR 6/4 orange yellowish-brown both surfaces, calcareous, laminated, shaley. Silty claystone is dominant rock type with tuffaceous siltstone occurring as basal 15 cm and the shaley claystone as interbeds 2-3 cm thick. Mollusk fragments occur in some beds. Unit contains thin (<1 cm) lignite lenses similar to 24. Contact sharp with 26.	1.4
Unit 24 – Lignite: 10YR 2/2 dusky yellowish-brown fresh surface, contains abundant clay and silt, laminated. Contact sharp with 25.	0.1 to 0.2
Unit 23 – Tuffaceous silty claystone: 5Y 8/1 yellowish-gray fresh surface, non-calcareous, weakly laminated, slightly shaley, contains occasional mollusk fragments - looks like small pelecypods. Fossils are noted 30 cm from base and become more abundant in upper beds. Carbonized plant debris noted in upper 15 cm. Contact sharp with 24.	1.1
Unit 22 – Lignite: 10YR 2/2 dusky yellowish-brown fresh surface, contains abundant clay and silt, laminated. Contact sharp with 23.	0.08
Unit 21 – Shaley claystone: 10YR 6/4 orange yellowish-brown fresh surface, contains abundant carbonized plant debris, calcareous, wavy laminated bedded. Unit weathers to paper-thin plates. Contact sharp with 22.	0.12
Unit 20 – Claystone: 10YR 8/2 very pale orange fresh surface, tuffaceous, contains slickenside surfaces, very calcareous, wavy laminated bedding. Contact sharp with 21.	0.2
Unit 19 – Silty claystone: 10YR 6/4 orange yellowish-brown both surfaces, calcareous, laminated, shaley. Contact sharp with 20.	0.7

Description of units	**Meters**
Unit 18 – Silty claystone and tuffaceous siltstone. Silty claystone: 10YR 6/4 orange yellowish-brown fresh surface, weakly calcareous, laminated, shaley. Tuffaceous siltstone: 5Y 8/1 yellowish-gray fresh surface, structureless. Two beds of tuffaceous siltstone occur at 1.4 m (8 cm thick) and 1.75 m (4 cm) from base. Contact sharp with 19.	1.9
Unit 17 – Siltstone: 10YR 8/5 pale yellowish-orange fresh surface, very calcareous, nodular, weakly lenticular to trough cross-bedded. Unit is fractured with fractures filled by calcite. Contact sharp with 18.	0.45
Unit 16 – Claystone: 5Y 3/2 olive gray fresh surface (moist), calcareous, laminated, shaley. Contact undulatory and scoured by 17.	3.0
Unit 15 – Claystone: 10Y 8/2 pale greenish-yellow fresh surface, fracture surfaces oxidize to 10YR 6/6 dusky yellowish-orange, very calcareous, structureless, blocky fracture. Contact gradational with 16 noted by a color and structural change.	1.3
Unit 14 – Tuffaceous claystone: N7 light gray fresh surface, weakly calcareous, laminated - define by thin layers of tuffaceous material, slightly wavy bedded. Contact gradational with 15 noted by loss of tuffaceous material.	0.2
Unit 13 – Siltstone with tuffaceous claystone. Siltstone: 5Y 7/2 yellowish-gray fresh surface, calcareous, contains occasional carbonized plant debris, structureless, contains occasional mollusk fragment. Tuffaceous claystone: 5Y 8/1 yellowish-gray fresh surface, non-calcareous, structureless, appears to be altered tuff bed. Tuffaceous claystone occurs as a 60 cm bed 1.4 meters from the base. Amount of plant debris in beds varies from none to abundant. Unit appears weakly medium-bedded. Contact sharp with 14.	8.8
Unit 12 – Siltstone: 5Y 7/2 yellowish-gray fresh surface, contains abundant gastropods – planispiral and semi-planispiral varieties - small less then 5 mm maximum, very calcareous, laminated, very shaley. Fossils have mud-filled cavities. Unit is last prominent ledge at top of pit. Contact covered with 13 and difficult to obtain due to colluvial action of upper units. True thickness of this unit unobtainable due to steep cliff exposure from open pit. Sample #980915C of siltstone with gastropods.	~2
Unit 11 – Argillaceous tuffaceous siltstone fining upwards into silty claystone. Argillaceous tuffaceous siltstone: 10YR 4/2 dark yellowish-brown fresh surface, contains small pieces of gastropods, very calcareous, sparkles - has abundant iridescent minerals. Silty claystone: 10YR 5/2 moderate yellowish-brown fresh surface, contains some small pieces of carbonized fragments of wood and plant debris, calcareous, weakly laminated, shaley, no gastropod fragments noted in this unit. Unit fines to silty claystone 1.1 m from base. Contact sharp with 12.	2.6
Unit 10 – Coal, #5 bed: N1 black fresh surface, shiny, good cleat development, Contact gradational with 11 noted by mixed rock types from unit 10 and 11.	0.35
Unit 9 - Silty claystone grading into carbonaceous mudstone. Silty claystone: 5Y 4/2 moderate olive gray fresh surface, contains gastropods - planispiral and semi-planispiral varieties - small less then 5 mm maximum, contains carbonized fragments of wood and plant debris, not calcareous, moderately indurated, laminated, shaley. Carbonaceous mudstone: 5Y 2/1 olive black fresh surface, laminated, very shaley. Fossils occur in partings and have mud-filled cavities. Fossils very abundant at top of unit near contact. Unit grades to carbonaceous mudstone 5 cm from top. Unit contains thin (<1 cm thick) lenticular seams of coal like unit 8 and black shale. Unit forms prominent ledge in pit. Contact gradational with 10 noted by decrease in silt and clay.	1.05
Unit 8 – coal, #4 bed grading to carbonaceous mudstone. Coal: N1 black fresh surface, shiny, good cleat development, contains silt and clay. Carbonaceous mudstone: 5Y 2/1 olive black fresh surface, laminated, shaley. Coal grades into carbonaceous mudstone at 15 cm from base. Contact gradational with 9 noted by lack of carbonaceous material.	0.4

Description of units	Meters
Unit 7 - Silty claystone grading into carbonaceous mudstone. Silty claystone: 10YR 5/2 moderate yellowish brown fresh surface, contains abundant gastropods – planispiral and semi-planispiral varieties – small less then 5 mm maximum, contains abundant carbonized fragments of wood and plant debris, non calcareous, laminated, shaley. Carbonaceous mudstone: 5Y 2/1 olive black fresh surface, laminated, very shaley. Fossils occur in partings and have mud-filled cavities. Unit grades to carbonaceous mudstone 10 cm from top. Contact gradational with 8 noted by decrease in silt and clay content. Sample #9808915B of silty claystone with gastropods.	0.4
Unit 6 – Coal, #3 bed: N1 black fresh surface, shiny, good cleat development, contains nodules and lenses (up to 10 cm thick and 80 cm long) of very dense, fine-grained sooty-like material (5y 2/1 olive black). Nodule and lens layer occurs 4-6 cm above base. Contact gradational with 7 noted by mixed rock types from unit 6 and 7.	0.4
Unit 5 - Silty claystone: 5Y 4/2 moderate olive gray fresh surface, contains abundant gastropods – planispiral and semi-planispiral varieties - small less then 5 mm (diameter) maximum, contains carbonized fragments of wood and plant debris, not calcareous, moderately indurated, laminated, shaley. Fossils occur in partings and have mud-filled cavities. Fossils very abundant at top of unit near contact. Unit forms first prominent ledge in pit. Contact sharp with 6. Sample #980915A of claystone with gastropods.	0.75
Unit 4 – Siltstone: banded N6 medium light gray and N5 medium gray fresh surface, calcareous, laminated to planar-tabular thin-bedded, soft-sediment deformed. Entire unit is very undulatory and pinches out in places. Contact gradational with 5 due to reworked upper surface of unit.	0.08
Unit 3 - Silty claystone: 5Y 3/2 olive gray fresh surface, 5Y 5/2 light olive gray (dry), very calcareous, laminated, slightly shaley. Unit contains thin (<1 cm thick) lenticular seams of coal like unit 1 and black shale. Contact sharp and undulatory with 4.	1.5
Unit 2 – Claystone: 5Y 3/2 olive gray fresh surface (moist), calcareous, laminated. Contact gradational with 3 noted by increase in silt content.	1.5
Unit 1 – Coal, #2 bed: N2 grayish-black fresh surface, shiny, good cleat development, contains silt and clay (noted at other locations). Contact gradational with 2 noted by mixed rock types from unit 1 and 2.	not measure d
Total thickness measured	**30.93**

Mets Sariyar Section (USGS3, pl. 1)

Date: September 2, 1998

Location: N40° 53' 10.59" by E43° 55' 32.38" The locality occurs along a cutbank of a small stream near the junction of two streams. The outcrop is on the north side of a small peninsula of land between the two streams, upstream from the confluence.

Name and age of deposit: Correlated to the black shale sequence of this report (Tbs, pl. 1). The units are presumably late Eocene in age?

Attitude of bedding: The attitude of the beds is N68E 50SE measured from the unit 3. Area of outcrop is very limited.

Other: Color scheme is from the abbreviated Geological Society of America's version of the Munsel color system.

Section measured from the bottom to the top

Table 11. Mets Sariyar measured section

Description of units	**Meters**
Unit 8 - Sandstone: 5Y 6/2 yellowish-gray fresh surface, fine-grained, poorly sorted, angular to subrounded, volcaniclastic, contains abundant mafic minerals, calcareous, nodular and structureless. Unit weathers to ledge.	0.8+
Unit 7 - Sandstone: 5Y 6/6 moderate yellow fresh surface, medium-grained, poorly sorted, angular to subrounded, calcareous, contains some pieces of transported lignite, laminated. Unit weathers to slope. Contact sharp with 8.	0.11
Unit 6 - Argillaceous siltstone: 5Y 6/4 dusky yellow fresh surface, changes to 5Y 7/2 yellowish-gray, calcareous, structureless. Unit weathers to slope. Contact sharp with 7.	0.25
Unit 5 - Lignite: 10YR 2/2 dusky yellowish-brown, contains areas of abundant clay, wavy laminated, pinches out into green claystone of 4 to the east, appears to thicken to west. Unit weathers to small ledge. Contact sharp with 6.	0-0.18
Unit 4 - Claystone: 10Y 5/4 light olive fresh surface, calcareous, structureless, slightly blocky fracture with fractures filled by calcite. Unit weathers to slope. Contact sharp with 5.	1.65
Unit 3 - Lignite: 5YR 2/1 brownish-black fresh surface, areas of darker color, thinly laminated, wavy, pinches out into green claystone of 2 to the east. Unit weathers to small ledge. Contact sharp with 4.	0-0.03
Unit 2 – Claystone: 10YR 6/5 moderate yellowish-brown fresh surface at base grades to 5Y 5/2 light olive gray fresh surface near top, brown portion calcareous – green is not, structureless, blocky fracture. Unit weathers to slope. Contact sharp with 3.	0.7
Unit 1 - Granule conglomerate: 5Y 6/4 dusky yellow fresh surface, clast supported, calcareous, contains limestone pebbles, lenticular, single bed. Unit weathers to ledge. Contact sharp with 2.	0.4
Total thickness measured	**4.12**

A backhoe-cut is exposed across and down stream about 15 meters. Some thin beds of coal were noted. Also coal fragments (lignite) were observed in scrap pile. Looks like most of coal has been removed from the outcrop. Another small outcrop of lignite occurs in western stream about 150 meters upstream.

Karmrakar Section (USGS4, pl. 1)

Date: September 16, 1998

Location: N40° 52' 37.58" by E43° 53' 45.41" The locality is north of Karmrakar village in second north-south drainage (counting from east), one with the limestone breccia at top of stream. The section starts at an interbedded siltstone and limestone near mouth of tributary. Section proceeds up drainage crossing the drainage many times. Section is very difficult to measure along here with much of it covered or difficult to access. This area may also be affected by the nearby thrust - other drainages show signs of shearing.

Name and age of deposit: Herein named the black shale sequence with this location being the type section. This sequence is a subunit of the Shirak Suite of Kharazian (1990). Based on stratigraphic position, the beds appear to be late Eocene in age.

Attitude of bedding: The outcrop occurs near the top of the Eocene section. The attitude of the beds is N28E 50NW on a sequence of interbedded claystone and volcaniclastic siltstone up near top of section. Area of outcrop is limited to only minor exposures along stream banks.

Other: Color scheme is from the abbreviated Geological Society of America's version of the Munsel color system. Artur Martirosyan and Gaggik Papian assisted in measurement of the section.

Carbonaceous material was difficult to determine. The villagers report burning rock from an outcrop northwest of the village but they remarked that it created a lot of ash.

Section measured from the bottom to the top

Table 12. Karmrakar measured section

Description of units	**Meters**
Thick soil horizon and alluvium - no further exposure	
Unit 29 – Claystone: N2 grayish-black fresh surface, weakly calcareous, wavy and shiny surfaces containing slickensides that have white streaks on them, structureless. Unit weathers to slope.	2+
Unit 28 – Volcaniclastic siltstone: 5Y 7/4 yellowish-gray fresh surface, mafic minerals abundant, calcareous, single bed. Unit weathers to ledge. Contact sharp with 29.	1.2
Unit 27 – Claystone: N2 grayish-black fresh surface, weakly calcareous, wavy and shiny surfaces containing slickensides, structureless. Unit weathers to slope. Contact sharp with 28.	1.5
Unit 26 – Volcaniclastic siltstone: 5Y 7/4 yellowish-gray fresh surface, mafic minerals predominantly, arenaceous – fine-grained sand (biotite and mafic minerals), calcareous, single bed. Unit weathers to ledge. Contact sharp with 27.	0.15
Unit 25 – Claystone: N2 grayish-black fresh surface, weakly calcareous, wavy and shiny surfaces containing slickensides, structureless. Unit weathers to slope. Contact sharp with 26.	5.05
Unit 24 – Volcaniclastic sandstone: 5G 5/1 greenish-gray fresh surface, coarse-grained, poorly sorted, subangular, biotite and mafic minerals abundant, very calcareous, planar-tabular thin-bedded. Unit weathers to ledge. Contact sharp with 25.	0.3
Unit 23 – Claystone: N2 grayish-black fresh surface, weakly calcareous, wavy and shiny surfaces containing slickensides, structureless. Unit weathers to slope. Contact sharp with 24.	1.15
Unit 22 – Limestone: 5YR 4/3 moderate brown fresh surface, finely crystalline, lenticular and discontinuous. Unit contains fractures filled with calcite. Unit weathers to ledge. Contact sharp with 23.	0.18
Unit 21 – Claystone: N2 grayish-black fresh surface, weakly calcareous, wavy and shiny surfaces containing slickensides, structureless. Unit weathers to slope. Contact sharp with 22.	4.5
Unit 20 – Fossiliferous limestone breccia: 5Y 7/1 yellowish-gray both surfaces, pebble to boulder clasts consist of limestone with some claystone and other rock types noted, clast supported, contains fossils or fragments of crinoids, corals, brachiopods - *Spirifer sp.*, gastropods, pelecypods, possible sponges or belemnites(?), coarsely crystalline, slightly recrystallized. Unit weathers away from slope to make large outcrop. Contact covered with 21.	5.8
Unit 19 – Covered interval.	6.1
Unit 18 – Claystone and with interbeds of volcaniclastic sandstone and volcaniclastic siltstone. Claystone: 5Y 5/1 olive gray fresh surface, magnesium staining common in partings, calcareous, weakly laminated, fractures into little pieces. Volcaniclastic sandstone: 5G 5/1 greenish-gray fresh surface, fine-grained, well sorted, subangular, biotite and mafic minerals abundant, very calcareous, structureless. Volcaniclastic siltstone: 5G 5/1 greenish-gray fresh surface, mafic minerals abundant, very calcareous, structureless. Interbeds are 1-5 cm thick and minor in occurrence. Unit contains fractures filled with calcite. Unit weathers to slope.	9.5
Unit 17 – Volcaniclastic sandstone: 5G 5/1 greenish-gray fresh surface, fine-grained, well sorted, subangular, biotite and mafic minerals abundant, very calcareous, planar-tabular thin-bedded. Unit weathers to ledge. Contact sharp with 18.	0.45

Description of units	**Meters**
Unit 16 – Claystone: 5Y 5/1 olive gray fresh surface, magnesium staining common in partings, calcareous, weakly laminated, fractures into little pieces. Unit weathers to smooth hard slope. Contact sharp with 17.	0.6
Unit 15 – Volcaniclastic sandstone: 5G 5/1 greenish-gray fresh surface, fine-grained, well sorted, subangular, biotite and mafic minerals abundant, very calcareous, planar-tabular thin-bedded. Unit weathers to ledge. Contact sharp with 16.	0.02
Unit 14 – Claystone: 5Y 5/1 olive gray fresh surface, magnesium staining common in partings, calcareous, weakly laminated, fractures into little pieces. Unit weathers to smooth hard slope. Contact sharp with 15.	0.5
Unit 13 – Volcaniclastic sandstone: 5G 5/1 greenish-gray fresh surface, fine-grained, well sorted, subangular, biotite and mafic minerals abundant, very calcareous, planar-tabular thin-bedded. Unit becomes shaley near top. Unit weathers to ledge. Contact gradational with 14 noted by mixing of unit rock types.	0.1
Unit 12 – Claystone: 5Y 5/1 olive gray fresh surface, magnesium staining common in partings, calcareous, weakly laminated. Unit weathers to smooth slope. Contact sharp with 13.	1.85
Unit 11 – Covered interval	9.0
Unit 10 – Claystone: 5Y 6/1 light olive gray fresh surface, calcareous, weakly thin bedded - defined by thin (<2-3 mm) light tan colored beds. Unit weathers to smooth hard slope.	1.1
Unit 9 – Covered interval	3.2
Unit 8 – Claystone: 5Y 4/2 light olive gray fresh surface, non-calcareous, weakly shaley. Unit contains yellow oxidized staining in partings. Unit weathers to loose slope.	1.5
Unit 7 – Covered interval	3.0
Unit 6 – Interbedded limestone and siltstone. Limestone: N5 medium gray fresh surface, finely crystalline, fractured. Siltstone: 5Y 6/2 dusky yellow fresh surface, very calcareous, weakly laminate. Limestone occurs as 10-40 cm beds and siltstone occurs as 5-10cm beds. Limestone 60% of unit. Unit is thin- to medium-bedded. Unit weathers to ledges and slopes.	2.5
Unit 5 – Siltstone: 10Y 5/2 pale olive fresh surface, slightly argillaceous, very calcareous, structureless, blocky fracture. Contact sharp with 6.	1.7
Unit 4 – Siltstone: 5Y 5/2 light olive gray fresh surface, very calcareous, smells slightly of sulfur, contains rare partially carbonized plant material, contains round and disc shaped reddish-orange oxidation spots (~ 1cm in diameter), structureless, blocky fracture. Unit weathers to break in slope. Contact gradational with 5 due to apparent lose of carbonized material.	1.5
Unit 3 – Claystone: 5Y 4/2 light olive gray fresh surface, slightly silty, calcareous, structureless. At 3.7 m unit becomes silty and blocky. At 6.6 m changes color to 5Y 6/2 yellowish-gray fresh surface, very calcareous, structureless, blocky fracture. Unit weathers to smooth hard slope. Contact gradational with 4 noted by increase in silt content.	9.4
Unit 2 - Silty claystone: 10YR 5/3 moderate yellowish-brown fresh surface (moist), very calcareous, structureless. At 4.5 meters color changes to 10YR 6/4 grayish-orange. At 6 m have silt-filled casts of worm(?) burrows. Unit weathers to smooth hard slope. Contact gradational with 3 noted by a color change.	12
Unit 1 – Siltstone: 10YR 7/6 grayish-orange fresh surface, slightly arenaceous, very calcareous, well indurated, wavy thin- to medium-bedded, fractured and jointed. Unit weathers to ledge. Contact with 2 covered by alluvium.	Not measured
Total thickness measured	**85.85**

Figure 1 Index map of Armenia showing locations of major solid fuel deposits. Location of the Shirak study area (white striped area) and the area of figure 2 are also noted (solid box). Adapted and modified from Pierce and others (1994).

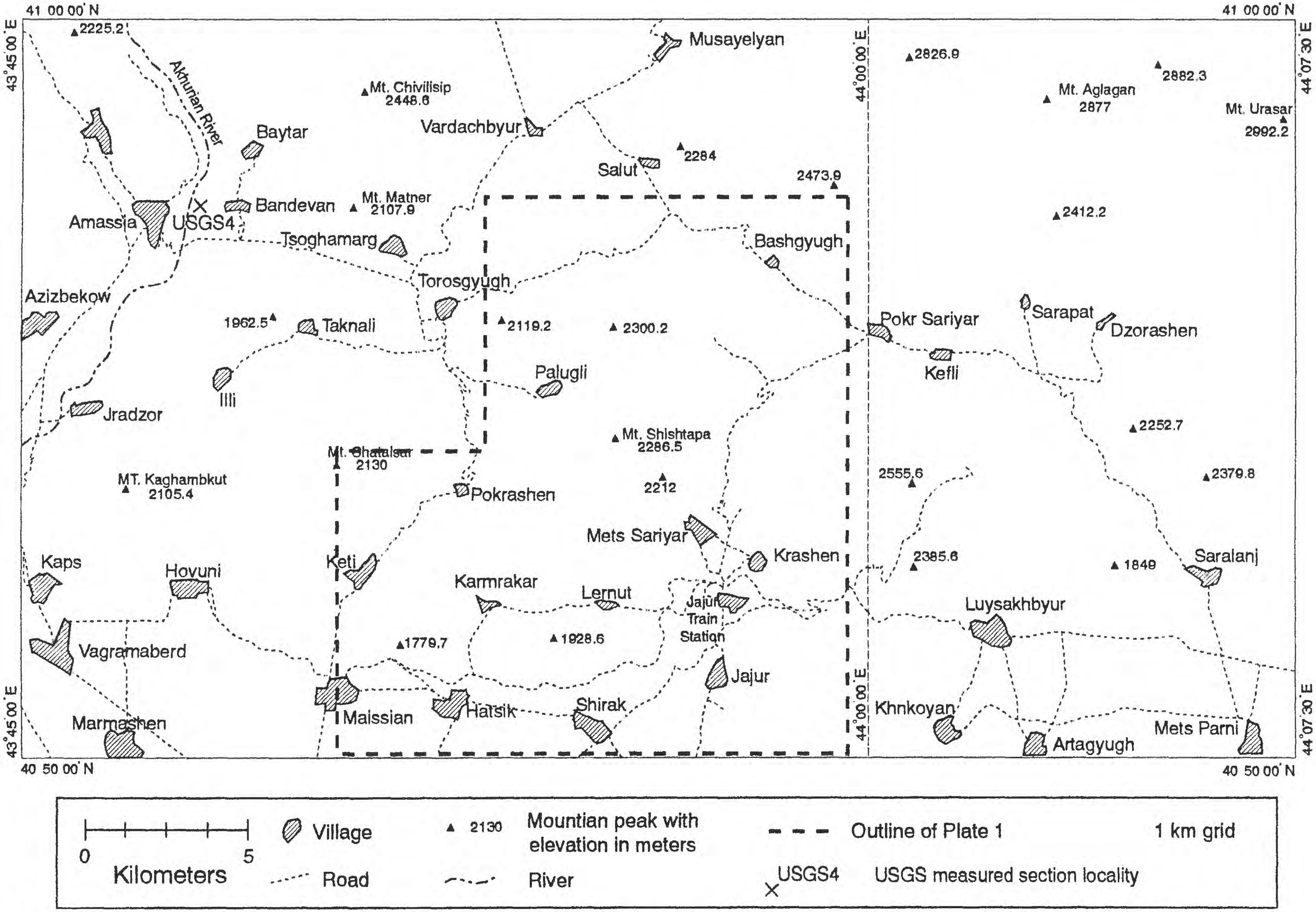
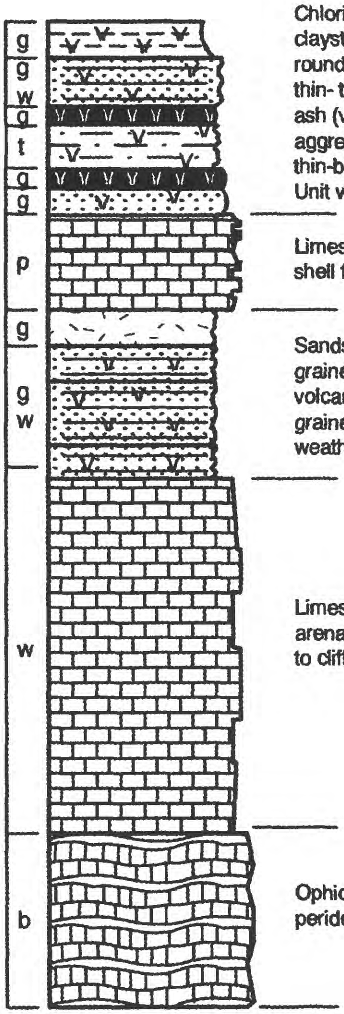


Figure 2 Index map showing regional areas of the Shirak region. Location of index map is shown on fig. 1. Base map digitized by Mihran Aslanyan.

Generalized Stratigraphic Section North of Karmrakar



Chlorite-rich series of interbedded sandstone, altered ash, tuffaceous siltstone, and claystone. Sandstone: white with green spots, fine- to medium-grained, subangular to rounded, contains glauconite and volcanic lithic fragments, carbonate cement. weakly thin- to medium-bedded, contains foraminifera (numulites), echinoderms, coral. Altered ash (vitric tuff): dark green, dacitic, dense, vitric, contains silt-sized grains of tuff aggregates. Tuffaceous siltstone: tan to light green, contains glass and tuff clasts, weakly thin-bedded. Claystone: dark green, waxy surface, contains ashy material, structureless. Unit weathers to soil covered slopes.

Limestone: light to dark purple, fine to coarsely crystalline, arenaceous, contains small shell fragments of microfauna. Unit weathers to ridge.

Sandstone and ash-flow tuff: Sandstone: green and white spotted, fine- to coarse-grained, angular to subrounded, siliceous (chert and clay cements), contains abundant volcanic lithic fragments, chlorite-rich, thin- to medium-bedded. Ash-flow tuff: green, fine-grained, dense, chlorite-rich, slightly porphyritic with plagioclase phenocrysts. Unit weathers to slopes.

Limestone: white to light pink, coarsely crystalline, partially recrystallized, slightly arenaceous in places, contains relic fossil forms, medium- to thick-bedded. Unit weathers to cliffs.

Ophiolite complex: black to white, black and green spotted, ultra-mafic gabbro and peridotite, coarsely crystalline, equigranular. Unit weathers to rocky outcrop.

Thickness not to scale

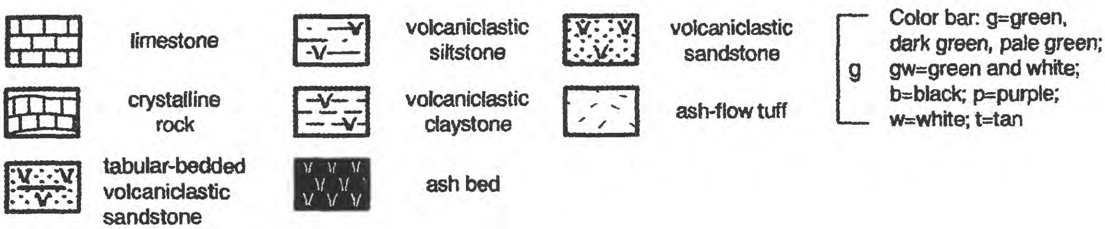
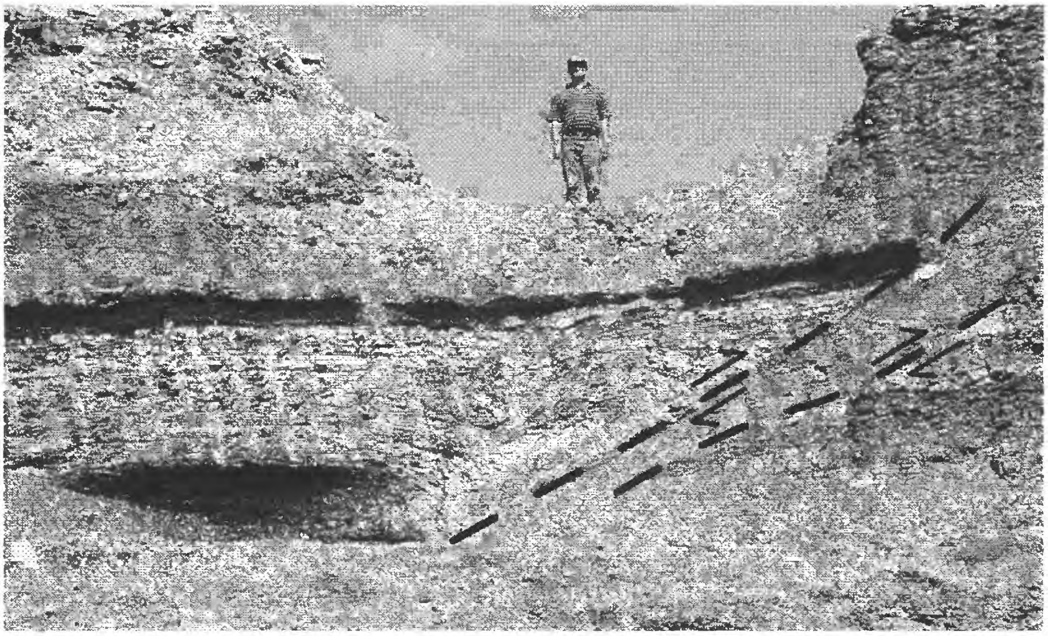


Figure 3 Generalized stratigraphic column of the Cretaceous section north of Karmrakar village. Some descriptive data from petrographic identification.

A)



B)

Figure 4 A) Small thrust fault at the Jajur Mine. Coal beds 3 (just left of picture) through 5 are repeated in this section. Note drag folding and thin slice of mudstone that occurs along the thrust plane. Person is ~ 1.5 meters tall for scale. B) Photo of eastern pit exposure. Coal bed 2 just below ground level in a hole at the back of the pit. Location of photo A is up and around the corner (top left of photo).