GEOLOGIC MAP OF THE NOR AREVIK COAL SITE, SOUTHERN ARMENIA

By

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INTRODUCTION

Purpose and Scope

The U.S. Geological Survey (USGS) signed a Participating Agency Service Agreement (PASA) with the U.S. Agency for International Development (USAID) to provide technical assistance to the Newly Independent States of the former Soviet Union to promote private-sector investments in the development of petroleum, natural gas, and coal resources. As part of this agreement, the USGS provided assistance to the Republic of Armenia in assessing the country's coal potential. This assistance involved regional reconnaissance, exploration drilling, geochemical analyses, and resource calculations. Coal is known to be present at 12 localities in Armenia, and an evaluation of each coal site contributed to a collective resource assessment for the country. Accordingly, an evaluation of the Nor Arevik coal site was conducted during the late spring of 1999.

Location

The Nor Arevik coal site is located in southernmost Armenia, north of the town of Megri (also spelled Megry or Meghri). Megri has a population of about 5,000 people and is about an 8-hour drive from Yerevan, the capital of Armenia (fig.1). The coal site (fig. 2) can be reached by driving north from Megri for about 15 km along the paved highway that parallels the south-flowing Megri River, and then proceeding southwest for about another 0.5 km on a steep dirt road that accesses several small farm houses with the collective place name of Khavot, an Armenian word meaning "rich in grapes." The coal site is small, covering only about 25 ha (1 ha=100 m by 100 m, or 10,000 m^2). Surface elevations range from approximately

Figure 1. Location map showing major cities, roads, and the location of the Nor Arevik coal site.

1,400 to 1,500 m above sea level. The nearest railroad runs east-west parallel to the Armenian-Iranian border, which is about 3 km south of Megri. However, this line, which connects Yerevan and Baku, has not functioned since the beginning of the conflict between Armenia and Azerbaijan.

Previous Geologic Studies

The first mention of the Nor Arevik coal site was in a report of a geologic survey of the Megri region conducted in 1869. This report noted the presence of one bed of com bustible shale (defined in a following section of our report) 0.40 m thick. A later report, published in 1917, mentioned the occurrence of coal as well as combustible shale in the Megri region, but no specific area was identified. In 1932, a geologist assigned to a nearby copper mine became interested in the coal site. As a result, the geology was mapped, exploration trenches were cut, sam ples of coal were collected for chemical analyses, and a report was supposedly written. This worker described two coal beds, 0.20 and 0.90 m thick. Unfortunately, chemical analyses were never made, and the report and geologic map have apparently been lost. In 1934, another geologist examined the coal site and concluded that it had little commercial significance. The first comprehensive study of the coal-bearing deposit, hereafter referred to as the Nor Arevik deposit, was conducted by S.A. Tarayan in 1941 and published in 1942. Tarayan (1942) mapped the coal site at a scale of 1:2,500, and examined the coal by making an unknown number of surface scrapings, 15 trenches, and 11 shallow shafts (none of

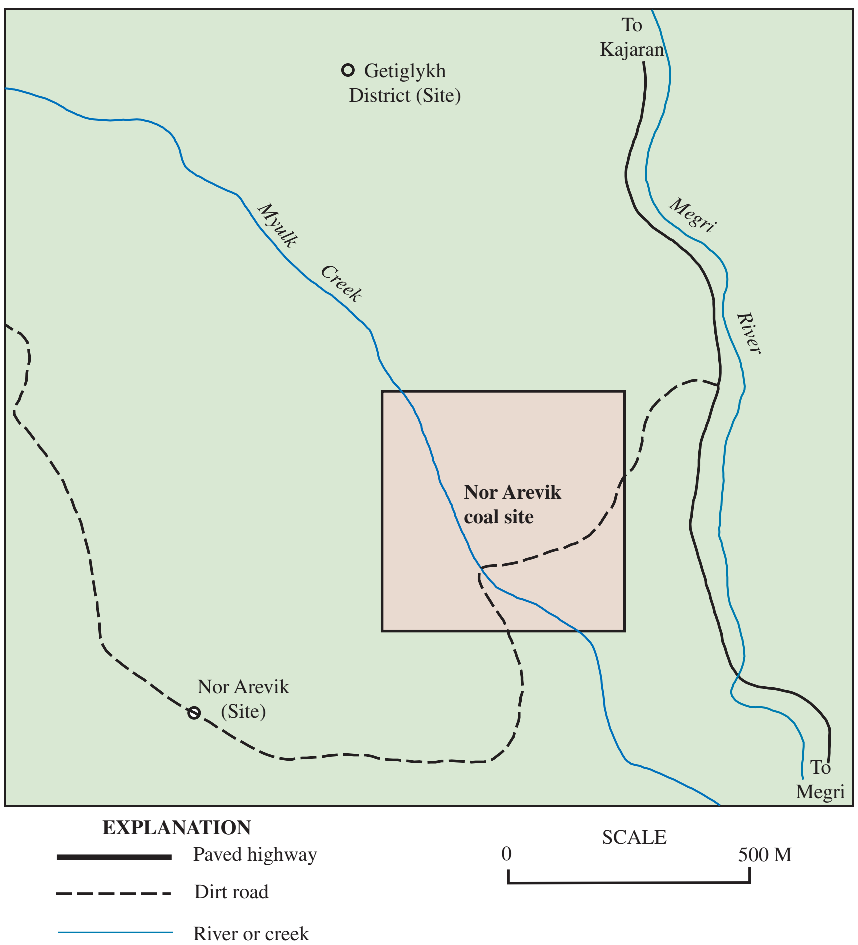

Figure 2. Nor Arevik coal site and surrounding geographic and cultural features.

which are evident today). He also collected samples for chemical analysis. His report includes a 1:2,500-scale geologic map, cross sections, and four plates showing correlations of coal beds and other lithologic units in the deposit. In 1993, geologists from the USGS visited the coal site, and several coal samples were collected for analyses (Pierce and others, 1994). The most recent study of the Nor Arevik deposit was conducted between 1993 and 1996 by A.G. Drobotova and Z.A. Saponjian, and was published in 1996. Drobotova and Saponjian (1996) cut 16 trenches, sunk 5 shallow shafts, and drilled 8 holes as part of their study; all mention of these features in our report is in reference to their exploration activities. Their report includes a geologic map of the study site at a scale of 1:1,000. Because their effort was directed more toward oil and gas exploration than coal, we found their report less useful to coal assessment than Tarayan's report.

Previous Mining Activity

Nobody seems to know when coal was first mined at the Nor Arevik coal site. However, a farmer in his 80's living at the coal site told us that he remembers, as a boy, his father removing coal from the southwestern corner of the site along the banks of a creek. This establishes a minimum period of about 70 years for coal extraction at the site. In the east-central part of the coal site, a patch of disturbed ground covering several tens of square meters is evidence of numerous attempts to mine coal. Although we refer to this patch as the "mine," it is important to understand that there is no actual mine present. Pierce and others (1994) reported that 600 metric tons of coal were supposedly extracted from the mine during the summer of 1993 for use in Megri at a central heating facility and for individual home heating. However, observations we made at the mine during our study do not support this amount of extraction unless combustible shale was also mined.

Acknowledgments

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GEOLOGIC SETTING

As shown on the geologic map of Armenia (Arakelian and others, 1971), as modified by Maldonado and Castellanos (2000), southern Armenia is a complex region of igneous bodies and sedimentary deposits separated by the northwest-trending Shishkert-Ghiratakh regional thrust fault. The fault is southwest vergent and has moved Mesozoic rocks over Cenozoic rocks. East of the fault, the upper plate contains a major anticlinal structure dominated by Jurassic to Cretaceous volcaniclastic sedimentary deposits. West of the fault, the lower plate is characterized by Eocene to Oligocene intrusive bodies containing a wide variety of rocks, ranging from granite to pyroxenite. In addition, some Tertiary extrusive and sedimentary rocks are known to be present. Massive sulfide deposits, consisting primarily of copper and molybdenum minerals, are present in the eastern part of southern Armenia, and several large open pit mines are currently operating there.

As shown on the geologic map of the Megri region by Khojabaghian and Marchenko (1988), the Nor Arevik deposit is completely surrounded by Paleogene intrusive rocks. Not shown on their map, but known to be present adjacent to the deposit, are two faults of regional significance (Grigory Harutunian, oral commun., 1999). Just to the west of the deposit lies the north-trending Debakli fault. This normal fault extends south from Lake Sevan in east-central Armenia into Iran. In the Megri region the fault plane dips at about 70° toward the east, and initial movement on the fault is known to predate the Nor Arevik deposit. Just to the east of the deposit lies the more local Megri fault, which subparallels the Megri River. This fault also trends north but its fault plane dips toward the west.

NOR AREVIK DEPOSIT

The Nor Arevik (also written Nor-Arevik) deposit is named for a small village that was once located about 0.75 km southwest of the Nor Arevik coal site (fig. 2). Nor Arevik was abandoned and dismantled during the 1960's as part of an effort to encourage larger collective farms. Although little trace of the village remains, the name continues to be associated with the deposit. Based on the geologic map of Khojabaghian and Marchenko (1988), the deposit is exposed over about 270 hectares (2.7 km^2).

Stratigraphy

The Nor Arevik deposit can be divided into three parts: in ascending order, they are the coal-bearing unit, the sandstone unit, and the conglomerate unit (fig. 3). The deposit is underlain by igneous rocks and overlain by gravel. At the Nor Arevik coal site the deposit generally dips toward the west. The coal-bearing unit and much of the sandstone unit underlies a west-sloping, undulating surface of grassy pastures, small irrigation ditches, and vegetable gardens (fig. 4). The slope ends at southeast-flowing Myulk (also spelled Miulk) Creek, which more or less parallels the contact between the sandstone and conglomerate units. West of

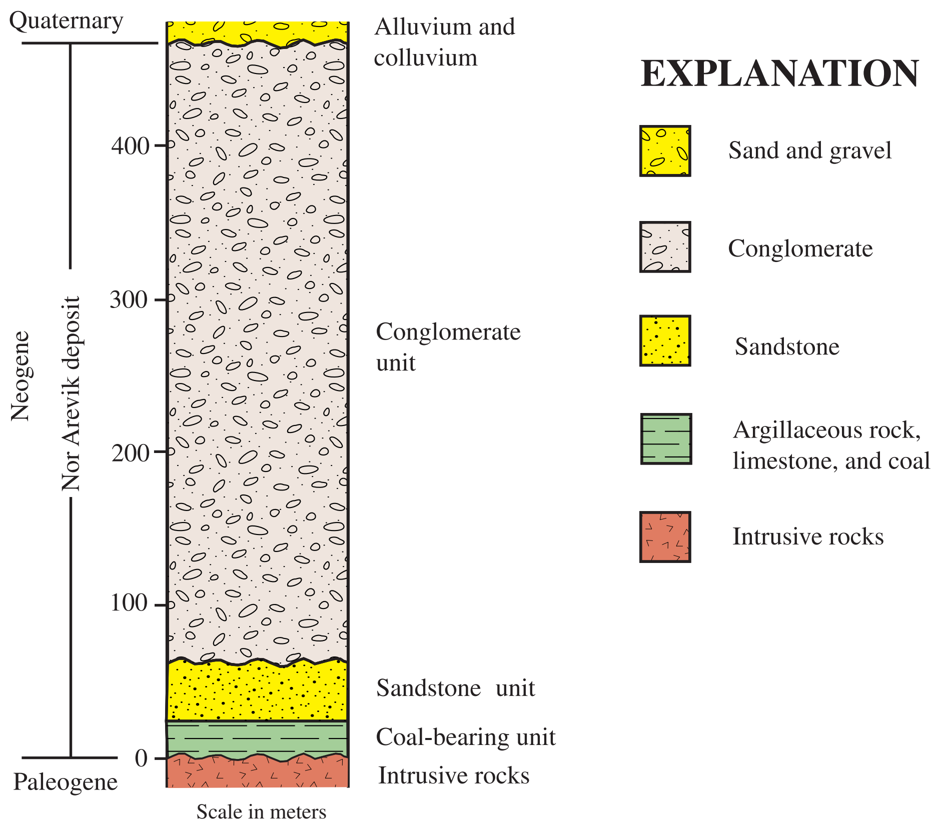

Figure 3. Stratigraphy of the Nor Arevik coal site.

Figure 4. View of the Nor Arevik coal site looking northwest. Southeast-flowing Myulk Creek fills the drainage on the left.

the creek the conglomerate unit forms an impressive cliff about 100 m high.

Underlying rocks

The Nor Arevik deposit lies unconformably on Paleogene acidic to basic intrusive rocks, and Tarayan (1942) reported that at the Nor Arevik coal site the rocks underlying the deposit are mostly granodiorite. The contact is erosional, and we observed as much as 20 m of relief, locally. Tarayan mentioned that at most places in the Nor Arevik area, the coal-bearing and sandstone units are missing, and the conglomerate unit lies directly on the intrusive rocks. Where this occurs, strata in the conglomerate are usually parallel to the erosional surface, but in some places the relation is angular. And, in some places, the conglomerate and intrusive rocks are separated by a fault. However, at the coal site the most common contact is between the intrusive rocks and the coal-bearing unit.

At the top of the dirt road leading to the study site, an erosional depression in the unconformity is filled with conglomerate. On outcrop the conglomerate weathers brown or maroon, is crudely stratified, and is lenticular in shape. It measures 49 m long and has a maximum thickness of 19 m. The conglomerate is matrix supported and consists of subangular to surrounded pebbles and cobbles. Some boulders are also present. Overall, clast size decreases upward. The clasts are of various intrusive rock, and the matrix consists of poorly sorted, very fine to very coarse grains of quartz and lithic fragments. At one exposure the conglomerate is sharply overlain by 1.5 m of rusty-brown, very fine grained sandstone with conglomeratic lenses as thick as 15 cm. The sandstone is sharply overlain by at least 1 m of banded rusty-brown and gray, homogeneous claystone. In some nearby exposures the sandstone is missing and the claystone directly overlies the conglomerate. Although conglomerate at the base of the coal-bearing unit is probably rare, it does constitute a basal conglomerate for the Nor Arevik deposit as a whole.

Coal-bearing unit

The coal-bearing unit underlies an area of about 6 ha at the Nor Arevik coal site. Examination of the unit is made difficult because it forms a dip slope that underlies a mantle of soil on which agriculture activities have been ongoing for many decades. As a result, natural exposures of the unit are generally absent. The lower part of the unit is artificially exposed in the immediate vicinity of the mine, but the ground has been so disturbed over the years that piecing a stratigraphic section together of even this part of the unit is impossible.

According to Tarayan (1942), the coal-bearing unit is as thick as 25 m in the central and northern parts of the coal site but thins to 10 m in the southwestern part of the site south of Myulk Creek. According to Drobotova and Saponjian (1996), the unit (their "productive strata") ranges from 5.5 to 38.5 m thick, with an average thickness of 21.2 m. Several tens of meters beyond the southern limit of the study site, the coal-bearing and sandstone units are absent, and the conglomerate unit rests unconformably on the intrusive rocks.

The coal-bearing unit consists of very fine grained sandstone, siltstone, mudstone, combustible shale, coal, and freshwater limestone, and, locally, conglomerate at the base of the unit (fig. 5). Coal is discussed at length in a following section of our report. Sandstone is relatively rare but might be more abundant in the lowest part of the unit just above the basal contact. Siltstone and mudstone are present as very thin to thin interbeds throughout the unit. Ironstone concretions are occasionally observed as float, and it is suspected that they are weathering out of thicker intervals of the mudstone. Combustible shale is very common and occurs in close proximity to coal beds; in volume, it exceeds the coal. Within the shale, yellow mineralization (jarosite?) is common along some bedding planes and joint surfaces, and very thin beds of gypsum are locally present. In addition, most of the shale contains abundant fossil plant debris, including whole leaves. White, low-spiraled gastropods about 2 mm in diameter are commonly observed as well. Trenches cut into the coal-bearing unit on the south-facing slope on the north side of the coal site reveal the presence of freshwater limestone. On Tarayan's (1942) plates this lithology is shown to be common in the upper one-third of the coal-bearing unit. The limestone is light brown on fresh surfaces and weathers light yellowish brown. It occurs mostly in thin beds but very thin beds are also present; medium beds are rare. Very thin to thin interbeds of combustible shale are common. Bedding planes in the limestone are somewhat wavy and commonly display fossil mats of broad-leafed plants. Small

Figure 5. Coal and combustible shale in the coal-bearing unit exposed at the mine site.

gastropods, similar to those observed in the combustible shale, are very common. White bivalves about 15 mm in size are rare.

In Soviet geologic reports, including Tarayan's, the word marl is ordinarily used for freshwater limestone. Marl is a term rarely used by American geologists. According to the American Geological Institute (AGI) Glossary of Geology (Jackson, 1997), the word marl is an old term loosely applied to a variety of soft, unconsolidated deposits consisting of an intimate mixture of clay and calcium carbonate that commonly forms in a freshwater environment. Russian geologic glossaries also define marl as a mixture of clay and calcium carbonate, but consider it to be an indurated rock. American geologists ordinarily use the term argillaceous limestone for this latter material.

Sandstone unit

The sandstone unit conformably overlies the coal-bearing unit, and where best exposed in the southwestern part of the Nor Arevik coal site, the contact is gradational over about 50 cm. According to Tarayan (1942), the sandstone unit ranges from 5 to 40 m thick. This difference in thickness results from the erosional nature of the overlying conglomerate unit. In the southwestern part of the coal site we measured a section of the sandstone unit and found it to be about 48 m thick. Here the unit consists of sandstone with isolated lenses of conglomerate (fig. 6). The sandstone is composed of subangular to subrounded grains of quartz and lithic fragments. The rock is very fine grained in the lower one-third of the unit, and poorly sorted, very fine to very coarse grained in the upper two-thirds of the unit. Outcrops are mostly light brown, but bands of yellowish brown and light greenish gray were also noted. Spheroidal-weathering calcareous concretions with diameters as much as 30 cm are common. Lenses of conglomerate, restricted to the upper two-thirds of the unit, consist of matrix-supported, subrounded to subangular pebbles and cobble of a variety of intrusive igneous rocks. These lenses can be as thick as 3 m at their midpoint.

Conglomerate unit

The conglomerate unit is the stratigraphically highest and most dominant unit in the Nor Arevik deposit. Tarayan (1942) reported that in the Nor Arevik area the unit can be as thick as 400 m. At the Nor Arevik coal site the unit forms an impressive cliff about 100 m high that extends for about 1.5 km along the west side of Myulk Creek (fig. 7). The contact with the underlying sandstone unit is erosional; as much as 3 m of relief was observed. Most exposures in the area weather light brown, but at the study site some of the unit weathers bluish gray. The conglomerate is clast supported and consists of subangular to subrounded pebbles,

Figure 6. Interbedded sandstone and conglomerate in the sandstone unit west of Myulk Creek. Outcrop height is about 30 m.

Figure 7. Conglomerate unit exposed in the cliff face west of Myulk Creek. Height of exposure is about 100 m.

cobbles, and boulders of various intrusive igneous rocks. According to Tarayan, granodiorite prevails. Lenticular interbeds as thick as 2 m of gray or red, medium-grained to very coarse grained sandstone consisting of quartz grains and rock fragments help define crude planar stratification in the conglomerate unit.

Overlying rocks

In the Nor Arevik area, the conglomerate unit is unconformably overlain by unconsolidated Quaternary colluvium. Tarayan (1942) reported that these sediments can be as thick as 30 m.

Structure

We observed no significant folds or faults in the vicinity of the Nor Arevik coal site, and none appear on Tarayan's (1942) geologic map. In general, strata dip toward the west at about 20°, but the strike can vary from northwest to northeast, attesting to subtle structural complexities. Several small isoclinal folds were observed in exploration trenches cut into the coal-bearing unit, and abrupt juxtaposition of differing shades of combustible shale reveal the presence of small, high-angle faults.

Age

According to Tarayan (1942), fauna collected in 1869 led early workers to consider the Nor Arevik deposit to be Miocene in age. However, gastropods collected by Tarayan indicated that the deposit is lower or middle Pliocene in age. Because the science of paleontology has evolved considerably since 1941, we decided to use the broader term Neogene to define the deposit, pending a more modern analysis of its fossil content.

Depositional History

Tarayan (1942) was probably the first to relate deposition of the Nor Arevik deposit to the development of a structural graben. He visualized a linear depression with a long axis that trended north-northwest. Moreover, he recognized the relation between increasing topographic relief with time and increasing-upward grain size within the deposit. Tarayan defined the actual boundaries of deposition for the coal-bearing unit at the Nor Arevik coal site by noting lateral thickness and facies changes within the unit. For example, the unit is about 25 m thick in the northern and central parts of the coal site, thins to about 10 m in the southwestern part of the site, and apparently thins to zero a few tens of meters beyond the site's southwestern edge. Accompanying this decrease in thickness is a lateral increase in the sand content of the unit. To this we add that coal beds, as shown on Tarayan's cross sections, tend to thin and split toward the north, whereas the total thickness of the unit remains constant in that direction. Tarayan defined the boundaries of deposition for the sandstone unit by outlining where the conglomerate unit is first observed to rest directly on the intrusive rocks beyond the study site. Tarayan's version of the depositional history is quite convincing, and after considering all other possible explanations for the Nor Arevik deposit, we concur with his model and here name the structural feature the Megri Graben. Although the deposit is apparently unique to the Nor Arevik area, a somewhat similar Neogene deposit is present about 10 km to the south, north of the town of Agarak (fig. 8). If these rocks are related to the Nor Arevik deposit, and we make a case for this later in our report, then the Megri Graben extended beyond Nor Arevik.

We propose the following chain of events to supplement and expand on the scenario proposed by Tarayan. Admittedly, much of what follows is speculative. The limited time spent in the field and the poor exposures of the deposit did not allow us to develop a more complete sedimentologic framework that might have added credence to our proposed sequence of events. Having said this, we believe that it is better to put forward a detailed scenario for consideration rather than dilute the discussion with broad generalities simply because conclusive evidence is lacking.

1. During the middle to late Tertiary, the area that is now the Megri region was uplifted, and early Tertiary intrusive rocks were eroded to a broad peneplain that we call the Megri erosional surface. It was during this time that isolated deposits of gravel, now represented by conglomerate at the base of the coal-bearing unit, were deposited in channels cut into the erosional surface.

2. During latest Tertiary, vertical movement along a zone of north-trending, subparallel, high-angle faults commenced, and opposing displacements on two adjacent faults created the incipient Megri Graben. It is quite possible that the faults bounding the graben were associated with the Debakli and Megri faults.

3. At the Nor Arevik coal site, the initial topographic relief surrounding the graben was probably relatively low, as only fine-grained detritus entered the depositional system. During this time a very low energy depocenter developed, and the various lithologies now contained in the coal-bearing unit were deposited. Where the local base level approximated the land surface, swamps developed, and peat accumulated. Where the base level exceeded the surface, shallow lakes developed and, argillaceous, calcium carbonate accumulated on the lake's bottom. Most likely, peat accumulated around the margins of the lakes at the same time that carbonate mud was being deposited in the lakes.

4. An increase in tectonic activity resulted in renewed uplift on faults bounding the graben, and at the coal site, the higher surrounding topography started supplying coarser grained detritus that began filling the depression. It was during this time that the sandstone unit was deposited. Perhaps the very fine grained lower one-third of the unit represents the overbank deposits of a low-sinuosity, sand-dominated fluvial system. However, the coarser grained, poorly sorted, upper two-thirds of the unit might represent the distal deposits of incipient, low-angle alluvial fans that began developing off the sides of the graben as uplift steadily increased with time. The isolated lenses of conglomerate observed in this part of the unit might represent gravel that was deposited in channels in higher energy parts of the system.

5. Suddenly, a dramatic increase in tectonic activity elevated the surrounding topography so that gravel filled the entire Nor Arevik portion of the Megri Graben. It was during this final stage of Nor Arevik depositional history that the conglomerate unit was deposited. Perhaps the unit represents coarse detritus that was deposited in a series of small, high-angle, coalescing alluvial fans that bordered the steep sides of the graben.

6. At the close of the Tertiary, localized uplift along the Megri Graben abated, and a general uplift of the entire region occurred. As a result, the uppermost part of the Nor Arevik deposit was eroded and is now either exposed at the surface or capped by Quaternary colluvium.

Today, only the Nor Arevik deposit and a similar deposit north of Agarak give evidence to deposition in the Megri Graben. But between the two exposures very small patches of "Tertiary-looking" conglomerate are reported to be present. It probably will never be known if deposition occurred along the entire structural trend, and the resulting rocks have simply been lost to erosion, or if the Nor Arevik and Agarak exposures represent unique depositional settings that did not exist elsewhere along the trend.

NOR AREVIK COAL SITE

Methodology

We began our work by studying translated copies of the reports of Tarayan (1942) and Drobotova and Saponjian (1996). Subsequent field work was devoted to examining the Nor Arevik coal site, collecting samples, and conducting a regional reconnaissance. For a base map we started with a 1955 Soviet topographic map (J-38-33-B-G) at a scale of 1:25,000 with a contour interval of 5 m. This map was then digitized and plotted at scales of 1:10,000 and 1:2,500, both with a contour interval of 25 m. Although we used these digitized maps to record field data, we decided that it was more efficient to simply modify the existing geologic map of Tarayan (Plate 1) rather than to create a new geologic map.

When modifying Tarayan's map, we found it very difficult to place reliable latitude and longitude tick marks along the margins by simply interpolating from the 1955 topographic map. Difficulty arose because of the differences in scale, the tendency for misleading adjustments to be made to small-scale maps created for topical studies (such as Tarayan's), and the amount of time elapsed between the topographical surveys used in constructing the two maps. Basically, we were trying to use Tarayan's map of the early 1940's and a topographic map of the mid 1950's to locate geomorphic and cultural features present in the late 1990's. Drobotova and Saponjian's map was not helpful because their map is a schematic, hand-drawn representation of an early 1930's topographic map. The best we can do is state that, based on a Geographic Positioning System (GPS) reading taken under less than ideal conditions, latitude 39°01'20" N. and longitude 46°12'15" E. lie within or very close to the coal site (Pierce and others, 1994).

Coal Geology

Tarayan (1942) recognized four categories of coal at the Nor Arevik coal site: bright coal, earthy coal, dull coal, and sooty coal. More recent workers have used the term brown coal in reference to the coal at this site. This term is part of the European coal classification system and is equivalent to lignite A or subbituminous coal. In our report, we do not differentiate among Tarayan's coal categories except in the discussion of coal quality.

Occurrence

Two coal zones are present at the Nor Arevik coal site in the upper one-third of the coal-bearing unit. Both zones are known to split toward the north. According to stratigraphic sections in Tarayan's (1942) report, the lower coal zone is present throughout the coal site. The stratigraphic separation between the base of the lowest coal bed in the coal zone and the base of the coal-bearing unit is about 15 m. Coal in the lower coal zone occurs as a single, thick bed in the southwestern and central parts of the site, but splits into multiple thin beds in the northern part of the site. Where a single bed is present, the thickness ranges from about 0.46 to 1.6 m. Where the coal has split, the zone contains from two to five beds ranging in thickness from 2 to 20 cm. In general, bed thickness decreases as the number of beds increases. The range of parting thicknesses is comparable to that of the coal beds. At the stratigraphic level of the lower coal zone, a lithologic cycle begins with combustible shale and changes upward to limestone, coal (the lower coal zone), limestone, and finally back to combustible shale.

Most of the coal in the upper coal zone has been lost to erosion. Where both coal zones are present, the lowest coal bed in the upper zone lies an average of 5 m above the highest coal bed in the lower zone. In the southwestern part of the Nor Arevik coal site, the upper coal zone is represented by a single bed 18 cm thick. In the northern part of the coal site, the zone is represented by three beds ranging in thickness from 8 to 46 cm, with a net coal thickness of about 80 cm. Partings range in thickness from 5 cm to 1.10 m. The stratigraphic separation between the top of the highest coal bed in the upper coal zone and the top of the coal-bearing unit is unknown.

Quality

According to Tarayan (1942), ash yields (basis unreported) from coal samples collected in 1941 are as follows: bright coal, 7–33 percent; earthy coal, 45–49 percent; and dull coal, 52 percent. Thus, his dull coal is more like a carbonaceous shale than a true coal [American Society for Testing Materials (ASTM), 1992]. Analyses reported for coal in the lower coal zone vary greatly. Ash yield ranges from 6 to 52 percent, sulfur content ranges from 3.6 to 8 percent, and calorific values range from 2,900 to 6,800 kcal/kg (5,220 to 12,240 Btu/lb) on an air dry fuel basis (sic; dry basis?). Only one analysis of the upper coal zone was reported by Tarayan, and its low calorific value of 2,480 kcal/kg (4,460 Btu/lb) was attributed by Tarayan to the poor quality of the sample collected.

In 1993, USGS geologists collected three channel samples from a coal bed partially exposed at the mine (Pierce and others, 1994). As-received analyses of these samples indicate an ash yield range from 39 to 62 percent and a total sulfur content range from 4 to 6 percent. Calorific values range from 4,410 to 5,910 kcal/kg (7,940 to 10,630 Btu/lb) on a moist, mineral-matter-free basis. The report by Pierce and others (1994) also contains complete proximate and ultimate analyses of the samples. During the course of our field work we collected channel samples from two parts of a coal bed at two separate exposures at and near the mine. As-determined analyses of these four samples gave an ash yield range from 27 to 42 percent and a total sulfur content range from 3 to 8 percent. Calorific values range from 5,400 to 6,670 kcal/kg (9,720 to 12,000 Btu/lb) on a moist, mineral-matter-free basis. Based on the calorific values obtained from both groups of samples, the most likely rank of the coal at the Nor Arevik coal site is subbituminous, although some bituminous coal might also be present.

A rank of subbituminous is also supported by Charles Barker (USGS, oral commun., 1994), who studied the vitrinite reflectance of the coal collected by Pierce and others (1994). Barker measured R_r at 0.46 percent and calculated R_{max} to be 0.49 percent.

Resources

Tarayan (1942) calculated coal resources at the Nor Arevik coal site for the lower coal zone in the southern part of the coal site combined with the upper coal zone in the northern part of the site using a specific gravity value of 1.4 g/cm^3. The resultant estimate was 8,000 metric tons. Drobotova and Saponjian (1996) also calculated resources as part of their study of the coal site. Unfortunately they did not distinguish coal from combustible shale. Moreover, they used an areal extent for the coal-bearing unit that includes vast areas where the conglomerate unit is known to rest directly on the intrusive rocks. Thus, we consider their resource values to be too high and do not report them here. Considering the relatively poor coal quality and the small size of the coal deposit, we chose not to calculate resources.

Combustible Shale Geology

Tarayan (1942) used the term combustible shale in the title of his report and a significant portion of his text is devoted to this rock. Combustible shale is a term seldom used in the United States. According to the AGI Glossary of Geology (Jackson, 1997), combustible shale is equivalent to tasmanite, which is defined as an impure coal transitional between cannel coal and oil shale. Russian geologic glossaries define the term combustible shale as a thinly laminated sedimentary rock containing between 10 and 80 percent organic matter, some of which is in the form of kerogen (a component of oil shale).

Occurrence

According to Tarayan (1942), unweathered combustible shale is a black, dense, fine-grained rock with a hackly fracture. Weathered rocks are brownish black to light brown and fissile. Pyrite is common on unweathered bedding planes, and weathered bedding planes are commonly ocherous. Very thin partings of sandstone or coal are rare. Based on the stratigraphic sections by Tarayan (1942), combustible shale occurs in five beds. The first bed, encountered at only one outcrop, is 21 cm thick and lies only 70 cm above the base of the coal-bearing unit. The second bed, located approximately in the middle of the coal-bearing unit, ranges from 0.55 to 3.30 m in thickness. The third bed is positioned about 65 cm above the second bed and is 30 cm thick. The fourth bed lies below the lower coal zone and is commonly separated from it by a bed of limestone. This combustible shale bed ranges from 0.70 to 2.4 m in thickness. The fifth bed is actually composed of several combustible shale beds, which lie above the lower coal zone and are commonly separated from it by a bed of limestone. The number of beds ranges from one to seven within a stratigraphic interval that ranges from 0.30 to 1.65 m thick. Bed thickness ranges from 5 to 50 cm. The stratigraphic separation between the top of the lower coal zone and the lowest combustible shale of the fifth bed ranges from 0.15 to 1.70 m.

Of the five beds, beds 4 and 5 are the most extensive, bed 2 is less extensive, and bed 3 is the least extensive. Because bed 1 is observed at only one outcrop, there is no way of judging how extensive it is.

Quality

Tarayan (1942) collected and analyzed samples of combustible shale from each of the five main beds. Average results (basis unreported) for all the samples are: ash yields from 70 to 76 percent and a calorific value of 1,560 kcal/kg (2,810 Btu/lb). During the course of our field work, we collected two channel samples from a carbonaceous bed directly underlying a coal bed at two separate exposures at and near the mine. As-determined analyses of these two samples indicate ash yields of 48 and 53 percent and total sulfur contents of 7 and 8 percent. Calorific values were 5,970 and 6,500 kcal/kg (10,740 and 11,700 Btu/lb) on a moist, mineral-matter-free basis. In addition, we collected one channel sample of a carbonaceous bed and two grab samples of another nearby carbonaceous bed in the southwestern part of the Nor Arevik coal site. As-determined analyses of these three samples indicate an ash yield range from 68 to 71 percent and a total sulfur content range from about 2 to 3 percent. Calorific values, determined on only two of the samples, were 3,890 and 4,060 kcal/kg (6,990 and 7,310 Btu/lb). Based on their high ash yield, the rocks are classified as carbonaceous shales.

Resources

Tarayan (1942) calculated resources for combustible shale beds 2, 4, and 5 using a specific gravity value of 1.9 g/cm^3. The resultant estimate was about 500,000 metric tons. For a slightly larger area than the Nor Arevik coal site, and taken to a depth of 300 m, Tarayan estimated resources of about 3,000,000 metric tons.

Discussion

It is unclear to us exactly which rocks at the Nor Arevik coal site Tarayan (1942) was referring to as combustible shale. At the time of his report, any organic shale in the Soviet Union with a calorific value of at least 1,200 kcal/kg (2,160 Btu/lb) that would burn if ground to dust could legitimately be called combustible shale. During the course of our field work, relatively thick intervals of what we would call carbonaceous shale were observed in the coal-bearing unit. Because Tarayan did not mention the presence of carbonaceous shale, it is tempting to think that he simply combined all carbonaceous rocks other than coal and referred to them, collectively, as combustible shale. Whether or not there is any combustible shale as currently defined in the AGI Glossary (Jackson, 1997) present at the coal site is unknown.

REGIONAL RECONNAISSANCE

Nor Arevik Deposit in the Getiglykh District

Tarayan (1942) mentioned the occurrence of a small outcrop of the coal-bearing unit about 0.5 km north of the Nor Arevik coal site. This outcrop is exposed in the floor of a small ravine cut into the upper slope of the Megri River valley in the Getiglykh District (fig. 2). Structural dip was reported to be toward the south-southwest at about 20°. Here Tarayan measured a complete stratigraphic section of the coal-bearing unit, which totals approximately 24 m in thickness. The section includes one coal bed ranging from 12 to 14 cm thick and three combustible shale beds ranging from 14 to 65 cm thick. The interval is underlain by intrusive rock and overlain by the conglomerate unit. Tarayan reasoned that because the thickness of the coal-bearing unit at Getiglykh is nearly equal to the thickness of the unit at the coal site, the two outcrops must be continuous, but covered by a veneer of Quaternary colluvium or concealed by dense vegetation. Despite considerable effort, we could not locate the Getiglykh exposure during the course of our field work.

Nor Arevik Deposit Along the Megri River

About 1.5 km north-northeast of the Nor Arevik coal site, an impressive thickness of the conglomerate unit is exposed along the western slope of the Megri River valley (fig. 8). The exposure extends for about 2 km northwest along the river to the confluence with the Ayri River (not shown on fig. 8) and then continues west-northwest for about 1.5 km. Both ends of the exposure are bounded by faults that place intrusive rock adjacent to

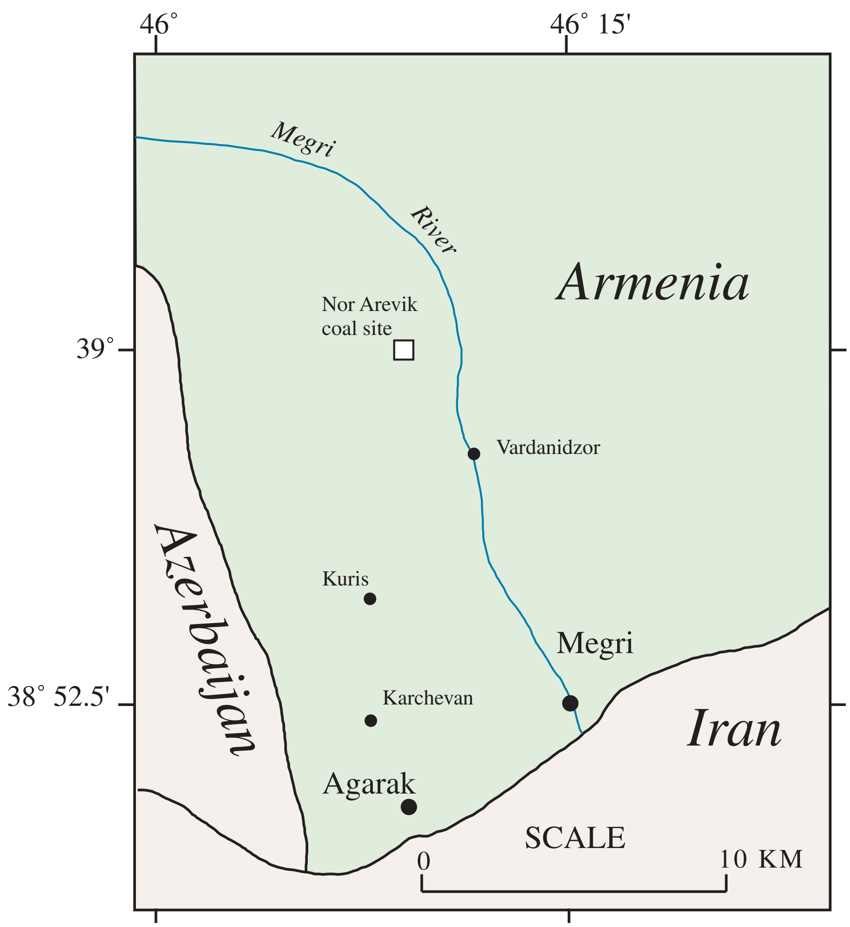

Figure 8. Location map showing the Megri region.

the conglomerate. Because the conglomerate dips toward the southwest, the logical place to look for the coal-bearing unit is along the base of the exposure, just above the level of the two rivers. We spent part of a day in this area examining the base of the exposure with binoculars and on foot, as well as interviewing local farmers. At most places the lower part of the exposure is covered by Quaternary alluvium, but where the base of the conglomerate unit is exposed, it rest directly on intrusive rocks; no coal is present. In addition, none of the farmers we talked to had ever observed coal in the area.

Neogene Deposits North of Agarak

Two exposures of Neogene rocks are shown on Khojabaghian and Marchenko's (1988) regional geologic map to be present a few kilometers north of the town of Agarak (fig. 8). The southern exposure lies about 3 km north of Agarak, just north-northeast of the village of Karchevan, on the road to the Agarak open pit copper mine (now inactive). A brick-red conglomerate unit crops out along the west side of the road for about 0.5 km. About 40–50 m of the conglomerate unit are exposed and the rocks dip toward the west. The unit consists of subangular to subrounded pebbles and cobbles of various intrusive rocks. The exposure is crudely planar stratified with layers of conglomerate as thick as 10 m separated by lenticular beds of poorly sorted, maroon sandstone as thick as 1 m. At most places the base of the conglomerate unit is covered, but at the southern end of the exposure the unit is observed to rest on a sandstone unit of which about 20 m is exposed. The contact between the conglomerate and sandstone units is erosional with 1–2 m of relief.

The sandstone unit consists mostly of beds and lenticular bodies of sandstone. Beds of sandstone, as thick as 40 cm, weather mostly light gray to light brownish gray, are fine grained, and contain fossil plant debris and small gypsum crystals. Yellow mineralization (jarosite?) is common and some rusty brown coloration is present as bands in the sandstone or as fracture coatings. Lenticular sandstone bodies, as thick as 2.5 m, weather mostly light orange brown, fine upward from very coarse to coarse grained, and have erosional bases. The frequency of these bodies increases upward in the sandstone unit. In addition, beds of medium-brown- to dark-brown-weathering carbonaceous mudstone as thick as 20 cm are common, and contain gypsum crystals, fossil plant debris, and yellow mineralization. Less common are wavy beds or nodules of brownish-white- to light-blue-weathering limestone as thick as 7 cm. Except for the carbonaceous mudstone and one coalified fossil root trace, no carbonaceous material was observed. Moreover, none of the local farmers or mine personnel that we talked with had ever noticed coal in the area.

East of the exposure, the lower part of the sandstone unit is present in a small hollow. Although the lowermost several meters are covered, it is clear that the unit rests on intrusive rock stained red by mineralization. We believe that the brick-red color of the conglomerate is somehow related to this red-stained intrusive rock.

The northern exposure lies about 4 km to the north beyond the Agarak mine. Khojabaghian and Marchenko (1988) show these rocks surrounding the village of Kuris, but we could find no sign of such rocks in the area.

In a stratigraphic column on Khojabaghian and Marchenko's map, the Neogene rocks north of Agarak are shown to be late Pliocene to Pleistocene in age, younger than the Nor Arevik deposit. However, based on the upward succession from sandstone to conglomerate that we observed near Karchevan, and the fact that the sedimentary interval rests on intrusive rocks, we believe that these rocks and the Neogene Nor Arevik rocks are, in fact, two exposures of the same deposit. Tarayan (1942) also considered the Agarak rocks to be equivalent to the Nor Arevik deposit.

Paleogene Rocks in the Megri Region

Khojabaghian and Marchenko's (1988) regional geologic map shows numerous exposures of Paleogene rocks in the Megri region referred to as the Bogats-sar Formation. As described in the map description, these rocks are lower Eocene in age and consist mostly of igneous rocks. However, the last entry in the description mentions the presence of lenses of marl and limestone. Based on the presence of at least some sedimentary rocks in the unit, we deemed it prudent to examine an outcrop of the formation. The formation is shown to be exposed in several areas along the highway from Megri to Nor Arevik. Several exposures are present along the west bank of the Megri River at the village of Vardanidzor, about 8 km north of Megri (fig. 8), but during a short reconnaissance of the area we observed no lenses of sedimentary rocks.

RECOMMENDATIONS

Because net coal thickness at the Nor Arevik coal site probably does not exceed 1.8 m, and the areal extent of the coal-bearing unit might not extend much beyond the coal site (25 ha), we consider the Nor Arevik deposit to be of only local importance. It is possible, of course, that the coal-bearing unit, with its coal and combustible shale, extends to the west under the conglomerate and sandstone units. The only way to test this hypothesis is to drill through the conglomerate and sandstone units; this expense is unwarranted based on the known coal characteristics at the coal site. Even if the coal-bearing unit does extend to the western margin of the Nor Arevik deposit, the areal extent is still very limited. However, the residents living at the coal site should be encouraged to mine and utilize the coal for domestic use, and, if possible, to develop a small cottage industry by selling the coal in Megri for the same use. Even the so-called combustible shale could be used to supplement fires burning other fuels.

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