Potential Minability and Economic Viability of the Antaramut-Kurtan-Dzoragukh Coal Field, North-Central Armenia: A Prefeasibility Study

By Douglas W. Huber and Brenda S. Pierce

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The Antaramut-Kurtan-Dzoragukh coal field is a newly discovered deposit in north-central Armenia. This prefeasibility study shows that a small surface coal mine having about a 20-year lifespan could be developed in this coal field.

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POTENTIAL MINABILITY AND ECONOMIC VIABILITY OF THE ANTARAMUT-KURTAN-DZORAGUKH COAL FIELD, NORTH-CENTRAL ARMENIA: A PREFEASIBILITY STUDY

By Douglas W. Huber[1] and Brenda S. Pierce[2]

ABSTRACT

The U. S. Geological Survey (USGS) conducted a coal resource assessment of several areas in Armenia from 1997 to 1999. This report, which presents a prefeasibility study of the economic and mining potential of one coal deposit found and studied by the USGS team, was prepared using all data available at the time of the study and the results of the USGS exploratory work, including core drilling, trenching, coal quality analyses, and other ongoing field work.

On the basis of information currently available, it is the authors' opinion that a small surface coal mine having about a 20-year life span could be developed in the Antaramut-Kurtan-Dzoragukh coal field, specifically at the Dzoragukh site. The mining organization selected or created to establish the mine will need to conduct necessary development drilling and other work to establish the final feasibility study for the mine. The company will need to be entrepreneurial, profit oriented, and sensitive to the coal consumer; have an analytical management staff; and focus on employee training, safety, and protection of the environment. It is anticipated that any interested parties will be required to submit detailed mining plans to the appropriate Armenian Government agencies.

Further development work will be required to reach a final decision regarding the economic feasibility of the mine. However, available information indicates that a small, economic surface mine can be developed at this locality. The small mine suggested is a typical surface-outcrop-stripping, contour mining operation. In addition, auger mining is strongly suggested, because the recovery of these low-cost mining reserves will help to ensure that the operation will be a viable, economic enterprise. (Auger mining is a system in which large-diameter boreholes are placed horizontally into the coal seam at the final highwall set as the economic limit for the surface mining operation). A special horizontal boring machine, which can be imported from Russia, is required for auger mining. Although auger-mining coal reserves do exist, the necessary development work will further verify the extent of these reserves and all of the other indicated reserves.

The following items are based on the detailed study reported in this publication.

Initial investment.—Following an investment of US $85,000 over a 12-month period in mine development drilling and other activities, a decision must be taken regarding further investment in an ongoing mining operation. If the new data support the opening of the surface mine,

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the $85,000 development cost is amortized over the first 10 years of mine production. If the new data do not support the opening of the mine, the $85,000 is considered a business development expense that may be written off against profits from other operations for income or other tax purposes or simply as a business loss.

Total capital required.—The equipment costs will reach a total of $900,500 which will be amortized over a 7-year period to establish estimated coal mining costs. Estimated working capital costs are $300,000, which will be borrowed.

Surface mining reserves.—Approximately 840,200 metric tonnes of surface minable coal reserves at 9.3 m^3 of overburden per metric tonne of minable coal is indicated. Recovery of the minable coal at 85 percent will yield 714,000 recoverable metric tonnes of marketable as-mined coal.

Auger mining reserves.—Auger-mining reserves of 576,000 metric tonnes are indicated. Recoverable auger-mining reserves of 202,000 metric tonnes (at 35-percent recovery) can be expected. Auger-mining production will vary according to the hole size being used, but, in either case, augering is a very profitable addition to the mining operation.

Cost and sales price.—A cost price range of $16.03 to $20.43 per tonne at the coal sales yard is estimated. Sale or market price for such coal is suggested to range from $20.04 to $25.54 per tonne at the coal sales yard. The cost and prices stated depend on whether the production level is 42,000 or 30,000 metric tonnes per year and whether coal is produced by low-cost auger mining. The sales prices are also dependent on the as-mined quality and market demand.

Comparison of projected energy prices.—To match the $8.81/Gcal price for natural gas fueling a proposed 50-MW (electricity generating) Fluidized Circulating Bed plant, the subject coal, at 4,673 kcal/kg (8,412 Btu/lb) (as-received basis), could be sold for as high as $40.67/tonne on an energy-content basis. A comparison with home heating natural gas in Yerevan, at 0.9 cents/m^3, indicates that the subject coal could be sold for as high as $51.32/tonne on an energy-content basis. The above energy comparisons are on an energy basis and do not include coal transportation or coal- and ash-handling costs.

Finally, this mine will require expert attention to detail. The mine can offer a coal product at a range of prices depending on the market demand for coal of different quality. That quality can be controlled to some extent by attention to detail during the mining process, the mining technique used, and the particular coal seam quality, thickness, and extent of outcrop coal degradation.

INTRODUCTION AND BACKGROUND

The U.S. Geological Survey (USGS) operated a coal exploration and resource assessment program in Armenia funded by the U.S. Agency for International Development (USAID). The USGS conducted detailed fieldwork on six coal fields in Armenia and exploratory drilling in one of those six coal fields, the Antaramut-Kurtan-Dzoragukh coal field. The Antaramut-Kurtan-Dzoragukh coal field is located in north-central Armenia (fig. 1) and covers a total area of approximately 20 km^2. Using data developed through the efforts of the USGS Coal Resource Assessment Team in north-central Armenia from 1997 to 1999, this prefeasibility study indicates that there are enough coal reserves of moderate quality to consider the development of a small surface coal mine in the northeastern quadrant of the Antaramut-Kurtan-Dzoragukh coal field, near the village of Dzoragukh.

Although it must be emphasized that the potential mine is a relatively small one, it must also be borne in mind that no ongoing coal mining experience, as such, exists in Armenia. The subject mine has the potential of providing a model for future coal mining as well as income and experience for local citizens and entrepreneurs. Concurrently, this local energy source will help to alleviate a chronic energy shortage with little or no lasting ecological damage to the environment.

Depending on market factors, anticipated miner productivity, and team work, there is good reason to expect the mine to be a very successful tax-paying business venture. The mine can supply heating fuel to local industry and citizens alike as well as provide the raw material for an acetylene production plant in a nearby city.

The coal resource assessment provided by the USGS gives sufficient information to warrant further small-mine development activities. These data, developed as part of the larger USGS study, can be found in other USGS publications (for example: borehole and thin section descriptions have been given by Pierce and others (1999); the geologic map of the mine area has been done by Pierce and others, USGS MF Map, in review).

Some future activities will be required before detailed mine planning or specific economic returns can be determined. These activities, which are discussed later in this report, include mine site photogrammetric mapping, additional outcrop trenching, mine development drilling, and additional coal quality evaluation. Also, some market development and coal business acumen may be required on the part of the business organization that plans to establish the mine.

MARKET COMMENTS

A coal market, as such, does not exist in Armenia. There is a recognizable demand but no supply (unless a source in Russia for a reported $50 per metric tonne can be considered a “supply”). Informal inquiry to officials in the Lori administrative district yields the information that the chemical plant in Vanadzor (an acetylene manufacturing facility, which converts carbide into acetylene by using heat and water) is looking for coal as a raw material in the manufacture of carbide. This chemical plant uses coal at the rate of 1,000 metric tonnes per 10,000 tons of acetylene. A supply of 1,000 metric tonnes of coal per month would yield 120,000 tons of acetylene per year in this plant. No acetylene is currently being manufactured because there is no affordable coal source.

Obviously, before proceeding with a coal-mining development project, it would be prudent to conduct a formal market analysis. In any case, the market potential for coal in Armenia appears to be very good. Historically, mainly imported and some indigenous coal have been used for home heating, for making briquettes, in district heating facilities, and in a copper smelter in Alaverdi (fig. 1) in northern Armenia. All of these historical uses are still potential uses.

Small exploratory coal mines in Armenia have been operated in several coal fields (Jajur, Antaramut, Nor Arevik, Ijevan) (fig. 1), but little coal production has ensued. In 1994-1995, at the Jajur location, USAID funded a small surface outcrop coal mine, as a humanitarian effort to alleviate a heating fuel shortage. About 50,000 metric tonnes of coal were produced and sold for approximately $20 per tonne. Because coal is readily consumed whenever it is available for sale in Armenia, this market for heating fuel continues to exist.

ANTARAMUT-KURTAN-DZORAGUKH COAL

Unpublished coal quality data from USGS coal exploration results indicate that the coal, which is Eocene in age, has an average calorific value of approximately 8412 Btu/lb (4673 cal/g) on an as-received basis and 15,326 Btu/lb (8514 cal/g) on a moist, mineral-matter-free basis in the area of the village of Dzoragukh. For the purposes of calculation in this report, we decided that an as-received value would be more appropriate.

Approximate ash yields for the coal beds in this area of the coal field average 39.9 percent (as-received basis). As-received moisture content in the study area averages 5.26 percent. A recent study was performed on a very small area of the Antaramut portion of this coal field by the Armenian Ministry of Environment (Keshabian and others, 1997). That report cited densities of approximately 1.65 g/cm^3 for coals in the Antaramut region of the coal field with analogous ash yields. Therefore, this value is the one we used for our reserve calculations (see below).

COAL RESERVE CALCULATIONS

USGS field geologists placed all borehole, trench, and outcrop data gathered as part of the resource assessment on a 1:5000-scale map for this study. Locations and elevations of boreholes were checked in the field according to topographic map locations. Detailed discussions were held with USGS field geologists about projected outcrop locality, bed dip, local and regional structure, lithology, and overburden details. Six additional trenches were specifically selected and dug for this economic analyses. Measurements (thicknesses) and other details were recorded before refilling the trenches.

USGS prepared and plotted a 1:5000-scale topographic map from a digitized 1:25,000-scale topographic map of Soviet origin. Because larger scale maps are still considered government proprietary in Armenia, none were available for any parts of the study area. The produced 1:5000-scale map was used to plot 15 cross sections to test (borehole) seam correlations and structure and to project coal seams to the surface. The above-mentioned trenches were helpful in understanding the local coal structure.

Three possible surface-mining areas were selected along a promising outcrop line. Each area contains at least two coal seams, and each area is bounded and separated from the others by faults. Each of the three areas appears to have potential for development into separate pits for a small surface coal mine.

The exploratory boreholes were placed for purposes of resource assessment, not for mine development, because assessment was the focus of the USGS project. For purposes of mine development, the boreholes are too widely spaced. However, data from the trenching sites selected by the USGS were combined with borehole data and helped fill in some areas. Before detailed mine planning can be accomplished, additional mine development drilling and trenching must take place.

The wide borehole spacing sometimes required projecting data from the actual borehole and trench locations to the desired locations of the vertical cross sections. Some cross sections were drawn directly through a borehole and trench. Because the cross sections were aligned along the strike of the coal seams (and structure), a projection of borehole data parallel to the seam strike and plotted at proper borehole collar elevation provided a reasonable view and detail of seam depth in relation to the high topographic relief of the area. Projected outcrop locations in many cases were verified by the trenches.

Because each of the three surface-mining pit areas was bounded by mapped faults (fig. 2), each was studied as an independent unit. “Working” cross sections were made for each area that contained the most typical representation of a mining pit area. The five cross sections (figs. 3-7) are typical representations of the “working” cross sections. However, other cross sections were used in this study, as figure 2 shows.

The following discussion on calculations for determining overburden volume and coal tonnage follows industry accepted procedure for dipping coal that outcrops.

OVERBURDEN CALCULATIONS

An estimated size for a mining pit was plotted on the selected “working” cross section. Such pits begin on the surface of the coal outcrop and extend down the projected 15^{o} dip of the coal to an estimated highwall (or final mining) boundary. As an estimated mining ratio starting point, an overburden amount of 10 m^3 for each metric tonne of coal was used. This ratio of overburden to coal (10:1) is usually near the upper economic limit for surface mining of coal for outcrop contour stripping of coal in similar deposits elsewhere.

The area of the overburden, as shown on the cross sections (figs. 3-7), is measured and calculated in square meters and converted to cubic meters by considering the cross section to be a 1-m thick “slice” or increment. In other words, 1 m of distance along the strike of the outcrop yields the overburden in cubic meters by multiplying the cross sectional area (in square meters) by 1 m. Using the measured distance along the outcrop strike that the cross section represents yields the cubic meters of overburden represented by each of the selected cross sections. The resulting numbers are added to reach a total cubic meter overburden figure for the mining pit being studied. Additional overburden amounts may have to be determined and added to the total. Such additional overburden includes pit end walls, any highwall setbacks, and other required rock removal work. Also included will be some of the overburden that has been placed in stockpiles during the initial mining phase and that will have to be rehandled (moved for surface reclamation purposes).

COAL TONNAGE CALCULATIONS

The first step in coal tonnage calculations for the selected pit is to plot vertical cross sections using drill hole, coal seam outcrop, and surface topography data. (Example of cross sections appear elsewhere in this report.) Cross sections display the coal seam at its proper dip, thickness, and its relation to the earth surface, as well as the location of the proposed limit of the mining excavation or highwall. A number of such cross sections are prepared which illustrate any changes in coal thickness and the effects of varying topography. Each cross section accurately represents a specific length of the pit, permitting the calculation of the volume and tonnage of coal in a manner similar to that used for overburden volume determinations.

Coal tonnage calculations are done in a manner similar to that used to calculate overburden, except the volume of coal is converted into tonnes through knowledge of the density of the coal, expressed as specific gravity. (Specific gravity relates all density numbers to a comparison with water, which is 1 t/m^3 and defined as a specific gravity of 1.0 g/cm^3). The coal studied has a specific gravity of 1.65 g/cm^3 (Keshabian and others, 1997), so that each cubic meter of coal represents 1.65 metric tonnes of coal.

First, the cross sectional area of the coal displayed is determined by measuring the down-dip length of the coal seam from minable outcrop to the proposed highwall limit and multiplying this length by the coal seam thickness. Second, this area (in square meters) is converted to a volume by multiplying the area by the length along the pit which the cross section represents. The resulting volume of coal in cubic meters is converted to tonnes by multiplying this number by 1.65.

The total tonnage for the mining pit is a summation of the individual cross section calculations.

Table 1. Total surface mining reserves

Pit	Minable tonnage	Ratio
East Pit	355,600	9.0:1
Central Pit	360,600	9.5:1
Western Pit	124,000	10.8:1
Total	840,200	9.3:1

Hence, the mine has approximately 840,200 metric tonnes of surface-minable coal, which can be mined at an in-place ratio of overburden to coal equal to 9.3 m^3 of overburden to each metric tonne of this minable coal. At an expected surface-mining coal recovery rate of 85 percent of minable coal, the ratio rises to 10.9:1 for the 714,000 tonnes of coal actually recovered, which is a reasonable final ratio for this mine. The 714,000 tonnes of recoverable coal is sufficient to provide for a surface-mine life of about 24 years at 30,000 tons per year (TPY) but at a mining cost higher than what would be attainable if auger mining were also used. The use of auger mining could raise production to 42,000 TPY. The lower cost of auger mining would also reduce the overall average cost of coal production.

Additional reserves are available for auger mining. This additional low-mining-cost coal reserve should be considered for mining when a final economic surface-mining highwall is reached. A decision regarding auger mining will need to be made near the end of the first full year of production mining and should include an analysis of the potential for an economic underground mine in the thicker #1 seam, which is not considered as a viable alternative on the basis of current data. The following discussion illustrates the potential of auger mining to raise the annual production from 30,000 to 42,000 metric tonnes per year for a life of 22 years at an overall lower per-tonne cost of coal.

AUGER RESERVES

The three surface-mining pits total 2,250 m in length. Along most of their extent, the two main coal seams and thinner rider seams will be considered for auger mining at appropriate times during the mining cycle. As soon as the final highwall is reached during surface mining, augering (into the highwall) of each seam segment should be done. (The final highwall is determined by the economics of mining, which sets the maximum depth of overburden that can be removed for the market value of the coal recovered.)

It is estimated that surface mining of the two main seams in this deposit, as proposed, will yield a significant length of exposed seams suitable for augering into the final highwall face. Any seams thicker than 0.4 m will be augered to a depth of at least 50 m into the highwall. Greater depths (to about 100 m) may be possible. To prevent subsidence (disruption of the surface above the augered highwall) and to minimize rock dilution, only about 35 percent of the in-place coal will be removed (a thin layer of coal is left on the overlying and underlying rock). At 35-percent recovery, the pillars left between the auger holes are of sufficient strength to support the overlying rock materials.

One augering machine will be used. Although none are currently available in Armenia, new or used machines are available in Russia (Kozlovsky, 1991). A twin auger machine that bores two holes will be employed. The machine obtained will be capable of boring both a 0.4- or a 0.9-m series of holes. Two sets of flight augers should be available in these two sizes to ensure maximum recovery of both seams.

The potential auger reserves are listed in table 2. These reserves are estimated on the basis of two coal thicknesses and total pit exposure for the pit lengths mentioned above.

Table 2. Potential auger mining reserves

Potential auger mining reserves			
Coal thickness (m)	**Highwall length (m)**	**Mining reserves[1] (metric tonnes)**	**Recoverable reserves (metric tonnes)**
> 0.4	1,550	58,000	20,000
> 0.9	4,500	518,000	182,000
Potential auger mining totals		576,000	202,000

[1] 50-m depth of augering shown. Auger reserves will double these figures if a depth of 100 m can be achieved.

TOTAL COAL RESERVES

The total estimated reserves available in the potential mining property studied are shown in table 3. The additional development drilling and other work required before a mining decision can be made will verify the tonnage and provide more accurate figures for determining the potential for auger mining.

Table 3. Total coal reserves

Type of mining	Recovery (%)	Minable tonnage (metric tonnes)	Recoverable tonnage (metric tonnes)
Surface mining	85	840,200@9.3 m^3/t	714,710
Auger mining Thin seams	35	58,000	20,300
Thicker seams	35	518,000	181,300
Total reserves		1,416,200	916,000 (rounded)

TYPE OF MINE

The proposed small surface mine has the potential to develop into a contour (outcrop) stripping and augering mining operation of the type found in the mountainous coal field areas of the Eastern United States and elsewhere. Through careful planning and execution, the mine can be designed and operated to improve the agricultural use of the land that is mined. This improvement is accomplished (if the land owner agrees) by converting suitable current pasture land or currently nonusable land into crop land. Reduced angles of slope and better drainage distribution over mined lands not only will increase crop acreage but will also improve crop and pasture yield as well. All vegetative materials (topsoil) will be saved and returned to the land following mining.

Premining site planning and construction will ensure that preexisting water flows will be retained at their original levels of quality and quantity. Additionally, all national and local regulations and laws will be adhered to.

MINE SIZE AND RESERVES

A 20-year mine life is suggested as an objective for this mine. Sufficient coal-mining reserves are estimated to exist for this purpose. Approximately 840,200 metric tonnes of minable coal have been identified at an anticipated recovery of 85 percent (dependent mainly on overall coal outcrop quality). The major portion of these reserves is deemed to be of market quality and can be mined by surface-mining methods within economic market limits. However, production from the surface-mining reserves alone, at the suggested 42,000-metric TPY level, would limit the life of the surface mine to 17 years. (Annual production at 30,000 tonnes would yield a surface mine life of 24 years but at a higher cost per metric tonne.)

A solution to increasing the amount of coal produced annually lies in the very great potential for auger mining beyond the economic limits for surface mining imposed by the ratios of rock overburden to coal tonnage. Reserves for such auger mining are estimated to be an additional 576,000 metric tonnes of minable coal. An anticipated recovery of 35 percent yields an additional 202,000 metric tonnes of high-market quality coal. In spite of the fact that auger mining will require the importation of the augering equipment from Russia (used equipment may be a possibility), the cost of such mining is low enough to justify the investment in the importation of required equipment.

An alternative to auger mining would be developing a small underground mine in the thicker #1 seam in the East Pit highwall. This possibility should also be considered after the mine development work is completed and early surface mining is underway in the East Pit. However, the data currently available support the auger-mining approach.

MINE PRODUCTION OBJECTIVE

As a means of setting a mining production objective, it was assumed that the coal market will develop steadily to 42,000 metric tonnes a year in less than 2 years. An examination of table 4 clearly shows that the total recoverable reserves of 916,000 tonnes listed earlier will provide the 840,000 recoverable tonnes required to size the mine at the 42,000 metric tonnes per year level for at least 20 years. Table 4 also illustrates that a small coal mine having an adequate reserve can develop into a thriving business entity while marketing an energy product at an energy price below that for other fuels. This subject is addressed in more detail elsewhere in this report.

Table 4. Production objective, potential gross annual income, and recoverable reserves required for the proposed surface mine

Production objective (tonnes)		Potential gross annual income			Recoverable reserves required (tonnes)			
Per mo	Per yr	$30/ton	$25/ton	$20/ton	5 yr	10 yr	15 yr	20 yr
1,000	12,000	360,000	300,000	240,000	60,000	120,000	180,000	240,000
1,500	18,000	540,000	450,000	360,000	90,000	180,000	270,000	360,000
2,000	24,000	720,000	600,000	480,000	120,000	240,000	360,000	480,000
2,500	30,000	900,000	750,000	600,000	150,000	300,000	450,000	600,000
3,500	42,000	1,260,000	1,050,000	840,000	210,000	420,000	630,000	840,000

MINE DEVELOPMENT REQUIRED

As stated previously, no mine development drilling or similar work has yet been undertaken. After the necessary permits and licenses required to proceed with mine development are received, additional geologic and mining data will be needed. Core drilling and trenching are required to verify the authors' projections and available coal quality data. A very accurate topographic map will need to be prepared by using photogrammetric methods. The precise location of all data, including pertinent geologic structure, will need to be placed on an accurate 1:500- or 1:400-scale map. Actual mine pit maps at a scale of 1:200 may also be required.

Coal outcrop locations need to be verified by trenching sufficiently to also determine the degree of degradation of coal quality by oxidation. Chemical analyses of a sufficient number of outcrop coal samples will be needed for this purpose. A full coal-quality laboratory has been established in Yerevan, Armenia, as part of the USGS program and is capable of producing the analyses required for this work.

Three potential surface-mining pits are planned. Only one pit need be opened in the beginning stages of this mine because the immediate coal market will not support a high initial volume of coal. Sufficient market does exist (Vartan Papian, Lori administrative district official, personal communication, 1999) to begin coal sales as soon as mine development allows. The mining will begin in the shallower outcrop area, so that the outcropping coal will be ready for market early in the mining operation. This coal will be mined and removed to a holding pile near the railroad to provide space for subsequent overburden removal.

COAL SALES/STORAGE FACILITY

As soon as the mine development work is completed and the decision to proceed with mining is made, a coal sales and storage facility needs to be obtained. The main administrative office for the business is planned for an identified area adjacent to the railroad in the nearby village of Tymanian, a short 4-km coal haul from the mine. This facility is ideally located to permit the rail hopper car loading required for the initial customer (the chemical plant in Vanadzor). However, its location next to a rail line will also facilitate a wider geographic range of future customers. It will also serve as a storage point for the coal that must be mined when uncovered in order to maintain uniform mining operations. A minimum storage capacity of 5,000 metric tonnes in open piles is suggested. (Spontaneous combustion in this coal is very unlikely during the possible maximum storage time of one month.)

The facility needs to be equipped with a platform scale suitable for weighing the 10-metric tonne mine trucks (which will provide management production/sales control and allow for the maintenance of local sales/dispensing records). Depending upon the contractual agreements with rail-delivered customers, another scale may be required on the car loader/conveyor system.

A security fence and other security methods will protect the assets, which will need to be attended by a guard during non-business hours. These assets include any stockpiled coal, a company office, vehicles, and equipment (2.0- and 0.5-m^3-wheeled loaders, a railcar loader, scale, and storage and maintenance facilities).

MINING SEQUENCE

1. The mining area (including the area to be mined, the appropriate topsoil storage pile area, and the temporary spoil area) needs to be surveyed. (Substantial survey reference monuments need to be located in accessible, protected places.) The location of the mine administrative area, including movable (or temporary) shop facility/vehicle and equipment parking areas should be established at this time. The security of the equipment and facility during non-operating times should be provided by appropriate guards and enclosures.

2. A drainage plan that will divert all rain (and snowmelt) water away from any mining area (or pit) needs to be prepared and followed. This work will require the construction of diversion ditches and, possibly, temporary collection and retention ponds both above and below the highwall economic mining limit. Provision must be made for temporary installation of a pump(s) at the temporary retention pond(s) to take care of excess seasonal rainfall or snowmelt. In any case, all such intercepted water flows from above the mining area, as well as any pit drainage water, should be accumulated in a retention pond(s) below the mining area until clarified by the natural settling of particulate matter before being allowed to flow into the natural adjacent drainage. No surges or water flow above the normal flows should be permitted.

3. Once the drainage installation phase has been completed, topsoil removal can begin. It is estimated that an average of 1 m of topsoil (plant growth) material will be removed from the surfaces to be disturbed by mining. This material should be stockpiled in an appropriate location in a rounded pile accessible to scrapers and seeded with grasses to minimize water and wind erosion. It is estimated that topsoil will be removed (and stored) initially from an area large enough to accommodate 3 months of mining activity. The size of future areas will be adjusted to meet the production requirements of the mining operation.

MINING PROCEDURE

It is suggested that actual mining begin at the eastern end of the East Pit (figs. 2, 3), shortly after surveying and layout of the mining area. Other work — that is, improvements to the access/haul road and installation of the mine administrative facilities (including electric power and telephone lines) – needs to be undertaken at this time.

SURFACE-WATER CONTROL

A surface-water drainage system needs to be installed. This work includes surface-water interception and runoff ditches, collector and settlement ponds, and final water-release control measures. Planning for and installation of these water-control facilities is a definite requirement to ensure minimal environmental degradation. Careful attention to existing irrigation systems is mandatory.

TOPSOIL REMOVAL AND STORAGE

Once surface runoff water control facilities are in place, topsoil removal and storage can begin. Scrapers, assisted by tractor-dozers as needed, should excavate the 1 m of topsoil over the entire area in the mining start-up area. A substantial area for long-term topsoil storage will be required below, at the East Pit end, and above the excavation location. The topsoil storage pile below the #2 seam outcrop needs to be located so that ample room remains for overburden from the initial cut from the #2 seam. Care should be taken to keep the water-drainage system intact.

The initial topsoil storage piles should be sloped and seeded to prevent erosion, because the piles will be in place for a long time. Most of the topsoil to be removed later in the subsequent mining operations should be respread on the reshaped, terraced areas from which coal has been mined.

OVERBURDEN REMOVAL

As soon as topsoil removal is well enough along, overburden removal can begin above the #2 seam at the eastern end of the East Pit (fig. 3). Heavy tractor-dozers equipped with single-shank hydraulic rippers can prepare a 50-m (uphill) by 100-m (along the crop) area above #2 seam for excavation by other tractor-dozers.

A note regarding ripping.—Consideration must be given to the fact that some of the overburden is of igneous origin. The tuffaceous material encountered may prove difficult and costly to rip, in which case some blasting may be necessary. Such a decision will be a judgement call. On the basis of an inspection of exposed rock faces in the vicinity, we estimate that blasting probably will not be required. In any case, the equipment obtained must include at least two of the heaviest tractor-dozers equipped with rippers available.

Excavation by Tractor-Dozer

Previously ripped overburden material can be excavated initially by tractor-dozers using the slot technique to move the initial pit material beyond the outcrop (a schematic of the overburden removal operation can be found in fig. 8). The excavation of the rock should be at a right angle to the outcrop and in a downhill working direction. A large Caterpillar D-9, Russian, or Komatsu straight blade tractor-dozer is recommended to work the slot along with two other dozers delivering material to the slot in an orderly, sequential manner. The two side dozers can work at an angle to the slot to enhance downhill work directions that will maximize production. Periodically, one of the two side dozers will move to the storage pile, which is being enlarged parallel to and a short distance (its edge is 10-15 m) beyond the outcrop. (The topsoil pile will also be located beyond the overburden pile being built. Care must be taken to keep these piles separate, and a water runoff ditch must be located between them.)

Excavation by Tractor-Scraper

As the level of the coal seam is approached, a 1-m buffer of overburden is left, and tractor-dozer work continues until the 15^{o} dip of the coal seam begins slowing rock production because of the uphill dozing effort required. At this point, the use of wheeled tractor-scrapers, assisted by a push tractor-dozer, is recommended. The slot-dozing team of three tractor-dozers can then move to the adjacent 50 x 100-m wide slot area (which is still above #2 seam and which has been under preparation in any case). The tractor-scrapers in the first slot will continue to remove the ripped overburden and continue building the pile outside the pit until the coal seam is uncovered.

COAL MINING

Equipment operators must pay careful attention to separating all rock from the coal; special training will be required to achieve this goal. A motor grader and other excavators need to be tested because each coal and rock interface has a different separation character. Experience has shown that some operators are especially talented at this work, the object of which is to eliminate any rock dilution in the quality coal product and also not to lose any coal.

The same careful attitude needs to be maintained throughout the coal removal process. Strict attention should be paid at all times to “no dilution” following “safety” and “environment” in this well-managed coal mine. Any stray rock that somehow gets onto the coal surface should be removed before the careful separation of coal from the underlying sedimentary rock continues. Where necessary, a thin layer of coaly material may be left to ensure the consistent quality of the coal product.

It is recommended that the coal be loaded into 10-metric-tonne tandem rear-end dump trucks by a track loader of 3-metric-tonne capacity. The coal will not require blasting or ripping, but a tractor-dozer may be required to excavate the coal into a pile for the loader.

The pit left by removal of the 1,500 more metric tonnes or more of #2 coal from the first slot provides an ideal location for depositing some of the overburden removed from the first 80 x 100-m slot above on the #1 seam. (Note that the pit width is 80 and 100 m along the highwall). There are 2,400 BCM (bank cubic meters) of overburden per meter of pit along the highwall in this area, only about 10 percent of which can be simply bulldozed over the edge into the mined-out #2 seam slot. The rest should be excavated and carried outside the pit by scrapers. (About 60 to 70 percent of the overburden outside the pit needs to be rehandled, but the reclamation “terracing” will reduce the haul distances.) Careful control of the amount dozed will allow a benching system to develop. As overburden removal and coal mining continues, transportation of overburden spoil outside the pit area will be gradually reduced. Some of the overburden can be respread directly on the terrace system being established as part of the surface restoration program.

A typical sequence of moving overburden off the coal to temporary storage is shown in figure 8. As mining activity continues, a concentrated effort should be made in the #1 seam area owing to the greater amount of overburden there. This effort will, in addition to uncovering the #1 seam, allow a system of benches extending to the west to be started. Using the dozers and tractor-scrapers, as described, to excavate and haul the overburden outside the pit area will ultimately provide for production of 2,500 metric tonnes of coal per month. After about 6 months (and nearing the end of the first year of full coal production of 30,000 metric tonnes), the final highwall at the #1 seam will be reached. Enough #1 seam will have been mined up to the highwall to permit a final inspection of the #1 seam and highwall conditions with an eye toward auger mining. A positive decision is anticipated, so that, early during the second year, auger mining can be added. A new annual production target of 42,000 metric tonnes per year is thus established for the second year of the mine life.

AUGER MINING

Auger mining will extend the life of the mine significantly and enlarge the annual production rate by about 40 percent to 42,000 metric tonnes per year. A dual-head, 1-m maximum diameter Russian auger system can be used to bore an "over-and-under" pattern in the 1.9-m coal seam. Information obtained in Armenia indicates that new (and possibly used) 1-m twin-head Russian machines (SHB-1) complete with two sets of auger cutting heads (in diameters of both 0.4 and 0.9 m) and auger flights for holes 50 m deep are available. The complete auger set can be obtained and shipped for an estimated $125,000 (current price).

It is recommended that the auger be operated by a crew of three operators on one shift. A single set of two side-by-side upper holes can be augered to a depth of 50 m. We estimate that a second set of holes, below and intersecting the upper holes, can be bored in one day. The machine can then be shifted 4 m along the highwall, and the sequence can be repeated. Approximately 200 metric tonnes of coal can be produced per operating day. It is assumed that auger locations will be available an average of only 25 percent of the time. The crew of three should be involved in mechanical maintenance when they are not operating the auger.

SURFACE RECLAMATION

As mining proceeds along the outcrop and the overburden material is deposited in the mined-out areas, reclamation of the surface needs to take place. Shaping of terraces, as planned, will eliminate the preexisting steep downhill slopes. A final gentle slope of 2° or 3° will maintain surface drainage without causing erosion. Terrace widths will vary according to the degree of the natural slope and the terrace bench height desired. At the East Pit, terraces about 35 m wide and with a 10-m bench height can be achieved.

Topsoil needs to be respread on the prepared terrace and pit endwall slopes during proper growing seasons. Seeding with local fast-growth grasses will minimize erosion, which is anticipated to be minimal in any event. Any gullies that form after rainstorms should be immediately filled in and reseeded.

As soon as the stockpiled overburden can be incorporated into the planned terrace land shape, it should be done. The stockpiled topsoil also needs to be respread as needed. By the time the East Pit is completed and restored, a period of 8 to 10 years will have passed. It is estimated that some of the restored surface (the terraces) will have been in agricultural production for 4 or 5 of those years.

CAPITAL REQUIRED

The purchase of land or mining leases for coal mining does not appear to be a requirement in Armenia. A severance tax for coal apparently does not exist, but it is reasonable to expect that such a tax will be levied in the future. Although the surface is owned by individuals, all mineral rights are still retained by the Government of Armenia. For this study, the only capital requirements considered were for preproduction expenses, purchase of equipment and facilities, and working capital for payrolls and other operating expenses. The study assumes a working capital of $300,000 which could be borrowed at a cost of 10 percent.

Of that $300,000, preproduction expense is approximately $85,000 (table 5). These funds provide for the mine development activities needed to further assess the economic viability of the proposed mining venture. No government subsidies or grants were assumed. Liquidated damages (for loss of crops during coal seam investigations, and so on) are included in the total cost of production. A total capital investment of $900,500 will be required, most of which will be invested in equipment and facilities during the first full year of production following the year of mine feasibility and development work. A breakdown of this investment follows later in the report (table 6).

All capital funds required for equipment and facilities are amortized as costs and are included in the total cost of producing coal later in this prefeasibility study. In this study, a 10-year amortization schedule was used for preproduction expenses of $85,000 and is included in the total mining costs listed later. The amortization schedules for equipment and facilities ($900,500) usually vary according to experience in the use of the equipment and tax regulations. For the purposes of this study, a 7-year schedule is used for the $900,500; such costs are also included in the total costs listed.

In the event that a decision is made to abandon the project following the expenditure of the $85,000 for mine development activities, the $85,000 must be considered either as a business loss or as a business development expense to be applied against income from other operations for income or other tax purposes.

PREPRODUCTION EXPENSE

The following list (table 5) shows the items used to estimate the preproduction expenses for the first year. All mine development costs are included. The total of these costs, amortized for 10 years, appears in Table 8 under the item preproduction expense amortization. Many of the following prices are based on personal experience in-country or on direct prices from the vendor (for example, the laboratory prices).

Table 5. Preproduction expense list (1 year)

Item	Cost (dollars)
Photogrammetric mapping services	10,000
Surveying	2,000
Trenching contractor, 12 mos @ $1,000/mo	12,000

Table 5. Preproduction expense list (1 year)—Continued

Item	Cost (dollars)
Drilling contractor, 6 mos @ $2,000/mo	12,000
Miscellaneous equipment rental and fuel	5,000
Laboratory charges and sampling	1,000
Supervision (mine engineer and geologist)	14,400
Miscellaneous cash outlay (property and crop damage)	5,000
Office trailer rental	1,000
Labor (mostly contractors)	15,000
Subtotal	77,400
Bank cost of funds (interest), 10 percent of money drawn	7,740
Total	85,140

EQUIPMENT AND ASSET LIST

This study uses more pieces of equipment than might be expected owing to the fact that the capacity of locally available equipment is smaller than that of equipment that can be obtained elsewhere (for example, local tractor-scrapers are less than half the size of equipment that would be chosen for the project in another locale). The costs of local equipment (obtained from the Republic of Armenia State Committee on Reserves) are surprisingly low, a fact that contributes to the relatively low cost of coal production in spite of the need for more equipment and personnel. However, informal review by a Lori administrative district official indicates that the prices used in this study are well above the prices for which most of this equipment could actually be obtained. If this assessment is true, these prices can be considered an absolute maximum, and actual costs will be lower than contained in this prefeasibility study.

A list of equipment needed at full production and the estimated cost of the equipment follow (table 6). Note that costs for much of the equipment were obtained from the GKZ, the State Committee on Reserves, which is the body responsible for approving all resource and reserve estimates in the Republic of Armenia and for approving mining plans for the Government of Armenia. In some cases, adjustments were made to provide for equipment larger than what is shown on the official list obtained from them.

Table 6. Equipment and assets, buildings and miscellaneous equipment, and coal sales/storage facility costs for proposed surface mine

	Cost (dollars)
1 motor grader	24,000
2 front end loader, 1 m^3, wheels	40,000
1 back hoe, 0.5 m^3, wheels	3,000
2 truck, rear dump, single axle, dual wheels	12,000

Table 6. Equipment and assets, buildings and miscellaneous equipment, and coal sales/storage facility costs for proposed surface mine —Continued

	Cost (dollars)
1 back hoe, 3 m^3, track type	28,000
2 front end loader, 3 m^3, track type	48,000
4 truck, rear dump, 10 m^3, tandem axle, dual wheels	72,000
1 tractor-dozer, tracks, with hydraulic blade (small)	14,000
1 tractor-dozer, tracks, with ripper and hydraulic tilt blade (medium)	30,000
8 scraper, 10 m^3, wheels, single engine	152,000
4 tractor-dozer, tracks, with hydraulic blade (medium)	112,000
2 tractor-dozer, tracks, with ripper and hydraulic blades (large)	80,000
1 vehicle, maintenance (grease/mech. truck with small air compressor and tool box)	8,000
1 welder, truck mounted	10,000
1 generator, mobile, with portable lights	15,000
1 air compressor, mobile (600-900 ft^3/min), truck-mounted	8,000
1 bus, 32 passenger	12,000
2 utility vehicle, 4-wheel-drive, van	20,000
1 fuel truck	15,000
1 shop equipment (tools, jacks, etc.)	10,000
1 augering equipment (SHB-1, dual head, with two sets of augers, 0.4- and 0.9-m diameter)	12.500
1 pump, 0.05 m pipe diameter, 500 l/min., diesel	1,000
1 pump, 0.1 m pipe diameter, 2,200 l/min., diesel	1,500
1 small tractor, 4 wheel-drive, with scarifier hydraulic blade	4,000
1 front end loader, 0.5 m^3, wheels (utility)	4,000
Total	848,500

Table 6. Equipment and assets, buildings and miscellaneous equipment, and coal sales/storage facility costs for proposed surface mine —Continued

	Cost (dollars)
Buildings and miscellaneous equipment	
Shop/shelter building (at mine)	10,000
Office trailer	3,000
Toilet and sanitary facilities	1,000
Trailer for lunch, training, and emergency care	2,000
Total	16,000
Coal sales/storage facility	
Buildings and permanent items (fence, gate)	20,000
Railroad car loader	15,000
Scale, truck	1,000
Loader, 15m^3, wheel (inc. above)	-----
Loader, 0.5 m^3, wheel, utility (inc. above)	-----
Total	36,000
Grand total	900,500

PERSONNEL REQUIRED

Armenian geologists have played an important role our coal resource assessment and are qualified to proceed with further coal mining development. In order to initiate mining, local excavation equipment operators and their equipment can be expected to serve as contractors. As quickly as possible, a high-quality work force will have to be assembled to operate company-purchased or company-leased equipment.

Although profitable surface coal mining is a production-oriented activity, it is also a coordinated team effort to produce the highest quality product possible at low cost and with the utmost care for the environment and safety of workers and local citizens. To accomplish these ends, a consistent on-the-job miner training program needs to be established.

An estimate of the personnel required to operate a small surface coal mine in the Dzoragukh area has been made. The number of personnel shown is higher than one might expect, but is necessary because of the smaller equipment available in Armenia. The wage rates used in this report are considered top wages in Armenia, which will attract the most qualified personnel available. However, because the wages are still relatively low on a world coal mining scale, the overall coal production costs will be relatively low.

During the 1-year development stage, contractors will need to be hired for the various services required. Once the decision to proceed with the mine has been made, a full complement of workers and staff should be hired quickly. Most of the job openings are for skilled equipment operators, similar to those found in highway and large dirt and rock excavation projects. A good supply of this type of worker exists currently in Armenia.

Skilled workers will be hired, but reorientation training and skill improvement training will need to be done for safety and environmental protection purposes. Where special skills are required for particular equipment operation for mining purposes, individual training can be conducted as an on-the-job procedure by the Superintendent Mining Engineer and(or) the Deputy Superintendent Geologist and the three supervisory personnel.

The mine workforce should become stable within the first year of production. We recommend that a total of 54 skilled and semiskilled equipment operators and technical persons be hired on a permanent basis. Of this total, five will be unskilled laborers, and four will be security guards. In addition, a total of five supervisory personnel will be employed on a permanent basis.

The ratio of 54 workers to 5 supervisory persons fits a generally accepted level of supervisory management practice. Safety, environmental aspects, and emergency conditions need to be well controlled.

The following list (table 7) displays the employment categories and job titles of the proposed mine workforce. The monthly salaries listed are intended to follow current levels for "excellent" employment in Armenia and assume a local labor market for all jobs. A high-caliber workforce will be required and should be possible to obtain. A low turnover for the mine's workforce should be an intended goal.

Table 7. Proposed mine personnel list and annual payroll for full production

Category	Individual (dollars per month)	Total annual (dollars)
Labor		
1 equipment operator, grader	400	4,800
5 equipment operator, front end loader	400	24,000
2 equipment operator, back hoe	400	9,600
6 equipment operator, tractor-dozer, med., small	400	28,800
2 equipment operator, tractor-dozer, large	450	10,800
8 equipment operator, scraper, wheel	400	38,400
2 equipment operator, light duty utility equipment	300	7,200
4 driver, truck, coal haul	350	16,800
2 driver, truck, regular	300	7,200
1 driver, bus	300	3,600

Table 7. Proposed mine personnel list and annual payroll for full production—Continued

Category	Individual (dollars per month)	Total annual (dollars)
Labor—Continued		
2 auger operator	400	9,600
1 mechanic, lead	450	5,400
2 mechanic	400	9,600
1 electrician	400	4,800
1 welder mechanic	400	4,800
3 helper, mechanic/electrician/auger	350	12,600
5 laborers/reclamation helpers	300	18,000
1 scale man/guard	350	4,200
4 guard (2 at mine, 2 at scales facility)	250	12,000
1 accountant/payroll clerk	400	4,800
Total labor work force per year		237,000
Supervisory		
1 superintendent (mining engineer)	650	7,800
1 ass't superintendent (geologist)	600	7,200
3 supervisor, shift	500	18,000
Total supervisory work force per year		33,000
Total work force per year		270,000
Plus 28 percent pension and other benefits (workman's comp)		76,600
Grand total		345,600

When all of the above factors are taken into account, the cost per annual tonne of production can be calculated (table 8). Estimated cost of production for both the 30,000- and 42,000-metric tonnes per year levels are listed in table 8. Assumptions made include the following:

- Uniform annual coal production of 30,000 TPY will be mined only from the 714,000 metric tonnes of recoverable surface mining coal reserves.

- Uniform annual coal production of 42,000 TPY will be mined from the 714,000 metric tonnes of recoverable surface mining coal reserves plus the 202,000 metric tonnes of recoverable auger mining coal reserves.

- The mine life is 20 years (sufficient recoverable coal reserves have been estimated to exist for a 20-year life).

•In calculating the 30,000 TPY coal-production level, both the labor and the equipment costs were calculated without the auger coal mining equipment and associated labor costs (which are included in the 42,000 TPY size mine).

•The equipment total cost ($848,500) was amortized over a 7-year schedule. Other amortization schedules could have been used for the purposes of this study, but the 7-year schedule is deemed to identify the mining costs adequately.

•Building and fixed assets costs ($52,000) and preproduction expense ($85,000) were amortized over the mine life of 20 years.

Table 8. Cost per annual tonne of production

Item	30,000 TPY strip mining (dollars)	42,000 TPY strip + auger (dollars)
Labor and supervisory	10.93	8.23
Supplies (15 percent of annual equipment costs)	3.62	3.03
Fuel (5 percent of annual equipment costs)	1.21	1.01
Working capital interest ($30,000)	1	0.71
Equipment amortization	3.44	2.89
Buildings and fixed asset amortization	0.09	0.06
Pre-production expense amortization	0.14	0.10
Total	20.43/tonne	16.03/tonne

Table 9 lists the sales prices per metric tonne of coal attainable with a 25-percent (before taxes) profit added to the total costs of production (tabulated in table 8). Sales prices are listed for both the 30,000- and 42,000-metric tonnes per year production levels. The sales prices shown indicate that the mining project, as described, is nearly a million dollar per year business venture.

Table 9. Proposed sale price of coal

	30,000 TPY strip mining (dollars)	42,000 TPY strip + auger (dollars)
Total cost	20.43	16.03
Proposed profit (25 percent before taxes)	5.11	4.01
Proposed sale price	25.54	20.04

COMPARISON OF PROJECT ENERGY PRICES ON AN ENERGY-EQUIVALENT BASIS

The above proposed prices are for sales at the Tymanian coal handling facility at the Tymanian railway station. The following discussion is on an energy-equivalent basis only.

When studying any fuel, a comparison with the prices of competing fuels may be useful to set a relative scale for various competing energy sources. The comparison is based on the energy content of each fuel in kilocalories per kilogram (British thermal units per pound). A complete analysis must take into account all cost elements in each fuel considered.

This study made a limited comparison between the price of the subject coal and the reported prices for natural gas (methane) for large-volume use (a proposed 50-MW electricity generating powerplant) (Burns and Roe Enterprises, 1998) and a lower volume natural gas consumer, such as individual household use.

Example 1: Low-volume user: household natural gas.—Natural gas containing 8,600 kcal/kg (Laviorov, 1985) sells for 51 drams for household use in Armenia (0.0059 drams/kcal). A comparison with coal containing 4,673 kcal/kg follows. One metric tonne of the subject coal contains 4,673,000 kcal/tonne.

$$\frac{4{,}673{,}000 \text{ kcal/tonne}}{8{,}600 \text{ kcal/kg}} = 543 \text{ equivalent gas units at 51 drams/unit}$$

Hence, 1 tonne of subject coal, as compared to this gas price, is worth (543)(51) = 27,713 drams and at 540 drams/$1 = $51.32/tonne.

Example 2: High-volume user: proposed 50-MW power station (data obtained from Burns and Roe, 1998).—The offered price of natural gas is $8.81/Gcal at the powerplant. This price in drams is 4,757.4 drams/Gcal (10^9 cal), 4.7574 drams/Mcal (10^6), 0.0047 drams/kcal (10^2).

The value of the subject coal in comparison with this gas price.—The subject coal has 4,673 kcal/kg (1 metric tonne is 1000 kg) or 4,673,000 kcal/tonne. The price in drams is (4,673,000 kcal/tonne)(0.0047 drams/kcal) equaling 21,963 drams/tonne. At 540 drams/$1, the price of the subject coal, in comparison with this gas price, is $40.67 per tonne.

CONCLUSIONS

On the basis of available information, it is the authors' opinion that a small surface-auger coal mine having a life of about a 20 years could be developed in the Antaramut-Kurtan-Dzoragukh coal field. Because the USGS project was a coal resource program and not a mine development program, additional mine development work, such as drilling, will be necessary to prove out the final feasibility of the mine. However, the mine development work may, in fact, expand the reserve base and thus increase the available tonnage and(or) mine life.

There is an immediate market for the Antaramut-Kurtan-Dzoragukh coal, so we fully expect the market to expand as the coal becomes available. Comparisons with natural gas, on an energy basis only, indicate that this coal will be very price competitive. Given these factors and the fact that coal is one of the few indigenous energy resources of Armenia, the Antaramut-Kurtan-Dzoragukh coal field warrants further detailed development work.

ACKNOWLEDGMENTS

Without the help of the USGS geologists Artur Martirosyan and Samvel Harutunian, this work would not have been possible. They provided long hours of geologic discussions, cross sections, detailed borehole descriptions, and mathematical calculations for conversion between systems. Grateful acknowledgment is made to these two individuals as well as Grigory Harutunian of the Ministry of Environment, Republic of Armenia, for sharing their geologic knowledge. We are also indebted to Gourgen Malkhasian, also of the USGS staff, for digitizing and producing some of the figures used in this report. Gaggik Papian translated the borehole descriptions for use in making the cross sections and mine layout. Irina Astvatsatouriants spent many hours translating this report into Russian for interested users. Finally, we express our thanks to Hamlet Amazaspian, Ministry of Environment, for providing to us many of the required Armenian governmental norms and regulations, for reviewing this document, and for his genuine interest in this project.

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Figure 1. Location of coal, carbonaceous shale, and oil shale deposits in Armenia.

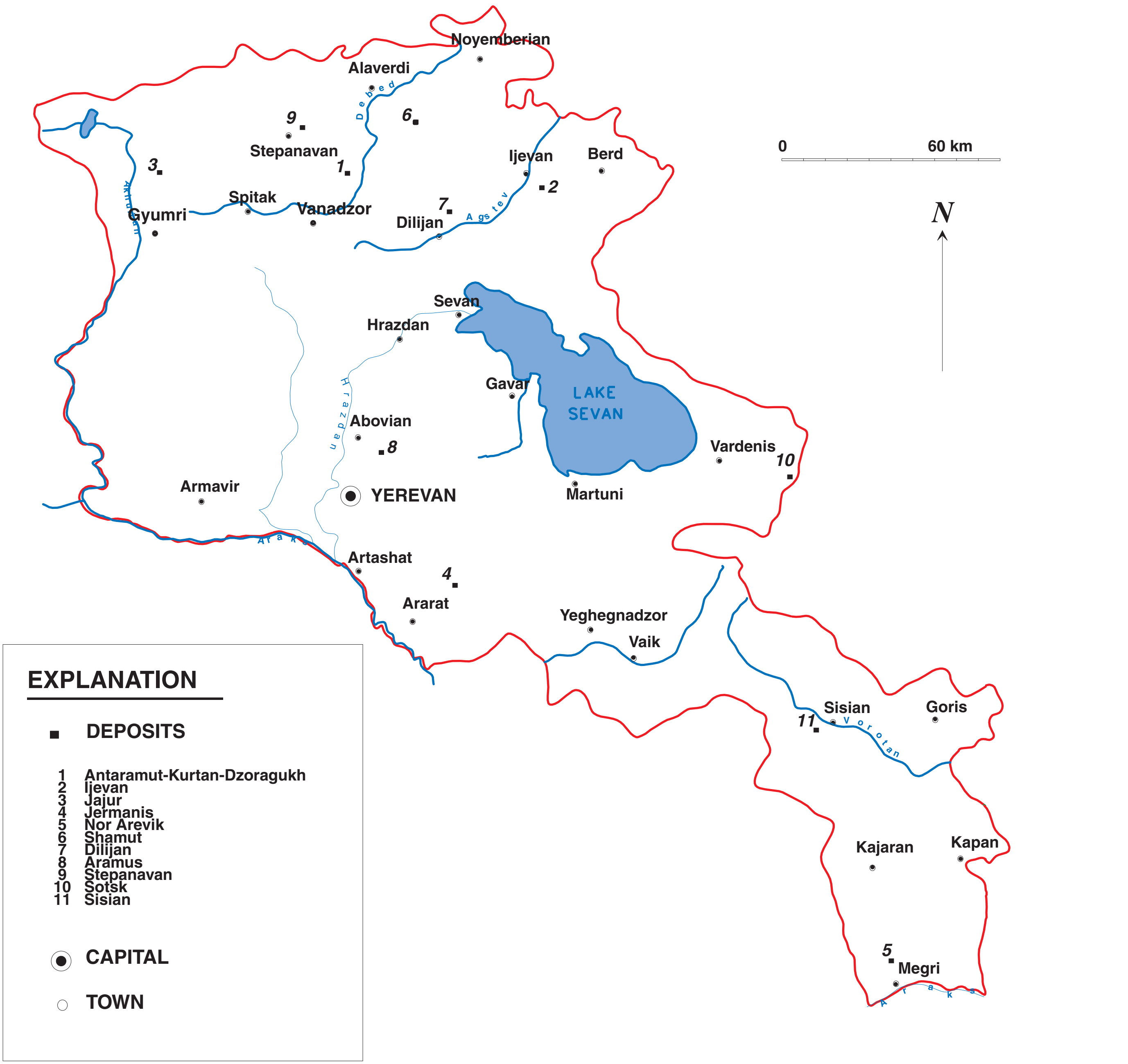
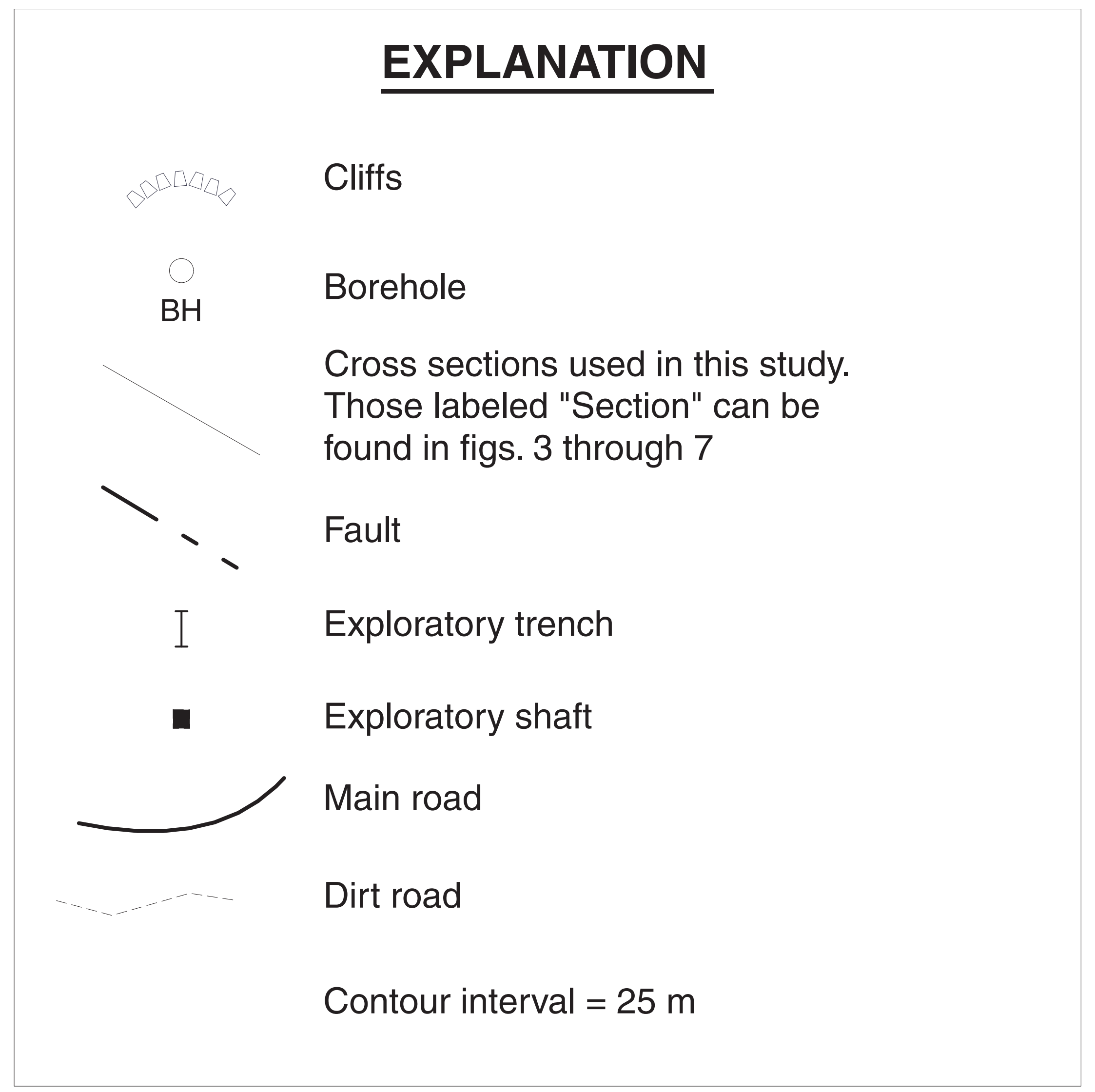


Figure 2. Topographic map and schematic of three proposed strip mines in the Antaramut-Kurtan-Dzoragukh Coal Field, near the village of Dzoragukh, in north-central Armenia. Figure is scanned from a 1:25,000-scale map and converted to 1:5,000 scale. Therefore, the scale can only be considered approximate. One cm is equal to approximately 50 m.



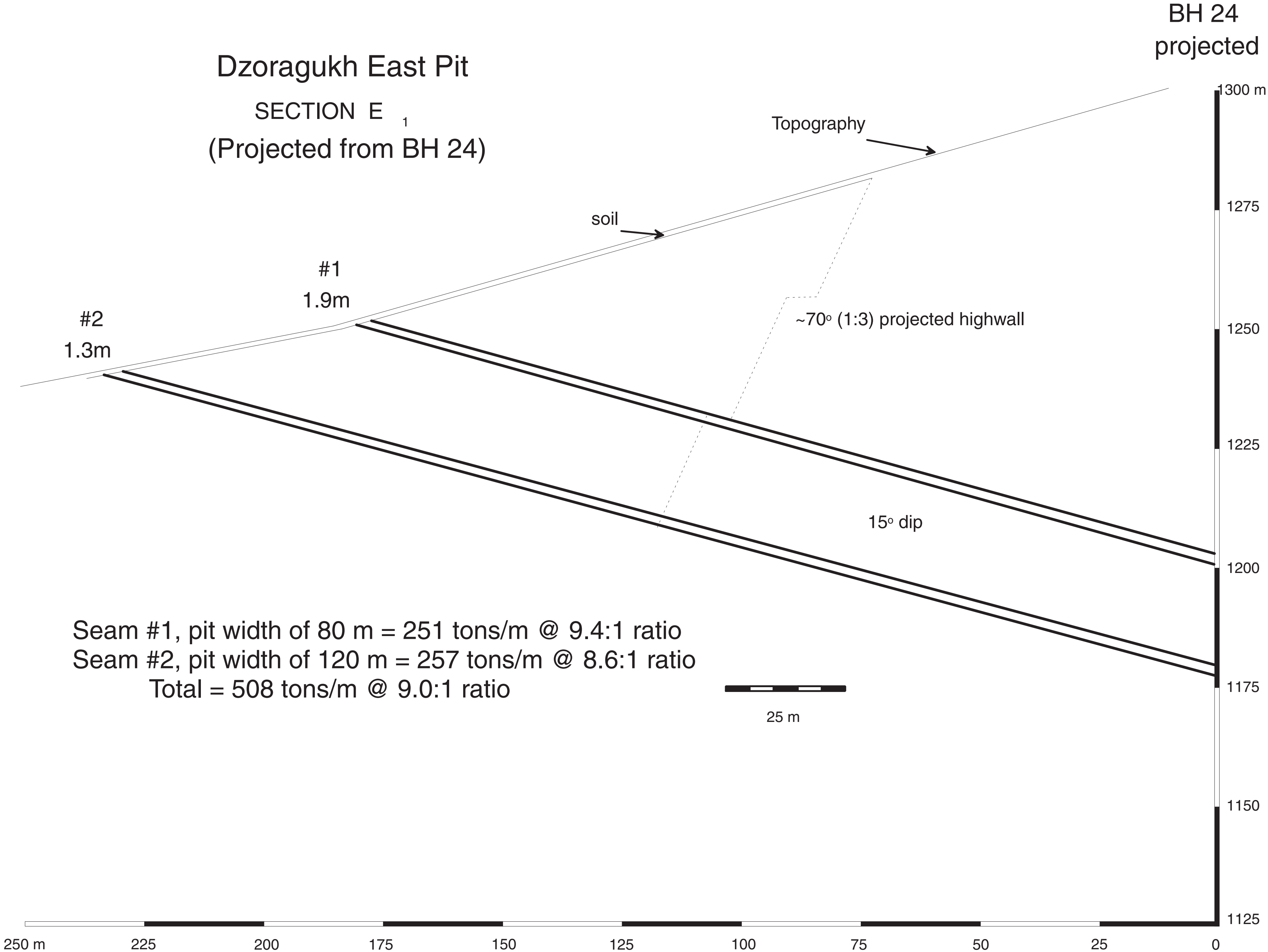


Figure 3. Representative cross section for the proposed East Pit of the Antaramut-Kurtan-Dzoragukh coal field, near Dzoragukh, Armenia.

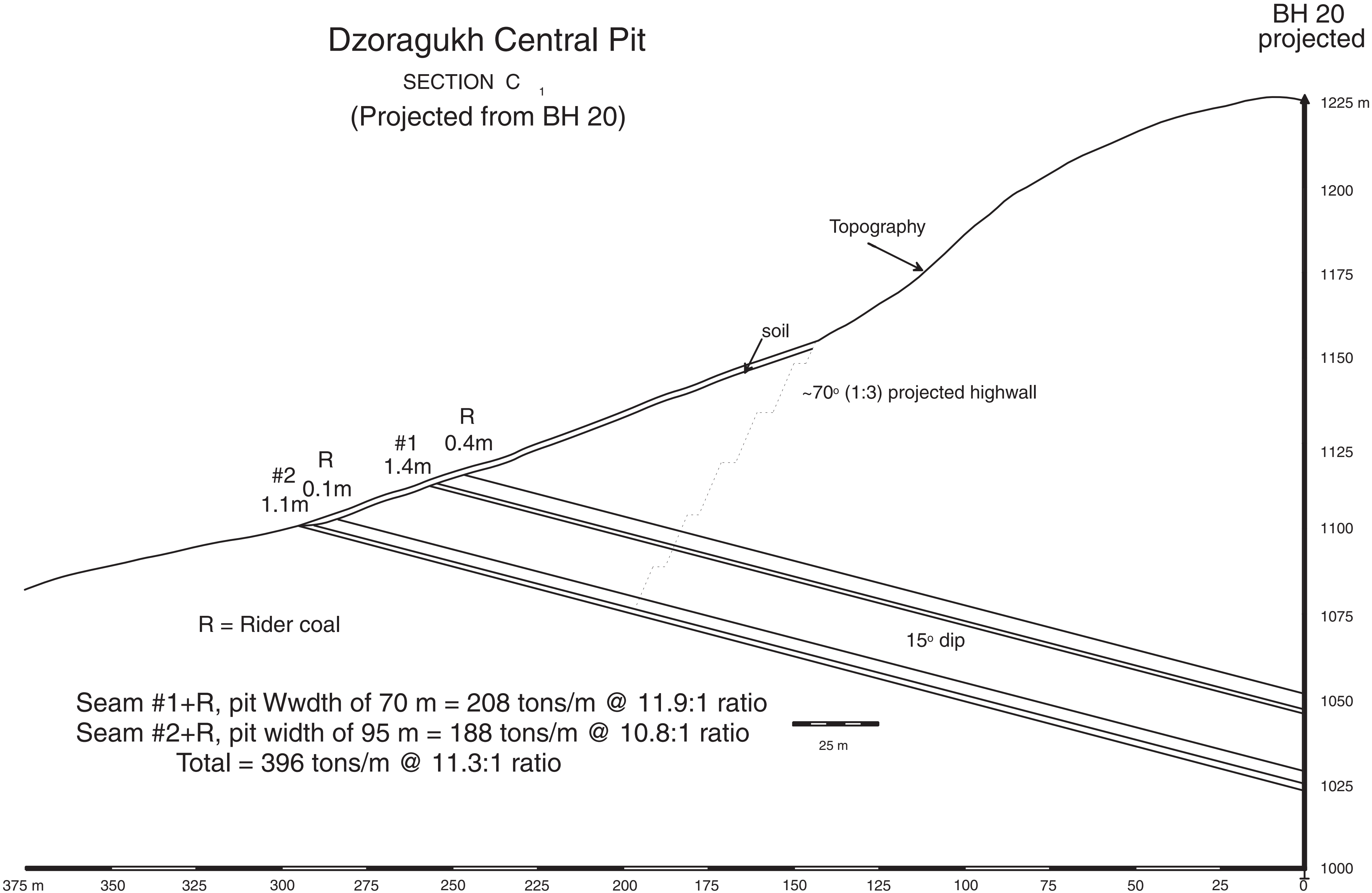


Figure 4. One of three representative cross sections for the proposed Central Pit of the Antaramut-Kurtan-Dzoragukh coal field, near Antaramut, Armenia.

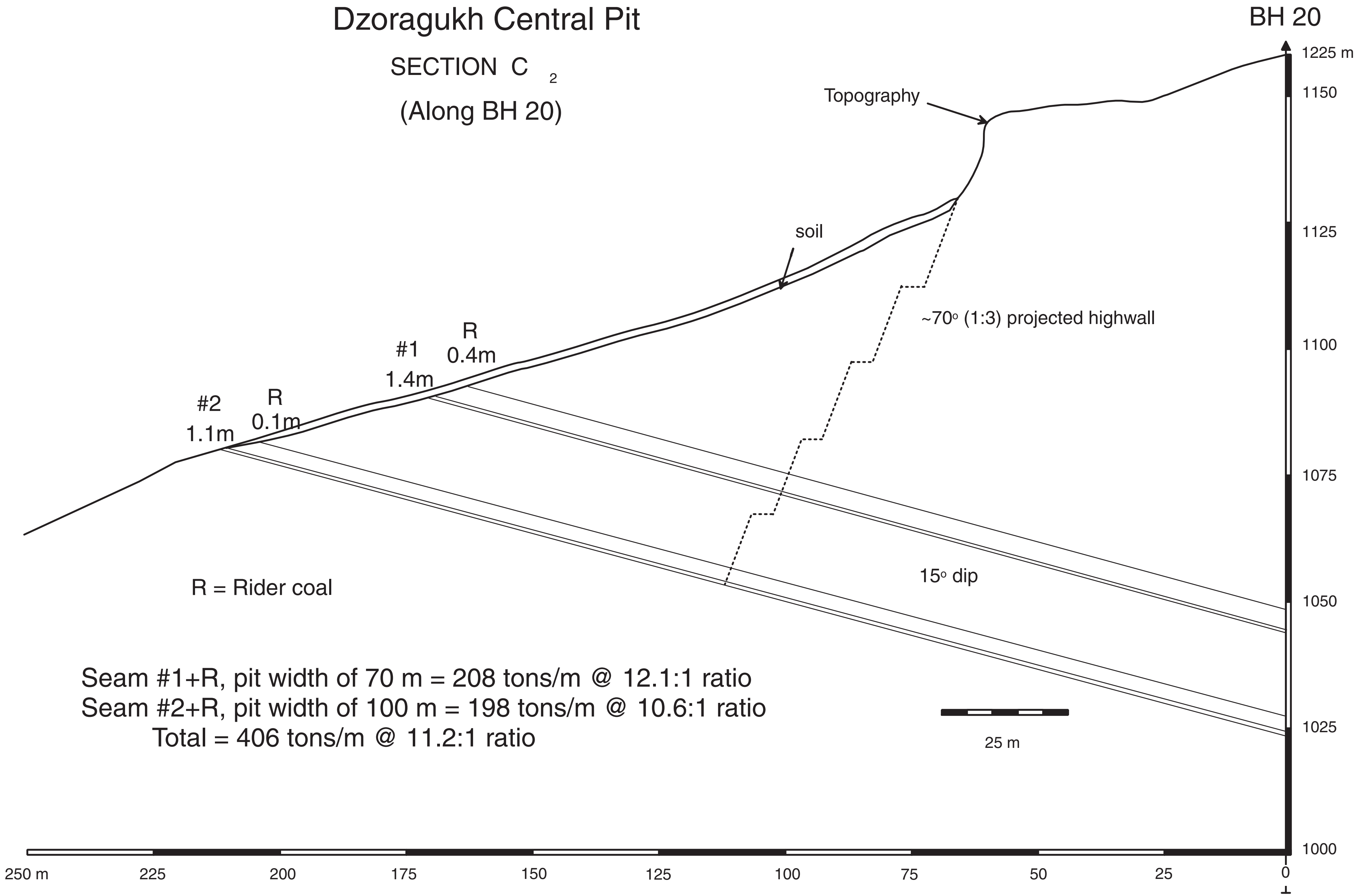


Figure 5. One of three representative cross sections for the proposed Central Pit of the Antaramut-Kurtan-Dzoragukh coal field, near Dzoragukh, Armenia.

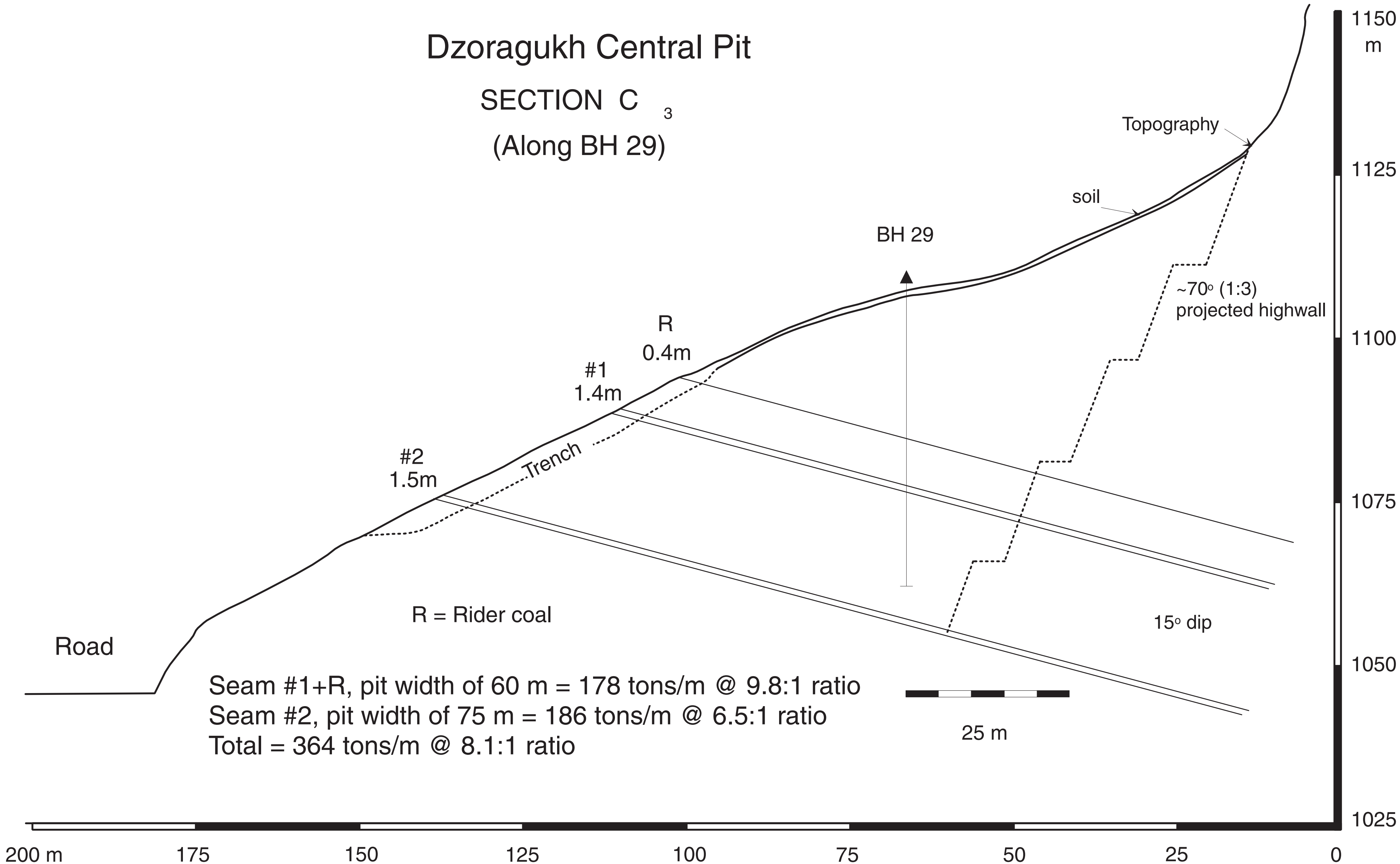


Figure 6. One of three representative cross sections for the proposed Central Pit of the Antaramut-Kurtan-Dzoragukh coal field, near Dzoragukh, Armenia.

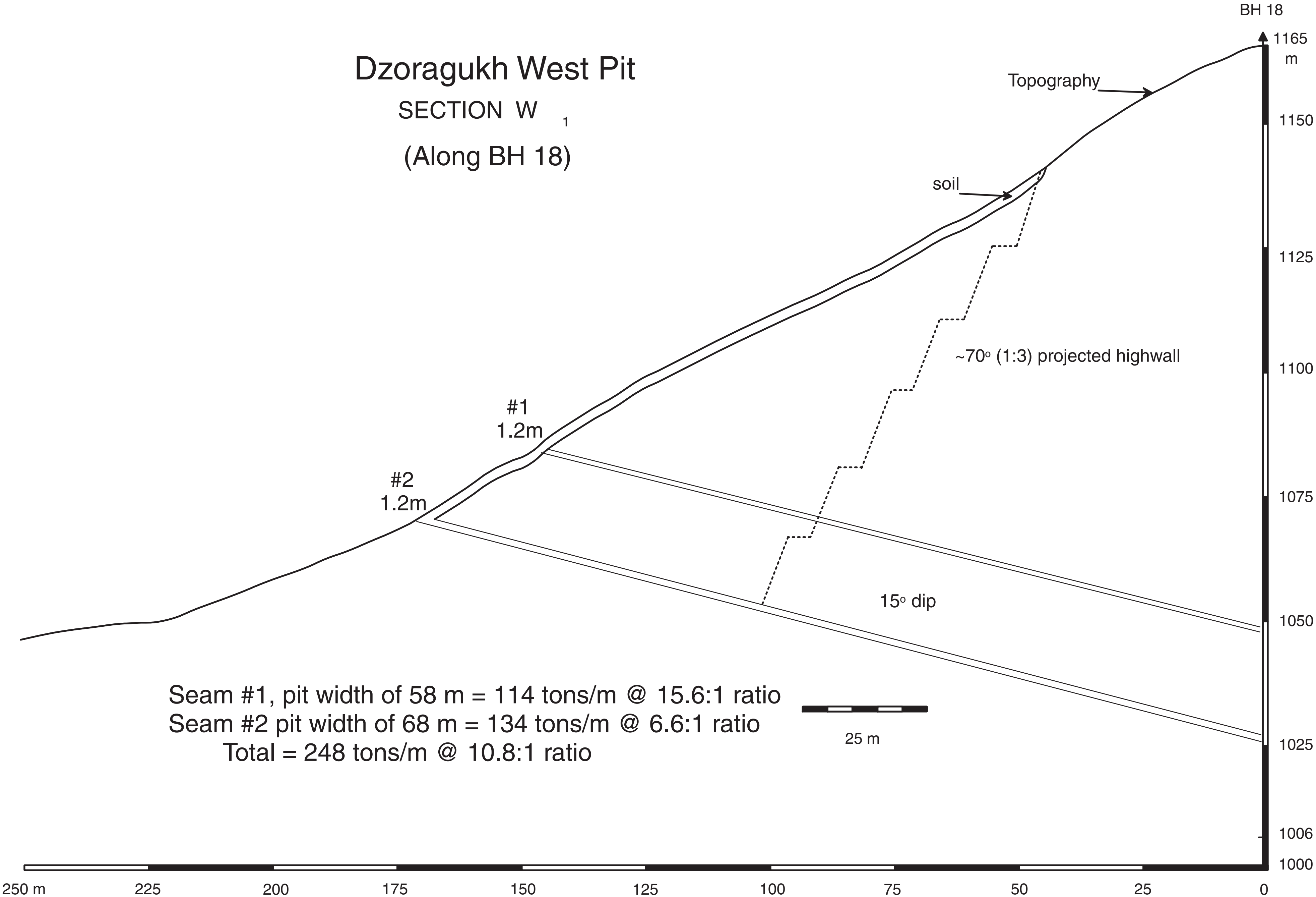


Figure 7. Representative cross section for the proposed West Pit of the Antaramut-Kurtan-Dzoragukh coal field, near Dzoragukh, Armenia.

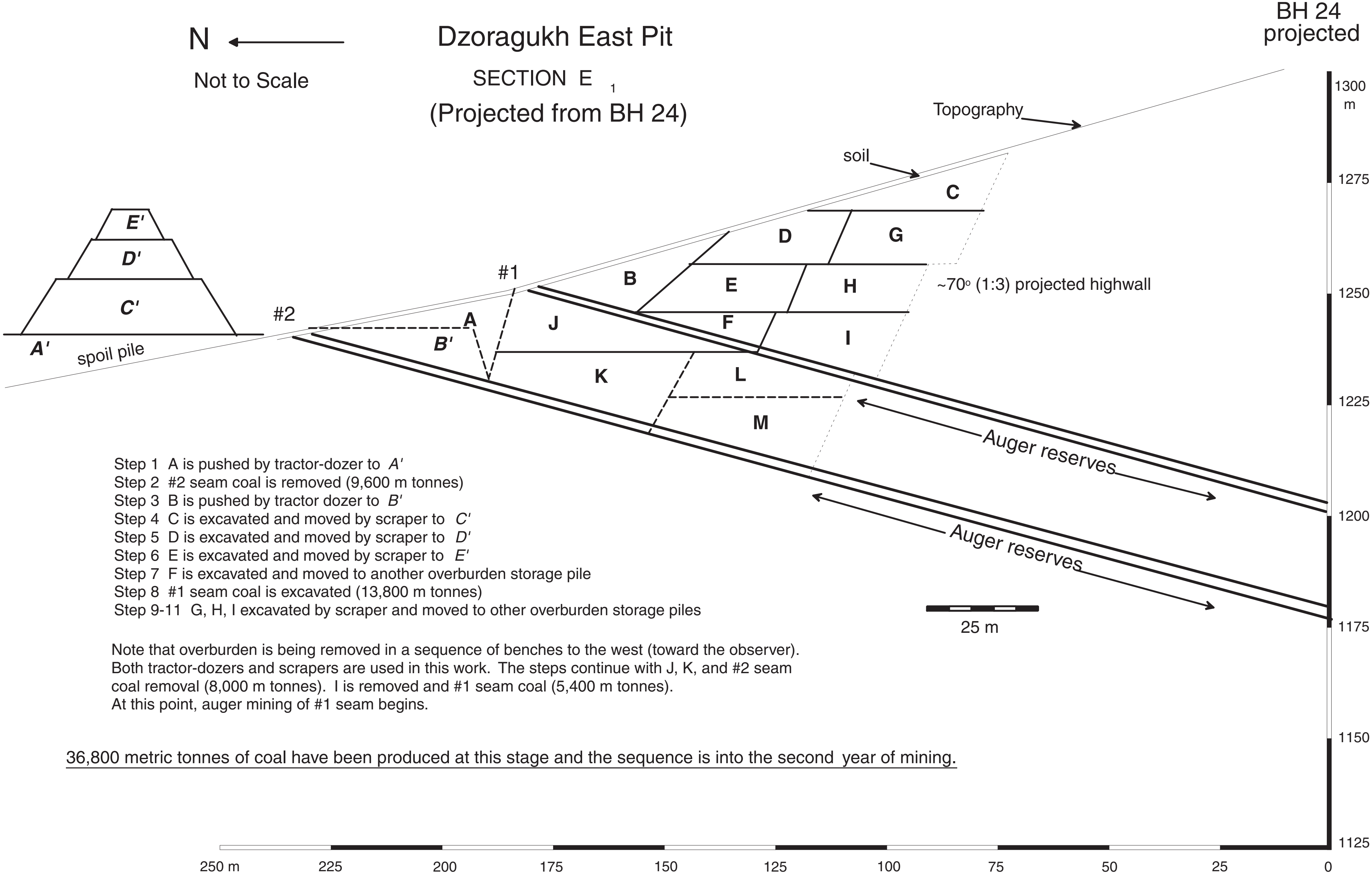


Figure 8. Schematic of overburden removal for the proposed East Pit of the Antaramut-Kurtan-Dzoragukh coal field, near Dzoragukh, Armenia.