The Engineering Geological Investigations on the Coruh-Yusufeli Dam Site and its Reservoir, Turkey

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Abstract

Coruh River is the most important river in the North-Eastern Turkey. Preliminary studies, aiming to determine the energy potential of this river, have resulted in selection of eleven dam sites, named Laleli, Kilicci, Gullubag, Ispir (Norgah), Cetinbogaz, Uzumlu (Arkun), Yusufeli, Inanli (Zeytinlik), Artvin (Deriner), Borcka and Muratli. These studies have also shown that landslides possibilities require major modifications in some of proposed dam sites. There are two complementary facieses in the region. In the south, the Jurassic and Cretaceous are represented by volcanogenic and carbonated flysch. The Eocene is characterized by an andesitic volcanism. Serpentinite, gabbro, amphibolite, green schist, pillow-lava, spilite, phyllite and graywacke in Lias occur in the north. Carbonated flysch of Malm comes discordantly over Lias. These series continue up to the end of the Cretaceous. The Upper Cretaceous is represented by volcanic rocks containing occasional sedimentary intercalations; basalt, dacite and dacitic tuff. The Eocene is represented by lithic tuff, andesitic lava and agglomerates. All the rocks are occasionally cut by granites. The impermeability of reservoir rocks seems to be satisfactory, but, some significant amount of water losses due to faults and fractures are sometimes encountered during water pressure tests in boreholes drilled at the Yusufeli dam site.

Introduction

The most important river of North-Eastern Turkey is Çoruh, which has an energy potential of 9 x 10^9 KWh. In order to use the energy potential of the river, a series of dames named Laleli, Kilicci, Gullubag, Ispir (Norgah), Cetinbogaz, Uzumlu (Arkun), Yusufeli, Inanli (Zeytinlik), Artvin (Deriner), Borcka and Muratli, have been designed upstream to downstream. The constructions of Borcka and Muratli have already been completed and Deriner dam is on the way. The Coruh River flows from south-west to north-east. The average discharge is 33 m^3/sec at the Laleli dam site, and 205.45 m^3/sec at the Muratli dam site (Ertunc, 2002).

Stratigraphy

Two different facieses are observed in the north-eastern and south-western parts of the Coruh River. Lias is represented by the Yusufeli formation in the north-east region of the investigated area. The Yusufeli formation is composed of serpentinizated gabbro, amphibolite at the bottom; spilite, metalava and green schist at the middle; and graywacke, slate and phyllite at the top. The Berta formation, which consists of alternations of basaltic-dacitic and sedimentary rocks are seen in Upper Cretaceous. Eocene is represented by the Borcka volcanics of lithic tuffs at the bottom and andesitic lavas and agglomerates at the top. The Pugey formation starting with basal conglomerates overlies granitic bedrock in the south-western region. This formation continues from Lias to Upper Cretaceous. The extension of the Pugey formation towards Oltu Brook starts with basal conglomerate in Malm and continues with flysch facies until the end of Lower Cretaceous; between these two, a volcanic intrusion composed of basaltic and rhyolitic agglomerates took place in Neocomian. In Eocene, a calc-alcalic volcanism (Laleli volcanics) consisted of andesite and andesitic pyroplastics is seen (Eroskay,S.O.1970). Plio-Quarternary aged,

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salty and gypsy Gullubag formation composing of mudstone, conglomerate and sandstone exists at the top (Gattinger,T.E 1955 and 1956).

The Yusufeli dam site is situated on the Ikizdere magmatics. The Yusufeli formation, the Berta formation, the Pugey formation and the Ikizdere magmatics crop out in the Yusufeli reservoir.

The Yusufeli Formation

The Yusufeli formation outcrops along the Coruh River between the north-east of Yusufeli town and south of Artvin city. The outcrops of this formation cover large areas on both sides of Coruh River. On the other hand, the Yusufeli formation is also observed along the Oltu Creek up to Dagyolu village. It is quite easy to observe the unit from bottom to top in the deep Coruh valley. From the bottom to the top, serpentinizated gabbro, amphibolites, spilite seen locally as pillow lavas, metalava and green schist, graywacke, slate and phillite are present. The dominant rock colors are black, dark green and gray. Folds, faults, overthrusts and young granite intrusions made geology of the area and the relations between the rock units complex. It is very difficult to estimate the original relationships. Therefore, it is not possible to observe a type section. The thickness of the unit is thousands of meters. Young granite intrusions formed amphibolites and milonitization near the contacts. The foliation zones formed due to the metamorphism are often distinguished between Artvin and Yusufeli. The bedding can be seen at the locations where the metamorphism is not effective.

Some samples of rock from the Yusufeli formation were taken and petrographically analyzed. According to these analyses, these rocks are metalava, metatuff, glassy tuff, lithic tuff, basalt, agglomerate, slate, slate-phillite, graywacke-slate and mylonite (along contacts with granite).

Berta Formation

The Berta formation lies along the banks of Coruh River between the eastern part of Sirakonaklar Creek, downstream of Cetinbogaz dam site and Yusufeli County. The outcrop seen in the eastern part of Zeytinlik village extends in the north-eastern direction up to the Berta military station and along Ardanuc highway. In addition, the Berta formation crops out between Artvin and the south of Borcka dam site. The Berta formation is composed of spilitic basalt, dacite and rhyolite alternation. It also contains mudstone, marl and limestone. Some sandstone and conglomerate layers are also observed at the upper levels of this deposit in the south of Borcka town. This rock unit is occasionally cut by dikes. Hydrothermal alteration zones cover large areas. Excessive silicification and chert are seen as alteration products.

The petrographic studies on the thin sections of some samples taken from the rocks are rhyolite, dacite, spilite, basalt, agglomerate, arenite containing volcanic rocks, vake, clayey biomicrite, biomicrite, conglomerates and various tuffs (glassy, pumice, lithic, silicified, dolomitized). The total thickness is more than 2000 m.

The Pugey Formation

Along the Coruh valley, approximately in the southern part of the Ispir-Erzurum highway, limestone-marl alternation, claystone, slate, marl, sandstone and conglomerate are interfingered with each other. Some volcanic intrusions are also seen among these rocks. The ophiolite can be recognized along the Ispir-Erzurum highway.

The limestone is gray, yellowish, green, black, brown, thin and moderately bedded, regularly jointed, recyristallized, thin calcite veined, very hard and competent. It contains some marl layers whose thickness varies from several millimeters to 1-2 meters. The marl is yellow, greenish, incompetent and easily crumbled. The claystone, slate, marl

are gray, brown, greenish, black, thinly foliated and incompetent. Some sandstone and coarse gravelly and blocky levels are also observed. The volcanic rocks are heavily weathered and crumbled.

Overlying the Yusufeli formation with an angular unconformity, some part of the Pugey formation with the Malm aged basal conglomerate, crops out along the Tortum and Oltu creeks. It consists of red, reddish brown, yellow, thin moderately and occasionally thick bedded conglomerate, sandstone and marl alternation in lower levels. The conglomerate contains limestone, radiolarite, basalt gravels 0.5-40 cm in diameter and is cemented together by limestone. The gravels are rounded, blunt and poorly sorted. The limestone-marl alternation with silexite located in the upper levels is thin, moderately-thickly bedded, dark gray, black, cream and extensively folded. The limestone layers form the ribs and marl layers which are not resistant to erosion form the grooves. During Neocomian, basalt and rhyolite settled between the other sediments.

The Ikizdere Magmatics

The Ikizdere magmatics crop out in the south-western part of the Kilicci dam site, at Ispir, Gullubag, Yusufeli and Deriner dam sites and their surrounding areas. In addition, their outcrops are seen along the Anuri creek and between the Cetinbogaz dam site and Sirakonaklar creek. The outcrops are irregular and they are probably extensions of a huge batholith (Rize Batholith) (Altinli,1970).

According to the field studies and observations of the samples taken from granite and granitic rocks forming the Ikizdere magmatics the following groups were identified: granodiorite-tonalite, adamellite, porphyric microgranite and granite-gneiss.

a) Granodiorite – tonalite group

The fresh surfaces of the rocks found in this group are generally light bluish in color. The crystal size changes between moderate and big. Plagioclases being generally 2-3 mm in diameter are dominant minerals. The rock consisting essentially of biotite also contains hornblende. The biotite is black colored when it is fresh but it is bright brown colored when it is weathered. The colour of the rocks becomes lighter when its biotite ratio reduces. During the microscopic examination its hypidiomorphic texture is easily distinguished. Average model analysis gives the following ratios: plagioclase 40-60%, quartz 10-20%, feldspar with potassium 10-15%, biotite 10-20% and others 5%.

b) Adamellite group

The name is used for the granitic rocks in which the ratio of feldspar may range between 1/3 and 2/3. The color of the rock changes from dark to light due to its dark colored minerals. The adamellite contains medium to coarse grained quartz, plagioclase, perthite and mafic minerals (mostly less than 10%). The average percentages of the minerals are plagioclase 35%, feldspar with potassium 20%, quartz 30%, biotite 10%, others 5%.

c) Porphyritic microgranite group

The mafic minerals are in very small amounts. It shows various textures. For microgranite, the texture is mostly aplitic; but, for porphyric types it gradually changes to felsic and granophyric textures. These changes are generally gradational. Microgranite is pinkish yellow or cream colored constituents. In porphyritic textured rock, the phenocrystalls may reach up to 0.5 cm in diameter. The rock mostly has a cherty appearance.

d) Granite-gneiss group

According to Spry's classification, these granitic rocks which are partially crumbled and eroded, named as the protomilonite. It may also be called as mylonite where the rock is excessively disintegrated.

According to the petrographic properties and

changes in the volumetric percentages of the minerals, it may be suggested that all these granitic rocks are fractions of a granite body. According to examinations of the samples and the field observations, the following properties of the granite were determined:

- The granitic rocks are in different textures (aphanitic, porphyritic and granophyric).
- Well developed flow structures and planes are not seen.

Geotechnical properties of the rock units in the study area

The geotechnical properties of the rock units found in the study area are given below:

The Yusufeli formation: Generally hard, competent and impervious. Some landslides occur due to the steep slopes and weathering.

The Berta formation: Lava, limestone, conglomerate levels are hard and competent. Tuff, mudstone and marl levels are incompetent. Hydrothermal alteration and excessive silisification are seen. Heavy alteration observed on the surface. Weathering and debris cause the landslides. The rock mass is generally impervious.

The Pugey formation: Limestone is hard and competent, not karstified. Claystone and marl are incompetent and impervious. Large landslides in the Pugey formation are due to the incompetent rock units. The biggest of them formed the Tortum Lake.

The Ikizdere magmatics: Very hard, competent, and weathered on surface. High water leakage may be expected through the dikes, faults and fractures.

The Yusufeli dam site

At the Yusufeli dam site, the thalweg elevation is 500 m, the maximum water level is 720 m and the average discharge is 125 m^3/sec. The Yusufeli dam site was located over the Ikizdere magmatics (Fig 1). During the investigation studies, 15 boreholes have been drilled and 4 galleries have been excavated at the Yusufeli dam site. The thickness of the alluvium is 42 m. After the 2910 measuring, the joint systems of the Yusufeli dam site are: N10° E 33° NW, N-S 77°E, N7W 42° SW, N36E° 68 SE°, and N74° W 79° SW. Because of these joint systems, the RQD values are fair and sometimes poor.

The Ikizdere magmatics are weathered at the surface and cut by dikes. The thickness of the dykes changes from 1 to 10 cm. There are many faults in different sizes at the dam site which are seen in the investigation galleries. Also the slide marks are seen on the walls of these galleries. The unit weight of the rock is 2.70 g/cm^3 and the uniaxial compressive strength is 155 MPa.

The Lugeon values of the water pressure tests of the boreholes in Yusufeli dam sites are given below (Table 1).

The water tightness of the dam site can be achieved by grouting.

Table 1: The Lugeon values of water pressure tests of the boreholes in Yusufeli dam site

Lugeon values	Number of the tests	Percentage of the tests in total
> 25	27	3.7
25 – 5	91	12.4
5 – 1	115	15.6
< 1	502	68.3
	735	100

The Yusufeli reservoir

The Yusufeli dam site was located over the Ikizdere magmatics and the reservoir area consists of the Berta and the Yusufeli formation, the Ikizdere magmatics along Coruh River and the Pugey formation along Oltu and Tortum creeks (Fig 2) (Baydar,O.et al 1970).

In the reservoir area, the Berta formation is impervious. The dacitic tuffs locating in this formation, which were hydrothermally altered and lavas, agglomerates show tendency of downward sliding between east of Cevreli village and Yusufeli county. The most significant one of these slides named Vecaket Landslide is located northeast of Yusufeli (Fig 3). In the spring of 1968, just after a heavy rain, this mass of 2 sq-km area in the left

Fig. 1: Yusufeli damsite view from upstream

bank of the Barhal creek, had slided down the slope, which resulted in plugging of the creek bed and formed a temporary lake and two workers for the road construction lost their lives. After this disaster, the Yusufeli County was evacuated for a short period. Meanwhile, the material in the river bed had been washed away by the creek. Today, the remnants of that material can be observed on the right bank of the Barhal creek. The type of the movement was avalanche and mudflow. This landslide covers a large area at the upper parts while it follows much narrower path towards down the Barhal creek. It is assumed that the thickness of the sliding mass charges between 100-250 m. After the construction of the Yusufeli dam, the impounding of the reservoir would accelerate the slides (draw down). It is not expected that the Vecaket landslide would affect the feasibility of the Yusufeli dam since the landslide area is very far from dam site. However, it would fill the dead storage partly and reduce the life of the dam.

The landslides locating around Gorgulu village by the Tortum creek are also active (Fig 3). At this location, the soil formed due to the weathering of Yusufeli formation slides (just like mud) down the bank towards the Tortum creek. The moisture content of the material, which changes seasonally, affects the type of the movement; rotational slide and mudflow. The slope is gentle, so, it reduces the velocity of movement. This area is located at the end of the Yusufeli reservoir, therefore, a probable slide mass will only fill a part of the dead storage while it will not create any risk for Yusufeli dam.

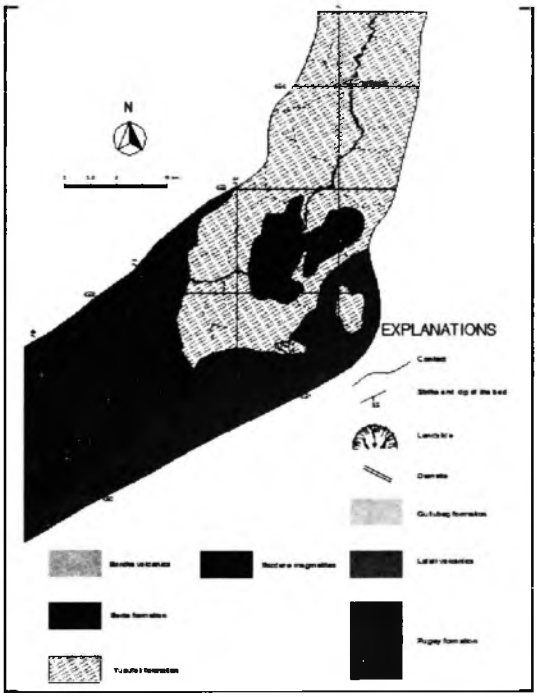

Fig. 2: Geological map of the Yusufeli and Inanli damsites and their reservoirs

The Yusufeli and Berta formations in the Yusufeli reservoir area are impervious. Along the Oltu creek, the limestone levels of the Pugey formation do not show any excessive solution traces. It is considered that no leakage will occur through the Pugey formation. In addition, there are no other basins at the downstream side by this path where the water would leak into.

The effects of the Zeytinlik reservoir's landslides on the Yusufeli dam

The possible effects of Havuzlu and Demirkent landslides on the Zeytinlik and Yusufeli dams have also been investigated. These landslides lie in the material formed from the disintegration of the Yusufeli formation constituents. The thickness of the Havuzlu slide (Fig. 5) is only 15 to 20 m at its toe, but exceeds 50 m at the lower section of the Havuzlu village. However, this thick part is quite far from the reservoir and is unlikely to affect the dam.

Fig. 3: The Vecaket landslide of Yusufeli reservoirs

Fig. 4: Mudflow near the Tortum valley of North-Eastern Turkey

Fig. 5: Havuzlu landslide view from upstream

Fig. 6: Inanli dam site and Demirkent landslide view from upstream

The town of Demirkent is located over the disintegrated material derived from the Yusufeli formation (Fig. 6). When the Zeytinlik dam is completed, almost 70 m of this material will be within the reservoir waters. Therefore, upon building of the dam, this material is expected to be mobilized towards the reservoir. The average material thickness is about 150 m. Such a landslide poses a great threat for both the Zeytinlik and Yusufeli dams. Therefore, the Zeytinlik dam site has been abandoned and a new (the Inanli) dam site has been projected at the upstream side of the Demirkent landslide. In this case, head drop due to the Inanli dam could be utilized by a power tunnel on the left slope (Ertunc,A.1990).

References

Altinli, I.E. (1970). Geology and engineering geologic investigation of part of Iyidere Basin's hydroelectrical development scheme. E.I.E. Publication. Ankara.

Baydar, O., et al. (1970). Investigation géologique de la region de Yusufeli, Ogdem, Madenkoy, lac Tortum et Ersis. Publication de M.T.A., no. 5202, Ankara

Eroskay, S.O. (1970). Geological report of the Laleli-Toskoy Diversion Tunnel., E.I.E. Publication, Ankara.

Ertunc, A. (1990). L'effet de glissements de terrain sur les future barrages en Turquie. 6th International Congress of IAEG, Amsterdam.

Ertunc, A. (2002). The recent investigations of the dam site possibilities on the Coruh River, Turkey. 9th International Congress of IAEG, Durban.

Gattinger, T.E. (1955). Bericht über geologische aufnahmearbeiten im gebiete zwischen Coruh and Erzurum, Nordost-Turkei. M.T.A. Rap no 2379, Ankara.

Gattinger, T.E. (1956). Bericht über geologische aufnahmeergänzungs und revisionarbeiten in den ostpontiden im bereich von vilayet Trabzon, Rize, Gumushane, Erzurum, Artvin und Kars. M.T.A., Rap no 2380, Ankara.