Public Data File 89-8D

BEDROCK GEOTECHNICAL PROPERTIES AFFECTING GROUND-WATER MOVEMENT IN THE U.S. COAST GUARD RESERVATION, KODIAK, ALASKA

by

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May, 1989

This report has not been reviewed for technical content (except as noted in text) or for conformity to the editorial standards of DGGS.

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SCOPE OF WORK

This project involved the investigation of certain environmentally impacted areas of the U.S. Coast Guard Station. The purpose of the report is to observe and assemble as much geotechnical information concerning the Kodiak Formation as reasonable given time and budget. The plan of investigation included four days in the field from 23 to 26 August 1989 examining critical locations. These locations included the Nyman Peninsula, the landfill areas near the Buskin River, and the Swampy Acres KEA Substation. Rock descriptions cited below are based solely on field hand-specimen observations; no microscopic work was performed.

The second phase of the geotechnical work consisted of library research concerning past laboratory testing of rocks of the Kodiak Formation. This was done in lieu of any lab testing during this study. The search included both published and unpublished sources consisting of reports by private consulting engineering firms as well as the files of the Alaska Power Authority and Alaska Department of Transportation and Public Facilities.

LITHOLOGY OF THE KODIAK FORMATION

The rock types present within the Kodiak Formation have been identified variously by different observers. These observations have included sedimentary terms, such as "interbedded sandstone (graywackes) and hemipelagic shales" (Nilsen and Moore, 1979), as well as metamorphic terms, such as "Kodiak slate belt" (Sample and Moore, 1987). Generally, Sample and Moore (1987, p.16) conclude that the turbidite sequence of the Kodiak Formation has recrystallized under metamorphic conditions that are transitional from the zeolite facies to prehnite-pumpellyite facies. Thus, we are dealing with rocks that have undergone recrystallization; because of the geotechnical nature of this part of the investigation, this report will utilize a metamorphic rock terminology.

In the three areas investigated, the Kodiak Formation varies from 10 percent phyllite and 90 percent metagraywacke to roughly 90 percent phyllite and 10 percent metagraywacke. The rock types are interlayered with bed thicknesses from less than 1 in.to 36 in. with an average of about 6 in. Slaty cleavage is extensive within the phyllite interbeds and poorly developed within the metagraywacke. Typically, the slaty cleavage is a glossy to polished surface in the phyllite layers, and dips slightly steeper than the bedding. As observed in handspecimen in the field the very-fine grained phyllite is dark-gray to black and fresh to faintly-weathered. The metagraywacke as viewed in handspecimen is medium to dark gray, fine-grained, fresh to faintly weathered and has the appearance on a broken surface of a sericitic quartzite. In natural exposures relict graded bedding is preserved.

For a more detailed description of bedrock lithology and structure in the Coast Guard reservation, see Solie and Reifenstuhl (1989).

Nyman Peninsula

This peninsula on the southeast side of Women's Bay is the site of the U.S. Coast Guard fuel-storage yard. Eight exposures were examined for their geotechnical characteristics. Lithologically the peninsula is an interlayered sequence of phyllite and metagraywacke with a prominent zone of metagraywacke comprising the northwest side of the peninsula. Bedding is closely paralleled by slaty cleavage with a strike that varies from 25° to 53° and dips 72° to 90° northwest (see also Solie and Reifenstuhl, 1989). Fracture spacing varies from extremely close to moderately wide, with several sets occurring.

The largest exposure occurs between the old powerhouse, building 189, and the new powerhouse, building N24. Here the lithology is 90 percent metagraywacke with 10 percent phyllite. The metagraywacke is exposed in a partially excavated exposure that is about 230 ft long and 10 to 50 ft high. The bedding varies from 4 to 36 in. thick and averages 9 in. Four fracture sets are present. The dominant fracture set strikes 157° and dips 50° northeast; this set is clean and smooth and has an 8-in.spacing. The second set strikes 150° and dips 80° southwest; this set is smooth, has quartz infilling, and has a 6in.spacing. The third set strikes 160° and dips 37° southwest; this set is rough, has iron-stained quartz infilling, and has a 24-in.spacing. The fourth set strikes 139° and dips 44° southwest; this set is moderately rough, has quartz infilling, and a 4-in.spacing. The metagraywacke at this exposure is a very strong, fresh to faintly weathered, hard rock with an estimated uniaxial compressive strength of greater than 30,000 lb/in.^{2} (greater than 200 MPa). Fracture set 2, near the southwestern end of the exposure, was observed to be dark and wet, indicating probable groundwater discharge.

A second important exposure occurs southeast of building N24 immediately across the road from the fence which borders the northeast side of the tank storage area. The rock layers of this exposure strike directly into the tank area and, therefore, represent part of the underlying bedrock. This exposure is a road cut that is about 100 ft long and 15 to 30 ft high; the toe of the cut is variably rubble covered. The bedrock is a dark gray to black very find-grained phyllite. The rock is mostly fresh with discontinuous faintly weathered areas represented by iron staining. Bedding is paralleled by slaty cleavage and strikes 50° and dips 77° northwest. Beds vary from 0.5 to 6 in. thick and average 2 in. thick. The dominant fracture set strikes 137° and dips 69° southwest. This set is smooth with rare iron staining and has a spacing that varies from 2 to 6 in. and averages 4 in. The secondary fracture set strikes 152° and dips 11° northeast. This set is moderately smooth, has quartz and clay infilling, varies in spacing from 2 to 18 in., and has an average spacing of 6 in. Field testing shows that an estimated uniaxial compressive strength for the moderately strong phyllite is 7,500 to 15,000 lb/in.^{2} (50 to 100 MPa).

Buskin River Landfill Area

This area lies on the northeast side of the Buskin River Valley in the hummocky topography near the toe of the valley slope. Five exposures were examined. The best natural exposure lies 200 ft east of the Buskin River Road near USGS observation well A-6. Here the lithology ranges from phyllite with 10 percent metagraywacke layers to phyllite and metagraywacke in equal proportions (50:50). The adjacent flat area with concrete slabs has marsh grass and much standing water including iron-stained puddle bottoms. These probably represent spring discharge; this flat area may be at or below watertable.

The best continuous exposure occurs at the KEA Airport storage yard which is east of the old Navy dump and south of the USCG landfill. This exposure is a rockcut about 200 ft long and 5 to 20 ft high excavated by drilling and blasting. The rock exposed is a dark gray to black, glossy phyllite. Bedding, which is closely paralleled by slaty cleavage, strikes 28° and dips 66° northwest. Bedding thickness varies from 0.1 to 6 in. and averages 2 in. The phyllite is fresh to faintly weathered; notice that iron staining on fractures and cleavage at the KEA Airport storage yard extends beyond the greatest depth excavated, about 20 ft. Field testing shows the phyllite is a moderately strong rock with uniaxial compressive strength estimated to be 7,500 to 15,000 lb/in.^{2} (50 to 100 MPa). The dominant fracture set strikes 111° and dips 82° southwest and is rough and iron stained. Its fracture spacing varies from 1 to 12 in. and averages 2 in. The secondary fracture set strikes 178° and dips 66° southwest. This set is iron stained, has some quartz fillings up to 3 in. wide, and has a rough surface. The third fracture set strikes 76° and dips 11° northwest. This set has a very irregular surface, is iron stained, and has a 12-in.spacing.

Swampy Acres KEA Substation

This substation is located within a rockcut which was excavated by backhoe ripping so that the exposure is 10 to 20 ft high and about 135 ft long. The exposure is entirely phyllite except for one metagraywacke bed about 3 ft thick in the southeast corner of the excavation. The phyllite is very fine-grained, black and is usually only faintly weathered with iron staining on joints and slaty cleavage. At the southeast corner of the excavation the bedding strikes 46°

and dips 75^{O} northeast. This is paralleled by a small fault with gouge 1 in.thick and brecciation with moderate weathering 16 in. thick.

The most prominent fracture set strikes 106^{O} and dips 80^{O} southwest. This has a rough surface. Fracture spacing varies from 1 to 16 in. and averages 3 in. The secondary fracture set strikes 122^{O} and dips 49^{O} southeast. The fracture surfaces are rough with limonite and quartz veins up to 6 in. wide. The spacing of the secondary fracture set averages 24 in.

The metagraywacke layer is hard; it barely scratches and breaks with a single blow of the rock hammer. This is a strong rock with an estimated uniaxial compressive strength of 15,000 to 30,000 lbs/in.^{2} (100 - 200 MPa). The phyllite is a moderately strong rock with an estimated uniaxial compressive strength of 7,500 to 15,000 lb/in.^{2} (50 - 100 PMa). Locally near the fault, however, where the phyllite is moderately weathered, it is a moderately weak rock with uniaxial compressive strength of 3,500 to 7,500 lb/in.^{2} (25 - 50 MPa).

At the toe of the rockcut within the 18-in.deep ditch, water discharges to the surface from the bedrock discontinuities. This seepage is less than 1 gpm. Green algae in this ditch suggest that discharge is continuous. The spring documents that this substation is in the zone of discharge of the fractured bedrock aquifer.

INDEX PROPERTIES

Two sources of information exist for index properties and strength properties. These include field observations made during August 1989 and literature citation. The index properties usually described for a rock type include porosity, density, sonic velocity, durability, and permeability. Porosity and permeability are discussed below in the section entitled Geohydrologic Properties. Sonic velocities are addressed by Allely (1989).

Density data on the phyllite and metagraywacke of the Kodiak Formation are not available. To date no laboratory test results have been identified. However, approximations can be made. First, we must assume that the phyllite has similar properties to slate, and second, the metagraywacke is similar to quartzite. Bell (1981, p. 105) cites a density of 2.66 to

2.67 for slate, also Krynine and Judd (1957, p. 49) cite a density of 2.77 for slate. No data are available for metagraywacke; however, Kynine and Judd (1957 p.49) cite a density of 2.64 for quartzite. Admittedly these data must be considered approximations.

Durability data in terms of L.A. abrasion and sodium sulfite soundness test results are not available. These tests respectively measure physical and chemical resistance. Some rock quality designator (RQD) information is available from drilling at Pillar Mountain and at Terror Lake. RQD is the ratio of the sum of lengths of all core pieces 4 in. or longer to the total length of the cored interval (Deere and others, 1967). These data present some information that reflects physical durability; but they do not reflect chemical durability. RQD numbers at Pillar Mountain (see Goodman, 1980, p. 42 for definitions and procedures) for HQ-diameter core which is dominantly phyllite range from 0 to 50 percent and average about 10 percent (R & M Consultants, 1982b, figure 4); in the lower parts of the same borehole where metagraywacke predominates, RQD ranges from 30 to 80 percent and averages about 60 percent. Thus the phyllite would be termed very poor quality and the metagraywacke would be termed fair quality.

The drilling at Terror Lake (Robert W. Retherford and Associates, 1978 and 1980) presents RQD data. However, the information is flawed because they were drilling with BX-sized equipment. RQD data is defined for only NX and larger core diameters. Despite this failing, the numbers when examined present a similar pattern to that found at Pillar Mountain. That is, the slate at boring T-22 has a zero RQD throughout the entire bedrock portion of the boring. Boring T-1 drilled through "graywacke with traces of argillite" has an RQD average of 54 percent. Boring T-26 drilled through only "graywacke" has an RQD of 80 to 100 percent except at fracture zones. Thus, the Terror Lake data rate the "slate" as very poor quality and the "graywacke" as fair to good.

STRENGTH PROPERTIES

Strength properties determined in the field were performed by the method termed "kicking the rock" by Hoek and Bray (1977, p. 99). Here they present simple field tests for approximating uniaxial compressive strengths utilizing a pocket knife and geologist hammer. By these procedures the phyllite is termed R3-Moderately Strong Rock with uniaxial compressive strength of 7,500 to 15,000 lb/in.^{2} (50 to 100 MPa). The metagraywacke was found to vary from location to location from R4-Strong Rock to R5-Very Strong Rock with uniaxial compressive strength of 15,000 to >30,000 lb/in.^{2} (100 to > 200 MPa).

Published textbook data (Bell 1981, p. 105) cite the following information for slate. An unconfined compressive strength of 96.4 MPa perpendicular to the slaty cleavage and an unconfined compressive strength of 72.3 MPa measured parallel to the cleavage. He also cites point-load tests with results of 7.9 MPa perpendicular to and 4.2 MPa parallel to the slaty cleavage, as well as a Youngs Modulus of 31.2×10^3 MPa measured perpendicular to the cleavage. Touloukian, Judd, and Roy (1981, p. 87) present data for quartzite and mica quartzite with results of 143.7 MPa and 112.4 MPa, respectively.

The data presented in the two paragraphs above refer to the strengths of intact small samples. The strength of rock masses is best characterized by the strengths of the discontinuites in that mass. Friction angles determined by Mohr Circle testing are commonly cited as strength data used in slope stability analyses. A friction angle of 25.5° was found for the dry phyllite sliding on dry phyllite. This result was obtained from samples from Pillar Mountain (R & M Consultants, 1982c, p. 45).

GEOHYDROLOGIC PROPERTIES

The following conclusions can be made based on the field observations during the present investigation. Little or no intergrain porosity remains in either the phyllite or the metagraywacke. The rocks have undergone recrystallization under low-grade metamorphic conditions; which, has very likely obliterated any minimal original porosity. The interlayered sequence, does, however, possess a secondary fracture porosity. This fracture porosity may possess some permeability due to the interconnection of the fractures and, thus, allow the transmission of fluids. Seepages were observed at several locations, with both fracture sets and slaty cleavage producing water at low discharges of less than 1 gpm.

During the investigation of the Pillar Mountain Slide within the City of Kodiak, a multi-level combined inclinometer-piezometer system was installed in one borehole (R & M Consultants, 1982a). These piezometers showed the Kodiak Formation to be a complexly fractured aquifer with several water pressure heads based on piezometers at seven different levels. A uniform increase in water pressure with depth was not observed. This indicates that water pressure and transmissibility is dependent upon different and variably interconnected fracture systems.

No diamond drilling or pump tests were performed during the present study. Rather a review of the published and unpublished literature was done to locate any results of previous testing of the Kodiak Formation. No data exist for the USCG Station itself. However, 15 miles to the west-southwest at the Terror Lake Hydroelectric Project, Robert W. Retherford and Associates under contract to the Alaska Power Authority performed extensive drilling and some packer tests. At the damsite, boring T-2 (Robert W. Retherford and Associates, 1978, fig. A-5), which encountered "interbedded graywacke and argillite", averaged 0.8 gpm in a zone 38 ft to 102.5 ft below the surface. Also, the same boring averaged 0.6 gpm in a packed zone 48 ft to 102.5 ft below the surface. The pressure during these two tests was not stated. At the damsite, boring T-1 (Robert W. Retherford and Associates, 1978, fig. A-4) encountered "graywacke with traces of phyllite". A packer test performed from 10 ft to hole bottom at 140.5 ft yielded a coefficient of permeability $K=3.81 \times 10^{-5}$ cm/sec. Within this borehole the rock quality designator (RQD) averaged 54 percent.

Later studies at the Terror Lake Damsite (Robert W. Retherford & Associates, 1980, p. 2-1) stated "...water pressure tests were made in nine of the holes to determine the permeability of the rock. The results are given with the particular bore hole logs." Searching these logs during the present investigation revealed that the permeability data are not included in the report. One bit of information from this report (Robert W. Retherford and Associates, 1980, p.3-2) states that a water pressure test in dark gray slate from 15.7 ft to 56 ft in boring T-22 "had nearly zero water loss indicating that all the fractures in this boring are tight".

Permeability data has been produced for laboratory test samples of slate from Iron River, Michigan (Touloukian, Judd, and Roy, 1981, p.76). Presumably, these data might apply to give some limits to permeability within the phyllite-rich sequences of the Kodiak Formation. Although not stated, these were likely to be intact rock specimens and the data may apply as minimum permeability limits. The mean of 12 samples (with foliation horizontal) was 4.4×10^{-9} cm/sec; the mean of 8 samples (with foliation vertical) was 9.4×10^{-9} cm/sec.

Three infiltration tests were performed within Pillar Mountain slide during the slope-stability study to determine depth to water table. The field data are available (R & M Consultants, 1982a, fig. 4) but are insufficient to calculate coefficient of permeability.

ACKNOWLEDGMENT

This study was funded by the U.S. Geological Survey Water Resources Division, Anchorage, Alaska (cooperative agreement no. 14-08-0001-A-0374).

REFERENCES CITED

Allely, R.D., 1989, Shallow seismic-refraction profiling of the U.S. Coast Guard Reservation, Kodiak, Alaska; Alaska Division of Geological & Geophysical Surveys Public Data File 89-8C, in press.

Bell, F.G., 1981, Engineering properties of soils and rocks: Buttersworth, London, 149 p.

Deere, D.U., Hendron, A.J., Jr., Patton, F.D., and Cording, E.J., 1967, Design of surface and near-surface construction in rock: Proceedings of the 8th Symposium on Rock Mechanics, American Institute of Mining Metallurgy and Petroleum Engineering, Minneapolis, Minnesota, p.237-302.

Goodman, R.E., 1980, Introduction to rock mechanics: John Wiley & Sons, New York, 478 p.

Hoek E., and Bray, J.W., 1977, Rock slope engineering, 2nd edition: Institute of Mining & Metallurgy, London, 402 p.

Krynine, D.P. and Judd, W.R., 1957, Principles of engineering geology and geotechnics: McGraw Hill, New York, 730 p.

Nilsen, T.H., and Moore, G.W., 1979, Reconnaissance study of Upper Cretaceous to Miocene stratigraphic units and sedimentary facies, Kodiak and adjacent islands, Alaska: U.S. Geological Survey Professional Paper 1093, 34 p.

R & M Consultants, 1982a, Hydrologic assessment of Pillar Mountain slide,Kodiak, Alaska: report prepared for City of Kodiak, 21 p.

R & M Consultants, 1982b, Pillar Mountain slope stability study: Results of 1980 core drilling program: report prepared for City of Kodiak, 148 p.

R & M Consultants, 1982c, Pillar Mountain slope stability study, analyses and conceptual remedial measures: report prepared for City of Kodiak, 66 p.

Robert W. Retherford Associates and International Engineering Company, 1978, Terror Lake Hydroelectric Project, Kodiak Island Alaska, Definite Project Report: report prepared for Kodiak Electric Association, v.1, 184 p.

Robert W. Retherford Associates and International Engineering Company, 1980, Terror Lake Hydroelectric Project, Kodiak Island, Alaska, supplemental geotechnical report, field investigations 1979: report prepared for Kodiak Electric Association, v.1, 148 p.

Sample, J.C. and Moore, J.C., 1987, Structural style and kinematics of an underplated slate belt, Kodiak and adjacent islands, Alaska: Geological Society of America Bulletin, v.99, p.7-20.

Solie, D.N., and Reifenstuhl, R.R., 1989, Bedrock geology of the U.S. Coast Guard Reservation, Kodiak, Alaska: Alaska Division of Geological & Geophysical Surveys Public Data File 89-8A, 32 p., 1 sheet, scale 1:12,000, 2 sheets, scale 1:6,000.

Touloukian, Y.S., Judd, W.R., and Roy, R.F., 1981, Physical properties of rocks and minerals: McGraw-Hill Book Co., New York, 548 p.