Copy 5 of 5 500.03 G

GB-11
Upper Gneiss

GB-11

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Bridge Canyon Project, Arizona

Geology of the

UPPER GNEISS DAM SITE

J. Neil Murdock
Assoc. Geologist

March 1943

Table of Contents

Illustrations

GEOLOGY OF THE UPPER GNEISS DAM SITE

INTRODUCTION

The Upper Gneiss dam site is the original Bridge Canyon dam site named by Larue (1) and is one of the four dam sites in this vicinity under investigation by the Bridge Canyon Project in northwestern Arizona. A concrete dam of about 690 feet above bedrock is contemplated, principally for the development of power.

SUMMARY

1. Geological conditions are favorable at the Upper Gneiss site for the construction of a concrete dam. A dam of approximately 690 feet will rest on good hard granite injection gneiss which is believed competent to hold any size or type of dam where unaffected by structural defects.

2. One vertical fault and one horizontal shear plane need further exploration before final conclusions can be reached as to the method of treatment.

3. Sound rock is exposed over most of the area so stripping will be confined to keyways and general shaping up.

4. Percolation tests show the rock to be impermeable below the depth of weathering. Bedrock was encountered at elevation 1152 in the deepest channel.

(1) Larue, E. C., U.S.G.S. Water Supply Paper 556 - Water Power and Flood Control of Colorado River below Green River, Utah, 1925.

5. Satisfactory natural deposits from which to obtain concrete aggregate are not available within reasonable distance of the dam site. It appears that the best possibility is to utilize the Redwall limestone which is found on the south rim and process aggregate by crushing. It is believed a satisfactory product can be obtained by this method.

LOCATION

The Upper Gneiss dam site is located on the Colorado River one half mile below Gneiss Canyon and about 1 mile below Bridge Canyon in Mohave County, Arizona. The dam site is about 23 miles northwest of Peach Springs, Arizona. This is the nearest town and railway junction. See Location Map.

ACCESSIBILITY

Transportation is a serious problem because of the inacessibility of the dam site. At present there are 22 miles of unimproved road from Peach Springs into Hindu Canyon and a 10 mile pack trail from Hindu Canyon down Bridge Canyon to the dam site. During the present investigation, equipment and supplies were carried by boat from Pierce's Ferry to the dam site. The distance from Pierce's Ferry to the dam site is 43 miles and the trip can be made in four hours when conditions are ideal which is when Lake Mead is at high stage. At times during high spring floods and also during extremely low water trip by boat becomes hazardous and at times impossible.

TOPOGRAPHY

The dam site is located in the narrow Granite Gorge cut by the Colorado river in the uplifted Kaibab Plateau of horizontal sedimentary rocks. With the exception of the flat shelf called the Tonto rim the sides of the canyon are impassable vertical cliffs many of which are 500 feet in height. The Tonto rim was formed by the soft shale weathering back leaving a narrow flat shelf of hard Tapeats sandstone. It is the only break in the cliffs and also the only continuous relief available, with slopes flat enough for shops, roads, and buildings without prohibitive excavation.

The river follows an irregular course inherited from an earlier and much higher topography and cuts across hard and soft layers alike with no regard for structure. The small side canyons within the inner gorge are influenced more by the resistance of the rock. Most of these have developed along lines of weakness. Softer mica schists, fractured gneiss, old shear zones and fault planes have been attacked by erosion more rapidly than the more massive rock and sharp reentrants are the result. Spillway draw below the dam site is in softer mica and garnet schists. The saddle at elevation 1800 on the right abutment is due to erosion on the fracture zone along the fault shown on the Geology Map. Other examples are evident near the site.

There is very little overburden on the abutments and that only in thin patches. The rock is unusually sound on the surface without the usual decomposition and alteration of the rock surface. Periodic scouring of the bedrock beneath the river channel has left the bedrock surface sound and hard as will be noted in the drill logs.

REGIONAL HISTORY

The history of the rocks is complex, especially that of the Archean gneiss which has been subjected to much metamorphism. Briefly, the history at the site is believed to be as follows:

A series of sedimentary shales, sandstones, and limestones were metamorphosed to various types of mica, garnet, hornblende, and diopside schists. The limestones were changed to marble. These schists were folded and then intruded by a pink biotite granite magma along the schistose planes forming a granite injection gneiss. Some zenoliths of the schists were not completely assimilated. Later dynamic stresses occurred which fractured the rock on definite planes. The horizontal slip plane shown on the map and sections is of this origin. Later intrusions of diabase followed these fractures and partially healed them. During the Algonkian era this mass of Archean gneiss was subjected to erosion and produced a relatively flat but irregular erosion plane. During Cambrian times the sea came in over this old erosion surface and deposited the Tapeats sandstone and later the shales and limestones. Deposition continued intermittently until the Cenozoic time when the region was arched up forming the Kaibab Plateau and the then existant Colorado river began cutting the Grand Canyon and the Granite Gorge.

ROCK FORMATIONS

ARCHEAN SYSTEM

BASAL GNEISS

The term 'basal gneiss' is given the Archean gneiss and schists below the Tapeats sandstone. At the Upper Gneiss site these rocks are granite injection gneiss and a series of schists. The granite injection gneiss is formed by fluid granite wedging its way along the schistose planes of the mica schists forming parallel bands of pink colored biotite granite and bands of fine grained mica and other ferro-magnesian minerals. The quality of this rock is excellent.

It is very hard, massive, resistant and impermeable and free from fractures as shown by the percolation tests during drilling. The schists are hard sound rock but are more easily weathered than the gneiss.

Where unaffected by structural defects this rock represents the maximum in crushing strength and is competent to hold any type or size of structure possible to build. Two structural defects are known, the horizontal fracture and the vertical fault or open fissure on the right abutment. These will be discussed later.

CONTACT OF THE SANDSTONE AND GNEISS

The contact between the Archean gneiss and the Tapeats sandstone is well exposed and was examined in many places. The Geology map shows stadia elevations along the contact. The surface of the gneiss represents the ancient land surface during Algonkian and early Cambrian times. The gneiss is weathered and altered from 3' to 15' in depth with the feldspars partially weathered to clay and the quartz is poorly consolidated in the matrix of clay and iron oxide.

In places where the clay covering is thin or absent the Tapeats sandstone is well bonded to the gneiss below but ordinarily from two inches to several feet of clay, now consolidated to dense red shale, covers the weathered gneiss. This shale grades into a coarse grained ferruginous arkosic sandstone.

No channels of gravel were seen and it is my opinion, based on tests on the Lower Gneiss site, that there will be no greater loss along the contact than in the sandstone above.

CAMBRIAN SYSTEM

TAPEATS SANDSTONE

The Tapeats sandstone of Cambrian age which overlies the gneiss varies from 60 to 130 feet in thickness at the dam site.

The formation is all hard sound rock with some vertical jointing. The bedding planes average about two feet apart with some strong cross bedding. The following is a section of the Tapeats sandstone measured on the left abutment where it breaks into Spillway draw:

Feet	Bright Angel shale above
19	Very coarse grained gritty quartzose sandstone
1	Varicolored dense shale
9.5	Coarse to medium grained quartzose sandstone
0.5	Fine grained poorly cemented soft sandstone
12	White coarse grained quartose sandstone. Cross bedded.
1	Varicolored sandy shale
14	Hard white quartzose sandstone. Cross bedded with many vertical contraction joints.
5.5	Chocolate colored arkosic sandstone.
0.5	Red sandy shale
4.5	Coarse grained, hard, well cemented, arkosic, sandstone.
0.5	Red sandy shale
15	Coarse grained, chocolate colored, cross bedded, arkosic sandstone with thin streaks of white sandstone.
1	Fine grained soft red sandy shale.
6	Coarse grained, chocolate colored, well cemented arkosic sandstone
90	Gneiss below

BRIGHT ANGEL SHALE

The Bright Angel shale overlies the Tapeats sandstone and is composed of 650 feet of shale sandstone, dolomite and limestone. A detailed section of the Bright Angel formation is as follows:

	Muav limestone above
150'	Alternating light green shale and gray limestone
100	Dark siliceous dolomite, hard and sound.
200	Alternating soft, green and red micaceous shale and light coarse grained, thin bedded, sandstone.
40	Bright red, fine grained sandstone, fairly well cemented.
145	Alternating coarse grained hard white sandstone and thin beds of soft green micaceous shale. The shale is easily weathered to soft clay.
15	Soft green micaceous shale. Very weak and easily weathered. This member is the softest and weakest rock in the vicinity and is unstable when saturated and under load.
650'	
	Tapeats below

The lower members of this formation weather to flat slopes and even undercut the massive limestone above so that the limestone breaks off in blocks leaving a perpendicular face. The impervious nature of this shale makes it acceptable to build a dam against but it is questionable if it would be advisable to rest a heavy load on these unstable members.

MUAV LIMESTONE

The Muav limestone is the upper formation of the Tonto group of Cambrain age and is mainly massive limestone beds separated by thin beds of shale. The formation is about 1140 feet thick, and forms the basal part of the high nearly perpendicular cliffs seen on each side of the canyon above the Tonto rim. The limestone is hard, dense and chiefly gray in color. It is not directly involved in the engineering features of the dam.

MISSISSIPPIAN SYSTEM

REDWALL LIMESTONE

The redwall limestone of Mississippian age overlies the Muav and outcrops as a massive vertical cliff of red color with occasional limestone caverns. The red color is due to weathered red clay from the Supai formation above, which is carried down over the face of the cliff by water and stains the rock. The color is gray on fresh unweathered rock. A general section of the Redwall formation is:

Supai above

150'	Gray limestone with thin members of shale, sandstone and some chert.
100	Fine grained dense gray limestone. Breaks with a concoidal fracture.
250	Coarsely crystalline gray limestone. Pure and uniform.
100	Crystalline gray limestone with about 25% white chert. Cavernous at the base.
600'	Muav below

Consideration is being given this formation as the source of all aggregate for construction. For a more detailed discussion of construction materials see geology report of the Lower Gneiss Site. (1)

QUARTERNARY SYSTEM

TALUS

A thin deposit of talus, mainly angular boulders, is found on the left abutment but the quantity is so small it is insignificant. The overburden in the river channel is chiefly silt and fine sand with some large boulders near the bedrock. This material is permeable.

(1) Murdock, J. Neil, Geology of the Lower Gneiss Dam Site, March 1943

STRUCTURAL GEOLOGY

The attitude of the sedimentary rocks is practically horizontal with a dip of less than one degree downstream to the northwest. The schistocity planes in the injection gneiss strike N. 15° E. and dip 75° west or downstream at the axis.

FAULTING

Some faulting and shearing has occurred at the site and two structural defects of this nature are readily apparent near the axis.

One is the fault or open fissure which is shown on the right abutment. See map and photographs. Although the affected zone is only 6" wide it has a marked topographic expression which shows up as a cleft in the hard gneiss. An exploratory drift is needed to completely evaluate conditions along this fault but from surface exposures it seems serious enough to require extensive special treatment, perhaps removal of the crushed material and backfilling with concrete. This area could be avoided by moving the axis upstream but the section is much wider here. The fault can not be traced to the river and it evidently does not extend beyond the point shown on the map.

The age of this fault is believed to be Pre-Cambrian and further movement is not anticipated.

The second defect is the horizontal slip or shear plane at about elevation 1300 which extends the full length of the right abutment and may be present on the left although it is not prominently exposed on the left abutment. This fracture is filled with a diabase sill downstream 1000 feet from the axis but the intrusive sill evidently is not continuous as it is not present where the fracture is exposed near the axis. This fracture is probably the result of horizontal thrusting during Pre-Cambrian times when the forces which produced metamorphism were active. The fracture is a shear plane along which there has been some slight displacement producing parallel fracturing. Here again a drift is needed to evaluate conditions beyond the effect of weathering but this fracture is believed not so serious but probably would require grouting.

JOINTING

Some prominent joints are present but of little importance. These joints were probably ancient shear planes and are now a plane of shistose material which weathers more rapidly than the gneiss and are essentially sound at depth. Percolation tests in the drill holes showed no deep contraction joints and it is believed the rock is free from small fractures which will allow seepage.

OTHER CONSIDERATIONS

There is a distinct advantage in the height of dam than can be built at this site. A dam of 790 feet above bedrock could be built at this site without going above the Tapeats sandstone and overlapping onto the shale. Also the contact of the gneiss and sandstone is 250 feet higher here than at the Lower Gneiss site. However, other consideration such as the wider section and limitation on high water elevation are not so favorable.

ENGINEERING FEATURES

RESERVOIR GEOLOGY

The reservoir will be in the inner gorge of the Colorado with side walls similar to those at the dam site except that the Archean gneiss disappears beneath the channel upriver and the Tonto group forms the inner gorge. Large faults cross the Plateau but these have no effect on the reservoir. The springs which develop along the inner gorge indicate the water table is tributary to the river and no loss is expected from the reservoir.

DIVERSION TUNNELS

Diversion tunnels in both abutments will be in hard sound granite injection gneiss with the outlet portals in hard mica schist if the tunnels extend that far down stream. See map. This rock is of excellent quality and should stand unsupported during construction. The effect of the fault in the right abutment may require supports in the fractured area for a short distance.

STRIPPING

Sound rock is exposed over most of the surface beneath the river channel. It will require only the necessary scaling and shaping up for keyways to encounter hard, sound rock suitable for bonding purposes.

EXPLORATION PROGRAM

Four diamond drill holes were drilled along the U-50 line to determine depth to rock and the character of the bedrock.

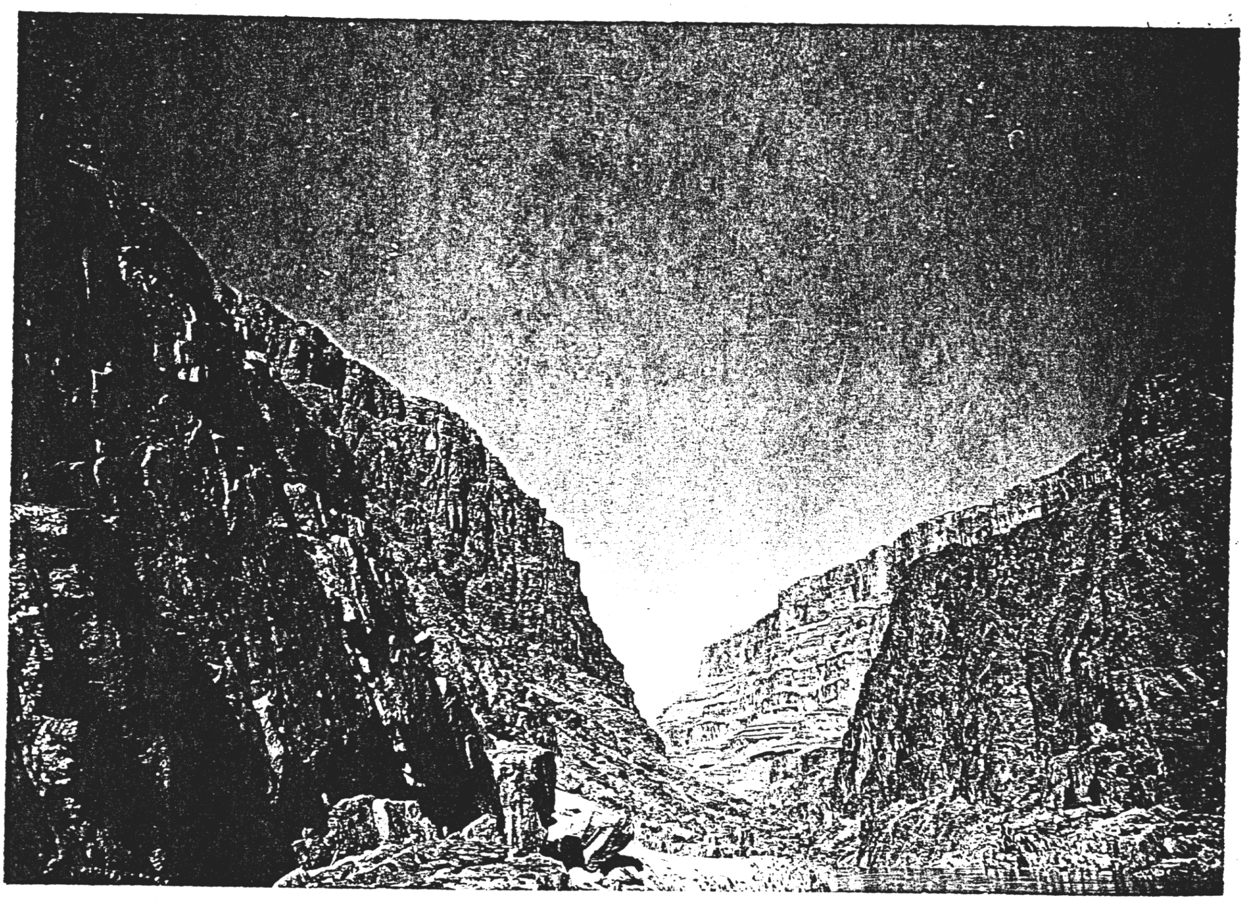
All four holes showed tight hard granite injection gneiss of the highest quality. The percolation tests showed some loss near the surface then became impermeable at greater depths when tested at 200 pounds per square inch pressure. Contraction joints probably accounted for the loss near the surface.

Except for structural defects (shear planes) already discussed it appears the foundation or abutments would take grout only in joints near the surface. No test pits or drifts were dug at this site. At the present time it appears that this site has been eliminated from further investigation. Should investigation be renewed at a future time, horizontal drifts on the fault and the horizontal shear plane would furnish information most urgently needed to properly evaluate conditions.

CONSTRUCTION MATERIALS

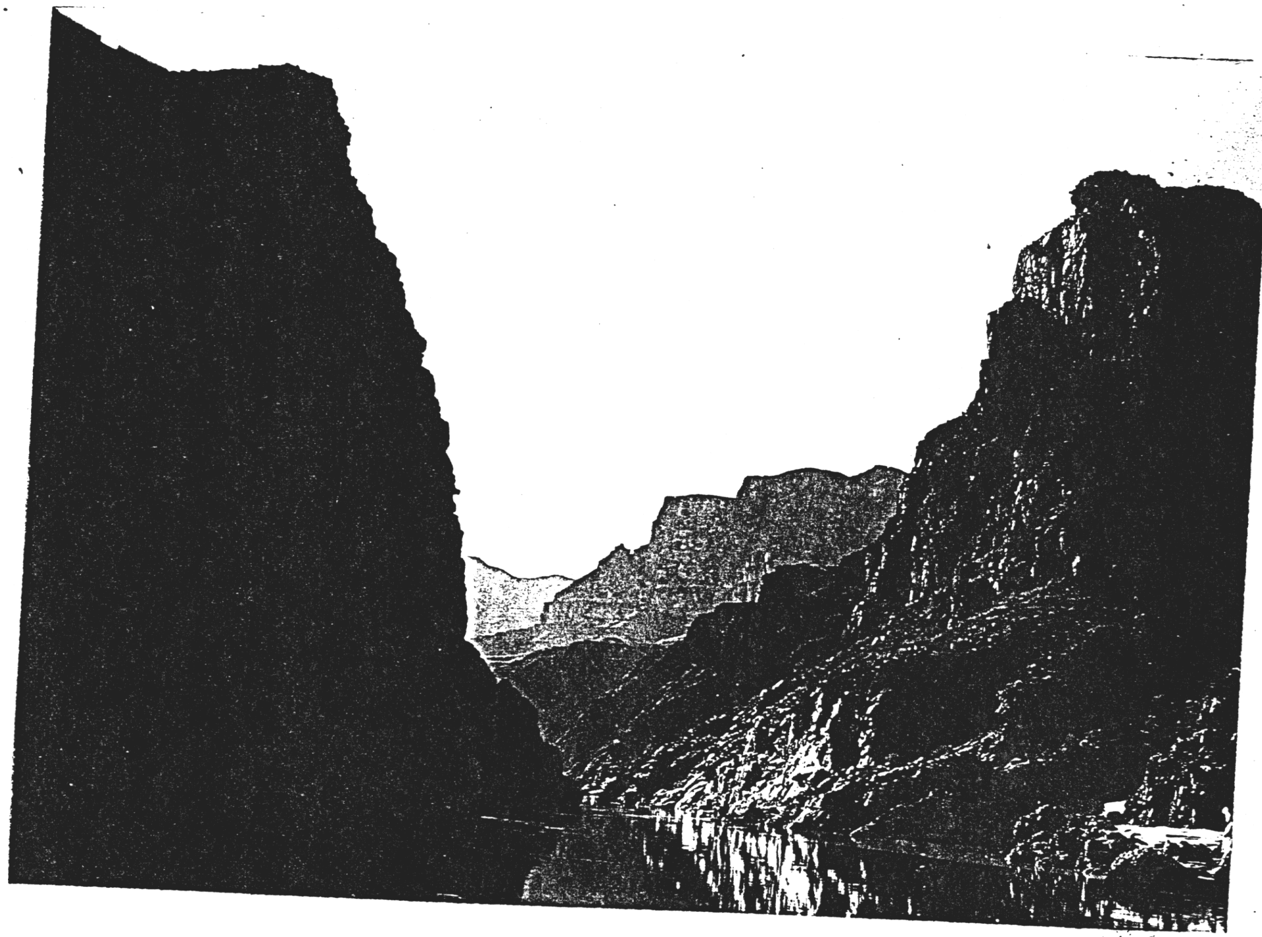
The problem of construction materials is the same as at the Lower Gneiss site. There are no suitable natural aggregates available within reasonable distance. It is believed that the Redwall limestone will provide a quarry from which suitable crushed aggregate can be processed. Samples including a carload of Redwall limestone have been submitted to the Denver laboratory for testing purposes.

J Neil Murdock



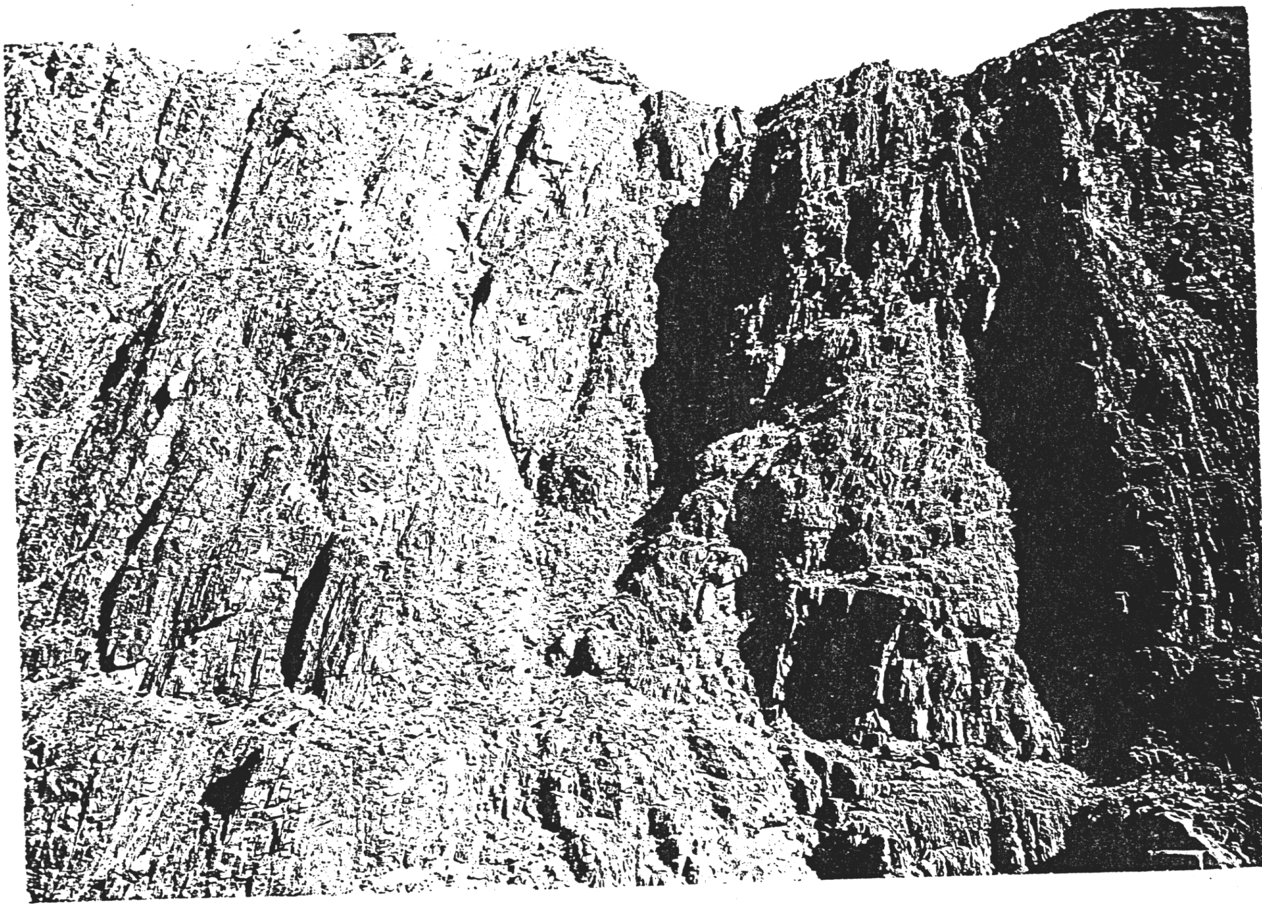
Profile of Upper Gneiss site from 2000 feet upstream. Fault or open fissure is seen on the right abutment.

Panoramic view of right abutment, Upper Gneiss site.



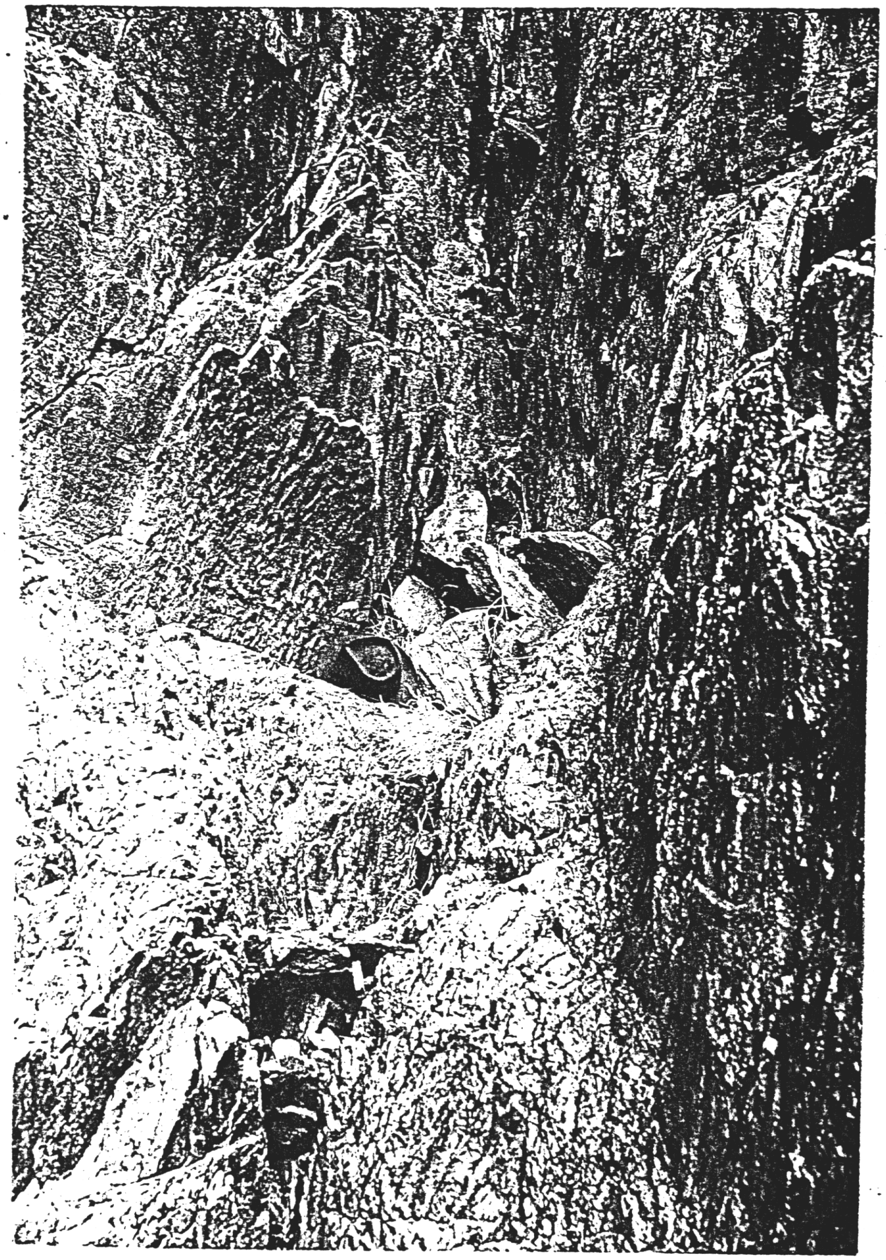
Profile of Upper Gneiss dam site from 2000 feet downstream

Panoramic view of left abutment, Upper Gneiss site.

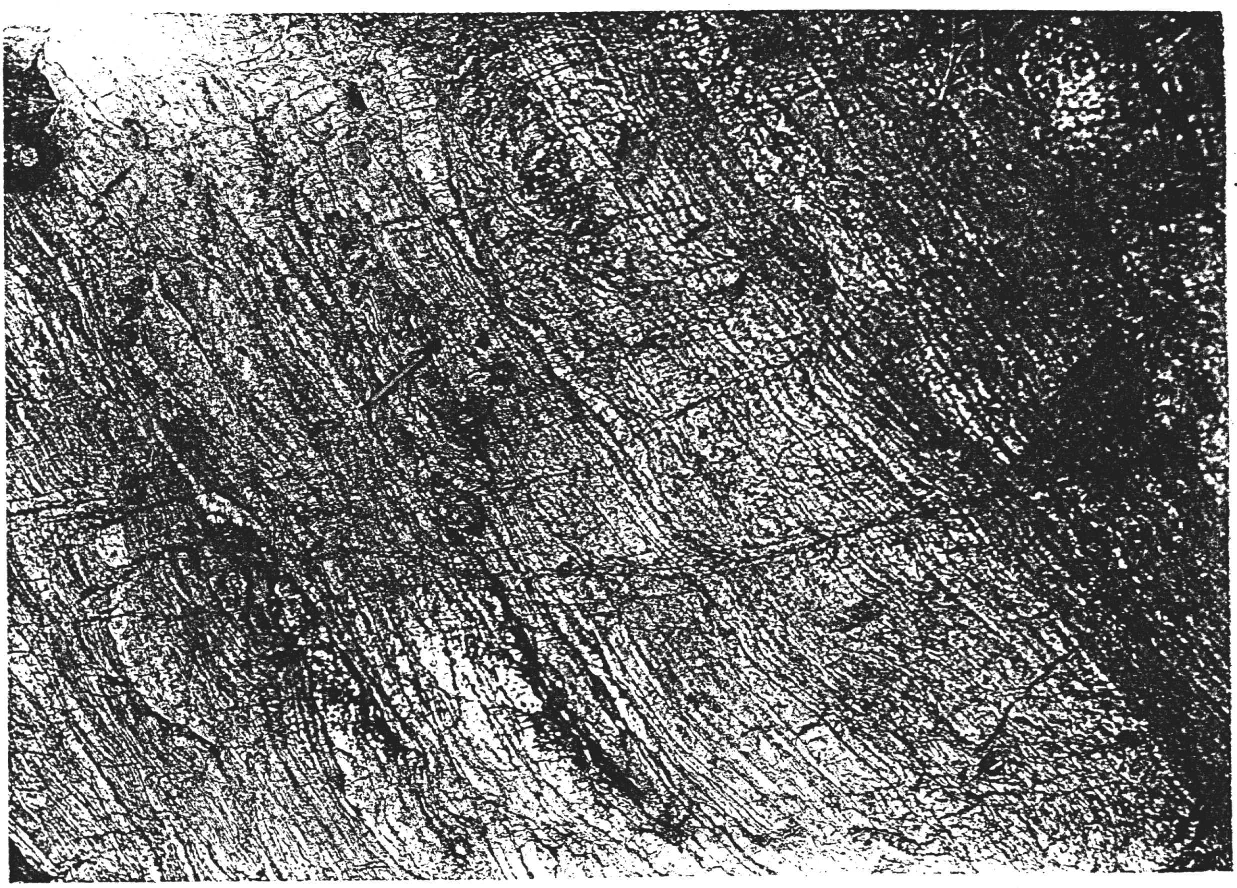


Right abutment Upper Gneiss site showing schistocity planes and two prominent joints.

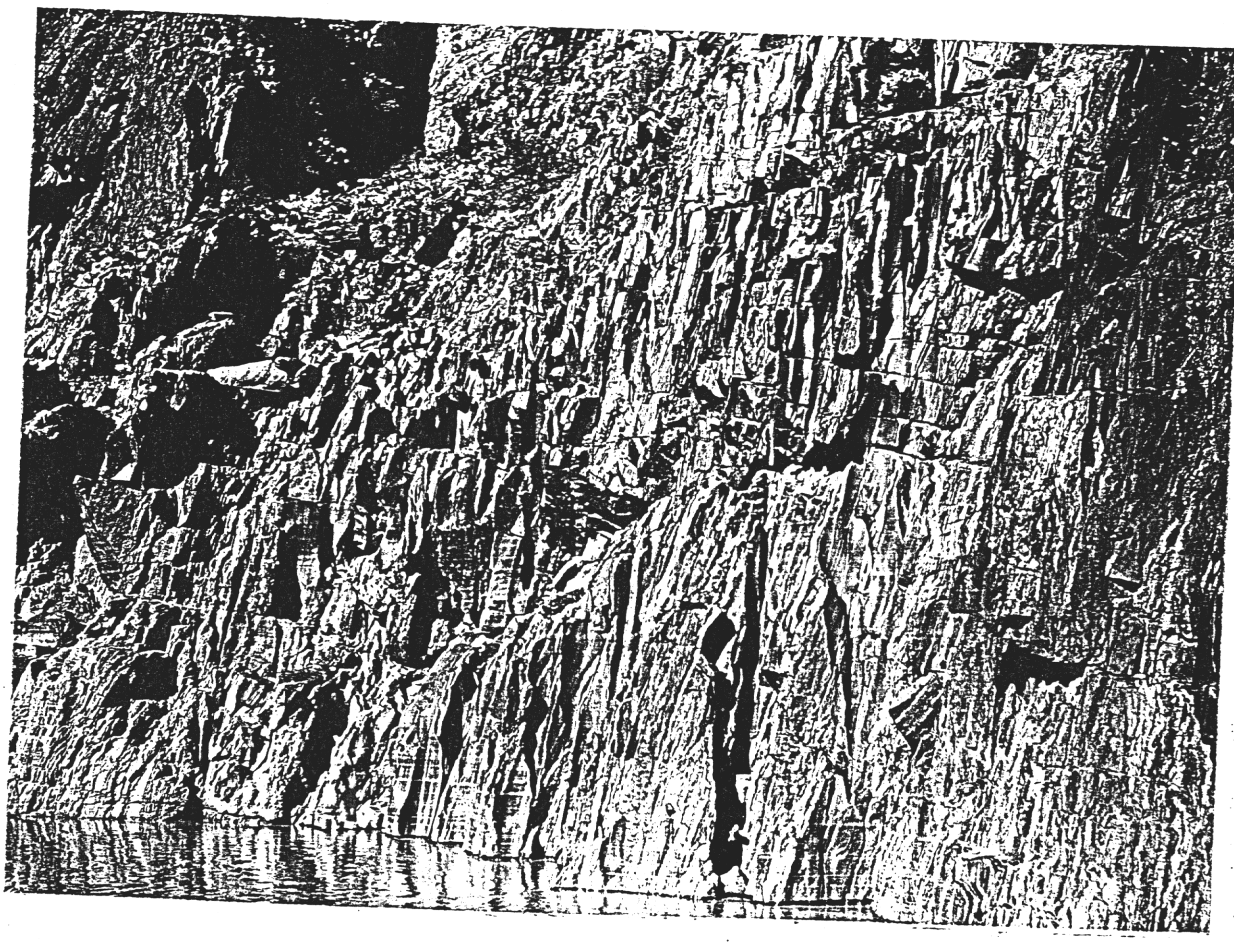
Detail of tunnel outlet portal and view of Spillway draw, Upper Gneiss site. Strata marked B. M. in foreground is a metamorphosed limestone in the mica schists showing sedimentary origin of the schists.



Close up of the fault or open fracture at Upper Gneiss site on right abutment. Rock is sound on each side with about 6" of crushed, platy, soft material which weathers more readily.

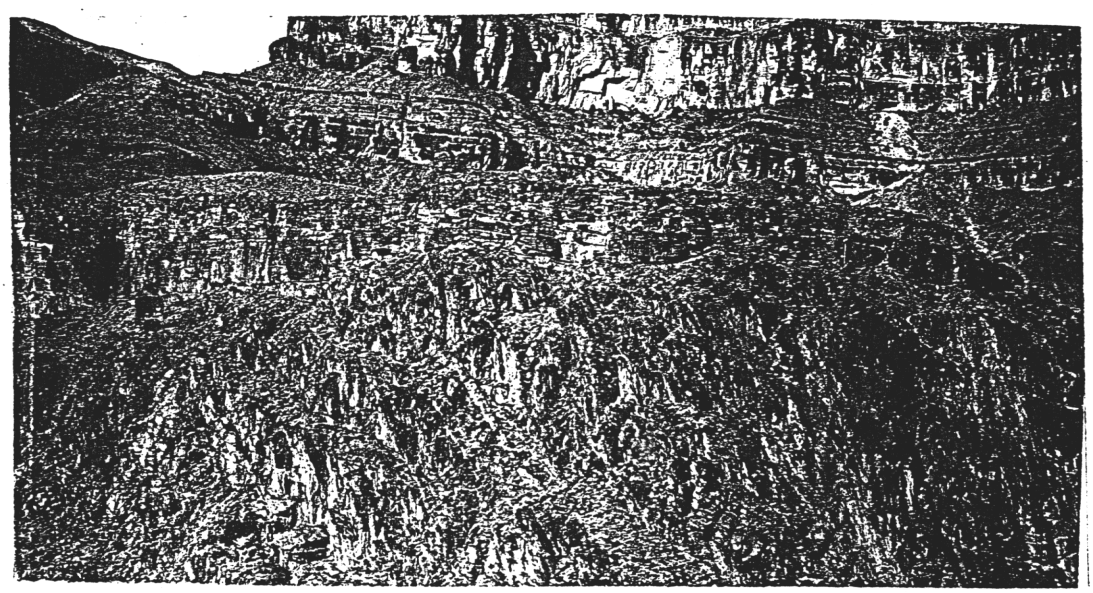


Right Abutment Upper Gneiss site. Close up showing the banded structure in the granite injection gneiss. Light streaks are coarse grained granite injected into fine grained biotite granite.

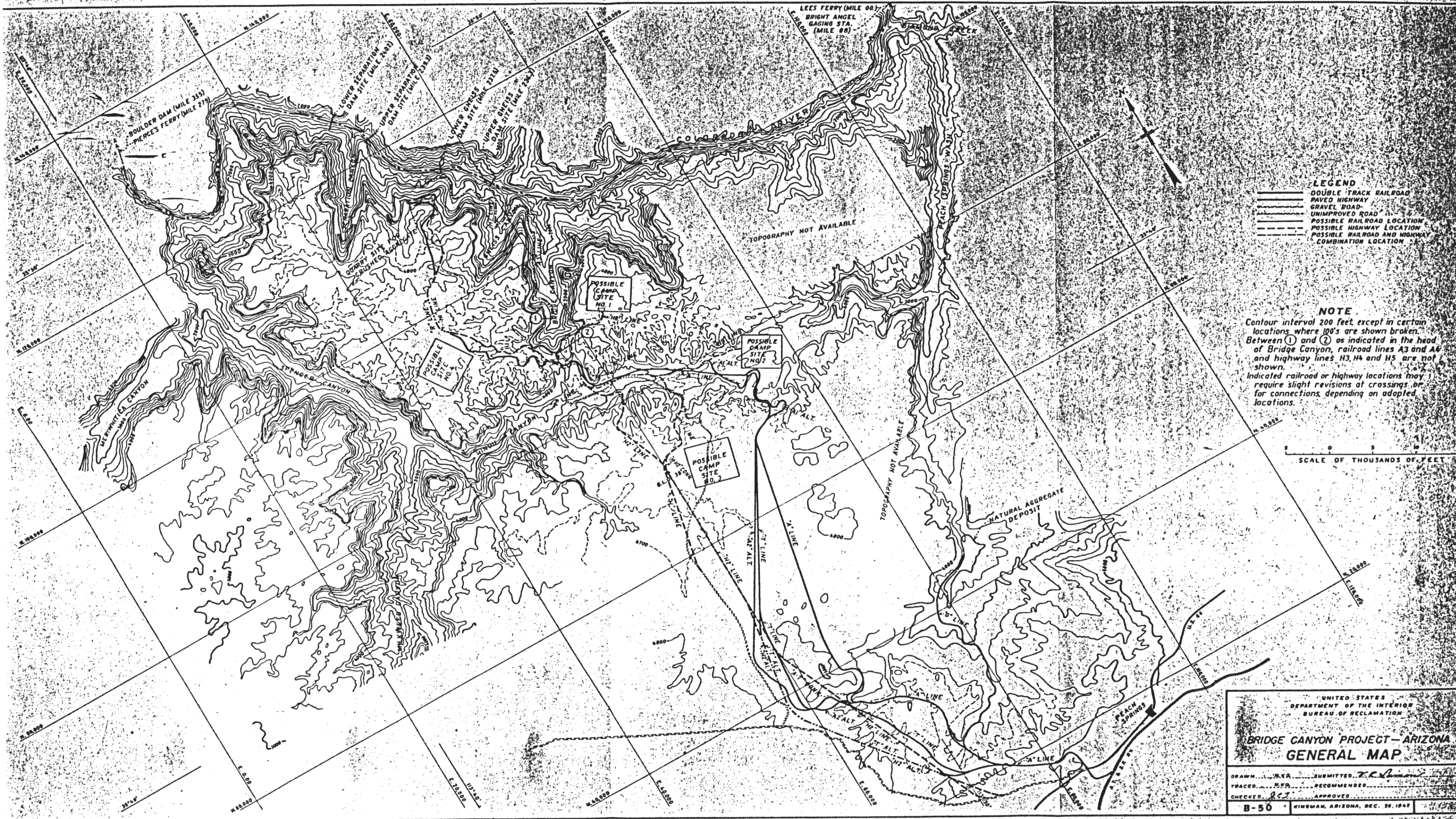


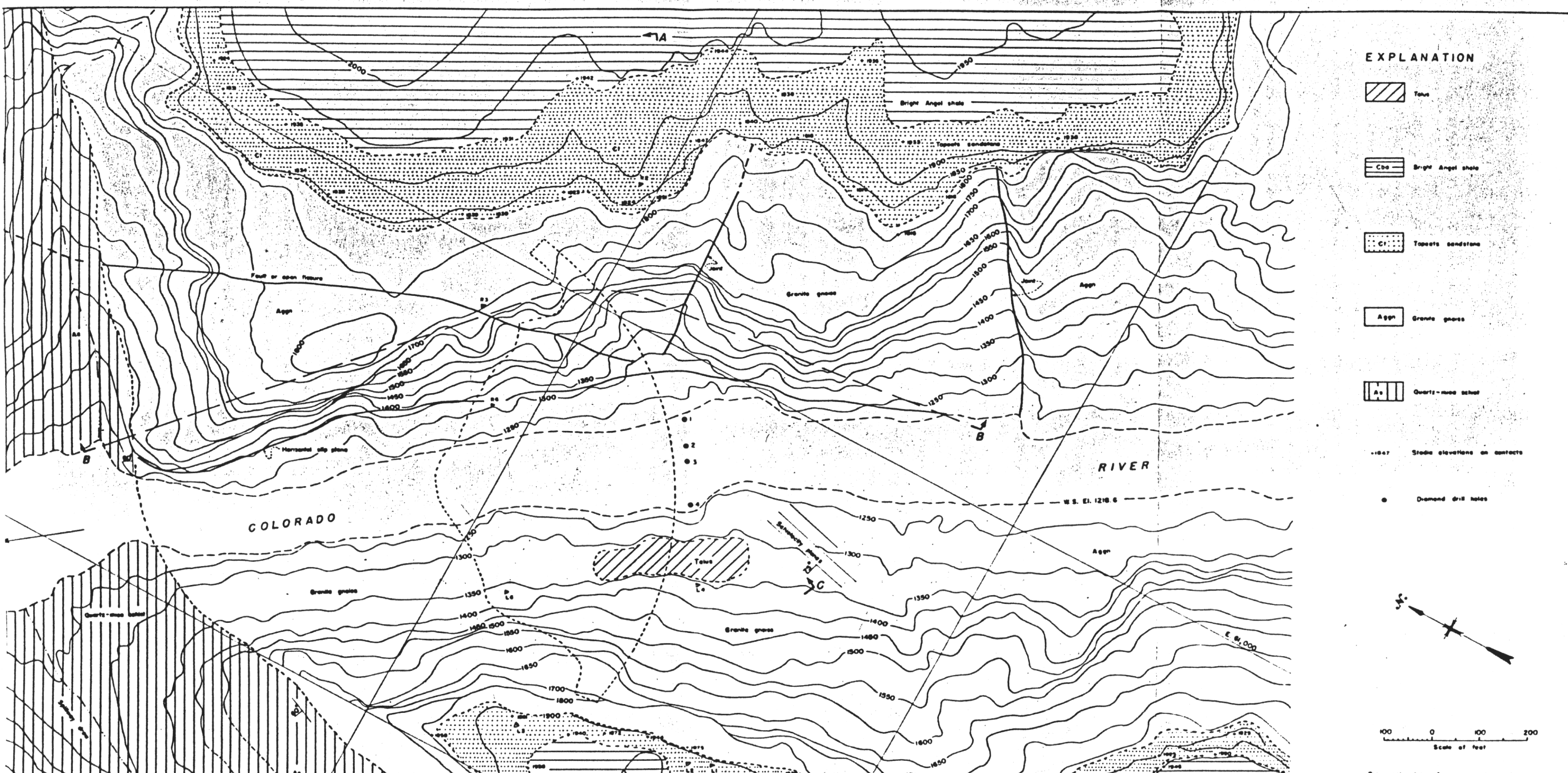
Upper Gneiss dam site on right side near axis. Shows fluting and polishing in the hard granite gneiss. This is a result of river action during flood season.

Fault or open fissure on right abutment of Upper Gneiss site.



Upper half of left abutment of Upper Gneiss site.


BOULDER DAM (MILE 355)
PIERCE'S FERRY (MILE 279)
LOWER SEPARATION DAM SITE (MILE 240.2)
UPPER SEPARATION DAM SITE (MILE 238.3)
LOWER GNEISS DAM SITE (MILE 237.5)
UPPER GNEISS DAM SITE (MILE 236.2)
LEES FERRY (MILE 00.)
BRIGHT ANGEL GAGING STA. (MILE 88)
COLORADO RIVER
QUARRY SITE FOR CRUSHED AGGREGATE
TOPOGRAPHY NOT AVAILABLE
POSSIBLE CAMP SITE NO. 1
POSSIBLE CAMP SITE NO. 2
POSSIBLE CAMP SITE NO. 3
POSSIBLE CAMP SITE NO. 4
MERIWHITICA CANYON
SPENCER CANYON
BRIDGE CANYON
NATURAL AGGREGATE DEPOSIT
PEACH SPRINGS
PEACH SPRINGS WASH
LEGEND
DOUBLE TRACK RAILROAD
PAVED HIGHWAY
GRAVEL ROAD
UNIMPROVED ROAD
POSSIBLE RAILROAD LOCATION
POSSIBLE HIGHWAY LOCATION
POSSIBLE RAILROAD AND HIGHWAY COMBINATION LOCATION
NOTE.
Contour interval 200 feet except in certain locations where 100's are shown broken.
Between ① and ② as indicated in the head of Bridge Canyon, railroad lines A3 and A4 and highway lines H3, H4 and H5 are not shown.
Indicated railroad or highway locations may require slight revisions at crossings or for connections depending on adopted locations.
SCALE OF THOUSANDS OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BRIDGE CANYON PROJECT—ARIZONA
GENERAL MAP
B-50
KINGMAN, ARIZONA, DEC. 26, 1947



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

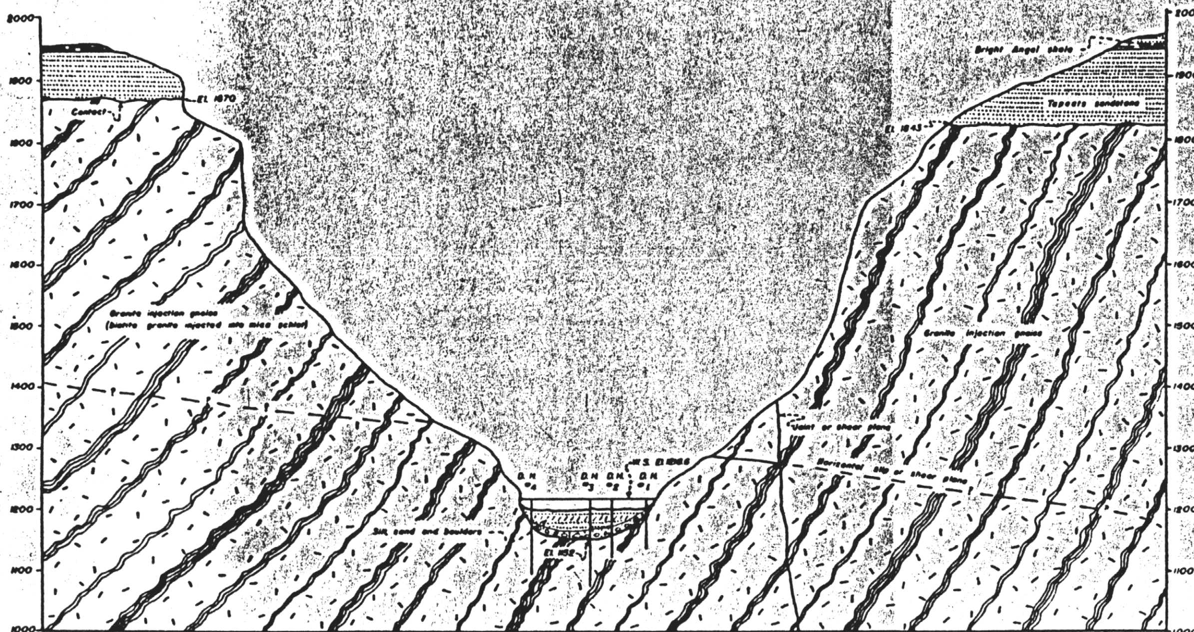
BRIDGE CANYON INVESTIGATIONS, ARIZONA

Geologic Map of the

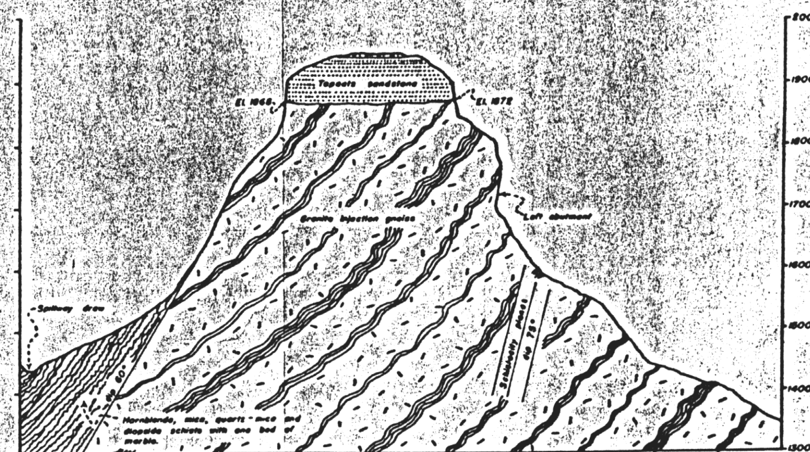
UPPER GNEISS DAM SITE

DRAWN JNM ___ SUBMITTED ___
TRACED JNM ___ RECOMMENDED ___
CHECKED ___ APPROVED ___

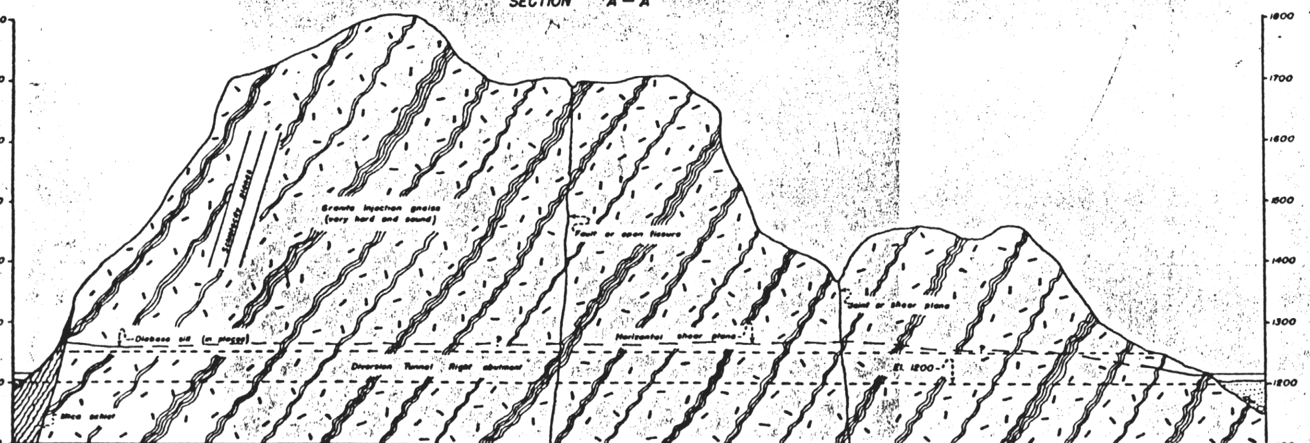
B 28 | PHOENIX, ARIZONA AUGUST, 1942



SECTION A—A



SECTION C—C



SECTION B—B

100 0 100 200
Scale of feet

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BRIDGE CANYON INVESTIGATIONS, ARIZONA
Geologic Sections
UPPER GNEISS DAM SITE

DRAWN: A.N.M. SUBMITTED: ____
TRACED: A.N.M. RECOMMENDED: ____
CHECKED: ____ APPROVED: ____

PHOENIX, ARIZONA FEB 1943

LOGS OF DRILL HOLES 1 - 4 U-50 Line

UNITED STATES
DEPARTMENT OF INTERIOR.
BUREAU OF RECLAMATION

PROJECT: Bridge Canyon FEATURE: Upper Gneiss Site HOLE NO: #1
LOCATION: U-50 Line 35' from Rt. Abutment in River N. 110,700 E. 60,866 DRILLER: Hall
COLLAR ELEVATION: AZIMUTH OF DIP: DIP:
BEGUN: Dec. 3, 1941 FINISHED: Dec. 10, 1941 DEPTH OF OVERBURDEN: 26.6 TOTAL DEPTH: 84'
EL. OF WATER TABLES:

Bit type: D.= Diamond; H.= Haystellite; S.= Shot; W.= Wash boring.

MATERIAL	BIT TYPE	DIAMETER HOLE	DIAMETER CORE	PERCOLATION TESTS: HOLE SEALED TO DEPTH CASING	HOLE SEALED TO DEPTH GROUTED	COLLAR PRESSURE	LOSS G.P.M.	REMARKS (Include core recovery in feet for each pull.)
0 to 1.5' Barge								
1.5 to 23' Water								
23 to 26.5'								
Silt and sand								
								Depth Recovery
	W							
Bedrock El. 1196	D		Bx					28 to 31' = 27"
26.6 to 44'			Bx					31 to 39' = 29"
Broken granite			Ax					39 to 48' = 65"
gneiss cut by								
pegmatites								
hard and sound								
								48 to 56' = 92"
				Packer at	Hole at			56 to 75' = 207"
44 to 76								
Dark grey								
gneiss fine				48	58	200	24	75 to 84' = 108"
grained and								
cut by granite							None	
dikes							Water	
							Loss	
							Below	
76 to 84'							58'	
Fine grained								
Gneissic granite								
Hard and sound								
								J. Neil Murdock
								Asst. Geologist
Bottom of hole #1								

UNITED STATES
DEPARTMENT OF INTERIOR
BUREAU OF RECLAMATION

PROJECT: Bridge Canyon FEATURE: Upper Gneiss Site HOLE NO: 2 U 50
LOCATION: 100' from right abutment N. 110,658 E. 60,830 DRILLER:
COLLAR ELEVATION: AZIMUTH OF DIP: DIP:
BEGUN: FINISHED: Dec. 14, 1941 DEPTH OF OVERBURDEN: 61.5 TOTAL DEPTH: 83'
EL. OF WATER TABLES:

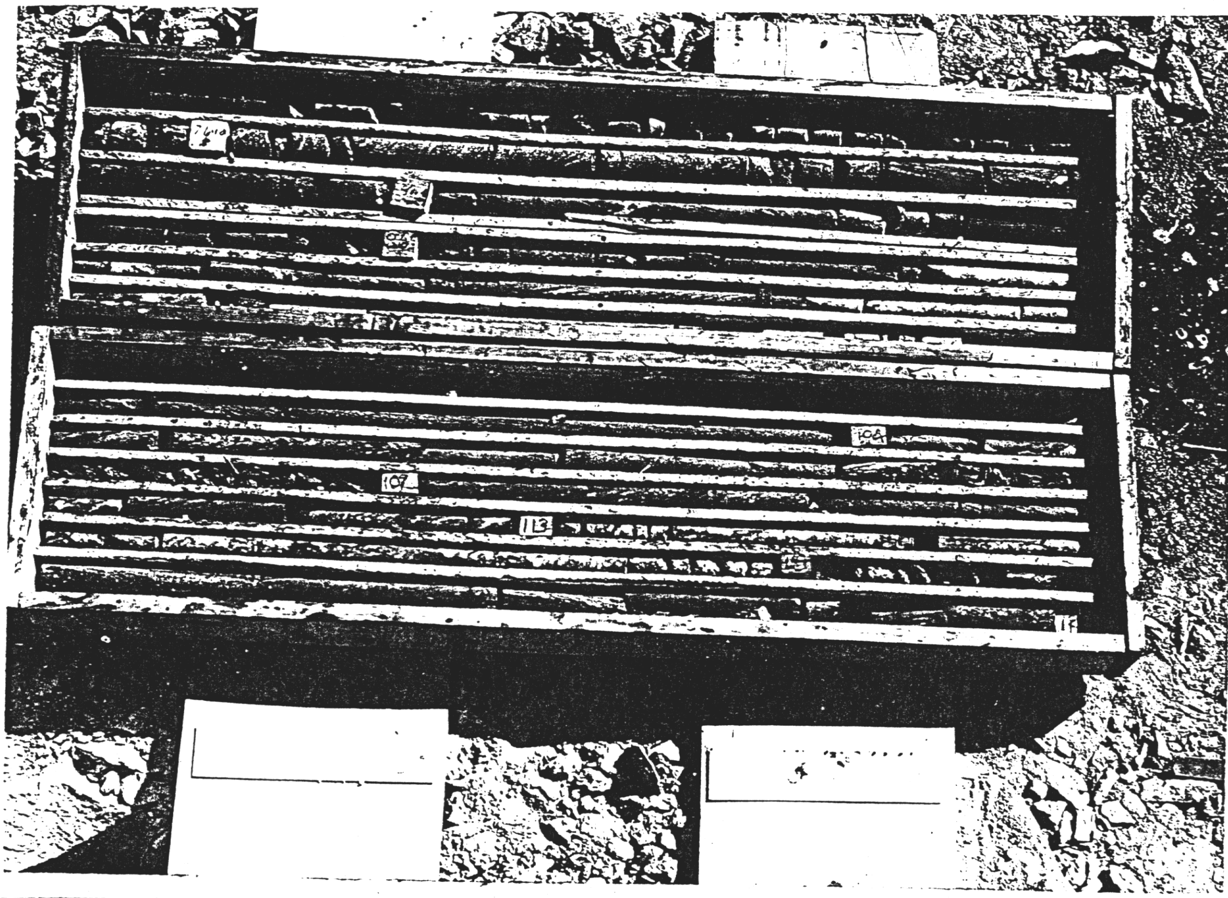
Bit type: D.= Diamond; H.= Haystellite; S.= Shot; W.= Wash boring.

MATERIAL	BIT TYPE	DIAMETER: HOLE	DIAMETER: CORE	PERCOLATION TESTS: HOLE SEALED TO DEPTH: CASING	GROUTED	COLLAR PRESSURE	LOSS G.P.M.	REMARKS (Include core recovery in feet for each pull.)
0 to 1.5' Barge								
1.5 to 32' Water								
32 to 56' Fine sand								
56 to 57.5' sand and gravel								Bedrock elevation approx. 1160
57.5 to 59' Boulder								
59 to 62' Sand and gravel								
62 to 63' Boulder								
63' Bedrock								
63 to 70' Soft granite gneiss								
70 to 83' Hard granite gneiss								
83' Bottom of hole								

BUREAU OF RECLAMATION

PROJECT: Bridge Canyon FEATURE: Upper Gneiss HOLE NO: #3 Line U-50
LOCATION: Line U-50 135' from Rt. abut. N. 110,656 E. 60,778 DRILLER:
COLLAR ELEVATION: AZIMUTH OF DIP: DIP:
BEGUN: Mar. 12, 1942 FINISHED: Mar. 29, 1942 DEPTH OF OVERBURDEN: 72 TOTAL DEPTH: 172'
EL. OF WATER TABLES: River
Bit type: D.-Diamond; H.-Haystellite; S.-Shot; W.-Wash boring.

MATERIAL	BIT TYPE	DIAMETER: HOLE	DIAMETER: CORE	PERCOLATION TESTS: HOLE SEALED TO DEPTH: CASING	PERCOLATION TESTS: HOLE SEALED TO DEPTH: GROUTED	PERCOLATION TESTS: COLLAR PRESSURE	PERCOLATION TESTS: LOSS G.P.M.	REMARKS (Include core recovery in feet for each pull.)
0 to 1.5 Barge								Ax Casing to 81.5'
1.5 to 26' Water								
26 to 57' Silt sand and gravel								
57 to 72' Sand gravel and boulders								
								Depth — Recovery
				Packer at	Hole at			72 to 76' = 48"
Bedrock El. 1152	W D		Bx					76 to 81' = 60"
				83	93	200	None	81 to 92' = 130"
			Bx Ax					
								92 to 99' = 84"
				93	103	200	None	
								99 to 113' = 168"
72 to 172'								
								113 to 118' = 60"
Massive pink granite gneiss with feldspar pegmatites				103	113	200	None	
								118 to 119' = 12"
Hard and sound some parting along planes of schistocity but no weathered joints evident				113	123	200	None	119 to 125' = 72"
								125 to 135' = 120"
								135 to 149' = 168"
				123	133	200	None	149 to 159' = 120"
								159 to 172' = 156"
				133	143	200	None	Rock hard and sound with no weak planes
				143	153	200	None	J Neil Murdock Asst. Geologist
				153	163	200	None	
				163	172	700	None	
Bottom of Hole								

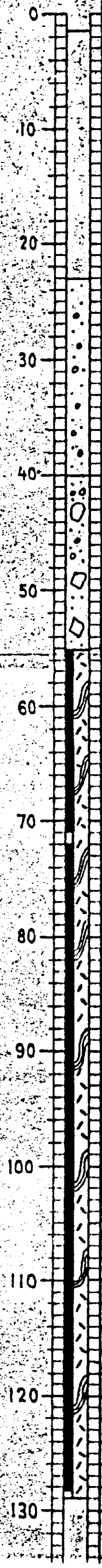


Core from Drill Hole #3 U-50 line Depth 72 - 172'

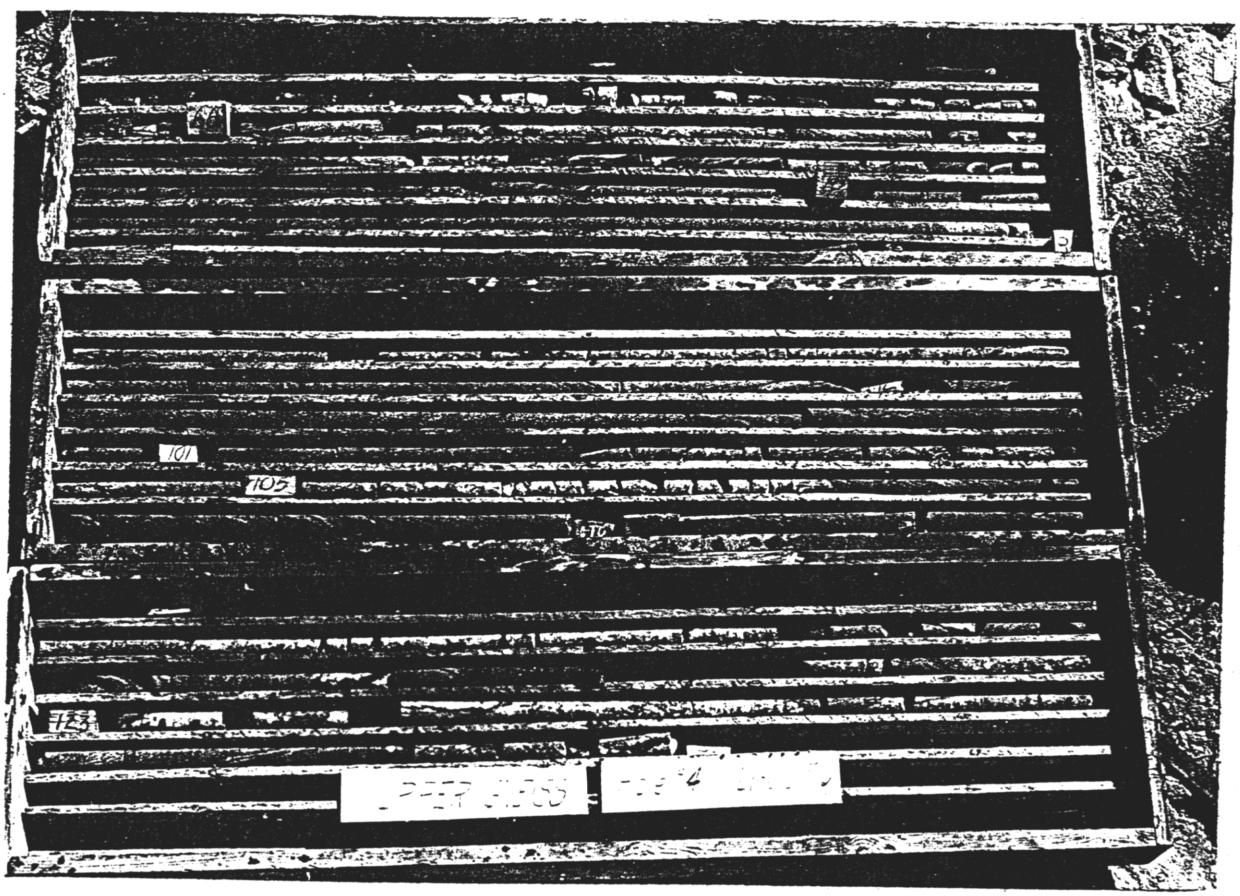
UNITED STATES
DEPARTMENT OF INTERIOR
BUREAU OF RECLAMATION

PROJECT: Bridge Canyon FEATURE: Upper Gneiss HOLE NO: 4 U-50
LOCATION: 180' from Rt. Abutment N. 110,630 E. 60,733 DRILLER: Larsen
COLLAR ELEVATION: AZIMUTH OF DIP: DIP:
BEGUN: Mar. 30, 1942 FINISHED: April 7, 1942 DEPTH OF OVERBURDEN: 35 TOTAL DEPTH: 129
EL. OF WATER TABLES:

Bit type: D = Diamond; H = Haystellite; S = Shot; W = Wash boring.



MATERIAL	BIT TYPE	DIAMETER HOLE	DIAMETER CORE	PERCOLATION TESTS: HOLE SEALED TO DEPTH CASING	PERCOLATION TESTS: HOLE SEALED TO DEPTH GROUTED	COLLAR PRESSURE	LOSS G.P.M.	REMARKS (Include core recovery in feet for each pull.)
0 to 1.5 barge								Ax casing to 60'
1.5 to 23' Water								
				Packer at	Hole at			
23 to 40' Sand and gravel								Depth Recovery
				62	72	50	15	
40 to 55' Sand gravel and boulders				72	82	200	None	60 to 72' 132"
				82	92	200	0	72 to 77' 60"
55' bedrock								
				92	102	200	0	77 to 90' 156"
				102	112	200	0	90 to 103' 156"
				112	122	200	0	103 to 115' 144"
								115 to 129' 160"
El. 1168.1 Bedrock								Hole abandoned when flood came down the night of April 7, 1942.
55 to 129'								
Massive hard								
granite gneiss								0.0 Gage = 1216.8
with veins of								gage
pegmatitic feldspar								Apr. 1 6.3
								60' 2
								70' 3 5.9
								77' 4 6.5
								99' 5 7.2
								103' 6
								115' 7 10.6
								129'
								Rock is of excellent quality
								J. N. Murdock Asst. Geologist
Bottom of hole El. 1090.1								



Core from Drill Hole #4 U-50 line Depth 55 - 129'